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Oil Conservation: Permanent or Reversible?
The Example of Homes in the OECD*

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ABSTRACT

This paper estimates the permanent and reversible components of changes in heating oil use in major OECD countries. We analyze and discuss changes in the share of oil in total final residential energy consumption, the share of oil-based systems among all heating systems (both central systems and room stoves), the trends in unit consumption in homes with oil-based central heating, as well as the trends in heating oil prices. We reveal the components of the rise in oil use through the mid 1970s, and detail the components of the decline since that time. Finally we comment on some of the causes for these changes.

We find that for seven major OECD countries, residential oil use decreased by 32% between 1972/3 and 1982, for a savings of about 1 million barrels per day (50 million tonnes of oil equivalent (MToe) per year). One fourth of these savings was caused by reductions in the numbers of homes heated with oil, the rest in reductions in oil use per oil heated home. During that time, however, the size and central heating penetration in these homes increased significantly, so these figures underestimated the real conservation efforts made to date. Of the total oil savings, we found 44% to be of a permanent nature, while the rest *could* be reversed with a continued slide in oil prices, although we judge it likely that most of these savings will remain and probably increase.

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Oil Conservation: Permanent or Reversible?

The Example of Homes in the OECD

Lee Schipper and Andrea Ketoff

1 Introduction

Patterns of oil use changed dramatically in the last twelve years, as industrialized countries experienced two major increases in the price of oil. In the beginning this was mainly a problem for the consumer, whose direct reaction was aimed at limiting the impact of oil price increases on the household budget. Consumers heated less, used less hot water, used equipment more efficiently, or switched away from oil if possible. As consumers began to pay more attention to energy performance when buying new devices, the industries that produce these goods began to provide new, more efficient technologies. Governments and public utilities, committed to lowering oil dependence, launched new regulatory and incentive programs, making energy and oil conservation an institutional issue. Although the final consumer ultimately establishes the patterns of energy use, the reactions of different actors have added up to the common objective of a reduction in oil consumption. While efficient energy use remains a general issue, the switch "off oil" has become a more specific objective affecting consumers' choices and behavior. How well has "off oil" succeeded? Is the initial oil *crisis* becoming an oil *turning point*? This paper answers these questions with respect to residential energy use in developed countries, through an analysis of permanent and reversible changes in the household sector of all major OECD countries, relying on published and unpublished data sources from the countries we have studied.

In our analysis of residential energy use in these countries, we have paid particular attention to the evolution of the stocks of energy using equipment and appliances, the consumption of each fuel for each purpose, and the changes in the climate, housing stock, incomes, and prices. We have prepared several reviews of the work and the methodology to date,¹⁻³ a data base,^{4,5} and a variety of special studies.⁶⁻¹¹ In this paper we show how residential oil use has evolved in seven of these countries [Canada (CDN), Denmark (DK), Federal Republic of Germany (FRG), France (F), Norway (N), Sweden (S), and the United States (US)], while we comment briefly on those for which data on oil use were of poorer quality [Italy (I), Japan (J)] or for which oil use was very minor [Netherlands (NL), and the United Kingdom (UK)].

To place this study in its proper perspective, we give first some background figures, shown in Table 1 and Figure 1. In 1980 the Residential/Commercial (R/C) sector accounted for 31.5% of actual final energy consumption in the OECD, and oil accounted for 36% of this sector's consumption, while R/C oil accounted for 20% of total oil consumption. In the seven countries we studied closely, these figures were 32.6%, 34.8%, and 20% respectively, so that these countries may be considered representative of the entire OECD. The US dominates these figures, because of its sheer size, but Germany and France made appreciable contributions as well. In all, these seven countries accounted for 70% of OECD R/C oil consumption in 1980. As we will see, the residential component of this oil consumption (typically 65%) has changed radically between 1960 and the present.

The first section of this paper defines and quantifies the components of changes in residential oil use. The second part discusses the *causes* for these changes, which may include changes in relative oil prices or personal incomes, changes in oil-using technology that influence the costs of using oil, or changes in funds or information available through public programs, i.e., "energy conservation programs".

Most of the data used in this report have never been published in an international context; many were made available by energy companies and authorities for the first time to any outside group. Because many readers may be unfamiliar with the data problem, we give it special attention in Appendix 1. Our measurement of the structure of oil use is also discussed therein. Unless otherwise stated, we adjust our heating consumption data to average weather, defined by the ratio of actual degree-days (base 18C) to the long term average, by using a simple linear method discussed in Appendix 2.

Part One: THE RISE AND FALL OF OIL USE IN OECD HOMES

Table 2 presents data showing the composition of energy use in the *residential* sectors of major OECD countries.* Figure 2 shows the share of heating oil, kerosene, and LPG. The rise of oil's share is clear, as is its fall. Note that this rise occurred at different rates, and that the highest levels obtained varied significantly from Sweden and Denmark, the highest, to the US, with the lowest share of countries shown. Note, too, that there is considerable variation in the make-up of the mix of remaining fuels.

2 Defining Components of Residential Oil Use

It is clear from Fig. 2 that many sharp changes in the quantities of oil consumed, and in the share of oil in residential final consumption have taken place between 1960 and 1982. In this study, we allocate changes in oil use into two kinds of components:

- Changes in the relative and/or absolute number of dwellings using oil as the principal heating fuel, which we call *structural*. Further we consider *substructural* factors, which measure the changes in size and types of dwellings, and the split between central and non-central heating systems.

Structural change occurs as existing homes convert away from/towards oil, as existing oil-heated homes are removed from the stock and new ones are built. *Structure* is measured by the share or number of homes using oil for heating. *Substructural* change occurs as dwelling size changes, as the relative numbers of single-family dwellings (SFD) and multi-family dwellings (MFD) with central heat (CH) or non-central heat (non-CH) change, or as the presence of oil-based water heating varies. Substructural change is measured by an index, called "weight factor", defined in Appendix 1.

- Changes in oil consumption per dwelling or per square meter, which we describe as changes in *intensity* or *unit consumption*.

A change in unit consumption can occur through various means. Either occupants reduce (or increase) oil consumption by changing indoor temperatures, the area heated, or by making other easily achieved "behavioral" changes in the way they heat, or they change the thermal characteristics of their homes or their heating equipment

* Data (and time) limit us to selected years, which differ among countries. In particular, we were unable to begin in the same initial year, 1960, in all countries, nor were we able to choose the same immediate pre-embargo year for the analysis. Note that these data represent the "residential" sector. The oil consumption data published by the OECD under the same heading, in general *do not*.

("technical change"), or they use a second or third fuel to provide "back-up" heating ("supplementary fuels"). In general, we consider "behavioral" and "technical" changes that reduce energy intensities "*energy* conservation", while structural changes and use of secondary fuels may lead to "*oil* conservation" per se, but not necessarily to energy conservation.

Increases in the total number (or share) of dwellings heated with oil, or the share of central heating, may increase total oil use; this does not necessarily mean that energy conservation, as reductions in energy intensity (or increases in efficiency) is not taking place at the same time. In the following discussion we review changes in structure, then changes in energy intensity, then changes in total oil use.

2.1 The Structure of Oil Use

The structure of oil heating is influenced by the rate of addition of new oil-heated homes, removals of old, as well as conversions of homes towards and away from oil. In most of the OECD countries, the rate of renewal of the housing stock has slowed considerably in the 1970s. This has diminished the impact of new, more efficient construction and equipment on the entire stock of dwellings, and increased the importance of changes in energy-use patterns in existing homes. Here we analyze both the variation in existing and new stocks.

2.1.1 Oil Heating in Existing Homes

The shares of dwellings heated with each fuel, in each country, are given in Table 3. Figure 3 shows the share of dwellings using oil as the principal heating fuel. The details of the sub-structure, and the weight index we form, are shown in Table 4.

The high share of oil in residential consumption (Table 2), and that of homes using oil as the principal heating fuel (Table 3), illustrates the dominant role played by oil in space heating in most countries. Until 1973, the share of oil-heated homes increased in all the European countries. While the share of homes in N. America using oil decreased slightly between the early 1960s and 1971-3, the absolute number was higher at the end of the period than initially. Only in Norway and the United States has the share of homes heated with oil remained under 50%.

As the stock of oil-heated dwellings increased throughout the sixties and early seventies, the energy intensity of the stock itself has increased as a consequence of the growing number of centrally heated dwellings, and of the growing share of single-family dwellings (henceforth SFD). Moreover, penetration of oil-based hot-water systems in homes heated with oil in central

systems increased in all countries, reaching 100% in Sweden and Denmark by 1970. In Canada, France, and Germany, these increased to levels between 40 and 70%, while remaining constant in the US at close to 35%. The increase in the "weight factor" (Table 4; see Appendix for definition) indicates that the *substructure* became more energy intensive.

After 1973, substructure continued to change towards greater energy intensity, as the use of kerosene, LPG, or even heating oil based non-central systems decreased rapidly. Towards the end of the 1970s, fuel switching began to reduce the absolute number of homes using oil, but this effect occurred unevenly. Multi-family dwellings (henceforth MFD) in most countries were converted from oil more readily than were SFD, because MFD tended to lie in dense areas, according to every country's census, where gas or DH were available, and connections to rapidly expanding natural gas or district heating were, relatively speaking, less expensive per dwelling for MFD than for SFD. These factors left proportionately more SFD using oil, driving the weight factor up in every country except Sweden, where rapid conversion of SFD to electricity and wood took place. As a result of all these changes, the number of oil-heated homes was lower in 1982 than in 1972 (or 1978) in every country (except in FRG), but the remaining oil-heated stock was more energy intensive in 1982 than in 1972.

The living area of oil-heated dwellings bears comment.* In most countries the oil heated SFD were the largest (measured by rooms per dwelling) of all in the 1970 - 73 period, and the incomes of the occupants were slightly higher than average. The average floor area of oil-heated SFD in 1981/2, a time for which more accurate data on floor area are available, was 125 m² in Denmark, 100-110 m² in Germany, 100 - 110 m² in France, 135 m² in Sweden, 160 m² in the US, and 120 m² in Norway. Area for Canada is uncertain, but probably close to 120m². Oil-heated MFD lay in the range 55-70 m² for all countries except for the US, for which area was close to 85 m². Data on these sizes in the early 1970s are unavailable. However, data from housing ministries in each country indicate that new oil-heated homes added since that time were usually larger than the average of existing homes. This implies that the average oil-heated SFD increased in size through the late 1970s, while in the early 1980s, the few new oil-heated homes were no longer significantly larger than existing ones.

The age of the building stock is an important determinant of energy consumption. By the late 1970s, the stocks of oil-heated homes in most countries were on the average considerably older than those heated by gas, electricity, or district heating, as new construction added to the total stock of these latter groups. This meant, in general, that oil-heated homes had the poorest thermal characteristics, and their numbers were not being increased by the entrance

* Heated area may be larger (because of heating of space not defined as living area), or smaller, as occupants close off rooms to save energy.

of newer, more efficient stock. However, the high consumption increased the incentive of owners of the largest and/or leakiest homes to conserve, add back-up fuels, or switch fuels entirely away from oil, as data from the Swedish surveys show.^{12,13} The remaining homes were more efficient and somewhat smaller, on the average, which reduced slightly the average oil consumption of homes using oil, both per dwelling and per unit area (Ref. 13). While this change is only well documented for Sweden, we suspect that it has some impact on the drop in unit consumption over all oil-heated SFD after 1978. In all there are many such small changes in the stock of oil-heated homes some of which cancel each other. However, we will see that the drops in unit consumption between 1973 and 1983 were larger than could be accounted for by anything other than by actual reduction of oil consumption in each and any kind of oil-heated home.

We conclude that while the share of homes with oil heat increased through the mid 1970s in most countries, it decreased after 1978 everywhere. The substructure of the oil-heated stock increased its energy intensity continually through the early 1980s. This change would have increased oil use per dwelling throughout the period. If the share of oil-heated dwellings had remained constant, total oil use in 1982 would have been considerably higher than it was in 1972. But the first oil embargo changed the oil market radically. In the following sections we examine some of the reactions that occurred.

2.1.2 Heating Fuels in New Homes

In Table 5, we show the share of principal fuels in new SFD and MFD (where the split is known) for two or more periods since 1975, as well as the share in the period 1970-74. We also show for reference the percentage of the 1982 stock that was built since 1974/5 for each country; with the exception of Canada (18%), the US (15.4%), and France (~20%, but the figure in the Table is higher since it includes only *centrally heated* new dwellings), the share of the 1982 housing stock built after 1974 was around 11-13%. This number reveals that the post-embargo construction makes up only a minor part of the 1982 stock. However in some countries these new dwellings have been heated by only one or two fuels, so they have an important impact on those classes of dwellings today. Nearly 40% of the electrically heated SFD-stock in France, Sweden, and the US, for example, was built after 1970.

