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ELECTRICITY AND THE HOME: AN INTERNATIONAL OVERVIEW OF TRENDS

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Electricity and the Home: An International Overview of Trends

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ABSTRACT

This report describes historical trends in residential electricity use and the forces underlying those trends in 11 industrialized countries, including the United States. It focuses on the period since 1973. It discusses the causes for the changes in electricity demand growth since 1973 in each of the main end-use markets for electricity, and discusses the reasons for the differences among the countries. We conclude by discussing some issues of importance for understanding the future direction of residential electricity use in the industrial countries.

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PREFACE

This project was initiated with assistance from the Electric Power Research Institute. The research is part of ongoing study of residential energy use in the industrialized countries. We acknowledge the contributions of Adam Kahane, and of those who provided information, particularly those in electric utilities and the appliance industries. A special thanks goes to Shell International Petroleum Company for its kind support and hospitality for Lee Schipper during 1986. Opinions are strictly those of the authors.

CONTENTS

1. Introduction

This report considers the evolution of residential electricity use in the U.S. and 10 other OECD countries since 1970. The share of the residential sector in total electricity demand has risen slowly in most OECD countries. The average share for the 11 study countries was 30% in 1983; the range was from 24% in Japan to 36% in the U.S. and the U.K. In the past decade, growth has been much slower than in the previous one. The reasons for this slower growth in recent years include saturation of equipment, changes in consumer behavior, and electricity conservation through more efficient equipment. Many of the same changes have taken place in all of the OECD countries, but there are also important differences among the countries. Using data assembled for 11 OECD countries, including the U.S., this report describes the changes each country has undergone, pointing out similarities and differences, and analyzes the differences among countries.

The large range of values for average annual electricity consumption per household shows that electricity is used quite diffferently among the OECD countries. In 1983 the average household used less than 700 kWh in Italy, but used 16000 kWh in Norway (Table 1.1). These two are outliers, however. More important is that most of the European countries and Japan have values in the range of 3000-4000 kWh, while the U.S. and Canada are over twice this amount. Ten years ago the difference between the U.S. and the other countries was greater. The other countries have gained on the U.S., which had the second slowest growth in total residential electricity demand in the 1973-83 period.[1]

Table 1.1. Residential Electricity Demand in OECD Countries

	Consumption per Household 1983 (kWh)	Total Demand Growth Rate 1973-83, %		Consumption per Household 1983 (kWh)	Total Demand Growth Rate 1973-83, %
Canada	11905	5.4	Denmark	3565	3.7
France	3580	8.2	Germany	3620	4.6
Great Britain	4085	-0.4	Italy	693	3.9
Japan	2850	5.6	Netherlands	3055	3.4
Norway	16000	4.7	Sweden	7940	6.8
United States	8990	2.8	AVERAGE (Wtd.)[3]	5867	3.4

To understand these differences, it is necessary to look closely at how electricity is used, which means looking separately at the main end-use markets. The importance of these markets

[1] Growth in Great Britain was slower -- negative, in fact -- due to the rapid penetration of North Sea gas into parts of the heating market previously claimed by electricity.

[3] Averages presented in tables in this report are simple averages of the values in the table except where it is noted that the value is a weighted (by the amount of each country's total electricity consumption) average.

differs among the countries (Table 1.2). Space heating is very significant in Canada, Sweden, and Norway; this goes a long way toward explaining the high average consumption in these cold-climate countries. Air conditioning claims a share over 10% only in the U.S., and is practically not present in Europe.

Table 1.2. Shares of 1983 Residential Electricity Consumption (%)

	Space Heat*	Water Heat	Cooking	Appliances	A/C
Canada	37	22	8	32	0-1
Denmark	13+1	8	15	63	0
France	29+7	12	6	46	~ 0
Germany	21+4	22	9	44	0
Great Britain	18+1	13	15	53	0
Italy	3	23	4	71	0-1
Japan	~ 0+8	14	5	68	5
Netherlands	1+1	26	3	69	0
Norway	31+25	23	3	18	0
Sweden	36+4	16	8	36	0
United States	17	16	7	47	13

* The first number refers to consumption for primary heating, the second to consumption for backup heating.

1.1. Why An International Study?

Although the changes in use patterns are occuring at different rates in different countries, many of the underlying factors or causes are similar. Therefore, study of these patterns across countries could reveal to us more about the components of change in electricity use (i.e., the technologies, behavioral changes, etc.) as well as the causes. In the end, the international comparison can be applied to understand any single country's consumption patterns. And energy and electricity-using technologies are now traded internationally; what is common in Japan or Germany today might be a household word tomorrow in the United States. International studies aid in predicting what changes might occur as technologies move from one country to the next.

1.2. Report Structure

Chapter 2 gives an overview of the changes in residential electricity use in the OECD countries since 1960. Chapter 3 looks in more detail at changes within each country since 1973, considering each end-use area separately. Chapter 4 focuses on the differences among countries in average consumption and in electricity market penetration, and discusses the reasons for those differences. The final chapter discusses some issues of importance for understanding the evolution of residential electricity demand in the U.S. and the other OECD countries. An appendix presents additional data assembled for this project.

1.3. About Data and Uncertainties

While a full expose on the difficulties of assembling comparable data on the residential sectors of so many diverse OECD countries is beyond the scope of this report,[4] several important points are worth mentioning.

Accuracy. We believe that total residential consumption for each country is accurate to ±3%. The uncertainties arise in part because of definition of farmhouses, which are sometimes undercounted, sometimes counted with associated process electricity consumption. Also, some countries do not count master-metered apartments in "residential", although our work at LBL has generally corrected this problem for the U.S., Canada, and Sweden, the major sources of the problem. Some countries do not include homes found in buildings whose dominate purpose is commercial premises.

The major market breakdowns (heating, hot water, cooking, appliances) are estimated from a variety of data sources, including tariff categories, actual metering, regression analyses, etc. We believe heating data accurate to within ±10%, hot water estimates to within ±20% in most cases, cooking estimates to within ±25%, and appliance use, always treated as a residual, to within +-15%. Significantly, bottom-up studies in each country, which estimate appliance use by appliance and use saturations to add these up over all households, tend to arrive at figures similar to ours, i.e., within 10%.

The household surveys we have used range from large (15-20 000 households in Germany, France, the U.K.) to moderately large (2000-5000 households in the Scandinavian countries, Holland, Japan, Canada, and the U.S. Some year-to-year fluctuation in reported equipment ownership is inevitable, and there are conflicts among different sources. We have compared our data with those of UNIPEDE, the European organization representing the major electricity interests in Europe, and found few conflicts, as should be the case since UNIPEDE obtains its data from country utilities. There is often confusion over ownership of an appliance vs. access (i.e., many families sharing washing facilities), and over the difference between a refrigerator and a fridge/freezer, and over the definition of a cooker (ie, cooktop only, oven only, or both).

We conclude that for the purposes of qualitatively describing the major forces that shape residential electricity demand, the data we have assembled over the 7 years of the LBL residential energy use project are more than sufficient. For formal statistical tests, however, these data would probably be insufficient, because they have already been subjected to a kind of informal "estimation"; our contribution herein is to take each country's estimates and place them into a common framework, which has added an additional judgemental estimate. For those interested in exploratory statistical work, we would be pleased to provide additional data.

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[4] For further discussion, see Schipper, L., Ketoff, A., and Kahane, A., 1985. "Explaining Residential Energy Use Using International Bottom Up Comparisons." *Annual Review of Energy* 10.

An important point must be made about the United Kingdom. While energy and electricity-use data are always taken from the U.K. *Digest of Energy Statistics*, data on structure are taken from many series of industry surveys that are rarely "published" and which cover only Great Britain (i.e., not including N. Ireland).

Climate Correction. All heating data are corrected to average climate, defined as the long term average number of degree days in the heating season to base 18C. See Meyers, 1986 or Schipper *et al.*, 1985 for explanation of methods.

Years Chosen. While total residential electricity use is defined for most countries for every year, the years studied in this report are those for which detailed structural data in each market exist. This is important because 1) we need to correct the heating data for variations in the average climate and 2) some countries do not define the residential sector consistently with the rest, so structural data and surveys were needed to adjust countries to a comparable basis among themselves as well as over time. We chose one or more years in the early 1960s (the earliest data would permit for some countries was 1963 or 1965), chose an immediate pre-embargo year (1972 or 1973 depending on surveys), a year before the second oil interruption (1978 or 1979), and 1983. In general, however, good data were also available for one or more years between 1973 and 1978, and for nearly every country since 1980, but time limitations forced us to concentrate on the years presented. In future work we intend to fill in the missing years and extend the data to 1986.

Dwellings and Population. In most tables we refer to consumption per occupied dwelling. Part of the reason for changes over time and for differences among countries is differences in the number of persons per dwelling. So that the reader can compute consumption per person, we present below the average number of persons per dwelling for 1983 for each country. Note that this refers to all dwellings; the value for dwellings with electric heat or electric hot water may be different.

Table 1.3. Average Number of Persons per Occupied Dwelling, 1983

Canada	2.9	Denmark	2.3
France	2.8	Germany	2.6
Great Britain	2.8	Italy	3.3
Japan	3.2	Netherlands	2.8
Norway	2.6	Sweden	2.3
United States	2.8	AVERAGE	2.9

When we give average use per dwelling for a specific use, the value always refers to that use in dwellings where it occurs. By contrast, per capita values always refer to the total use of electricity for a given purpose divided by the total population in a country.

2. Residential Electricity Demand Since 1960: An Overview

Average growth in residential electricity demand over the past 20 years has been higher in Europe and Japan than in the U.S. This difference is mainly attributable to the differences in penetration of appliances and electricity heating, which was higher in the U.S. than elsewhere at the beginning of the period. Growth in appliance ownership was responsible for high growth rates from 1960 through around 1973, when electric heating began to become popular. By the early 1980s, more efficient appliances and tighter new homes dampened growth in demand in most countries. Average growth in electricity demand per household between 1978 and 1983 was generally less than 2% per year, and was negative in some countries.

Average growth in residential electricity demand between 1960-65 and 1983 in the 11 OECD countries in our study ranged from a low of 3.8% per year in the U.S. to a high of 9.4% per year in Sweden. (Growth rates for different periods are given in Table A-1 in the Appendix.) On a per household basis, growth was lowest in the U.S. and highest in Sweden, where heating accounted for 2/3 of the total growth in sales.

Since electricity demand grew faster than that for other energy types, the share of electricity in residential energy demand increased in all countries through 1973, and increased further through 1983 in all countries except Great Britain (Table 2.1). Norway has an unusually high electric share because of the availablity of low-cost hydroelectricity.

Table 2.1. Share of Electricity in Residential Energy Demand

	1960-65	1972-73	1983		1960-65	1972-73	1983
Canada	7	18	31	Denmark	5	7	15
France	6	8	18	Germany	5	11	17
Great Britain	9	18	17	Italy	-	10	15
Japan	15	22	28	Netherlands	-	10	12
Norway	36	52	68	Sweden	8	14	32
United States	10	18	28	AVERAGE(Wtd.)	9	19	25

For the 1960-65 period, the following years apply: Canada, 1961; Denmark, 1965; France, 1962; Germany, 1960; G. Britain, 1960; Italy (total residential use is very uncertain); Japan, 1965; Netherlands (total energy demand is unknown); Norway, 1960; Sweden, 1963; United States, 1960.

Although the electricity market changed in different ways in different countries, it is possible to divide the period since 1960 into four periods. The dividing points for these periods correspond roughly to the major changes in the world price of oil. In nearly all cases, growth in residential electricity demand per household was less in each successive period (Table 2.2). (Per capita growth rates are somewhat higher since people/household decreased by 10% between

1960 and 1973, and by 10% again between 1973 and 1983.)

Table 2.2. Average Annual Growth in Residential Electricity Demand per Household (%)

	1960-73	1973-78	1978-83
Canada	5.4	3.0	1.9
Denmark	7.8	4.5	-0.5
France	9.9	9.0	5.8
Germany	9.8	5.4	1.7
Great Britain	6.8	-1.2	-1.3
Italy	10.9	4.0	1.6
Japan	10.4	5.7	1.8
Netherlands	8.1	3.8	-1.5
Norway	4.0	3.6	2.8
Sweden	9.7	5.5	6.5
United States	4.3	1.7	-0.2
AVERAGE (Wtd.)	-	2.3	0.9

2.1. Four Periods of Residential Electricity Demand

2.1.1. 1960-1973: Growth in appliance ownership

Growth in residential electricity demand was considerable everywhere in the 1960s. This was less the case in the U.S. than in Europe and Japan, where growth averaged over 10% per year in most countries. This difference in growth rates reflected increase in appliance ownership from very low levels of penetration in most European countries in the early 1960s. In 1960, refrigerator saturation was 41% of households in Germany, 46% in Denmark, 22% in Great Britain, and <5% in Japan. By 1973, more than 80% of all households in these countries (~ 70% in Great Britain) owned refrigerators, and half owned freezers or freezer-fridge combinations. The growing ownership of appliances (which also increased in size during the period), increased the share of residential energy use met by electricity. Electricity met the need for home conveniences not previously satisfied: automatic clothes and dish-washing, television, refrigeration with compressors, instead of ice, and motor-driven appliances. All during this period, the real price of electricity was decreasing, assisting the increase in use.

2.1.2. 1973-1978: Slower but continued growth

By 1973, residential electricity use was growing somewhat slower in the high-income countries (Denmark, Norway, Sweden, Canada, and the U.S.). This trend was less evident in other countries. Demand was still climbing rapidly in Japan and Italy, countries with the lowest incomes at that time. In the UK residential electricity use beginning to decline, as all the competitive markets lost share to gas.

Differences in the growth rates reflected different levels of appliance saturation in the early 1970s. Growth in electricity use was still dominated by the appliance market and by electric cooking. There was limited penetration of heating and hot water markets (except in Norway), although point-of-use water heaters were popular in the UK, Germany, and France. Lighting levels were also increasing in most countries.

The 1973 price rise for oil, then the most popular heating fuel in all the European countries except Holland and the UK, caused a wave of interest in electric heating. In Norway and Sweden, large numbers of conversions to electric space and water heating began in the mid-1970s. In other countries, the share of electricity for space heating increased mainly in new homes, though the electric share of the hot water market in existing homes increased. In the U.S., where electricity gained more than 40% of new homes by the early 1970s, the attractiveness of heat pumps and exploitation of regions without ready access to natural gas boosted the electric share of new construction to over 50%.

The rise of electric heating in some countries and the continued growth in appliance ownership in others kept overall growth rates for residential electricity use high through the late 1970s. While real prices inched upward in most countries, significant increases did not occur until the late 1970s (or early 1980s). Significantly, the ratio of the price of electricity to the price of oil was far lower in the mid-1970s than in the late 1960s; this ratio fell even more in 1979 and 1980.

2.1.3. 1979-1983: Conservation and conversion

After 1979, demand in many of the countries began to stagnate or even fall. Many appliances had reached reached near to the peak of their saturation, and the impact of more efficient electric appliances became appreciable by the early 1980s. Similarly, the building shells of new homes built for electric heating became increasingly tighter, reducing the average consumption for heating. Higher electricity prices also induced conservation by families using electricity for hot water, heating, and cooking, as well as for lighting. Use per customer for each specific purpose levelled off or fell.

After oil prices shot up in 1979, electric space heating grew in importance in countries with relatively cheap electricity, and in France. This accounted for 1/2 to 2/3 of the growth in electricity use in Norway, Sweden, Canada, and France, and also contributed to growth in the U.S. Heating probably accounted for 1/3 of the growth overall in the 11 countries. In Norway and Sweden, electricity became less costly than oil for space heating (assuming 66% efficiency of conversion of oil to heat); in Canada the price of electricity lay close to that of natural gas. In these three countries substantial conversions to electricity occurred. One-third of the oil-heated SFD stock in Sweden converted to electricity alone, or in combination with wood and oil, between 1978 and 1983. In Norway, most homes always had electric heating equipment alongside that for oil and/or wood, and simply used more electricity and less oil. In France, all-electric new homes were promoted successfully, although the variable cost of electricity was greater than that of oil. In the other countries, where higher oil prices meant higher electricity prices as well, electric heating barely kept its market share.

