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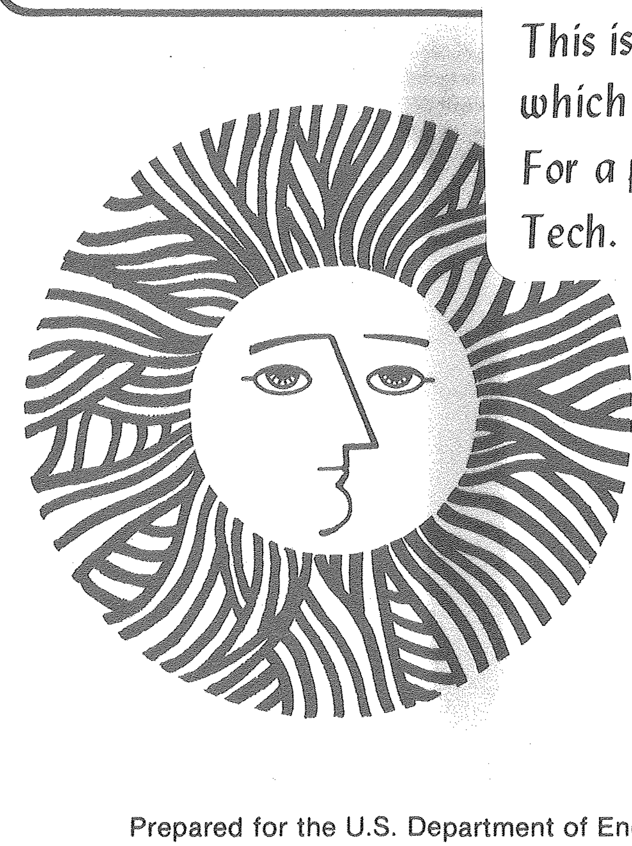

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PROGRESS IN RESIDENTIAL ENERGY CONSERVATION

- A MULTI COUNTRY PERSPECTIVE -

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PROGRESS IN RESIDENTIAL ENERGY CONSERVATION
-A Multi-Country Perspective-

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ABSTRACT

The importance of understanding historical and present day patterns of energy use is illustrated with a summary of a recently completed, comprehensive data base of residential energy consumption from 1960 to 1978 in seven OECD countries. Time-series data on key structural factors, energy-using stock, unit energy consumption, and total consumption are summarized for the major end-uses: space heating, hot water, cooking, and electric appliances. Indicators of intensity are developed, and comparisons of space heating and other uses among countries are discussed. Using such indicators, the historical development of energy use in this sector can be analyzed for the first time. Evidence of a marked slowing of the growth in residential energy demand -- and signs of a possible decline -- are presented. It is argued that such information is vital to understanding the setting in which new energy-saving technologies are implemented, yet few nations or international agencies are providing this kind of data or analysis. Integration of detailed macro-descriptions of present day energy use patterns with measured savings from new conservation techniques is vital for understanding future energy demands in the residential sector, which are still overstated by many national governments.

Prepared for the conference "New Energy Conservation Technologies", sponsored by the Int'l Energy Agency, Berlin, April,1981. Research supported by the US Department of Energy. See "Indicators of Residential Energy Use and Efficiency" (L. Schipper, A. Ketoff, S. Meyers, LBL-11703, 1981) for a complete description of the LBL data base described herein. Opinions strictly those of the authors. *Also affiliated with the Beijer Institute of Energy and Human Ecology, Stockholm.

1 Introduction

Many exciting projects are underway in the industrialized countries to see how we may obtain energy services in the home with less energy. But what is the setting in which these new onservation technologies are to be implemented? How much energy has already been saved in our homes? And how do we accurately measure progress in energy conservation?* We would like to discuss these questions in this paper.

For the last two years we have been conducting a detailed study of residential energy use in many countries. After collecting and studying hundreds of official, private, and academic studies, reports, and other data, we have assembled a time-series of energy consumption by both end-use and energy type for several OECD countries: Canada, France, West Germany, Italy, Japan, Sweden, and the United Kingdom (UK). Although this information is vital to understanding the progress and potential of conservation, much of it is unavailable through "official" government channels. Unfortunately, the International Energy Agency and other groups remain glued to manipulating ratios of energy use to gross national product. Elsewhere it has been shown that such a ratio tells us almost nothing about energy use efficiency, or changes in efficiency. [2]

Why are such historical studies or surveys important to planning the R&D effort in conservation? Simply put, we cannot be sure where we are going, or where we want to go, until we know where we have been and where we are! That is, we cannot describe the energy savings from a particular idea or technology unless we know how much energy is consumed for various purposes, and why we consume as much -- or as little -- as we do. Looking at the state-of-the-art, for example, in low infiltration experimental homes tells us little about the infiltration levels existing in the housing stock, or in additions to the stock. Yet whether low energy homes can be mass produced in the future might depend on how well "medium" energy homes are performing (and selling) today. Unless we can compare experimental homes with existing homes we cannot say how much energy they will save when projected on a nationwide basis. This makes it difficult to decide how important research in this area will be, and how big the ultimate payoff will be.

