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INTERNATIONAL RESIDENTIAL ENERGY END USE DATA: ANALYSIS OF HISTORICAL AND PRESENT DAY STRUCTURE AND DYNAMICS

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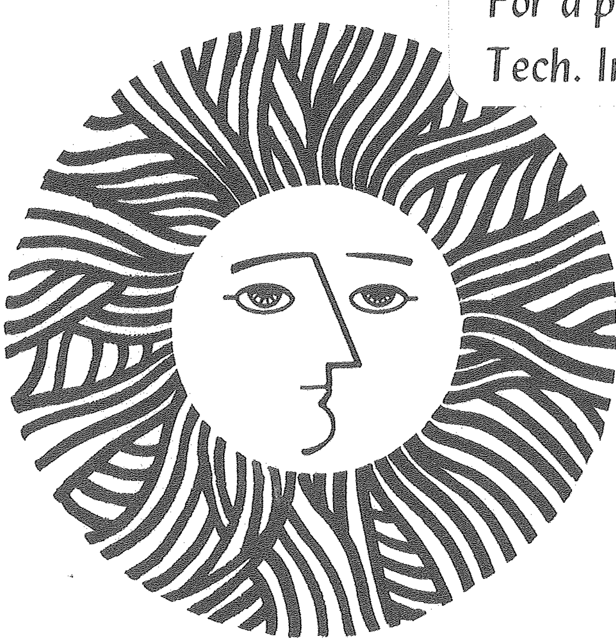

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DISCLAIMER

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ABSTRACT

International comparisons of residential energy use have been hindered in the past by lack of data and common measuring systems. In this paper we report on ongoing efforts to disaggregate data on residential space comfort and appliance energy use for major OECD countries. Indicators of structure (i.e. dwelling size, number of appliances, incomes) and of intensity (energy use per degree day, etc.) are developed for various countries and compared. It is shown that in certain countries there is much room for energy conservation by reductions in energy intensity even as structural factors -- rising incomes -- increase energy use.

1 THE RESIDENTIAL ENERGY USE PROBLEM

A characteristic of residential energy use in most developed countries is its growing importance in any country's energy budget. Residential energy use, particularly electricity use, typically grew faster than almost all energy uses in a country, rivaled only by gasoline. This is not surprising: most OECD countries have exhibited profound and steady growth in real disposable income since 1960.

Unfortunately, data on the uses of energy in the residential sector have been particularly difficult to come by, especially in European countries. Because such information is important to understand future demands for energy, opportunities for conservation (as more efficient use), the impact of higher energy prices on families, and the possible impacts of sudden shortfalls in supply, the lack of information is appalling. For example, the OECD, and most member countries, as well as the UN, kept until recently only information on the "other" sector, a hodge-podge classification that counted everything not in transportation or industry and often included agriculture. Not surprisingly, most OECD nations found themselves with few ideas for energy saving in the residential sector at the macro level; while a host of technical programs were developed to improve particular components of buildings or appliances, there was little ability to predict the impact of such programs upon future energy consumption.

This problem has also hindered international efforts at understanding the demand for energy. In Griffin's epic study (1) the author was forced to model residential energy use by using the "other sector" -- containing residential, commercial, agriculture, etc--as these are the only totals that are kept by the OECD prior to 1974. This is truly unfortunate: while commercial energy use depends on the service fraction of GNP and floorspace, residential energy use depends on numbers of households, personal income, appliance and heating equipment stocks. When the energy use totals for these two subsectors are combined, the results of Griffin's otherwise important work in modelling are diluted.

Pindyck (2) took another approach, modelling demand after the shares of income spent for fuels and electricity. While this approach singles out a particularly valuable economic quantity, income share to energy, it still tells us little about consumption and the energy intensity, or energy use per unit of output, for each important use. We learn nothing about <u>how</u> to conserve energy. Moreover, we are totally unable to discuss consumer lifestyles quantitatively as they pertain to energy use.

Recently, however, the Energy Information Administration of the US Dept. of Energy asked the Lawrence Berkeley Lab (LBL) to begin assembling data on residential energy use in seven important OECD countries, Japan(J), Sweden(S), Canada(CDN), W. Germany(D), France(F), Italy(I) and the United Kingdom (UK), countries that represent a spectrum of incomes, climates, lifestyles, and fuels used as well as energy efficient technologies. Additionally other data has been assembled on several other countries in the OECD, and on Kenya, Korea, and other developing countries as well. LBL also possesses a data base on US residential energy use.

Paper One (3) in this study appeared in 1979 and describes some methodological issues apparent at the outset of the study. The present paper reports on progress so far in assembling and analyzing data. No attempt will be made to specify all data assembled to date. Instead we will show what kinds of factors seem to be important to the historical (1960-1980) development of energy use. We emphasize that this paper summarizes our work; subsequent reports will detail the references, methods, caveats, and results.

As described in Paper One, a disaggregated approach has been followed from the beginning. Table One, from Paper One, lists the main energy uses in homes, and their rough proportions of total end use energy in the home.

Our approach follows the structure-intensity format used in Schipper and Lichtenberg(4) or in WAES(5);

Energy Use = Activity Level times Energy/Unit Activity

Data sources on structure are well known, though often unfamiliar to energy researchers. We found it necessary to comb much data from housing ministeries, censes, utility surveys, and housebuilding companies. The latter are important because we try to capture not only the state of the building stock in a given year, but also the characteristics of each year's new stock.

Data sources for energy end use estimates have been varied. We encountered ten careful studies of historical demand by function in Germany, several from Japan (and the U.S.), but only one each from Italy, France, and Canada and virtually nothing of a historical nature from Sweden, where information is scattered through a score of unrelated studies. Not surprisingly, then, we turned to unofficial data sources; oil and gas companies, electric utilities, trade associations, housing and census bureaus, academic research groups, even professional societies. Additionally, we found a host of studies, at least one per country, that have attempted to reconstruct energy end use for at least one key year.