2.1.4. After 1983

Indications are that the impact of tighter building shells and more efficient appliances continues to be felt as the role of end-use devices built since the late 1970s is increasingly important in determining overall consumption. Gas is more available in Germany and France, and has been introduced in Denmark as well. In most countries, electricity prices have reached a plateau after several years of growth, or even have fallen slightly. Incomes grew in 1984 and continued upward in 1985, and electricity use, from preliminary indications, increased from growth in heating as well as increases in appliances. Appliance sales data from European countries show a definite upturn (reflecting both replacement as well as new purchases, but saturation data also show increases), although total load growth was clearly inhibited by the efficiency of new systems.

Variability in electricity use depends as much as or more on the structure of consumption as on the intensity of use. Simple extrapolation of historic trends, or aggregate forecasting based on a price/income/consumption relationship, may fail to reflect the vital structural and intensity changes among and within the components of household electricity use.

2.2. Economic Factors

2.2.1. Evolution of electricity prices

Both the level of stocks and unit consumption are influenced by the price of electricity and its change over time. Differences in the price of electricity among the countries are an important factor in explaining differences in market penetration and average consumption of electricity-using devices. Figure 2.1 shows the evolution of average residential electricity prices since 1960 (in constant US $, using 1981 exchange rates).[1] Prices have historically been lowest in Canada and Norway, countries with substantial hydroelectricity, and have also been relatively low in Sweden and the U.S. In the other countries, there was decline in real prices through around 1973, and then varying degrees of increase since then. (Since the average price of electricity obscures differences in the rate structure among countries, comparison among countries whose average price is fairly close should be made with caution.)

Figure 2.2 shows how the ratio of the price of electricity for heating to that of oil (in terms of heat content) has declined in all countries. As the ratio drops below 2:1, electricity becomes

[1] 1981 exchange rates in fact reflect the approximate average rates during the entire 25 year period of study. It makes no sense to use year to year fluctuations in currency, since these give a very deceptive picture of the fluctuations seen by consumers.

close to equal with oil in terms of fuel cost (since 1/3 to 1/2 of the heat content of the oil may be lost in conversion). This happened in several countries by the end of the 1970s, and was one of the factors behind the growth in use of electricity for heating.

2.2.2. Income

Income plays a key role in determining demand, since it governs consumer ability to buy larger houses, appliances, and other equipment that use electricity, as well as their capacity to buy electricity. Not surprisingly, higher income countries consume more electricity (per capita) than low. This comparison is somewhat misleading due to the patterns of electric space heating, but even if we focus only on appliances, we find higher incomes correlated with higher consumption (see Chapter 4). In general, per capita income grew rapidly through 1973, slower through 1979, and then stagnated in most countries thereafter (see Figure 2.3). High income growth in some countries (i.e., Norway, Japan) did, however, contribute to strong growth in electricity use during the 1970s.

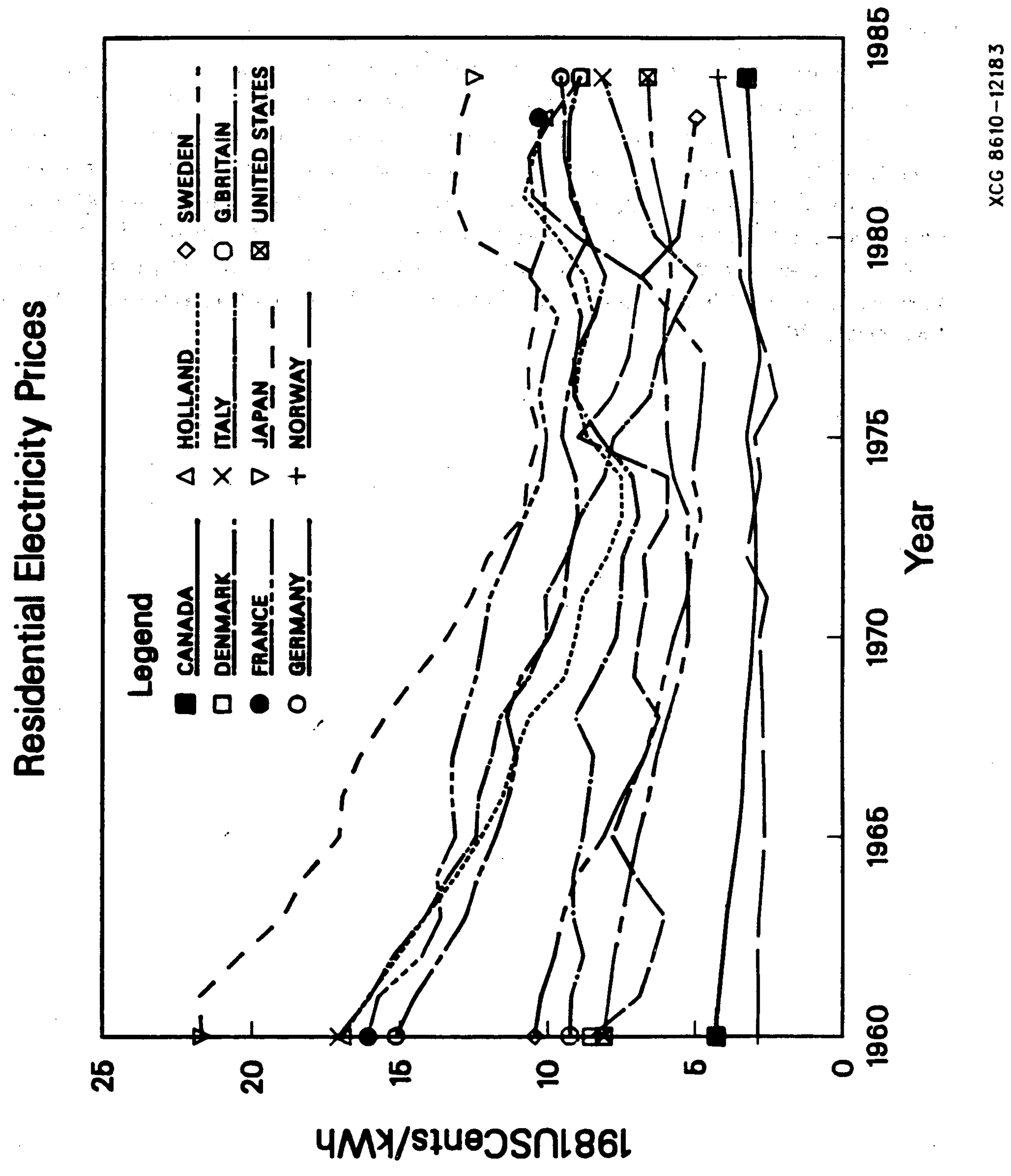
Residential Electricity Prices
Legend
CANADA
DENMARK
FRANCE
GERMANY
HOLLAND
ITALY
JAPAN
NORWAY
SWEDEN
G.BRITAIN
UNITED STATES
1981USCents/kWh
25
20
15
10
5
0
1960
1965
1970
1975
1980
1985
Year
XCG 8610-12183

Figure 2.1

Electricity Heating Price to Fuel Oil Price
for O.E.C.D. Nations

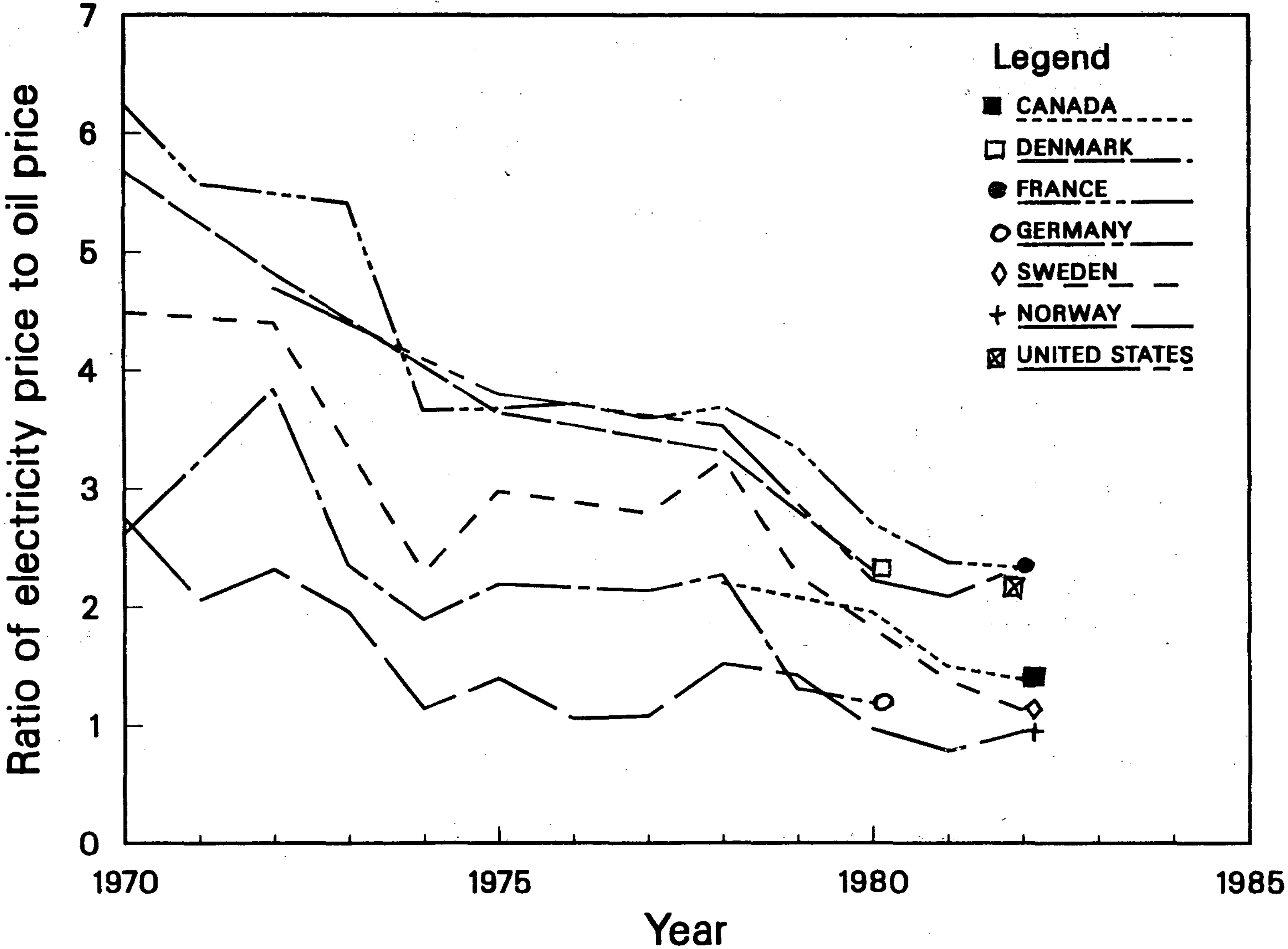

Figure 2.2

XCG 853-119

Disposable Income Per Capita

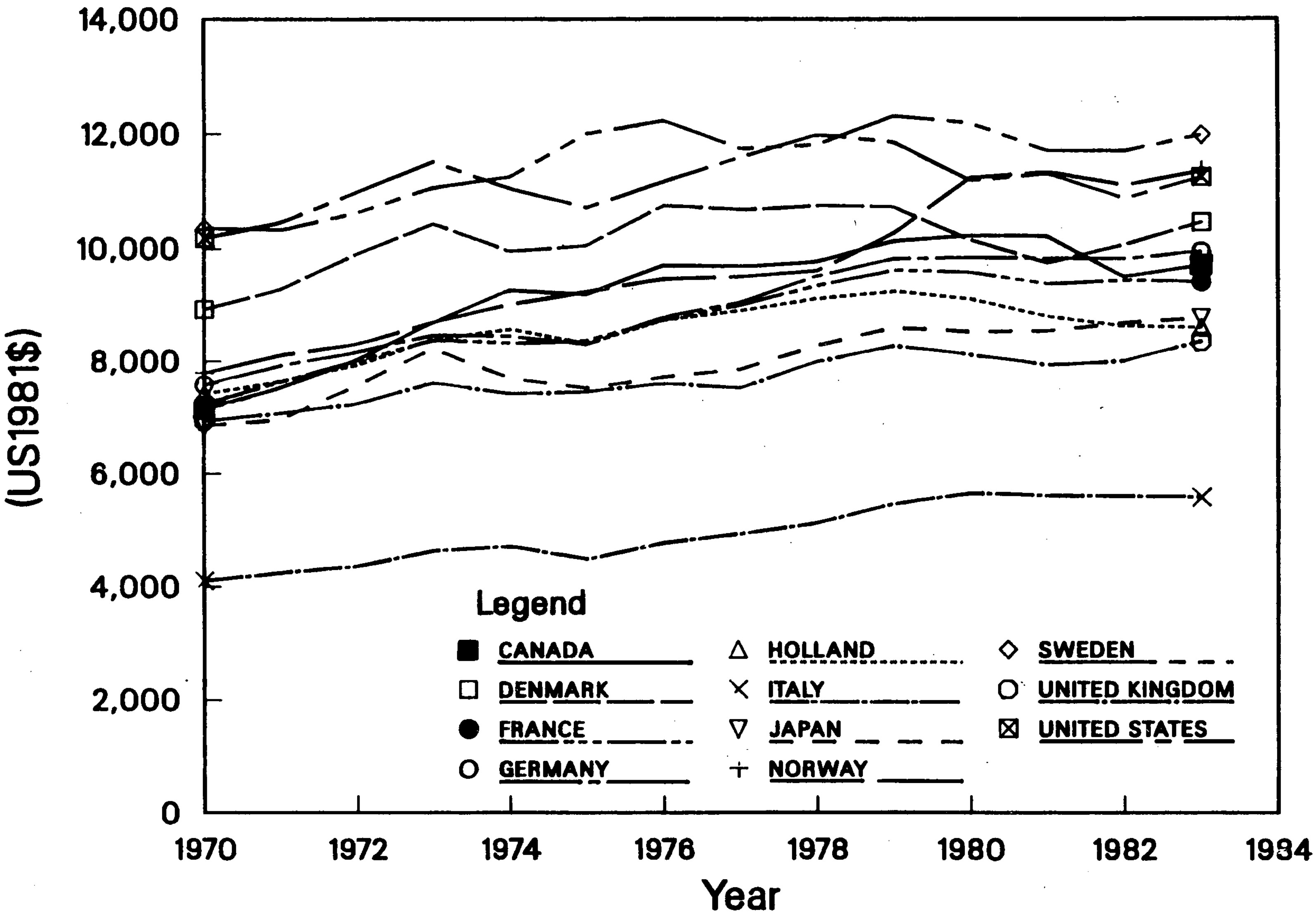

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Figure 2.3

3. Changes Since 1973 in Residential Electricity Demand

Average electricity consumption per home increased in all countries except Great Britain between 1973 and 1978. Between 1978 and 1983 there was little or no increase, except in France and Sweden. In the countries with strong growth, heating accounted for the major part. In Denmark, Great Britain, Netherlands, and the U.S., the level in 1983 was less than in 1978.

The main growth market for electricity has been space heating. Estimated total consumption doubled in the U.S between 1973 and 1983, but this was much less than the growth in Canada, Denmark, France, and Sweden. The main reason for the growing market penetration of electric heating was its popularity in new homes. In Canada, Sweden, and Norway, however, many homes converted to electric space heating from oil or other fuel-based heating systems. Average electricity consumption for heating declined in nearly all countries because the new homes entering the stock were increasingly more heat-conserving.

Electric water heating and cooking both made modest gains in market share in most countries, though there appears to have been some decline in average use. Average electricity use per household for appliances grew in all countries except the U.S. This was because saturation levels were higher in the U.S. in 1973. Growth in Europe began to slow by the end of the 1970s as the improved efficiency of new appliances began to have a significant effect.

Major changes in the use of electricity have taken place since 1973, sparked first by increased oil prices, and later by increased electricity prices, slower income growth, and technological change. Growth rates of electricity sales varied among the countries, as did the shares going to each end-use category. Part of the change was structural, arising because people did different things with electricity, and part was due to changing intensity -- use of more or less electricity to perform certain tasks. This chapter outlines the key features of change in each major end-use market with respect to these two elements.

Average electricity consumption per home increased in all countries except Great Britain between 1973 and 1978 (Table 3.1). The total percentage increase ranged from around 10% in the U.S. to 42% in Japan. Between 1978 and 1983 there was little or no increase, except in France and Sweden. In Denmark, Great Britain, Netherlands, and the U.S., the level in 1983 was less than or about the same as in 1978.

