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INTERNATIONAL ANALYSIS OF RESIDENTIAL ENERGY USE AND CONSERVATION

Lee Schipper

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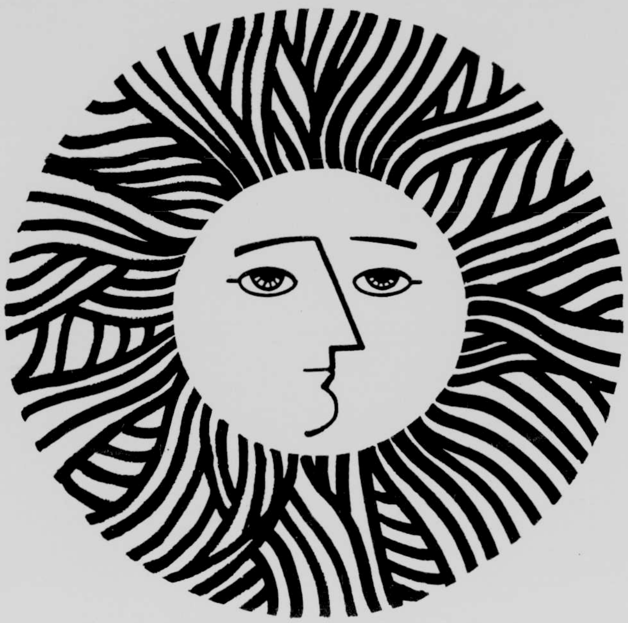

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A number of comparisons of energy use among industrialized countries have appeared recently (RFF, 1978; Schipper and Lichtenberg, 1976) that shed light on the link between energy and the economy. While the data presented from the industrial, transportation and energy sectors has been extremely detailed, data on the use of energy in homes and buildings has been difficult to assemble. Yet there is much interest in conservation in this sector. International comparisons of use and conservation, in the residential sector, might prove extremely useful to analysts exploring the economics and technology of conservation. Moreover, careful disaggregation of data in this sector is necessary in order to forecast future energy demand, particularly that of oil and electricity.

For these reasons the Energy Information Administration of the DOE asked the Lawrence Berkeley Laboratory to collect and begin analyzing data on residential energy use from seven major countries: Canada, Japan, the United Kingdom, West Germany, France, Italy and Sweden. This introductory paper discusses methodology and some of the preliminary findings of the study.

I. Residential energy consumption can be described by two vectors: the economic activities of the household or amenity demand D_i, and the direct energy intensities of each demand E_i. In Table 1 the most important activities are listed along with measures of D and E. Total energy use is then given by

$$\sum_i D_i * E_i .$$

The structural component, D, deserves further analysis, because several attributes of a particular piece of capital equipment or its utilization are important for energy. For example, space heating is governed by the size of the dwelling (more accurately, the area of outer surfaces), which is also a measure of standard of living when expressed in m^2 (dwelling area)/capita. The fraction of the dwelling heated, and of course the indoor temperature might be considered lifestyle parameters influenced by economic forces as well as traditions. Finally the climate, while certainly a structural or physical attribute of the demand for heating, exerts its influence through the temperature difference between indoor and out (see below); temperature preferences influence greatly the overall importance of climate (Pilati, 1977; BEPS, 1979).

Any thoughtful analysis of residential space heating must try to quantify all of these factors. For the present work we label the size of the dwelling (and its type) as an economic structural factor, while we denote the indoor temperature (or its surrogate, the base temperature used in degree-day calculations) as a lifestyle factor. Similar breakdowns are given in Table 1 for other important residential energy uses.

