Title
Lifestyles

Authors
Bradshaw, TK

Vine, E

Barth, G

Publication Date
2024-03-29

Peer reviewed

Annu. Rev. Energy. 1989. 14:273–320

LINKING LIFE-STYLES AND ENERGY USE: A MATTER OF TIME?[1a]

Lee Schipper, Sarita Bartlett, Dianne Hawk, and Edward Vine

Energy Analysis Program, Applied Science Division, Lawrence Berkeley Laboratory, Berkeley, California 94720

INTRODUCTION

Energy use varies widely among families living under similar physical conditions. Figure 1, for example, shows total electricity use (space and water heating, cooking, and appliances) plotted against income in virtually identical homes occupied by similar families in Sweden in 1977. All families paid approximately the same unit cost for electricity. Because the homes have similar levels of insulation (carefully measured in experiments) and use the same electric heating systems, the variations in energy use are not caused by differences in heating system efficiency or building thermal integrity. The variation in energy use therefore suggests that many factors besides the characteristics of the houses influence household energy use.

Can we explain the differences in home energy use shown in Figure 1 by examining the variation in prices and incomes? Income is certainly a determinant of energy use in the long run, but the data in Figure 1 exhibit a wide variation at a given income. For example, indoor temperature, appliance size, house area, income, and home energy use all increased in Sweden in the 1950s and 1960s. However, energy use in the homes shown in Figure 1 grew little between the late 1960s and 1977, because ownership of heating systems and other appliances was nearly saturated for families in these houses when the homes were first built. Such saturation reduced the impact of higher incomes on energy use. Changes in energy use could still occur, however, as a result of changes in the characteristics of appliances (e.g. size and efficiency) or in their use. Rises in income broaden the options of activities one can engage in and increase the amount of material goods one can acquire. In the

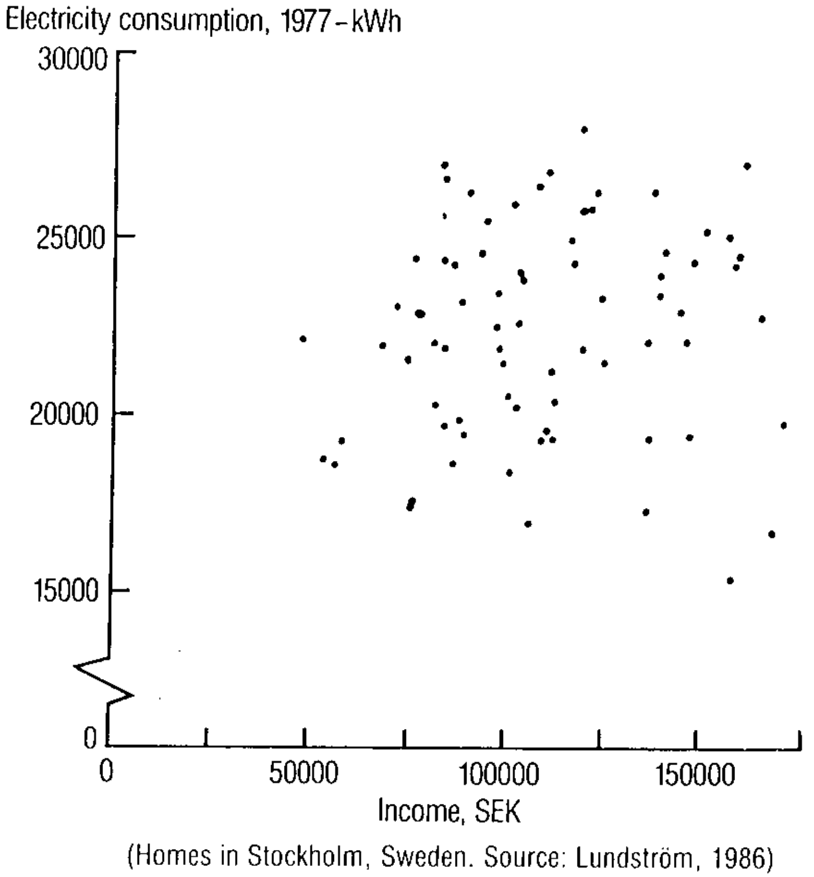


Figure 1 Correlation between total household income and electricity consumption in 1977 for all houses. Source: (3). The sample contains several thousand detached single-family dwellings.

future, however, income changes alone may not drive important changes in energy use.

Similarly, energy prices are an important determinant of household energy consumption. During the years following the first two oil price shocks (1973–1974 and 1979–1980), high energy costs caused many households to use less heat and hot water, while stimulating the purchase of more efficient appliances and cars. When electricity prices increased in Sweden, heating energy use fell. Swedes also reduced their driving, as did residents of the United States. Some of these changes in the use of equipment reversed when prices fell. Future energy prices will doubtless have some impact on the demand for heating or driving, as well as on the efficiency of the technologies that use energy. However, for most other consumer activities (such as going to movies or using a video recorder), the cost of energy is a small portion of the total cost, and, therefore, energy prices should have a relatively small impact on consumers' decisions. As long as energy prices do not rise abruptly, consumers' decisions about what kinds of houses they live in, how far they travel to work, and what they do in their free time will also remain relatively free from energy-price considerations.

Thus, aside from income and prices, what does account for the variability in energy use shown in Figure 1? Many authors have found that household characteristics, such as family size and composition, as well as the number of hours the house is occupied, are important determinants of household energy use (1–3). Household characteristics influence occupant behavior and, therefore, differences in such attributes may lead to significant differences in energy use. If these characteristics change over time, then energy use may also change. The resulting changes in energy use may be independent of and of similar magnitude to changes caused by incomes or prices. Thus, our central thesis in this paper is that changes in the patterns of consumers' activities, which we call their life-styles, can lead to substantial changes in energy use, particularly in the very long run, even with little change in energy prices or incomes.

In this paper, we explore the links between life-styles and energy use. While we focus on the United States, we illustrate some points using examples from other countries, particularly where these countries differ significantly from the United States. And while individuals may make conscious decisions to save energy by either changing the amount of heating or driving they demand, or by changing the efficiency with which energy is used for these tasks, we focus on changes in an individual's or household's activities that are not motivated per se by a desire to save energy. Finally, we study observed behavior, and do not focus on values and attitudes that motivate people.

We believe that we gain a better understanding of how energy use is changing by finding out which activities are important to determining energy demand. Understanding the underlying forces that drive these activities, including both economic and noneconomic forces, allows a better understanding of the future of energy demand.

To understand the relationship between life-styles and energy use, we first review the structure of energy use by end-use sector. We then propose a scheme for measuring consumer activities, which leads to a new description of consumers' energy use. We review demographic and social factors that may constrain activity choices, then return to the activity-based description of energy use to speculate on how changes in consumer activities could cause important changes in sectoral demand in the future.

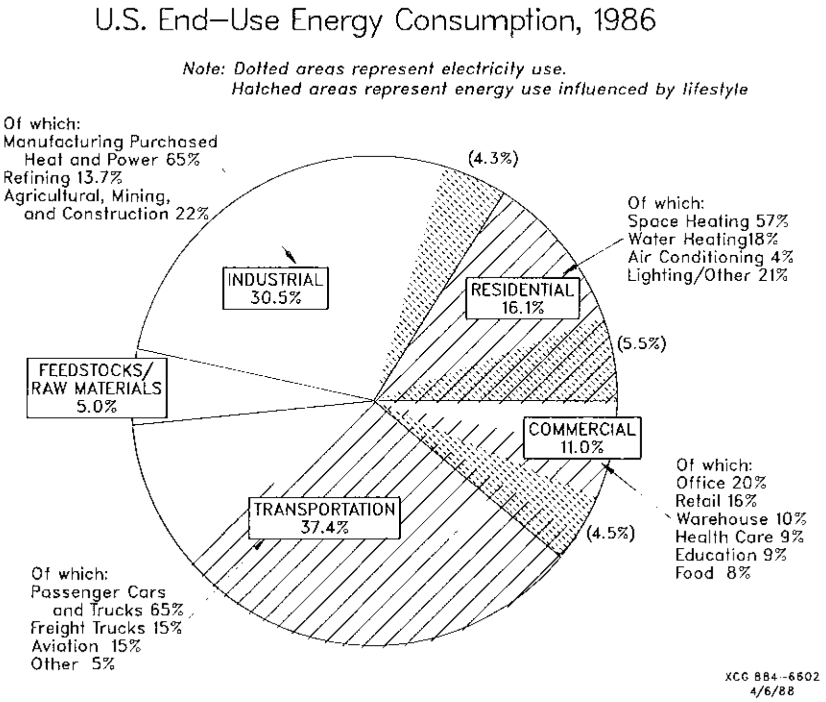


Figure 2 US end-use energy consumption, 1986. Source: LBL calculations, based on (13)

ENERGY DEMAND AND CONSUMER ACTIVITY

Figure 2 illustrates US energy use by sector in 1986. Consumers, as individuals or with other people, use energy directly in their homes and cars. They also use energy indirectly, through their demand for transportation services, their demand for personal services in buildings in the service sector, and their choices in family business, personal care, and free time.[1b] We have indicated the approximate portion of each sector's energy use that consumers influence in this fashion, which we call *personal energy use*. We also indicate the portion of these uses that are met by electricity. In the following section, we briefly review the characteristics of each sector.

[1b]Personal services include restaurants, lodging, retail stores, places of assembly or cultural interest, and other services where consumers (as customers or visitors) dominate the use of space in buildings. In this report, we do not consider industrial energy use or freight, nor buildings where occupancy and use are dominated by employees, rather than customers or consumers.

Residential Sector

Energy used in the home accounts for 15–30% of energy use, and 20–35% of electricity use, in industrialized countries. Space heating is the most important end-use (60–75% of all energy consumed in the home) (4, 5). Water heating accounts for about 10–20%, while cooking, lighting, cooling, and miscellaneous appliance use make up the remaining share. Table 1 gives an approximate breakdown of US home energy use for 1986 (adapted from 6).

Physical characteristics of homes and appliances influence household energy consumption. Dwelling type has a small influence on energy use; families in apartments tend to use less energy than those in detached or semidetached dwellings, because apartments are smaller and have fewer outside walls than detached houses. Dwelling size is a key determinant of household energy use. Equipment ownership is also important: in the United States and most industrialized countries, 80% or more of all homes have central heating and the major energy-using appliances—equipment for refrigeration, washing and drying, air conditioning, ventilation, television, etc. Considering all factors, we estimate that as much as 50% of total energy use in a given home is solely dependent on the characteristics of existing equipment and the dwelling characteristics (7, 9), while the balance is determined by the characteristics of the occupants and their activities in the home. Some uses, like space and water heating or cooking, are very dependent on home occupancy; other uses (e.g. refrigerators) are almost independent of house occupancy (unless, for example, the refrigerator doors are opened very often).