Following the scheme outlined above, we present in Table 2 some basic data on residential energy use for the countries we have studied. Note that not all countries' data sets are complete at this time; nevertheless the results we cite, based both upon our surveying of existing studies and our derivations from other data show the pattern of residential energy use is changing in different countries. We give residential use on several bases:

* Space heating per capita, per household, and per square meter (where possible) normalized to degree days;

* Water heating and cooking, the two uses with the greatest substitution among fuels and electricity; we show values per dwelling, but the reader may use the table to find the values/capita, often useful.

* Electric specific appliances, that is, those that use primarily electricity for motors and very little heat energy. This is difficult to follow in countries where washers produce their own hot water. Only in Italy is hot water produced by electric washers recognized explicitly.

Appliance energy use is examined on a per capita, per household, and per unit of real disposable income basis. Real income is measured in 1970 units of real currency, translated into US dollars at some nominal exchange rate. This rate can be replaced by purchasing power parities in future analyses, but our present purpose is to see how each country's energy use has varied internally. Aside from space heating, we warn readers away from comparisons of energy uses across national boundaries until more is known about equipment, equipment use (like quantities of hot water consumed) and other aspects of lifestyle that bear on energy use.

2 STRUCTURE

What factors influence the development of energy use shown? One kind of factor is activity mix or structure. Measures of activity describe the economic structure of a country, and the lifestyle or habits or demography of the population. For example, the number of houses per capita (the inverse of household size) is important, since more houses (or households) per capita means more outer wall area per capita, in turn leading to greater heating use. Additionally we may find that houses themselves increase in size over time. Finally there may or may not be structural shifts among different kinds of houses. Unfortunately only a few countries maintain accurate data on the size and typology of homes over a long period of time. We do not dwell on the exact definitions of household, though they may be important, nor do we discuss here the reasons why families have become smaller, why houses have increased in size in some countries but not elsewhere, why the split of dwellings

(SFD/MFD) has changed. But we note that these quantities directly influence the demand for heating and for other forms of energy used for other tasks (see table 2).

While it is difficult to quantify all of the influences on the kinds and sizes of houses people buy and inhabit, it is important to note a few. Tax policies influence how much a family can afford to pay for a single family dwelling, and whether that purchase is subsidized through deduction of mortgage interest. Loan Interest subsidies are another. Thus it is not clear to what extent the mix of houses, or their size, truly reflects consumer preferences. According to Prof. Arne Elmroth of Sweden's Royal Institute of Technology (priv. comm.) the outer area of new dwellings in Sweden has increased greatly in the last decade relative to surface area. The reasons include both changes in shell shapes(more corners, etc) and reductions in the height of buildings. Is this an expression of lifestyle or consumer preference towards new wall shapes or lower structures? Or are the new shapes necessary to attract buyers, the lower buildings the result of rules requiring elevators? It is important to try to measure the effect these structural parameters have on the amounts of energy demanded, even if we cannot explain them satisfactorily in terms of prices and income or as facets of consumer preferences.

It appears, to the surprise of many, that structural changes, related to increases in income (or activity levels) may account for much of the increase in space heating use in most countries in Europe. Assuming that increases in central heating penetration usually mean greater indoor temperatures, we must assume that indoor temperatures have climbed steadily. Additionally the Swedes report that indoor temperatures have increased in centrally heated homes themselves overtime. While we have not found any direct evidence of decreases in thermal integrity of building shells, there is ample evidence that building shells have become progressively tighter since 1945 in Sweden.(6)

Central heating penetration continues to increase. In 1980, only Sweden, Canada (and the US) exhibit virtual saturation of central heating by any form. Germany is intermediate, France, Italy and G. Britain still growing markedly, while Japan remains without central heat. This means that there is still potential growth in heating demand in major countries.

While indoor temperature may be a good example of a lifestyle variable (subject to economic forces, culture or cultural perceptions of comfort, government edicts) (See Fisk[7]), climate is a structural parameter that enters in the heat equation. We give tallies of degree days, and their respective bases, in Table 3. No two countries' systems are strictly comparable, but this table illustrates the great differences among the populations we are studying. Threshold heating temperatures or periods, assumed indoor temperatures, the contribution of heat from solar gain and appliances all differ among countries. Fig.1, from BECA (8), shows heating consumption versus degree days for a variety of climates, countries and homes. The overall variation of heating with climate can be seen. At the same time, the variation in intensity (see below) is also noticeable: at a given climate some countries use less energy to provide heat than others, per unit of space. Moreover, our data sources show considerable variability in heating use due to year to year variations in climate.

What about measures of activity levels besides those of space heating? Structural data on appliances are very important for understanding the tremendous increase in electricity use seen during the 1960:1975 period. The dominant cause for this growth is the acquisition of appliances, much more so that the increased energy use or size of individual appliances. For example, data from France, Italy, Sweden, and Germany show little change in annual energy use for electric stoves and in most cases refrigerators. On the other hand, many refrigerators in Europe do not contain large freezing compartments that freeze to minus 15 degrees C. This feature, common in the US or Canada, increases energy requirements for refrigeration.

In Table 4, we list the saturation of major appliances for most countries in our study (9). Growth rates for ownership of the major appliances fell typically in the 10-20%/yr range through the early 1970s. Available information does not tell us all we would like to know about the characteristics of each appliance. Still it is easy to see that the growth in stocks drives the growth in electricity consumption. And there appears no trend towards American size refrigerators, American/Canadian levels of hot water consumption, or American-sized washers, dryers, TV, etc.

Here we see a difficulty for analysis of behavior and energy use. In fact it is <u>very</u> important to understand the characteristics and use patterns of major appliances. We suspect that the estimates of annual energy use do not carefully count both technical efficiency and usage patterns. That is, we really do not yet know how much hot water, at what temperature, is consumed by people in various countries. Yet a prescription for motivating consumers to save energy by changing hot water use requires we understand how hot water is used, and where the big--and small--savings through behavior change may lie. While today most countries residential energy use is dominated by heating, the non-heating component in the US, Canada, and Sweden is large and it is growing in other countries relative to heating. Therefore the consequences of a careful attempt to reduce non-heating energy use could be much greater in the future. As we suggest, however, that effort will depend greatly on intimate knowledge of how appliances are used.