The implications of this breakdown can be seen dramatically in Figure 1, adapted from Lönnroth et al (1978) and other Swedish sources. Here is shown the relative increase in the use of energy for space heating in Sweden: a) the factor "increase in number of homes" corresponds to the net increase adjusted for the declining number of people/house; b) the factor "increase in area" accounts for the fact that total dwelling area in Sweden increased faster than population; so did the number of dwellings because families have become smaller, thereby increasing outside wall area per capita, therefore heat losses; c) the factor "temperature increase" was very important during this period. All of these factors contributed in the way estimated to increasing energy use for space heating. Not shown on the curve are rising incomes, falling (real) energy prices, or increased thermal resistance of all structures, nor a gradual shift in the fraction of single family/multiple family dwellings, nor the increase in the actual volume of a dwelling heated fully. Each of these factors should be studied separately in order to make projections of future demand. While we do not find fault with the many econometric studies that have analyzed prices, incomes, and residential demand (see especially Griffin, 1979) we feel that these are extremely limited in value since they do not make use of any physical data on the actual systems using energy. Our goal is thus to systematize these variables so that their contribution to the dynamics of residential energy use can be understood.

II. Links Between Energy Use, Lifestyles and Economic Factors

To the modeler or conservation analyst, the factors that influence final demand for energy are extremely important. How are they linked to the factors in Table 1? Here we broadly describe some of these links.

A. Demographic Factors

While most studies normalize energy demand to households or population, the size of households is important. Put another way, the number of households in the population and their size each influence energy demands. This is because the split between apartment and detached houses, as well as the utilization per capita of a given appliance depend on how many people live in each household. While small households can make use of smaller appliances, particularly room air conditioners, these devices suffer from dis-economies of small scale. That is, smaller refrigerators, ovens and water heaters have greater surface-to-volume ratios and therefore greater heat losses. Smaller room air conditioners in the U.S. in 1972 were less efficient than larger (Moyers, 1973). A small family using a small storage-type water heater "wastes" more energy in standby losses because the heater is on less (fewer baths, fewer dishes, fewer clothes to wash). As families become smaller in the U.S., the refrigerated volume/person will grow until the stock of large refrigerators, appropriate for larger families, is gradually replaced by smaller.

A more fundamental consideration affects space heating. For a given standard of comfort, measured as house-area/person, smaller families tend to require more heat/person than larger, since smaller houses have more outer surface/floor area than large. In apartments, of course, this need not be the case because of shared walls (though Sweden may be an exception -- see below).

These considerations may seem trivial, yet they are fundamentally important to accurate modelling of energy use. This is because the <u>number</u> of appliances, their <u>size</u> and energy intensities (as well as intensities of use) all multiply to give total energy demand, particularly for electricity. Prognoses of demand built only upon income and energy prices might miss completely the effects of saturation, unit appliance-size, number of households/total population, and so forth.

B. Income

Income is an important variable influencing the ownership of energy consuming devices and the marginal propensity to use them. All OECD countries exhibited rapid rises in the saturation of space heating (i.e., temperature increases), dwelling size, appliance ownership, etc. in the 1950s and 1970s, resulting generally in higher rates of increase of residential fuel and electrical use, compared to the U.S., where disposable incomes rose earlier but more slowly.

However, data indicate that capital substitutes conveniently (and profitably) for energy in major energy using residential equipment (Schipper and Darmstadter, 1978; Hirst and Hoskins, 1977).

Low income groups may have to forego these investments, relying instead on second-hand stock, while middle and high income groups, who have access to capital, may allow stock to turn over more quickly. This suggests that as incomes <u>and</u> energy prices rise, the effect of more appliances will be offset by the efficiencies of new devices. In the highest income countries, among the well-to-do (Canada, U.S., Sweden), gains from thermal insulation and more efficient major appliances can more than affect gross increases in consumption due to the proliferation of truly small appliances -- coffee grinders, hi-fidelity, hair-dryers. In the U.S., for example, yearly refrigeration electricity use (frost free) averages between 1200-1500 kWh/yr. Studies (Hirst and Hoskins, 1977; A.D. Little, 1977) suggest that half to three fourths of this may be saved at constant refrigerator size. But this savings, 600-1000 kWh/yr, more than covers the needs of an affluent home for all minor appliances, TVs and lights. Thus, the rapid growth of appliance energy use with income (elasticity $>$ 1.0) should slow (elasticity $<$ 1.0) as saturation approaches and then reverse as conservation outpaces marginal increases in the stock of small appliances.