The data presented in the first part of Table 5 show that, through the early 1970s, oil was the overwhelming favorite fuel among new SFD, and even MFD, in Europe and Canada. But the number of oil heated homes rose even more rapidly, because of conversions (not shown) from other fuels to oil. These choices accounted for most of the rise in oil use during the period up to 1973.

Did the first oil shock influence the share of heating fuels in new dwellings after 1974? The answer is yes. The share of oil heating in new homes dropped in all countries after 1975, although less rapidly in Denmark and Germany than in other countries. Oil heating still represented about 40% of the new stock in Germany through 1981, and persisted in 20% of new Danish construction (dropping from almost 50% before 1974). In France, oil heating (10% of the new dwellings in 1982) is still high in isolated SFD, while it has fallen close to zero in new apartment buildings, which are located closer to urban energy networks. In these countries, the relative prices of electricity or gas were not so low as to make a *rapid* shift to these fuels attractive, but gas and electricity did gain market share at the expense of oil. Some delay was also caused by the lead time needed for extending the gas and district heating networks to areas where oil was previously popular. Indeed, most (63%) new construction since 1979 in all countries has been SFD. Except for Sweden, the share of oil in SFD is higher than in MFD, because SFD lie farther from gas or district heating. The combination of these effects leaves a substantial share of new dwellings with oil. But while electric heating, another alternative, is popular in France, it is expensive in Germany and Denmark, leaving oil as an important choice in these two countries. Thus, we understand why oil remained popular in new homes in France or Germany or Denmark: Alternatives were expensive and only slowly mobilized.

We conclude that the first oil shock depressed the share of oil in new homes, while the second shock all but eliminated it except in a few countries. While new oil-heated homes in every country are considerably less energy intensive than old, as evidenced by the introduction or strengthening of building codes between 1976 and 1978, their numbers are only large enough to have an impact upon average unit consumption in Germany and Denmark. Overall, then, changes in fuel choice in new homes ultimately have had an impact on oil use by reducing markedly the share of oil in new dwellings.

2.2 Unit Oil Consumption 1970 -- 1982.

From Tables 2 and 3, we could estimate average oil consumption per dwelling over time and over all kinds of dwellings and systems. This would be somewhat misleading, however, because of the changes in substructure. We therefore examine unit consumption by dwelling type first, concentrating on data for SFD with central heating, which dominate total consumption in every country.

2.2.1 Single-Family Dwellings with Central Heat

Table 4 indicates that by 1972/3, central heating accounted for the majority of oil systems, and single family dwellings the largest subset in almost every country. By 1982/3 SFD with CH dominated residential oil consumption. We therefore examine these important consumers here. Table 6 displays unit consumption data, in GJ/dwelling aggregated over all single-family dwellings with central heating (both with and without hot water) for each country and year.* The first line for each country gives total oil consumption *per dwelling*, corrected for yearly climate variations. The second entry gives the assumed, imputed, or measured consumption for hot water, the third entry gives the estimated penetration of hot-water systems. The last entry gives the *space heating* component, in MJ/degree-day, making comparisons among countries with greatly differing climates (Cf. the degree-day totals in the Appendix, Table A1) possible.

We noted above that home size and heated area vary considerably among these countries. Scaling by heated area changes the "rankings" in energy intensity somewhat, since the US and Sweden have the largest heated areas. Using estimates of heated area for 1981/2, we express this last quantity over the entire period, in kJ/deg.day/m², in Figure 4.**

These data reveal a range of changes in each country as well as differences among countries. First, there was a great difference in intensity among countries before 1973, much greater than is explained by differences in dwelling area or hot-water use. Second, consumption per degree-day dropped measurably in every country in 1974/5, however rebounding in most countries after 1975, except for Sweden and the US.

The period after 1979, by contrast, was marked by greater drops in unit consumption than previously experienced, typically 20% except in Sweden, where consumption had fallen continuously after 1973. In most countries, unit consumption fell to less than 2/3 of its pre-embargo value. The rapidity of this decline in all countries except Sweden, leads to the conjecture that most of the drop was caused by changes in behavior, i.e., temperatures, shortened

* The sample consists of data from *measured monthly consumption* in Germany (1967-83), consumption from billing records in Denmark and Sweden (1970-83), consumption from national surveys in the US (1978-82), Sweden (1977-82), France (1973-81), Denmark (1972-77), and consumption estimated from sales for Canada and the US (1970-1982). The hot water figure must be estimated and extracted in order to make the comparison realistic, since levels of hot water penetration differ greatly among countries. Moreover, division of heating use by degree-days is necessary in order to compare different countries. However, only consumption per dwelling is actually measured.

** Dividing each country's consumption by a constant floor area (for that country) introduces a small error. Although heated area may have decreased between 1972 and 1982, because consumers heat less of their homes today than before, floor area did increase somewhat in most countries during the same period. The error we introduce is probably small, certainly less than the important differences in sizes among countries and far less than the overall decrease in oil use per dwelling. If we knew the floor area from the 1970-75 period more accurately, the curves in Fig. 4 would start out at higher levels, because floor area was smaller then. Thus Fig. 4 underestimates slightly the reduction in intensity.

heating season, reduced heated area and hot water use, or by use of secondary fuels (discussed below). Technical modifications to dwellings were not insignificant, particularly improvements in boiler maintenance or even purchase of better equipment, according to surveys carried out in each country, but it is difficult to conceive of retrofitting all oil-heated dwellings in such a short time as to cause a 20% drop in consumption.

2.2.2 Multi-family Dwellings

Data on MFD are not as reliable as those for SFD, but we discuss them briefly for completeness. We illustrate oil heating intensity in apartments in Sweden, Denmark, Germany, and France in Fig. 5. Oil intensity fell with increases in price. The penetration of hot water did not change significantly in these countries, although it ranges from 100% (in Sweden and Denmark) to 50% (in France and Germany). Moreover, the use of secondary fuels appears far less important than in SFD. Therefore, these figures are readily comparable, and all countries show oil conservation.

Sweden, with the greatest number of degree-days and the largest apartments, had the smallest absolute consumption throughout most of the study period, as well as the lowest intensity (in kJ/deg-day/m^2), and both of these indicators moved downward slowly during the entire period. Because virtually no oil-heated apartments in Sweden had individual meters to measure consumption in each apartment, there was little reason for occupants to respond to higher prices in the short run. Yet by 1982, consumption was significantly lower than it was in 1973. While consumption also fell in the other countries, the fluctuations were greater.*

Although the overall drop in unit consumption in apartments does not appear as great as that in SFD, it is clear that energy was saved. Similar drops appear to have occurred in apartments still using stove heating (with LPG, heating oil, or kerosene). Thus, energy intensity in apartments decreased even as substructure moved towards increased energy intensity.

* Significantly, however, consumption per sq. meter in apartments and SFD is the same in Sweden, and, at a higher level, in the US. In these two countries submetering of heat in MFD is almost unknown. In the other countries, where some recording devices are present in many apartments, MFD do indeed have lower intensity.

2.2.3 Secondary Heating Fuels

An additional phenomena that became more prevalent in every country after 1978 was the use of secondary fuels for space heating. While this practice was always common in stove-heated homes, it was uncommon in homes with CH until recently. Secondary fuels may not be less expensive than oil, but their localized use allows dwelling occupants to turn off or turn down a central system. Use of secondary fuels could account for a significant drop in oil intensity without necessarily representing increases in efficiency or changes in comfort. We reason, however, that secondary fuel use may change rapidly with changing oil prices (or with the prices of secondary fuels), since such use requires continual activity on the part of occupants. Therefore, it is important to account for secondary fuel use as much as possible.

Data on the ownership of equipment for using secondary sources among all dwellings are good, particularly for SFD, from most countries, but the use of secondary fuels in *oil-heated* dwellings is not known for some. Only the Swedish SFD survey (Ref. 12) and the Norwegian Household Energy Survey¹⁴ published the use of oil, wood, and electricity in various combinations, although similar information was gathered in the US and France.

In France, electricity and wood served as secondary sources in more than 40% of *all* homes in 1982, compared with 25% of *all* homes in Canada in 1981. One quarter of all oil-using homes in the US (38% of all SFD), 45% of oil-heated SFD in Sweden, and 22% in Denmark, used secondary systems in 1982. We could not determine the extent of wood, electricity, or even coal using equipment in oil-heated homes in Germany, but there is widespread use of small electric heaters and still a great capacity to use coal as a secondary fuel. In Italy, there is an increasing use of secondary fuels -- mostly electricity -- as the CH systems become individually metered with the introduction of natural gas. Wood is important in rural dwellings, and combinations of electricity, kerosene, and LPG are common in homes without central heat. In Norway it is difficult to decide which energy source is the "primary" heating fuel; indeed, only a minority of homes, predominantly apartments, use a single source.

The potential impact of secondary fuels in any country can be seen from actual Swedish data (Ref. 8, 12, 13). Figure 6 shows consumption of oil for heating and hot water in 1982 in single-family dwellings using oil and a combination of wood and/or electricity. The shares of these three classes are also shown by the relative widths of the bars representing the three classes of homes shown. This shows that only 58% of the SFD with oil as the main fuel used *only* oil. The impact of wood and electricity in reducing oil use is clear.

If we estimate the *useful* heat derived from these three fuels, counting oil at 66% efficiency, wood at 55% efficiency, and electricity at 95% efficiency, the consumptions per dwelling all come out close to 87 GJ of *useful* energy. If we examine only non-farm dwellings, we find that *oil* consumption is 820 MJ/m² in homes using only oil, 550 MJ/m² in those also using

wood, 465 MJ/m^2 in those using oil and electricity, and 410 MJ/m^2 in those using all three fuels. This calculation takes into account that the largest "oil-heated" dwellings used three fuels, the smallest only oil. This is important and intuitively correct; those with the largest homes tend to have the largest expenditures for heating and would be most likely to seek the capability to use alternatives to oil such as are presented by wood and electricity.

Norway and Japan represent special cases. In these countries, use of two heating fuels is the rule.* In Japan, where central heating occurs in only about 4% of all homes -- those in the far north -- about 75% of all households used small kerosene heaters as principal or secondary heat sources all through the 1970s, although the fraction began to dip as LPG and LNG became more popular (Ref. 1,5). All Japanese homes possess at least one "kotatsu", or electric foot heater, but electricity is expensive in Japan. Norway represents the European equivalent in style; while more than half of all homes used oil or kerosene throughout the 1970s, the combination of wood, oil, and electricity characterized most SFD and even many MFD.¹⁵ Kerosene and electricity or wood were yielding to oil in central systems when the first oil embargo brought back wood, and accelerated the move towards electricity. In 1983, only a minority of SFD used exclusively oil in central systems, but oil use was still important in apartment blocks (Ref. 14). Most wood in Norway is gathered,¹⁶ and electricity is less expensive there than in any other OECD country. Because of these combinations it is very difficult to track the evolution of oil use from before 1973 in Japan and Norway; only total use can be estimated.

3 Changes in Oil Use: Structure, Intensity, and Conservation

We have combined the information on oil use into a variety of indicators in Table 7. The total number of dwellings heated by oil, as well as their share, are shown in the first two columns. (Recall Figures 2 and 3, which showed the shares of oil in total energy use and oil based heating systems in seven countries.) Next, we display the weight factor, as defined above, and then the average consumption of oil for heating (and hot water) per dwelling, averaged over all dwelling and system types. Total oil consumption in PJ is shown in the last two columns. Figure 7 shows the evolution of the weight factor in each country.

The changes in oil heating over time are illustrated for Germany in Fig. 8. Growth in total oil use is broken down into the growth in number of homes and growth in consumption per home. Not shown is the increase in area per home that occurred because new homes with oil-based CH were always larger than those already in the stock.¹⁷ However, growth in the weight factor is shown, as are the shares of oil-heated homes with CH and hot water.

* This was also the case in the UK until natural gas entered the heating market in the early 1970s.

The increase in the thickness of the wedge between the number of dwellings and total consumption, therefore, represents both increases in unit consumption (including the effects of hot-water and central heating penetration), and increases in the weight factor. The narrowing of the wedge after 1973, and even more so after 1979 represents a drop in overall energy intensity compared with the peak in 1972; indeed, the "total use" curve drops below the "number" curve after 1981, indicating that average intensity now lies *below* its 1960 value, in spite of the enormous increase in living standard represented by the weight factor.

Although the falling price of oil through the early 1970s (cf. Ref. 1) doubtlessly stimulated the great swing to oil from homes with solid fuels as well as any kind of non-central system, it is clear that the major factor behind the increase in total use was an increase in the total number of centrally-heated, oil-based homes in Germany between 1960 and 1970. This increase continued, albeit at a slower rate, through the early 1980s. The detailed data on consumption in SFD and MFD with central heat show only a slight increase per dwelling between 1967 and 1973 and a decrease in consumption per sq. meter, suggesting that real increases in comfort were obtained without additional oil use, through improvements in building shells as well as equipment.