Table 3.1. Average Electricity Consumption per Home (MWh)

	1973	1978	1983	AAGR 73-83		1973	1978	1983	AAGR 73-83
Canada	9.4	10.9	11.9	2.4%	Denmark	2.8	3.7	3.6	2.2%
France	2.1*	2.7	3.6	6.8%	Germany	2.6	3.3	3.6	3.1%
Great Britain	4.7	4.4	4.1	-1.3%	Italy	1.5	2.1	2.2	3.4%
Japan	1.9	2.7	2.9	4.0%	Netherlands	2.7	3.3	3.1	1.2%
Norway	11.6	14.3	16.0	3.2%	Sweden	4.2	5.8	7.9	5.8%
United States	8.2	8.9	9.0	0.9%	AVERAGE	4.7	5.6	6.2	2.9%

* 1975

Growth in the use of electric space heating was partly responsible for growth in use per household. This is evident when consumption for heating is removed (Table 3.2).

Table 3.2. Average Electricity Consumption per Home for Non-Heating Uses (MWh)

	1973	1978	1983	AAGR 73-83		1973	1978	1983	AAGR 73-83
Canada	7.6	7.4	7.5	-0.1%	Denmark	2.6	3.2	3.0	1.3%
France	1.5*	1.9	2.3	5.3%	Germany	2.0	2.5	2.7	2.7%
Great Britain	3.1	3.5	3.3	0.6%	Italy	1.5	2.1	2.2	3.5%
Japan	1.7	2.5	2.6	4.2%	Netherlands	2.6	3.2	3.0	1.4%
Norway	6.2	6.9	7.1	1.4%	Sweden	3.4	4.1	4.7	2.9%
United States	7.4	7.8	7.9	0.6%	AVERAGE	3.6	4.1	4.2	2.2%

* 1975

Figure 3.1 shows how the estimated shares of the end-uses in total electricity consumption changed between 1973 and 1983. Growth in the share of space heating was substantial in Canada, Denmark, and Sweden, and was also significant in the U.S. and France.

3.1. Space Heating

Electricity consumption per capita for space heating grew considerably in most of the countries (Table 3.3). Great Britain and the Netherlands, countries where gas is readily available, and Italy, where electric heating is used only in warmer regions, were exceptions to this trend. Growth was strongest in Canada and Sweden, countries where electricity prices remained relatively low, and in France, where electric heating was aggressively promoted. Though not indicated by Table 3.3, it is important to know that most of the growth took place after 1978.

Table 3.3. Electricity Consumption per Capita for Space Heating* (kWh)

	1972/73	1983	AAGR		1972/73	1983	AAGR
Canada	523	1546	10.8%	Denmark	76	223	9.8%
France	181**	474	12.0%	Germany	209	367	5.1%
Great Britain	523	286	-5.5%	Italy	22	19	-1.3%
Japan	49	72	3.8%	Netherlands	33	24	-3.2%
Norway	1853	3404	6.1%	Sweden	333	1424	13.2%
United States	255	392	4.3%				

* Includes secondary heating except for Canada and the U.S.

** 1975.

The growth in electricity use for space heating was driven by increase in the number of dwellings heated electrically. Increased use of electricity for secondary (i.e. backup) heating also played a modest role. These changes were moderated by a decrease of some 10-15% in the intensity -- electricity use per household -- of electric space heating. This reflected both conservation in existing homes and the entrance of new, tighter homes into the stock.

3.1.1. Market penetration of electricity

The share and number of homes with electric heating grew several-fold in Canada, Scandinavia (though remaining relatively unimportant in Denmark), and France (Table 3.4). Growth of electric space heating in the U.S. and Germany was slower, while the market share actually contracted in Great Britain. Use of electricity as primary space heating source remains unimportant in Japan. In Italy, the electric share has grown in non-central-heated homes and second residences (mainly in the South where the mild climate does not justify the installation of a central heating system). Electric heating with fixed radiators ("central") remains insignificant, as the national utility strongly discourages its installation.

Table 3.4. Percentage of Homes with Electricity as Main Heating Fuel

	1972/73	1983		1972/73	1983
Canada	7	23	Denmark	2	6
France	5*	15	Germany	4	9
Great Britain	13	12	Italy	6	8
Japan	..	2	Netherlands	1	..
Norway	31	49	Sweden	6	24
United States	10	18	AVERAGE	6	15

* 1975

The countries that had the greatest increase in electric heating penetration -- Canada, Sweden, and Norway -- also had relatively little increase in the price of electricity. Electricity prices increased at about the same rate in France and Germany, yet France saw twice as much increase in electric heating penetration. This reflects the strong promotion of electric heating by the French government.

Growth in market penetration by electric heat in the U.S. was slower than in some other countries in part because the U.S. had one of the highest penetrations already in 1973. This was due in part to the presence of cheap electricity in the Northwest and the Tennessee Valley Area. The prices of oil and gas moved up less rapidly than in other countries, and electricity was expensive in the important area of oil heating, the Northeast. Not surprisingly, there were few conversions to electricity.

3.1.1.1. Electric heating in new homes

In most of the countries, the growth in penetration of electric space heating was primarily due to its popularity in new homes. The share of new dwellings with electric heat grew after 1973 in most countries (Table 3.5). This was not the case in the U.S., where it was already high in 1973. The growth was most striking in France and Sweden. The electric share grew but remains low in Denmark, did not grow very much in Germany, and declined (losing out to gas) in the U.K.

The penetration of electric space heat depends upon forces besides just the relative price of electricity. These include the nature of the technologies used, the cost of installation, availability of gas or district heating, and building traditions. In the U.S., Canada, Germany, and France, electric heating has a higher penetration in apartments than in SFD; in Sweden and Denmark, the reverse is true (primarily because of the popularity of district heating for apartments).

Table 3.5. Percentage of New Homes with Electric Heating

	1973	1978	1982/83		1973	1978	1982/83
Canada	-	-	-	Denmark	8	14	18
France	4	35	44	Germany	6	9	7
Great Britain	22	13	7	Italy	-	-	-
Japan	-	-	-	Netherlands	0	0	0
Norway	-	-	-	Sweden	28	56	47
United States*	54	58	58				

* Does not include mobile homes.

3.1.1.2. Conversions to electric heating

The role of conversions was minor except in Sweden, Norway, and Canada, where electricity prices remained low relative to competing fuels.[1] In Sweden and Norway, conversion to

[1] These countries have the largest share of hydroelectricity in their systems.

electric space heating by existing homes was the dominant structural change. At least 1/3 of the homes using electricity in 1983 used a different fuel in 1975. In Sweden after 1979, between 70,000 and 100,000 SFD joined the stock of electrically-heated homes each year through conversion (only about 20,000 new SFD with electric heating were built annually). In Norway, many of the homes using electricity as a principal fuel in 1983 used it as a secondary fuel before 1978. In Canada, 40% of the additions to the electrically-heated stock from 1981 to 1983 were the result of conversions, primarily from oil. In France, by contrast, the number of conversions in SFD after 1975 amounted to 20-25% of the number of new electric-heated SFD, and in the U.S., the role of conversions was even less important.

The rapid increases in penetration of electric heating in Norway and Sweden bear comment. By 1977, the variable cost of electricity for heating in Norway was lower than for oil (assuming oil burned at 70% efficiency). By 1981, the same point was reached in Sweden and parts of Canada, but virtually nowhere else. Because of charges for heating connections and for the wattage connection, however, not all homes found it advantageous to switch to electricity. The speed at which homes converted to electric heating suggests that once a clear price advantage, say, 25% lower variable costs, has been achieved, electric heating expands vigorously through conversions from other fuels. Concerns about the long-term cost of supply in Norway and uncertainty over the cost of electricity once today's nuclear plants are phased out in Sweden may have moderated the rush to electricity. Now that oil prices have dropped drastically, oil is less costly than electricity in Sweden and Norway; it will be interesting to see whether users with multiple equipment (half of the electrically-heated SFD in either country) switch back to oil in 1986 or 1987.

3.1.1.3. Changes in electric heating equipment

The shares of different kinds of electric heating systems in the electrically-heated stock changed between 1973 and 1983. In the U.S., the share of electric warm air furnaces and direct resistance heat fell as heat pumps gained ground. Heat pumps did not gain very much ground elsewhere. In Great Britain, France, and Germany, the role of storage systems, which were the most common mode around 1970 (taking advantage of low off-peak electricity rates), diminished in the 1970s. Storage heating yielded its share in new construction to gas systems in the U.K. and to gas and other electric systems in Germany. (The low levels of insulation in British dwellings made it difficult for storage heaters to provide enough heat by early evening; this may explain their decline in popularity as gas became available and cheap.) In France, low prices and tighter building shells made direct-acting heating attractive and affordable after 1975. Heat pumps entered the market too, reaching 6% of the electrically-heated homes.

In Sweden, the desirability of a system that could use electricity and/or oil and/or wood boosted the role of hydronic electric systems. These electric boilers are now found in one third of the electrically-heated stock. Many of these systems were originally oil boilers that were simply converted to electricity using plenum heaters. One reason for the popularity of these systems is that the 1983 building code (ELAK) required either an extremely tight building shell (R-33 wall, R-47 ceiling) in combination with direct acting radiators, or less stringent practices for other systems ("only" an R-19 wall and R-28 ceiling). These choices cost about the same, but the tighter thermal requirements presented a greater technical challenge; hence the hydronic systems came to dominate in new construction. The Swedish experience suggests that source flexibility might be an important factor in determining the success of electric heating technologies elsewhere.

Supplementary fuels. An important aspect of the electric heating scene was the growth in the use of other fuels (especially wood) as supplements to primary electric systems. In Sweden and Norway, more than half of the homes with electric heat use wood and some use kerosene as well. In Denmark some wood, kerosene, or trash is used in about 1/3 of the homes with electric heating. In the U.S. in 1982, around 25% of the electrically-heated homes also used wood, and 7% used kerosene. About the same share of electrically-heated homes in Great Britain used a second fuel -- mostly LPG or kerosene -- in 1983.

Electric backup heating. The use of electricity for supplementary heating grew in Scandinavia, Germany, and probably in the U.S. By 1983, roughly 12% of U.S. homes, 10% of Canadian, 11% of Italian, 18% of French, 23% of British, 25% of Danish, 33% of German, nearly 40% of Dutch homes, and virtually all in Japan used electricity -- usually small, portable heaters -- to supplement fossil fuel heating systems. The lower values for the U.S., Canada, and France reflect the availability of wood for backup heating.

3.1.2. Intensity

Average electricity consumption for space heating in homes with primary electric heat is lower today than in the early 1970s (Table 3.6). This is due mainly to the rapid entry of new, well-insulated homes into the stock and decreased use (due to retrofit and behavior change) in existing homes. The use of non-electric supplementary fuels (especially wood) also played a role. Changes in the dwelling mix and in dwelling occupancy had only a small role in the change except in France, where as share of single-family houses increased from 31% to 56%.

Table 3.6. Average Electricity Consumption for Primary Space Heating (MWh/dwelling)

	1972/73	1983	Change,%		1972/73	1983	Change,%
Canada	26	19	-27	Denmark	12	8.2	-33
France*	6.7	7.4	+10	Germany	11	9.5	-10
Great Britain	8.8	5.9	-33	Italy***	-	-	-
Japan**	-	-	-	Netherlands	-	11/6	-
Norway	14	13	-11	Sweden	10	12	+20
United States	7.5	5.9	-21				

Slash separates Single-Family from Multi-Family dwellings.

* First year is 1975. ** There is very little use of electricity as primary heating fuel.

*** Data for primary heating are not available.

The above data do not distinguish between single-family and multi-family housing. In France, there was decline in heating intensity for single-family houses (from 11 to 10 MWh), and a slight decline for multi-family housing. In Denmark, there was considerable decline for both housing types (from 14 to 10 MWh and from 10 to 6 MWh, respectively).

Conversions to electric space heating had an upward effect on intensity in Norway, Sweden, and France. This was because the shells of converted homes were not as tight as those used in electrically-heated buildings constructed after 1975. The relative improvement over time in new homes varied among the countries. In France, the pre-1975 stock of electrically-heated SFD used 11.2 MWh/home in 1983, while the post-1975 stock averaged only 9 MWh. A similar drop occurred in Sweden, and, taking account for the use of wood, in Norway as well. Since electrically-heated homes were initially the best insulated in most countries, these further improvements are noteworthy.

3.2. Water Heating

3.2.1. Market penetration of electricity

The percentage of homes with electric water heating has increased in most countries (Table 3.7). Growth was especially strong in France, Italy, and Sweden.

The penetration of electric water heaters is significantly higher than that of space heating except in Sweden and Denmark. Electric water heating was common in European homes long before space heating. It was installed in many dwellings independently from the heating fuel choice, especially in non-centrally heated homes. This has been very common in Italy, Holland, Germany, the U.K., and Japan, where electric point-of-use systems remained popular even with the arrival of oil and gas heating. Homes where electric space heating was chosen frequently used the same fuel for their water heating systems. This is common in Scandinavia, the U.S., and France. Finally, increasing numbers of homes with oil-based space-and-hot-water heating systems (in the U.S, Canada, Germany, Sweden, Denmark, Norway, and more recently, England) acquired electric water heaters because these allow the oil system to be turned off in the non-heating months.

Table 3.7. Electric Share of the Water Heating Market (percent of homes*)

	1972/73	1983		1972/73	1983
Canada	48	51	Denmark	4	10
France	18	28	Germany	46	45
Great Britain	40	33	Italy	35	51
Japan	4	7	Netherlands	21	18
Norway	80	90	Sweden	9	26
United States	27	32	AVERAGE	30	36

* Based on share with respect to all homes.

Boilers are gradually gaining in popularity over point-of-use systems in Europe. Larger tanks have come to dominate the market in the U.K. and Holland, and even in France and Germany; these were always the main forms in North America and Scandinavia. Part of this difference in structure in Europe is due to the fact that most washing machines and dishwashers are coupled to cold tap water, and heat water electrically from within the machine, therefore lowering the water heating system load.

3.2.2. Intensity

Estimates of electric water heating intensity are very rough. Scattered measurements and estimates suggest that there have been some changes, and that these differed among countries (see Table A-3 in the Appendix). There appears to have been a slight decline since 1973 in Canada, Great Britain, and the U.S. In general, the decline in average household size probably pushed consumption down, while greater penetration of boilers has pushed consumption up.

More clear than the changes over time are the large differences among countries in intensity. Estimated average electricity use for water heating ranges from 1-2 MWh in central Europe to 4-5 MWh in North America. This reflects diversity in technologies as well as in habits (see Chapter 4).

3.3. Cooking

3.3.1. Market penetration of electricity

Electric cooking gained market share at the expense of solids, gas and LPG. It gained everywhere over city gas and over natural gas in Germany, Canada, and the U.S., but lost in importance to gas in the U.K. In France, electricity's share rose in the 1970s, while in Italy gas cooking has always dominated the market. In Holland, Italy, and France, mixed electric/gas systems have become common. The penetration of electric cooking equipment is largely a result of fuel choices in new homes, and electric connections are typically less expensive than gas connections.

Table 3.8. Electric Share of the Cooking Market (percent of homes)

	1972/73	1983		1972/73	1983
Canada	82	91	Denmark	54	75
France	39	46	Germany	63	76
Great Britain	41	38	Italy	2	4
Japan	52	56	Netherlands	9	11
Norway	95	100	Sweden	85	94
United States	39	54	AVERAGE	51	59

Electric cooking has diversified from a single principal stove/cooker to include a variety of specialized devices. The penetration of microwave ovens, principally since 1980, has grown to over 42% of homes in Japan in 1985, 20% of homes in the U.S. and Canada, and to around 15% in Norway and the U.K. It remains at less than 2% in Germany, Sweden, and the Netherlands, but is growing rapidly there now. Electric juicers, egg cookers, coffee makers, deep fryers, toasters, and other devices appear on surveys in most countries. Since many of these produce cooking heat or hot water, they relieve the main stove of much of its work. These devices represent what the Japanese utilities call "quality intensive" household appliances; they make kitchen tasks easier and actually save energy.

3.3.2. Intensity

Average electricity consumption for cooking is even more difficult to estimate than for hot water. Two factors that have affected it are change in the number and extent of meals taken at home and the transfer of functions to small specialized appliances. It is likely that use of these appliances saves electricity. Smaller volumes are heated for far less time than when water is boiled on a stove for coffee, or when two potatoes are baked in a large oven.