Sonderegger (7) compared energy use in similar homes among families who remained in the same home over time and those who moved. He found that an important component of home energy use depended on the behavior of the family itself, as distinct from the physical characteristics of the home and its equipment. In a detailed study of 300 families' home and automobile energy use in Michigan, Gladhart et al (2) found that family size, age distribution, the number of wage-earners in the household, and the time the house is occupied were significant determinants of household energy use. Lundstroem (3) and Gaunt (1), analyzing data similar to those in Figure 1,

Table 1 Residential energy use in the United States in 1986

(Quadrillion Btu)	Total	Fuel	Electricity
Space heat	5.84	5.50	0.34
Water heat	1.57	1.15	0.42
Cooking	0.48	0.30	0.18
Appliances, lights, A/C	1.88	0.00	1.88
Total	9.77	6.95	2.82

Source: (4, 5)

found bathing behavior to significantly affect household energy use (see also 8). Lutzenheiser (9) found that the specification of end-use technologies explained 55% of the variation in household energy use, while the characteristics of the occupants (e.g. family size and age) explained about 30%. When both sets of variables were included in the model, more than 66% of the variation in household energy use was explained. A principal finding common to all of these investigations was that a significant component of home energy use variability was not explained by income and energy prices alone.

Services Sector

The services (commercial) sector comprises personal, government, and business services, carried out mainly in nonresidential buildings. This sector is responsible for 10–15% of energy use (15–25% of electricity use) in the industrialized countries (10). The use of fuels and electricity in the services sector in the United States is shown in Table 2. As a share of its total use, this sector uses significantly more electricity than the residential sector. Space-heating energy use requires about 50% of service sector energy use, less than in homes, since lighting, machines, and ventilation use considerably more energy in nonresidential buildings.

Among the subsectors, there are significant differences in energy-intensity (Figure 3) and in the type of energy used (fuel or electricity). These dif-

Table 2 Energy use in the services sector in the United States in 1986[a]

	Area (10^6 sq.ft.)	Energy (Quads)	Electricity (Quads)	Fuel (Quads)	Share for personal energy
All buildings	58229	5.82	2.56	3.26	—
Assembly	7339	0.51	0.16	0.35	1.00
Education	7321	0.59	0.19	0.40	0.20
Food sales	712	0.15	0.08	0.08	0.80
Food services	1281	0.27	0.14	0.14	0.90
Health care	2107	0.43	0.14	0.29	0.10
Lodging	2785	0.45	0.19	0.27	0.20
Stores, small Services	12805	1.04	0.54	0.50	0.80
Office	9546	1.17	0.59	0.58	0.05
Public order	680	0.00	0.00	0.00	0.00
Warehouse	8996	0.68	0.28	0.41	0.00
Other	1726	0.17	0.10	0.08	0.20
Vacant	1931	0.14	0.07	0.07	0.00
"Personal share"	23814	2.29	1.01	1.28	—
Personal share of total	38.4%	35.2%	35.7%	34.7%	—

[a] Estimated from NBECS 1986 (area) and NBECS 1983 (intensities). The personal share is estimated by summing the fraction allocated to the personal share, as given in the last column, times the area or respective intensity.

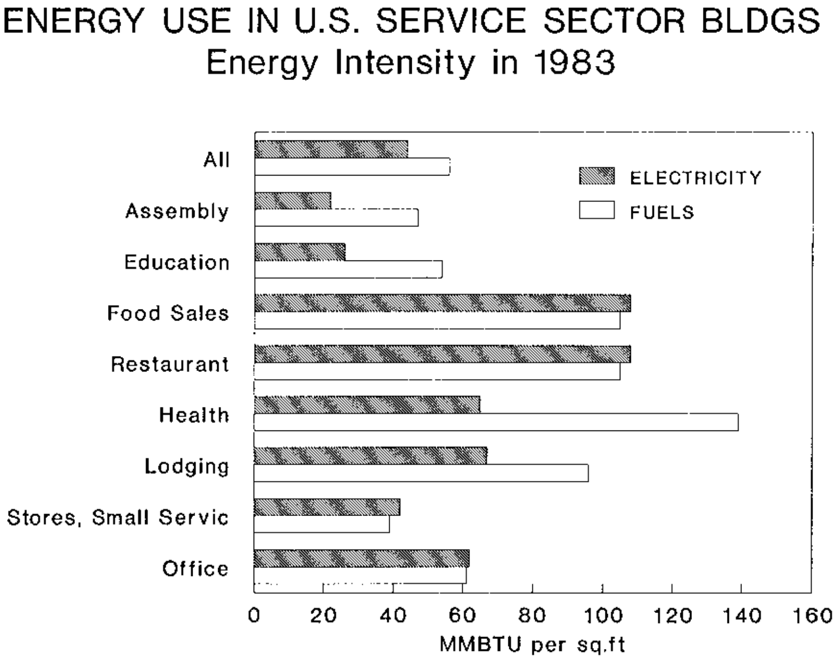


Figure 3 Energy use in US service sector buildings. Energy-intensity in 1983. Shown are fuel and electricity use per square foot of different building types, from a national survey. Source: NBECS (12).

ferences result from the mix of end-uses demanded by the various subsectors. Offices and stores use mainly electricity (about 50% of total energy used) for lights, machines, and equipment; schools, hospitals, and hotels generally use gas and liquid fuels for space and water heating. Because of this variation in intensity and energy type among subsectors, total energy use for services depends on the distribution of service sector buildings by type of establishment.

Subsectors heavily influenced by consumer activities include retail stores, entertainment, restaurants and hotels, and leisure services. Today, these subsectors account for 40% of total energy use in the US service sector. This share has probably increased since the 1970s, because these kinds of services have grown more rapidly than other services. The national surveys (11–13) show that the floor space area of these sectors increased more rapidly than the total area of service buildings. The service sector share of total energy use has increased in most countries, because many subsectors have become more fuel- or electricity-intensive. That is, some subsectors require more fuel or electricity today per unit of economic output, building area, or employee than in the early 1970s.

Table 3 Energy use for US passenger transportation in 1986 (Quadrillion Btu)

Mode	Free time	Family business	Vacation	To/from work	Total
Car	3.59	3.88	0.25	4.03	11.75
Rail[a]	0.003	0.000	0.010	0.059	0.07
Bus[b]	0.017	0.066	0.024	0.054	0.16
Air	0.000	0.000	1.227	0.307	1.53
Total	3.61	3.95	1.51	4.45	13.51

[a] Commute rail is considered 75% commuting, 25% family business.
[b] Buses are 75% transit, 12.5% family business, 12.5% free time; intercity bus and rail is all free time.

Transportation Sector

Transportation accounts for more than 20% of total energy use in Europe and Japan, and nearly 30% in the United States (Figure 2). Passenger transportation accounts for 75% of sectoral energy use. Almost all energy used is in the form of liquid fuels. Passenger transportation energy use can be divided into different modes ordered approximately by the share of total passenger-kilometers traveled: car, air, bus, rail, and other modes. The level of energy use depends on motorization (numbers of vehicles and access to vehicles), mobility (passenger- or vehicle-kilometers traveled), vehicle size, load factors, and the characteristics of the engines themselves. Table 3 shows passenger energy use by mode in the United States.

Over the last 40 years, land passenger travel has increased, and shifted from collective modes to cars, which are more energy-intensive, and to airplanes. Higher incomes and falling real fuel prices encouraged this switch. In addition, cars became larger and more powerful. While the oil crises halted or interrupted this trend in the United States, they only slowed the trend in Europe and Japan. As a result of these and other changes we review below, energy use in the transportation sector grew faster than in the other sectors in most industrialized countries during the last 40 years.

Kitamura (14) provided an interesting alternative approach to analyzing current and future travel demand. He classified "life-style" variables by income life cycle (households with children, couples without children, single individuals, and single parents), age, and the number of employed persons in the household. He also examined travel behavior by the same categories,. focusing on driver's license possession, mobility, trip quantity and purpose, and dependency on public transit. He found that women tend to be less mobile and more transit dependent. He also noted that ". . . the roles played by the individuals and their lifestyles have systematic impact on their travel behavior. In addition, the systematic variations observed along lifecycle stages at the individual level indicate the important effect that the interaction among household members exerts upon each member's travel behavior." We pursue these findings below.

CONCEPTUAL FRAMEWORK

In this section, we present a conceptual model for organizing and integrating observed behavior patterns to help identify how these patterns affect energy use. The concepts included in the framework have been expounded on by academics from many disciplines who have sought to define and analyze human "life-style" (15a). Table 4 traces the process through which the needs, wants, values, and emotions of an individual or group are manifested in behavior. This behavior results in a pattern of energy use.

Motivations to Act

People's actions arise ultimately from physical and psychological needs, values, and emotions (15b, 16). We do not attempt to measure these fundamental motivations, however. Instead, we focus on more directly observable phenomena that constrain or encourage action: economic and de-

Table 4 Conceptual framework

Motivation to Act:	Needs, Wants, Values, Emotions
Factors that Enable or Constrain Action:	Socioeconomic and Environmental Factors Demographics Economics Physical infrastucture a. communal/societal b. personal, privately owned Social and legal infrastructure
Manifestation of Constrained Values and Emotions:	BEHAVIOR/ACTIVITIES
Measured by:	Types and Location of Activity Recent expenditure patterns Historical expenditure patterns Frequency, Duration and Sequence of Activity Time Mileage
Consequence:	Type and Quantity of Energy Use

mographic factors, physical infrastructure, and the force of tradition and custom (17).

Factors that Permit or Constrain Action

Socioeconomic and environmental factors permit, encourage, or constrain the realization of needs, wants, values, and emotions through behavior. These factors feed back to influence individual or group needs, wants, values, and emotions (18, 19). Demographic factors include household composition (e.g. the gender and age of each member), education, occupation, size of household, marital status, race, and employment status. Economic factors include income, assets, and the prices of goods and services. Physical infrastructure is divided into two categories, the larger communal infrastructure, and infrastructure acquired for personal or private use. Communal/societal infrastructure includes the transportation network (e.g. roads, bridges, parking lots, public transportation, and airports), public or private nonresidential buildings, and the availability of natural resources (e.g. gas and electricity). Physical infrastructure acquired for personal or private use can be rented or owned for use by an individual or a defined group of individuals. Personal infrastructure includes the dwelling (characterized by building type, location, size, age, and duration of tenure) and the equipment stock (e.g. the number, type, and energy-using characteristics of such appliances as space and water heaters and cooking and lighting equipment). Finally, the social and legal infrastructure are powerful factors that permit, encourage, or constrain action. This category includes laws governing business hours, prescribing the quantity and quality of resources available to consumers, and social mores (e.g. attitudes about women's working outside the home). This social infrastructure comprises the values held by the broad social organization (such as a country) of which most individuals are members.

Measures of Observed Behavior

Behavior or activity can be observed and measured (20, 21, 17). We can measure people's activities by measuring the allocation of specific resources—temporal, financial, and material—across activities. First, the type, location, and participation level of activities performed can be qualitatively measured (What is being done and where? Are people cooking, watching television, or driving to work?). Through direct questioning, we can determine what people do, where they do it, and with whom. From historical expenditures for a specific group of individuals, we can assess the expenditure pattern by identifying the collection of and characteristics of owned or rented goods, which we also denote as the personal physical infrastructure. From a survey of personal physical infrastructure, we can identify what people do and sometimes where they do it (e.g. if they have purchased a television and video recorder in the past, we can infer that watching movies is an activity that people participate in at home). For recent past expenditures, we can also quantify what activity is performed and where, in terms of money. We can infer whether these expenditures led directly to energy use in or out of the home (e.g. heating fuel or gasoline), or indirectly to energy use out of the home (e.g. for a concert). By comparison with the survey of personal physical infrastructure, the recent monetary expenditure patterns can illuminate trends in new activities.