This pattern is typical for most European countries we have studied, although there are important exceptions. We can highlight the most important changes that took place after 1960:

- During the period up to 1973, the numbers of oil-heated homes increased more than four-fold in Germany, Norway, and France, but much more slowly in the remaining countries, where oil had a larger share initially. Increases in the numbers of dwellings and their substructural weight accounted for at least 90% of the increase in total oil use, as the German example illustrates. Real oil prices dropped by a few percent per year through 1971 in every country.
- After the first oil shock, the share of oil heat and the share of oil in final consumption fell fastest in Sweden, the US, and Canada, where it was already losing to other fuels, but only slowly in the other countries, because of the lack of substitutes. Increases in the numbers of oil-heated homes (and/or the weight factor) offset partly or completely the reductions in oil use per dwelling in France, Germany, and Denmark. Real oil prices increased rapidly, then stabilized and even fell slightly between 1976 and 1978.
- After the second oil shock, by contrast, both unit consumption and the numbers of oil-heated dwellings decreased markedly. This period gave the appearance of a "flight" from oil, as oil use dropped by over 25% between 1979 and 1982 in every country except France. Real prices shot

up again between 1979 and 1982, then flattened and even fell slightly.

4 Savings in Oil 1972-1982

To see what the impact of the change in oil use has been, we calculate the components of this change over the entire study period. We first telescope the indicators from Table 7 into indices of changes (Table 8), by indexing the relative values of the indicators for each pair of adjacent periods.

Several important features are common to most or all countries. First, the sub-structure of the stock of oil-heated buildings has become more energy-intensive during the entire period studied, as indicated by the increasing weight factors. Second, the rates of increase in the numbers of dwellings were high through 1972 in most countries in Europe, varied between 1972 and 1978, then were uniformly negative after 1978. Finally, total oil use was lower in 1982 than in 1972, in spite of structural and substructural growth in some countries. In all countries, oil use, measured by its share in total residential energy consumption, was heading back towards its level of the early 1960s (Cf. Table 2) and actually below its absolute value in 1960-63 in Sweden, the US, and Canada.

4.1 Components of the Savings 1972-1982

Total savings of oil have two components, a structural one and an intensity one, which *multiply* to give total savings. That is, the intensity (energy/dwelling) and the structure of oil use (numbers of dwellings, type or weights) have both changed. This breakdown illustrates the importance of each component as well as that of the interactive term.

We measure changes caused by *structural change* by multiplying 1972/3 unit consumption (I_{72}) by the change in the number of oil-heated SFD and MFD, which we call dS . This shows how much more/less oil would have been used if unit consumption had not changed but the building stock structure had changed to its latest value. We measure change caused by *changes in unit consumption* by subtracting 1981/2 unit consumption from that for 1972/3 (1971 for Canada) and multiplying the result, dI , by the number of dwellings with oil heat in 1981/2 (S_{82}).

This procedure can be described by a simple linear algebraic decomposition. If I_{72} and S_{72} represent intensity and structure, respectively for 1972 (and similarly for 1982), and dI and dS represent the differences between these parameters in 1972 and 1982, we can write dE , the change in energy use, as

$$dE = (S_{72} + dS)dI + I_{72}dS = (I_{72} + dI)dS + S_{72}dI.$$

Using the first formulation, we can denote the first term in parentheses (times dI) as the intensity component, the change in energy use with 1982 structure and the observed change in intensity dI , while the second term is the change in energy use resulting from the observed structural change *if* 1972 intensity had remained in 1982. Note that the cross term is assigned to "intensity change".

These changes are shown for Germany in Fig. 9. In each figure, the vertical axis represents the *structure* S , as the number of oil-heated dwellings, while the horizontal axis represents the *intensity* of oil use, I , measured in GJ/dwelling. (Subscripts give the years actually measured.) The product of these two, i.e., the area under the curve, gives total oil consumption. The relatively small consumption in 1960 is clear from Fig. 9, and the relative changes in both S and I through 1972 are clear as well. The enormous increase in S , almost a factor of 5, is far larger than that for I (a factor of about 1.3), which is nevertheless appreciable. Similarly, the components of change between 1972 and 1982 are also clear from Fig. 9; here the increase in S is more than balanced by the decrease in I , so that total oil use decreased by somewhat greater than 10%. That I only fell by about 30% is a reflection of the increase in the weight factor during this period; unit consumption in homes with central heat fell by over 45% during this period (cf. Table 6), but the share of central heat and the share of SFD increased enough to cut this drop to only 30%. *The effect of substructure is thus important, because it can obscure the magnitude of conservation in homes with central heat before 1972, i.e., in the cohort of oil users that survived the entire post-embargo period.*

Having estimated the effect of changes in structure and changes in intensity, we can calculate the total oil savings arising because of both of these factors, using the formula given above. In Table 9, we show the components of oil savings. It can be seen that oil savings in every country, measured as the percent reduction in 1972/3 consumption (Col. 9), are appreciable. Given the increases in the weight index, these savings are even more impressive. However, they arise from different components. In Sweden and Canada, the absolute number of oil-heated dwellings has dropped 21 and 27% respectively, in the US 15%. In Sweden and Canada, therefore, close to half of the change in oil use arose from structural changes, the rest from changes in intensity. In the US and France, intensity dropped considerably more than the number of dwellings. In Norway, the number of homes using oil as the principal fuel decreased greatly, but the effect of two- and three-fuel homes blurs the details of the change and makes it equally difficult to state the reduction in unit consumption. Nevertheless, here, as in Sweden and North America, oil use decreased markedly by 1981, and this decline continued rapidly through 1983.

In the other countries, the situation is quite different. We noted above the changes in Germany. In Denmark, structure has barely changed, since the increase in the number of oil-heated SFD more than cancelled a decrease in oil-heated MFD (and a sizeable decrease in MFD using kerosene), but intensity dropped more than in any other country. In France, there was a small increase in the number of oil-heated dwellings through 1978, reversing thereafter. The drop in unit consumption in France was appreciable. Thus, in these three countries the oil drop has been caused mostly by a rapid decrease in the intensity of use, both in new and in older homes.

The reductions in total oil use in Scandinavia and North America are significantly greater than those in Germany and France. We attribute this to both the greater availability of less-costly substitutes (S, CDN, US) and the higher standards of heating and hot water use prevalent before 1973 (in DK, S, CDN, and US), which yielded to great savings after that year. Note, however, that the reductions in unit consumption in SFD in Germany and France were among the greatest we observed, reminding us that the increase in the numbers of oil-heated homes with central systems offset much of the great reduction in oil intensity in these countries. By the late 1970s, however, oil use was falling rapidly in these countries as well. What caused these reductions? Obviously higher prices played a key role. But all countries adopted conservation programs, too. We deal with possible and probable causes of these oil reductions in Part Two.

Part Two: DISCUSSION

5 Causes of Conservation

So far we have discussed the *components* of oil savings in 7 countries in detail, noting some of the aspects of change in other countries. Tables 2 and 3 showed the role of oil in residential consumption in two ways, either as the share of oil in final residential energy use, or the share of oil as the principal fuel in heating systems. Measured either way, Denmark and Sweden were the most oil intensive countries before the oil crisis. The Northeastern United States and Canada, where the oil heating share surpassed 50%, fell close to this group of European countries before 1973, but the US as a whole had by far the lowest oil dependence in the residential sector of the countries we show in detail. While oil or kerosene was used in at least 50% of Japanese and Norwegian homes in 1973, the share of oil in final consumption was still lower than in the other European countries or Canada.

Since 1972, these rankings have changed considerably as Tables 2 and 3 show. Nevertheless, *consumers in all seven countries in the present group have reduced oil use appreciably between 1978 and 1982*. This reduction did not occur immediately after 1973 in each country, because oil prices stabilized around 1976, and because substitute fuels and conservation required substantial time to be mustered. In this section, we discuss the general causes for conservation, leaving detailed intercountry comparisons for future work. While our study of the *causes* of these changes is only partially complete at this time, we discuss them here briefly. We believe that the most important *causes* of changes in oil use have been higher oil prices, energy-saving programs, and new technologies, including those that make economic use of secondary fuels.

5.1 Prices

Higher oil prices certainly played a key role in the move away from oil, or to less oil per dwelling. Table 10 shows oil prices in real local currency and indexed to 1972=100 for 7 countries. (Data sources and exchange rates are given at the end of the Table. We have not translated oil prices into a common currency because of the conversion problems discussed in Ref. 1.) The increase in all countries is clear. After 1981, the strengthening dollar caused real prices to increase in most countries while levelling off and then falling in the US, but by 1983 real prices appear to have stabilized or fallen in most countries, based on preliminary data. The drops in energy intensity that followed the price increases in 1973/4 and 1979/81 and the increase in some countries when prices fell after 1976 suggest that higher prices are the principal cause of the decreased intensities over the short run.

The changes in relative prices are often noteworthy and could stimulate massive conversions from oil to other fuels. Fig. 10 shows the ratio of the price of electric heating to that of oil, both accounted for at their delivered energy values*. In Sweden and Norway, electricity is far less expensive than oil for heating purposes, if the efficiency of conversion of an oil system is taken as 65% and that of electricity as 95%. The rush to electricity in these countries is therefore not surprising. The shift in France, however, is more difficult to explain, because electricity there is still 60% more expensive than oil under these assumptions.** In Canada

* Average electricity prices as given by statistical yearbooks must not be used for this comparison, since they are significantly higher than those charged to heating customers. For Denmark, this difference is small (but electricity was expensive); in Canada and Norway the difference is probably small but electricity is inexpensive. For France, Germany, and Sweden we used prevalent heating tariffs, because they allow for significant differences. For the US, there is enormous variation in tariff structure and prices: by the late 1970s, however, average and heating prices were close. For gas these variations are not important any more because the "average price" for all residential is so close to the price for heating gas, and relatively independent of the fixed charge.

** Incentives to install electric heat probably play an important role in France.

and the US there are great regional differences in electricity and gas prices, and the need for air conditioning often makes an electric heat pump a desirable feature in a new home¹⁸, but there is little evidence of conversions from oil to electricity. In Denmark, electricity prices are highest, relative to oil, and consequently there have been fewer conversions to electricity, and a relatively high share of oil in new SFD.

Another common substitute for oil is gas. Gas is popular in France and Germany but only now (1983/4) available in Denmark; in these countries, it is not significantly cheaper than oil, while gas prices are still considerably lower than oil prices in North America. Gas is gaining from oil in all five countries (and Italy and Japan as well) in both existing and new homes, but non-existent in Sweden and Norway. In the UK and Holland, gas has dominated the heating market since the early 1970s. It is also worth noting that wood has become an important substitute for oil in some countries, principally where it is cheap or free, i.e., in all of Sweden and Norway and large parts of Canada and the US.

The overall comparison shows that a substitute fuel must be considerably cheaper than oil to cause defections from oil to that fuel, but a small price differential is all that is necessary for the share of the substitute to increase in new homes. Concerns about the *availability* of oil certainly stimulated many conversions to other fuels in the US and elsewhere in 1979 and 1980. Of course other factors may cloud the simple price comparison, such as heating system and connection costs and incentives.¹⁹ However, it appears that if houses are built very tight, as in Sweden, fuel choice is less critical to the prospective homeowner because the absolute differences in yearly costs will be small. Indeed, homes using electricity were built tighter than those using gas or oil in virtually every country before 1973.

5.2 Incomes

We mentioned changes in incomes in several contexts so far.* There is no question that income growth before 1973, combined with falling oil prices, fueled the move to oil-fired central heating and hot water systems, as well as increased ownership of electric appliances. Moreover, oil users (with CH) tended to have the highest family incomes in all the countries we studied through 1972, but this distinction blurred as CH penetration increased and fuel used diversified. The overall picture shows residential end-use energy grew as fast as, or faster than incomes, before 1973.

* These are given in Reference 1. Again, we prefer to deal with real income growth in each country's own currency, leaving intercountry comparisons to our other work.

In our econometric study (Ref. 11), however, we found that the long-term income elasticity of total energy use was less than one, if home size and central heating penetration, which are co-linear with income, are included along with prices and incomes, as explanatory variables. We found little evidence that energy use per dwelling continues to increase once the major energy uses are satisfied; new uses like home computers or communication equipment are not energy intensive at all, particularly compared with space and water heating. While higher incomes permit people to continue to use oil and maintain a reasonable standard of indoor comfort, high incomes also allow users of oil flexibility in choosing new systems, conservation investments, or even new homes.

But when incomes fall, does energy use in existing equipment and houses fall? Denmark and Sweden suffered from stagnation in income or expenditure growth after 1977, recovering only in 1982/83. France, Canada, and the US faced a similar situation in the early 1980s. Similarly, unemployment grew in all countries. We do not doubt that this contributed to depressed unit energy consumption, but we believe the effect *minor*.