The few estimates quantifying electric cooking intensity show a slow decrease over time. Manufacturers report improvements in the efficiency of new stoves and ovens. Family size, habits, and house occupancy (i.e., the number of meals cooked at home) have changed since 1970. These changes could well have caused a greater effect than that of higher efficiency of new equipment, which turns over slowly. In Sweden, unit consumption of city gas for cooking in homes with only cooking stoves decreased by 60% over 25 years. Causes for this include smaller families and less eating at home today than in the 1960s, and preparation of simpler meals. Typically, both spouses now work, and children get hot meals in school.

3.4. Electric Appliances

This end-use category includes "electric-specific" uses. That means uses that exclusively or almost exclusively use electricity. This includes food refrigeration and freezing, clotheswashing and drying, dishwashing, lighting, TV and video equipment, and the numerous other small home appliances.

Estimated average electricity consumption per household for appliances as a group grew considerably in most of the countries (Figure 3.2). There was no or only modest increase in the U.S., Denmark, and the Netherlands. In most countries, however, the increase of the early and mid-1970s slowed noticeably by the end of the decade. The growth came about because the average household gained more appliances. Moreover, certain important appliances, notably refrigerators, freezers, and clotheswashers, grew in sizer and features, increasing electricity use significantly. After around 1975, new, more efficient appliances entered the stock, and these pushed downward on average consumption. Size and features still increased in some cases. In most countries, estimated consumption per household stagnated or fell in the early 1980s. In some countries, increases in appliance size or number of features have led to higher consumption, even as efficiency has increased.

The main reason for the different trend in the U.S. from much of Europe was that the penetration of electric appliances was at a more advanced stage in the U.S. in 1970. Despite the "catching up" of Europe and Japan, average consumption is still higher in the U.S. by a factor of two or more. This is a function of both structure (penetration and characteristics of appliances) and intensity (average use per unit of service), which we discuss below.

3.4.1. Market penetration and structural change

Growth in the penetration of major appliances was higher in Europe and Japan than in the U.S. between 1970 and 1983 due to the reason mentioned above. (See Table 3.9). This pushed up electricity use significantly in those countries. The relative increases in penetration have been greatest in France, Germany, Japan, and Italy. The increase in Sweden was caused principally by growth in the fraction of households occupying SFD. Saturations are higher in SFD, not simply because incomes tend to be higher, but because living space is greater.

Penetration of refrigerators was already high (85-100%) in 1972, but many of them did not have a freezer compartment. The penetration of refrigerators with a freezer compartment was strong in Europe in the 1970s. Growth in penetration of separate freezers, which are major electricity users, has been considerable everywhere except in Japan and the U.S. For the U.S., this was perhaps because refrigerators have large freezer compartments.

Penetration of clotheswashers also increased everywhere except in Japan and the U.S. These appliances heat their water internally outside the U.S. and are thus bigger consumers. Clothesdryers have not penetrated very much outside the U.S. except in the U.K.

For France and Germany, growth in penetration of dishwashers was an important factor. This was also an area of growth in the U.S., though these appliances in Europe are higher electricity users because they heat their water internally. There has been almost no penetration of dishwashers in Japan.

Table 3.9. Market Penetration of Major Electric Appliances (% of homes)

	Refrigerator*		Freezer		Clotheswasher		Dryer		Dishwasher	
	1972/73	1983	1972/73	1983	1972/73	1983	1972/73	1983	1972/73	1983
Canada	99	100	37	55	45	67	42	62	11	34
Denmark	97	100	46	61	44	62	1	11	7	21
France	87	100	8	34	65	87	0	1	5	21
Germany	89	100	25	52	71	86	2	10	6	23
Great Britain	71	96	3	32	67	80	26	38	1	2
Italy	87	97	1	14	62	80	0	2	6	11
Japan	100	100	0	0	96	98	0	9	0	1
Netherlands	91	97	19	46	86	88	6	12	3	11
Norway	89	97	57	75	72	79	22	30	3	17
Sweden	94	99	60	83	49	60	9	21	11	30
United States	99	100	34	37	70	70	38	45	25	36

* By 1983 some households had more than one refrigerator in most countries.

The market penetration of smaller appliances -- color TV, VCRs, and smaller devices -- has also increased, though this has not had a large effect on consumption. Color TV penetration rose to above 90% in most countries, and in all there is more than one TV (color or BW) per household. VCRs have also proliferated at a high rate. Penetration in 1984 was between 20% and 30% in most countries, and as with microwave ovens, has grown principally since 1980. They are not an important source of kWh sales, however.

Along with growing penetration, there has been increase in appliance size and features. A 1981 survey in Denmark found that 70% of the refrigerators built before 1970 were less than 175 liters in volume, but only 50% of all refrigerators were that small in 1981. We estimate that new models of refrigerators grew by 22% in volume between 1970 and 1980. Danish households were already well appointed in 1970; we believe that growth in volume was even stronger in Great Britain, Central Europe, and Japan. It appears that average volume more than doubled in Japan, and the presence of freezer compartments became more widespread. There has also been increased penetration of the frost-free feature, which increases electricity use.

3.4.2. Intensity

Average consumption is determined by the efficiency, size, and features of the appliances as well as by usage patterns. It appears that changes in the latter have not been a major factor. Though there are few measurements that would allow assessment of changes in average unit consumption of particular appliances, estimates indicate change in some areas (Table 3.10).

Average consumption of refrigerators and freezers has increased in many countries because greater size and use of automatic defrost has had more effect than improved efficiency. The U.S. is the exception to this, as these appliances were already large in the early 1970s, and the considerable efficiency improvement in new appliances brought average consumption down. For the other major appliances, the estimates show either decline in average consumption or no change.

Table 3.10. Unit Consumption of Major Electric Appliances (kWh)
(Average over Entire Stock)

	Refrigerator[a]		Freezer		Clotheswasher[e]		Dryer		Dishwasher[e]	
	1972/73	1983	1972/73	1983	1972/73	1983	1972/73	1983	1972/73	1983
Canada	-	-	-	-	-	-	-	-	-	-
Denmark	730	700	700	900	545	480	450	400	435	475
France[b]	425	540	740	720	300	300	-	-	470	440
Germany	375	480	680	580	350	280	450	290	-	400
Great Britain	300	300	975	780	200	200	300	300	500	500
Italy	180	220	490[c]	470	450	410	540[c]	500	1000	1050
Japan	700	600	-	-	-	37	-	-	-	-
Netherlands	440	400	520	550	455	275	-	400	875	475
Norway	600	600	750	750	500	500	600	600	-	300
Sweden	600	510	1040	900	500	350	400	225	-	295
United States[d]	1400	1290	1390	1220	90	85	1110	1080	250	250

(a) The 1983 values include a higher proportion of units with freezer compartments. (b) First year is 1975. (c) 1980. (d) First year is 1977. (e) Washers and Dishwashers vary as to the proportion producing hot water themselves or drawing from hot-water tanks. Washers do not heat water in the U.S. and Japan.

Lighting is an important consumer in this end-use category. We suspect that average consumption declined somewhat, due both to energy-conserving behavior and the increased use of flourescent lights.

New appliance efficiency. The average efficiency of new appliances has improved markedly in Europe and North America (Table 3.11). All European manufacturers (Philips of Holland, Electrolux of Sweden, and those in ZVEI, the Central Group of the Appliance Industry in Germany) report significant improvements in their appliances since 1975. These were paralleled in Japan for TV, air conditioning, and refrigerators. The largest improvements have affected refrigerators and freezers.

Table 3.11. Reduction in Electricity Consumption of New Electric Appliances

Country	Refrigerator	Freezer	Washer	Dryer	Dishwasher	Oven	Cooling	Years
				(% reduction)				
Denmark	25-35	30	25	10	24	15	-	70-84
Germany	24	-	15	-	27	14	-	78-84
Japan	60	-	-	-	-	-	32	73-84
Netherlands	30	27	70	-	26	-	-	71-83
Sweden	-	56	-	-	33	-	-	75-83
United States	42	37	-	-	-	-	23/20*	72-84

In Germany, the Netherlands, and the U.S., figures represent sales-weighted averages (expected annual consumption for different models of each kind of appliance, weighted by the actual appliances sold). For Sweden, the improvements reflect those demonstrated by Electrolux (the largest seller). For Denmark, a rough estimate of sales-weighted average improvement was made by Statens Husholdningsraad.

* The figures refer to central and room air-conditioners respectively.

Data from Danish and Swedish surveys show that when households with similar appliances are compared, consumption in households with more recently purchased devices use less electricity than those with older devices. Since most appliances run relatively independently of consumer behavior (excepting hot-water using devices), the stagnation in use/household even with rising saturation is an indication that the newer models really use less electricity. In the countries with higher incomes, this suggests that growth in size or features has not been enough to overcome the greater efficiency.

3.5. Overview of Changes for Residential Electricity

For all of the countries together, about half of the 43% total growth in electricity demand between 1972/73 and 1983 was caused by increase in the number of homes. The rest was caused by more electricity use per home. Figure 3.3 illustrates the changing contribution of the different end-use markets to change in demand per capita. Much of the increase in electricity demand per capita was due to growth in the heating market. Overall, total consumption for home heating grew by 60-65%, while consumption for all other uses grew by only 12%.

Structural growth was slowing, even in the heating market, by the early 1980s, and conservation was beginning to have a notable impact on use through replacement of older equipment. As a result, growth in per capita use slowed after 1979 in most countries.

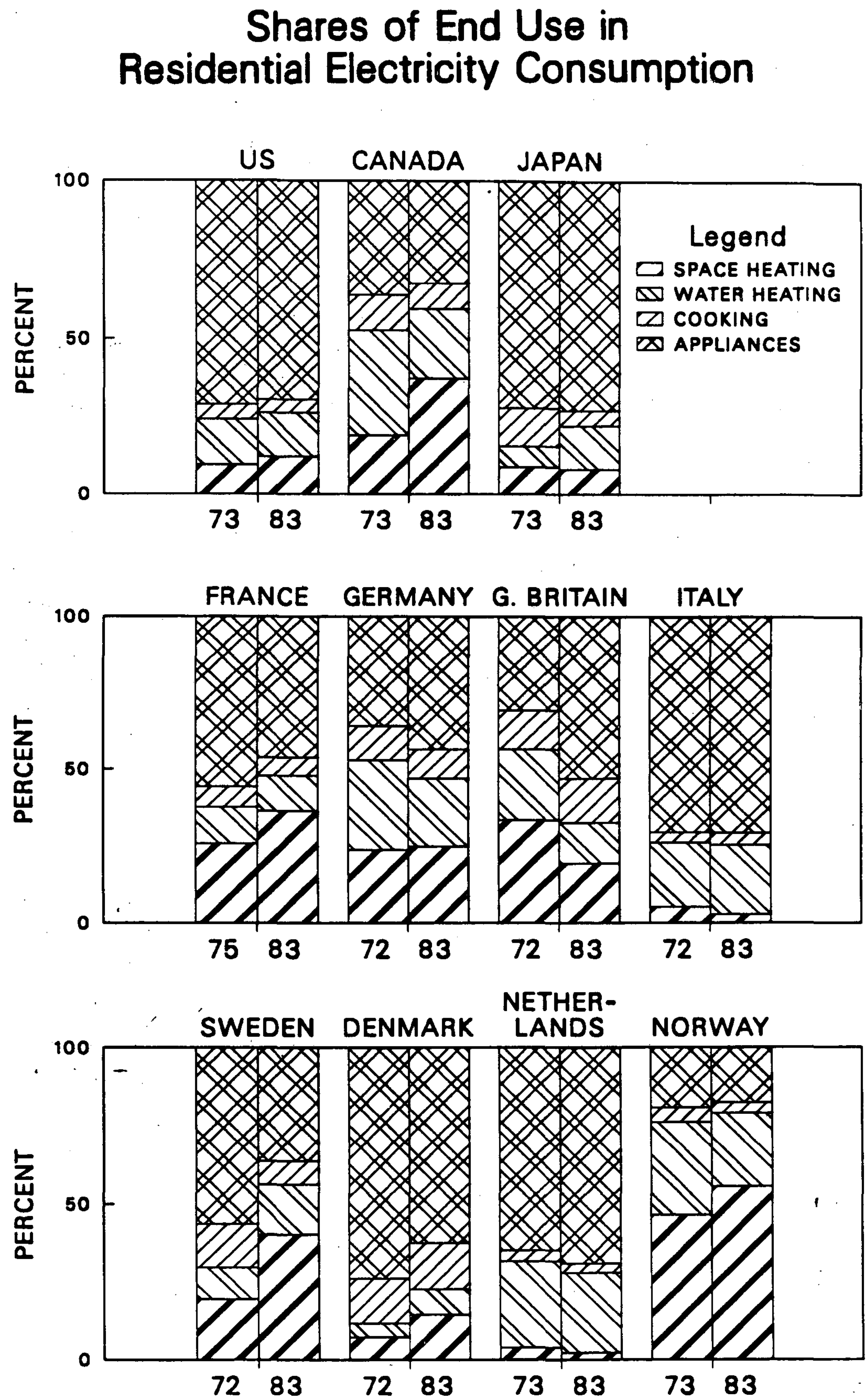

Figure 3.1

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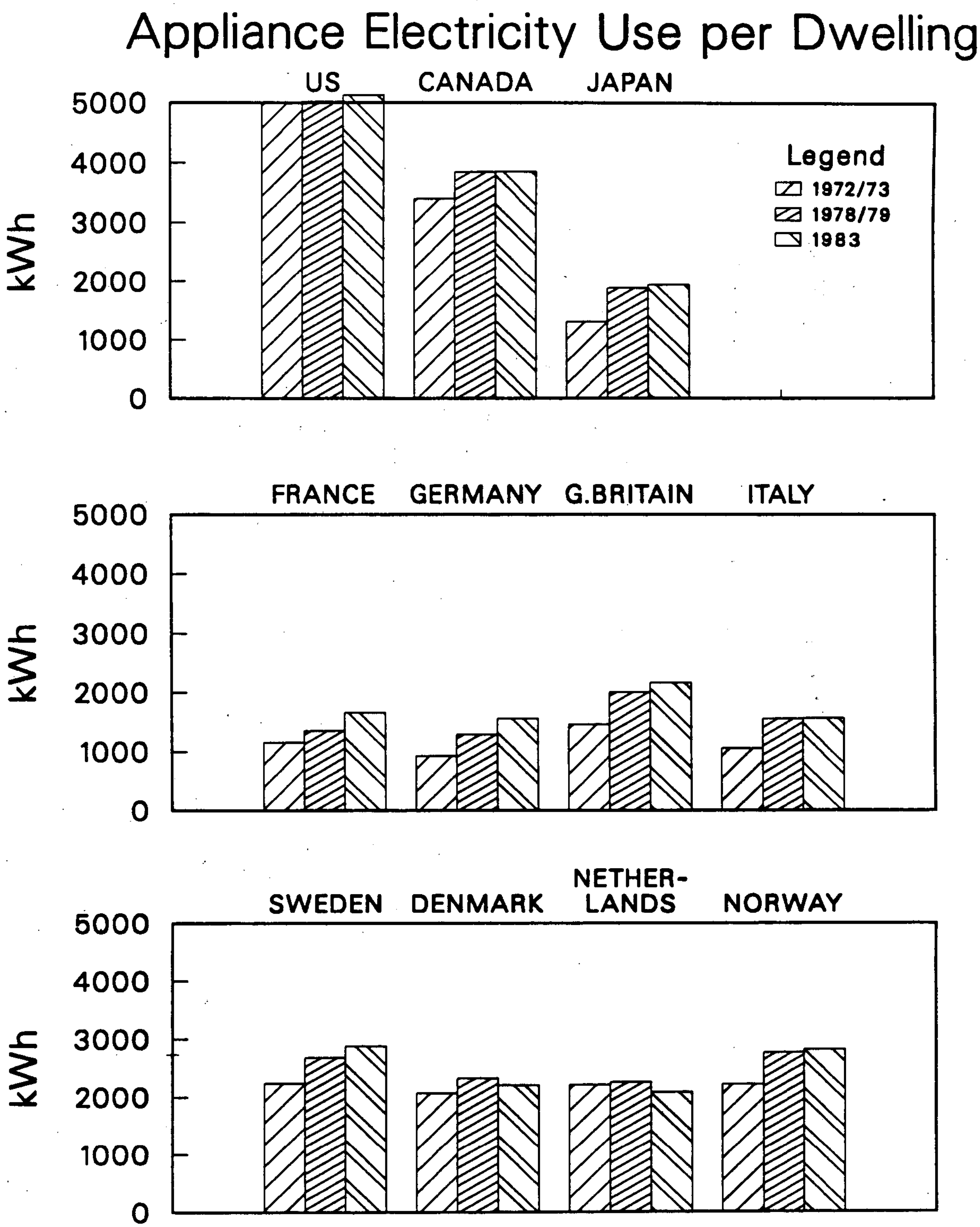
Appliance Electricity Use per Dwelling
US
CANADA
JAPAN
Legend
1972/73
1978/79
1983
FRANCE
GERMANY
G.BRITAIN
ITALY
SWEDEN
DENMARK
NETHER-
LANDS
NORWAY
kWh
5000
4000
3000
2000
1000
0