Second, the frequency, duration, sequence, and coincidence of activities can be quantitatively measured (in units of time). In particular, we can often infer how important energy-using goods are used from time studies. For transportation activities, mileage is a good unit of duration. We then combine information acquired through these different measurements to understand what activities consumers engage in, how often, for how long, and where. Energy use is a "consequence" of these activities.

Analysis

In this study, we focus on the US consumer—the individual and the household—as the unit of analysis. First, we characterize the US consumer's activity patterns using the measures described previously. Second, we match the level and pattern of energy used by this group to its activity patterns. We demonstrate that different patterns of activities result in different quantities and types of energy resources being used, and with different temporal patterns. Our goal is to show how changes in activities in the past have affected energy use, and how future changes in activities could affect energy use. Where possible, we will identify changes in the behavior of a given group of people as well as changes in the mix of groups in the society that may cause changes in the aggregate collection of activities. While we acknowledge the fundamental role of incomes and energy prices in shaping the demand for energy, we focus here on other forces that can change energy demand relatively independently of those forces.

MEASURING ACTIVITY

In this section, we examine the measures of those activities introduced in the previous section: personal consumption expenditures, ownership of and access to energy-using consumer goods, time use, and distance traveled.

Personal Consumption Expenditures

The total amount of goods and services households can purchase in a given year is constrained by the household's income and personal savings. How households allocate their incomes among goods, services, and savings reveals their economic preferences. By examining consumer expenditure data, we can ascertain how much money the average household spent for an assortment of goods and services in a given year. To some extent, the types of goods and services households purchase portray what members of the household do. This information can be used to infer energy consumption.

Between 1950 and 1986, disposable income per household increased from $15,660 to $22,505 (in 1983 dollars) (22–26). Because household size decreased, per capita income increased even more. During the same time period, the share of income spent on consumption goods and services was around 92% of disposable income, and the remaining 8% was allocated to savings. Figure 4 shows the expenditures per capita (excluding insurance, social security, and similar expenditures), and Figure 5 presents the shares, allocated to eight categories of goods and services in 1950 and 1986. As disposable incomes increased over time, the proportion of the budget spent on food and beverages or apparel fell, while the share for housing expenditures grew from 27 to 35%. The largest component of the increase for housing was

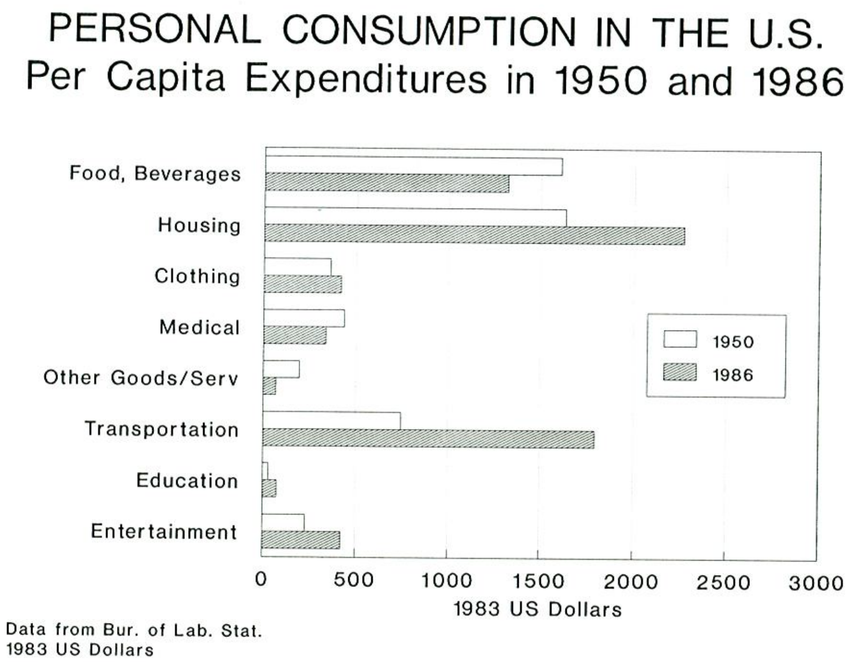


Figure 4 Personal consumption in the United States. Food includes tobacco and alcohol; housing includes housing ownership and operations and fuel; transportation includes transportation equipment, operation expenses (such as fuel), and transportation services; expenditures not included in the named categories are contained in "other."

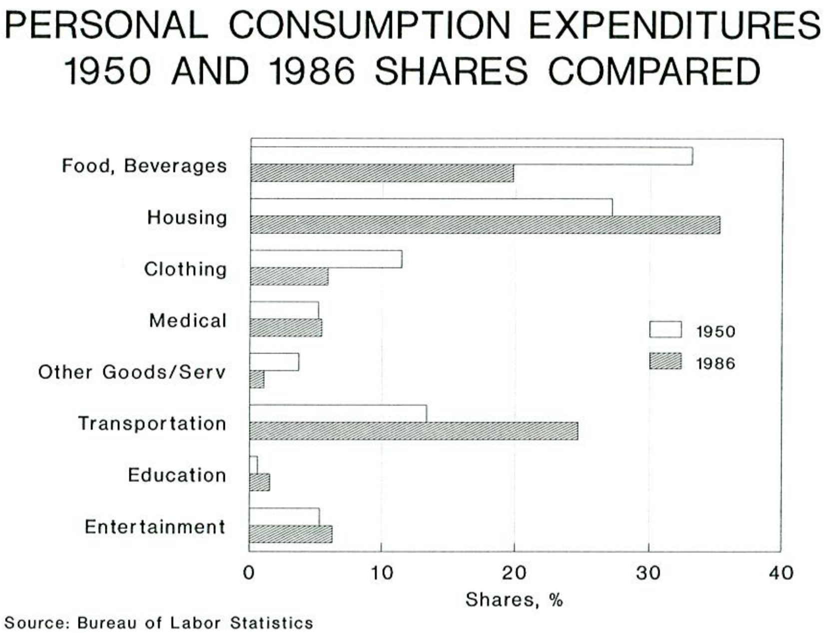


Figure 5 Personal consumption expenditures: 1950 and 1986 shares compared.

for shelter, e.g. rent and mortgage payments, but there were also increases in the share of expenditures for energy and utilities (from 4% in 1950 to 9% in 1983). Additionally, the proportion spent on all other goods and services increased. The most noticeable growth in expenditures was in transportation, for which expenditures grew from 13% of total expenditures in 1950 to 25% in 1986. The growth in this share can be attributed to the increased expenditures for auto purchases, maintenance, and gasoline, and for public transportation (including airfares). The share of expenditures for recreation grew from 5% in 1950 to 6% in 1986. The share spent on education grew from 1 to 2% during the same period. Figure 5 shows that the magnitude of growth in this period for entertainment, recreation, and transportation was nearly a factor of two.

Direct expenditures for energy are not insignificant. Taken together, consumption expenditures for all direct purchases of energy—household fuels or electricity and gasoline—increased gradually to 9.5% of household expenditures in the early 1970s. This share jumped after the price shocks of 1973 and 1979, reaching 11.5% of expenditures in 1983, but in time fell back as consumers economized, energy prices fell, and incomes grew.

Many expenditures are complementary. For example, if a household purchases a home, it will also purchase furniture, insurance, and other related goods. As recreation expenditures, including those for entertainment (mostly out-of-home activities) increased, so did the demand for transportation. This example shows how a change in expenditures for a nonenergy item (recreation) may imply expenditures for an important energy item, gasoline for transportation. Expenditures for air travel, whose share of total expenditures has slightly increased, have a substantial associated fuel cost component.

Substitution between categories has also taken place, often with important energy implications. In the 1950s, the increase in automobile ownership caused expenditures for public transportation (mostly expenditures for buses and trains) to decrease, and expenditures for private transportation to increase. Then, as the demand for air travel increased, the share of public transportation expenditures rose again. Each of these substitutions increased energy demand per dollar spent for transportation.

While the consumer expenditure data provide a profile of what goods and services households are purchasing during a given year, and how expenditures on these goods and services have changed over time, the data can provide only a limited picture of what people do. The expenditure data are not decomposed by the price and quantity components. This has important implications with respect to coupling expenditures to activity and to energy use. If there is a change in expenditures over time, we are unable to determine how much of this change was caused by a variation in price and how much by a variation in quantity. We cannot therefore determine how activities associated with these expenditures have changed. Nor can we determine changes in energy used, either as direct purchases, or as energy required for the associated activities.

In addition, we cannot determine changes in the quality of the goods and services the households have purchased. Changes in the quality of a purchased good or service may vary over time, especially if the disposable income per household has increased. For example, video recorders substitute for black-and-white television, while gourmet foods replace canned items. Finally, expenditure data do not show how households actually use the goods and services they have purchased. Thus, expenditures data alone cannot really map out the activities in which the households participate. In addition, the relationship between expenditures and travel is not explicit in the expenditure data. Therefore, to gain a better understanding of the activities in which households are participating, we need to examine what types of goods and services households own and how they use them.

Personal and Social Infrastructure: Ownership of and Access to Energy-Using Goods

Characteristics of the stock of energy-using consumer goods are important indicators of how consumers could use energy. Since these stocks reflect

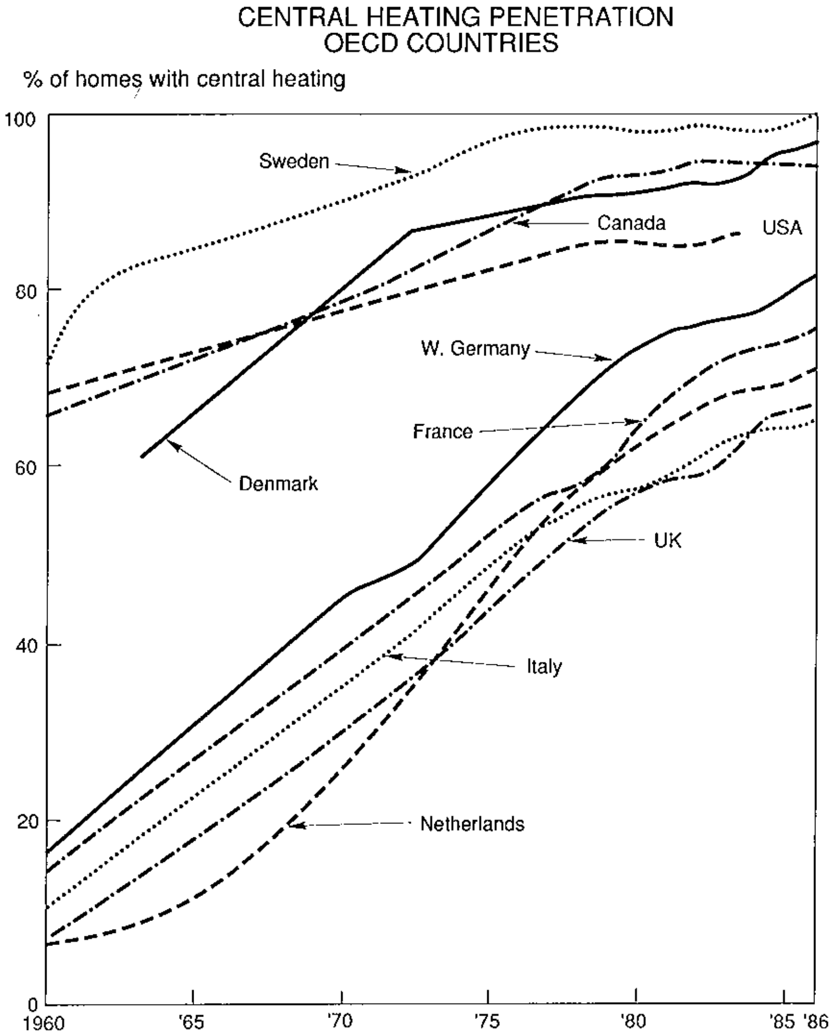


Figure 6 Central heating penetration in OECD countries. Source: 4; LBL Data Base.