First, the drop or stagnation in income is small compared to the relative increase in oil prices, the effect of which appears to dominate changes. Second, the drop in oil intensity is much greater than the drop in incomes. These two effects together suggest that a slight drop in income accounted for only a small part of the drop in oil use. Furthermore, the drop or stagnation in income may have retarded oil conservation in several ways. Fuel conversion and conservation requires capital, which, even if available through government programs, is scarce in hard times. Thus, conversions from oil, as well as conservation investments, could have proceeded more rapidly if income growth had been stronger. Finally, new housing and equipment replace old more rapidly in good times. In countries with relatively low residential energy-use levels, like Italy and Japan, higher incomes mean larger dwellings and more equipment, particularly for central heating. In these countries, a return to economic growth means more of these amenities. But in Northern Europe and N. America these uses are saturated; new equipment and housing will mainly reduce average energy intensities.

Whether total energy use increases with recovery depends on whether new technologies improve faster than household formation and equipment ownership increases; in Sweden, Denmark, and the US it appears that energy use/household could decrease steadily enough to hold down total residential energy use through the end of the century, although a slight increase is possible. Below, however, we argue that the likelihood of an increase in oil use, and particularly a return of oil's domination in the residential market, is very improbable. Thus, we conclude that the overall impact of slowed economic growth has probably retarded movements away from oil, and that return of real growth will not push up oil use very much in the medium term. We return to this point later on.

5.3 Energy Conservation Programs

Have government programs aided oil savings? A variety of energy saving programs have been instituted by the countries studied, usually to reduce oil and energy use by subsidizing consumers' and builders' costs for investing in energy savings, sometimes to create employment, always to gain popularity with voters. More specific goals of reducing oil dependence mark each country's program as well. The rapid drop in oil use has now continued for several years, suggesting that energy conservation policies and programs may now be "working". While a complete review is out of the scope of this article (see Joerges et al.²⁰ or CEC²¹), there is general consensus that programs *have accelerated savings somewhat or even caused some savings that would not have occurred otherwise*. Still, higher prices appear to be the most important *cause* of savings; the interaction of higher prices and programs is significant, too.

In particular, programs have been aimed at three components of oil use, encouraging alternatives to oil as a heating fuel by subsidizing alternatives (Sweden, Canada), supporting conservation investments in existing homes (all countries), and requiring improvements in shells and equipment in new homes (most countries or states/provinces), often through the public housing loan system. The first two of these thrusts are passive, making incentives available but requiring little of existing building owners. Only Denmark has adopted mandatory inspections of existing boilers and the requirement of a heat inspection before sale of an existing house, while France has developed several persuasion programs, such as that encouraging the limiting of temperatures and delay of the onset of the heating season, and (in 1974/5) restrictions of oil deliveries. Requiring improved thermal insulation in new homes unfortunately could not have much impact on oil use, except in those three countries (DK, F, FRG) where significant numbers of oil-heated dwellings have been built after the new codes came into effect.

The main focus of programs, then, has been provision of funds for investments in existing homes, and of information to all energy users. However, if we accept our contention that much of the savings in the majority of countries are *simple* technical or behavioral fixes that were introduced rapidly when oil prices rose, then it is difficult to contend that they would not have occurred anyway in the oil-heated stock, *sooner or later*, without the help of investment programs. But the evidence of large investments in a majority of the oil-heated building stock is lacking, except in Sweden, where the program raised the rate of investment by occupants of SFD in conservation to nearly 66% between 1974 and 1982. This suggests that there may be a continued need for programs already in place in the other countries. As these programs continue to mature, they could accelerate such investments in all countries, or increase the investments' size and scope. In the 1980s, the impact of programs should become more visible as oil prices stabilize and oil users who want reduced oil costs face sizeable investments in

their homes. Moreover, we believe that the pervasive information campaigns contributed greatly to the rapid decline in oil intensity after 1979. Consumers were clearly better prepared to reduce oil use by that time than they were in 1973.

5.3.1 Secondary Fuels

We consider the use of supplementary heating fuels to be both a component and a cause of oil conservation. We estimate their impacts here. Judging from their high documented penetration, secondary fuels had the greatest impact on unit oil consumption in Sweden. The *Residential Energy Consumption Survey*²² shows that consumption of oil per degree day in SFD in the US tends to fall markedly as one moves north. While improved weatherization in colder climates is partially responsible, we believe a major role has been played by increased wood heating; only about 3/4 of the oil-using SFD reported using oil as the principal fuel in 1981; wood supplied much of the rest. Wood appears to be important in Canada (Imperial Oil Co., and Shell Oil Co., priv. comms.), as is inexpensive electricity. The smallest impacts of secondary fuels appear to be in Denmark, Germany, and France, because electricity is expensive and wood not nearly as widely available as in the aforementioned countries. Oil itself as a secondary source has seen a curious revival in the US, where small kerosene heaters (of questionable economic merit) became popular again after 1979. As stated in the first part, dual-fueled homes are the rule in Norway and Japan.

Overall, we estimate that the use of secondary fuels is responsible for at most 20% of the actual *decline* in unit oil consumption in SFD in Sweden, Canada, and parts of the US, but less important in MFD in any country. The impact is considerably smaller in France and Denmark and probably least in Germany.

6 Oil Savings: Permanent or Reversible?

The permanence of the drop in oil use depends on whether it was caused by modifications to the building stock and heating equipment through substantial investment, including conversions away from oil, that are virtually permanent, or by behavioral measures (popularly called "sacrifices") that can be reversed, or by improved maintenance of systems, which, once learned, might nevertheless be abandoned if oil prices decrease. We also classify as permanent the reductions in energy intensity caused by modifications to the building shell or heating system, although they would allow indoor temperatures to creep upward somewhat if energy prices fell. We classify behavioral changes as temporary in the sense that they could disappear ("wear off") if prices fell.

We would like to try to ascribe the savings observed to various technical and behavioral changes that buildings and families respectively have undergone since 1973. We cannot determine exactly the components of the drop in unit consumption without recourse to data on indoor temperature, monthly energy use, and the presence of other sources of heat, such as appliances. However, several facts stand out from our data that allow us to make *rough estimates* of the nature of changes in oil use.

We classify conversions away from oil as permanent; only in Sweden and Norway is dual fired equipment (oil + electricity/wood) so important for using electricity or wood that those using these latter fuels today could switch back to oil on short notice. We estimate that in these countries 80% of the structural change is actually permanent. About 20% more homes than those that actually used oil in Sweden in 1982 could still burn oil in their furnaces, but burned wood or used electricity instead. Thus, not all the structural change in Sweden is permanent. In Norway, multi-fueled equipment is even more prominent. A much smaller share of conversions in Canada and the Northern US also reflect switch to wood as the principal fuel without necessarily eliminating access to oil-heating equipment.

The changes in unit consumption differ among countries. In Sweden, the drop in unit consumption has been slow but steady. Temperatures are still high, heated area still greater than nominal dwelling area. Oil intensities fell slowly but gradually, and the number of homes that undertook substantial retrofits is among the highest among all countries studied (Refs. 8, 12). Based on these characteristics of the change in Sweden, we estimate that 75% of the drop in intensity there is permanent. The rest is caused by lower temperatures or reduced hot water use, and by use of secondary fuels, which we deem reversible.

In France, Germany, and Denmark, there were precipitous drops in 1973/4 (which were reversed somewhat by 1976), and 1979/81, which only began to flatten out in 1982. In the US and Canada, the changes were also rather rapid, especially after 1979. These drops are too steep to be technical in nature, since the entire oil-heated stock could not have been retrofitted in two years to produce a 20-30% drop in unit consumption. In our judgement, most -- 75% -- of the drop in unit consumption in these countries was caused by purposeful changes in behavior or very simple measures to improve boiler efficiency through better maintenance; this part of the drop in intensity is reversible, and could gradually evaporate if prices fell over several years. This is consistent with estimates made by authorities for France.²³ However, it is probable that technical improvements will supplement or replace some of the behavioral changes in the 1980s.²⁴

We can now estimate the permanence of the oil change. While these permanent and reversible shares are not exact, they illustrated the differences among the components of oil conservation in the sample of countries. Using these factors, we transform "structural" and "intensity" changes given in Table 9 into "permanent" and "reversible" changes, shown in Table 11. Our analysis indicates that only in Sweden are the oil savings overwhelmingly permanent, and only in the US and Canada is the permanent component close to 50% of the total "savings". However, the numbers of oil-heated dwellings are now decreasing in Denmark, France, Germany, and Norway as well as in the first three countries. Therefore, residential oil use will probably slide downward for several years to come, as more of the changes becomes permanent, even if the pace of retrofitting decreases.

7 Will Oil Return?

Although our estimates of "permanent" and "reversible" change in oil use are at best rough, they shed light on whether oil use is on the way out of the residential market. Recall the shape of Figure 3, which featured a strong rise in the use of oil in most countries through 1973, a plateau or gradual fall from 1973 until 1978, and a distinct fall after 1978 that seems to be continuing through 1983. This shape suggests that the heating oil era is on its way out.

Could anything bring back oil? We do not think so. Heating oil will probably remain limited to smaller markets, homes far removed from gas or district heating networks, while losing single-family dwellings in countries with cheap electricity or wood.

We pointed out above that the early 1980s were a time of deep recession and high unemployment. We believe that while brighter economic times -- an upturn -- will allow somewhat greater energy use in homes in the short term, that such an upturn will also hasten the replacement of poorly performing equipment with better houses, appliances, hot-water heaters, and heating systems, and will encourage greater renovation and retrofit of structures. Moreover, greater economic activity allows more families to invest in non-oil equipment. Since the demographic driven expansion of the housing stocks of most colder OECD countries is now maturing, and equipment ownership is growing only slowly, the coupling that characterized higher incomes in the past with higher oil use is probably much weaker today than it was earlier in Sweden, Denmark, W. Germany, and N. America. It is hard to believe, for example, that more rapid economic growth would lure builders or buyers back to oil based systems in new construction in increasing numbers. Therefore, we do not believe that an economic upswing will have more than a minor effect on oil use, as long as the price of oil remains high; more likely, an economic upswing (with stable or rising oil prices) would accelerate the drop in the number of oil-heated homes and increase investments in

conservation technology.

If oil prices fell considerably for many years, and economic growth were strong, however, conversions away from oil would probably stop, more homes among those still using stoves would chose oil as a fuel when converting to central heat, conservation investments would slow, and the share of oil in newer homes would increase again. We will not judge the likelihood of these pre-conditions, but we assert that both must occur in order to "bring back" oil. Even if all of the "reversible" part of the oil savings were to disappear, current trends in the numbers of oil-heated homes point to greatly decreased oil use during the coming years. We believe that the main uncertainty facing the oil OECD residential oil market is how far use will drop, and how fast. The general trend illustrated in Figure 2, i.e., the bell-shaped rise and fall in oil, will continue downward in every country.

8 Conclusions

From this review of oil heating since 1960 in nearly a dozen countries, including a detailed look at seven countries, we conclude that oil is on the way out of the residential market in the developed countries, after a dramatic increase between 1955 and 1972. The conditions for each country studied often differed significantly in 1973, yet the oil backout is continuing everywhere.

Structure -- increases in home size and comfort and preference for oil over solid fuels -- drove up oil use by 40 to 500% in the European countries between 1960 and 1972, with increases in North America much smaller. These increases were driven primarily by rising incomes, since the rise in the number of homes with oil-based central heat was far greater than the increase in consumption per home induced by falling oil prices. Falling oil prices (Ref. 1), however, certainly contributed to the rush towards oil in homes already possessing central heat from solid fuels.

After the first oil embargo, households reduced oil use considerably, but much of the reduction in unit consumption disappeared by 1978. The effects of the second oil shock (1979) were far more permanent, as homes converted from oil to other fuels for heating and hot water in increasingly greater numbers, and oil intensity fell rapidly in most countries. However, only in Sweden is as much as 75% of the savings in oil virtually permanent, i.e., caused by major changes to dwellings and equipment. In most other countries, more than half of the reduction in oil use has arisen from rapid decreases in oil intensity, caused predominantly by behavioral change and inexpensive modifications to homes and equipment. Secondary fuels have played a small but non-negligible role as well in allowing those still using oil to use less. In France and Germany, significant oil savings arising from reductions in unit consumption

were masked by the rapid increase in the penetration of central heating and, in Germany, by the continued increase, through 1981, in the number of homes using oil. After 1979, unit consumption plunged in every country, and by 1982/3 was at least 25% below its 1973 value. Higher oil prices appear to be the principal reason for these savings, but the impact of government programs, particularly in France, Denmark, and Sweden cannot be overlooked.

In most countries, the homes heated with oil are among the oldest and largest. Therefore, there remains a considerable conservation potential in these homes. This point was made repeatedly by the CHIP study of retrofit in Canada,²⁵ and is reinforced by the surveys of retrofit behavior in every other country. Whether some of this potential will be "traded" for higher comfort levels remains to be seen. However, the large numbers of homes built in the 1960s and 1970s in France, Germany, and Denmark where oil was the principal fuel remain in the stock as oil users. The low age of these homes may explain why conversions to other fuels have proceeded so slowly in these countries compared with others. As the oil-using equipment in these homes finally begins to age, we expect interest in conversion to other fuels or in higher-efficiency oil burning equipment.