C. Energy Prices

Energy prices influence the decision to buy an appliance, its size, its utilization and its efficiency. The latter effect is particularly important when technical progress makes more efficient devices available for a small increase in capital cost. High energy prices may spur this progress. Hitachi Corporation, for example, raised the Energy Efficiency Ratio (EER) of its small (6600 BTU/hr) room air conditioner from 7.5 to 11.7, and plans to improve the present machine considerably. Not surprisingly, the price of residential electricity in Japan passed 10¢/kWh in 1978. But rising incomes have allowed a surge in air conditioners, so that at least 20% of all Japanese homes now have some kind of air conditioner. Energy prices, however, appear to affect the efficiency of models available, and probably to some extent the number of hours of cooling used (or capacity) installed. Ironically (see E. Berndt, 1978), increased efficiency lowers the marginal cost of an hour or extra room of cooling (or one degree of indoor temperature), so it is possible that part of the savings from higher efficiency will be "banked" as an increase in cooled houses or rooms cooled, or a decrease in temperature, compared to otherwise.

D. Capital Equipment Prices; Interest Rates

Since residential energy use is tied to stocks of capital equipment, the cost of this equipment might be an important consideration. Though collection of data on all appliances might be difficult, we will attempt to get more information on existing major appliances. Clearly, incomes and equipment prices, and to a certain extent energy prices and efficiencies (Berndt, 1978), will determine how much refrigeration a family buys.

Consumer credit may plan an important role in the expansion of appliance stocks. This is particularly true in countries with high marginal tax rates, like Sweden. There, buying capital goods on time is attractive because the interest is tax deductible (since the effective cost is half the nominal cost). This according to Lönnroth et al (1978), is a factor in the recent expansion in electricity use for appliances in Sweden.

Interest, tax, and other policies are crucial to the mix of single family (SFD)/multiple family dwellings (MFD). Architect Åke Daun (Daun, 1979) argues for the case of Sweden that various indirect subsidies reduce the cost of SFD, relative to MFD, by almost $5,000, or $500/yr at 10% nominal interest over 30 years. Tax policies -- full deduction of interest expenses in Sweden, nearly full deduction in the U.S. (after the "zero bracket amount"), but a limit of 7,000 FFR/yr in France (about $1600) may influence both the propensity to buy as well as the size of home affordable. Since most larger apartments in Sweden require "insats" or a condominium down payment, the meaning of "rent" is even unclear. Government subsidies for home loans will also affect the size of the buyer market, possibly the rate of production of homes. In virtually every country, new homes have lower thermal losses than older, but are also bigger, though the former usually more than offsets the latter. Thus, housing policies as well as prices or rents should be considered along with energy prices and demographic factors in order to sort out reasons why one country's stock has different physical characteristics from another's.

III. Problems Associated with Analysis of Specific Energy Uses

When a set of data on energy uses is assembled, it should be examined on a like-kind basis. That is, heating (cooking, hot water) should be disaggregated by fuel and appliance type. Here we remark on some of the problems that first arise when the major uses are compared.

A. Heating

It goes without saying that different energy sources have different inherent conversion efficiencies within the house. Electricity will convert delivered electricity into 80-300 percent as much sensible heat; the low value arises from a hot air furnace with somewhat leaky ducts, the high value obtains with a heat pump of COP = 3. If the primary energy content is measured, then this factor is diluted by .85 to .26, depending on convention and actual thermal efficiency of electricity production. (See Schipper and Lichtenberg, 1976A, Appendix). Similar considerations would apply in theory (BEPS, 1979) to all energy sources: It takes energy to get energy! And various fuels deposit from 5% (wood, leaky fireplace) to 90% (well-tuned, large oil burner) of their calorific content in the heat delivery system (ducts, pipes, fans), which itself may be lossy. A full evaluation of efficiencies here is beyond the scope of our present project (see BECA, 1979), but it is important to consider improvements in combustion efficiency, heat delivery, and thermal integrity of the structure separately. For our purposes, we look at energy use per structure for each kind of fuel or system.