Another important reason for looking at historical consumption patterns, of course, is to be able to chart progress in energy conservation. The leaders of the largest OECD countries have committed their nations to achieving reductions in energy growth, yet surprisingly little analysis is underway to examine in detail changes in energy use.

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*By conservation is meant a reduction in the energy used to carry out a task (energy intensity) through either technical means or changes in lifestyle or behavior, both motivated primarily by the desire to reduce energy costs. [1]

2 The Data Problem

Unfortunately, most of the information released by the IEA does not allow meaningful comparison of conservation progress either within or among countries. This is particularly true in the residential sector. Comparison of our own estimates of residential energy use for the seven "major" countries -- based on our extensive data base of national literature and studies -- with those given by the IEA convinced us that the latter are severely flawed and probably unusable as representations of residential energy use (see Table 1). The basic problem is that the IEA data for residential energy use includes considerable quantities of energy that was actually consumed in the commercial sector. Inspection of the IEA residential data reveals that fuel consumption is usually conspicuously absent from the "commercial" or "public sector" rows, lying instead in the "residential" row. [3] Of course, the problem lies not just with the IEA, but also with the responsible agencies in the member nations. It seems that the IEA editors report the information provided by their official in-country contacts without notifying the reader what the sectoral classifications do and do not include. Although some researchers have used the entire "other" sector as an object for modelling (for example, J. Griffin, Energy Conservation in the OECD 1975-2000), the use of IEA's residential sector will lead to difficulties since it is not defined consistently over time or among countries.

Even if the residential totals were reliable, however, the kind of information that the IEA (and other official agencies) report is too aggregated, and contains little on housing or appliance stock, climate, or other factors that must be included in any reasonable analysis of conservation. To be sure, quality residential energy use data is not easy to come by: our long months of "unearthing" attest to that!

3 Measuring Aggregate Conservation Progress

Macroscopic data -- averages over an entire stock or some large subset of the stock -- can be useful indicators of conservation if properly assembled. An examination of pre- and post-embargo residential energy consumption in the OECD countries reveals that the high growth rates of the 1960's have slowed considerably since 1973 (Table 2). By itself, however, this tells us little about conservation, since the difference could be due to changes in the growth in energy-demanding units. Thus, it is essential to look at structural factors that affect residential energy consumption -- not only the number of dwellings, but the fraction of "single-family" dwellings, the penetration of central heating, the number of people per dwelling, dwelling size, and of course, the relative saturation of appliances.

These structural parameters explain many of the changes in consumption over time or differences among countries. Dwellings have increased in size in most countries, but the number of persons per dwelling has generally decreased, with the result that dwelling area per person increased 20-35% over the 1960-78 period in the studied countries (see Figure 1). Thus, there is more space to be heated per person, and more heat loss surface per person. On the other hand, there are fewer users of hot water. The expected decrease in hot water use per dwelling has not occured in most cases, however, as other structural changes -- the increase in the saturation of hot water-using appliances -- have tended to override the decrease in users per dwelling. Much of the increase in dwelling area per person came about because families habe become smaller (and more affluent). The trend toward smaller families may continue (not without limit, however), but this tends to mitigate the move toward larger dwellings.

Two structural factors contributed strongly to the rise in average energy consumption per dwelling observed in almost all of the countries over the 1960-1973 period (see Table 3): increasing penetration of central heating, from a low of 10-20% in most of Europe in 1960 to 50% or more in most countries by the oil embargo (see Figure 2); and the rapid growth in saturation of major appliances. Typically, refrigerators increased their saturation by as much as four fold; dishwashers, clothes washers, freezers, and televisions increased by even greater amounts. While cooking appliances were virtually saturated, there was a marked transition in all of Western Europe from cooking based upon solid fuels to gas or electricity. Only if changes in structure continued at the observed rates could energy use grow at anywhere near its historical rate. Such increases are very unlikely.