Figure 3.2

Electricity Use per Capita by End Use

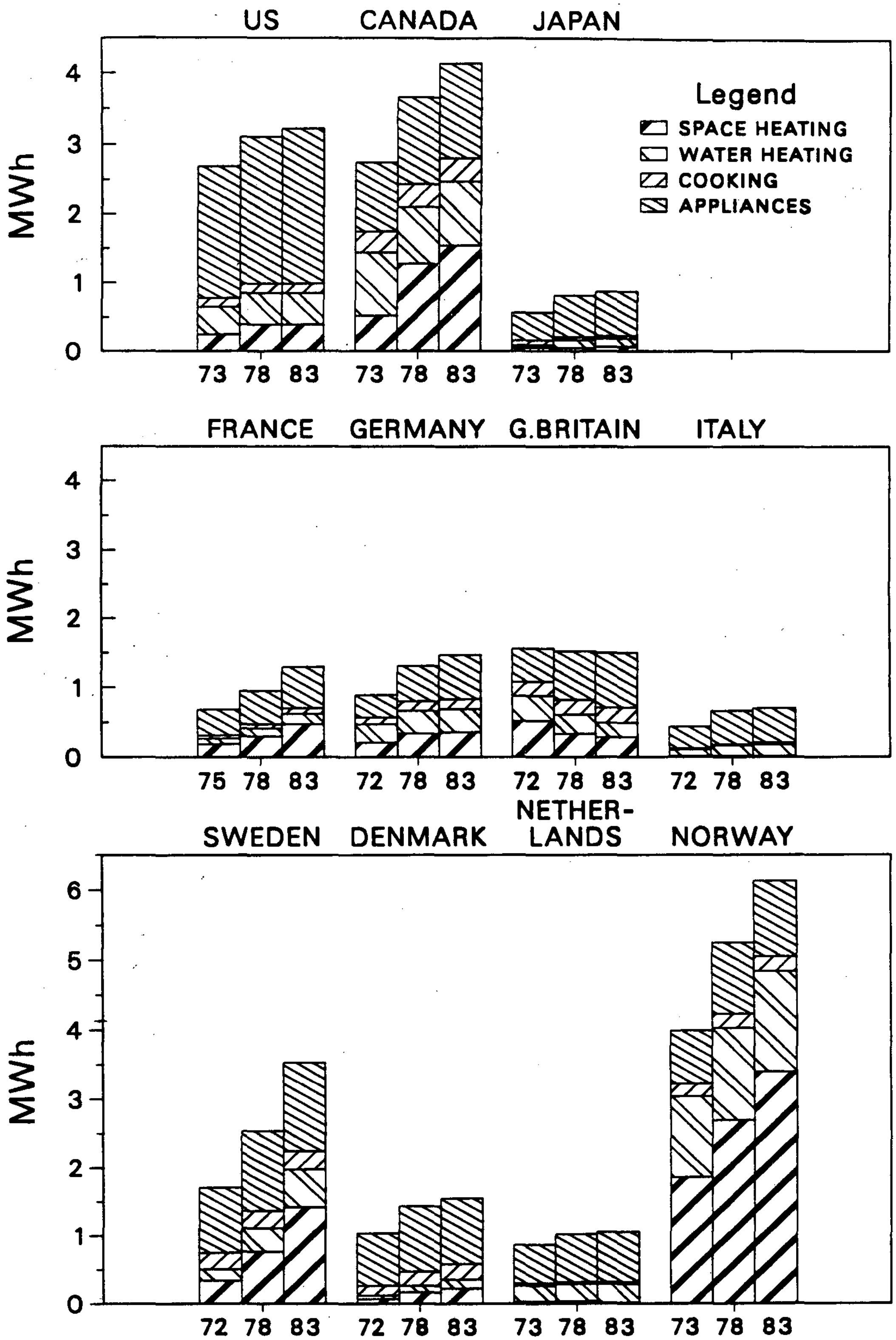

Figure 3.3

4. Explaining the Differences Among Countries

There are considerable differences among the OECD countries in both electricity's market penetration and average consumption in each end-use market. In the U.S., electricity has a relatively high market penetration in space heating, and is about in the middle of the pack in water heating and cooking. Saturation of most appliances is highest in the U.S., but the difference is much less than 10 years ago. The long-run level of electricity prices relative to competing fuels is clearly an important determinant of market penetration. Income is also important in the appliance market, where households in the lower-income countries have fewer and smaller devices. Behavior partly explains differences in heating and hot water use.

Average consumption for water heating and appliances is much higher in the U.S. and Canada than in Europe and Japan. Denmark, Sweden and Norway come closest to the U.S. This reflects the high income level of these countries. The size and efficiency of devices are generally more responsible for the differences than are household use habits, though the latter influence the former over the long run. European appliances are on average smaller, and probably more efficient, than those in North American homes.

Electricity consumption per household differs considerably among the OECD countries, as we described in Chapter 1. Both structure and intensity account for differences between the U.S. and Europe. Among European countries, structural differences are greater than differences in intensity. In this section we look to the end-use markets, considering both structure and intensity, to uncover the reasons for inter-country differences.

Some structural elements of the residential sector as a whole affect more than one end-use market. Household size is important for water heating and some appliances. The U.S. and Canada have more persons per household than the Scandanavian countries and Germany (see Table 1.3). Dwelling size and type affect consumption for space heating as well as for appliances. The average house is far larger in the U.S. than in the other high-income countries, and larger houses admit larger appliances, particularly in kitchens.

Families in multi-family dwellings (MFD) are smaller than those in single-family dwellings (SFD) and, with smaller incomes and significantly less living area, tend to have fewer major appliances. In the U.S., Canada, the U.K., and the Netherlands, SFD dominate (roughly 70% of the stock), although these tend to be the semi-detached types in the latter two countries. In the other countries, MFD have roughly equal or greater share (see Table 4.1).

Many of these differences are related to income. In the U.S., higher incomes (and low taxes) permitted families to own large homes, and permitted people to live alone, rather than remaining longer in the family nest. Income and tax policies also play a role in determining the appliances and other equipment that come a new home.

4.1. Space Heating

4.1.1. Market penetration

The penetration of electricity as primary heating fuel ranged from near nil in Japan and the Netherlands to near 50% in Norway in 1983 (see Table 3.3). The U.S. level of 18% was higher than most countries. Not surprisingly, the countries with the highest electricity prices show the lowest penetration (Denmark, Germany, Japan, Netherlands), and the countries with the lowest prices show the highest penetration (Sweden, Norway, Canada). The U.S. and France are intermediate.[1]

The high penetration in Sweden and Norway is partly due to the massive conversions to electricity after 1979. In Canada, conversion also contributed to the rise of electric heating. In Germany, France, Denmark, and the U.S., electric heating rose principally because of fuel choices made in new homes.

Low electricity prices help electricity to penetrate the heating market, but other factors are also at work. Electricity does not compete directly with other fuels everywhere in a country. The extent of the piped gas network influences the overall level of electricity penetration. In the U.K., nearly 50% of the electric heating systems lay where piped gas was not present in 1983. In the U.S., this percentage was 65% in 1982 among single-family dwellings. Where district heat is available for apartments, electricity loses out in what would otherwise be a favorable market for it.

Social and economic factors also influence electricity penetration. In many countries income or social class is associated with particular heating systems. In Great Britain and Germany, for example, storage systems based on electricity are found mostly in rental housing, and more among lower income classes than are oil- or gas-based heating systems. In France, electric heating is more diffused in smaller apartments that are occupied by lower income households.

Electric heating has penetrated different strati of the dwelling stock in different countries. Penetration of electric heating in new apartments in many countries was higher than it was in new single-family dwellings. Housing policies and financing play a role here. In Sweden before 1973, electric heating had lower initial costs and dominated new construction initiated by builders, while oil heating dominated new construction initiated directly by final buyers, and had considerably lower running costs.

The penetration of different heating technologies differs considerably among countries. In the countries where electric heating as a principal source is found in more than 5% of homes, storage systems, furnaces/boilers, heat pumps, and direct resistance all share the total picture,

[1] The French and U.S. heating markets have many similarities: climate, high share of electric heating among new homes, high price of electricity compared with fuels. In both, the growth in new homes heated with electricity is the major factor adding load. A difference is the relative high share of heat pumps in the U.S.

with each strong in one or two countries. Heat pumps are most popular in the U.S. due to the relatively warm climate and the demand for air conditioning.

4.1.2. Intensity

Differences in average intensity (adjusted to similar climate) over all electrically-heated homes reflect differences in the thermal integrity of homes, the occupant behavior (ie., indoor temperature, heating hours), the type and efficiency of the heating system, the mix of dwellings in the electric-heated stock and dwelling size,[2] and the prevalence of secondary heating fuels. These differences in the structure of electric heating mean that one must be careful in comparing electricity use per electrically-heated dwelling.

Table 4.1. Electricity Intensity for Space Heating, 1983 (per degree-day)

	kWh/dw	kJ/m^2	SFD Share		kWh/dw	kJ/m^2	SFD Share
Canada	4.2	150	55	Denmark	2.5	95	73
France	2.9	122	56	Germany	3.0	144	44
Great Britain	2.0	102	35	Norway	3.1	124	74
Sweden	2.3	69	91	United States	2.7	81	56
AVERAGE	2.8	110	60				

Long-term heating degree-day values, with base 18 C, are as follows: Canada - 4580, Denmark - 3122, France - 2450, Germany - 3113, Great Britain - 2823, Italy - 2140, Japan - 1975, Norway - 4069, Sweden - 4011, U.S. - 2172.

Estimated unit consumption for electric heating, adjusted for climate and home living area,[3] is lowest in Sweden. Given that most of the electrically-heated stock in Sweden is composed of detached houses, this low value is testimony to the tightness of Swedish homes. The U.S. is next lowest, followed by Denmark. Tight building shells are responsible for the low values in Sweden and Denmark. In Denmark, many homes with electric heat also have kerosene or wood stoves for secondary heating. England is low because electric heating is primarily storage heating and is mostly found in multi-family housing, and because indoor temperatures are very low (electricity is used mainly among lower income groups). In the U.S., the widespread use of heat pumps may be partially responsible for the low value. The U.S. also has a lower share of single-family houses than the Scandanavian countries.

It is difficult to tell the degree to which behavior (low temperatures, intermittent heating, use of secondary fuels) rather than efficiency is the cause for low intensity in some countries. It appears that electricity prices may affect behavior more than efficiency. Surveys suggest that

[2] Apartments usually use less energy for heating per square meter due to their having less surface area exposed to the outside (because of shared walls and ceilings).

[3] We have estimated home living area for some countries based on data for all homes, but data from Denmark, France, Norway, Sweden, and the U.S. refer to homes with electric heating.

Swedish households heat to the highest indoor temperatures (20.5 C averaged around the house during the winter), with Norwegian and Canadian homes a few degrees lower. In the U.S., the average daytime temperature for electrically-heated homes was around 21 C in 1982. By far the lowest reported temperatures were in British (15-16 C) and Japanese (13-14 C) dwellings; electricity is expensive in both countries (though there are also other reasons for the low temperatures).

Historically low electricity prices have not always led to low efficiency in electric heating. Swedish building practices evolved far faster than in any other country towards efficiency over a long period of time, even as electricity prices remained relatively low. Canada and Norway, also low-price countries, and colder than Sweden, might be expected to use more insulation but this is not the case. In 1984, new electrically heated homes in Sweden used 20-30 cm of mineral wool in their walls, vs. 15-20 cm in Norway and 10-15 cm in Canada. The reason is that Swedish authorities have since 1963 included financing of insulation in new-home loans; no such features were included in home-loans in any other country (often homes supported by state grants did require a degree of insulation higher than otherwise used, but these homes never represented the high share they did in Sweden (80-95%). Significantly, Swedish homes were built to *better* than code requirements since the early 1960s. Indeed, we believe that the evolution of tight houses encouraged the development of electric heating when oil was otherwise significantly less costly.[4]

4.2. Water Heating

4.2.1. Market penetration

Electricity's share of the water heating market ranges from 7% in Japan up to 90% in Norway (see Table 3.7). Mostly, it is between 25% and 50%. The U.S. is intermediate at around 32%. Electricity prices clearly play a role here, though point-of-use electric water heating was prevalent in the 1960s even where prices were high because of the lack of central hot water systems.

4.2.2. Intensity

Intensities for water heating reflect quantities (and temperatures) of water consumed as well as differences in efficiency. Intensity is much lower in central Europe than in Scandinavia and N. America. The difference probably reflects the use of instantaneous heaters (as opposed to central hot water tanks) in central Europe as well as different bathing habits. Additionally, most washers and dishwashers in Europe heat their own water independent of the main system. This is partly because, unlike in the U.S., many homes in Europe did not have centrally-

[4] See Schipper, L., Kelly, H., and S. Meyers, 1985. *Coming in From the Cold.* Cabin John, MD: Seven Locks Press.

supplied hot water when clothes and dishwashers became popular.

Table 4.2. Electricity Intensity for Water Heating, 1983 (MWh/dw)

Canada	5.1	Denmark	3.0
France	1.5	Germany	1.1
Great Britain	1.0	Italy	0.8
Japan	4.0	Netherlands	1.9
Norway	4.0	Sweden	3.5
United States	4.0	AVERAGE	2.7

The data suggest that use is significantly higher in countries that have the highest incomes, and, with the exception of Denmark and the U.S., the lowest electricity prices. In the "low user" countries tanks are smaller and point-of-use much more common than in the high-user countries.

4.3. Cooking

4.3.1. Market penetration

The penetration of electricity as main cooking fuel ranges from only 4% in Italy to 100% in Norway (see Table 3.8). The U.S. in 1983 was at 50%; this is less than most countries. The relative prices of electricity and gas are clearly important. Where gas is available and relatively inexpensive (Great Britain, the Netherlands, and the U.S.), the electricity share is lower. Electricity has gained market share in Germany and France despite the expanding availability of gas. It has also gained somewhat in the U.S.

4.3.2. Intensity

Estimates of average consumption for electric cooking are rough, but it appears that consumption is lower in Europe than in the U.S. and Canada. This could be due to the size of ovens. In many countries electric cooking is found in much greater proportion in SFD (where gas is unavailable), accounting in part for high level of use.

Table 4.3. Electricity Intensity for Cooking, 1983 (MWh/dw)

Canada	1.3	Denmark	0.7
France	0.9	Germany	0.5
Great Britain	0.9	Italy	0.9
Japan	-	Netherlands	0.8
Norway	0.6	Sweden	0.5
United States	0.7	AVERAGE	0.8

4.4. Electric Appliances

The electricity intensity shown in Table 4.4 is a function of the penetration of different devices, their efficiency, size and features, and their usage by people. The price of electricity and income shape these factors. Average electricity consumption for appliances and lighting in 1983 ranged from a high of over 5000 kWh/hh in the U.S. to a low of around 1600 kWh/hh in Germany and Italy. Appliance ownership does not differ enough to explain the difference in consumption. Most of the difference is explained by the fact that North American appliances each use considerably more electricity than those in Europe. This results in part from habits (wash frequency, etc.) and the size and features of the appliances (such as the frost-free option in refrigerators). But it appears that European appliances are on average more efficient than those in North America.

Table 4.4. Electricity Intensity for Appliances*, 1983 (MWh/dw)

Canada	3.9	Denmark	2.2
France	1.7	Germany	1.6
Great Britain	2.2	Italy	1.6
Japan	1.9	Netherlands	2.1
Norway	2.8	Sweden	2.9
United States	4.3	AVERAGE	2.5

* Includes lighting.

When electricity use for appliances is normalized by income, we see that high level of use is somewhat correlated with low electricity price (see Figure 4.1). Income, which shapes ability to buy appliances, or to buy larger ones, pushes use up, while prices influence consumption through both size of appliance (or utilization) as well as through efficiency. The level of use in the U.S. is relatively high considering the level of electricity prices.

