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RESIDENTIAL ENERGY USE AND CONSERVATION IN DENMARK: 1965-1980

Lee Schipper

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Lee Schipper

Energy & Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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ABSTRACT

New data have been assembled to quantify patterns of residential energy use in Denmark from 1965 to 1980 by fuel and end-use. Indicators of the structure and intensity of energy use are developed from basic data and reviewed. Changes since 1972 are quantified and compared with those observed in other countries. Reduction in oil use in oil-heated dwellings is shown to be the largest among OECD countries. Elements of past, present, and future Danish conservation policies are reviewed. While many of these are unique and far reaching, the predominant cause of conservation through 1980 has been short term measures stimulated primarily by higher energy prices.

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1 INTRODUCTION

Average energy use in Danish households, adjusted for climate, was one of the highest in Europe in the early 1970's. By 1980, energy use in Danish centrally-heated houses, relative to climate had dropped to one of the lowest. Denmark's high standard of living, among the highest in Europe, with a relatively large (57%) share of single-family dwellings and virtual saturation of all important electric appliances and hot-water equipment makes this energy reduction particularly notable. This change has been so dramatic that Denmark has been included in the LBL study of the residential sectors of major countries in the Organization for Economic Cooperation and Development (OECD).[1]

In the present study we first analyze previously unpublished data on energy use in the residential sector, and form indicators of important trends in energy use. Such indicators are a prerequisite for understanding changes in residential energy use that have occured in response to higher energy prices, government conservation programs, building codes, new technologies, turnover of the housing stock, and demographic factors. We then discuss some of the policy initiatives that have been undertaken in Denmark, and compare changes in energy use patterns with those observed in other countries. Details of the yearly calculations of energy use and structure are presented at the end of this paper in the form of an appendix.

With slightly over 5.1 million inhabitants, Denmark does not account for a very large share of total OECD energy use, but its high standard of living and housing makes it interesting for comparisons with other cold OECD countries where central heat is almost universal, such as Sweden, Canada, or the USA. There are almost no published data on the energy consumption patterns of Denmark's residential sector by fuel or end use. Only the studies by Noergaard[2] have attempted to review historical trends in energy use and equipment in the residential sector. A variety of data sources were reviewed for our analysis, including much unpublished material provided by the energy industries and by the Energy Ministry (EM). We reconstructed residential residential energy use by dwelling type, purpose, and fuel for years between 1965 and 1980, as detailed in the appendix.

2 DETERMINANTS OF RESIDENTIAL ENERGY USE: TRENDS SINCE 1965

Table 1 presents selected housing, economic, and demographic data for Denmark. By 1965 the penetration of central heating had passed the 65% mark, the level reached in France and W. Germany fifteen years later. The rise in central heating after 1965, however, was still important in Denmark since

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Abbreviations used herein include SFD and MFD (single and multiple family dwellings), CH (central heating) DH (district heating), DD (degree-day centigrade), dw (dwelling). Where critical, original Danish terminology is given in the text.

centrally heated dwellings used more than twice the heat energy, and usually much more energy for hot water than dwellings with stoves (kakkelovne).

Real personal disposable income per capita during the study period (1968-1980) increased until 1976, averaging 2.8% year. This increase allowed growth in equipment ownership, which continued through the early 1970s as the number of dwellings heated with oil continued to increase even after the oil price shock of 1973.

During the same period the number of occupants per dwelling decreased from 2.97 in 1965 to 2.43 in 1980, making it one of the lowest among the OECD countries. At the same time, dwellings, particularly SFD, became larger. Together, these factors caused a marked increase in heated area per capita, a trend characteristic of all the countries we studied.

The increase in energy prices and the fall in disposable incomes after 1976 conntributed to a reduction in the growth of energy demand in the mid-1970's. This slowdown in economic activity was more marked in Denmark than in the other high-income countries we studied and may account for the large relative energy savings. Indeed, real income per capita declined each year after 1976, and income per household was only marginally higher in 1980 than it was in 1970. A declining savings rate somewhat buffered personal consumption from similar changes. Given the increases in fuel prices experienced in Denmark (as shown for oil and district heating in Table 1), a great reduction in energy use per household would not be surprising.

Fuel choice trends parallel those in other OECD countries. Table 2 shows the strong move away from solid fuels and non-central heat to oil and district heat, with electricity appearing in the mid-1970s. In 1965, solid fuels accounted for 15% of the central-heat (CH) systems ("central varme") and 65% of the non-central (non-CH) systems ("ovne"). Solid fuels disappeared quickly; non-central systems fueled by cleaner kerosene ("petroleum") stoves were slower to disappear. City gas accounted for a small share of central heat and even some stoves in apartments but has never been a major fuel for heating. However, it supplied a large (>40%) share of cooking energy needs and satisfied part of the demand for hot water. When natural gas from the North Sea is introduced into Denmark in 1982, it is expected to have a major impact on the fuel balance.

As central heating became universal, oil and district heating (DH) assumed nearly all of the energy requirements for space heating. The number of DH systems in Denmark is large, and the share of dwellings with DH (30%) is the largest in the OECD, particularly the share of SFD. Although an increasing share of district heating is provided by combined heat and power, the largest part of heating in Denmark has always been provided by direct use of heavy oil. This oil dependence means that Danish households felt the full weight of the oil price shocks.

The fact that the number of dwellings heated by oil increased continuously even through 1980 illustrates Denmark's problem in having no short-term alternatives to oil except conservation. By contrast, the share and absolute number of oil-heated dwellings began decreasing in 1979 in North America, Sweden, Germany, and France. In spite of the 10% increase in the saturation of dwellings with central heat, oil use in Denmark actually increased by less than 1% in 1977 (over 1972). The quantity of oil burned directly decreased by 26% between 1977 and 1980 (and by about 10% more in 1981), even though centrally-heated space was still increasing. Thus there is prima facie evidence for radical change in consumption in Denmark.

Denmark's electricity demand has grown more rapidly, both for heat and for non-substitutable uses (i.e., motors and communications). As seen in Table 3, appliance saturation rapidly increased during the 1960s and 1970s. These increases in appliance ownership were the primary driving force behind the 6.5% annual growth rate in electricity use per household through 1977. Recent growth, however, has been caused primarily by new electric-heating customers, and appliance electricity use appears to have fallen. Indeed, total electricity use in 1980 was lower than in 1979, while heating increased, which implies that appliance electricity use decreased markedly.

3 TRENDS IN ENERGY CONSUMPTION

The data assembled in Table 4 show important trends in energy intensity in Danish households. We show energy intensities (energy use per unit of activity) for each of several years between 1965 and 1980. We give end-use (or delivered energy) except where noted.+ The calculations and year tables are shown in the Appendix. In Figure 1 the intensities for each use are displayed.

These figures aggregate many different kinds of users and energy sources, factors that greatly affect the values. For example, cooking includes fueled and electric systems, and hot water includes combined heat-hot water systems as well as individual tanks and quick-recovery units. The composition of the dwelling stock by vintage, dwelling type and occupany has an important impact on energy use per dwelling or per capita. These factors may account for some of the changes observed in energy use over the study period.

In 1970, the average oil-heated SFD in Denmark used about 180 GJ for heat and hot water, more than than the average in Sweden, Germany, or the USA. Only oil-heated homes in Canada used more, but the Canadian climate is nearly 50% more severe. Use in apartments was also relatively high. High energy use can

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+ Primary energy, as given therein, counts district heating at 75% conversion efficiency and electricity at 34.6%, the OECD average for 1960-1978. These figures were used in our studies of other OECD countries (Ref. 1).

be explained in part by extra heating in farmhouses for processes, high indoor temperatures (estimated as high as 23° C by Noergaard (1977)), and the large gross dwelling areas (as great as 131 m^2 for detached houses in 1980). Further, insulation was not made mandatory nationwide until 1961, so a large portion of the existing stock was poorly insulated.

Because of Denmark's high standard of living, energy uses for hot water and appliances were also relatively high. The resultant share of consumption devoted to space heating, which fell from 78% in 1965 to under 70% in the late 1970s, was about average for OECD. We have noted increases in the penetraton of central heat, hot water, substitution of electric for gas cookers, and a continuing increase (through 1977 at least) in the use of electricity for household appliances. We believe that hot water use per dwelling, at least for oil and DH, has decreased. Cooking habits have changed because of the changes in appliances and household size; we draw no conclusions about stove efficiency. We attribute most of the decrease in total energy intensity to decreases in heating, particularly after 1978. Even with the uncertainties in the non-heating components of residential energy use, it is clear that there has been a drastic drop in energy per dwelling and energy per capita.

4 COMPARISON WITH OFFICIAL FIGURES

Our results appear to be in good agreement wwith those published by Danish agencies. Actual energy deliveries to a variety of customers are registered by the Danish Energistyrelsen (ENS), including single-family dwellings, farms, industry, various classes of commercial buildings (including apartments, which are not shown separately) and transportation. In the 1981 Energy Plan (EP-81)[3] and the supporting material prepared by EM, these data are analyzed using assumed conversion efficiencies, and re-aggregated for five major building types. Some of the data sources are identical to those used herein.

In EP-81 these data are converted to indicators of net (useful) energy using assumed conversion efficiencies for fuels, electricity, and district heating.[4] These indicators permit either comparison of total heating and hot water energy use in all buildings, or estimates of heating energy use delivered to the room or tap, including local conversion and distribution losses in each building type, for each year since 1972. To determine gross energy for this comparison, we divided the overall conversion factor that EP-81 attributed to the entire heating system in Denmark into net energy. This factor includes the effects of structural changes, different fuel mixes, different efficiencies in different building types, and changes in the efficiency of production of DH. In our study, we avoided making assumptions about all these factors by using observed or estimated energy consumption.