Indeed, it can be seen from Table 3 that several countries have experienced <u>decreases</u> in end-use energy per dwelling since the oil embargo (Canada, France, Sweden, and the United Kingdom); and in the others, the increase is modest. Part of this decrease, however, is also due to a structural change: the continued penetration and substitution of electricity for other fuels. The large increase in the share of electrically heated dwellings in France and Sweden since 1972 might be counted as oil conservation, but reductions in energy use for heating in electrically heated dwellings (a change in intensity) have not been observed. Because Swedish officials count purchased energy, not primary or oil-equivalent, a switch to electric or district heating gives an apparent energy saving that is more a fiction of accounting. Since electricity has practically no conversion losses inside the building, the same house will use less end-use energy if it is electrically rather than oil-heated. One must be careful not to confuse this substitution effect with a real change in intensity. In Sweden, some 25% of the reduction in space heating energy consumption in oil-heated dwellings is due to the introduction of wood stoves and, to a lesser extent, electricity.

Because so many factors affect average energy use per dwelling, it is not a very useful indicator of conservation. To accurately portray energy use patterns, we have attempted to disaggregate residential energy consumption by the major end-uses: space heating, hot water, cooking, and electric-specific appliances.* This is usually done "from the bottom up." That is, total consumption for each end-use is calculated from estimates of unit consumption and the number of energy-using devices. Although the data are sometimes weak, we feel that the time-series we have developed are reasonably accurate, particularly those for space heating, by far the most important end-use in terms of energy consumption. In Table 4 we present a summary of key end-use indicators.

4 Some Reasons Why Energy Use Differences Exist

Structural factors help to explain differences among countries in end-use energy intensity as well as internal changes over time.

The space heating indicator "Heat per dwelling per degree-day" reveals rather large differences in energy consumption between North America and Western Europe. But are these differences due more to efficiency (tighter houses), behavior, or structural factors -- dwelling size, central heating penetration, the fraction of single-family dwellings? The average size of a home in the U.S. (120 m^2) is 50% greater than similar averages in most of Western Europe. It appears also that internal temperatures in central European and especially English homes are lower than those in North America; and central heating is still far from universal in most of these countries. In Sweden, however, internal temperatures, central heating penetration, and dwelling area per person are close to North American levels. Knowing these features, the indicator for Sweden provides strong evidence for the greater thermal integrity of the Swedish housing stock. While it is true that Sweden has a higher proportion of multi-family dwellings (55%), this difference is not critical, since heat losses per inhabitant or per square meter of dwelling are nearly equal for single and multiple family dwellings (largely due to the fact that most multiples are unmetered).

The problems inherent in making international comparisons are illustrated by the case of Japan, where dwelling area per person is significantly less than in Europe or North America, and the presence of true central heating is rare. The most common form of heating in Japan are small gas, oil, or electric stoves (called "Kotatsu") located in convenient places, such as in sitting rooms, or even under tables. While there are some buildings in northern Japan where winter temperatures are comparable to that of Northern Europe, most of Japan simply does not need to (or chooses not to) heat in the Western sense.

Hot water energy use also shows considerable variation among countries. Although estimates of energy use for water heating are often rather uncertain, consumption levels in North America and Scandinavia are significantly greater than in central Europe or Japan. Is this the effect of prices? Culture or hygiene? The presence of more central heating? Probably all of these. We suspect also that the instant-on water heaters common in Germany, Italy, France, and England reduce the effective consumption of energy per unit of water delivered. At the same time, however, they certainly interact with the habits associated with using hot water, since the rate of flow is limited compared to that enjoyed from a faucet or shower connected to a large central storage tank. Accounting problems are also present, since many hot water installations are really classified as washing machines, dishwashers, or

*The latter refers to electricity other than that comsumed by primary space heating devices, hot water devices, and kitchen ranges).

kettles.

In the area of cooking, we see smaller variation among countries, although Germany and Sweden seem to use less energy for cooking per dwelling than the others. In almost all cases, there has been a decided decline in estimates of cooking energy use. A problem here are the specialized devices that reduce the use of the stove or oven in favor a less energy-intensive cooking implement; these are difficult to include under "cooking". Still, the trend over time is that fewer meals are cooked at home, due in large part to the absence of people in the house during the day, as both parents work and children receive hot meals at school. This trend has been noticed in Italy, [4] and we found that use of gas for cooking in several hundred thousand apartments in Stockholm has fallen 60% between 1960 and 1980, indicating that people are cooking and eating differently today compared with 1960. These data remind us that lifestyles are constantly evolving, and that devices that seem appropriate and marketable today may be less interesting in the future as lifestyle and demographic trends change usage patterns.

Our data reveal the most striking differences in electric-specific appliance energy use. Here it is important to look carefully at the nature of the energy services offered by the electric appliances. For example, refrigerators, freezers, and most washers are much smaller in Europe and Japan than in the US or Canada. Thus, measures of annual energy use may not reveal whether the device in question is more efficient (in the sense that it requires less energy per unit of service) in one country or the next. At the same time, the size of an appliance is not necessarily a measure of the amenity it delivers.