expenditures made as investments over longer periods of time, in contrast to expenditures in a given year, the extent of such stocks is not reflected in current expenditure data. Home heating and driving represent the two most important personal uses of energy. Behind these uses lie ownership of central heating equipment (Figure 6) and cars (Figure 7). During the 1950s–1960s in the United States, and 1960s–1970s in Europe, ownership of central heating systems and cars increased rapidly. Since personal transport uses more energy

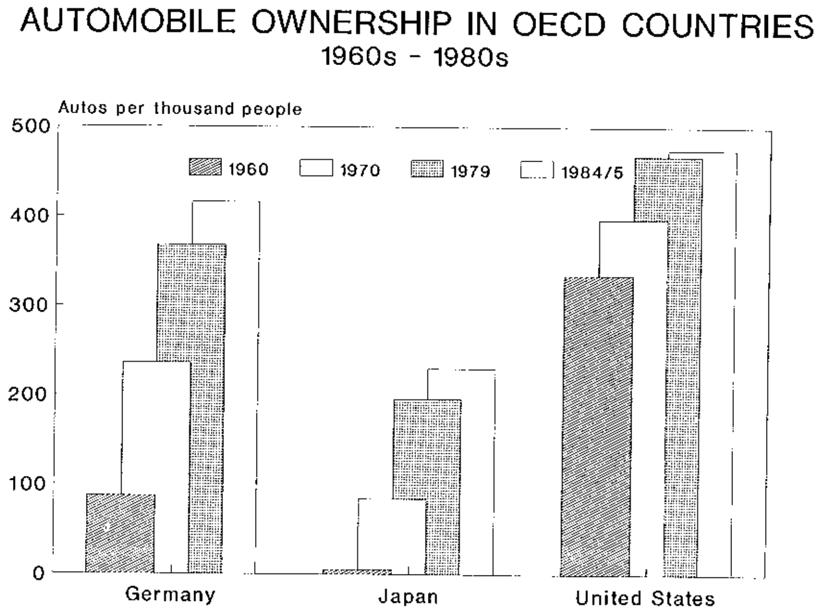


Figure 7 Automobile ownership in OECD countries. Source: Shell Int. Petroleum Company and LBL Data Base.

per passenger-kilometer than mass transit, and central heating systems tend to use twice the energy per square meter of floor space of room heaters, personal energy use rose rapidly. This increase in ownership level had a greater impact on energy use than changes in levels of use of systems (e.g. miles/vehicle/year and hours of heating in homes with central heat). Ownership of major household appliances followed the same pattern as that of cars and heating equipment. For example, in The Federal Republic of Germany, energy use for heating, appliances, and automobiles increased at more than twice the rate of personal income between 1960 and 1973 (27). The increases in equipment ownership, and thus energy use, were clearly income-related. In the United States, the increase in ownership of these goods was spread out over a much longer time, so that the increase in energy use for these purposes was considerably slower.

Ownership of automobiles requires further discussion. Among the industrialized countries, the level of ownership of the car ranges from 50–60% of households in Japán to more than 85% in the United States; the average for all industrialized countries is about 70%. In the United States, there is now on average more than one car for each licensed driver, up from 0.7 in 1969. These figures indicate a saturation in access to cars in the United States.

In Germany, this figure was 0.8 cars per driver in 1985. However, the potential for a significant increase in access remains, especially for particular groups of people. For example, in Germany, only 60% of women eligible to drive have driver's licenses.

By the late 1980s, equipment ownership growth slowed in the United States, Europe, and Japan as market saturation was approached. Growth in energy use for space heating stalled or even reversed in North America and Scandinavia. In the United States and some Northern European countries, increases in appliance efficiency offset the impact of greater ownership between 1978 and 1985. As a result, household electricity use for major appliances fell. In Italy, Japan, and Britain, however, the size of major appliances sold is still growing significantly, offsetting improvements in efficiency, so that electricity use per device has not decreased significantly. For automobiles, saturation and efficiency improvements led to a reduction in gasoline use in the United States. In most other countries, however, car ownership increased markedly, and mileage efficiency (miles per gallon or mpg) did not improve significantly, leading to overall increases in gasoline use. Thus, changes in the level of ownership of energy-using equipment still had a significant impact on energy use through the 1980s. As market saturation approaches, however, size, performance, and utilization, not acquisition, will be more important factors in determining energy use, unless new energy-intensive appliances appear. Consequently, how people spend their money, what type of home or car they select, and how they use their homes and cars will be very important influences on energy use in the years ahead. Unless energy prices are extremely high, many of these choices will be made with little regard for energy prices.

The kinds of new goods consumers are acquiring have changed. Less energy-intensive goods are gaining in popularity. For example, small, specialized cooking devices tend to use less energy than large ovens or ranges. Electronic goods (e.g. video recorders) are also popular acquisitions, and, unlike other household equipment, they consume trivial amounts of energy. Thus, the new consumer goods entering the home should not by themselves significantly increase home energy use. However, some of these new technologies have had significant indirect effects on what people do. During the 1950s, the spread of television substantially reduced movie-going, even though mobility was increasing. Cable and satellite television, video recorders, and home computers have made both leisure and work in the home more attractive and more productive. Efficient jet aircraft made long-distance vacations affordable in terms of money and time. Microwave ovens permit more rapid cooking, contributing to the decline in cooking energy use per household observed in most countries (4). The use of prepared and frozen foods reduced the amount of time spent cooking and shopping. And new clothing materials and detergents permitted consumers to wash clothes in cooler water (e.g. 40–60° C). People are changing their utilization of what they already own (or have access to) and their acquisition of new equipment is changing what they do. In the following section, we examine how people spend their time.

Time Use

Time budget surveys reveal how much time individuals spend at different activities during the course of the typical day or week (28). These surveys classify activities by purpose (e.g. work, family and personal care, family business, and free time) and sometimes by location (e.g. at home, in a bar, at work, and in transit). Changes in the time spent performing a given activity require trade-offs among other activities (i.e. if the time spent performing one activity increases, the time spent performing another must decrease).

Robinson (29) carried out a survey of time use in several thousand American households in 1985. We have aggregated 40 categories of time use in the United States (29) into four main categories and several subcategories, presented in Figure 8: work ("contracted time"), family business ("committed time"), personal care ("necessary time"), and leisure ("free time"). Table 5 presents the breakdown of time use by major categories and subcategories in 1975 and 1985 for both men and women.[2] The largest component of time use was personal care, requiring an average of 78 hours per week (46%), including 8 hours spent eating (both in and away from home). Work accounted for 23 hours per week, and family business (shopping, etc) accounted for 26 hours per week. Free (leisure) time totaled an average of 42 hours (25%) per week. The largest subcategory of free time was devoted to electronic media (e.g. television viewing), which accounted for 16 hours per week.

Changes in aggregate time use are caused by changes in the makeup of society (e.g. gender, family structure, age distribution, employment levels of men and women) or by changes in what any group within society does. Between 1975 and 1985, there were slight changes in the distribution of time spent across categories. The average working time increased, while the time spent on family care and free time activities decreased correspondingly. The overall change in time use observed between 1975 and 1985 is due to both an increase in the employment of women and a decrease in leisure time of both men and women. Figure 8 shows a substantial increase in the amount of time women spent working (from 15 hours per week in 1975 to 21 hours in 1985). If the time use only of employed women during the same period is considered, there is no increase in the amount of time women spent working per week. Therefore, the increase in the average number of hours women spent working

[2]These data exclude time spent on vacations away from home.

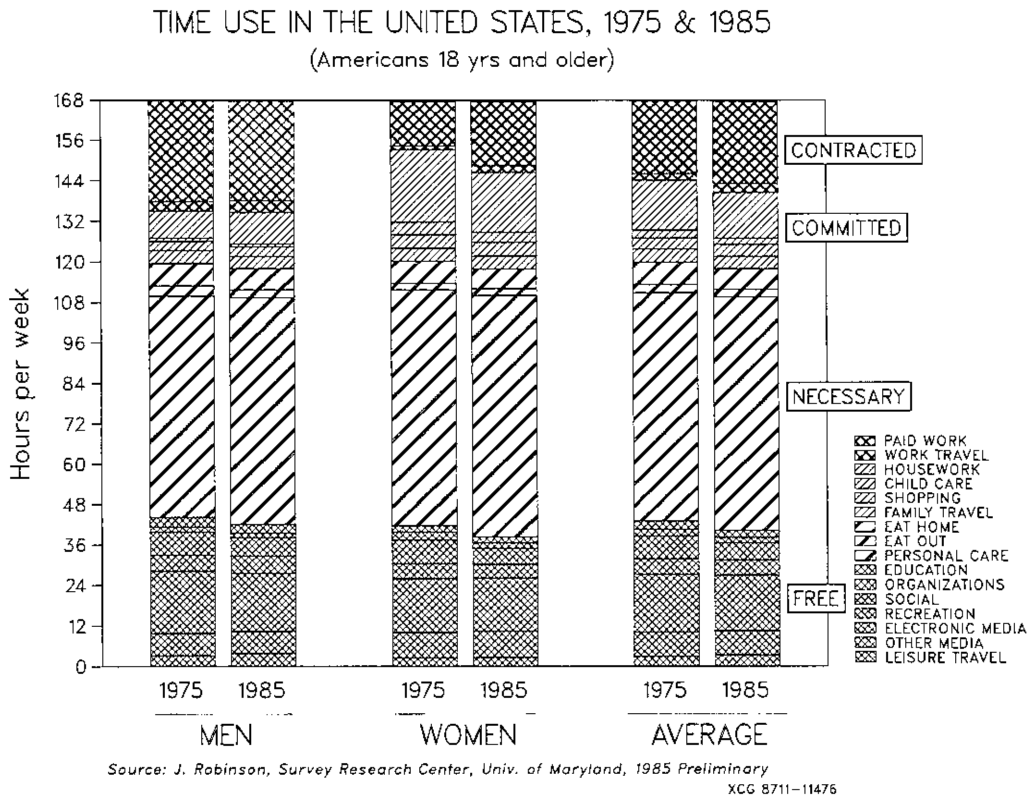


Figure 8 Time use in the United States, 1975 and 1985. Americans 18 years and older. "Contracted" includes work time and travel to/from work; "Committed" includes family business; "Necessary" includes personal care, sleep, and eating; "Free" includes leisure activities. Source: (29).

Table 5 Time use categories

Category	Subcategory	1975 Hours per week	%	1985 Hours per week	%
Work		24	14	27	16
	Work	22		24	
	Travel to work	2		3	
Family care		25	14	23	14
	Housework	15		14	
	Child care	2		2	
	Shopping	4		3	
	Family travel	4		4	
Personal care		77	46	78	46
	Eating at home	7		6	
	Eating away from home	2		2	
	Personal care	68		70	
Free time		43	26	40	24
	Education	2		2	
	Organization	2		2	
	Recreation	5		5	
	Social life	7		5	
	Electronic media	17		16	
	Other media	7		7	
	Leisure travel	3		3	

Source: (29)

can be attributed to an increase in the participation of women in the labor force. Nearly offsetting the increase in the time women spent working were corresponding decreases in the time women spent doing housework. The amount of time spent by employed men doing housework increased, but not enough to offset the decline in the time spent by women doing housework (29). Free time decreased for both men and women.