Results are compared in Table 5, which shows the EP-81 indicator in terms of gross energy/m^2 of floor area. We have aggregated SFD and MFD consumption of heat/ hot water, but used the same data for floor area in our analysis. In spite of the minor effects of differences in accounting for district heat and

electricity, the two assessments of Danish energy use show good agreement, particularly when their relative changes are compared.

Are these indicators reliable? We believe they are. The estimates for oil heating per dwelling were made by one major supplier, and agreed with those supplied by a competitor and with the Dansk Kedelforening (DKF) energy balances for 1972. The Teknologisk Institut (TI) investigated oil and district heating in SFD and MFD from 1975-79 and, in some cases, 1972.[5] The DKF, TI, and ENS figures, which are not totally independent of each other, indicate lower energy intensities in 1975 than in 1972, leveling or slightly declining use to 1978, and a further drop in 1979, which continued through 1981.

5 ENERGY CONSERVATION IN DENMARK

5.1 Trends Since 1972

How much has energy use changed since 1972? Unfortunately, the values in Table 4 are somewhat inappropriate for answering this question, because they do not contain enough structural data that describe the dwelling stock, weather, and other factors. Therefore, we form summary values to relate aggregate energy intensities to structure. These are shown in Table 6. Quantities marked with an asterisk (*) refer to "oil-equivalents"; here we count DH and electricity as oil at a nominal 66% conversion efficiency. Accordingly, the actual quantities of these two fuels consumed are multiplied by 1.5 in forming these indicators. This manipulation removes some of the bias introduced in comparing different countries or periods with differing relative penetration of electricity and district heating, which have fewer losses within the building than combustion systems. Indicators so treated include average energy use for space heating per degree-day (or per floor area), and per capita energy use for water heating.

The indicators in Table 6 show energy use relative to important driving structural factors, resulting in a somewhat different picture than the data in Table 4. For example, the heating indicator ($kJ/DD/m^2$) grew somewhat less rapidly in 1965-72 than GJ/dwelling because average floor area grew. Appliance electricity per unit of income also grew significantly more slowly than it did on a per household basis. Water heating energy use per capita grew more rapidly than use per dwelling because the number of people per dwelling decreased significantly, increasing the impact of standby hot-water systems losses relative to actual consumption of hot water.

The trends in energy use per dwelling lead to the conclusion that significant conservation has taken place in Denmark since 1972, particularly after 1977. The drop in energy intensity is even more dramatic when one considers that there are more central systems and larger appliances in 1980 than in 1970 or 1972. Intensity in centrally-fired homes using oil or district heat (shown in the Appendix) fell 20-45% during the post-embargo period. When dwelling

area is included in the evaluation (estimated in Table 6), even greater decline is seen. Furthermore, the proportional decline in MFD is almost as large as in SFD. Something is sparing in the state of Denmark!

5.2 Actions Causing Energy Conservation

Is the drop in the heating indicator a real sign of conservation? While there is little evidence of the large-scale use of electricity or wood as back-up to oil, there has been a great increase in the sales and use of small stoves ("braendeovne") that burn paper and wood. Although no official figures on the consumption of fuel in these ovens exist, recent Gallup polls indicate that about 25% of all SFD had at least one such oven by 1980. The impact of these systems has been large enough to cause a decrease in burnable waste at waste-burning plants, but the calorific content of the wood and waste actually burnt is not known.* In Sweden, with abundant forests, surveys show that nearly 20% of all SFD now use about 10GJ/yr of wood for back-up heat,[6] enough to account for about 1/4 of the reduction in oil heat per dwelling observed in Sweden. Using the Swedish figure as an upper limit, we estimate that at most 10% of the 45% drop in oil use per dwelling in Denmark was supplied by heat from back-up sources.

The Energisparudvalg (Danish Energy Conservation Agency) has commissioned yearly surveys of energy conservation attitudes and actions through Scantest, a private firm.[7] These surveys show a continued increase in adoption of savings measures between 1978 and 1980, occurring in some cases after a drop in the years after 1974. We summarize key findings in Table 7. There seems to be an upswing in every measure in 1980 that exceeds even the 1974 (post-embargo) interest in conservation and certainly reveals an increase in activity over 1976-78, when prices were lower.

One oil company estimates that the drop in oil use per SFD between 1970 and 1980 was caused in similar proportions by better equipment, inproved thermal integrity of structures, and lower temperatures. Household temperatures appear to be 16-19°C today compared with 20-23°C before 1973.+ Unpublished information collected by TI confirms that the rate of renovation of oil-burning equipment has increased notably. These changes shorten the real heating season, and therefore oil-burning equipment is used more efficiently. On the other hand, the efficiency of hot-water production in oil-based facilities decreases because the heating part of the system is used relatively less. Thus it is difficult to separate the effects of changes in fuel conversion efficiency from those of thermal integrity and changes in indoor temperature

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* P. E. Grohnheit, Risoe Nat. Lab, (priv. comm.).

+This is an average over the whole house. According to the Scantest poll half of all households still maintain over 20° C in living rooms. The total area heated has undoubtedly decreased.

or hot water stock.

In homes heated with district heat the drop in energy use has not been as great as in oil-heated dwellings, but is still significant. Some of the savings in DH accrue at the point of production, and so are not reflected in our figures. There is less evidence of savings of electric heat because electrically-heated houses are the newest and most efficient, and the relatively high price of electricity has climbed less than that of oil or DH (Table 1). Unfortunately we could not get data on the breakdown of measures taken by type of dwelling, fuel, or heating system.

By 1980, 50% of respondents to the Scantest poll indicated that they limited their use of appliances, an increase from 39% in 1977. This change is reflected in the indicator in Table 6. Data collected for EP-81[5] show that most major appliances offered for sale today are considerably more efficient than those available before 1975, and the potential for further improvements remains good.

These changes in consumption are consistent with the increases in real prices for oil and district heat of 200% and 85% respectively, which occurred in 1974/5 and after 1979. Real prices for electricity did not increase markedly until 1979, from which time decreases in the appliance indicator were noted. Although the cost of electric heat is higher than that from oil (at 66% efficiency), the difference has narrowed somewhat. Electric heat appears attractive as well because of its lower installation cost to home builders. As a result of these factors, the share of electric heat may grow, although the availability of natural gas will clearly affect the pattern of fuel choice in the future.

5.3 Adding Up Savings since 1972

How much energy have Danish households saved? We measure conservation from the changes in energy intensities, and measure savings as conservation per home multiplied by the number of homes. If homes in 1980 were heated with the 1970 intensities, 1980 heating energy use per dwelling would have been about 45% higher than it actually was, and energy use for hot water certainly would have been higher. Noergaard (1977) noted that the standard of comfort, which increased through the mid-1970s, has fallen again as people responded to higher energy costs. One oil company estimated that without conservation, energy costs today would account for as much as 25% of personal income of Danish families in oil-heated SFD. Savings have arisen primarily from changes in heating and, to a lesser degree, hot water use.

The hot-water indicator was lower in 1980 than in 1977, but was still higher than in 1972, because the number of central hot-water systems continued to increase. We estimate savings of 3GJ/dw from conservation. Appliance electricity use stopped growing relative to disposable incomes in 1979. This appliance energy indicator, which grew at nearly 6%/year through 1977, fell

after that time, although it is still growing in other OECD countries (Ref. 1). It appears that Danish electric appliances use perhaps 300kWh/dw less in 1980 than we would expect, given growth in the stock since 1972.

To quantify the total savings, we apply the 1970 use patterns to the 1980 structure. Corrected for climate, Denmark would have used about 48GJ/dw more oil for space heaing in 1.14 million oil-heated dwellings, 16GJ/dw more DH in 0.6 million DH-heated dwellings, and more kerosene, gas, and solid fuels in those homes still using these fuels in 1980 than was actually the case. Averaged over the entire 1980 stock, these differences amount to about 36GJ/dw, far greater than the absolute increase in electricity use for appliances, or in hot water use. If we add 1 GJ/dw for more efficient use of electric appliances and 3 GJ/dw savings for reduced hot water use to the savings for heat, total conservation reaches 40GJ/dw (compare with actual energy use/dw in 1980 of 92GJ/dw). Even if we use a somewhat lower base figure for oil heating intensity, as indicated by one company for 1970/72, the savings still would be about 34GJ/dw. Energy use/dwelling in 1980 would have been about 126-132 GJ without conservation, but instead was 28-33% less. The total oil savings over all dwellings, including oil used to produce DH (at 75% efficiency), are about 75PJ.

Structural changes are important to the calculation. The number of people/dwelling has dropped between 1970 and 1980, which has reduced hot-water needs somewhat (though not standby losses) and possibly allowed homes to be unheated more during the day. Otherwise, the structural characteristics of the dwelling stock have not changed much, and SFD are actually larger in 1980 than in 1970. Although we did not count these changes in the calculation of savings, they are reflected in the indicators in Table 6.

A calculation of conservation in Denmark also must take into account the impact of rising standards of living on the base. We do this by comparing 1980 energy-use structure with 1970 and 1980 intensities on a per-dwelling basis. Central heating penetration increased by nearly 10% during those ten years, and the availability of hot water increased as well. These factors would have pushed up energy use per dwelling in 1980 in Denmark by at least 10% over the 1970 value. Conservation therefore reduced energy use per dwelling, relative to this theoretical increased value, by about 35%.