4.1 Prices and Incomes

We are presently analysing the role of relative energy prices and income levels in explaining differences over time and among countries in more depth. In general, we can say that most other Western nations paid dearly for residential energy use, compared to the US or Canada. At the same time there were notable exceptions: electricity in Sweden, and natural gas today in the UK. Not surprisingly, those countries with the lowest electricity prices tend to have the highest levels of appliance electricity use. This is illustrated in a cross-sectional plot of average 1978 residential electricity prices against appliance electricity consumption (Figure 3). It is interesting to note that there seems to be a threshold of consumption (at around 4 kWh/dw/day); higher prices do not seem to cause electricity use to drop much below this level.

Rising levels of disposable income allowed the rapid structural growth in energy services -- more central heating, dwelling area, appliances -- that took place in the 1960s and early 1970s. One would expect electricity consumption to be most affected by income, since that governs the ability to purchase (and to a lesser extent, use) appliances. Figure 4 illustrates the strong correlation between disposable income and electricity consumption per dwelling in France and Germany. The steep slope seen in France during the 1970s can be attributed to the intensive campaign to encourage electric heating. In Germany, on the other hand, electricity consumption per dwelling has grown slower than disposable income in the mid-late 1970s.

5 Conservation Since 1973: Some Discrete Observations

In Figures 5 and 6 we illustrate the dramatic reductions that have occurred in space heating energy demand per dwelling since the oil embargo. Here we aggregate only dwellings heated by the same fuel (oil and gas). Some of the data include new additions to the stock (which are presumably more efficient), while some of it follows the same group of dwellings over the period (Canada and Germany oil heating). Decreases in 1978 consumption from 1972 levels are on the order of 15-20%.

If there had not been any dramatic changes, we would not be too surprised. Real heating prices did not rise up drastically during the mid-1970s in Europe, and the real crunch did not arrive until 1979. As might be expected, data for 1979 from Sweden, France, and Germany show a further sharp drop in space heating energy demand in oil-heated dwellings: an additional 6-7% reduction (from 1972 levels) in all three cases!

6 The Role of Behavior in Assessing Conservation Progress

We have already alluded to the importance of lifestyles and behavior as factors affecting differences in energy consumption over time and among countries. We know that behavior patterns, reflected as indoor temperature settings, bathing practices, hot water use, or cooking habits, explain in part the differences among countries in energy demand for the various end uses. [5] We have also seen evidence that prices affect both efficiencies and lifestyles in the short and long run. It may be that the notion of conservation with constant amenity level is misleading in the face of greatly increased energy prices. These changes in lifestyle and behavior are significant for the future of many prospective conservation technologies. Changes in heating demands or household size, for example, can remove so much of the demand for an amenity like heat or hot water as to make many sophisticated systems uneconomic, since their energy saving characteristics pay back over so few units demanded. Heat pumps, solar systems, and advanced furnaces may be a few examples. This is not often acknowledged by supporters of various systems.

On the other hand, some of the savings brought about by capital investment efficiency improvements will doubtless be cashed in for greater amenity levels. If the marginal cost of heating, hot water, cooling, or refrigeration is considerably lower due to high efficiency devices, then people are likely to demand a little more of the amenities for which these devices are used. Studies of the energy saving potential of a device should try to take this effect into account. However, we disagree with those who suggest that efficiency improvements brought about by standards might <u>increase</u> energy use relative to today's level. As energy prices rise, higher efficiency devices merely keep the consumer from losing ground.

7 Summary and Conclusions

There has been much talk about conservation, and much more conservation than most realize. Yet there is still confusion in national and international circles about the state of the art, and how far that art has penetrated everyday life. Little is known about the components of energy conservation that we have observed: structure, behavior and lifestyle, intensity. Worse, few official prognoses have been able to deal successfully with conservation and its effect of reducing markedly future demand for both oil and other energy forms.

The data we have collected show that it is possible to construct a detailed portrait of historical and present residential energy use. To be useful, such a portrait much have enough richness of detail as to permit analysis of the factors that shape residential energy demand. Both further research and enhanced communication of data are necessary:

- It is imperative that nations and regions set up straightforward mechanisms with energy suppliers, housing companies, manufacturers of household equipment, and owner/tenant groups to improve data flows from the residential sector. National governments should step up their surveying of energy use and of the energy use characteristics of new homes and equipment.

- The IEA must begin the arduous task of collecting and analyzing data from member countries that will explain differences among countries, and suggest how we can learn from the experience of others. Indicators such as those we have presented here should be used to assess the progress made in each country, and perhaps shed light on the effect of government programs. Certainly, more evaluation is needed as to the affect of past and ongoing conservation programs.

- The de facto changes in consumption of the past eight years should be carefully analyzed with an eye toward estimating the effects of behavior, technical fixes, and government and utility programs.