But is the whole house heated? In Japan, no, at least not today. Data on actual homes show a scatter of 6 GJ - 100 GJ of heating fuel use in the Tokyo area (Shoda et al, 1979). Indeed, if the Japanese would begin to heat every room of every house, heating use there could grow several fold. Instead, small kerosene room heaters or electric (under the table) floor heaters are used. In Germany, too, central heating is still not saturated (SRI, 1975), while in France, nearly 50% of all dwellings are classified as "dwellings without central heat," though presumably small electric heaters or fuel stoves keep the brave French warm, to the extent that these cold homes remain north of the immediate Mediterranean region. In Sweden or the United States, by contrast, nearly every home has central heating (or at least heat in nearly every room).

Climate, of course, plays a big role in heating habits. Southern Italy and France, southeastern Japan, and a few parts of the U.S. have very few days of heating need, but most of the population in our study lives in a region of between 1000-4000 Heating Degree Days (HDD) (celsius) (Table 2). Yearly variations reach $\pm$ 15%.

Nominally, HDD are measured as the yearly integral of the difference between a base temperature, T_{base}, and the outdoor temperature, T_{out}. Then, for each year,

$$HDD = \int_{\text{Jan. 1}}^{\text{Dec. 31}} (T_{base} - T_{out})\, dt$$

$$T_{base} \equiv T_{indoor} - \text{correction factor}$$

$$\text{where} \quad T_{in} - T_{out} \equiv 0 \text{ if } T_{out} \geq T_{base}$$

Analogous definitions exist for cooling.

That is, degree days depend on the adoption of an instantaneous base temperature, T_{base}; for an outdoor temperature above this level, no heat is needed. Moreover, heating season is often defined to begin when the daily average temperature falls below a different base temperature. In general, such a "season" will have fewer degree days than one taken over the whole year. For example, Swedish ASHRAE (VVS Tekniska Föreningen) reported in its Sept. 1977 Journal that Sweden had heating degree days (by either definition of base temperature) in July, 1977! It is doubtful, however, whether many furnaces were turned on, except possibly in second homes.*

The difficulty with an international study is that HDD are differently defined in each country. This depends partly on lifestyle, i.e., indoor temperature, but also on a more important quantity, "free heat." As Schrader shows (Schrader, 1977) space heating energy use/unit time, $\dot{Q}_s$, can be conveniently described by a simple relationship between the lossiness of the house (in watts/^{o}C temperature difference), the indoor and outdoor temperatures, free heat, F, and the fuel-to-delivered heat efficiencies, η. If $\dot{Q}$ represents power (energy/unit time),

$$\dot{Q}_s = \frac{W}{\eta} (T_{in} - T_{out} - \frac{F}{W})$$

where $F = \dot{Q}_{sun} + \dot{Q}_{people} + \dot{Q}_{appliances}$ (gained by the house)

and $\dot{Q}_{appliance}$ depends on their utilization, intensity and location in the house. F/W appears as the "correction factor" above.

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*The author experienced this on July 4, 1978, hence the term "second," not "summer," home!

Schrader's equation illustrates a crucial point. The "true" heating demand, in degree days, depends on the yearly integral of the entire term in brackets; in a given climate physically similar homes that are well endowed with people, appliances, or south facing windows, will have fewer true degree days, that is, the heater will come on less to maintain T_{in}. This is also clearly a function of the lossiness of the house W; low values mean high thermal integrity so that free heat supplies a larger fraction of heating needs, and more free heat is actually captured. Indoor temperature is also important. Schrader combines them into one called the reference temperature, T_R, effectively the actual average outdoor temperature at which the heater must come on. Since free heat also depends on sunlight and people, it easily varies by a large amount over the diverse regions we are considering. We give some examples from the national literature we have already surveyed (Table 3).