Our preliminary assessment of available data suggests that the growth in non-heating energy use in residences has been propelled largely by structural growth, ie, that of incomes. This is consistent with an important finding of Dunkerely et al. (10,see also 1 and 2) that incomes, rather than prices, explain much if not most of the growth in energy use in residences. The income elasticity has been considerably greater than one, particularly before 1973, but lower afterward. This finding, coupled with knowledge of the saturation of appliances, the characteristics of new models, and the fact that most new kinds of home appliances tend to be non-energy intensive (ie, involve little or no use of heat) suggests that future structural changes, ie, the onset of ownership saturation, will retard the growth in the residential demand for energy, particularly electricity, in the future, relative to rising incomes. The slowdown in the growth of electric appliance energy use relative to income, which we observed in every country, is suggestive that this taking place already. That is, consumers may not have made great changes in the way they use existing appliances, but the rate of increase in ownership/use of appliances is slowing.

3 ENERGY INTENSITY

If structural factors, predominantly rising incomes, cause most of the growth in energy use in homes in the past, then the prospects for conservation look bright. This is because much of the structural change of the past is slowing down. Families will not shrink indefinitely, incomes are not growing as fast as in the past, and equipment saturation is near peaking. Only freezers and dryers represent major unfulfilled demands for energy using services in homes in the countries we studied. Indeed, examination of energy intensities based upon heat,hot water or cooking/house or electric appliance electricity/income show marked retardation or cessation in the growth that was so prominent before 1972.

Table 2 shows data on energy intensities of heating, and yearly energy use/hh for cooking and hot water. While we have little indication of the true energy intensity of the latter two uses, (cf our remarks above under Structure) we can compare energy intensities of heating and find remarkable differences, with Sweden showing very low intensities compared with other countries. Some representative intensities for France, Sweden, and the US are shown in Fig. 1. The potential for conservation, ie reduction in energy intensity, appears great,particularly when homes in Sweden are compared against those in the US Stock or those built to proposed building standards, whose consumption is predicted by a computer program. We will study this further in future work.

What about appliance energy use? As noted above, intensities are difficult to measure(compare the quantities proposed in Table 1) so we often settle for annual energy use, a quantity that mixes lifestyle with intensity. From data compiled by UNIPEDE,[9] we show some estimates of average annual electricity use per appliance for several countries (Table 4). Following a scheme that has attracted considerable attention(11) we separate obligatory electrical uses--motors, lights--from low-temperature heat applications provided by appliances.

The data in Table 4 are only rough estimates. Nevertheless they indicate some agreement among countries. High energy use for washers, for example, may be explained by the fact that some washers produce their own hot water electrically, while others, as is the case in the U.S. take hot water from central tanks. We found widespread use of "point of use" or "instant" water heaters using gas or electricity in Japan, England, France, Italy, and Germany, but we have found no careful study of the differences in efficiency coupled with differences in habits that evolve around this interesting technology. Thus we must refrain from any comments on intensity here.

What is needed is more information about the role of behavior in reducing energy intensities, and on the kinds of price and information stimuli that will motivate this behavior. For example, proper use of curtains will greatly decrease heat losses from a house. These will be recorded in our data as decreases in energy intensity. Different cooking habits , while actually a lifestyle question, could be recorded as less energy used/meal. A survey taken by M. Janice Hogan of the Univ. of Minnesota (1980, priv. comm.)indicates that behavioral factors are important to achieving savings we think of as "technical" in the areas of cooking and hot water use, particularly for washers . It would be valuable to quantify the role of behavior here to be able to see whether we may have over- or under-estimated the energy savings we expect from a given technical measure.

What may happen to intensities or annual energy use in the future? Energy prices are now rising, often spectacularly, as shown in Table 5 In Japan, for example, residential electricity prices hit ten US cents/KwH in 1978; they are rising in every other country, though more slowly in Sweden and Canada than elsewhere. On the other hand, these prices often fell, in real or even in nominal terms, in nearly every country between 1960 and 1972. Subsidies of certain fuels (kerosene or gas in Japan, electricity in Italy) are disappearing if not already gone; all countries have felt the 1979/80 OPEC price hikes and increases in the cost of all forms of base load electric power. Only occasionally are there noticeable decreases in energy prices, not all of which are shown here. (natural gas in England, oil and gas in resource-rich parts of Canada).

What economists and engineers alike expect, therefore, is increased interest in technologies that use energy more economically in the home. Most countries have labelling programs, though only some (the US as of 1982, California and other states at present) have standards on major appliances. We can compare heating use on a per square-meter -degree-day basis, as Fig 1 shows, and find both remarkable international differences in efficiency, as well as changes over time within individual countries. On the other hand, many measurements must be made in every country before these observations can be translated into overall savings in each country over time. This is particularly true of appliance energy use and lifestyle, about which so little is known at present.

4 CONCLUSIONS

What tentative conclusions do we read from these preliminary data? First, we repeat our observation that the rapid rise in fuel and particularly electricity use appears caused by rising incomes and increased ownership of energy using devices. But these devices are saturating even as incomes continue to rise. Hence we expect considerably less growth in energy use relative to incomes in the future.

Second, there appear to be several levels of energy/electricity use per household or per capita. Comparison across incomes suggests that electricity prices in particular, which seem to vary more than fuel prices, are extremely important determinants of consumption. New appliance costs are also important, but are at this time beyond our study scope.

It comes as no surprise, however, that the Swedes and Canadians consume the most electricity for appliances in both an absolute sense and relative to income. These countries enjoy the lowest electricity prices.

A related conclusion from the data available to use so far is the clear departure from pre-1972 growth patterns. While space heating use has decreased somewhat in all countries, particularly when the increase in central heating since the embargo is counted, appliance energy use and in some countries energy consumed for hot water and cooking (to the accuracy of the estimates) has not grown as fast as before. Some of this change is coincidental to the embargo and arises because key uses, such as hot water or refrigerators, have approached saturation.