A most important task for conservation researchers in the coming years is to relate micro-level research to developments in macro trends. Conservation technologies can not be looked at in isolation from the way energy is now being used, or from the people who are using it.

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3. International Energy Agency, 1980. Energy Balances of OECD Countries, 1974/1978.

4. Ente Nationale d'Idrocarburi, 1979. End Uses of Energy in Italy, Rome.

5. Schipper, L., and A. Ketoff,. International Residential Energy Use Data: Analysis of Historical and Present Day Structure and Dynamics, (To be published in the Proceedings of the Conference on Consumer Behavior and Energy Use, Banff, Canada, Sept. 1980).

Acknowledgements

Our project would have been impossible without the cooperation of many people and organizations. We thank in particular G. Coaker (Shell Canada), Rick Moll (Statistics Canada), P. Suding (EWI, Koln), K.F. Holm (German Esso), Gaz de France, AEE, the Ente Nazionale Idrocarburi (ENI, Rome), the Swedish Oil Cooperative OK, Swedish Esso, the Swedish State Power Board, the Swedish Gas Association members, IEE (Tokyo), G. Leach (IIED, London), Shell UK, British Gas, and the Electricity Council.

Tables:

Figures:

Table 1. Comparison of LBL and IEA residential energy data (1978)

Country	LBL (PJ)	IEA (PJ)	Comment
CANADA	1298	1113	IEA (and Stat.Canada) omit large apartment buildings -they are left in commercial sector
FRANCE	1487	1740	IEA includes commercial sector solid fuels (and probably some oil)
GERMANY	2070	2388	IEA includes commercial sector solid fuels
ITALY	1210	1243	IEA includes commercial sector solids and gas (and probably oil)
JAPAN	1077	2055	IEA includes commercial sector oil
SWEDEN	371	490	IEA includes commercial sector oil
UK	1619	1526	Reason for discrepancy unclear

Data are total end-use energy consumption. LBL data are adjusted to normal climate, usually amounting to a 3-5% change in annual consumption.

Table 2. Average growth rates in residential energy consumption (%/yr)

	1960-78	Pre-embargo	Post-embargo*
CANADA	3.3	4.0	1.4 (74-78)
FRANCE	5.4	7.6	0.7 (73-78)
GERMANY	4.3	5.3	3.3 (75-78)
ITALY	7.0	9.3	2.4 (72-78)
JAPAN	5.8	7.8	3.2 (73-79)
SWEDEN	2.0	3.1	0.5 (72-78)
UK	0.5	0.4	1.4 (75-78)
US	2.3	3.7	0.8 (74-78)

Source: LBL Data Base. End-use energy.
* 1974 values were not available for all countries.

Table 3. End-use energy per dwelling (GJ)

	1960-65	70-73	78
CANADA	164	181	170
FRANCE	42	83	80
GERMANY	62	84	87
ITALY	24	59	63
JAPAN	21	33	36
SWEDEN	98	110	102
UK	88	83	81
US	140	170	150

Years covered: see Table 4; for U.S. -- 1960, 1970, 1978.
Source: LBL Data Base

Table 4. Indicators of End-use Intensity*						
	1960-65	70-73	78	60-65	70-73	78
	Heat per degree-day (MJ/dw)			Cooking (GJ/dw)		
CANADA	28.6	31.5	28.7	6.8	4.5	3.2
FRANCE	16.0	30.6	26.1	2.4	4.4	7.8
GERMANY	16.6	22.8	23.1	4.5	2.8	2.3
ITALY	9.8	27.1	22.4	3.4	3.6	4.6
JAPAN	6.2	12.1	11.2	4.7	5.4	5.1
SWEDEN	18.5	20.3	19.1	3.2	2.9	2.7
UK	23.6	19.9	19.4	7.8	7.2	8.3
US	-	-	35.0	-	-	7.4
	Hot water (GJ/capita)			Appliance electricity (kWh/dw)		
CANADA	4.7	7.6	10.5	2225	3665	4320
FRANCE	1.1	3.0	3.8	535	1115	1470
GERMANY	1.1	3.2	4.7	375	950	1225
ITALY	0.9	1.2	2.1	255	1060	1455
JAPAN	1.6	2.6	3.8	640	1345	2055
SWEDEN	5.8	9.4	10.7	1770	2680	2910
UK	4.7	5.9	4.3	705	1315	1975
US	-	-	9.5	-	-	5925

Source: LBL Data Base. US data based on the Oak Ridge Residential Energy Use Model.
Years covered: Canada -- 1961, 1971, 1978; France -- 1962, 1973, 1978; Germany -- 1960, 1972, 1978; Italy -- 1960, 1972, 1978; Japan -- 1965, 1973, 1979; Sweden -- 1963, 1972, 1978; UK -- 1961, 1970, 1978.
Heat per degree-day uses normal climate for each country, adjusted to an 18^{o} C base to allow comparison. Hot water/capita refers to the total population, and thus includes the effect of increasing saturation of hot water facilities. Appliance electricity does not include electricity used for space heat, hot water, and primary cooking devices.