To show where people are spending their time, we transformed the traditional time use categories into ones that are fixed in space or location, making some assumptions about the locations of activities whose locations are not specified by the survey sources. All activities were classified as at home, away from home in the services sector, at work, travel, and other, representing outside recreational activities. The last group was then split equally between homes and services.

Figure 9 illustrates the resulting allocation of time use by location in 1975 and 1985. In these years, the time spent in the home declined slightly from 75% to 73%, as did time in services (from 6% to 5%), which yielded more time for work (from 12% to 14%), and for transit (from 5% to 6%). These increases can be attributed principally to the higher participation rate among women in the labor force.

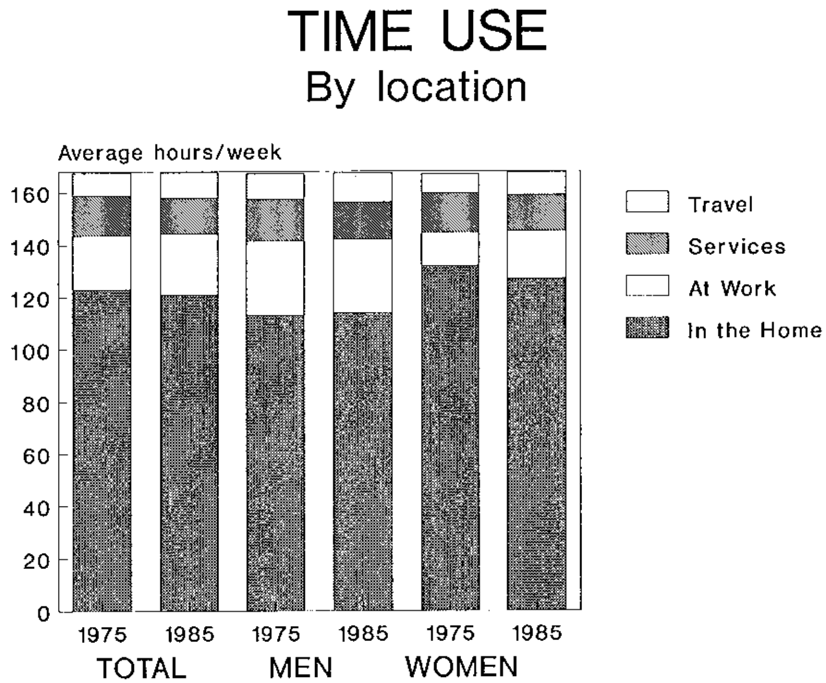


Figure 9 Time use by location. Source: This study. Recreation time was divided equally between the services sector and home. For some of the original activity categories, time that was assumed to be spent in the home: social, 75%; organizational, 25%; recreational, 15%; educational, 10%. The remaining time for each activity was assumed to be spent in the services sector. 5% of work time was assumed to be carried out in the home.

Gershuny & Jones (28; see also 30) report somewhat different trends in time use in Europe. While time spent for sleep is similar in most countries, time spent for eating varies significantly, from only 60 minutes per day in the United States to 100 minutes in France. Leisure time has increased in most European countries since the early 1970s and 1980s, in contrast to the United States. Time spent for leisure travel also increased. Gershuny & Jones also report that for some activities and countries, time spent may change in the opposite sense as participation. In the United States, for example, more meals are eaten away from home, but less time is spent, as fast food becomes more popular. Thus, time surveys do capture differences in the way people live in different countries, and how those modes of living change over time. In this sense, time budgets are useful indicators of differences in life-styles.

We have shown that people are spending their time differently today than even 10 years ago. Gershuny's work suggests that over longer periods of time, time for work, family business, and leisure has changed significantly, while time for personal care has remained roughly constant. Our analysis shows that people are spending more time away from home. To see whether this trend is reflected in mobility, we next review measures of distance traveled.

Distance Traveled

Distance traveled is the spatial analogue of time spent as a measure of the duration and frequency of transportation. There are significant differences in per capita travel (measured in passenger-kilometers) among countries, with the United States almost 40% higher than in Europe. In the United States in the 1960s, the level of travel was already considerably higher than in much of Europe today, yet travel still increased in the United States. The high level of US travel, and continued growth, makes it difficult to believe that travel is saturated anywhere.

Per capita travel in all countries over the past 30 years has increased (Figure 10). The main components of this change are increased ownership of automobiles and modal shifts, from bus and rail travel to car and air travel. In

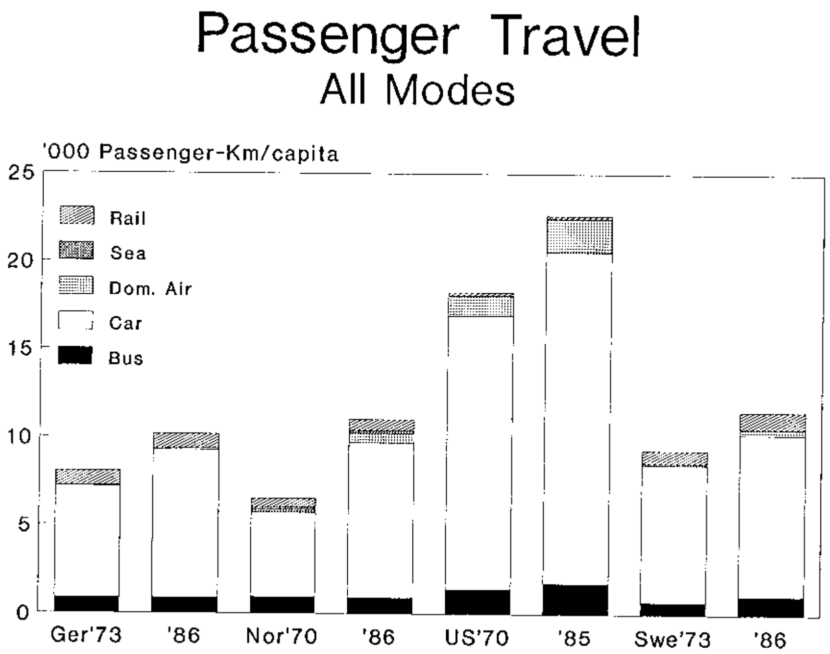


Figure 10 Passenger travel, all modes. Source: Individual Country Transportation Surveys, and LBL Data Base.

North America the automobile accounts for 90% of personal miles traveled, and in Europe, more than 80%. Today, distances traveled by bus and rail are steady, but air traffic continues to increase. Use of cars ranges from 10–12 thousand kilometers/car/year in Europe to 18 thousand kilometers/car/year in North America. Although distance driven per car tends to fall with increased car ownership, the total number of vehicle- or passenger-kilometers per capita has increased in almost every industrialized country as car ownership has spread. Moreover, the shift from buses and rail to cars and air, respectively, speeds up travel, so people travel further in a given amount of time. More recently, shifts have favored air transport, which now contributes significantly to the increase in distance traveled. In the past, the modal shifts were tied to increases in incomes that permitted car ownership and purchase of airplane tickets. Now most of the US population has access to cars and can afford air travel, and an increasing share of Europeans and Japanese are reaching the same level of access. Thus, both the choice of mode and the distance traveled have become more unconstrained.

The proportions of trips for different purposes have changed over time. Figure 11 illustrates the changing purpose of automobile travel in the United

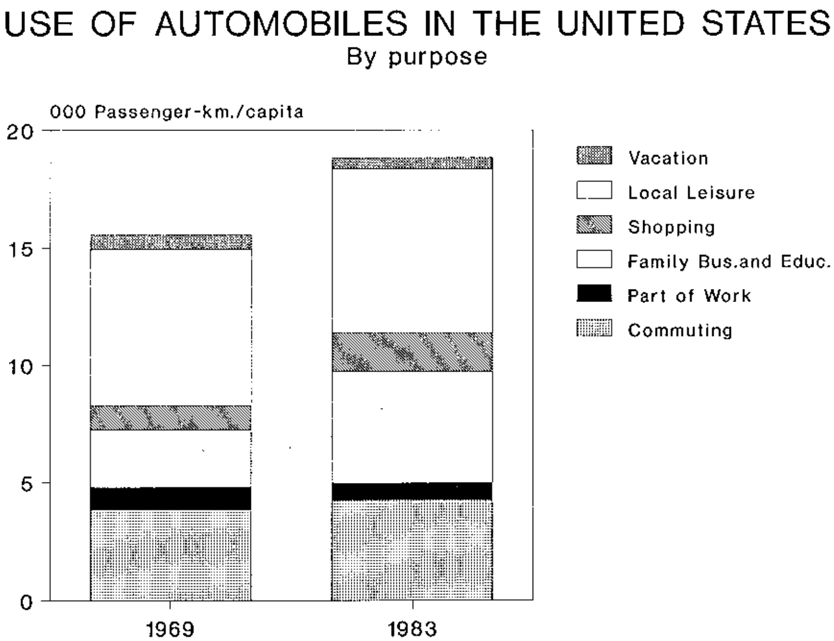


Figure 11 Use of automobiles in the United States. Passenger-km per capita by purpose. Calculated from the NPTS 1969 and 1983.

States over 14 years. In the 1960s, trips to work gained in share; in the early 1970s, shopping gained in importance; and in the late 1970s, leisure and vacation grew once more. However, the increase in women's working pushed up miles driven for commuting again in the 1980s. These changes in what consumers do and where they do it have had an important influence on the total distance traveled.

Although local travel dominates total travel (in terms of distance traveled), long-distance business and vacation travel is increasing, as more income is available and the real cost of air travel has fallen. Use of the automobile accounts for only a small share of long-distance vacation travel in the United States, but in Europe the automobile has been more important; that is, a larger share of total automobile miles are for vacation travel. However, by the 1980s, air travel was competing with automobiles as the most important mode for vacations. In Germany, for example, both car and air gained in share of vacation passengers and passenger-kilometers at the expense of rail, between 1960 and 1986, but air gained from cars after 1976 (31). Partial or total decontrol of air markets, and the entry of charter and package operators into the air market in Europe and Japan have led to significant and continued growth in air travel for vacation.

MATCHING ENERGY USE WITH SECTORS

Synthesis: The Changing Patterns of Energy Use

Figure 2 showed various components of energy use by sector. Clearly, the sectors are not totally independent of each other. A most elusive, but all-important, driver of changes in energy use is the intersectoral shift of activities among sectors. For example, up to the present, increased use of services has resulted in increased mobility; people have to get to and from personal services. Similarly, as mobility increased, food eaten outside the home and participation in sports and recreation increased. In Europe, the share of single-family houses in the housing stock is slowly increasing. Since these houses tend to be located away from city centers, this trend promotes automobile transportation instead of mass transit. Conversely, apartment buildings tend to be located in built-up areas where parking is scarce or even prohibitive, thus discouraging automobile travel. This interaction between the kinds and locations of homes and the demand for transportation is important in determining individual energy use in transportation.