4.4.1. Market penetration

Market penetration of refrigerators, clothes washers, and TVs is roughly similar in all countries, while that of freezers, dishwashers and dryers varies significantly (see Table 3.9). Nearly all homes have a refrigerator, though this obscures the differences in size and features that exists. The penetration of clothes washers is lower in the U.S. than in some other countries. This may be due to the larger size of this appliance in the U.S. and the fact that renters tend not to have one of their own. The penetration of separate freezers is also lower in the U.S. than in some other countries. This may be due to the large freezer compartments that are standard on U.S. refrigerators.

In general, the higher the income, the greater the stock of appliances. Saturation of dishwashers in particular appears to depend on income levels. The high income countries -- the U.S., Canada, and Sweden -- have the highest saturations (37%, 34%, 31% respectively).

Germany, France, and Italy follow with levels ranging from 15% to 25%. The saturation of clothes dryers varies greatly around the countries in the study, from a high of 45% in the U.S. to a low of 10% in Denmark and Germany (and close to zero in Italy, France, and Japan). Habits and climate are important in determining penetration of clothes dryers.

4.4.2. Intensity

Size and features, efficiency, and usage all affect average consumption of appliances. Many appliances in N. America are larger than in Europe, and those in Scandinavia are larger than those elsewhere in Europe. In N. America, 18 cubic ft. (510 liters gross) is the average size for refrigerators. New models generally fall between 300 and 400 liters in Scandinavia, are somewhat less in England and on the continent, and are around 200 liters in Japan. (The largest model sold by Philips in 1985 held 450 liters, including freezer compartment.) The presence of smaller refrigerators reflects differences in food shopping habits as well as in kitchen size.

Appliance features differ among countries. In Europe, a classification system separates freezers that freeze fresh food solid and keep it for long periods from freezer compartments that can only keep already-frozen food a few days. Roughly half of the refrigerators in Scandinavia, Germany, and England have the former, vs. almost all in N. America. These consume considerably more electricity than do simple models that cool but do not freeze. Automatic defrost is the rule in Scandinavia, but is the exception in the rest of Europe and Japan. Most clotheswashers in Europe warm water within the machines, and at least half of all European machines are front-loading, which reduces water needs significantly.

In comparing particular American and European/Japanese appliances (principally refrigerators, freezers, and clothes washers), we find that there are differences in technologies that probably account for much of the difference in electricity use. It appears that American appliances -- particularly refrigerators, freezers, and washers -- are less efficient than those in Europe. This point of view was elicited from representatives of Philips, Electrolux, and ZVEI, and found as well in the Energy Report of the Dutch Appliance Industry. European manufacturers cited motor efficiency, compressor design, insulation, and overall design as contributing to the lower specific consumption of European appliances. Refrigerators are an example. The range in estimated average annual consumption, from 200-300 kWh/yr for refrigerators in Italy and Japan, to 600-800 kWh/yr in Scandinavia, to over 1000 kWh in the U.S., is too large to be explained only by differences in size and features. We judge that about half of the difference in consumption/liter between American and European refrigerators or freezers represents efficiency differences, with the rest representing features.

While there are great differences between N. America and Europe, there are few apparent differences in efficiency of appliances around Europe. This is because appliances are made and offered by the same firms. For example, most of the same models of refrigerators appear in the 1985 Philips catalogues for France, Sweden, Denmark, and Holland. Electrolux, Sweden's largest appliance maker, offers the same models in high-priced Denmark as in lower priced Sweden and

Norway. Our conversations with utility and appliance experts in each country reinforce the indication that it is the offering of the manufacturers, more than the choice of the consumer, that influences the efficiency of appliances the most (though it is true that the great difference in electricity price between Denmark and Sweden and Norway has led to more of the very-efficient models being sold in Denmark).

Household occupant behavior primarily affects lighting, washing, and drying. Estimates of average annual use per home for lighting vary from a few hundred kWh to 1500 kWh, with the U.S., Canada, Norway, and Sweden lying towards the high end of the range and Japan, France, Germany, and Denmark lying towards the lower end. Home size is one reason for the difference in levels, but habits, related to the price of electricity, are such that people use lighting more sparingly in Central Europe than in North America.

4.5. Overview of Determinants

Several factors share in determining national levels of average household electricity use. These include the degree of electricity penetration in the end-use markets, equipment efficiency and size, and user behavior. Climate is important in determining heating and air conditioning needs. Average electricity consumption is highest where electric space heating and hot water are prevalent, and where appliances are widespread.

Within any given end-use market, intensity varies by roughly $\pm$ 30%, with North America generally at the high end, Scandinavia in the middle, and Central Europe, Italy, and Japan at the low end. Intensity depends both on the equipment and its usage. Price affects efficiency, as rising prices provoke manufacturers to build more efficient appliances, and also the size and features of appliances. Households in low price countries appear to choose larger appliances. In Germany, Netherlands, and Denmark, appliance energy use is low, and prices are high. In the U.S. Norway, Sweden, and Canada, appliance use is higher and prices are lower.

Figure 4.2 shows the correlation between average electricity use per home in 1983 and the long-run average price of electricity (in US$). Historically low prices encourage electric heating and this results in high average use (Canada, Norway, Sweden, and to a certain extent the U.S.). Of course, climate also affects average usage. When only non-heating consumption is considered, the differences are smaller, although higher income and lower price countries still lead (Figure 4.3). The U.S. stands out in part because of the use of air conditioning, in part because of high appliance electricity consumption.

Household income is an important factor. The countries with the lowest incomes have the fewest appliances. In the U.S., income growth was highest in the 1960s and early 1970s, when stocks were accumulating, and this may partly explain why appliances have been larger. High incomes also contributed to the larger size of American homes, which permits larger kitchen appliances.

Lifestyle and habits explain some of the differences in electricity consumption levels. The most important cultural differences have to do with home heating habits. People in different countries live with different levels of comfort, though as building efficiency increases over time, we may see gradually less difference in heating habits. Societies also have different habits with respect to bathing, cooking, and the amount of time spent in the home. The amount of time spent in the home is conditioned by climate, urban geography, and cultural habits. Such habits are partly responsible for the higher level of residential electricity use in the U.S.

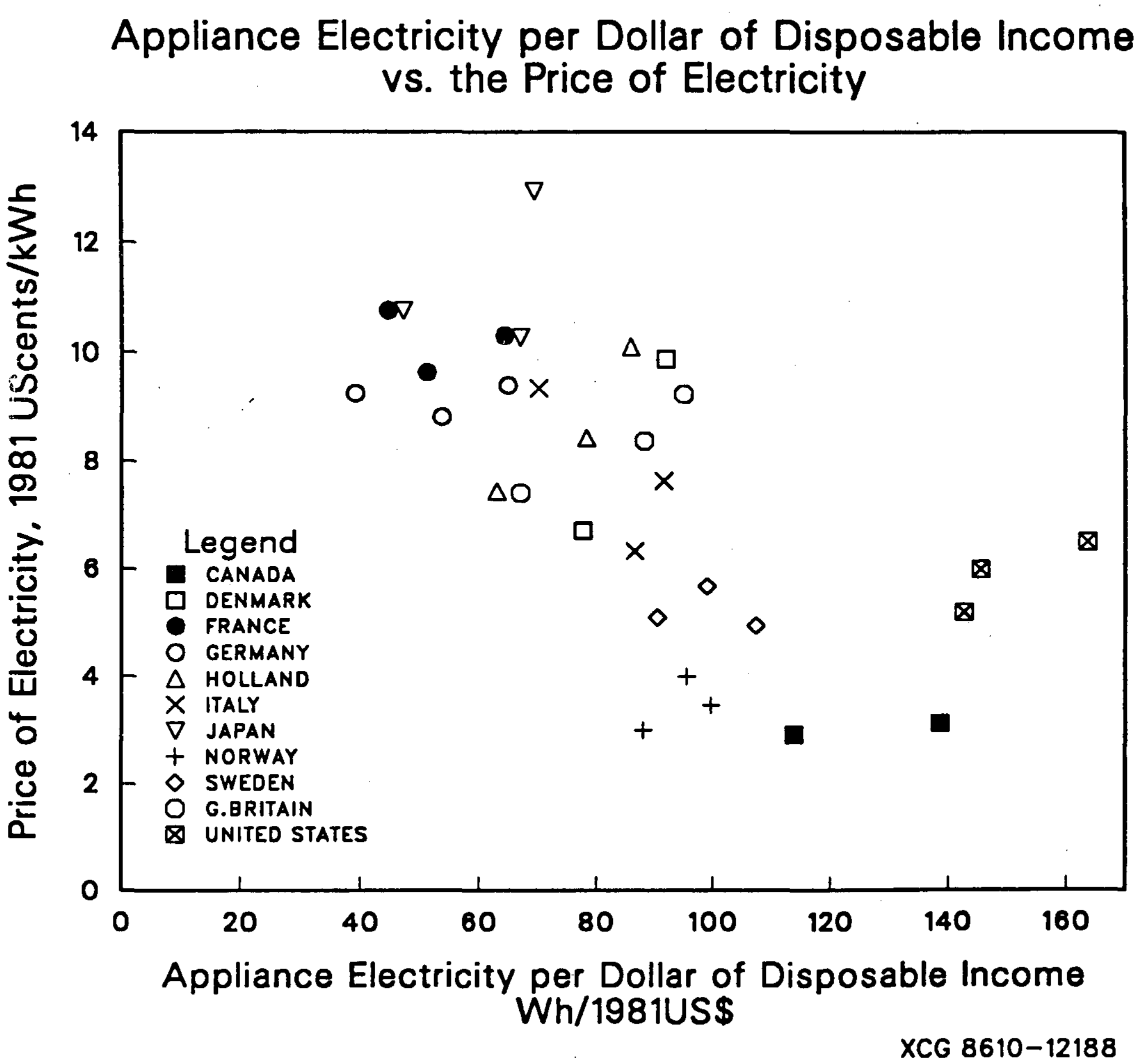
Appliance Electricity per Dollar of Disposable Income
vs. the Price of Electricity
Price of Electricity, 1981 UScents/kWh
0
2
4
6
8
10
12
14
0
20
40
60
80
100
120
140
160
Appliance Electricity per Dollar of Disposable Income
Wh/1981US$
Legend
CANADA
DENMARK
FRANCE
GERMANY
HOLLAND
ITALY
JAPAN
NORWAY
SWEDEN
G.BRITAIN
UNITED STATES
XCG 8610-12188

Figure 4.1

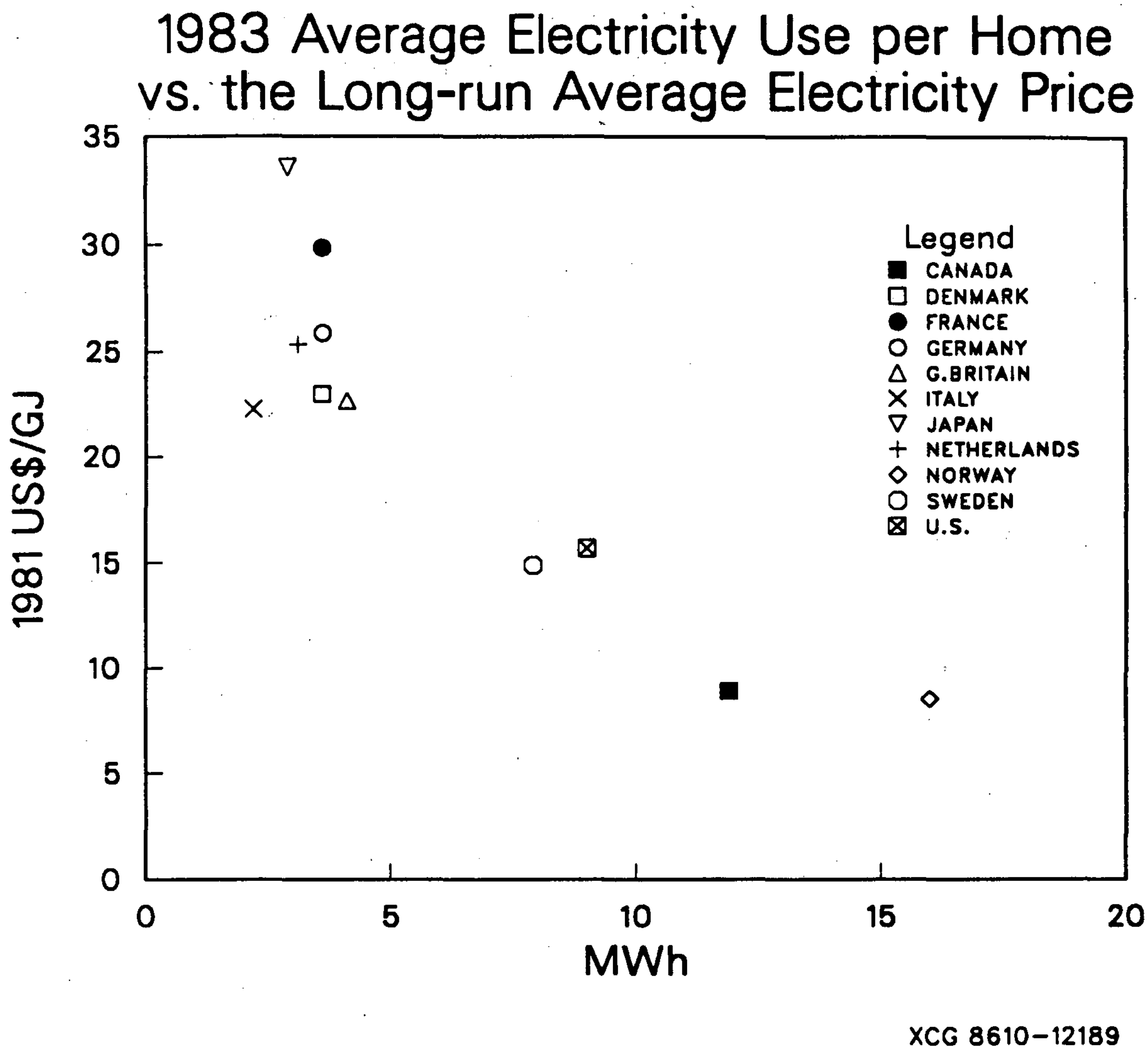
1983 Average Electricity Use per Home
vs. the Long-run Average Electricity Price
1981 US$/GJ
35
30
25
20
15
10
5
0
0
5
10
15
20
MWh
Legend
CANADA
DENMARK
FRANCE
GERMANY
G.BRITAIN
ITALY
JAPAN
NETHERLANDS
NORWAY
SWEDEN
U.S.
XCG 8610-12189

Figure 4.2

1983 Average Electricity Use per Home for Non-Heating Uses vs. the Long-run Average Electricity Price

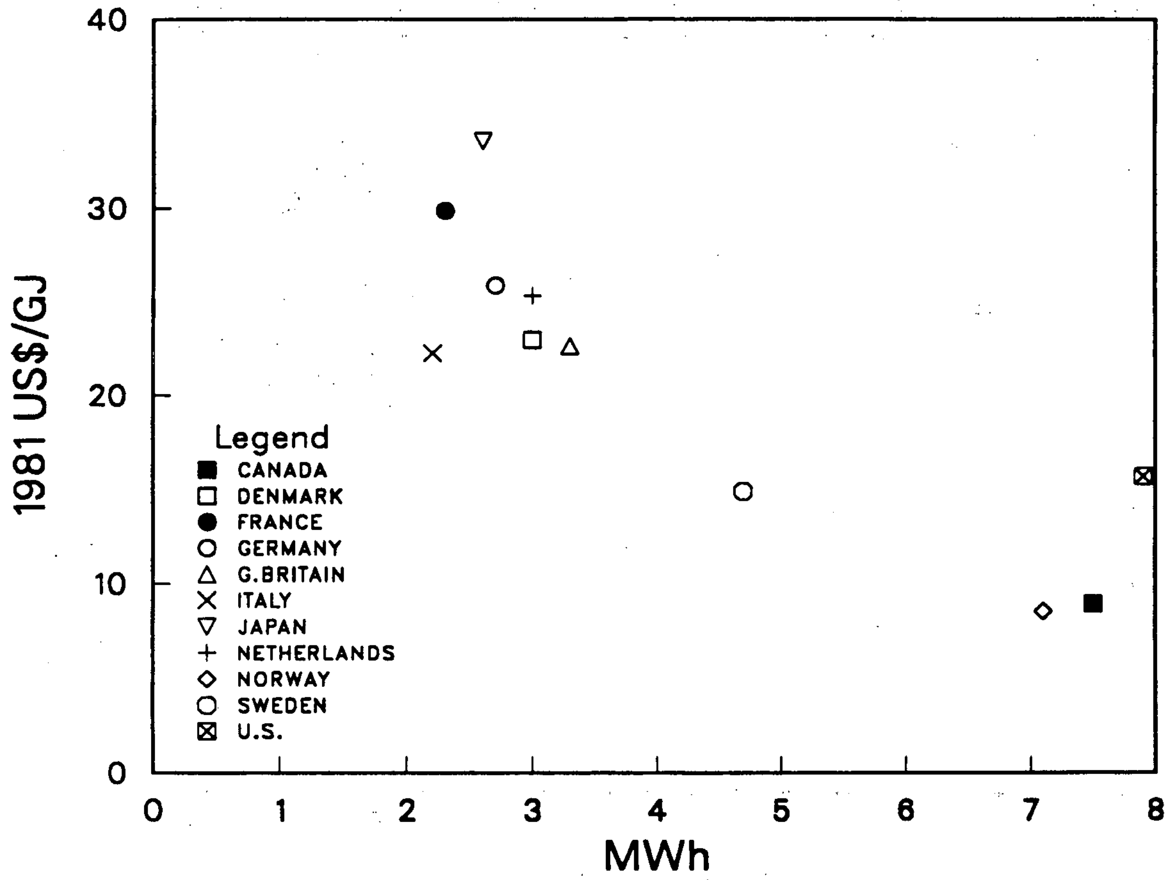

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Figure 4.3

5. The Direction of Residential Electricity Demand: Some Issues

Electricity is likely to increase its penetration in each end-use market, but each use is becoming more efficient. Increased efficiency may encourage greater electricity penetration, perhaps balancing the downward effect of increased efficiency on total sales. New uses -- computers and VCRs -- are generally low consumers, and tend to be capital intensive. The main potential growth areas for residential electricity use are space heating, water heating, and the three major appliances whose saturations are still under 50% in most countries: freezers, dishwashers, and clothes dryers. The major unsaturated market remains space heating. Although electric heat enjoys an important role in new construction in many countries, the housing turnover rate is slow. In the long run, construction of very heat-conserving homes and the trend toward more apartments are factors that seem to favor use of electric heat.