*In order to avoid the structural bias that accompanies changes in the penetration of electricity, we have divided electricity consumption (and district heat, which like electricity has its conversion losses outside the building boundary) by a hypothetical conversion efficiency of 65% in developing aggregate indicators for space heating and hot water.

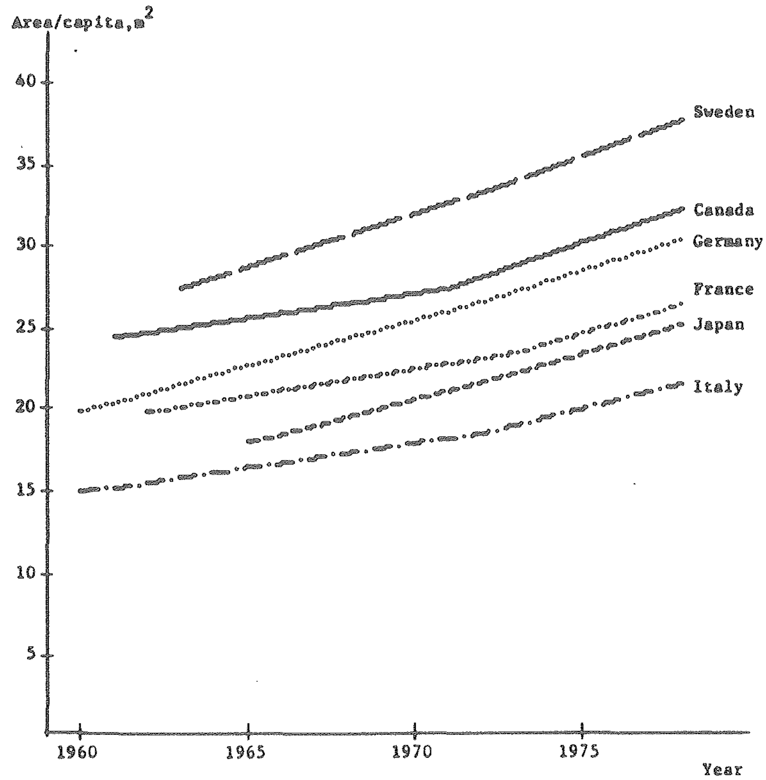


Figure 1. Average dwelling area per capita