How have the changes in consumers' activities affected energy use? Figure 2 showed the share of personal energy use in the United States in a single year. In most countries, this share has grown over time. For example, Figure 12 shows that in Germany the personal component grew from 33% of total energy use in 1950 to more than 50% by 1986. Our preliminary investigation of energy use in the United States and Norway reveal the same trend.[3] These figures suggest that, in general, the per capita amount and the share of personal energy use (of total energy use) increase with income. That is, comfort and mobility have become more important in causing changes in energy demand, while the share of energy used in production—primary and secondary industries, business services to these industries, public administration, and freight—has decreased. More recently, growth in personal energy use has slowed because of the saturation of markets for energy-using goods, and price-motivated increases in efficiency and behavioral changes. The evidence from Germany (Figure 12) indicates that personal energy use can increase only if activities become more energy-intensive, or if people choose more energy-intensive activities, particularly driving. These trends also show that variability in personal energy use is an increasingly important source of uncertainty in future overall energy use. In the next section, a simple model of time use suggests how energy demand might grow with changing activities.

Money, Time, and Energy

Figure 13 compares time use and energy use for several activities in the United States in the mid-1980s. Data were aggregated from 15 sectors of energy use (32, 11–13, 33), and nearly 40 sectors of time use (34; see also 35, 36).[4] Personal energy use includes energy used in homes, for personal transportation, and for personal services. After subtracting the 14% of time people spent at work in 1985, we found the following:

1. Travel (excluding travel for holidays) requires less than 6% of time, and 49% of personal energy use;
2. Activities at home constitute 72% of time, and 41% of personal energy use.
3. Personal services (leisure and family business) take 8% of the time and 10% of the energy.

With these comparisons, we can deduce the energy-intensity of activities in each location. We do this by matching time and energy use.[5] Figure 14

[3]These shares are slightly different for the United States (cf Figure 2), because US data include refinery energy use.

[4]Time spent at work, not elsewhere considered in this study, is shown for completeness in the figure, but excluded from the calculations cited below. Since time surveys omit families away on vacation, we have omitted air travel and 25% of bus and rail travel as well, and counted only 20% of the energy consumed in hotels.

[5]We have divided total US personal energy use for each purpose by the total time an individual over 16 devotes to each activity in one week. Dividing by total population affects the scale but not the relative intensities. Recall that the calculations exclude energy and time use related to being at work, and energy and time use related to vacations.

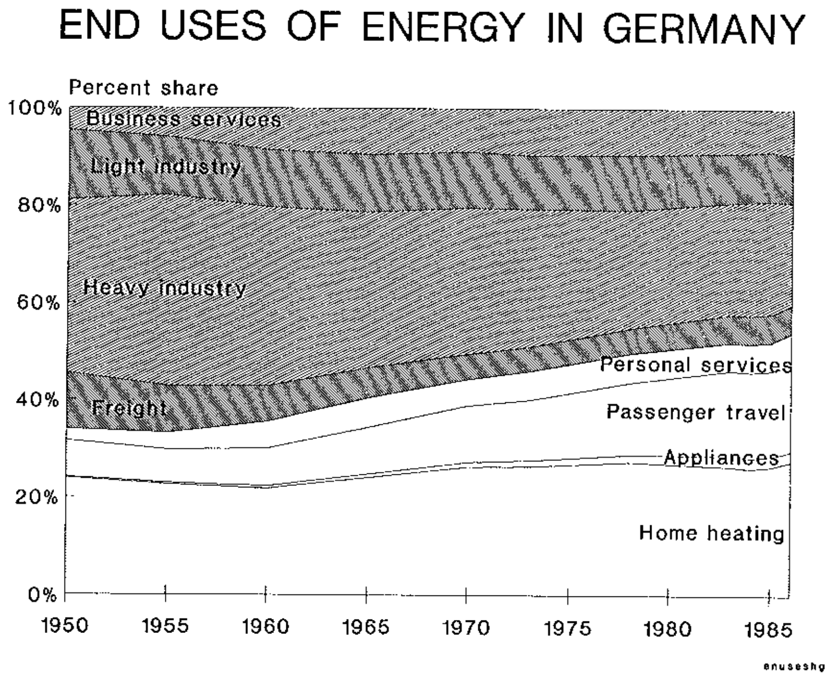


Figure 12 End uses of energy in Germany. Source: (27).

indicates that total energy use per person and per unit of time in the United States is less in homes than in service buildings. This is surprising, because space and comfort conditions are roughly comparable. The difference reflects differences in occupancy and uncertainties in measuring time use outside the home. The difference in intensity means that, other things being equal, spending more time in service-sector buildings and less time at home raises total personal energy demand. Additionally, the service sector is more dependent on electricity than the residential sector. Thus, a shift in occupancy from the residential sector to the service sector would raise electricity use slightly.

Figure 14 also shows that a minute spent traveling uses 8 and 12 times as much energy, respectively, as a minute spent in service buildings or at home. Trade-offs between time spent in transport and time spent at home are more significant than those between the home and personal services or other buildings, where energy use per unit of time for comfort is roughly the same. Therefore, we believe that the most important consequences for energy demand of changes in the mix of personal activities will arise in the transportation sector, in connecting home, work, and leisure or family business. Thus,

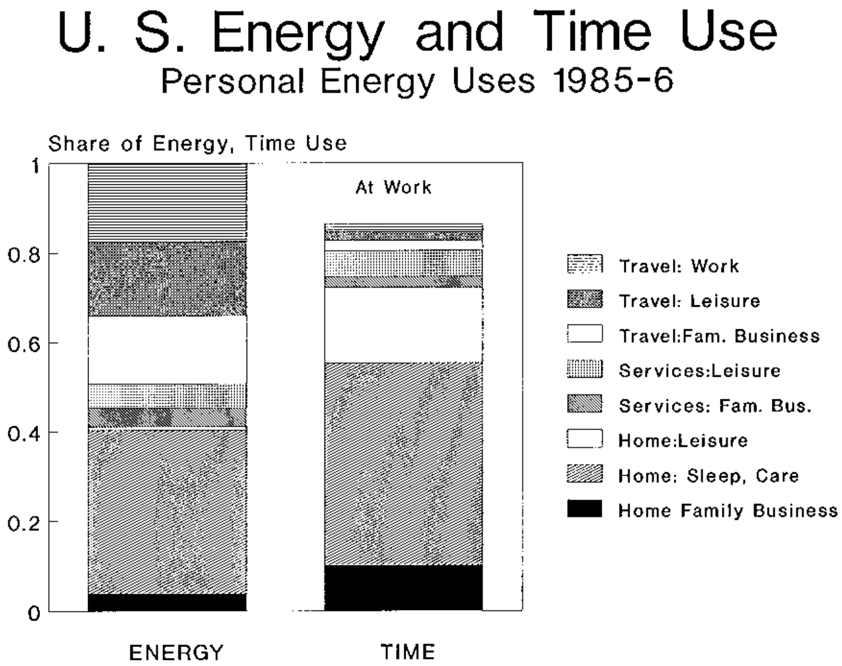


Figure 13 US energy and time use. Individual energy uses in 1985–1986. Source: See text. Assumptions for energy calculations: Homes, as estimated from (6): Leisure includes 10% of home electricity use for appliances; home family business includes 25% of hot water use and electricity for washing and drying. The remaining home energy use is counted as Sleep and Care. Services sector energy use, as estimated from (12, 13): Family Business, use 80% of the energy used in shops, 5% of that for offices, and 50% of that for food stores; Leisure, 90% of energy consumed in restaurants, 20% of that consumed in places of lodging, all energy consumed in places of assembly, 20% of that for educational establishments, and 20% of "other." Transportation: Energy use per passenger-km as estimated from ORNL 1988 for each mode and purpose, is multiplied by passenger-km for each mode and purpose to give total energy use by mode and purpose, which is them summed over modes.

understanding whether society will be more or less mobile in the future is crucial to understanding future energy demand.

At present, Americans and Europeans spend about 1 minute traveling for every 4–5 minutes of out-of-the-home leisure and shopping. Americans spend slightly more time and travel faster, thereby going considerably farther. In no country is there evidence that travel time and distance has saturated. Instead, people have been spending more time away from home. Unless people begin to spend less time or move shorter distances traveling to services, work, and leisure, or participate in these activities less frequently, energy demand for transportation will increase. In the next section, we consider possible changes in these patterns of peoples' behavior.

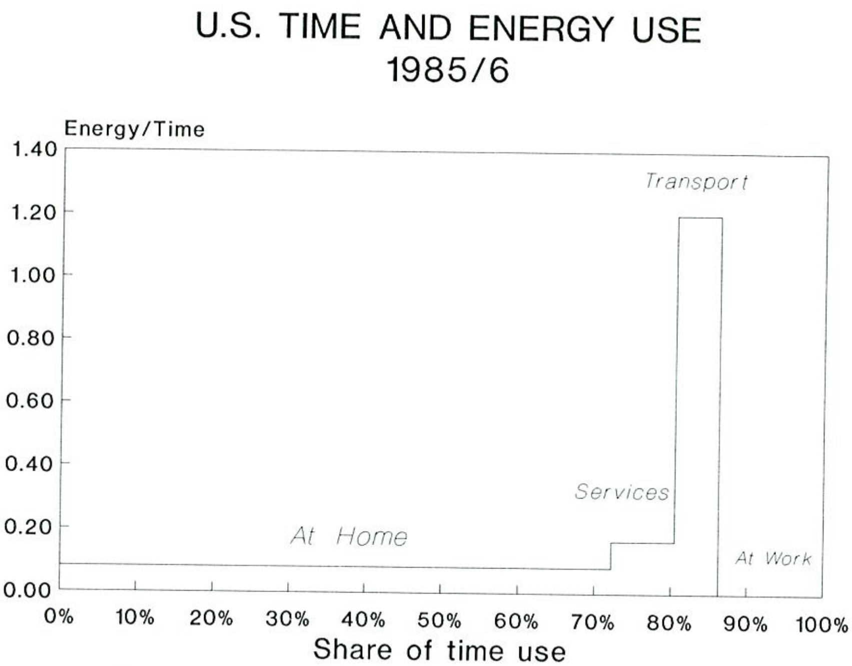


Figure 14 US time and energy use 1985–1986. Personal energy uses in homes, in the service sector, and for travel are divided by the times spent in these activities, to illustrate relative energy-intensities.

CHANGING ENERGY USE PATTERNS: PAST, PRESENT, AND FUTURE

In order to understand how energy use in the residential, services, and transportation sectors will be changing in the near and long-term future, we return to our conceptual framework and review important boundary conditions that permit, encourage, or constrain individual action. First, we review past energy demand forecasts to see if and/or how they incorporated the concepts that we have been discussing. Second, we focus on demographic, social, and legal factors. After discussing these factors, and how they influenced energy use in the past (or in the present), we return to the sector breakdown to see what changes are likely to occur in each sector and also to explore more speculative changes.

Life-style in Energy Demand Forecasts

To see how life-style variables have entered into energy forecasts, we reviewed five studies of future energy demand: three studies produced in the mid-1970s for the United States (37–39), one recently prepared for Japan (41), and a world scenario (40). The general goal of each of these studies was to identify "reasonable" future levels of energy use by manipulating those factors that had historically driven energy demand [e.g. growth in the Gross National Product (GNP)] or that appeared to be potentially important in the future (e.g. increasing end-use efficiency).