It is the presence of free heat that makes possible dramatic reductions in the quantities of fuel consumed for heat, that show up in our various projections under the heading "space heating." Elsewhere (BECA, 1979) we report on tests of homes in several countries in our present sample that reduce consumption by space heating equipment by 50-80% compared with average whole heat homes already in existence. The key question we will explore in the future is the economics of retrofit of existing houses as well as the improvement in new home building practices. But econometric measurements of heating fuel use, incomes and prices

(Griffin, 1979) obscure the possibilities for conservation. Equally important, failure to deal adequately with these subtleties of space heating could cause either over or understatement of future growth conservation prospects.

B. <u>Individual vs. Collective Metering: Apartment vs. Detached Housing</u>

One especially acute problem arises in Sweden, namely the use of master metering for hot water and space heat, both from apartment boilers and from district heat. Studies have clearly shown that zero marginal cost pricing (collective metering) almost always increases use significantly (EBU, 1975). Indeed, it was suggested (Schipper and Lichtenberg) that actual consumption in Swedish apartments, per head or per unit of area, was close to that in homes because of the lack of metering. While new data (SIND, 1979) soften this finding, the difference between apartment and detached homes is clearly eroded.*

This has important bearing on the calculation of future heat demand according to housing stock. If apartments are already metered, conservation will come primarily from investment in the building shell and equipment; if individual metering has to be introduced, a large immediate, additional savings potential exists. But it is often remarked (Lönnroth et al, 1978) that truly well

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*Apartment boilers tend to be better maintained than those in homes, and transfer more heat to rooms. Since the ratio of outer wall to floor area is normally much lower for apartments than for single family dwellings, these two factors should push fuel consumption/m^2 far below that of single family dwellings. But the observed difference is not that great.

insulated, individually metered apartments might use too little heat to make investment in district heating profitable; fixed charges would be spread over too few units of consumption. In any demand model, these issues must be sorted out if an accurate coupling of heat demand and sources conservation and housing types is to be made.

C. Water Heating

The differences in water heating practices are as important as those of space heating. Beyond the characteristics of different fuels, however, lie other problems.

We discovered, for example, that washing appliances in France, Italy, and elsewhere, but not in the U.S., usually produce their own hot water at the point of use. This hot water is not normally recorded as such , although one report,(ENI 1978,), suggested that of the 825 kWh normally assigned to dish washing in Italy (1975), 690 kWh actually heated water for washing, but this was not included under hot water (1090 kWh)! When water is otherwise heated by the same fuel (or electricity) in a storage system, point-of-use saves standby losses only as long as the water output temperature is not significantly higher than necessary. According to an analyst (Lapillione, private communication) this was not always the case.

Similar is the problem of the independent point-of-use water heater, especially common in West Germany and now Japan (SRI, 1975). When all hot water is provided at the point of use there are not standby losses in the house, so efficiency depends on the heat transfer from heating element to water. This may be crucial, so statements about water heating efficiency should be based on actual fuel studies of equipment, not on macro data. The same is true for the water temperature difference. One Japanese study (Shoda et al 1974) noted that among houses surveyed, inlet water temperature varied by nearly 10°C between summer and winter. Water use (liters/day) varied considerably, while output temperature varied less.

Also important to consumption is the question of metering. In Sweden much apartment hot water was until recently unmetered. Studies suggest metering reduces use drastically (EBU, 1975). Moreover, many apartment dwellers take their hot water from enormous cisterns. Statistically, the odds that the hot water will run out during lavish baths are low compared with smaller individual units. In earlier work it was suggested that these two factors give Swedes a propensity to "waste" hot water relative to families with similar incomes in other countries (Schipper and Lichtenberg, 1976 A). Complicating the Swedish situation is the paucity of official data on hot water, which instead is alternatively combined with space heat <u>or</u> with "household energy," depending on whether the water is headed with oil or electricity. This shows that hot water use deserves careful study.