While rising incomes themselves will not alone cause a major rebound in oil use, a combination of rising incomes and a prolonged period of falling oil prices could reverse many of the short-term savings made in existing homes and increase the popularity of oil once again in new construction and modernization. But rising incomes will also fuel conversion of aging oil-burning equipment to other fuels, provided oil prices remain high. And in most of the countries we studied substantial public and private investment in alternatives to oil heating is now maturing. It is likely that continued conversions away from oil will offset any increases in the use of oil in existing or new homes for many years to come.

The sample of countries we studied reduced *residential* oil from its 1972/3 value by 33%. Since these countries accounted for nearly 70% of the OECD residential and commercial oil use in 1980 and had the same level of overall oil use in the R/C sector as the remaining OECD countries, it is tempting to conclude that the calculations and conclusions herein could describe the residential sectors of other OECD countries. However, reductions in oil use in the R/C sectors of Italy and Japan do not appear to have been as great as in the countries we studied, so we cannot generalize to the entire OECD. In Austria, Belgium, Finland, and Switzerland, however, appreciable reductions have been reported. We suspect, therefore, that the overall reduction in the residential use of oil in the OECD, between 1972/3 and 1982, is probably close to 30%, somewhat lower than in our seven study countries alone. Moreover, 42% of the decline in residential oil use in the seven countries was permanent; the permanency of the decline in the entire OECD is probably very close to this level as well. Overall, governments have met a very important energy policy goal announced in the 1970s, the reduction of oil use.

APPENDIX 1: The "Bottom Up Approach": Data Sources and Limitations

1. Remarks on Data

The work we report is based on a "bottom up" picture of actual consumption in the residential sector combining information on structure with that on unit consumption. For oil consumption, we have obtained survey information from oil companies, survey companies, and national authorities in all of the countries we have studied; data for Canada and the US before 1978, Italy, and Japan are the probably weakest, while those for the other countries are generally good and available for virtually every year since 1970. Limitations on our own resources, however, have permitted us to concentrate on detailed descriptions of only a few key years between 1960 and 1982, which may vary from country to country because of varying data quality and availability.

Information on the building stock and its energy using equipment was made available from censuses and building registers as well as from private, yearly surveys taken for fuel and electric companies. Quality varied from year to year. One of our major tasks in this project was to make sure that these data and the indicators we developed from them were comparable over time and among countries.

Although reducing residential oil use has been a goal of the governments of every country we have studied, so-called "official" data on residential oil use are rarely available. This is usually because oil *deliveries* (as opposed to use) are usually recorded as a residual after transportation and industrial uses have been counted. Unfortunately, delivery data do not specify the nature of the consumer and, hence, confuses residential and non residential uses. Part of the confusion arises because only three OECD governments support yearly, combined surveys of energy use and housing/building stock characteristics (France [Ref. 23] Sweden [Ref. 12], US [Ref. 22]), and only France regularly incorporates the results into a set of energy use balances by fuel and end-use for the residential sector proper. In Germany²⁶ and the UK,²⁷ delivery data, without reference to structure, are published yearly, from which recognized authorities, such as the Verein der Deutschen Elektrizitaetswerken in Germany or the Energy Technology Support Unit in the UK, produce analyses of "residential" energy use regularly. In Japan, the Institute for Energy Economics performed surveys of residential energy use patterns in 1973 and 1979, with a survey for 1984 forthcoming; otherwise, there are no regularly reported data that include all fuels. Energy companies in every country produce and usually provide detailed studies of the energy structure of households as well as their consumption. This is particularly true for oil. Thus, in every country the basic data on energy and oil consumption are available, albeit rarely published by a single official source.

Most countries, the United Nations, the IEA, and the EEC, however, tend to rely on the "other sector" as a proxy for residential, or their analyses focus on this sector *per se*. But non-residential buildings (and other users in the Residential/Commercial (R/C) sector) have different characteristics from homes: different occupancy schedules and densities, a different mix of energy needs/uses (heating, cooling, hot water, processes), a different sensitivity to variations in weather, and, perhaps most important, a different coupling between occupants, managers/owners, end-use technologies, and energy prices/costs. Finally, the share of residential energy use in the R/C sector has changed in almost every country, falling steadily in most cases. Actual reductions in energy use in homes are in part masked by increases in use in other buildings, in part because floor area in non residential buildings may have grown

more rapidly than in homes. Therefore, it is difficult, if not impossible, to judge the nature of changes in energy use in homes using data on the R/C sector, without recourse to data on the *structure* of energy use, i.e., the number, size, type, and age of homes, and unit consumption (per home or even per square meter of heated area). But the inhomogeneous nature of the R/C sector makes its *total* consumption itself (as presented for example, by an analysis for the Common Market [CEC])²⁸ an inappropriate indicator of the behavior of any of its components. We prefer to isolate residential buildings, non-residential buildings, and non building uses such as street lighting, sports arenas, utilities, etc., and study each part separately.

Data on oil present particular problems. Gas, electricity, and to some extent district heating *use* can be studied from delivery data because information on sales by subscription and tariff category often reveal the stock of appliances in question, and there is no problem of tertiary stockage, i.e. changes in stocks in the consumer's own supply. Oil deliveries, on the other hand, as well as those of other liquid or solid fuels, do not necessarily represent consumption because they do not account for variations in tertiary stocks. Moreover, deliveries are reported by distributors or refiners aggregated into very uncertain categories; "apartments" are confused with commercial buildings (and counted that way officially by many countries), and the category says nothing of the number of households or the nature of their equipment. Therefore, we deem deliveries of oil to the R/C sector inadequate as a measure of oil use or conservation in the residential sector.

Fortunately, we have obtained excellent data on unit oil consumption ("bottom-up") for single-family dwellings (henceforth SFD) in all countries we have studied and for multifamily dwellings (henceforth MFD) in most. There are a few important limitations on our figures for oil consumption (other than actual errors in reading consumption or bills), however. The most important is the sampling error that arises if the sample of oil-heated homes is different in vintage, geographical distribution, size, or the demographic attributes of the occupants of the homes, from the actual population. Part of this problem is due to the limitations of the population, which may purposely exclude the newest homes, or exclude homes that only use oil irregularly, i.e., use oil in combination with other fuels. Therefore, the total consumption obtained from multiplying unit consumption by the number of consumers may be somewhat more inaccurate than unit consumption.

A final uncertainty pertains to proper counting of farmhouses, and of homes that are also used for commercial purposes, or that lie in office buildings, as these may be excluded from certain surveys of "residential" customers. Farmhouses are counted in all the SFD surveys we have examined, but most exclude apartments in commercial buildings, although their numbers were counted in surveys of the building stock. They typically account for only 5% of the oil-heated stock, so small errors in unit consumption will be unimportant for the portrait presented herein.

2. Structure and Intensity

The principal indicator of the structure of heating is the number or share of dwellings using a particular fuel. But the substructure of use is also important. Substructure refers to the presence of central heating, usually a furnace or boiler with a hydronic or hot air system distributing heat to almost every room, vs. non-central heating, i.e., one or more room stoves; to the mix of single-family dwellings vs. apartments; to the use of oil for hot water as well as

space heating,* the distribution of oil-heated dwellings among climate regions, or the area of a given kind of dwelling. All these factors cause intrinsic changes in oil consumption that may or may not be directly related to consumers' actions to save oil; indeed, they may increase oil use even as consumers are reducing oil needs through other means. Therefore, their impact must be estimated.

Single-family dwellings with central heating, for example, tend to use more fuel than MFD with the same equipment, or than SFD with kerosene heating stoves, in which temperatures are usually lower and fewer rooms heated or heatable. We estimate this effect by forming an index or weight of substructure, assigning a weight of 1.0 to SFD with central heat, 0.5 to SFD with non-central heat or MFD with central heat, 0.33 to MFD with non-central heat. These figures roughly represent the differences in consumption per dwelling using oil, kerosene, and LPG with central and non-central heat in 1972. The dominant changes in the substructure within a country will be captured by changes in the substructure weight factor; similarly, gross differences between countries will also be clear.

The increase in the *nominal* area of homes contributes to the increase in oil use. The average area of oil-heated homes of a given kind (ie., SFD, MFD) changes because of new construction (or addition) and removal, as well as by conversions of existing homes towards or away from oil, homes that may be larger or smaller than the average existing oil-heated home. Area is usually specified to tax and building authorities and defined for each country. However, dwelling areas is not always known by principal fuel, and we cannot always specify *heated area*, which may be larger or smaller than the nominal area. Fortunately, a few countries' surveys (Denmark, Sweden, US, Germany) measure or estimate area at the same time as oil consumption is surveyed. We present data, where known, on changes in oil consumption per unit area.

The use of oil for domestic hot water, heating also affects the unit consumption of oil.** By comparing oil-heated homes with/without hot water we can estimate hot water use (Ref 9). Fels and Goldberg²⁹ report some success in measuring hot water use and its change (in American homes) with monthly data from samples of individual homes. Our data are not this carefully detailed, as few representative measurements of fuel used for hot water have been made, but we must estimate the share of oil use for hot water in order to estimate the space heating component for comparison among countries and to correction for variations in climate among countries or over time. Where there is evidence of changes in hot-water use we report it; indeed, there is evidence in many countries that consumers have disconnected the hot-water function of the oil heater. However, the penetration of oil-based hot water in homes with central-heating has not varied as much within a country over time as it varies among countries. Where possible, therefore, we point out these intercountry differences but we do not pursue changes within a country over time.

For a few countries, data permit us to measure short-term variations in oil intensity, i.e., on a monthly or quarterly basis. This allows us to estimate changes in unit consumption into very short-term changes as well as long term trends, using the methods discussed in Fels and Goldberg (Ref. 27). It is desirable to further break down changes into behavior, and into

* Note that in Denmark and Sweden "heating" (opvarmning, uppvärmning) almost always refers to both space heating and water heating. In other countries, and in this paper, we separate these two different end-uses whenever possible.

** There are very few homes using oil for hot water but not for space heating.

various kinds of technical change (boiler/furnace, hot water, shell system improvements), but we found that data limitations -- the lack of monthly or weekly consumption data in most countries -- make it difficult to quantify these details credibly. We find that we can explain most of the changes in oil use as changes in the numbers of dwellings using oil, their weights, unit consumption for heating, and in some cases changes in oil use for hot water.

3. Accounting Formalities

In this study 1 m^3 of #1 heating oil (fyringsolie in Danish and Norwegian, heating gasoil in British, fuel or mazout in French, leichtes Heizöl in German, eldningsolja in Swedish, but usually #2 heating oil in the US) = 35.6 GJ, unless otherwise noted; 1 m^3 (530 KG) of LPG (GPL in French, gasol in Swedish, Flaschengas in Germany, flaskegas in Norwegian and Danish) = 24.4 GJ; 1 m^3 of kerosene (abbreviated kero: petroleum in Danish, petroleum lampant in French, paraffin in Norwegian and British, fotogen in Swedish) = 33.1 GJ; 1 m^3 of heavy fuel oil, used in apartments and some multi-building systems in Sweden (kwatercentraler), Denmark (blokkcentraler) and Germany (Blockheizung) = 38.9 GJ.

While kerosene and LPG are usually minor fuels, we have taken care to note where they are included in our sample. Kerosene is almost only used in heating stoves (except for some central heating in the US), while LPG may be used for central or room heating, hot-water, and cooking (which we exclude). We include kerosene use with oil in data from every country, and include LPG for France, Denmark, US, Canada, and Japan. In Sweden, LPG use is insignificant, while in W. Germany it is small and usually counted with gas. In the US, LPG use is still important in mobile homes and in rural areas.

We count the multi-building heating systems using oil under oil heat; otherwise, we include district heating systems, usually owned by public or private companies that sell heat, as such, ignoring the actual fuels used to produce hot water or steam in the system. The fraction of input energy made up by oil varies greatly between countries, but it has fallen sharply, particularly in Denmark and, recently, in Sweden. Unfortunately, there is always some confusion between district heating and oil use in group centrals, particularly in the data for Denmark, where these systems are most prevalent, but district heating systems per se dominate. Because of the rapid change, we do not consider the fuel make-up of district heating directly. Moreover, we are looking primarily at *consumer reaction* to changes in energy prices and other forces. While consumers do not choose fuels for district heating, the prices they pay for district heating depend in large part on the fuels chosen by district heating companies.

A similar situation holds for electricity. Most countries have reduced the oil inputs to primary electric generation, but every country counts input energy differently. In our work, we have adopted a standard conversion factor of electricity to primary energy use, 2.89, corresponding to the OECD average for 1960 - 1978, and converted district heating at an efficiency of 75%, or 1.33. These figures are meant to be illustrative for comparison purposes, not exact. Detailed study of actual primary energy use in each country was beyond our purpose.