In most of these studies, life-style is defined as a pattern of behavior. The studies by the Stanford Research Institute (SRI) and the Japanese Ministry of International Trade and Industry (MITI) are purely qualitative in their treatment of life-style concepts. The remaining three studies describe both qualitatively and quantitatively many of the life-style characteristics we have discussed here.

MOTIVATIONS All the studies discussed current needs, wants, and values, and possible future changes in these factors. The Edison Electric Institute's (EEI) study examined social values and changes that occurred during the United States' transition from an industrial to a "postindustrial" society. Although values guided EEI's selection of scenarios, they were not incorporated in their input-output models, nor were they directly related to changes in individuals' daily behavior patterns. Similarly, while Goldemberg et al attempted to create an energy use scenario in which "the human condition on this globe" was improved, the values underlying this objective were not explicitly integrated in the scenario or related to individuals or organizations. In contrast, the MITI study considered changes in people's attitudes and qualitatively described how these increasingly dominant values will change individual behavior. SRI's study also examined how individual behavioral changes result from changes in values (in particular, the values of the post-industrial society). Finally, the National Academy of Sciences study (CONAES) explicitly related social value changes to changes in individual behavior patterns.

FACTORS THAT PERMIT, ENCOURAGE, OR CONSTRAIN ACTIVITY Although all of the studies categorize the population by demographic characteristics, only the CONAES and MITI studies relate changes in the distribution of the categories (such as an increasing share of elderly people) to changes in aggregate behavior patterns (more leisure activities). Economic factors, such as disposable incomes, that permit, encourage, or constrain activity, were incorporated in all the scenarios, but the emphasis on these factors varied from study to study. All the studies anticipated increased energy prices in the future, leading to improved equipment and building efficiency. In the EEI model, changing economic factors (e.g. prices, personal income, and GNP) almost exclusively induced changes in efficiency. In contrast, in the CON-

AES study, changes in economic factors accompanied changing values to induce behavioral changes. Only the MITI and CONAES studies detail the physical infrastructure of the society—household equipment and vehicles, for example—that permits, encourages, or constrains activity, and use this ownership information as an indicator of what people do, and hence how much energy they use (EEI, Goldemberg et al and SRI did consider dwelling types, but related this information to energy-efficiency considerations). Each study contemplated changes in social and legal infrastructure, such as government policies and programs aimed at reducing resource use (energy taxes and rationing). However, other changes such as the increasing social acceptance of women's employment were not related to shifts in daily family activities and behavior patterns.

ACTIVITIES The activities most commonly treated by the studies were "free-time" activities and travel. Four of the five studies discussed the amount of free time available to individuals and commented on the activities that individuals engage in during their free time (MITI, Goldemberg et al, EEI, and CONAES). As a result of changing economic factors, the emergence of time-saving technologies, and value changes, the amount of free time available in the future was expected to increase (however, one of EEI's scenarios anticipated a decrease in free time). In the EEI and CONAES studies, this extra free time was spent in activities related to the arts, sports, nature, and education. In the MITI study, the additional free time was spent in the services/commercial sector (e.g. shopping, entertainment, dining out, sporting events, and vacationing in hotels and resorts). (Goldemberg et al did not contemplate the use of this extra free time.)

How people spend their free time, and where they spend it, can be related to the use of energy-using equipment. However, only CONAES and MITI directly related the change in the amount of free time and those associated activities to energy use, CONAES quantitatively and MITI qualitatively. As we will discuss in the following sections, the amount of free time available in the future is an important source of uncertainty in understanding future energy demand.

All of the studies discussed transportation, especially automobile travel (air travel is mentioned in a few studies). The SRI study qualitatively described how transportation energy use could decline in the future due to (*a*) the restructuring of society into smaller communities that would reduce need for transportation and (*b*) shifting modes of transportation from private to public transport and walking. In contrast, the MITI study expected the amount of personal transportation to increase in the future due to increased leisure time; commercial transport was also expected to increase as the demand for goods increased.

In one of the CONAES scenarios, a significant change in personal travel patterns led to a reduction in kilometers per vehicle per year. This reduction was the result of changing patterns of vehicle use caused by both high energy prices and changing values and preferences; for example, carpooling would result in an increased vehicle load factor for commuting and an increase in the length of each commute trip to account for pick-up and drop-off of passengers. On the other hand, Goldemberg et al assumed that personal travel patterns in the industrialized countries would remain constant.

What is important about CONAES and Goldemberg et al is not whether the parameters used in their scenarios were right or wrong, but that specifying these parameters of activity allows readers to judge the appropriateness of the bottom line, energy demand. All of the studies we reviewed agreed that demographic and sociopolitical factors will play an important role in shaping future activities that affect energy demand. We review some of these important factors next.

Important Boundary Conditions and Constraints on Future Activity and Energy Use

While few energy studies explicitly describe the human activities that give rise to energy use, most studies, including those reviewed above, acknowledge the role of these activities. Most energy studies also acknowledge the importance of both demographic and sociopolitical factors that encourage and constrain activity.

DEMOGRAPHICS Demographic characteristics have an important impact on the use of homes, commercial buildings, and transportation services. We consider demographic characteristics that apply to the household, because, for most analyses, the household is the basic unit of consumption. This is because most energy-using goods in homes (or on the road) are shared by household members. Changes in household size, age distribution, employment, and urbanization affect the use of these goods, and thereby energy, in important ways.

To illustrate these relationships, Figures 15 and 16 show energy use for seven different family types. The households were from a US national energy survey (32). We analyzed only those homes that used natural gas as the main space heating fuel.[6] Consequently, electricity was used principally for appliances, lights, air-conditioning, and cooking (ownership of major appli-

[6]By focusing on gas heat, we avoided the problem of comparing different energy sources (e.g. electricity and gas) being used for the same purpose. In our sample, total gas use reflected heating and water heating, with a relatively small amount for cooking. Electricity was used for cooking in approximately 50% of these homes and for water heating in 10–15% of homes, but these differences among households had only a small impact on the average energy use shown here.

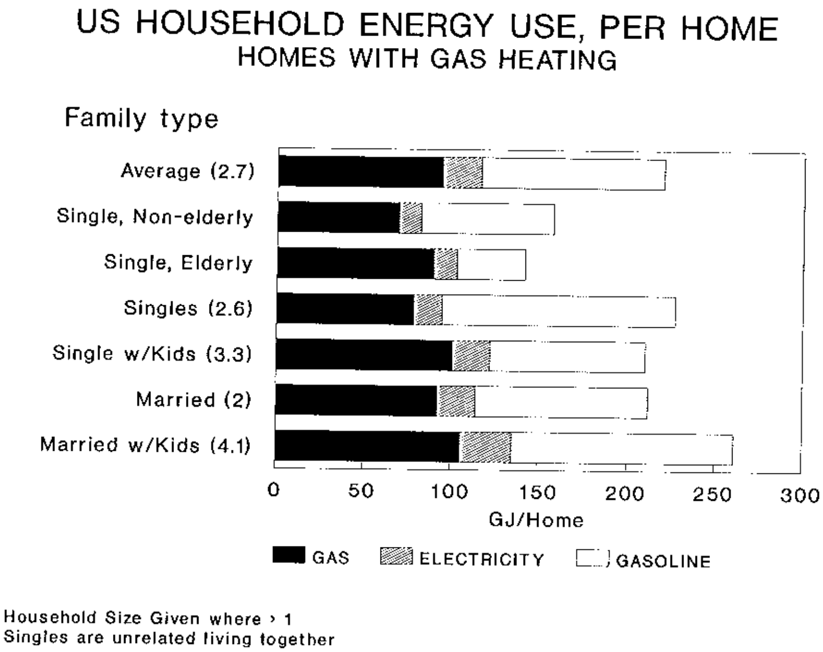


Figure 15 US household energy use per home: homes with gas heating. Data are from RECS (32). The family size is shown where greater than one. Gasoline consumption was estimated by multiplying the number of miles driven by 18 mpg; other energy figures were taken directly from the RECS survey.

ances did not differ significantly from one group to the next). Gasoline use was estimated by multiplying the total miles driven per household (as reported in RECS) by 18 miles per gallon (mpg), the estimated US fleet average mpg for 1984–1985. With these approximations, differences in household energy use should illustrate differences among household characteristics.

We found household size to be an important determinant of household energy use: larger households use more energy for heating, appliances, and transportation than smaller households. However, on a per capita basis, the relationship is reversed: smaller households use more energy per capita than larger households. This finding becomes more important when one takes into account the worldwide trend toward smaller households. In most countries, household size has been falling: couples are having fewer children, these children tend to leave the family home earlier in life than they did in the past (increasing the number of single-person households), and people are living longer. As an example, household sizes fell from 2.9 to 2.4 in Sweden, 3.6 to 2.6 in the Netherlands, 3.4 to 2.8 in the United States, and 4.5 to 3.2 in Japan between 1960 and 1985.

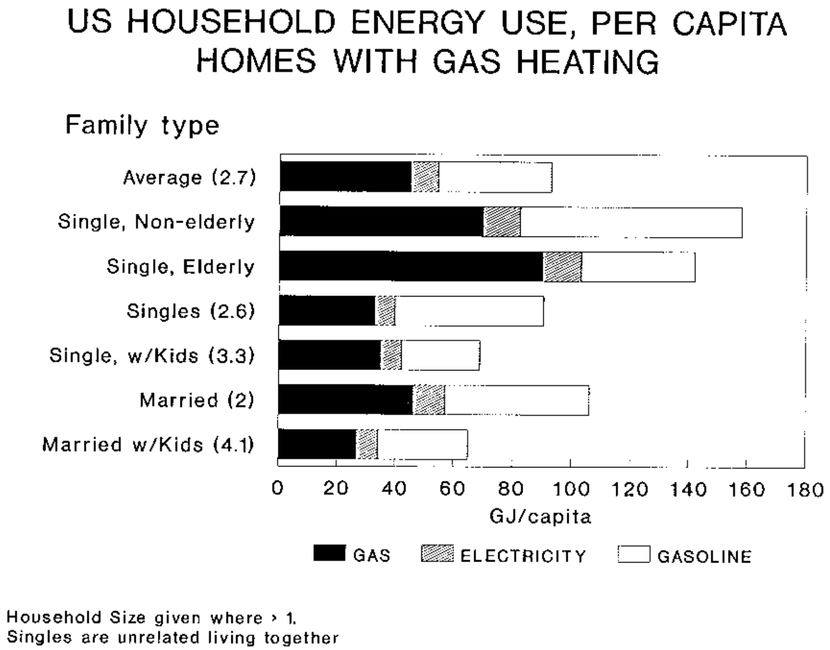


Figure 16 US household energy use per capita: homes with gas heating. As in Figure 15, but on a per capita basis.

The ages of household members are also an important determinant of energy use. In Figures 15 and 16, we compared the energy use of "elderly singles" (60 years or older) with "other singles." Because only 10% of the elderly singles were employed, in contrast to 75% of the other singles, we presume that the elderly were home more than other singles. Not surprisingly, single elderly people in the United States tend to use more energy than other singles for both heating and appliances [although the low-income elderly use less (42)]. Figures 15 and 16 also show that the elderly own fewer cars and drive considerably less than other groups, a fact reflected in the estimate of gasoline use.