The prominence of Swedish (and to a certain extent Canadian) low heat losses is not clear from this comparison, because we have not disaggregated space heating by dwelling type or age and presence or absence of central heating. Available data however, appear to make this possible for some countries, and measurements of actual groups of homes are available to us from each country studied. But the levels of saturation of central heating in most countries are still growing, suggesting that here space heating needs will continue to grow, though at a reduced rate. In the future we hope to include in our survey data gathered from BECA (8) that shows the space heating needs of typical new centrally heated homes built before and after the institution of new building norms ushered in after the 1973 Oil Embargo.

Because the use of electricity for heating may arise out of deliberate government policy we find it crucial to separate this use, which is growing in some countries, from other uses of electricity. In Sweden (12) electric heating comprises a major part of the growth in use between 1972 and 1979. Growth in electric heating has also been dramatic in France. One issue that arises when aggregated data are examined is how to count the resource energy consumed by electric heat. Our scheme, which treats each kind of use and energy source separately, at least in the initial analysis, avoids that problem. In future work we will try to separate the components of growth in each energy source.

Now that most families have acquired the means to use energy for the most important amenities (cooking, hot water and heating using electricity, gas, or liquid fuels; refrigeration, TV, some kind of washing device, minor appliances) conservation need not be seen as a threat to the acquisition of appliances. The prospects for savings based upon replacement of inefficient devices with new ones are somewhat bleak until the stock begins to turn over. The time period for appliances is short;for houses very long. Along with Noergaard (13), we find great room for improving efficiency, even in"major appliances" in Europe that are small by US standards.

In the area of space heating, increases in central heating point up opportunities to improve building shell characteristics in existing homes, and to demand the most effective space heating devices be put on the market. The EEC (Common Market), has considered a 9 country wide standard on the nominal performance of space heaters to encourage improvements in efficiency. But official forecasts in Germany, Italy, France, and the UK have avoided making any detailed comments on the prospects for improved weatherization of existing homes or the impacts of better built newer homes upon future energy demands. While there are retrofit studies published or underway in each country(14), none (except Sweden's[6]) have made any noticeable impact upon energy planning as far as we could tell. No country (except Sweden) has tried to analyze so far the results of public monies or loans handed out to building owners or private families who have made conservation investments. A Swedish Study, the "Starre" report(15), did analyze the grants disbursed in 1977/8 and found less energy saved per unit of investment than hoped for. These are compared with the official plan (16, based upon 6). The main problem was that most investment funds flowed towards facade renewal, which gave obvious non-energy benefits to the houses that were treated. But these investments were found to have low rates of return unless a part of the investment was allocated not to energy conservation but to home improvement, perhaps a legitimate use of public funds but not that use for which the money had been available. We expect that we will soon encounter similar evaluations elsewhere.

One important final lesson is that government authorities responsible for overall energy planning or even residential planning seem very ill informed about the nature of energy use, the state of information, or the dynamics of the last 7 years. This is reprehensible, because such knowledge seems crucial to energy planning in general, to the design of conservation programs and the measurement of their success, and to the design of R & D.

5 IMPLICATIONS FOR THE STUDY OF BEHAVIOR AND ENERGY

Our work thus far leads us to certain important ideas about the interaction of consumer behavior and energy use. First, there is an enormous variation in energy use per family for a given end use , a variation too large to be explained only by technology. We suggest that behavior--the way people use hot water, their preference for frozen rather than fresh foods--plays a key role here. But much remains to be quantified.

Another interesting question is the role of energy prices. While formal study of the role of prices and incomes will come later in our work, we can say that all indications from our data are that prices are important determinants of energy use and intensities. For example, electric appliance electricity use/incomes is highest in the low electricity price countries and lowest in those countries with high prices. Heating use--ie the penetration of central heating-- seems to depend directly upon income, while its efficiency depends on price. The Swedes, paying more than the Canadians for heat in comparable climates, live in somewhat more efficient homes. These findings are not surprising, but we have never seen data quantifying the differences in both structure and intensity before.

An additional question that arises is that of the most effective means for carrying out a conservation program. By 1979 it appeared that new appliances in most of the countries we study were beginning to show improved energy efficiencies. Heating use, adjusted for climate, seemed to have stabilized. Were these changes the results of higher prices alone, or were government programs important? How much information are consumers now soaking up in their efforts to economize on energy use? Ultimately we feel that our quantification will provide some of the answers to this question by pinning down how consumers have changed their energy use in the face of stiff price increases, new technologies, and more information. For the time being we can only speculate.

Finally, there is one additional point worth raising. We have seen over the years many attitude surveys about energy use and conservation, about preferences for one kind of heating over another, or about knowledge of the energy problem in general. Many negative conclusions are popularly drawn, particularly that consumers do not care about energy problems or conservation. A recent Wall Street Journal Article (12 May 1980, Page 1) by J. Kronholz, for example, asserted that drivers in France were paying little concern to energy conservation. The evidence offered was that gasoline consumption in France was 21% higher in 1979 than in 1973. Yet buried in the same article were the data that the numbers of autos had increased in the same period by 22%, and that miles driven had also gone up steadily. Therefore gallons/car/year had decreased! But miles per gallon, a sure sign of conservation, therefore must have increased in France all along! At the same time the growth in autos in France had been cut in half since 1972. All along the real increase in prices was only on the order of 20% for the 72-79 period. Given the modest price increase, the reduction in the growth rate of automobile ownership, the increase in miles per gallon and the still low saturation cars in France (1 per 3 people by 1980) it seems that the observations are completely consistent with a view that conservation is taking place even as structural growth is continuing though slowed.

The problem is that the measurement of conservation--here we argue properly measured in terms of intensities (like gallons per mile) or noticeable slowing in structural growth--has been overlooked. The popular measure, gasoline consumption, is increasing and this brings "bad tidings". We suspect that this measurement problem has in fact hindered much of our popular and serious research to find out what consumers are up to regarding energy use.