APPENDIX 2: Climate Correction

Because of the importance of yearly variation in climate conditions, as measured by degree-days, we developed time series of degree-days for each country. Our figures are shown in Table A-1. We used conventional, population weighted degree-day figures generally used by government and the oil industry to establish the actual weather in each country. We then adjusted these figures to a common base, 18C, for purposes of intercountry comparison, by adjusting degree-day figures by an amount equal to the product of the length of the heating season (in days) and the change in base (in degrees). This procedure introduces a small error, because a change in base itself causes a change in the length of the heating season. We ignore degree-days outside of the heating season, and we observe the heating threshold, i.e., degree days in Sweden and Germany are not counted in the spring and the fall unless the outdoor temperature falls below a threshold, usually 12 C.

In most countries, the overall climate index was taken as representative of that for oil, although oil tends to be used more in the suburbs and rural areas than gas. However, oil users in the US, France, Italy, and Sweden reside in colder climates than those using other fuels; in Sweden this difference is small (about 5%) and can be ignored. For the US we used the degree day count that reflects distribution of oil-heated homes; for France we could not obtain these data.

If the number of degree-days in a given year varies by $1+v$ over its long-term average, then consumption for space heating is multiplied here by $1/[1+v]$ to arrive at a "climate corrected" total. Other methods that correct part of total residential consumption by less than v (Carlsson, Ref. 14), or by greater than v ³⁰ are also reasonable. These are discussed in Schipper 1984d.³¹ Note that the climate correction is only applied to the space-heating part of oil use.

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Table 1. Energy Use in OECD countries in 1980, according to the OECD

	Total Energy,	Oil,	Oil Share,	Residential & Commercial			Res. + Comm.		Oil Share
	PJ	PJ	% of total	Res., PJ	Comm., PJ	% of total	PJ	% of oil	of R+C, %
CANADA*	6361	3475	53.7	1103	838	30.5	666	19.2	33.8
DENMARK*	609	491	80.6	228	65	44.8	172	35.0	75.5
FRANCE*	6078	3893	64.8	7700	295	33.5	1063	27.3	53.2
GERMANY*	8257	4833	58.5	2211	889	38.8	1743	35.7	53.9
NORWAY*	690	362	52.4	749	62	30.5	68	18.8	31.6
SWEDEN*	1357	862	63.6	427	57	35.7	329	38.2	68.1
USA*	54764	29899	55.8	12483	4681	35.7	4664	15.6	27.2
TOTAL 7	77450	43748	56.5	18301	6968	32.6	8705	19.9	34.5
HOLLAND	2186	872	39.9	652	231	40.4	104	12.0	11.8
ITALY	4408	2729	61.9	1253	111	30.9	740	27.1	54.2
JAPAN	11252	7299	64.9	2101	253	20.9	1270	17.4	54.1
UK	5770	2707	46.9	7538	751	39.7	303	11.2	18.7
TOTAL 11	101065	57352	56.8	23845	8314	31.8	11122	19.6	35.0
Other OECD	10665	6457	60.5	2474	502	27.9	1443	22.3	48.5
Total OECD	111729	63808	57.1	26319	8817	31.5	12565	19.7	35.8

NOTES TO TABLE 1: Figures are from OECD "Yearly Energy Balances", in which energy is accounted at its delivered values, not corrected for climate. The split between Residential and Commercial is from those balances and shown for comparison with our own figures. Individual country data, including our own studies, show without doubt that the OECD balances allocate much of the "commercial" sector oil consumption into "residential".

LPG is counted with oil, but the OECD treatment of district heating is uncertain. Electricity is counted at its end-use value, 1 kWh=3.6 MJ.

The seven countries selected for detailed study are marked with an asterisk (*).

Table 2. Residential Fuel-use Breakdown
Percent of Delivered Energy for All End-Uses

Country (year)	Total PJ	Oil %	Gas %	Coal/Coke %	Wood %	DH %	Elec %
CANADA							
1961	732	55	20	14	<-	..	11
1971	1126	53	28	3	<-	..	17
1976	1244	45	32	1	<-	..	22
1981	1176	32	37	2	<-	..	29
DENMARK							
1965	170	53	2	26	<-	13	6
1972	241	71	2	2	<-	18	7
1977	237	67	2	2	<-	18	11
1982	176	57	2	3	<-	22	15
FRANCE							
1962	651	24	8	62	<-	1	5
1973	1364	62	12	17	<-	2	8
1978	1426	54	18	11	<-	3	13
1981	1336	52	21	9	<-	3	15
GERMANY							
1960	951	17	5	73	<-	1	5
1972	1792	58	10	18	<-	3	11
1978	2070	58	18	7	..	3	15
1982	1933	47	24	8	1	3	17
JAPAN							
1965	525	19	18	48	<-	..	15
1973	977	58	16	5	<-	..	20
1979	1183	49	21	2	<-	..	28
NORWAY							
1960	74	19	..	->	45	..	36
1965	79	20	..	->	31	..	48
1973	109	37	..	->	11	..	52
1978	121	29	..	->	11	..	60
1981	130	21	..	->	16	..	63
1983p*	..	18	..	->	14	..	68
SWEDEN							
1963	262	55	2	11	21	3	8
1972	367	71	1	1	5	9	14
1978	349	57	1	..	6	15	22
1982	334	42	..	..	11	18	29
USA							
1960	7870	36	43	9	3	..	9
1970	10465	27	51	2	4	..	16
1973	11510	28	50	1	4	..	18
1976	10995	25	50	1	5	..	19
1978	11625	24	47	1	6	..	21
1981	10840	18	49	1	8	..	25
1982p	10255	15	49	1	9	..	26

NOTES TO TABLE 2: LPG is counted with oil for every country except Germany and Japan, where it accounts for less than 2% of consumption and is mixed in with gas. However, cooking uses are ignored in subsequent discussion.

All data are climate-corrected. Wood consumption is understated for Canada because its secondary wood use is not recorded by surveys. Gas is city gas in Sweden and Denmark, and predominantly city gas in Germany and Japan before 1970.

The arrow (-> or <-) means that the data are aggregated into the column to the immediate right (left); this implies that the contribution from the column with the arrow is probably much less than that in the column indicated by the arrow.

(..) denotes not used or less than 0.5%.

(*) denotes data taken from a household survey of over 2000 homes; total consumption was unavailable.

(p) indicates preliminary value.

All values corrected to normal climate. Totals may not add to 100 because of rounding off.

Sources: LBL data base (Refs 2, 5-9). Individual country estimates taken from major oil companies, Housing Ministries, Energy Ministries, Utility Associations. For most countries our calculations differ radically from OECD statistics labelled "residential" (Cf. Table 1).

Table 3. Primary Space Heating Fuel

Country Year	Dwellings 10 ⁶ Units	Oil	LPG	Piped Gas	Electric	District Heat	Coal/ Coke	Wood	Other
(% of dwellings)									
CANADA									
1961	4.6	59	<-	19	..	..	22	<-	..
1971	6.0	57	1	31	6	..	1	4	..
1977	7.2	45	1	38	14	..	..	2	..
1981	8.0	34c	1	41	21	..	..	3	..
DENMARK									
1965	1.60	46	<-	1	..	19	33	<-	..
1972	1.86	62	<-	2	1	30	6	<-	..
1977	2.02	59	<-	2	3	32	3	..	..
1982	2.2	54c	<-	2	6	36	2	1	..
FRANCE									
1962	14.6	12	3	6	10	0.7	68	<-	<-
1973	17.3	50	3	12	4	1.6	26	<-	3
1978	18.6	45	3	18	10	3	18	<-	3
1981	19.6	41	4	22	13	3	15	<-	2
GERMANY									
1960	15.4	14	->	1	..	1	84	<-	..
1972	21.4	48	->	11	4	5	32	<-	..
1978	23.4	53	1	15	7	5	19	1	..
1982	24.3	52	1	23	8	7	8	1	..
1983/4	24.7	50	1	24	7	8	9	1	..
NORWAY ^c									
1960	1.08	13	..	..	16	0	4	67	..
1967	1.22	28	..	..	29	0	2	41	..
1973	1.37	52	..	..	28	0	2	21	..
1980	1.53	33	..	..	48	0	1	19	..
1983	..	25	..	..	50	0	..	25	..
SWEDEN									
1963	2.8	57 ^c	0	1	..	4	15	24 ^c	..
1972	3.3	69 ^c	0	2	6 ^c	17	1	6 ^c	..
1978	3.6	57 ^c	0	1	15 ^c	24	..	4 ^c	..
1982	3.7	44 ^c	0	..	21 ^c	30	..	4 ^c	1
USA									
1960	53.0	32	5	43	2	..	12	4	..
1970	64.5	26	6	55	8	..	3	1	..
1973	69.3	25	6	55	10	..	1	1	..
1978	77.2	21 ^c	5	55	16	..	1	1	..
1981	83.2	17 ^c	5	55	19	..	..	2	..
1982p	..	15	5	57	16	..	1	6	0.1
Northeast US									
1970	15.5	54	1	37	3	..	3	1	..
1978	17.0	55	1	37	6	..	1	1	..
1981	17.9	48	1	41	7	..	1	1	..

NOTES TO TABLE 3: (c) indicates that a large share of these dwellings are known to use a second fuel. (p) indicates preliminary value.

For all countries, the principal fuel used is indicated. For Canada, France, and the US, the figures reflect occupied dwellings; for other countries, all dwellings. "Other" includes "unknown", or combinations of three or more fuels and systems; in the case of France the figures refer to the share of non-heated dwellings.

For Norway (1983) and the US (1982), the total number of dwellings was not known for the most recent year.

Sources: Government and private surveys in each country (see Refs. 2, 5-9).

Table 4. Substructure of Oil-Heated Stock

Country Year	Dwellings w/oil,10 ⁶	Type, %				Weight Factor	Oil Based Hot Water,% ¹	
		SFD		MFD			in SFD	in MFD
		Central	Non-Central	Central	Non-Central			
CANADA								
1961	2.67	70	30	<	<	0.75	-	-
1971	3.47	59	10	31	<	0.80	17	38
1976	3.23	61	6	33	<	0.80	22	39
1981	2.75	65	4	31	<	0.85	25	42
DENMARK								
1965	0.75	43	9	33	15	0.69	32	26
1972	1.16	58	5	29	9	0.78	55	27
1977	1.19	62	3	30	5	0.80	61	30
1982	1.18	65	2	30	3	0.82	65	30
FRANCE								
1962	2.14	10	27	36	27	0.51	-	7 -
1973	9.05	26	19	35	19	0.59	14	18
1978	9.09	34	14	38	14	0.64	20	21
1981	8.63	38	12	38	12	0.67	23	22
GERMANY								
1960	2.08	21	26	27	26	0.56	-	7 -
1972	10.35	35	19	31	14	0.64	30	15
1978	12.40	44	13	33	10	0.70	34	18
1982	12.60	46	11	34	9	0.71	-	58 -
1983/4	12.45	46	12	34	8	0.72	-	57 -
NORWAY								
1960	0.14	6	16	46	32	0.48	2 ^[2]	28 ^[2]
1967	0.34	8	50	23	18	0.51	2 ^[2]	10 ^[2]
1973	0.70	8	55	16	20	0.51	2 ^[2]	10 ^[2]
1980	0.50	16	52	17	15	0.55	2 ^[2]	6 ^[2]
1983	0.41	18	58	21	3	0.59	2 ^[2]	6 ^[2]
SWEDEN								
1963	1.56	27	5	64	4	0.63	22	58
1972	2.23	41	1	56	2	0.70	40	56
1978	2.06	44	0.3	55	0.2	0.72	44	55
1982	1.63	44	0.2	56	0.2	0.72	44	56
USA								
1960	19.6	..	..	..	..	..	-	37 -
1970	20.5	62	10	24	4	0.80	-	37 -
1973	21.5	..	..	..	..	0.81 ^[2]	-	37 -
1978	20.0	65	10	23	4	0.82	-	34 -
1981	18.3	65	10	22	4	0.82	-	47 -

NOTES TO TABLE 4: The weight factor measures "substructure", where an SFD with central heat ("central", henceforth called CH) is given a weight of 1.0, an SFD with non-CH or an MFD with CH a factor of 0.5, and an MFD with non-CH 0.33.

An arrow (-> or <-) denotes that the information is contained in the adjacent column as indicated. "x" indicates that LPG is counted in gas statistics and unavailable.

For France, we assume that half of the dwellings labeled "non central systems" by our sources are SFD, half MFD.

(1) Fraction of homes with oil heat that also have oil-based hot water. The breakdown into SFD and MFD, where known, is shown. The sum of these two give the total penetration of oil-based hot-water systems among oil-fired dwellings. In almost every case, oil-based hot water systems are found only in homes with central heating, and with oil as the principal fuel. Hot water figures are estimated from surveys that include questions about hot water (Germany, Canada, US, France) or from penetration of hot water overall and known penetration of oil-based central heating (Sweden, Denmark, Norway).