A final economic factor is worth mentioning. Many countries (Japan, France, Sweden, Kenya) give nighttime tariff reductions for electricity-based production of hot water or space heat.

This may lead to considerable energy losses but makes good economic sense where electrical loads are uneven, since the water can be "charged" at even, low power all night, at the off peak rate, and eventually by the sun during the day. We indicate when possible the number of households using this system. Again, measurement of total kWh consumed would give a misleading picture of energy-use economies realized.

C. Cooking

Saros (1978) made a brief comparison of energy use in France, Sweden and the U.S. Finding great disparities in new household use of energy for cooking, he noted, "The differences in energy consumption for cooking are to a great deal explained by behavioral factors. The Swedes do not seem to devote as much time for cooking as the Americans and the French...." While this speculation sounds reasonable, it is the Americans who traditionally spend the most money on meals eaten away from home, followed by the French. In fact, accounting problems explain much of the apparent difference in cooking energy that Saros found. Moreover, an increasing amount of food preparation is carried out with machines besides the stove, as Nørgaard points out in the case of Denmark (Nørgaard 1979a, 1979b). Yet the fraction of meals eaten at home, and even the number of meals per day actually cooked, which might depend on how many people in the family work or the scheduling of children's meals, clearly influence energy use for cooking.* At present the relatively small share of cooking in the household energy budget precludes further investigation of Saros' observations, but a

*This point is discussed in ENI, 1978.

future look into the subject seems warranted.

D. Refrigeration

In nearly all countries refrigeration is now saturated, but growth has been dramatic in the last 20 years (Table 4). However, the size, features and construction of the actual models in use may each separately influence energy use/year by a factor of five. A small (100 L) manual defrost machine with compressor outside, no skin heater, and good insulation, seals and motor might only consume 20 kWh/m; a 600 L frost-free skin heater-equipped model with compressor inside, poor construction and inefficient motor, might use 200 kWh/mo. Ideally, the present study would examine the existing stock (or at least surveys of households) to see how the various factors enter. For the present however, we merely try to characterize the size of new models and the penetration of frost free. In Japan and Sweden monthly electrical consumption is beginning to figure in advertising.

However, only in Sweden did we find volumes as great as in the U.S., and only in Sweden had freezers penetrated so greatly. One speculative explanation is simple -- few fresh vegetables are available in Sweden in the winter; autos and shopping centers are more prevalent, making large grocery purchases easy.

E. Washers

We noted above that the most important information about dish or clothes washers is whether or not hot water is prepared in them. Additionally, information on frequency of use is important. Some studies (DOE,1978; Horovitz,1976) have estimated energy use per unit weight of clothes cleaned for a given water temperature; in Japan and the U.S. cold water wash is not uncommon.

IV. Energy Indexes

Is it possible to collapse all the information about residential consumption into a single index? We think not. The reasons that climate, income, energy prices and other factors influence consumption for different activities in different ways. Instead we suggest that the groups be kept in disaggregated form:

I. Space Heat
   (Space Cooling - U.S., Japan)
II. Hot Water, including washers
III. Cooking
IV. Refrigerators (and freezers)
V. Lights, TV
VI. Miscellaneous Small Appliances
VII. Special Large Heat Using Appliances, if any (dryers)

It would then be possible to construct a hypothetical home perhaps based on Sweden, the highest income country in Europe in our study, and characterize the home size, refrigerator size, hot water consumption in liters, number of meals cooked/year, and stock of other appliances for which unit consumption appears not to vary greatly from one country to the next. The only major appliances that are expected to increase energy use significantly are clothes dryers and freezers. One could compare the per household consumption of energy, then, based upon this standard home with the full complement of amenities, including house heating adjusted for climate. In this way, both structural and intensity or efficiency features of the consumption in each country can be compared. This comparison will appear at the end of our work.