5.4 Comparison With Other Countries

The impact of conservation in Denmark has been the greatest among all OECD countries. In Figure 2 the heating indicator for all homes in several countries is shown. The decrease shown for Denmark is clearly the greatest observed. Reductions in heating fuel use in dwellings with central heat have averaged about 22% in the U.S. (1970/80), 22% in the Federal Republic of Germany (1972/80, with 35% achieved in oil-heated homes), 25% in France (1973/80), 20% in Sweden (1972/80, less if extra wood use is counted), and about 15% in Canada (1971/78).[8] Increases in equipment ownership in France and

Germany were greater than in Denmark, so the savings in heating in those countries are obscured. The appliance indicator fell in Denmark after 1977, in contrast to other countries.

Danish households averaged 33 MJ per dwelling per degree-day for heating in 1970. This value is close to that of France, which has far less central heat and smaller dwellings, and to those of Canada and the U.S., both of which have more central heat, larger dwellings, and more SFD. Conversely, Sweden, also a major user of district heat, used significantly less energy in 1970 (22 MJ/dw/dd), as did Germany (26 MJ/dw/dd), with smaller homes and less central heating.+ Thus Denmark had relatively high heating intensity, and high energy use per capita or per dwelling in 1970-72. Even if estimated dwelling areas are factored in, Denmark still has higher household heating energy intensity than Sweden.

By 1980, however, the heat indicator in Denmark had fallen to 23 MJ/dw/dd, much closer to Germany (21 MJ/dw/dd), Sweden (16 MJ/dw/dd), and well ahead of the U.S. and Canada. Total energy use per dwelling, adjusted for climate, also fell to below the average of the countries we have studied. Thus, the Danish achievements in conservation are noteworthy.

6 ENERGY CONSERVATION PROGRAMS

How much more energy can be saved in Denmark and why has so much energy been saved so far? We believe that rising energy prices, stagnation of per capita income, and a pervasive energy conservation program all contributed to achievements in Denmark through 1980. In this section we discuss the important aspects of national conservation programs in Denmark.

The programs in Denmark can be divided into several phases:

- Extensive conservation information has been available from government and private organizations since 1974.

- A program of grants ran from 1975 to 1978 to stimulate conservation retrofits in existing homes. The program distributed Dkr 870 million+ (of which Dkr 540 million went to homes through 1977) stimulating an additional Dkr 2100 milllion in private investment in conservation. The results were disappointing to officials, because a major portion of the funds was spent on ineffective measures.

+ Because this indicator counts district heating and electricity as if oil converted at 66% efficiency, some of the bias from the shift towards greater electric and district heating are removed.

+ US$1 = 5.5-7.0 DKr during the latter half of the 1970s, rising to 7.5 DKr in 1981 and 8.5 DKr in 1982.

* A second grant program was started in 1978/9 that limited the measures that were eligible for support to those on the so-called "positive list". In 1978-1980 Dkr 250 million were distributed to rental dwellings, and Dkr 200 million were given as tax credits to owners of dwellings. The government supported training of 700 consultants, and tax subsidies for homeowners were introduced, but only 20% of those polled in 1980 were aware of this program (Ref. 7). Corrected for inflation, this second program was smaller than the first.

* Taxes on oil and electricity were increased in 1979 and again in 1980.

These measures certainly had some effect on energy use through 1980, although most of the drop occurred after 1979. However, a series of far-reaching measures taking effect after 1979 may have a profound effect on future energy use.* Consider these elements of the Danish program:

* A new building code (BR-77) took effect in early 1979.[9] Walls must be 50% tighter than 1961-79 requirements; floors over open air 55% tighter; roofs 55% tighter; and for glazing, k=2.9 $w/m^2/C$. According to unpublished material gathered by Noergaard (and Ref. 3) as well as other sources, houses built to BR-77 standards will be extremely tight compared with earlier practice and the stock as a whole. The impact will be felt in the late 1980s as housing construction picks up and the stock turns over more quickly than today.

* Annual inspection of residential oil burners is now mandatory. Only 38% of homeowners indicated they had yearly inspections in 1980.

* Mandatory labelling of the energy characteristics of heaters, appliances, and other devices is being considered in the 1982 parliamentary session.

* Existing houses must be "labelled" to disclose their energy characteristics. The features of the law, in summary, are as follows:

An income-tax free subsidy equal to US$1000/dwelling is available for consulting and carrying out the recommendation of a consultant. The work must be carried out by a firm, not do-it-yourself. The subsidy is income-tax free. For owner-occupied dwellings the subsidy decreases from 20% in 1981/82 to 7.5% in 1984; for rented dwellings the decrease is from 30% to 10%. Once the thermal efficiency of a building has been improved an energy certificate is issued. After 1985, the purchaser of any

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* These laws include "Lov om Begraensning af Energiforbruget i bygninger" (Law on Limiting Energy Use in Buildings), Ministry of Housing, 1981; "Lov om maerkning og oplysningspligt vedroerende forbrug af energi" (Law on labelling and information requirements regarding energy use), Energiministeriet, 1982 (not yet approved).

building is entitled either to the label or the consultant's report, and the subsidies will be discontinued.

This Danish policy package strives to make new and existing homes and systems considerably more efficient, and to increase the level of information in the marketplace. Moreover, the programs provide subsidies for owners of rental housing, long recognized as an area where marketplace incentives are very weak.[10] As a result the advantages to renters or owners of rental property are more comparable to those who own their own dwellings and thereby gain tax advantages from borrowing money for conservation investments. According to the background analysis accompanying the new laws, this new investment program will increase gross savings in the pre-1980 residential stock by 30PJ over what would obtain without a program, at a cost of Dkr500/GJ saved, by 1996. By comparison, oil in 1980 cost Dkr 60/GJ in 1980 prices. The nominal rate of return is 12%.

It is hard to believe that existing programs, beyond information provided by authorities, were the primary cause of the drop in energy intensity in Danish homes through 1980. This does not mean that programs did not induce conservation, rather that the dominant savings through 1980 arose from higher prices and lower income growth.

Uncertainty exists about the future impact of the program. Controversy continues about whether to make the retrofits suggested by the labelling law mandatory, and whether the 1985 deadline for labelling all homes before sale will be upheld by future parliaments. There is some well-founded suspicion that some of the technical improvements required and/or subsidized will be offset by higher indoor temperatures, as the relative cost of heating is lowered through greater efficiency. The question of whether the permanence of energy savings depends upon behavior permeates many of the discussion documents prepared for ED-81.[11]

We believe that the present and proposed program will allow Danish households to substitute permanent, technical energy-saving measures for what appear to be effective but chilly reductions in heating use. Frequent inspection and maintenance of fuel systems, more information on the energy properties of existing homes, and far tighter new dwellings should keep energy use down and falling. As disposable income rises again, the dwelling and appliance stock will turn over more quickly, causing more savings.

7 CONCLUSION

There is no doubt that energy conservation has reached further in Denmark than in any other OECD country. The radical changes in heating energy use over the few years since 1978 clearly suggest that indoor temperatures have dropped considerably. One must surmise that Danes are not altogether comfortable at home, which is confirmed by the author's experience during a very cold period in January, 1982. The enormous difference between required new

practices and the energy properties of existing homes suggest that unless heating prices fall steeply in real terms, the Danes will make substantial technical progress in reducing heating and hot-water energy losses. This may permit indoor temperatures to increase somewhat while still reducing energy needs.

We conclude that conservation has reduced average energy use per dwelling by over 30% compared to 1970/72 practices. The savings are even greater when real increases in the standard of living, as measured by equipment ownership and characteristics, are considered. Danish conservation programs have contributed somewhat to these savings but will play a greater role in the 1980s and 1990s as the effects of information, system inspections, and capital stock turnover are realized.

Epilogue

Heating intensities for most forms of central heat dropped in 1981, as did electricity for appliances. According to unpublished estimates made available to the author by the Energy Ministry in early 1983, heating intensity may have increased slightly in 1982. Not surprisingly, the survey responses shown in Table 7 showed increased conservation activity in 1981 but turned towards less conservation in 1982. Stability of oil prices probably explain the slight rebound in 1982.

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Table 1

DENMARK: HOUSING AND ECONOMIC DATA

	1965	1970	1972	1975	1976	1977	1978	1980
Population, 10^6	4.77	4.91	4.98	5.03	5.07	5.09	5.10	5.12
Dwellings, 10^3	1606	1788	1860	1990	2008	2017	2040?	2106
People/dwelling	2.97	2.75	2.68	2.53	2.52	2.52	2.50	2.43
CLIMATE (Degree-Days Centigrade)								
DD (base 17C=2897)	3058	3141	2757	2588	2877	2720	2879	2997
DD (base 18C=3122)	3283	3366	2982	2813	3102	2945	3104	3222
Index (3122 DDC=100)	105.2	107.8	95.5	99.0	99.4	94.3	99.4	103.2
INCOME (1970 Danish Kroner (Dkr_{70})								
Prices (1970=100)	73.8	100	113	156	170	189	208	256
Pers. Consumption, 10^9Dkr	56.18	68.3	69.8	76.1	83.5	83.8	83.1	83.6
-"-/cap., 10^3Dkr	11.78	13.9	14.0	15.4	16.5	16.4	16.2	16.1
Savings Rate (% of Cons.)	8.6	7.0	6.5	6.0	5.7	5.5	5.3	~5.0
Disp. Income/cap., 10^3Dkr	12.8	14.88	14.93	16.11	17.40	17.39	17.18	16.94
ENERGY PRICES (1970 Danish Kroner (Dkr_{70})								
Heating Oil, Dkr/GJ	8.0	7.4	8.12	12.9	13.38	13.61	13.61	24.3
Elec., Dkr/100kWh	14	15	14	17	16	15	16	20
Elec., Dkr/GJ	38.9	41.7	38.9	47.3	44.5	41.4	44.5	55.6
District Heat, Dkr/GJ	-	10.3	11.7	21.5	18.4	18.9	18.9	21.8

Demographic data were taken from Noergaard 1977, and various editions of the Statistisk Aar bog or Tiaarsoversigt, provided by the Energiministeriet. Disposable income/capita is derived from personal consumption and the approximate savings rates (expressed as percentage of the personal consumption shown), deflated by the consumer price index. Prices were calculated by the Risoe Nat'l Laboratory for the MEDEE-3 model and by Jesper Schmaltz-Joergensen at Risoe.