6 SUMMARY AND FUTURE WORK

We have assembled end use estimates for each country, with the quality of the estimate varying greatly. Our future work includes finalizing these estimates by checking among years for consistency and adding new data now available to use from fuel suppliers and other analysts. We expect to be able to improve our estimates for those countries where no studies have been previously performed. We would also like to study the differences in patterns among types of dwellings, particularly among the various kinds of multifamily and single family dwellings, as well as simply between these two classes.

Additionally we are at a point where we can begin to compare the importance of lifestyle differences in causing--or resulting from--differences in energy use. In particular the use of the refrigerator and its size, heating habits, and hot water are all important uses of energy in the homes that depend greatly on lifestyles. We would like to make these lifestyle-energy connections quantitative wherever possible.

Another important area for our future work is that of economics. To date there have been few studies of the economics of energy end uses in the home, only studies of energy consumption. We believe that our data and preliminary analyses will allow careful economic analysis of the major energy uses. Related to this problem is the question of the changes in consumption since 1972 brought about, we suspect, by higher energy prices and in some cases by important end use conservation policies. Few if any countries have tried to monitor or analyze their own progress--we propose, however, to make an international comparison of progress.

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11) Anon., 1978. End Uses of Energy in Italy in 1975. Roma, Ente Nazionale Idrocarburi (Special report on "Settore Domestico").

12) Energisparkomitteen, Dec. 1979. This standing committee in Stockholm publishes quarterly analyses of aggregate and sectoral energy consumption with some structural data that may influence the figures. Oddly enough, they never specify whether heating use is measured on a season or calendar year basis.

13) Noergaard, J., 1979. Energi og Husholdninger. Lyngby:Danmarks Tekniske Hoejskole.

14) Leach, G. et al, 1978. A Low Energy Scenario for the United Kingdom. London: Int'l Inst. for Environment and Development. Leach's study includes a detailed study of retrofitting of the UK building stock from which many of our figures are taken. Other retrofit studies have been carried out at the Battelle Inst., Frankfurt, W. Germany; at the Joint Research Center, Ispra, Italy; by Noergaard; by Scanada Consultants in Toronto, Canada; and by numerous others [See BECA, Ref. 8, for a more complete list].

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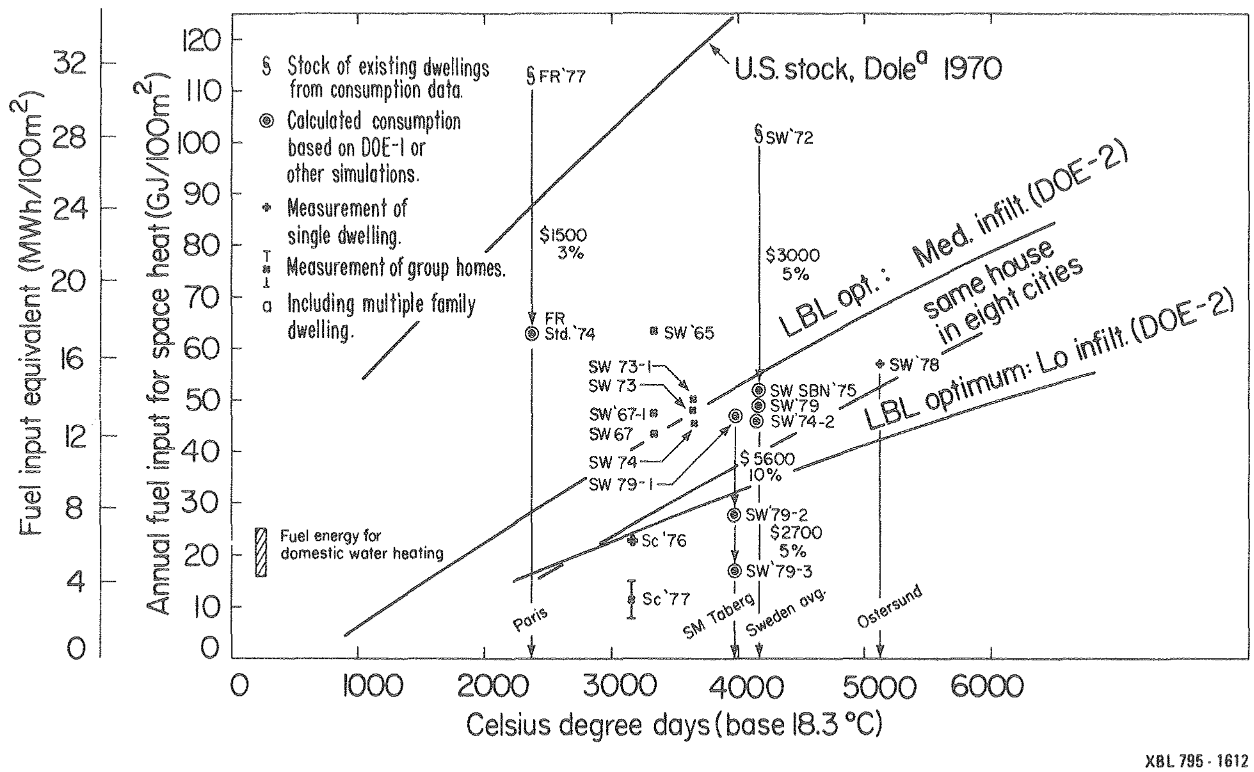

Fig.1. Annual Fuel input for space heat for European and American homes. Shown are lines representing existing US stock,calculated fuel use for homes built to medium and lo infiltration BEPS using DOE-2 simulation model, and points for 1)French [FR 77] and Swedish [SW 72] stock as they were for central heat in those years. Other individual or groups of dwellings are shown. From BECA, Ref. 8