Future residential electricity demand will be shaped by changes in existing end-use markets and the penetration and intensity of new uses for electricity. In this chapter we discuss some key issues in these areas.

5.1. New Technologies for Today's Uses

Electricity penetration in the traditional end-use markets -- particularly space heating -- will be more important than growth of new uses. Since growth in the number of households is slowing in OECD countries, the possibility of conversions to electricity is important. Technological change that gives electricity a competitive edge will be important in both instances. Gains in efficiency that help electricity penetrate also tend to reduce unit consumption.

5.1.1. Space heating

In the U.S., the advance of electric heat pumps has probably allowed electric heating to gain market share that would otherwise have gone to natural gas. In Europe, electric heat pumps have penetrated the heating market much more modestly. This is largely due to the colder climates and the lack of demand for air conditioning. Ducted heating systems are also less common; most heat pump systems in Europe are hydronic. (In the U.S. the marginal cost of heat pumps is low because most new homes would have air ducts for a heating system and need an air conditioning device anyway. The same has occurred in Japan, where air conditioning units have a heat pump that provides supplementary heat) .

Outside of the U.S., the heat pump has enjoyed its best success as a primary heat source in Sweden. Swedish units, which have been aided by generous subsidies, use outdoor air, ground water, ground heat as heat sources. They are financially attractive only in older homes with high heating needs. Newer homes are so well insulated that most of the heating requirements come during the few months when the heat pump has its worst performance. In Germany and France, heat pumps were backed by public subsidies, but still gained only a small market share: about 2% and 5-6% of electrically heated homes, respectively (1983). About half of the German systems use fuel during the coldest periods; otherwise owners pay a higher charge for electricity. In France, the dominant heat pump system also uses an existing boiler as a complement for cold periods. In Japan, heat pumps with variable speed motors now serve as a source of supplementary heat in 25% of homes (60% of new air conditioners have this bimodal feature), but the final cost of this heat is too great to make the devices useful for heating entire houses. Typical consumption is only 500 kWh/yr.

The key point is that in Europe, heat pumps are seen as oil-savers, while in the U.S. they are electricity savers (compared in most cases to a system of electric resistance heating and air conditioning). Systems in Europe will suffer in popularity with the oil-price decline; this is not the case in the U.S.

5.1.2. Water heating

Two kinds of water-heating technologies in use in Europe stand out as different from those commonly used in the U.S. The first is the "quick-recovery" or "point-of-use" device, which may have a small amount of storage capacity. Such devices provide an energy-saving advantage since there are virtually no standby or circulation/distribution losses. In homes where hot water for dishwashers and clotheswashers is provided in the machines, these water heaters are efficient choices.

A newer technology is a heat pump that provides hot water. These have become popular (installed on as many as 25% of all new homes) in Sweden. They operate from the stream of exhaust air from the mechanical ventilation systems found in almost all new SFD and many existing MFD. When the house is outfitted with a hydronic space heating system, surplus heat can be used for space heating. The advantage of this system, which is not expensive, is that it works against a fairly constant load, domestic hot water demand being roughly constant through the year, and it works off the high temperature (20C) of exhaust air.

5.1.3. Appliances and lighting

Technological improvement has and will continue to increase the efficiency of electric appliances. In the countries with growing saturation (France, Italy, Japan), the relative number of newer, more efficient appliances increases rapidly. In the more saturated countries (U.S., Canada, Sweden, Denmark) further growth in penetration will be slow, and replacement will dominate change. This means that while unit consumption will fall only slowly, overall growth in consumption will be slower.

We believe that as ownership levels of major appliances approach market saturation, the major manufacturers will increasingly use quality as the major selling factor. Energy efficiency may be a byproduct of this. For example, better-insulated refrigerators run less and make less noise. The vacuum or microwave dryer, for example, will dry clothes with less noise and waste heat, and with less heating of clothes. Use of electronics promises to decrease electricity intensity and increase quality.[1] Increasing production for export from Japan, Taiwan, and Korea promises to push American and European manufacturers towards more electronics.

Electricity use for lighting appears poised to decline as all the major firms market mini-flourescent bulbs with incandescent-like spectra.

5.1.4. Some lessons for the U.S.

Electricity-using technologies in use in other countries could reduce electricity consumption if adopted in the U.S. Clotheswashers, refrigerators, and freezers, hot-water heat pumps from Sweden, and, most recently, halogen-lamp cooking elements (introduced by Philips and Thorn EMI in Europe) would reduce electicity use in existing applications. If the largest refrigerators, freezers, and clothes washers on sale in Europe today replaced those in the U.S., electricity use for these applications would decrease significantly, probably by 1/3. Very tight Swedish wooden houses with electric heating, now being assembled in many places in the U.S., would reduce electricity intensity for heating, but could also help electric heat to gain market share.

The key factor here is the manufacturers. Conversations with manufacturers and authorities in Europe downplay the importance of consumer decisionmaking in choice of efficient appliances. In countries where the major manufacturers have simply eliminated less efficient models, so that the traditional choice between models identical except for energy efficiency is gone, efficiency has shot upward, while in countries with choice (the U.S., the U.K., Canada) efficiency of many appliances has improved more slowly. None of the major European or Japanese manufacturers with whom we have spoken felt that incremental capital cost of more efficient designs was an issue. Given the strong opposition by U.S. appliance manufacturers to minimum efficiency standards, the U.S. could be left behind in the push for greater quality and energy efficiency if foreign manufacturers turn greater attention to the U.S. market.

5.2. New Uses for Electricity

There are many new uses for electricity that presently have low saturation, but they are mostly modest consumers of electricity. VCRs and home computers are becoming very popular, but these uses are time-intensive. The plethora of small kitchen appliances consume little and appear to save energy and electricity compared to using larger ovens for the same job. In a few colder countries (Sweden, Canada, Norway), electricity is used in growing amounts for saunas, auto engine block or passenger compartment heaters, but these do not appear to be signficant elsewhere. Security lighting could see greater penetration, but with the new generation of high

[1] See Walker, W., 1985. Information technology and the use of energy. *Energy* 13:5, 458-476.

efficiency bulbs (11 watts of a Philips or Osram lamp gives the effect of 60 watts) annual consumption would be only a few hundred kWh. Of course, it would be improper to assume that today's limits to imagination limit the new uses for electricity. But there is nothing on the horizon that seems likely to add significantly to average household consumption.

5.3. Demographic and Lifestyle Changes

Families are getting smaller, and the percentage of single-person households is growing. Populations are aging. These factors may increase the share of apartments in the housing stock. Apartment dwellers have less need for some appliances -- they may share a washer and dryer with other households -- and less space for others.

The work force is changing, as are work hours and workplaces. If these changes keep people at home more, some uses of electricity in the home could increase, and people might buy more electricity-using goods (with, however, minimal demands on electricity). More do-it-yourself work would increase demands for tools and time at home to work with them. If on the other hand, increased leisure time means that people spend more time away from home -- presumably managing home energy use with small computers -- more electricity use would effectivly be transferred from the residential to the commercial or transportation sector.

5.4. Outlook for Residential Electricity

Electricity is likely to increase its penetration in each end-use market, but each use is becoming more efficient. Increased efficiency may encourage greater electricity penetration, perhaps balancing the downward effect of increased efficiency on total sales. New uses for electricity are penetrating the market, but they are generally low electricity consumers and tend to be relatively capital-intensive.

Despite the attention on new uses of electricity, the main potential growth areas for residential electricity use are space heating, water heating, and the three major appliances whose saturations are still under 50% in most countries: freezers, dishwashers, and clothes dryers. The major unsaturated market remains space heating. Although electric heat enjoys an important role in new construction in many countries, the housing turnover rate is slow. This means that the growth in kWh sales arising from electric heating will only be rapid where conversions are occurring at a high rate. Even with high oil prices, this occurred only in three countries. In Germany, Denmark, and even in the U.S., electricity seems to penetrate principally where gas (or district heat) is unavailable. The outlook for electric heating before the oil price crash was mixed, and the near-term outlook must be judged as limited.

In the long run, several factors seem to favor electricity over other fuels in competitive markets. In the space heating market, very tight houses reduce the need for a heating system and thereby reduce heating system needs to a few electric resistance heaters. The trend toward smaller households (encouraged by the aging of the population) may mean more apartments, which are more likely to use electric heat. In the water heating market, point-of-use water heaters eliminate storage needs and pipes, and, compared with gas, have no need for exhaust. For cooking, increasing use of specialized electric cooking devices may lead to the all-electric kitchen becoming more common. Of course, the competitive situation in each country depends on equipment costs, reative prices, possible biases of homebuilders, and government policy.

The upward pressure on electricity sales from growing penetration may be balanced by the increasing efficiency of each use. The extent of this effect will depend on appliance manufacturers' offerings, possible government intervention in the market, and the rate of equipment turnover.

5.4.1. Directions for U.S. residential electricity use

In 1983, residential electricity use in the U.S. was around 7.5 MWh per home for non-heating uses, and 1.5 MWh per home for heating. We see the effects of increased efficiency, coming both from the U.S. and abroad, and the increases in penetration of uses, as pushing these values to around 8-9 MWh and 2-2.5 MWh, respectively. The non-heating figure depends more on efficiency than on structure, while the heating figure depends critically on the increase in penetration of electric heating. We do not foresee a great increase in average use for electric heating. Since about 20% of the dwellings that will be in existence in the year 2000 will be built in the next 15 years, and since electric heat has garnered 45-50% of new homes, this means that the share of homes with electric heating will increase from about 18% in 1983 to 25-30% in 2000. But with each new home comes a small average decrease in heating demand per home because of efficiency improvement.

This prognosis assumes that electricity prices remain near their 1985 levels in real terms. Higher prices would decrease the market share of electricity and intensity somewhat, lower prices the reverse, although the reactions are not symetrical and deserve special study. The main features that we see are the following.

• Increase in the share of electric heating, principally through the new home market, will push sales upward. A similar trend will occur for hot water, and more homes using oil/wood for space heating will use electricity for water heating. Electric cooking will increase its market share.

• The intensities of each of these major uses will fall. Overall there will be a net average growth/capita of perhaps 10% by the year 2000. There will, of course, be wide regional variations in saturation and in intensity.

• Electricity use per home for appliances will probably not grow much, although some load growth for freezers, dryers, and air conditioners will occur. Appliances will gradually continue their increase in efficiency. Home electronics will not be an important source of new kWh sales.

• Smaller family size will push up per capita use, as more single-person households (and retired couples) continue to use the same complement of appliances they had as members of larger households.

• Greater use of the home for social and work-related activities, could push up electricity use somewhat, while increased leisure time away from home would transfer consumption to the leisure-service industries like places of assembly, hotels, restaurants, and stores.

5.5. Implications for Planning and Forecasting

An understanding of future electricity use should always take into account the dynamics of each individual end-use market. Top-down econometric methods can give us some insights into the direction of electricity use. But complementing this approach with a detailed market-by-market comparison of trends and possibilities is important in assessing the most realistic directions for residential electricity consumption. We have discovered that by 1985, virtually every national electric authority, and all the utilities with which we met, used a relatively disaggregated bottom-up approach to analyze the present market and forecast the future. While the bottom-up approach suffers from data uncertainties, it allows these to be viewed directly, while the top-down modelling approach essentially hides them.

There is room for moderate growth in household electricity use in the U.S., but there is also the possibility of a conservation surprise -- pressure from foreign appliance manufacturers, new technologies eliminating heating water for washing, adoption of Swedish home-building techniques -- that could limit this increase. Utility analysts inthe U.S. would thus be counseled to look around carefully (including overseas) to see where electricity use is headed.

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Data Appendix

TABLE A-1 - Average Annual Growth Rates of Residential Energy and Electricity Use

Country	1960 - 1972/3		1972/3-1978			1978-1983			1960 - 1983		Years
	Total %	Per HH %	Total %	Per HH %	Per Cap. %	Total %	Per HH %	Per Cap. %	Total %	Per HH %	
Canada											
Energy	3.9	0.1	-0.4	-3.7	..	0.6	-2.1	..	2.2	-0.7	60-73-78-83
Electricity	8.3	5.4	6.2	3.0	5.0	4.7	1.9	3.5	7.1	1.7	
Denmark											
Energy	5.0	2.8	-0.2	-1.3	..	-4.7	-6.2	..	0.3	-1.5	65-72-78-83
Electricity	10.1	7.8	6.2	4.5	8.9	1.2	-0.5	1.1	6.2	4.5	
France											
Energy	-	-	3.0	1.5	2.8	-1.4	-2.6	-1.9	-	-	75-78-83
Electricity	11.7	12.3	10.5	9.0	10.0	7.0	5.8	6.5	-	-	
Germany											
Energy	5.4	2.6	2.5	1.3	-	-1.4	-2.4	-	3.1	1.2	60-72-78-83
Electricity	12.7	9.8	6.6	5.4	6.7	2.5	1.7	2.5	8.8	6.8	
Great Britain											
Energy	-	-	1.1	0	0.9	1.2	-0.2	0.8	-	-	72-78-83
Electricity	7.8	6.8	-0.4	-1.2	-0.1	-0.4	-1.3	-1.0	-	-	
Italy											
Energy	9.3	7.5	2.4	1.1	1.6	-1.5	-3.5	-2.2	5.1	3.4	60-72-78-83
Electricity	12.5	10.9	5.3	4.0	4.5	3.5	1.6	2.8	8.7	7.0	

TABLE A-1 - Average Annual Growth Rates of Residential Electricity Use

Country	1960 - 1972/3		1972/3-1978			1978-1983			1960 - 1983		Years
	Total %	Per HH %	Total %	Per HH %	Per Cap. %	Total %	Per HH %	Per Cap. %	Total %	Per HH %	
Japan											
Energy(dw)	8.6	5.2	4.5	2.7	-	1.4	0	-	5.6	3.2	65-73-79-83
Electricity(dw)	14.0	10.4	7.5	5.7	6.5	3.2	1.8	3.1	9.3	6.8	
Netherlands											
Energy	-	-	3.9	2.2	-	-0.9	-3.7	-	-	-	60-73-78-83
Electricity	10.9	8.1	5.6	3.8	4.7	1.3	-1.5	0.8	7.7	5.0	
Norway											
Energy(dw)	3.1	1.2	2.3	0.7	..	1.8	0.5	..	2.7	0.9	60-73-79-83
Electricity(dw)	5.9	4.0	5.3	3.6	4.7	4.2	2.8	3.8	5.6	3.8	
Sweden											
Energy(dw)	3.8	2.0	-0.9	-2.3	-	-1.1	-1.6	..	1.5	0.08	60-72-78-83
Electricity(dw)	11.7	9.7	7.1	5.5	6.8	7.05	6.5	6.9	9.4	7.9	
United States											
Energy	2.9	0.1	-0.8	-2.7	..	-2.4	-3.6	..	-0.5	-2.4	70-73-78-83
Electricity	6.9	4.3	4.0	1.8	2.9	1.8	1.1	0.7	3.8	1.6	

The last column gives the years measured. In some cases, use per household refers to all dwellings (indicated by "dw").