The exchange rates have been (approximately) $1US= 7.3 Dkr (through 1971), 5.3-7.0 Dkr (1972-1980), 7.5 Dkr (1981), 8.5 Dkr (mid-1982).

Climate data are from Teknologisk Institut (TI); based on a temperature of 17C in shadow during the heating season. The correction for sunlight is not included here. To convert approximately to an 18C base we add 225 degree-days; the climate index given is for the new base.

Table 2

DENMARK: HEATING FUEL, CENTRAL AND NON-CENTRAL HEAT

(10^3 Dwellings)

	1965		1970		1972		1977		1980	
	SFD	MFD	SFD	MFD	SFD	MFD	SFD	MFD	SFD	MFD
Dwellings	895	710	1002	787	1047	813	1116	891	1194	913
Central Heat, %	65	71	85.6	81.2	89.1	83.8	94.0	85.5	95.5	87.7
Central heat:										
Oil,LPG	323	247	621	315	670	332	741	360	769	367
City Gas	3.8	8.2?	5.7	26.1	5	20	2.6	7.8	2.8	9
Solids	127	64	16.5	16.1	12	15	4.7	1.7	8.6	1.0
District	128	183	206	285	240	310	255	390	284	407
Electric	-	-	7.9	5.7	10.0	6.5	57	11	78	21
Total CH	582	502	857	648	936	683	1060	770	1142	802
Non-Central Heat:										
Kerosene	69.9	113	65.2	113	55	105	30.0	62.8	30.2	50
City Gas	0	2?	0.3	2.4	1.0	9	1.0	30	1	35
Solids	244	94	79	24	60	18	25	28	23	22
Total	314	208	145	139	110	132	56	121	54	107
Dwelling Area:										
m^2/dw(1)	86	55	93	58	-	-	102	62	-	-
m^2/dw(2)	111	66	120	70	123	73	127	75	130	75
m^2(1)/capita	24.5		28.4		33.2		~35		~37	
m^2(2)/capita	30.7		35.6		37.7		41.3		44.0	

Census or BBR data were used for 1965, 1970, 1977, and 1980; 1972 is interpolated based on data from Shell and DEFU (see appendix). We have ignored "barraker" and summer homes but include farmhouses. For 1965 and 1970 "tofamiliehus" (duplexes up and down) were counted as SFD, but these are counted as MFD by BBR-77 and BBR-80. These numbered 119,000 in 1970, of which 75% had central heating.

The structure of non-central heating and of solid fuels is from oil company estimates. Gas heating is from the censes; we estimated non-central values from indicators of number of heaters in FDG data and as residuals from non-central heat in the censes, after removing kerosene and solids. For "other" and "unknown" heating systems we used the following rules: in SFD, "other" was presumed to be solids, and "unknown" district heat. In MFD, "unknown" was presumed to be district heat.

Data on dwelling area include estimates using two definitions: (1) compiled by Noergaard (1977) from censes, counting net area, and (2) given by BBR-77 and BBR-80 as "heated area", counting gross area. Noergaard's data are used to extrapolate (2) to 1965,70, and 72. (2) is used in Tables 5 and 6.

Table 3

DENMARK: ELECTRIC APPLIANCES SATURATION AND UNIT CONSUMPTION

	1961	1965	1970	1972	1975	1977	1978	1979	1980
HOUSEHOLDS	1547	1667	1855	1894	2020	2089	2115	2140	2158
Kitchen range									
-Stock, %	~15	31	46.7	53.7	62.4	67.4	69.9	71.7	73.6
-Consumption,KWh						800			700
Hot water heater									
-Stock, %	1.1	2.0	3.7	5	6	7	8	8	9
Dish washer									
-Stock, %	0.13	1	4.7	7.0	15.5	16.8	18.1	18.2	
-Consumption,KWh	-			435	500	505	505	500	495
Refrigerator									
-Stock, %	46.0	76.0	88.0	87.0	81.0	77.0	75.0	73.0	71.0
-Consumption,KWh				385					365
Combi									
-Stock, %		2.2	6.7	9.6	18.6	23.1	25.0	26.9	28.7
-Consumption,kWh				730					710
Freezer									
-Stock, %	3.0	12.0	35.3	45.6	55.6	58.7	59.0	60.7	62.2
-Consumption,KWh				1100	1075	1050	1025	1000	970
Clothes washer									
-Stock, %	11.0	23.0	38.2	43.5	48.8	53.0	53.9	54.7	55.0
-Consumption,KWh				545					505
TV B/W									
-Stock, %	56.0	71.0	76.1	71.1	58.8	49.3	45.0	42.7	40.9
-Consumption,KWh				130					125
TV Color									
-Stock, %	-	-	2.5	8.6	28.7	45.0	50.5	57.3	62.9
-Consumption,KWh	-	-		175					160
Clothes dryer									
-Stock, %		-	0.5	1.3	3.1	6.0	7.4	8.7	9.2
-Consumption,KWh				450	430				420
Total Cons., TWh	~1.53	~2.65	4.18	5.0	~6.00	7.11	7.52	8.0	7.64
-Appliances	-	2.0	3.17	3.77	-	4.86	-	-	4.69
-Cooking	-	0.53	0.66	0.75	-	1.00	-	-	1.1
-Water Heating	-	0.12	0.19	0.28	-	0.43	-	-	0.58
-Space Heating	-	~0.0	0.18	0.20	-	0.81	-	-	1.24

Data on saturation of electric appliances are taken from DEFU-81. We assume that these saturations apply to farms, whose consumption is counted in the totals. Unit consumption estimates are made by Husholdingsraad and DEFU, using the distribution of sizes in stock, inquiries about useage frequency, and characteristics of actual models.

TABLE 4

RESIDENTIAL ENERGY USE IN DENMARK 1965-1980

	1965*	1970	1972	1977	1980
TOTAL, PJ	170.0	220.9	232.1	237.2	193.5
Oil, %	53	69	69	67	61
Gas, solid fuel,%	21	7	5	4	3
Dist. Heat, %	13	17	18	18	22
Electricity,%	5	7	8	11	14
End-Use Energy, GJ/Dw	105.8	123.8	124.1	117.8	91.7
Primary Energy, GJ/Dw	121.7	146.9	150.4	150.0	122.8
Heat, GJ/Dw	82.8	95.1	94.2	87.0	63.1
% elec., DH	19	28	30	35	37
Hot water, GJ/Dw	14.8	19.5	19.8	19.5	18.7
% elec., DH	21	31	34	39	42
Cooking, GJ/Dw	3.7	2.9	2.8	2.7	2.6
% elec.	34	47	53	67	74
Appl. Elec., GJ/Dw	4.5	6.4	7.3	8.7	8.0
Appl. Elec., MWh/Dw	1.25	1.78	2.01	2.44	2.22

Data are assembled from the individual year tables shown at the end of the study. All heating figures and totals are corrected to normal climate (see Table 1). Fuels refers to liquids, solids, and gas, elec. to electricity, DH to district heat, all counted at the point of consumption. The shares of these in actual consumption are shown. In the primary energy figures, DH production was counted at 75% efficiency, electricity at 34.6% efficiency (including conversion and distribution losses), consistent with other LBL studies. Actual practice in Denmark differs somewhat. In the end-use intensity figures, the shares of dwellings with fuel, DH, and electricity are shown.

* 1965 data are very approximate.

TABLE 5

INDICATORS OF RESIDENTIAL ENERGY INTENSITY IN DENMARK

EP-81 ("Rumopvarmning inkl. brugsvand") and LBL Figures Compared

	1972	1975	1977	1980
EP-81:				
Heat+Hw, GJ/m^2	0.76	0.62	0.64	0.54
Net/Gross	0.62	0.63	0.64	0.67
Gross, GJ/m^2	1.23	0.98	1.00	0.81
LBL:				
Heat+Hw, GJ/m^2	1.17	-	1.02	0.78
Area, SFD+MFD, $10^6 m^2$	182.6	200.0	210.6	221.9

The EP-81 figures are from Energiplan 81. The estimated unit areas are taken from BBR and are slightly different than those shown elsewhere in this paper. The ratio Net/Gross is estimated by EP-81 and reflects both the conversion of fuel to useful heat in buildings as well as the different mix of fuels to provide hot water and space heating. The LBL analyses count energy at the building boundary only.

TABLE 6

INDICATORS OF RESIDENTIAL ENERGY INTENSITY IN DENMARK

	1965	1970	1972	1977	1980
Heat, MJ/dw/DD	26.5	30.4	30.2	27.9	20.2
Heat*, MJ/dw/DD	28.4	33.2	33.2	31.5	23.0
Heated area/dw, m^2	91	98	101	104	107
Heat*, kJ/DD/m^2	315	340	330	300	215
Hot water, GJ/capita	5.0	7.1	7.5	7.7	7.5
Hot water*, GJ/capita	5.6	7.6	8.4	8.8	8.7
Appliance Electricity, (kWh/Dkr_{70}):					
	0.035	0.043	0.051	0.055	0.056
(US$)	0.26	0.32	0.38	0.41	0.42

Data are assembled from the individual year tables shown at the end of the study. The figures marked with * are adjusted so that end-use values of electricity and district heating were multiplied by 1.5 to give them the values that would agree with oil consumed at 66% efficiency. Data for 1965 are very approximate. The appliance indicator is given in US dollars using an approximate conversion rate based on the 1980 purchasing power parity for Denmark, as estimated by the OECD.