TABLE 1 CHARACTERIZING RESIDENTIAL ENERGY USE

		MIXED USES		
		D		E
Activity	Range of Residential Use	Structure	Behavior or Lifestyle	Intensity
Space Heat House	40%-80%	House size, Type	Indoor Temperature, Fraction of House Heated	Q/m^2 - DD
Space Cooling	~5% (Japan, US) ~30% (warm U.S.)	House Size, Type	Indoor Temperature, Number of rooms cooled	Q/m^2 - DD
Space Heating System		Saturation of Central Heat by Fuel		$\frac{Q_{delivered}}{Q_{consumed}}$ ("First Law Efficiency)
Space Cooling System		Room or Central		$(\dot{Q})_{out}/Q(\text{electric})_{in}$ [EER]
Hot Water	5%-30%	Type of Equipment, Saturation, by fuel	(Liters/yr) Outlet temperature	$\dot{Q}/(1) \times (\Delta T)$
Cooking	3%-6%	Equipment Saturation, by fuel	Meals cooked/yr	Q/yr Presence of other fuel or electric cooking devices
		ELECTRIC USES ONLY		
Refrigeration, Freezing	3%-6%	Saturation	Size, Options	Q/yr
Television	$\lesssim$2%	Saturation	Size, Options, Hrs/yr	$\dot{Q}$ watts
Dishwasher	~2% + H_2O	Saturation	Size, loads/yr	Q/load Source of hot water?
Clotheswasher	~2% _ H_2O	Saturation	Size, KG/yr	Q/KG Source of hot water?
Dryer	~2%	Saturation	Size, KG/yr	Q/KG Use of sun

NOTE: Q measures energy; $\dot{Q}$ measures power (energy/time); m^2 - dwelling floor area; L - H_2O consumption, refrigerator volume; KG - weight of clothes; ΔT - temperature difference; DD - Degree Days

TABLE 2/I
RESIDENTIAL ENERGY USE BREAKDOWN: PRELIMINARY RESULTS

	UK		CANADA		GERMANY		SWEDEN	
	61	77	60	76	60	77	60c	77
HEATING								
Occ.Dw.106	15.9	20.3	4.4	7.0	16.2	24.2	2.58	3.58
Pers/Dw	3.0	2.8	3.9?	3.1	3.5	2.6&	2.8	2.4&
Dw Area,m2	-	80&	-	-	67.6	75.1&	73.2	81.8&
SFD,%	-	49	65	56&	48	45&	47	45
Central Heat,%	8	51	67	84	14	57	75	97
Fuel Heat,%	-	-	99	87	99(1)	89(4)	100	65(22)
Fuel/Dw,GJ	-	-	140	132	54	70	58	83
Fuel/Dw/DD,MJ	-	-	30	28	17	21	14	20
Elec. Heat,%	0/65	11/72	0.5	13	0	7/33	0	13
Elec/Dw,GJ	-/3	17/2	79	87	-	33/2	-	75
Elec/Dw/DD,MJ	-/1	8/1	17	18	-	?	-	14
TOTAL FUEL,PJ	-	927&	413	776	800	1485	226	300
TOTAL ELEC.,PJ	33	68	2	79	0	70	0	32
HOT WATER								
Fuel Share,%	-	66&	34	46	28	61	75	87*
Fuel/Dw GJ	-	18&	-	30	-	9b	?	22
Elec. Share,%	35	66	47	51	19	39	-	13
Elec/Dw,GJ	7	6	-	23	7	6	-	14
Tot HW/cap,GJ	-	5.7	6.0	7.7	1.7	2.9	?	8.4
COOKING								
Fuel Share,%	74	63**	42*	12	89	29	32	~2
Fuel/Dw,GJ	-	7**	-	7a	3.8	5.0	?	?
Elec Share,%	35	41**	58*	88	11	71	68	~98
Elec/dw,GJ	5	4**	-	3.6	2.5	1.7	2.2	3.1
Total Cook/cap,GJ	-	2.1&	1.1	1.2	0.9	1.2	?	1.0
APPLIANCES								
Per Dwelling,KWh	750	1810	1100	4100	215	1535	970	3130
-----------,GJ	3	7	4	15	1	6	4	11
Per $ Disp.Inc,KWh	0.3	0.2	0.2	0.5	0.02	0.1	0.2	0.4
TOTAL ENERGY								
Total,PJ	1484	1586	734	1297	1000	1970	?	379
Gas,PJ	140	701	142	405	53	321	?	?
Nat. Gas,PJ	0	690			0	281	-	-
			136	393				
City Gas,PJ	137	5			48	30	?	4
LPG,PJ	3	6	6	12	6	27	?	?
Oil,PJ	73	147	416	571	111	1106	173	235
Coal,PJ		344				28	20?	0?
	1132	96	14	780	172			
Wood,PJ		65				26	10	?
Elec,PJ	138	309	80	289	46	271	26	78
Dist. Heat,PJ	?	?	?	?	10	64	-	52
Elec.,TWh	38	87	22	80	13	75	6	22