US figures are somewhat uncertain, because, according to the RECS (Ref. 22), there were in 1981 some homes with oil-based hot-water but not heat, mostly homes now using wood for their principal space heating fuel or homes using LPG for water heat but not oil for space heat.

(2) Figures very approximate or interpolated.

Sources: LBL data base; Danmarks Statistik; Statistics Canada; Agence Francaise pour la Maitrise de l'Energie (AFME), Centre d'Etudes et de Recherches Economiques sur l'Energie (CEREN), LBL-IES French Data Base; Hauptberatungsstelle fuer Elektrizitaets Wirtschaft, Esso, and private surveys (Germany); Statistisk Sentralbyraa (Norway); LBL Swedish Data Base; US Annual Housing Survey, Census, Residential Energy Consumption Survey(s). US data for 1960 and 1973 were unavailable. Hot water data from other years are from the Annual Housing Surveys and the Residential Energy Consumption Surveys.

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Table 5. Main Heating Fuel in New Homes

	SFD	MFD	SFD	MFD	SFD	MFD	SFD	MFD	SFD	MFD	Fraction of Stock Built After 1974
CANADA	<u>1971-75^a</u>		<u>1976-80</u>		<-		<u>1981-82</u>		<-		
Number (000)	906	414	953	357	<-	<-	37	11	<-	<-	18.3%
Oil,%	26	14	10	6	<-	<-	5	4	<-	<-	
Gas,%	40	36	45	29	<-	<-	49	31	<-	<-	
Elec,%	30	50	39	65	<-	<-	32	65	<-	<-	
Other,%	4	0	6	0	<-	<-	14	0	<-	<-	
Dist.%	0	0	0	0	<-	<-	0	0	<-	<-	
DENMARK	<u>1970-74^a</u>		<u>1975-79^a</u>		<u>1980-82^a</u>		<u>1981^d</u>		<u>1982^d</u>		
Number (000)	164	75	136	78	50	17	na	na	na	na	12.9%
Oil,%	55	29	42	21	22	11	23	17	20	13	
Gas,%	<1	1	<1	<1	1.4	<1	4	2	?	?	
Solids,%	0.8	<1	<1	0	<1	0	..	..	..		
Elec,%	11	1	20	3	26	6	30	?	23	5	
District.,%	33	68.	36	74	46	64	42	81	50	76	
FRANCE ^b	<u>1970-74^a</u>		<u>1975-79^a</u>		<u>1980</u>		<u>1981</u>		<u>1982</u>		
Number (000)	824	1215	921	1071	212	138	205	130	192	132	22.5% ^b
Oil,%	65	60	29	14	22	3	24	4	17	1	
LPG,%	5	1	2	2	3	6	4	7	6	8	
Gas,%	21	25	20	44	24	40	24	45	24	49	
Solids,%	2	2	2	1	1	0	0	0	1	1	
Elec,%	7	2	47	24	50	42	48	34	52	32	
District,%	0	10	0	15	0	9	0	10	0	9	

Table 5 (Continued). Main Heating Fuel in New Homes

	SFD	MFD	SFD	MFD	SFD	MFD	SFD	MFD	SFD	MFD	Fraction of Stock Built After 1974
GERMANY	<u>1970-74^a</u>		<u>1975-79^a</u>		<u>1980^f</u>		<u>1981^f</u>		<u>1982^f</u>		
Number (000)	2830		1821		249	114	220	118	189	126	11.4%
Oil,%	59		54		50	30	50	27	48	24	
Gas,%	20		24		38	56	37	58	38	60	
Solids,%	3		2		2	0.5	3	0	3	0	
Elec,%	6		9		7	6	8	7	8	7	
District,%	13		11		1	7	1	7	1.5	8.5	
SWEDEN	<u>1971-75^a</u>		<u>1976-80^a</u>		<u>1980</u>		<u>1981</u>		<u>1982</u>		
Number (000)	206	251	196	75	36	16	34	18	29	18	12.0%
Oil,%	39 ^e	31	10	20	9	11	7	15	4	17	
Solids,%	..	..	8	<1	7	<1	12	0.1	8	1	
Elec,%	53	8	69	18	52	9	55	11	64	14	
District,%	7	61	12	61	22	73	24	73	22	68	
USA	<u>1972-75</u>		<u>1976-79</u>		<u>1980</u>		<u>1981</u>		<u>1982</u>		
Number (000)	4132	2898	4692	1810	957	545	819	447	632	374	15.4%
Oil,%	9	5 ^c	9	5	3	2	2	2	3	2	
Gas,%	46	34 ^c	38	28	41	30	41	32	40	28	
Elec,%	43	60 ^c	50	66	50	66	50	66	50	68	
Dist.,%	0	0	0	0	0	0	0	0	0	0	
Other,%	2	1	3	1	6	2	7	0	7	2	

NOTES TO TABLE 5: Data for the first period are taken from a survey undertaken between 1975 and 1977; we presume there were few removals or conversions, so that the distribution in the year of the survey reflects that when the homes were built. Where totals add to less than 100, "other" or solids have been omitted. "Fraction of Stock Built after 1974" gives the fraction of the 1982 stock completed 1975 or later.

(na)- not available. (..) indicates near zero share. Arrows (-> or <-) indicate data aggregated into adjacent columns, as shown.

a - Estimate based on a survey taken after the period.

b - Covers only homes with central heating (including electricity), about 90% of all completions in 1970, 95% in 1975, and nearly 100% by 1982.

c - 1974-75

d - Based on share of floor area of new construction for years shown.

e - Includes 2% with combination boilers (oil and wood).

f - Based on permits granted ("Baugenehmigung") for the year shown.

Sources: see Table 4.

Table 6. Oil Use in Single-Family Dwellings with
Central Heating Based on Heating Oil

	1970	1972	1973	1975	1976	1977	1978	1979	1980	1981	1982	1983
DENMARK												
Cons.,GJ/dw	..	194	..	148.5	162.8	164.8	160.8	147.6	133.6	108	116.9	117.0
Hot Water,GJ/dw	..	32	..	30	29	28	28	27	26	23	23	23
Hot Water,%	..	100	..	100	100	100	100	100	100	100	100	100
Heat, MJ/DD	..	52.0	..	42.0	42.6	43.8	43.2	38.6	34.5	27.3	30.0	30.1
CANADA												
Heat,GJ/dw	175.1	169.5	174.5	171.5	167.0	161.3	151.1	147.2	142.7	139.8	127.7	125.8
Heat, MJ/DD	38.2	37.0	38.1	37.4	36.5	35.2	33.0	32.1	31.2	30.5	27.9	27.5
FRANCE												
Cons., GJ/dw	..	..	150	118	120	121	121	110	101	104	..	..
Hot Water,GJ/dw	..	..	42.7	24.3	33.1	32.2	33.9	31.0	22.6	20.5	..	..
Hot Water,%	..	..	52.9	56.1	56.8	57.5	57.9	58.4	58.8	59.2	..	..
Heat, MJ/DD	..	..	52.0	42.5	41.2	41.9	41.3	37.7	35.9	37.7	..	..
GERMANY												
Cons.,GJ/dw	165	161	157	136	137	141	137	126	107	107	103	98
Hot Water,GJ/dw	18	18	18	16	17	17	17	16	15	15	15	15
Hot Water, %	65	67	68	70	72	73	75	76	75	74	73	73
Heat, MJ/DD	49.6	47.5	45.5	39.9	40.0	43.9	40.0	36.4	30.8	30.7	29.4	27.8
SWEDEN												
Cons., GJ/dw	159	169	..	150	144	141	137	129	121	116	115	114p
Hot Water,GJ/dw	35	35	..	35	34	34	33	32	30	29	28	28p
Hot Water,%	100	100	..	100	100	100	100	100	100	100	95	95
Heat, MJ/DD	30.9	33.4	..	29.4	27.7	27.0	26.1	24.6	22.6	21.8	21.7	21.4p
USA												
Cons., GJ/dw	203.0	220.2	203.3	...	185.0	...	169.8	160.0	134.9	129.4	141.2	..
Hot Water,GJ/dw	40	40	39	...	38	...	36	35	34	33	33	..
Hot Water, %	30	30	30	...	31	...	32	33	33	34	34	..
Heat, MJ/DD	65.2	71.1	65.4	...	59.1	...	54.0	50.6	42.2	40.3	44.4	..

NOTES TO TABLE 6: For each country, the first entry gives the climate corrected oil use per single-family dwelling (SFD) inclusive of hot water use (except for Canada). The estimated use of oil for hot water *in SFD with oil-based hot water* appears next (except for Canada), followed by the penetration of oil-based hot-water in oil-heated SFD, except for Sweden and Denmark, where penetration is virtually 100%. Finally, the space heating component, in MJ/DD_{18C} is shown.

Consumption is the average consumption of heating oil per dwelling for heating and hot water (whether or not present), except for Canada, where only estimated consumption for heating is shown. *All values corrected to normal climate.*

Heated area per dwelling in 1981/2 was approximately 135m²/dw in Denmark, 130m² in France, 125m²/dw in Germany, 150m² in Sweden, and 161m² in the US, according to surveys. Heated area is unknown for Canada, but we believe it to lie around 140m².

Sources:

Canada. Data from a major oil company. Oil-heated hot water is found in only 20% of dwellings in 1971, rising to 27% in 1981. We estimate about 45GJ/dw for hot water in 1971, falling to approximately 35-40GJ/dw in 1981.

Denmark. Data from two oil companies and a detailed housing survey (see Ref. 7). Hot water in about 100% of dwellings. We assume 35GJ/dw in 1970, falling to 25GJ/dw in 1982. About 30% of oil-heated dwellings had some kind of supplementary heating in 1982, but the impact of these heaters was probably less than 10GJ/dw.

France. Data from the Agence Francaise pour la Maitrise de l'Energie (AFME), and from yearly surveys by the Centre d'Etudes et de Recherches Economiques sur l'Energie (CEREN).

Germany. Data from a major monthly oil survey, as published by Deutsche Esso. About 65-75% of SFD had oil-based hot-water, (as shown) consuming about 18GJ/dw in 1970; changes shown are assumed, not measured, but have only a small impact on the corrected total consumption per house. Climate data based on a "normal year" of 3113 DD₁₈, that is, the official total of 3613DD₂₀ adjusted downward by 2⁰ times 250 heating days.

Sweden. Data from four oil companies, several oil studies, Cent. Bur. of Statistics *Single-Family Dwelling Energy Statistics*, and LBL studies (see Ref. 2 [appendix in English], 8). Includes two-family dwellings, or about 6% more dwellings than houses. The penetration of oil-based hot water was virtually 100% through 1980, but then fell somewhat as wood and electricity were used instead in about 5% of dwellings. Consumption is assumed to be 35GJ/dw in 1970, falling to 28GJ/dw in 1982. Furthermore, homes in 1981 and thereafter that used only oil used about 20GJ/dw more than the average shown here, because of the use of wood and electricity.

USA. Figures are for heating season beginning in the fall of the year shown, ending in the spring of the following year. Data from Fuel Oil and Oil Heat dealer survey. See also Ref. 9.

Table 7. Oil Use in Four Periods: Aggregate Structure and Intensity

Country	Structure			Intensity	Oil Consumption	
	Dwellings w/Oil, 10 ⁶	Share %	Weight Factor	GJ/dw ..	Heat,HW PJ	Other PJ*
CANADA						
1961	2.67	59	0.75	145	387	..
1971	3.47	57	0.80	172	597	..
1978	3.23	45	0.80	173	560	..
1981	2.75	34	0.82	137	376	..
DENMARK						
1965	0.75	46	0.69	124.7	93	1.5
1972	1.16	62	0.78	152.7	177	1.0
1977	1.19	59	0.80	130.6	156	1.0
1982	1.18	54	0.82	83.4	102	0.9
FRANCE						
1962	2.14	15	0.51	50.0	107	50
1973	9.05	52	0.59	86.8	785	54
1978	9.09	49	0.64	79.4	722	54
1981	8.63	44	0.67	74.1	640	54
GERMANY						
1960	2.1	14	0.56	76.9	160	
1972	10.4	48	0.64	99.5	1031	..
1978	12.4	53	0.70	92.3	1193	..
1982	12.6	52	0.73	72.5	913	..
NORWAY						
1960	0.17	13	0.48	83	14	..
1973	0.70	52	0.51	59	41	..
1981	0.48	33	0.59	57	27	..
SWEDEN						
1963	1.56	57	0.63	92	144	..
1972	2.23	69	0.70	116	260	..
1978	2.06	57	0.721	96.4	198	..
1982	1.63	44	0.718	85.2	138	..
USA						
1960	19.6	37	na	144.5	2813	10
1970	20.5	32	0.80	142.1	2818	10
1973	21.5	31	0.81	149.9	3223	10
1978	20.0	26	0.82	139.5	2790	10
1981	18.3	22	0.82	106.6	1951	10

NOTES TO TABLE 7: "Oil" here includes LPG and kerosene for heating and hot water, denoted "Heat, HW". "Share" is the fraction of all dwellings that use oil, LPG, or kerosene for heating. [*] "Other Oil" refers principally to "cooking" and some hot water.