TABLE 7

CONSERVATION MEASURES UNDERTAKEN BY DANISH HOUSEHOLDS

Percentage of Households Responding

	1974	75	76	77	78	79	80
Lower temperatures in living room	45	53	58	73	67	69	72
Shutting off rooms	62	57	65	63	60	63	64
Showering instead of taking a bath	28	27	43	58	58	59	63
Checking oil burners yearly	-	-	-	-	-	33	38
Limiting electric appliance use	-	-	-	39	46	40	50
Invested in conservation this year	-	-	-	36	24	20	32

Source: Scantest, for Danish Conservation Agency

APPENDIX

In this appendix we describe the data sources and methods that were used to assemble the series of residential energy use in Denmark from 1965 to 1980. Consumption is disaggregated by fuel and end-use in a series of matrices, with heating and appliance ownership structure given as well. For central heating and hot water we give penetration and consumption in SFD and MFD separately. All shares and average values are corrected for climate. Figures for heat by fuel, however, are given as observed; total heat (and the total for each fuel consumed) is given both ways. Special treatment in individual years is described in notes after each table.

1 DATA SOURCES

The "residential sector" (boligsektoren) as such is not counted in Denmark by official energy agencies. However, residential space heating and hot water ("rumopvarmning incl. brugsvand") are estimated together in the official yearly energy balances from the Energistyrelsen (ENS).[1] ENS registers deliveries of all heating fuels to categories of buildings such as farmhouses and other "low dwellings", as well as classes of commercial buildings, including apartments. The yearly energy balances published through 1978 by Dansk Kedelforening (DKF) and Danske Elvaerkers Forenings Udredningsafdelning (DEFU)[2] estimated of residential energy use by fuels and components (heating and non-heating, stoves, appliances) from 1972 until 1978. There have been a few studies of end-use consumption in the residential sector, however, notably those of Noergaard (DEMO) (1977 and 1979) and WAES.[3] There was also a study prepared by the Ministry of Housing (Boligministeriet, or BM)[4] that covered much of the sector from 1972-1977.

Because the official and/or published data were not sufficient for a comparison of Denmark with other countries in our study, we made a major effort to collect data. Additional material was made available to us by/from the Energiministeriet(EM), BM,[5] ENS, two oil companies, DEFU,[6] Danske Elvaerkers Forening (DEF),[7] Foreningen Dansk Gas (FDG),[8] Danske Fjernvarmevaerkers Forening (DFF), Teknologisk Institut (TI), and DKF. Material was collected and embellished by Birch og Krogboe, Virum, who, along with Mr. Olaf Smith-Hansen (EM) helped in collecting and transmitting information and coordinating the author's several visits to Denmark.

Synthesis of all these information sources has been difficult. The various utility associations do not keep detailed records on numbers of customers by type or their consumption for each of their members, hence unit estimates from other sources were used together with the numbers of customers estimated by the Census or BBR. For district heating, there were no officially published sales totals. For pipeline gas the numbers of dwellings with gas heat were given in BBR but the yearly data from FDG could be used only for a rough estimation of non-heating consumption in residences, for which totals could be estimated.

Demographic data were assembled from various censuses and other sources; no attempt was made to divide carefully the population into ordinary dwellings and institutions, in part because the number of dwellings or families in the latter is small, and the number of dwellings in non-residential buildings is also small. Heating structure and other data on housing were taken from the 1965 and 1970 Censuses as well as from the Bolig og Bygning Register (BBR) for 1977 and 1980.[9] Living area was estimated in two ways; according to the net or gross living area calculated from the census and the census of new housing by Noergaard (1977 and 1979), where heated area was estimated. The latter is about 16% higher than the former, consistent with data sources from other countries. The former (net area) seems intuitively too low, therefore we used the gross area.

Disposable income was derived from personal consumption and an approximate savings rate given for 1966, 1971, and 1976 in the Stat. Abstract for wage-earning households. The resulting figures, along with those for heating structure were shown in Table 1 in the text.

2 METHODS

The basic approach taken here was "bottom-up", using estimates of unit consumption and equipment ownership to derive totals consumption for each fuel and end-use. The censuses give the fuels used in central and non-central systems in SFD, lumping kerosene, LPG and heating oil together. We assume all central systems use heating oil or LPG, while all non-central oil-based systems use kerosene ("petroleum"). We used oil company estimates of the numbers of solid-fuel based stoves, particularly in apartments. We do not know how much wood is used, though TI suggests that there may be more than 10,000 homes using straw ("halmfyr"). Our consumption figures include estimates of wood and straw for 1970, 1977 and 1980 provided by an oil company; these are shown separately. We do not count "brandeovne", although they were present in 1/4 of all SFD by 1980.

For apartments there is little detail on the kinds of non-central (i.e., room) systems; our estimates were provided by an oil company, based on the likely decay of these systems from 1970, when they were last treated carefully in the census, and on the sales of kerosene, gas, and solid fuels. We used judgent in trying to assign fuel types to "other" and "unknown".

We used some estimates of sales to check these results, but found that the only reliable totals for sales were for oil products to SFD, city gas in 1980, and electricity. The consumption totals for 1972, and 1974-78 published by DKF/DEFU were useful, but we felt it necessary to re-derive them whenever possible. Fortunately, DKF/DEFU note assumptions about use/dwelling, at least for central heating, making comparisons possible. For other fuels, sales to residences and other buildings are still not clearly distinguished. The TI study systematically reviewed DH and oil unit consumption, dwelling characteristics, and other relevant data from the period between 1970 and 1979, but

only treated energy use thoroughly for the 1975-8 period.

In accordance with our evaluation of Swedish data, we assumed that centrally-fired systems (including district heating and gas) include domestic hot water production; that electrically heated homes also use electric hot water; and that there were a limited number of gas-fired instant water heaters (geysers, "gennemstroemmings apparater"). Hot water production was separated based on a variety of sources and experience with data from Sweden. We noted the number of LPG and gas stoves in the 1970 census to estimate stove types in later years, assuming that by 1977 that those with neither electricity or city gas had LPG.

For oil and district heating use, we extended a survey covering 1972-79 published by TI to include 1970 and 1980 on the basis of unit consumption estimates and ENS balances. We assumed that reductions in 1977 fell mostly on the heat side, while reductions in 1980 hit hot-water use as well, which otherwise had climbed through the 1970s. For MFD there were some data given by TI for 1972 through 1977 covering oil and DH. One oil company supplied unit consumption estimates for 1970, 1977, and 1980.

3 CLIMATE ADJUSTMENT

The adjustment for climate was made differently than is the practice in Denmark. Figures from TI that give the number of centigrade degree-days to base 17C without counting the effect of sunshine were adjusted upwards by 225 DD (i.e., 1 degree times 225 heating days) to provide a base consistent with that used for other countries in our OECD study. It was assumed herein that the base adjustment did not vary from year to year with the climate index; this approximation has at most about a 1% affect on the total number of degree-days in a year.

Having estimated the number of degree-days we use the yearly index, divided into the heating component of each fuel or dwelling's share in total energy use, to arrive at an adjusted total. The ENS uses a formula by which the actual consumption is multiplied by

$$1 \,/\, [1/2 \,(\, 1+ \{\text{Actual DD} \,/\, \text{Normal DD}\})]$$

to get the "normal" consumption. The difference between their method and ours is small compared to total consumption, but may be significant compared to the actual yearly variation, particularly as the consumption of heat has dropped relative to that of hot water. We chose our method because actual heating consumption is divided by actual degree-days at various points in our subsequent analysis. The number of degree-days given by TI, our adjustment, and the yearly variation, were shown in Table 1.

4 DATA FOR INDIVIDUAL FUELS

In the following matrices, we present reconstruction of residential energy use in Denmark for several years between 1965 and 1980. The matrices show total fuel consumption in PJ, the number of consuming units, and the unit consumption. Usually the totals are aggregated over SFD and MFD and include central and non-central systems using the same fuel, but where possible SFD and MFD (separated by a slash) and central and non-central systems are kept apart. The most uncertain estimates are marked with "?"; where elements do not apply we leave a blank or a "-".

Climate-adjusted totals are shown for each fuel in the last column in each matrix. Climate-adjusted heating appears in parentheses in the total row, and the climate corrected total consumption is shown as well. The shares of each source and purpose are all based on the adjusted total.

Important indicators are shown at the end of each table. These include summary shares of principal fuels and in actual energy consumed, various energy intensities and intensity indicators, and structural indicators.

Housing. Multiple-family dwellings (MFD) include ordinary apartments (etageboliger, flerfamiliehuse), rooms in other buildings, and single rooms ("klubvaerelser"). Single-family dwellings (SFD) include detached farms and other dwellings (parcelhus), doublehouses ("dobbelthuse", "tofamiliehuse", though these are counted as MFD in some studies), row and townhouses ("raekke og kaedehuse"), but not summerhouses. In 1970, there were 17,000 doublehouses; uncertainties of this magnitude may arise in comparing our data for oil and district heat with other studies. For 1972 housing data were interpolated from all sources. For other years the censuses were used.

Oil. Oil data were taken from records of two oil companies, TI, DKF/DEFU energy balances, and ENS balances. The oil companies provided estimates of unit consumption for oil, LPG, and kerosene for heating and hot water. Total LPG consumption is shown separately in the total oil column, and the part used for stoves is estimated in the cooking column; otherwise LPG consumption for central heating is included in the oil heating totals. The only years for which actual numbers of LPG stoves are known are 1965 and 1970; other years are extrapolated. Total consumption of LPG and kerosene is estimated by DKF/DEFU from total non-industrial consumption of these fuels; solids were estimated herein based on material supplied by the oil company.