TABLE 2/II
RESIDENTIAL ENERGY USE BREAKDOWN: PRELIMINARY RESULTS

	FRANCE		ITALY		JAPAN	
	62	77	60	75	65	77
HEATING						
Occ.Dw.,10^6	14.6	18.3	12.8	16.1	20.9	32.0
Pers/dw,	3.2	2.9	3.9	3.5	4.5	3.4
Dw Area, m^2	65	72	58	69	72.5	77.1
SFD,%	62	58	23	29	71	65
Central Heat,%	20	58	–	43	4	12
Fuel Heat,%	20d	55d	71	90	67h	97h
Fuel/Dw,GJ	73d	89d	22	70	14	9
Fuel/Dw/DD,MJ	24d	33d	10	33	10i	8i
Elec. Heat,%	0/–	3/4	–	6	16j	40j
Elec./Dw ,GJ	–	31/45	–	14	2	2
Elec./Dw/DD,MJ	–	12/17	–	7	1i	2i
TOT.FUEL, PJ	514e	1177e	201	1019	197	305
TOT.ELEC.,PJ	1e	33e	4	14	6	22
HOT WATER						
Fuel Share,%	–	74	–	34	k	k
Fuel/Dw,GJ	–	12	–	16	k	k
Elec Share,%	11	28	9	42	k	k
Elec/Dw,GJ	–	7	3	4	k	k
Tot HW/cap,GJ	1.4	3.9	0.9	2.0	1.6	3.3
COOKING						
Fuel Share,%	95	90	94	99	k	k
Fuel/Dw,GJ	2.4	4.7	3.4	5	k	k
Elec Share,%	5	10	6	1	kl	kl
Elec/Dw,GJ	3	3	3	3	kl	kl
Tot Cook/cap,GJ	0.7	1.4	0.9	1.4	1.7	2.9
APPLIANCES						
Per Dwelling,KWh	534	1418	220	670	940m	1853m
———————,GJ	2	5	1	2	3m	3m
Per $ Disp.Inc,KWh	0.09	0.14	0.1	0.2	0.2n	0.1n
TOTAL ENERGY						
Total,PJ	686	1540	386g	1018	526	1076
Gas,PJ	72	353	?	250	136	439
Nat.Gas,PJ	|	|	?	|	|	|
	38	289		209	207	257
City Gas,PJ	|	|	?	|	|	|
LPG,PJ	34	64	?	41	140	182
Oil,PJ	158	836	?	622	60	325
Coal,PJ	|	147	?	|	66	20
	433			40		
Wood,PJ	|	25	?	|	42	5
Elec,PJ	23	175	34	106	78	287
Dist. Heat,PJ	?	4	0	0	0	0
Elec.,Twh	6	49	9.4	29	22	80

NOTES TO TABLE 2:

Occ. Dw. refer to households except when the number of households is greater than the number of dwellings, as is the case for Germany and Japan in the first year given. Persons per dwelling considers only conventional dwellings from single detached(including farms) to multiple, but excludes persons in institutions, military barracks, etc. Single family dwelling definitions vary among countries, but in Sweden, Germany, Italy, and France they includes one and two family dwellings and row houses. In UK the totals are enlarged by great numbers of the latter. In Canada row houses are excluded here. In Japan the definitions do not generally correspond to those in Europe.

In Heating, fuel heat includes all fuels except district heating. Only for Germany and Sweden the figures for the district-heated share are given in parenthesis. For France the figures refers only to central heating. Electrical Heat refers only to central heating for Canada and Sweden. For UK and Germany the two figures presented show first central, then portable electric heating under both saturation and consumption. For France the second figure refers to all systems while the first is only central. For Italy and Japan, where central electric heat is insignificant, the figures refers to all systems.

In Hot water, saturation may add to less than 100 as some homes have none, or more than 100 because of multiple equipment. In the case of UK and Japan the totals refer to numbers of appliances per home. In each country a small percentage of homes have no hot water except for kettles.

Appliances exclude where possible cooking. We have extracted electric cooking from data from Canada (1000 kWh/yr),Sweden(abt 600 kwH/dw in 1960,800 in 1977) where sources gave only electricity. We have also attempted to extract electric water heating from Swedish data. As small electric heaters are often missed there is a chance that some of this heating has been counted both under heating and also under appliances.

Fuel totals come from Intl. Inst. of Env. and Devt. and Dept. of Energy, (UK), Stat. Canada and Canada Shell (Canada), Deutsche Esso, BP, and various German reports (Germany), Agence pour les Economies d'Energie and CEREN (France), ENI, WAES, and ENEL (Italy),and the Inst. for Energy Economics (Japan). We have separated LPG from oil totals in some countries and shown it under gas. Where solids or gases are only given in the aggregate we give the aggregate figure on the intermediate line. We give only district heat in those countries and years where it amounts to at least a few percent of total consumption. Dwellings in France, Sweden, and Germany had district heating. The Swedish/German figures for the number of dwellings are given in parenthesis in the breakdown of fuel heated dwellings. Energy consumption is given in totals. In Germany, 10-12% of the DH fuel total can be given to hot water, in Sweden about 18%.

As an example of our calculations, consider the case of the United Kingdom. Data for N. Ireland was unavailable, so averages apply to Gr. Britain only. Using a survey of England/Wales,North Scotland, and South Scotland, average consumption per customer excluding off peak meters was adjusted for increased consumption in winter months due to heating, about 500 kWh/hh, and cooking was removed using the 1978 saturation (45.3%) and 1977 unit consumption (1190kWh).

The residual was assigned to appliances, though some hot water probably remains. For 1961 the actual data for England/Wales were used, whereby all heating,water heating, and cooking were removed, and these averages were used for all of UK,the weights of North Scotland being small. This method gave a much smaller consumption/hh for 1978 for England and Wales. The reason is that most water heating appears on unrestricted tariffs. When the England estimate for hot water use/customer is restored, appliance consumption approximates that derived from the all-GB survey. The figures given thus arise from English data but check well with those data we received from Scotland. For UK, most data on ownership refer to Great Britain only.

a) Gas cooking, water together. Our breakdown is shown, based upon Ontario estimate of hot water gas use. b) Hot water uncertain. c) Demog. data 1960,energy 1963. d) Only central heating. e) Includes second homes. g) These data appear unobtainable. Estimate of total from WAES. h) Refers to homes with at least one fuel stove, plus part of the homes that have a gas stove (the other share of gas stoves being owned by homes already considered fuel heated, thus having at least one fuel stove). i) HDD base = 14 degree C. j) Only stoves, no kotatsu (small heaters for feet) considered. k) These data are available only for 1973 . For that year, it is possible to know the amount of each fuel for each end use, but not the share. l) Electricity is almost not used for cooking tables, only for rice-cookers and microwave ovens. m) Includes some electric appliances for cooking (microwave rice cooker). n) Disposable Income not available, so we use Private Income.

*, 1961 data. **, 1972 data. &, 1975 data.

All figures are approximate and should only be used as indicators.