TABLE A-2 - OWNERSHIP OF ELECTRICITY-USING DEVICES IN OECD COUNTRIES

Country	Households	SPACE HEAT		HOT WATER	COOKING	COOLING	APPLIANCES						
		Main	2nd	Main	Main		Fridge[a]	Freezer	Washer	Dryer	Dish	TV[b]	VCR
	10^6	%	%	%	%	%	%	%	%	%	%	%	%
Canada													
1973	6.4	6.9	-	48.2	81.7	6.6	98.6	37.3	45.0	41.7	10.7	33/63	0
1978	7.55	15.9	14.4	51.2	87.9	15.2	99.4	47.2	59.1	56.0	23.9	25/72	-
1983	8.66	23.3	9.7	51.1	91.0	17.0	99.6	54.6	66.8	62.4	34.1	87/11	18
Denmark													
1972	1.8	1.6	~10	4	54	0	87/10	46	44	1.3	7.0	71/9	0
1980	2.1	-	-	-	73	0	71/29	62	55	9.1	18.4	41/63	5
1983	2.1	5.9	~30	10	75	0	71/32	61	62	11	21	77/27	10
France[c]													
1973	17.32	-	-	-	-	-	86.6*	7.5	64.7	-	4.6	77.9	0
1975	17.84	5.3	30.6	18.0	38.7	..	90.8*	12.9	69.0	-	7.3	84.1	-
1983	20.11	15.3	29.3	27.0	44.6	..	104.4*	33.8	86.5	-	21.4	98.5	-
Germany[d]													
1972	21.25	4.5	20	46	63	0	89*	25	71	2	6	21/83	0
1983	25.1	9.1	33	45	76	0	101*	52	86	10	23	77/38	8.6
Great Britain													
1972	18.32	13	>60	40	41	0	71	3	67	26	1	17/95	0
1983	20.57	12	10	33	38	1	70/26	32	80	38	2	97/82	22
Italy													
1972	15.5	5.8	4.7	35.3	1.6	1.0	87	0.5	62	-	6.3	-/81	0
1980	17.7	6.9	7.6	46.0	1.0	0.5	96	11	79	0.3	10	13/80	-
1983	18.5	8.0	11.3	51.2	4.1	0.4	97	14.2	80.1	1.8	10.6	54/66	-

TABLE A-2 cont'd - OWNERSHIP OF ELECTRICITY-USING DEVICES IN OECD COUNTRIES

Country	Households	SPACE HEAT		HOT WATER	COOKING	COOLING	APPLIANCES						
		Main	2nd	Main	Main	-	Fridge[a]	Freezer	Washer	Dryer	Dish	TV[b]	VCR
	10^6	%	%	%	%	%	%	%	%	%	%	%	%
Japan													
1973	31.9	0.1	90	4.4	52	14.9	103*	0	96.3	0	0	95	0
1983	37.4	2	93	7.2	55.5	49.6	108*	0	98.4	7	~1	100+	15
Netherlands													
1973	4.05	1.5	50	21	9.4	0	90.9	19.4	85.5	6	3	13/81	0
1983	5.06	0.5	80	18	11	0	97	46	88	12	11	80/35	10
Norway													
1973	1.37	31	50	80	95	0	79/10	57	72	22	3	7/64	0
1983	1.58	49	28	90+	100	0	74/23	75	79	30	17	70/25	~5
Sweden[e]													
1972	3.1	6	5	8.9	85	0	94	60	49**	9**	11	15/70	0
1983	3.5	24	12	26	94	0	77/22	83	60**	21**	30	97/20	15
United States													
1973	69.35	10.4	-	27	39	45	99	34	70	38	25	100/60	0
1978	77.13	15.9	-	31	50	54	100	36	69	43	32	-	-
1983	83.92	18.5	5	32	54	59	100	37	69	45	36	39/71	25

NOTES:
a - A slash separates simple refrigerators from fridge/freezer combinations. A * indicates that the data are for the number of refrigerators per 100 homes.
b - A slash separates BW from color TV.
c - Main space heating includes all CH and non-CH non-associated systems. Secondary heating includes heating equipment associated with other main heating systems, and backup radiators. Cooking includes dual fuel cooking equipment.
d - Heating percentages refer to occupied dwellings; other figures refer to households.
e - ** indicates possession, not access; 25% of families had access to washers in basements or washing rooms of apartments, 15% had access to dryers.

TABLE A-3 - ESTIMATED ANNUAL ELECTRICITY CONSUMPTION BY END USE

Country	SPACE HEAT	HOT WATER Main	COOKING Main	COOLING	APPLIANCES Total	Fridge	Freezer	Washer	Dryer	Dishwasher	TV	Lights
	MWh	MWh	MWh	MWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Canada												
1973	26.1	6.6	2.7	->	3399	-	-	-	-	-	-	-
1978	21.7	5.0	2.3	->	3847	-	-	-	-	-	-	-
1983	19.1	5.1	2.1	->	3853	-	-	-	-	-	-	-
Denmark												
1972	13.6/9.5	3.1	0.75	-	2070	385/730	700	545	450	435	130	-
1980	9.4/5.6	3.0	0.71	-	2330	365/710	970	505	420	495	160	-
1983	9.0/6.0	2.95	0.70	-	2210	350/700	900	480	400	475	140	-
France[a]												
1975	10.7/4.9	1.5/1.2	0.8/0.5	->	1130	425	740	300	-	470	200	-
1983	9.6/4.7	1.7/1.3	0.9/0.6	->	1700	540	720	300	-	440	165	-
Germany												
1972	10.6	1.0	0.45	-	930	375	680	350	450	-	100	200
1978	-	-	-	-	1295	-	-	-	-	-	-	-
1983	9.5	1.13	0.44	-	1560	480	580	280	290	310	150	270
Great Britain[b]												
1972	8.76	1.64	1.08	-	1460	300	975	200	300	500	500	320
1978	5.74	1.16	0.96	-	2007	300	840	200	300	500	420	340
1983	5.86	0.89	0.89	-	2168	300	780	200	300	500	320	350
Italy[c]												
1972	-	0.72	0.73	0.91	1060	180	-	450	-	1000	150	200
1980	-	0.84	1.03	0.87	1560	240	490	450	540	1320	100/260	270
1983	-	0.80	0.90	0.80	1570	220	470	410	500	1050	80/220	265

TABLE A-3 cont'd - ESTIMATED ANNUAL ELECTRICITY CONSUMPTION BY END USE

Country	SPACE HEAT	HOT WATER	COOKING	COOLING	APPLIANCES							
	..	Main	Main	-	Total	Fridge	Freezer	Washer	Dryer	Dishwasher	TV	Lights
	MWh	MWh	MWh	MWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Netherlands												
1973	-	-	-	-	2215	440	520	455	-	875	175	500
1978	-	-	-	-	2260	-	-	-	-	-		
1983	11.1/5.5	1.89	0.95	-	2090	400	550	275	400	475	112	800
Norway												
1973	14	4.1	0.58	-	2222	600	750	500	600	-	110	800
1979	13	4.0	0.55	-	2770	-	-	-	-	-		
1983	12.5	4.0	0.54	-	2820	600	750	500	600	300	120	1000
Sweden												
1972	11.2/7	4.5/2.5	0.70	-	2236	440	900	500	500	400	285	625
1978	-	-	0.60	-	2686							
1983	12.7/6.3	4.5/2.5	0.50	-	2881	510/900	-	350	225	295	140	630
United States[d]												
1973	7.5	4.5	1.0	1.8	5005	-	-	100	990	365	425	-
1978	7.0	4.3	0.8	2.0	5020	1400	1390	90	1110	250	800	900
1983	5.9	4.0	0.7	1.9	5125	1290	1220	85	1080	250	800	900

For Space Heating, Hot Water, and Cooking, where two values are given, the first refers to SFD, the second to MFD. For Fridge, where two values are given, the first refers to units without freezer compartment, the second to units with.
Except for Italy and the U.S., air conditioner use is included in Total of Appliances.

a - France: The values for space heating refer to central heating systems (chauffage electrique integre). Hot water refers to systems in households where no HW is produced by central heating system. Cooking refers to only-electric equipment. The values for appliances refer to SFD and MFD.
b - Great Britain: Heating is from storage heating central systems.
c - Italy: Use for main electric space heating systems is unavailable. Average for primary and secondary electric systems was 220 kWh in 1983.
d - United States: The values in the Appliances section for 1973 are estimates for 1969. They are from a different source than the estimates for 1978 and 1983 and may not be comparable.

TABLE A-4 - RESIDENTIAL ELECTRICITY CONSUMPTION BY END USE

Country	Pop. (10^6)	Homes (10^6)	Main Heat	2nd Heat	Hot Water	Cooking	Appliances	Cooling	Total Elec Sales TWh	Per dw kWh	Per Cap. kWh
					TWh						
Canada											
1973	22.04	6.40	11.53	..	20.3	6.8	21.8	<-	60.3	9375	2722
1978	23.55	7.55	25.8	..	19.4	7.8	29.0	<-	82.0	10862	3478
1983	24.91	8.66	38.5	..	22.8	8.3	33.44	<-	103.0	11905	4139
Denmark											
1972	4.98	1.86	0.38	<-	0.23	0.75	3.84	0	5.20	2796	870
1978	5.10	2.02	0.84	0.06	0.51	1.08	4.91	0	7.39	3658	510
1983	5.11	2.20	1.05	0.09	0.65	1.16	4.9	0	7.84	3564	1534
France											
1975	52.79	17.8	7.69	1.85	4.36	2.47	20.61	..	36.98	2078	701
1978	53.28	18.7	12.63	3.41	5.73	3.40	25.44	..	50.61	2706	950
1983	54.65	19.9	20.86	5.03	8.18	4.17	32.98	..	71.23	3579	1303
Germany											
1972	61.67	21.25hh	9.04	3.87	16.06	6.11	19.72	0	54.8	2580	889
1978	61.33	24.2	17.12	3.74	19.54	8.6	31.3	0	80.3	3320	1309
1983	61.42	25.1	18.64	3.91	20.15	8.5	39.6	0	90.8	3620	1478
Great Britain											
1972	55.78	18.56	21.80	7.35	20.07	11.08	27.05	0	87.4	4710	1570
1978	56.16	19.62	17.47	<-	15.8	13.06	39.38	0	85.7	4370	1562
1983	56.38	20.57	14.95	1.2	11.2	12.2	44.6	0	84.1	4086	1490
Italy											
1972	54.4	15.5od	1.2	<-	4.95	0.83	16.63	<-	23.65	1526	435
1980	57.9	17.7od	1.1	<-	8.40	0.84	27.61	<-	37.98	2146	656
1983	59.3	18.5od	1.1	<-	9.31	1.62	29.00	<-	41.04	2218	693

TABLE A-4 cont'd - RESIDENTIAL ELECTRICITY CONSUMPTION BY END USE

Country	Pop. (10^6)	Homes (10^6)	Main Heat	2nd Heat	Hot Water	Cooking	Appliances	Cooling	Total Elec Sales TWh	Per dw kWh	Per Cap. kWh
					TWh						
Japan											
1973	109.1	31.9	-	5.3	4.17	7.5	42.2	1.67	60.8	1906	557
1979	115.7	35.4dw	-	6.1	13.6	4.7	66.7	3.06	93.9	2652	812
1983	119.3	37.4dw	-	8.61	15.0	5.28	72.5	5.28	106.7	2852	894
Netherlands											
1973	13.44	4.05od	0.16	0.28	3.02	0.39	7.10	0	10.96	2706	815
1978	14.04	4.4	0.22	0.28	3.53	0.47	9.94	0	14.36	3264	1023
1983	14.39	5.06	0.17	0.175	3.94	0.47	10.58	0	15.35	3054	1067
Norway											
1973	3.96	1.37	4.22	3.12	4.69	0.75	3.03	0	15.81	11565	3990
1979	4.07	1.50	6.25	4.75	5.43	0.82	4.16	0	21.41	14250	5255
1983	4.13	1.58	7.81	6.25	5.94	0.86	4.47	0	25.34	16000	6136
Sweden											
1972	8.12	3.3dw	2.41	0.29	1.4	1.96	7.81	0	13.88	4200	1709
1978	8.28	3.6dw	6.00	0.38	2.81	2.11	9.67	0	20.97	5790	2533
1983	8.33	3.71dw	10.66	1.20	4.68	2.22	10.69	0	29.45	7940	3535
United States											
1973	211.9	69.35	54	*	84	27	347*	56	568	8190	2682
1978	222.6	77.13	86	*	103	31	387*	83	690	8945	3100
1983	234.5	83.92	92	*	107	32	430*	94	755	8995	3217

An arrow indicates that the consumption is included under the category to which the arrow points.

* The Appliance category includes portable electric heaters.

TABLE A-5 - SHARES OF TOTAL RESIDENTIAL ELECTRICITY CONSUMPTION

Country	Elec. Sales TWh	Main Heat	2nd Heat	Hot Water	Cooking	Appliances	Cooling
				Percent			
Canada							
1973	60.3	19.0	*	33.7	11.2	36.1	<-
1978	82.0	31.5	*	23.7	9.4	35.4	<-
1983	103.0	37.4	*	22.1	8.1	32.4	<-
Denmark							
1972	5.20	7.3	<-	4.4	14.4	73.8	0
1978	7.39	11.4	0.8	6.9	14.6	66.4	0
1983	7.84	13.4	1.1	8.3	14.8	62.5	0
France							
1975	36.98	20.8	5.0	11.8	6.7	55.7	..
1978	50.61	25.0	6.7	11.3	6.7	50.3	..
1983	71.23	29.2	7.1	11.5	5.9	46.3	..
Germany							
1972	54.8	16.5	7.1	29.3	11.2	36.0	..
1978	80.3	21.3	4.7	24.3	10.7	39.0	..
1983	90.8	20.5	4.3	22.2	9.4	43.6	..
Great Britain							
1972	87.36uk	25	~8.4	23.0	12.7	30.9	0
1978	83.71uk	18.4	~2	18.4	15.2	50.0	0
1983	83.05uk	17.9	1.4	13.2	14.5	53.1	0
Italy							
1972	23.65	5.1	<-	20.9	3.5	70.3	<-
1980	37.98	2.9	<-	22.1	2.2	72.7	<-
1983	41.04	2.7	<-	22.7	3.9	70.7	<-

TABLE A-5 cont'd - SHARES OF TOTAL RESIDENTIAL ELECTRICITY CONSUMPTION

Country	Elec. Sales TWh	Main Heat	2nd Heat	Hot Water	Cooking	Appliances	Cooling
				Percent			
Japan							
1973	60.8	~0	8.7	6.9	12.3	69.4	2.7
1978	93.9	~0	6.4	14.5	5.0	71.0	3.2
1983	106.7	~0	8.1	14.1	4.9	67.9	4.9
Netherlands							
1973	10.96	1.4	2.6	27.6	3.6	64.8	0
1978	14.36	1.5	2.0	24.6	3.3	69.2	0
1983	15.35	1.1	1.1	25.7	3.1	68.9	0
Norway							
1973	15.81	26.7	19.7	29.7	4.7	19.2	0
1979	21.41	29.2	22.2	25.4	3.8	19.4	0
1983	25.34	30.8	24.7	23.4	3.4	17.6	0
Sweden							
1972	13.88	17.4	2.1	10.1	14.1	56.3	0
1978	20.97	28.6	1.8	13.4	10.1	46.1	0
1983	29.45	36.2	4.1	15.9	7.5	36.3	0
United States							
1973	568	9.5	*	14.8	4.8	61.1	9.9
1978	690	12.5	*	14.9	4.5	56.1	12.0
1983	755	12.2	*	14.2	4.2	57.0	12.5

An arrow indicates that consumption is included under the heading to which the arrow points. (..) indicates the amount is negligible.

* Included as residual with Appliances.

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