V. Data Sources

It may be worthwhile to review the kinds of data sources that contribute to understanding residential energy conservation. So far we have found that a few countries have successfully collected data from many sources and presented a clear picture of residential energy use in time that can be broken down into many of the factors we have investigated herein. The French Agence pour les Economies de l'Energie, for example (The Energy Conservation Agency) analyzed and published data for each year following the 1973 Embargo. For most other countries, however, data must be gathered from several kinds of sources:

1) Housing surveys (number of houses, size, population)
2) Energy supplier associations (number of housing units using a given energy form for a given purpose)
3) Energy users or appliance associations (appliance saturation)
4) Statistical abstracts, government ministries (energy prices)
5) Research organizations (data on actual measurements of consumption)

The implications of this list should be clear -- Government energy organizations, outside of the case of France (and the U.S.) seem least informed on energy end use data which, we argue herein, is essential for informed decisions on energy conservation. Moreover, most of the yearbooks from the United Nations, OECD, or Common Market list energy only by type of supply - usually residential use is classified together with non-industrial, non-transportation use as "other."

On the other hand, residential energy use in the OECD has grown at a high rate in the period 1960-1979; much of this growth reflects increased disposable income, but much of the future growth could be offset by conservation, particularly in large, heat using applications, heating, hot water, and refrigeration. Information is the key to better utilization of energy in residences. Perhaps the results of our survey will include greater attention paid to data and analyses of residential energy use.

Conclusions

Initial consideration of rough data on residential energy use in OECD countries suggest wide variations that may indicate opportunities for energy conservation. Preliminary inspection of detailed data assembled so far indicates that much of the variation of energy use depends on structural or lifestyle factors such as incomes, house or appliance size, hot water and indoor temperature habits. On the other hand, there appears to exist a wide range of energy intensities within each narrow end use category; each of these ranges suggests that there are interesting prospects for energy conservation in any one country based on technologies or ideas common elsewhere. Interesting examples worth immediate attention include thermal integrity of building shells (Sweden), efficient refrigerators (in kWh/month/liter)(U.S.), small room air conditioners and heaters (Japan), point of use water heaters (Japan, Germany, Italy).

Perhaps more important than the study of any technology, however, is the understanding of the interaction of incomes, energy prices, structural and lifestyle factors, climate, and technology with the demand for energy in homes. In the past, lack of data and greater lack of interest clouded the understanding of how households use energy. It is hoped that the present work will improve that understanding, as well as our ability to model conservation strategies, policies, and future energy demands in the U.S. and in important overseas consumers of energy.