Heating oil consumption per dwelling was given by TI for a variety of kinds of SFD: stuehus (farmhouses); parcelhus og raekke/kaedehus (free-standing or row houses), and dobbelthus (duplexes). Tofamiliehus (up/down duplexes or maisonettes) were counted in MFD. For SFD a weighted average over types was made for 1977 and extrapolated to 1980 and 1972. Our result agreed with estimates made by two oil companies during the period covered by TI; the totals agree relatively well with those given by ENS for SFD between 1972 and 1980, so we believe that the extrapolations to 1972 and 1980 of TI data were

reasonable.

Hot water consumption was separate from heating assuming that all central systems provide both services. The values agree with those found in our Swedish study and Noergaard, who suggests that full use of hot water requires 5.4 GJ/person/year net, requiring about twice as much total energy (i.e., gross) if oil is the source because of conversion losses, particularly during the non-heating months. Most of the conservation of oil observed was attributed to changes in heating habits, but some was accrued to hot water as well. Oil consists primarily of light heating oil ("fyrings olie") at 35.9 MJ/l, although some heavy oil ("fuelolie") and LPG ("flaskegas") are used in this sector. All our original data were in energy units, however.

Gas. We counted gas (city gas) at 16.38 MJ/m^3. LPG is included with oil as heat and shown under cooking as well. There were some data on total gas consumption available from Foreningen Dansk Gas (1970, 1980) and DKF/DEFU (1972,1977), but only the data for 1980 allowed a reasonable estimate of the numbers of customers using hot water heaters, space heaters, and cookers. However, our estimates are very rough because these figures are incomplete. Heating is modelled after oil (central) and kerosene (non-central) while hot water "guesses" are based in part on experience with apartments in Germany and Sweden. The most uncertain quantities are marked with "?".

Solids. Data on solid fuels consumption come from an oil company, which also estimated the penetration of wood and straw. These agree with unpublished data from ENS (P. Hoffmann, ENS, priv. comm.). Estimates for 1972 and 1977 were also available from DKF/DEFU. The oil company gave unit consumption for SFD and MFD; we have guessed the breakdown into CH and non-CH and guessed the fraction of dwellings also deriving hot water from these fuels in central systems. For 1977 and 1980 we assume that dwellings in the censuses listed as "other" fuels used wood or straw. We do not count consumption in brandeovne unless they are hidden here as principal heat sources.

District Heating. Our estimates for total consumption in 1972 through 1980 are taken from ENS; those for 1970 were based on the unit consumption data from 1972 adjusted for 1970 climate. TI also estimated unit consumption for 1975-78; these estimates agree roughly with the ENS figures using the structural data from the censuses. Using the unit consumption figures for 1975-78 from TI (which do not agree with those derivable from ENS because of definition differences) we use the variation in ENS-derived unit consumption to estimate that for the TI figures for 1972 and 1980. These are then used to find total consumption, given the number of dwellings with district heating as listed in BBR. The breakdown between heat and hot water is based on Swedish experience, consistent with our split for oil, but without the large losses during the non-heating months.

Electricity. Electric power consumption is estimated from Ref. 6 (DEFU75 and DEFU81) and yearly breakdowns of consumption by customer type for 1977 and 1980 made by Danske Elvaerks Forening (DEF). Figures in the two DEFU reports were manipulated so that summer houses were removed while appliance energy use of farmhouses was added in. Summer houses consumed about 120GWH in 1970 and 400 GWH in 1980, predominantly as heat.

The non-heating component was divided by DEFU and further by us into hot water, stoves, lighting, and other appliances. The results were gathered for each year from 1970 to make sure that a reasonable smooth time-series was obtained. Electric appliances and their consumption were estimated in Ref. 6. These reports correct household consumption for consumers living in farmhouses, which is not done in the DEFU-DKF balances or DEF statistics covering 1976-1980. The saturation figures for electric appliances given in these reports in non-farm dwellings were assumed to apply to farmhouses. We have followed DEFU-81 and multiplied the consumption of electricity for non-heating purposes in SFD by the number of farmhouses and added this to "residential"; we have also excluded summer houses from these totals, consistent with our treatment of other countries.

DEFU and DEF estimate the penetration of electric heating by counting anyone using more than 10MWh per year in a SFD and 6MWh/yr in an MFD as a heating customer. This procedure could result in an excess of electrically heated dwellings when comparison is made with the available censuses. However, there are also dwellings with electric heat that use less than these levels of electricity use. In data made available privately (J. Moeller, DEFU, priv.comm.), classification by consumption and by actual heating type for one large Danish utility were compared, and it was seen that these two effects tend to cancel very closely. However, because of growth in the number of subscribers, the number of electric heating customers at the end of the year overstates the actual year-round total. This leads to overestimation of consumption, but may also lead to undercounting, since those customers who start late in a year may never consume enough to be counted as "electric heat".

We define electric heating as central, in contrast to official Danish practice. We use census data as a complement and attribute the residual of electric heat in the DEF statistics to users without heat or those with electric water heaters but not heating. Since there were still 90,000+ dwellings in the late 1970s without electric heat but with electric hot water devices, it is not unreasonable to assume that many non-heating customers fall into the heating class. The average use per customer recorded as electric heating, however, is thus reduced by an unknown amount by the presence of these customers since they tend to use less than heating customers. Moreover, it is likely that some electric heating customers have back-up fuels or use electricity as a back-up. The most widespread non-central fuel is kerosene, excluding the brandeovne. We have no accounting of this situation, but imagine that it contributes to the excess of electric heating customers over those giving electric heat as their principal source in BBR.

Appliance electricity includes the consumption of electricity for motors, lights, and other non-heating uses, although hot water in washers, and some small portable heaters are included as well. The DEFU/DEF figures are adjusted for appliance use based on average consumption in homes without heat. It is assumed that all heating customers have hot-water heaters, and that a large number of additional water heaters exist in other homes, presumably those without central heat. The total number of hot-water heaters is given in DEFU-81 for every year since 1971, as are estimates of yearly energy use for every other major appliance. Our figures for hot-water use include SFD and MFD with central heat and other homes, respectively. Each year's assumptions are shown in the notes to each table.

Totals. Here we give the totals for each fuel and each end-use. We also show totals adjusted for climate, both by fuel and for heat alone in parentheses. The totals for each use on a per dwelling basis are also shown, as are the shares of each end use, based on the climate-adjusted consumption.

Indicators. The most important structural and intensity indicators are given in the second part of each year's table. Values marked with * count electricity and district heating at 1.5 times actual consumption of these sources.

1965. The year 1965 was estimated from the 1965 census and data on the consumption of electricity. All data on unit consumption of fuels, however, were "synthesized" from 1970 figures, changes in climate and dwelling size, and a judgemental effect of income. Thus the 1965 unit consumption figures should not be used for any detailed comparison with other years. However, structural growth and changes undoubtedly dominate changes between 1965 and 1970. Therefore, the aggregate intensities and indicators are probably reliable signs of the magnitude of change in overall energy use between these two years.

5 UNCERTAINTIES

There were several disagreements in the literature that we have not resolved. Virtually all of the uncertainties or ambiguities are traceable through the year tables. Hence, the reader can change any of the summary values according to different assumptions or data. However, we believe that the indicators and intensities are robust.

Most important, the definition of "district heat" is confused. We believe we have included all heat provided by public and semi-public systems that may or may not be co-produced with electricity. DKF/DEFU lists 200,000 apartments as obtaining heat from "blokcentraler" ("kvartercentral" in Sweden, heating centrals) in their 1976 balance; this appears to mean central boilers in apartments or in groups of apartments. Often district heating systems mean those that expand as the number of customers grows, while centrals refer to sytems built to provide only heat to a predetermined load. We have used BBR

to get our final figures for numbers of district heating customers. We believe these are consistent with the estimates of sales of district heating to residential customers we were given. We count district heat consumption at the building boundary, excluding thereby production and distribution losses in the pipeline system.

There is also ambiguity over the definition of residential electricity consumption, its magnitude (see above) and the presence of electric heating. We estimated total residential electricity consumption, including that for farms, but excluding summer homes, from two DEFU reports. We counted electric heating as "central" heat, consistent with our treatment of Sweden, because night-time storage heating does not exist. The 1970 census and BBR appear to count electric heating differently according to whether the system is based on a central hot-water or air-borne system or individual radiators. The number of "oven" using electricity is small and mostly in apartments. However, gas heat is counted both ways, central and room heat. In Table 1, we distinguish these kinds to the extent possible.

As the TI discussion clearly showed, there were many divergences between their findings and those of the official balances published by ENS. These differences arise both out of differences in definition of customer type or sector and differences in accounting, for example, between district heat counted at the building boundary, the radiator, or the heat plant itself.

Another major disagreement we found in the published and unpublished literature was over the quantity of solid fuels used, where one oil company indicated far greater use than EM, ENS, or DKF/DEFU in their energy balances. When we assume unit consumption figures (based on Swedish experience from the 1960s) and multiply the number of central and non-central systems we obtain figures for consumption close to those suggested by the oil company and far higher than any other estimates. While Denmark does not have a great supply of wood, the high oil price in the late 1980s may have sustained overall solid fuel consumption into the 1980s, as we observe in other countries.