Sources: see table 4.

Table 8. Indices of Changes in Residential Oil Use

Country	Number w/Oil	Relative Change in ... (no change = 1.00)			
		Weight Factor	Total Oil	Oil/ Dwell	Oil/Dw, Weighted
CANADA					
1961-71	1.30	1.07	1.54	1.19	1.19
1971-78	0.97	1.0	0.94	1.00	1.00
1978-81	0.85	1.03	0.67	0.79	0.76
DENMARK					
1965-72	1.55	1.12	1.89	1.22	1.08
1972-77	1.03	1.03	0.88	0.85	0.84
1977-82	0.99	1.03	0.65	0.66	0.62
FRANCE					
1962-73	4.23	1.16	7.33	1.74	1.50
1973-78	1.00	1.08	0.92	0.91	0.84
1978-81	0.95	1.05	0.89	0.93	0.89
GERMANY					
1960-72	4.97	1.14	6.44	1.29	1.13
1972-78	1.20	1.09	1.16	0.93	0.85
1978-82	1.02	1.04	0.77	0.73	0.76
NORWAY					
1960-73	4.1	1.06	2.93	0.71	0.67
1973-81	0.69	1.16	0.66	0.97	0.84
SWEDEN					
1963-72	1.42	1.11	1.80	1.26	1.13
1972-78	0.92	1.03	0.76	0.83	0.81
1978-82	0.79	1.00	0.70	0.88	0.88
USA					
1960-73	1.09	na	1.14	1.04	na
1973-78	0.93	1.01	0.87	0.93	0.92
1978-81	0.85	1.0	0.70	0.77	0.97

NOTES TO TABLE 8: Each index gives the change in the indicator shown during the period given. Values greater than 1 mean increases in the indicators between the period(s); values less than 1, reductions. The indices are multiplicative, so that a change in the number of dwellings, times the change in unit consumption (oil/dwelling), gives the change in total oil consumption. Weight factors can be used to reflect the change in the substructure; the change in the number of dwellings is multiplied by the change in the weight factor, while the change in unit consumption is *divided* by the same change in weight factor.

Consumption and unit figures for Norway do not exclude oil as a secondary source in 1960, accounting for the high figure/dwelling, and figures for 1978 were unavailable.

Sources: see table 4.

Table 9. Oil Savings 1972-1982

Country	Structure		Weight	Intensity	Structural	Intensity	Savings:	
	Change Wtd, %	Change Unwtd, %	Change %	Change Unwtd, %	Component I(dS),PJ	Component S(dl),PJ	Total (PJ)	Oil Reduction % Of 1971/3 Use
CANADA								
1971-1981	-18%	-21%	+3%	-20%	-122PJ	-96PJ	-218PJ	-37%
DENMARK								
1972-1982	+7%	+2%	+5%	-43%	+3PJ	-82PJ	-79PJ	-44%
FRANCE								
1973-1981	+8%	-5%	+13%	-15%	-36PJ	-109PJ	-145PJ ¹	-18%
GERMANY								
1972-1982	+39%	+22%	+14%	-27%	+224PJ	-340PJ	-116PJ	-11%
NORWAY								
1973-1981	-21%	-31%	+16%	-3% ²	-13PJ ²	-1PJ ²	-14PJ	-33%
SWEDEN								
1972-1982	-26%	-27%	+3%	-28%	-70PJ	-52PJ	-122PJ	-47%
USA								
1973-1981	-14%	-15%	+3%	-29%	-480PJ	-792PJ	-1272PJ	-39%
TOTAL SEVEN ³	..	..	..	..	-494PJ	-1472PJ	-1966PJ	(-32%)

NOTES TO TABLE 9: The *Structure Change* gives the percentage change in the number of dwellings using oil, both weighted (*Wtd*) by the weight factor defined in Table 4, and unweighted (*Unwtd*). The *Intensity Change* gives the change in oil use per oil-heated dwelling. The two components are defined in the text. The *Total Savings* refer to the change in oil use. All changes refer to the years shown for each country.

(1) Excludes 10PJ reduction in "other" oil (hot water and cooking);

(2) Figures uncertain because of oil use in mixed systems where oil was not the predominant fuel.

(3) Note that the initial and final years are not the same for every country.

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Table 10. Residential Heating Oil Prices
Real (1970) local currency per GJ

	1970	1972	1975	1978	1980	1981	1982	AAGR
CANADA								
CDN\$/GJ	..	1.33	1.65	1.98	2.23	2.86	3.12	8.5
Index	..	100	124	149	168	215	235	
DENMARK								
DKR/GJ	7.4	8.1	12.9	13.6	26.4	29.25	30.9	14.3
Index	91	100	159	168	325	361	381	
(Kero, 33.7MJ/l)								
DKR/GJ	..	..	..	19.7	30.3	33.8	35.7	..
FRANCE(35.48MJ/l)								
FFR/GJ	6.85	6.77	10.2	10.7	17.7	19.8	21.2	12.1
Index	101	100	150	158	261	292	313	
GERMANY (35.6MJ/l)								
DM/GJ	3.25	3.08	5.99	5.70	10.7	11.8	11.90	14.5
Index	106	100	194	1.85	347	383	386	
NORWAY (35.1MJ/l)								
NOK/GJ	7.46	8.1	13.1	13.5	22.3	25.95	24.9	11.9
Index	92	100	162	167	275	307	304	
(Kero, 33.7MJ/l)								
NOK/GJ	12.5	12.8	17.1	16.9	25.8	29.4	29.9	8.0
Index	98	100	138	132	202	230	234	
SWEDEN (35.6MJ/l)								
SEK/GJ	5.0	4.7	8.2	9.0	15.8	20.1	23.1	17.3
Index	106	100	174	191	336	428	491	
USA								
USD/GJ	..	1.31	1.85	2.01	3.14	3.52	3.26	9.5
Index	..	100	141	153	240	269	249	

NOTES TO TABLE 10: AAGR, average annual growth rate, calculated between 1972 and 1982.

In 1970, 1 USD = (approximately) 7.5 DKR, 1.05 CDN\$, 4.8 FFR, 3.6 DM, 6.8 NOK, 5.15 SEK.

In July, 1984, 1 USD = 10.5 DKR, 1.33 CDN\$, 8.6 FFR, 2.89 DM, 8.2 NOK, 8.35 SEK.

Sources: LBL Data Base. Canada, US values from Energy Information Agency. Danish values from Energistyrelsen. French values from AFME. German values from Bundesministerium fuer Wirtschaft. Norwegian and Swedish values from respective Statistical Offices.

Table 11. Residential Oil Savings 1972-1982: Permanent or Reversible?
 Seven OECD Countries
 (Actual periods given)

Country	Components ¹		Reversible (PJ)	Total Savings	
	Permanent (PJ)	(%)		Absolute (PJ)	Share of Oil Use, %
CANADA					
1971-1981	-146PJ	67%	-72PJ	-218PJ	-37%
DENMARK					
1972-1982	-17PJ	21%	-62PJ	-79PJ	-44%
FRANCE					
1973-1981	-63PJ	43%	-82PJ	-145PJ	-18%
GERMANY					
1972-1982	+139PJ	-120% ²	-255PJ	-116PJ	-11%
NORWAY ³					
1973-1981	-13PJ	78%	-1PJ	-14PJ	-33%
SWEDEN					
1972-1982	-95PJ	78%	-27PJ	-122PJ	-47%
USA					
1973-1981	-678PJ	53%	-594PJ	-1272PJ	-39%
TOTAL SEVEN	-873PJ	44%	-1093PJ	-1966PJ	-32%

NOTES TO TABLE 11:

(1) The components were derived from the structural and intensity components in Table 9. The Structural component was considered "permanent" except in 20% of the dwellings in Sweden that maintain multiple fueling capacity. The Intensity component was considered 25% permanent (i.e., technical improvements to the building shell and boiler) and 75% reversible (behavioral change) in all countries except Sweden, where 75% of the intensity changes appears to be technical and the rest equally shared by behavior and use of secondary fuels.

(2) Because of the great increase in the number of oil-heated dwellings, the permanent reduction in oil use from reduction in intensity is far less than the increase from structure. Therefore the figures are somewhat misleading.

(3) Figures for Norway are uncertain because of domination of mixed systems, whose changes are probably significant. This drop is thus predominantly reversible.

Table A-1. Heating Degree-Days

	Official (Base Temp.)	This Study (18C)
CANADA	..	4581
DENMARK	2987 (17C)	3122
FRANCE	2450 (18C)	2450
W.GERMANY	3613 (20C)*	3163
NORWAY	3680 (17C)	3910
SWEDEN	3760 (17C)	4010
USA	..	2600
(Oil)	..	2950**

NOTES TO TABLE A-1: For each country the long-term average is used; derivation is given in Refs. 5,7,8,9.

* - 20C is indoor reference temperature, but heating days are counted only when the daily average is less than or equal to 15C.

** - Based on the distribution of dwellings with oil as principal heating source in 1980 and the average values of DD in those areas. In 1960, the distribution gave 0.5% more DD, in 1970 0.5% less.

Sources: Canada, Shell Oil Co., Canada; Denmark, Energistyrelsen, based on Teknologisk Institut without adjustment for sun (225 heating days, based on monthly averages); France, Agence Francaise pour la Maitrise de l'Energie (AFME); Germany, Deutscher Wetterdienst and Esso (250 day season); Norway, Statistik Sentralbyraa, Meteorologiska Institut (225 day season assumed); Sweden, Oeverstrelsen foer Ekonomiska Foersvar, VVS Tekniska Foereningen (250 day season calculated from VVS monthly heating day averages); US, LBL calculations (Ref. 9) based on population weighted distribution of oil-heated dwellings.

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- 5 Oil Heating Intensity in Multi-family Dwellings with Central Heating, 1962-1980, in kJ/deg. day/m^2 .
- 6 Use of Oil and Secondary Fuels in SFD in Sweden, 1982. The vertical axis gives GJ/dwelling. The horizontal axis gives the proportion of dwellings using the combinations shown. For combined systems, the quantities of alternative fuels are also shown, here figured at their combustion values.
- 7 Evolution of the Weight Factors in Seven Countries. The weight factor was calculated by dividing the oil heated stock into single- and multi-family dwellings, both with and without central heating. Weights were 1.0 for SFD with CH, 0.5 for SFD without CH and MFD with CH, and 0.33 for MFD without CH.
- 8 Factorial Analysis of the Evolution of Total Oil Use in the Federal Republic of Germany. The values of total oil use, total oil heated dwellings, and the weight factor for each year were compared with 1960 values (=100). Below the straight line, the actual saturation of central heating and oil-based hot water in oil-heated homes are shown. "Total Oil" crosses below "Number of Oil Heated Dwellings" in 1982 because oil use per dwelling in 1982 fell below its 1960 value. The shaded areas give the changes in the three major factors.
- 9 Total Oil Use and its Structural and Intensity components in Germany, 1960, 1972, and 1982. The vertical axis gives the relative number of dwellings (with the actual numbers shown for reference) in the three years; the horizontal axis shows the intensity of oil use, and the area under each year's rectangle is proportional to total oil use.
- 10 Evolution of the ratio of the price of heating electricity relative to the price of heating oil. For Germany, Sweden, and France, actual heating prices were used; for the other countries, heating prices were close to average prices.

ENERGY USE AND OIL USE IN OECD NATIONS (1980)

OECD NATIONS (111.73 EJ)

SEVEN NATIONS (77.45 EJ):
CANADA, DENMARK, FRANCE, GERMANY,
NORWAY, SWEDEN, USA.

FIG. 1

OIL ENERGY SHARE* OF RESIDENTIAL ENERGY USE IN OECD COUNTRIES

*INCLUDING LPG AND KEROSENE.

FIG. 2

SHARE OF DWELLINGS WITH OIL HEAT IN OECD COUNTRIES

FIG. 3

OIL HEATING INTENSITY
SINGLE FAMILY DWELLINGS
SPACE HEATING: KJ / DD / M²

FIG. 4

AVERAGE OIL CONSUMPTION
FOR CENTRAL HEATING IN APARTMENTS
Adjusted for climate and area

Figure 5

SWEDEN USE OF SUPPLEMENTARY FUELS IN OIL-HEATED SINGLE-FAMILY DWELLINGS

FIG. 6

WEIGHT FACTORS SUBSTRUCTURE OF OIL-HEATED HOUSING STOCK

FIG. 7

Factors Driving German Residential Oil Use

FIG. 8

GERMANY CHANGE IN RESIDENTIAL HEATING OIL USE

FIG. 9

ELECTRICITY HEATING PRICE TO FUEL OIL PRICE RATIO FOR O.E.C.D. NATIONS

FIG. 10

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