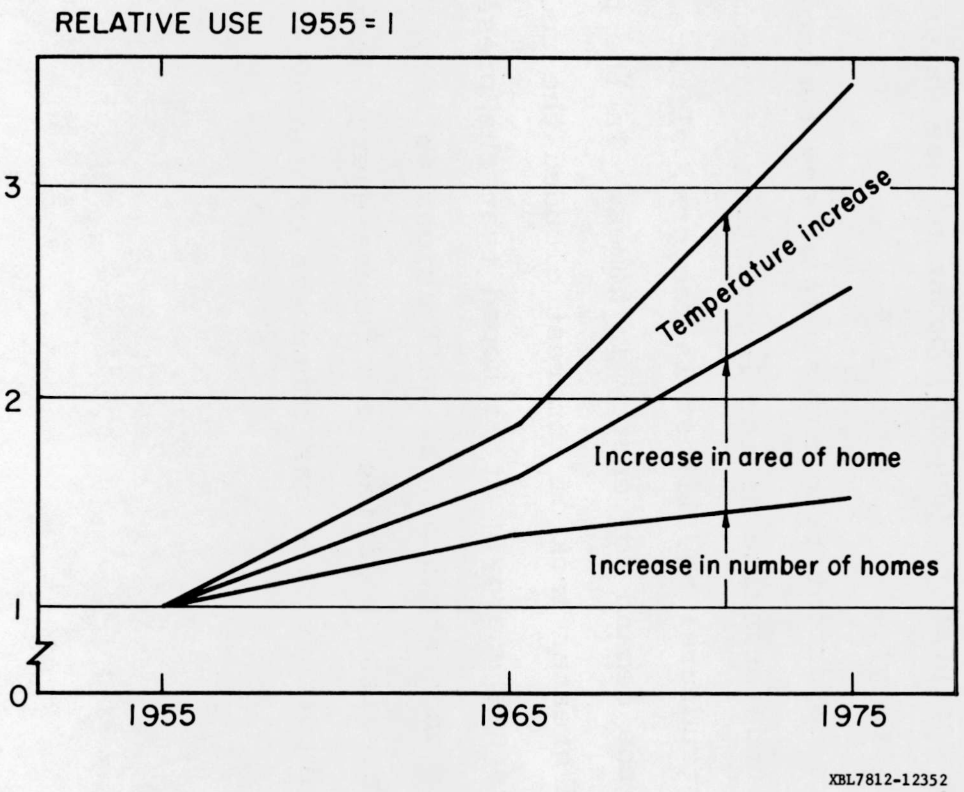

Figure 1. Growth of space heating in Sweden and its underlying factors.

Table 1

Characterizing Residential Energy Use

MIXED USES

Activity	Range of Residential Use	D: Structure	D: Behavior or Lifestyle	E: 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		$(\dot{Q})_{out}/Q(electric)_{in}$ [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	≲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

Heating Degree Days

Country	Base		Source
Japan - Tokyo	$14^{o}C$	1,000	Ins. for Energy Economics, Tokyo
	$18^{o}C$	1,800	Shoda et al 1979
Italy - South	-	600-900	ENI, Rome
North	-	2500-3000	ENI, Rome
France-Paris	$18^{o}C$	2373	"Chauffage au gaz des Locaux." In Saros 1978.
United States-			
Minneapolis	$11.7^{o}C$	2924	NBS Building, Science Series 116, No. 19178
-	$18.3^{o}C$	4617	
Washington	$11.7^{o}C$	1098	
-	$18.3^{o}C$	2340	
San Francisco	$11.7^{o}C$	298	
-	$18.3^{o}C$	1690	
Sweden - Stockholm	$20^{o}C$	3570	ÖEF, Stockholm
	$17^{o}C$	5200	(Schipper and Lichtenberg and references therein)

Notes: The Japanese figures essentially apply to homes without/with central heating, respectively. The two American figures apply to very lossy and very tight homes, respectively, in the sense that the lower base temperature allows a much better fit of heat consumption to degree days when very efficient houses are examined. The Swedish figures represent two conventions; the former, applied by the Engineering Societies and assembled by the Oeverstyrelsen för Ekonomiska Försvar, ignores many hours in the spring and fall if the average daily temperature does not fall below 12 or 13°C, while the latter adds up degree hours as long as the outdoor temperature is below the threshold, conforming to heating habits in electrically heated homes.

Table 3

Free Heat

Country			Source
England	SFD	5,900 kWh	(1)
France (Paris)	SFD	4,350 kWh	(2)
Sweden	SFD -Average	3,000 kWh	(3)
	SFD - well-insulated	11,000 kWh	(3)
	SFD - (low energy house)	6,750 kWh	(4)
U.S. -"BEPS"	SFD	5,000 kWh	(5)
Denmark - Zero Energy House		7,310 kWh	(6)

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Table 4

Saturation of Refrigerators

	1955	1965	1975	Source
France	7.5	58.7	88.5	Inst. Nat. des Stastitiques Economiques (INSEE)
Italy	31.5(1960)	66.3	89.6	(1978) ENI
Germany	8.0	74.0	92.0	Hauptberatungsstelle fur Elektrizitäts Anwendung
Sweden	-	75.0	95.0	Centrala Driftledningen
Japan	28.0(1962)	51.4	96.7	Ministry of Int'l Trade and Industry
United States	-	99.0	99.0	Merchandising Weekly; Oak Ridge National Lab.

Figures give the percentages of all households possessing a refrigerator.

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