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RESIDENTIAL ENERGY USE - DENMARK

(APPROXIMATE VALUES: SEE NOTES)

Year: 1965 | Population: 4.77×10^6 | Occ. Dw: 1.606×10^6

SFD: 56.2% | DI/cap, (10^3Dkr$_{70}$): 12.9 | Climate: 3283 DD_{18}

	Heat	Hot Water	Cooking	App.	Total	Corrected
Oil,LPG, (PJ)	68.4	14.6	2.0	-	85.0	81.6
-Stock,(10^3)	323/247	323/247	373/31			
-Unit Cons,(GJ)	152/78	30/20	3.5	-		
Kero, (PJ)	8.8	-	-	-	8.8	8.4
-(non CH)(10^3)	69.9/113	-	-			
-Unit Cons,(GJ)	63/39	-	-	-		
Gas,(PJ)	1.0	0.6	2.1	-	3.7	3.6
-Stock,(10^3)	3.8/8.2	2?/5?	164/536	-		
-Unit Cons,(GJ)	100/65?	20/15?	3.0	-		
Non-CH	/2.0	125?	-	-		
-Unit Cons,(GJ)	58/29?	4.0?	-	-		
Solids, (PJ)	43.5	3.25	?	-	46.7	44.8
-Stock,(10^3)	127/64	75/50?	?	-		
-Unit Cons,(GJ)	140/90	30/20?	-	-		
Non-CH,(10^3)	244/94	-	-			
-Unit Cons,(GJ)	63/48	-	-	-		
District, (PJ)	18.3	4.9	-	-	23.2	22.3
-Stock,(10^3)	128/183	<--	-	-		
-Unit Cons,(GJ)	73/49	20/13	-	-		
Elec,(PJ)	0.00	0.43	1.91	7.20	9.54	9.54
Elec,(TWH)	0.00	0.12	0.53	2.00	2.65	
-Stock,(10^3)	~0	33.2	540	1606		
-Unit Cons,(GJ)	0	10.5	3.6	4.48		
-Unit Cons,(MWh)	0	2.9	1.0	1.25		
TOTAL,(PJ)	139.9(133.0)	23.8	6.0	7.2	176.9	170.0
Total,(GJ/dw)	86.6(82.8)	14.8	3.7	4.5	110.1	105.8
Shares	(78)	(14)	(4)	(4)	(100)	

STRUCTURAL INDICATORS:		ENERGY USE INDICATORS:	
% dw oil heat	47	GJ/dw, end-use	105.8
% dw elec heat	0	GJ/dw,primary	121.7
% dw dist heat	19	Heat/dw/DD,MJ	26.5/28.4*
% dw other	34	Heat/m^2/DD,kJ	292/312*
% oil, end-use	53	HW/cap,GJ	5.0/5.6*
% elec, end-use	6	Appl elec/DI,kWh/Dkr_{70}	0.035
% Central Heat	65/71	Climate(DD18=3122)	1.052
% Hot Water(bath)	64/65		

NOTES: These figures were extrapolated from those for 1970 using equipment saturation from the 1965 Census and utilities and specific consumption estimates shown in the 1970 table. Central heat intensity from oil and DH was reduced 10% to account for the fact that the oil heated dwellings changed in size by about that amount between 1965 and 1970 because the new additions, predominantly fueled by these souces, were considerably larger than the existing stock.

Figures for solid-fuel and gas fueled dwellings with central heat were reduced by 5%; figures for non-central heat were not changed. All figures were adjusted for climate. Hot water intensity was also reduced somewhat.

Figures for electricity were derived from DEFU-75, excluding summer homes.

Cooking intensities reflect the predominance of SFD in the electric and LPG markets and the larger families in 1965 compared with later years.

RESIDENTIAL ENERGY USE - DENMARK

Year: 1970 | Population: 4.91×10^6 | Occ. Dw: 1.784×10^6
SFD: 56.0% | DI/cap, (10^3Dkr$_{70}$): 14.88 | Climate: 3366 DD_{18}

	Heat	Hot Water	Cooking	App.	Total	Corrected
Oil,LPG, (PJ)	127.4	24.4	1.1	-	151.9+1.5	144.2
-Stock,(10^3)	621/315	621/315	320/25	-		
-Unit Cons,(GJ)	162/85	30/20	3.2	-		
Kero, (PJ)	8.8	-	-	-	8.8	8.2
-(non CH)(10^3)	65.2/113	-	-	-		
-Unit Cons,(GJ)	65/40	-	-	-		
Gas,(PJ)	2.5	0.8	1.6	-	4.9	4.7
-Stock,(10^3)	5.7/26.1	5?/20?	120/480	-		
-Unit Cons,(GJ)	110/70?	25/15?	2.7	-		
Non-CH	0.3/2.3	100?	-	-	-	
-Unit Cons,(GJ)	60/30?	4?	-	-		
Solids, (PJ)	10.5	0.6?	?	-	11.1	10.3
-Stock,(10^3)	17/16	10/10?	?			
-Unit Cons,(GJ)	150/100	35/25?	-	-		
Non-CH,(10^3)	80/24	-	-	-		
-Unit Cons,(GJ)	65/50	-	-	-		
District, (PJ)	33.0	7.8	-	-	40.8	38.4
-Stock,(10^3)	206/285	206/285	-	-		
-Unit Cons,(GJ)	84/55	20/13	-	-	-	
Elec,(PJ)	0.65	0.68	2.4	11.3	15.0	15.0
Elec,(TWH)	0.18	0.19	0.67	3.14	4.18	
-Stock,(10^3)	7.9/5.7	65	556/277	1784		
-Unit Cons,(GJ)	54/38.9	10.5	2.9	6.33		
-Unit Cons,(MWh)	15.0/10.8	2.9	0.8	1.76		
TOTAL,(PJ)	182.8(169.6)	34.8	5.1	11.4	234.1	220.9
Total,(GJ/dw)	102.5(95.1)	19.5	2.9	6.40	131.2	123.8
Shares	(78%)	(15%)	(2%)	(5%)		

STRUCTURAL INDICATORS:		ENERGY USE INDICATORS:	
% dw oil heat	62	GJ/dw,end-use	123.8
% dw elec heat	1	GJ/dw,primary	146.9
% dw dist heat	28	Heat/dw/DD,MJ	30.4/33.2*
% dw other	10	Heat/m^2/DD,kJ	320/340*
% oil, end-use	68.9	HW/cap,GJ	7.1/7.6*
% elec, end-use	7	Appl elec/DI,kWh/Dkr_{70}	0.043
% Central Heat	86/81	Climate(DD18=3122)	1.078
% Hot Water	88/85		

NOTES: The main assumptions are given in the text. Structure based upon estimates supplied by Shell and the 1970 Census (Boligtaellingen).

The figures for heating energy use were supplied by an industry source, based on sales estimates, stock of dwellings and heating systems, and estimates of unit consumption. We added figures for non-heating gas and LPG, based on the numbers of stoves given in the Census.

Electricity consumption was derived from DEFU 75 and DEFU81, with second homes excluded. The total electricity consumption is somewhat uncertain. For electric hot water, the consumption was estimated at 3.5MWh/SFD with CH, 2.5MWH/MFD with CH, and 3MWH/dw for other hot water heaters, the saturation of which was given in DEFU-75 and DEFU-81.

RESIDENTIAL ENERGY USE - DENMARK

Year: 1972 | Population:4.98×10^6 | Occ. Dw:1.87×10^6
SFD: 56.5% | DI/cap,(10^3DKR$_{70}$):14.93 | Climate: 2982DD$_{18c}$

	Heat	Hot Water	Cooking	App.	Total	Corrected
Oil, LPG,(PJ)	118.0	26.7	0.75?	-	144.5+1.0	151.0
Stock,(10^3)	670/332	670/332	250?	-		
-Unit Cons,(GJ)	140/73	30/20	3.0?	-		
Kero,(PJ)	6.8	-	-	-	6.8	7.1
-(non CH)(10^3)	55/105	-	-	-		
-Unit Cons,(GJ)	57/35	-	-	-		
Gas,(PJ)	1.76	0.50?	1.8	-	4.06	4.2
-Stock,(10^3)	5/20	10?	600			
-Unit Cons,(GJ)	100/50	20?	3.0	-		
Non-CH(10^3)	0/9	80?	-	-		
-Unit Cons,(GJ)	/40	4?	-	-		
Solids, (PJ)	7.6	0.6?	-	-	8.2	8.6
-Stock,(10^3)	12/15	10/10?	-	-		
-Unit Cons,(GJ)	130/80	35/25?	-	-		
Non-CH(10^3)	60/18	-	-	-		
-Unit Cons,(GJ)	65/50	-	-	-		
District, (PJ)	33.2	8.3	-	-	41.5	43.1
-Stock,(10^3)	240/310	240/310	-	-		
-Unit Cons,(GJ)	75/49	18.8/12.2	-	-		
Elec,(PJ)	0.70	1.02	2.7	13.6	18.0	18.0
Elec,(TWH)	0.19	0.28	0.75	3.78	5.0	
-Stock,(10^3)	10/6.5	94	1000	1870		
-Unit Cons,(GJ)	48/34	10.6	2.7	7.27		
-Unit Cons,(MWH)	13.3/9.5	2.9	0.75	2.02		
TOTAL,(PJ)	168.1(176.0)	37.1	5.3	13.6	224.1	232.1
Total, (GJ/dw)	89.9(94.2)	19.8	2.8	7.3	119.8	124.1
Shares	(76%)	(16%)	(2%)	(6%)	(100%)	

STRUCTURAL INDICATORS:		ENERGY USE INDICATORS:	
% dw oil heat	62	GJ/dw,end-use	124.1
% dw elec heat	1	GJ/dw,primary	150.4
% dw dist heat	29	Heat/dw/DD,MJ	30.2/33.2*
% dw other	8	Heat/m^2/DD,kJ	300/330*
% elec, end-use	8	HW/cap	7.5/8.4*
% oil, end-use	69	Appl elec/DI,kWh/$_{70}$	0.051
% CH	89.1/83.8	Climate (DD18=3122)	0.955
% HW	92/90		

NOTES. Structure and consumption data are based upon interpolation between Census 1970 and BBR 1977, material provided by Shell International, and WAES, and the DKF-DEFU balance for 1972. "To-familiehuse" are counted with SFD.