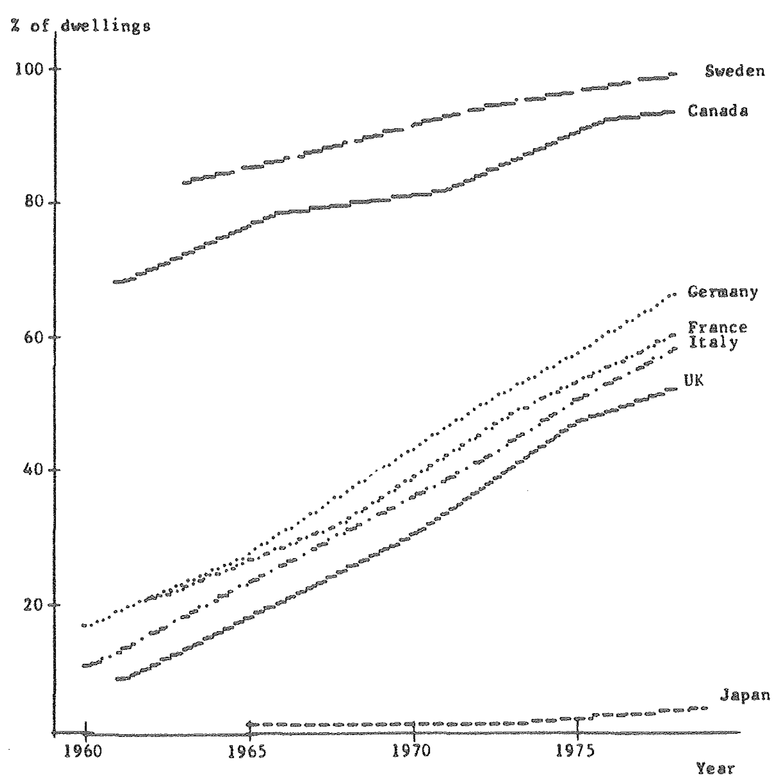


Figure 2. Central Heating Penetration

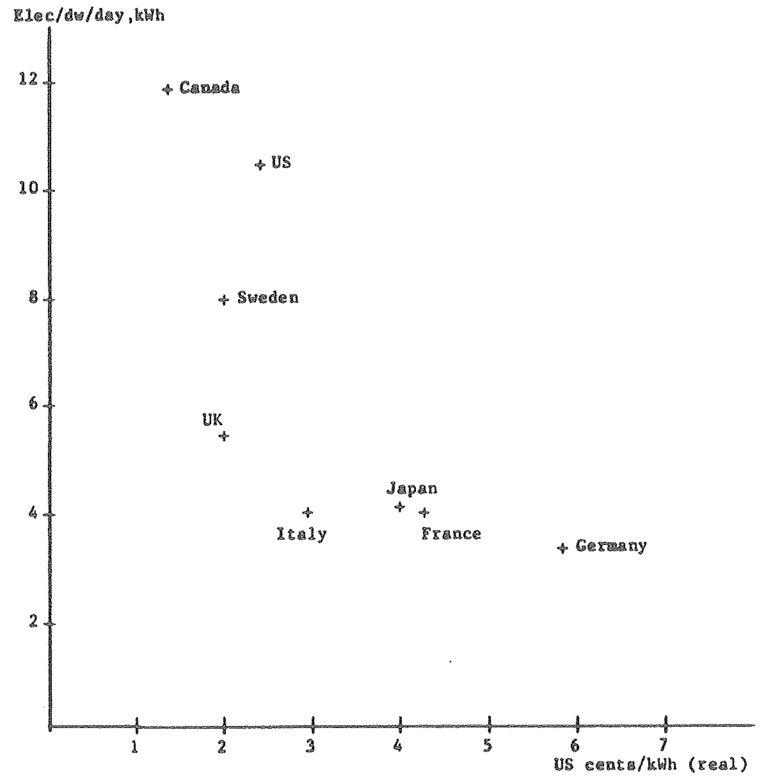
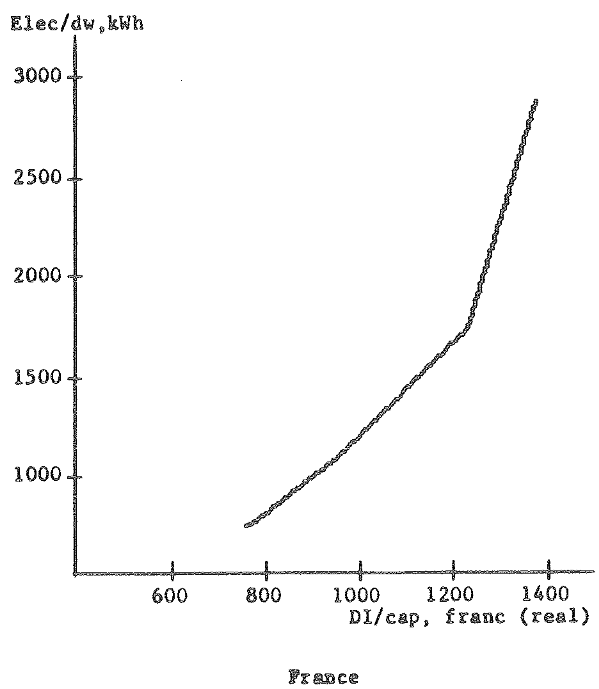


Figure 3. Electricity price and appliance electricity use, 1978



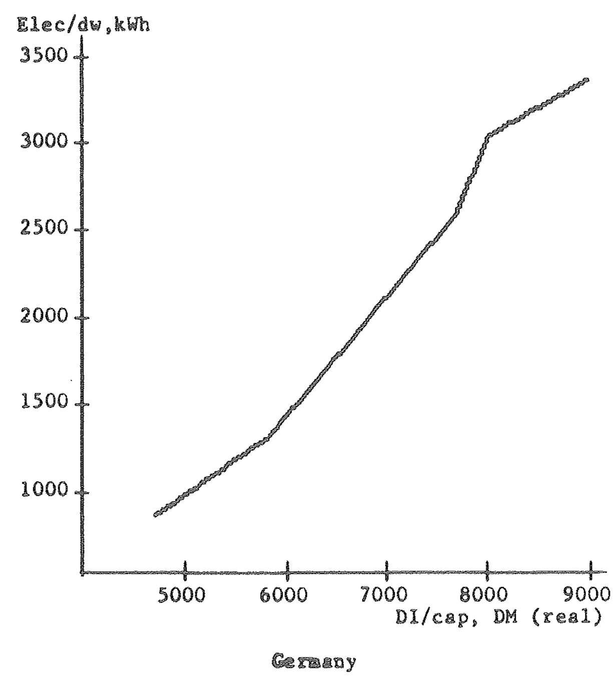


Figure 4. Electricity Consumption and Disposable Income: France and Germany. Shown are total electricity per dwelling and disposable income per capita in real currency.