TABLE 5
DOMESTIC ELECTRICITY PRICES
Nominal and Real Prices (UScents/kWh)

YEAR	NOMINAL	REAL	YEAR	NOMINAL	REAL
CANADA	$=1.143		*USA*	$1=$1	
1960	1.4	1.8	1960	2.6	3.4
1965	1.2	1.4	1965	2.4	3.0
1970	1.3	1.3	1970	2.3	2.3
1972	1.4	1.3	1972	2.5	2.3
1975	2.0	1.4	1975	3.6	2.6
1977	2.1	1.3	1977	4.1	2.6
JAPAN	$=245 Y		*FRANCE*	$=4.01 Fr	
1960	4.6	8.0	1960	5.3	7.8
1965	4.8	6.2	1965	5.3	6.5
1970	4.8	4.8	1970	6.0	6.0
1972	4.8	4.3	1972	6.3	5.6
1975	6.8	3.9	1975	7.9	5.2
1977	8.0	3.9	1977	9.2	5.0
W GERMANY	$=1.71 Dm		*ITALY*	$=804 Li	
1960	9.2	11.8	1960	5.5	8.1
1965	8.3	9.3	1965	5.2	6.0
1970	7.9	7.9	1970	5.0	5.0
1972	8.4	7.6	1972	5.2	4.7
1975	10.4	7.7	1975	6.4	3.7
1977	10.5	7.2	1977	7.6	3.2
SWEDEN	$=4.08 Skr		*UK*	$=.433 L	
1960	2.9	4.3	1960	1.6	2.3
1965	2.7	3.4	1965	2.8	2.3
1970	2.3	2.3	1970	2.0	2.0
1972	2.4	2.0	1972	2.2	1.8
1975	3.1	2.1	1975	4.4	2.4
1977	4.2	2.3	1977	6.1	2.4

Given are average prices in each country's nominal and real(1970)values converted to nominal dollars using exchange rates of March 1980. These have fluctuated widely during 1979 and 1980. Prices for heating electricity are considerably lower than these averages, particularly in W Germany and UK. All price data are from the OECD.

Table 5--continued--
DOMESTIC GAS PRICES
Nominal and Real Prices (US$/GJ)

YEAR	NOMINAL	REAL	YEAR	NOMINAL	REAL
CANADA	$=1.143		*USA*	$1=$1	
1960	.83	1.08	1960	.99	1.30
1965	.84	1.01	1965	.98	1.21
1970	.84	.84	1970	1.05	1.05
1972	.84	.78	1972	1.17	1.09
1975	1.08	.76	1975	1.73	1.25
1977	2.61	1.58	1977	2.20	1.41
JAPAN	$=245Y		*FRANCE*	$=4.01 Fr	
1960	5.30	9.26	1960	3.46	5.11
1965	4.87	6.36	1965	3.29	4.07
1970	4.51	4.51	1970	2.89	2.89
1972	4.77	4.29	1972	3.71	3.31
1975	8.73	5.06	1975	5.71	3.74
1977	9.85	4.84	1977	5.78	3.15
W GERMANY	$=1.71 Dm		*ITALY*	$=804 Li	
1960	4.65	5.98	1960	1.32	1.95
1965	4.01	4.49	1965	1.23	1.43
1970	4.54	4.54	1970	1.23	1.23
1972	6.69	6.03	1972	1.55	1.40
1975	7.54	5.60	1975	2.25	1.32
1977	12.99	8.94	1977	4.47	1.91
SWEDEN	$=4.08 Skr		*UK*	$=.433 L	
1960	4.60	6.83	1960	2.31	3.38
1965	4.34	5.3	1965	2.37	2.96
1970	4.04	4.04	1970	2.33	2.33
1972	4.09	3.44	1972	2.43	2.08
1975	5.29	3.60	1975	2.84	1.54
1977	8.63	4.78	1977	3.79	1.52

Given are average prices in each country's nominal and real(1970) values converted to nominal dollars using exchange rates of March 1980. These have fluctuated widely during 1979 and 1980. Prices for heating gas are considerably lower than these averages before 1972, particularly in W Germany and UK, but the prices in the late 1970's begin to reflect the preponderance of heating gas in these averages. All price data are from the OECD.

TABLE 3
Degree Day Estimates

Country	Base	Avg.DD	Notes and Source
CANADA	18 C	4580	Shell Canada
FRANCE	18 C	2200	IEJE, Grenoble
W.GERM.	19 C	3420	Esso, Deutscher Wetterdienst
JAPAN (Tokyo)	14 C	1000	Inst. for En. Econ., Tokyo, for homes w/o central heating
	18 C	1800	Shoda et al.,1979, homes with ch
ITALY	18 C	2140	Ist. Fisica Atmosfera,CNR,Rome (Pop.Wtd.Avg.)
- North	19 C	2275	
- South	19 C	872	
SWEDEN	18 C	4217	Sw.Ass. Htg.Rfg.Eng.(VVS),Stockholm

TABLE 4
SATURATION AND YEARLY CONSUMPTION:
ELECTRIC APPLIANCES in 1977

	COOKING		WATER HEATER		DISH WASHER		CLOTHES WASHER		REFRIG + FREEZER	
	%	kWh	%	kWh	%	kWh	%	kWh	%	kWh
CANADA	86		50		22		76		99/54	
W.GERM	71.3	600	39.0	1500	15.0	880	88.0	450	140	400/750
FRANCE	8.0	875	27.0	1700	12.0	900	72.3	300	116	410
ITALY	1.2	910	41.0	1080	9.7	1200	75.0	550	97	222
SWEDEN	95.	830	15@	2500@	17.0	370	50.0*	400*	160	660
UN.KGDM	44.7	1970	66.1	1575	3.0	465	75.7	195	115	445

Source: UNIPEDE. German data from Verein der Deutschen Elektrizitaet Werken. Canadian data from Annual Household Surveys.
@Swedish Hot Water estimated from central systems in centrally heated all electric homes. *Building-size appliances are not considered.
Other Swedish data from FERA.