Specific consumption for heating in non-central and non-oil heated dwellings was approximated from Shell estimates for 1970, as well as figures supplied by TI, DEFU-DKF, and another oil company. Hot water in centrally heated dwellings is assumed to require about 20% of total consumption of oil.

Total electricity consumption was estimated from DEFU-75 and DEFU-81. For electric hot water heaters, the same assumptions made for 1970 were used.

RESIDENTIAL ENERGY USE - DENMARK

Year: 1977 | Population: 5.09×10^6 | Occ. Dw: 2.012×10^6

SFD: 55.6% | DI/cap, (10^3Dkr$_{70}$): 17.39 | Climate: 2945DD$_{18c}$

	Heat	Hot Water	Cooking	App.	Total	Corrected
Oil, LPG, (PJ)	119.8	27.2	0.4	-	146.4+1.0	154.7
-Stock, (10^3)	741/360	741/360	135?	-		
-Unit Cons, (GJ)	134/57	28/18	3.0?	-		
-Kero, PJ	4.3	-	-	-	4.3	4.5
-non-CH, (10^3)	30/63	-	-	-		
-Unit Cons, (GJ)	65/38		-	-	-	
Gas, (PJ)	2.25?	0.45?	1.4	-	4.1	4.2
Stock, (10^3)	2.6/8	2.5/5?	465	-		
-Unit Cons, (GJ)	125/80?	20/10?	-	-		
Non-CH, (10^3)	1/30	75?	-	-		
-Unit Cons, (GJ)	75/40	4?				
Solids, (PJ)	3.75	0.15?			3.9	4.1
-Stock, (10^3)	4.7/1.7	4/1?	-	-		
-Unit Cons, (GJ)	125/80	25/18?	-	-		
Non-CH	25/28	-	-	-		
-Unit Cons, (GJ)	65/40	-	-	-		
District, (PJ)	32.1	9.8	-	-	41.9	43.8
-Stock, (10^3)	255/390	<--	-	-		
-Unit Cons, (GJ)	71/36	20/12				
Elec., (PJ)	2.93	1.54	3.6	17.5	25.6	25.8
Elec., (TWH)	0.81	0.43	1.0	4.87	7.11	
-Stock, (10^3)	57/11	145	1355	2012		
-Unit Cons., (GJ)	45.7/33.1	10.6	2.6	8.7		
-Unit Cons, (MWh)	12.7/9.2	2.9	0.73	2.42		
TOTAL, (PJ)	165.1(175.1)	39.2	5.4	17.5	227.2	237.2
Total, (GJ/dw)	82.1(87.0)	19.5	2.7	8.7	112.7	117.8
Share	(74%)	(17%)	(2%)	(8%)	(100%)	

STRUCTURAL INDICATORS:		ENERGY USE INDICATORS:	
% dw oil heat	59.6	GJ/dw,end-use	117.8
% dw elec heat	3.3	GJ/dw,primary	150.0
% dw dist heat	32.1	Heat/dw/DD,MJ	27.9/31.5*
% dw other	5.0	Heat/m^2/DD,kJ	265/300*
% oil, end-use	67	HW/cap,MJ	7.7/8.8*
% elec, end-use	12%	Appl elec/DI,kWh/Dkr_{70}	0.055
% CH	94/85.5%	Climate Index ($3122DD_{18c}$)	0.943
% HW	~97/95%		

NOTES:

Heating structure is based upon BBR 1977 and material supplied by Shell. "Tofamiliehuse" are counted with MFD. The specific consumption figures for non-central systems were provided by Shell, reconciled with material from TI, DEFU, DEFU/DKF, and ENS, reflecting in particular the TI investigation of specific cosumption for oil and DH in centrally heated dwellings. The gas figures are extremely rough estimates based on material provided by FDG for 1975 and 1980.

Dwelling area is based on BBR: 127.5 m^2 for SFD, 75m^2 for MFD: Noergaard gives considerably smaller estimates for 1975 because of a different definition of "area".

Electricity use is calculated from DEFU-81 and the Danske Elvaerkers Foreningen yearly report. We assume slightly higher unit consumption for electric heat and fewer subscribers than Danske Elvaerks Foreningen. Our figures reflect BBR, which has lower number of electrically heated homes, and therefore greater consumption/home. It is assumed that subscribers using barely more than the tariff-cutoff do not have electric heat.

For electric hot water, the unit consumption figures assumed are 3.3MWH, 2.3MWH, and 2.8MWH per dwelling (SFD-CH, MFD-CH,and unspecified).

RESIDENTIAL ENERGY USE - DENMARK

Year: 1980 | Population: 5.12×10^6 | Occ. Dw: 2.109×10^6
SFD: 56.7% | DI/cap, (10^3Dkr$_{70}$): 16.4 | Climate: 3222DD$_{18c}$

	Heat	Hot Water	Cooking	App.	Total	Corrected
Oil, LPG (PJ)	90.8	25.4	0.3?	-	115.7+0.8	113.7
-Stock, (10^3)	770/367	<-	100?	-		
-Unit Cons, (GJ)	95/48	25/17	3.0?	-		
Kero (PJ)	3.8	-	-	-	3.8	3.7
-(non CH) (10^3)	30/50	-	-	-		
-Unit Cons, (GJ)	60/38	-	-	-		
Gas, (PJ)	1.8	0.4?	1.0	-	3.2	3.1
-Stock, (10^3)	2.8/9	83?	360	-		
-Unit Cons, (GJ)	90/45?	20/10?	2.7	-		
Non-CH	1/35	70?	-	-		
-Unit Cons, (GJ)	60/30?	4?	-	-		
Solids, (PJ)	3.04	0.15?	-	-	3.2	3.1
-Stock, (10^3)	8.5/1.6	5/1?	?	-		
-Unit Cons, (GJ)	100/60	25/15?	?	-		
Non-CH, (10^3)	22/22	-	-	-		
-Unit Cons, (GJ)	60/35	-	-	-		
District, (PJ)	33.4	10.2	-	-	43.6	42.4
-Stock, (10^3)	284/407	<-	-	-		
-Unit Cons, (GJ)	69/34	20/11	-	-		
Elec, (PJ)	4.45	2.07	4.07	16.9	27.5	27.4
Elec, (TWH)	1.24	0.58	1.1	4.69	7.64	
-Stock, (10^3)	78/21	195	1565	2109		
-Unit Cons, (GJ)	48.2/33.1	10.6	2.6	8.0		
-Unit Cons, (MWh)	13.4/9.2	2.95	0.71	2.22		
TOTAL, (PJ)	137.3(133.0)	38.3	5.4	16.8	197.8	193.5
Total, GJ/dw	65.1(63.1)	18.7	2.6	8.0	93.7	91.7
	(69%)	(20%)	(3%)	(9%)		

STRUCTURAL INDICATORS:		ENERGY USE INDICATORS:	
% dw oil heat	57.7	GJ/dw,end-use	91.7
% dw elec heat	4.6	GJ/dw,primary	122.6
% dw dist heat	32.7	Heat/dw/DD,MJ	20.2/23.0*
% dw other	5.0	Heat/m^2/DD,kJ	190/215*
% oil, end-use	60.7	HW/cap,GJ	7.5/8.7*
% elec, end-use	13.8	Appl elec/DI,kWh/Dkr_{70}	0.056
% Central Heat	95.1/87.7	Climate Index(DD18=3122)	1.032
% HW	~99/98		

NOTES: Structural data are from BBR-80; "tofamiliehuse" are counted with MFD. The apartments with "unknown" or "other" heating systems were distributed among district heating, gas, and oil; SFD were alloted to solids and DH. Figures for oil heating are from the Shell, BP, and ENS. Hot water use is now estimated at 25% of total uncorrected oil use in dwellings with central heating, reflecting greater savings on heating side. District heating figures are from ENS.

The number of gas installations are from FDG; we assume 2/3 of "rumopvarmning" went to the residential sector, based on number of residential and non-residential heating customers; that their number of "apparater" in kitchens corresponds to the number of kitchens with gas cooking (excepting about 100,000 LPG stoves); that the average water heater (gennemstroemmnings) uses 3.5 GJ/yr. We assume that sales to "husholdninger" cover these water heaters and kitchens, while sales to block centrals and other centrally heated units include an additional amount of water heating counted for now in space heating, but probably less than 15% of the space heating total.

Solids: The structure is from BBR, with consumption proportioned from estimates provided by Shell. Non-central heat with solids was estimated as a residual after kerosene, gas, and electricity were removed. Figures for solids include 0.6PJ straw and wood, and are thus considerably higher than those implied by total consumption of solids given in DKF/DEFU 78.

Electricity; structure from DEFU81 and material provided by EM. Saturation of each device given in DEFU81 through 1979 with predictions for 1980. Electrically heated dwellings were derived from BBR-80, slightly fewer than those given by DEFU, who count consumers over a certain yearly level as "heating" and arrive at about 10,000 more SFD and 5,000 more MFD than we. Based on our Swedish data we assume that these "extra" homes do not use electricity as the predominant source of heat, or have large useage of hot water or other electric services; hence the true number of homes using electric heat as the primary heating source is less than that given by DEF, and the average consumption per customer is greater than that shown in DEF. The assumed hot water intensities (see 1970) are 3.2 MWH/SFD, 2.3 MWH/MFD,and 2.8MWH/other water heater.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720