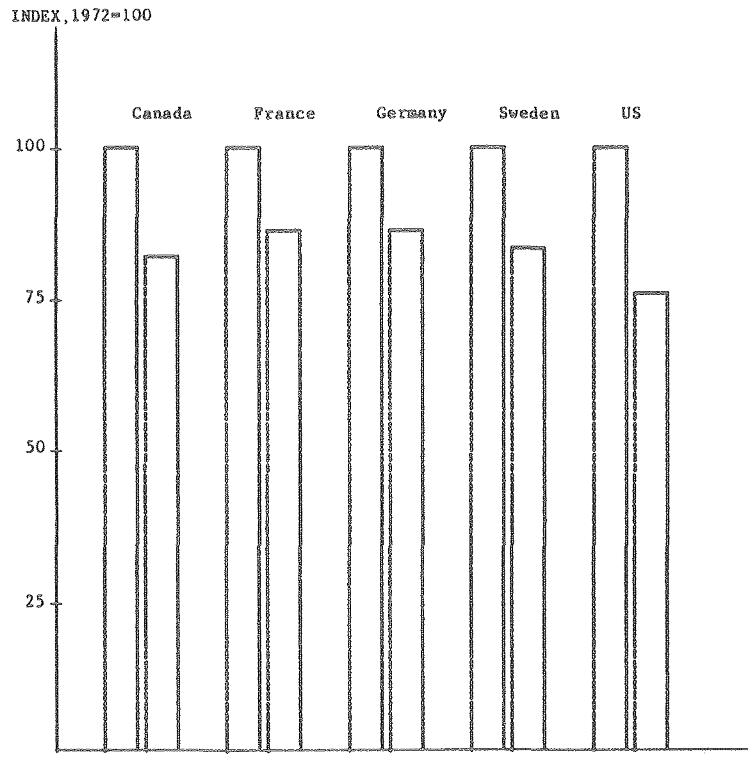


Figure 5. Conservation in oil-heated dwellings: 1972/78 (climate adjusted)
Canada. sample of Toronto houses; France. all centrally-heated dwellings, Germany: sample of one/two-family dwellings, Sweden: all single-family dwellings, US: survey of distributors (houses)
Sources: Canadian oil company, Agence pour les Economies D'Energie, German Esso, Swedish OK, Fuel Oil and Heat

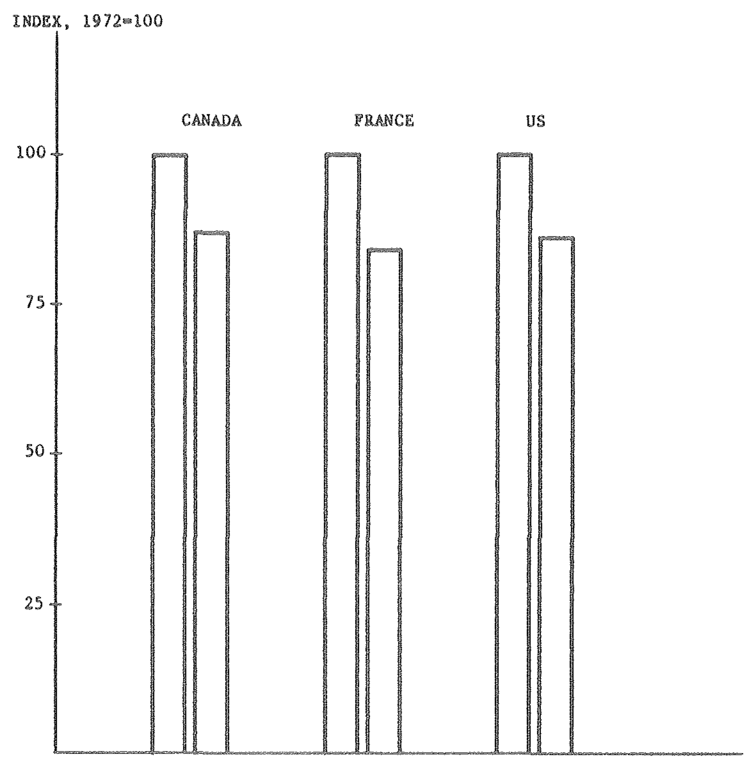


Figure 6. Conservation in gas-heated dwellings: 1972/78 (climate adjusted)
Canada: all dwellings; France: all centrally-heated dwellings; US: all dwellings

Sources: Canadian Gas Association, Agence pour les Economies D'Energie, American Gas Association.