Using Figures 15 and 16, we depict how household and transportation energy use changes as the family moves through the cycle. Income tends to increase as family members move through their career paths. Also, as the family grows, it tends to move into larger homes (and, in the past, into homes with central heating, which is now virtually saturated). These changes increase space heating energy use. Once families move into homes with central heating, though, energy use in the home only rises slightly with income. Residential energy use typically increases with the birth of children, then rises slightly, peaking when the children are in their teens (2). Some of the

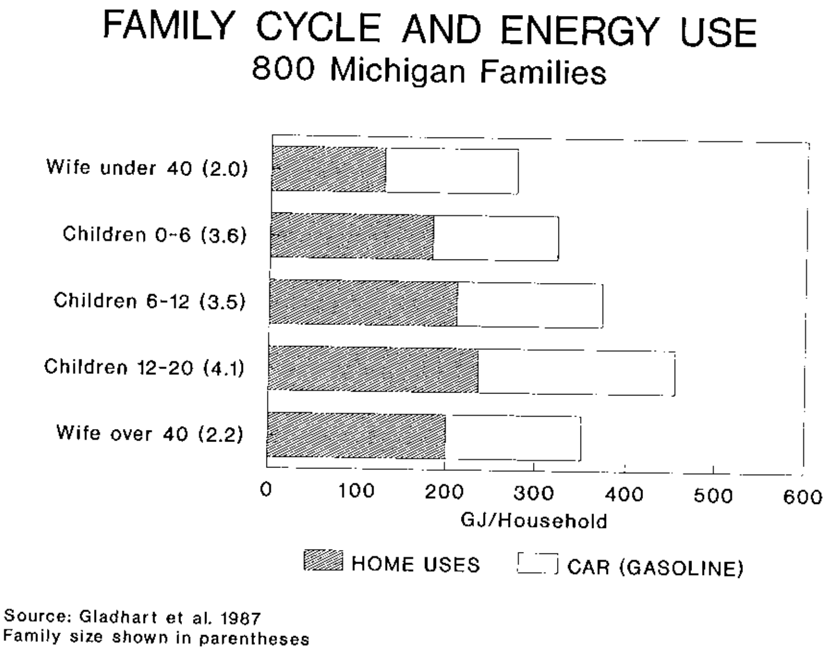
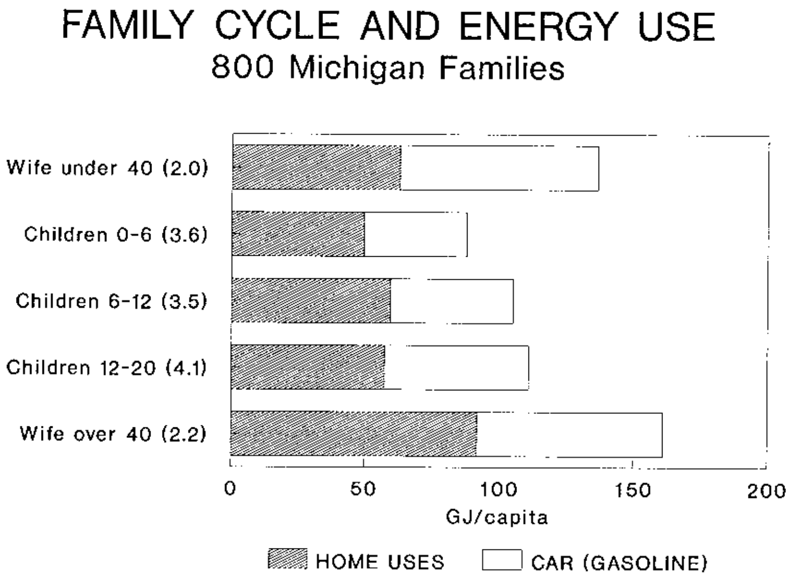


Figure 17 Family cycle and energy use. 800 Michigan families. The data show energy use per household for all home uses and driving. "Wife under 40" and "Wife over 40" are childless couples. Data from (2).

variation in home energy use depends on activities that take place in the home during certain phases of the family cycle. For example, Gaunt (1) found that teenagers showered more than other children. Automobile use also rises as children become more active. In sum, families with children heat their homes and drive their cars more than those without children, other things being equal. As the children leave the nest, household energy use falls again slightly, but not to its original pre-children level, since the family is wealthier and owns more energy-intensive goods. As one and then both parents retire, home energy use per household increases as the house is occupied more, but transportation energy use falls. Figure 17, taken from a study of families in Michigan (2), portrays this evolution of household energy demand through the family cycle. The increase as children grow older is significant, although the marginal change in energy use is small. Note again that in per capita terms (Figure 18), energy use is higher at the beginning and end of the family cycle because the household is smaller.

Figures 15–18 imply great differences in per capita energy use arising from differences in household composition. Thus, a change in the mix of house-



Source: Gladhart et al. 1987
Family size shown in parentheses

Figure 18 Family cycle and energy use. 800 Michigan families. Same as Figure 17, but on a per capita basis.

holds will affect energy use significantly. In the United States the typical family with children (married parents, 2.1 children, in Figure 15 or 16), with the lowest per capita energy use, makes up an increasingly smaller share of the total number of households. Single-person households, households consisting of unrelated persons, single-parent households, and elderly households are increasing. This shift tends to raise per capita household energy use, and transportation energy use as well.

There are more subtle changes in energy use that can occur as the demographic structure of society evolves. Fewer children means more time available for leisure and work for women. Female labor force participation is increasing in the United States. For families in which both parents work, automobiles become increasingly important to allow parents to visit schools, run errands, and commute to workplaces. Not surprisingly, two-worker households have significantly different driving patterns than one-worker households. In every country, single-person households, two-worker households, and single-parent households are increasing in number, while the number of married couples with children is decreasing.

Finally, the number of elderly (over 60 in this study unless otherwise stated) as a share of the total population is also growing in industrialized countries. In 1985, they spent one hour more per week traveling for leisure than the national average. In addition, people over 65 spent five hours more than the national average per week using electronic media in the home. Extrapolation of present patterns would indicate a reduction in energy use for driving as the population ages, but an increase in home energy use as more one- and two-person "elderly" households are formed. But these "elderly" are changing, as people are living to more advanced ages: A new generation of active retirees is forming, whose energy-related behavior is not well known. Tomorrow's energetic retirees (in their 70s and 80s) could carry with them their mobility patterns of younger years, while they continue to live in homes originally built to house families with two or three children. While these retirees will eventually swell the ranks of the less-energetic geriatrics (high 80s and 90s), their energy use could remain high on a per capita basis because they could keep the same energy-using capital (homes and cars) and habits (heating and driving) they had previously. It is difficult to predict net change in energy use patterns caused by the aging of society. However, even if average household size remains constant, these shifts in age and employment compositions of households could affect energy demand for homes and driving.

Some of the demographic changes we have reviewed are intertwined with incomes and elements of public policy. Public child care facilities and liberal maternity leave policies mean that more women can work. The aging of society will depend on our ability to pay for improved standards of medical care. The increased numbers of people living alone depends on their being able to afford to live alone. And the ability of the elderly to continue to live in their family homes depends on how well their savings and pensions, including social security, support them in retirement. But these contingencies depend on social policies as well, some of which we review next.

SOCIAL AND LEGAL INFRASTRUCTURE Culture and government policies affect energy use by influencing how and where people live, how they move about, and what they do. The role of women in society, for example, illustrates the relationship between social mores and energy use. More women are currently participating in activities previously dominated by men. More women are employed, more are going into higher education, and more are delaying and even forgoing marriage and childbearing. As a result, there are more single people and more childless couples, resulting in more households and smaller household sizes (see previous section). Another impact of the changing role of women is in transportation. In Germany (Figure 19), for example, the proportion of younger women with driving licenses today is close to that of men, even though it remains significantly lower for the older

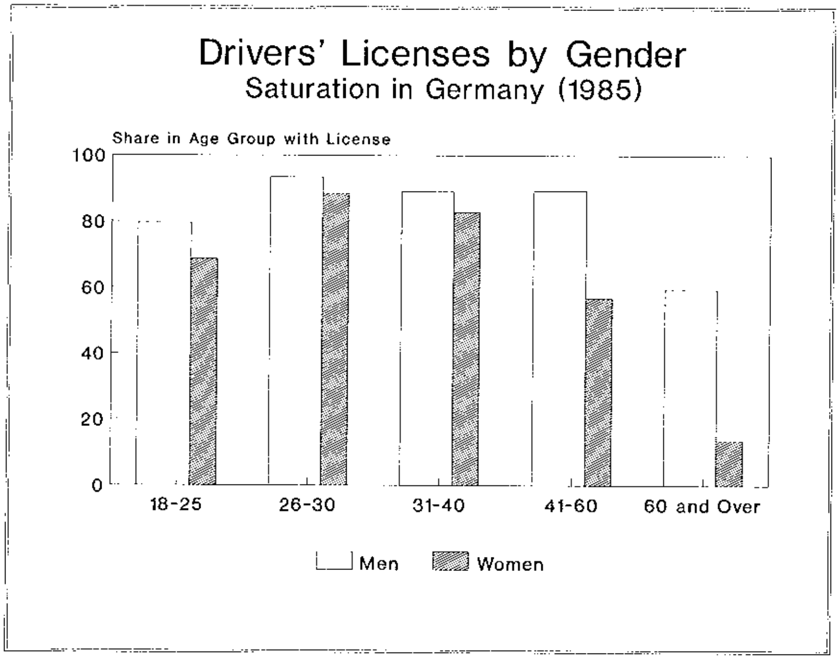


Figure 19 Males and females with drivers' licenses in Germany in 1985. Source: (31).

generation, reflecting past customs. Over time, the fraction of women with driver's licenses will approach that of men, which is already the case in the United States. Increases in women driving, particularly for work-related purposes, was an important source of increased driving per capita in the United States between 1969 and 1983 (43–49). Yet women still only drive half as much as men (50). Closing the gap in participation and distance driven could increase gasoline use significantly in every country.

Where people go is also a function of social tradition that may limit the times when facilities are open. Longer opening hours for shops, places of work, and entertainment (following relaxation of government restrictions) have led to more off-peak use of transport and greater use of buildings (and, therefore, heating, lighting, and air-conditioning, during these extra hours). When these services were only open during restricted hours (still the case for shops in much of Europe), there was more demand for transportation services during peak hours, but little demand off-peak.

Extending opening hours also entails extending working hours, leading to longer work days and/or more part-time jobs. Changes in working hours influence energy use in transportation and buildings. Shorter (or more flexible) working hours per person allow more time for combined trips (i.e.

stopping off on the way to/from work). Increased part-time work means more commuters. Extended business hours increase the total amount of energy use in buildings (energy use per employee or customer may increase or decrease, depending on occupancy). One social change that may reduce occupancy in service-sector buildings is increased use of the home for conducting paid work ("telecommuting") and accessing services (e.g. shopping via mail catalogs or electronically via cable television). This change alters both commuting and home energy use patterns, while reducing occupancy in places of employment and services. Such changes in the work and services environment could have a fundamental impact on energy use.

Not all "work" appears in national accounting systems (e.g. personal tax filings by the US Internal Revenue Service, or consumption and expenditure surveys conducted by the US Bureau of Labor Statistics). "Informal work" [i.e. unpaid work for one's self (do-it-yourself) or for others (e.g. babysitting and bartering)] is increasing (51–53). These changes in work patterns can cause significant changes in the utilization of buildings, if people stay home more to work (53). The rise in informal production can affect travel: where services or do-it-yourself are important, people tend to remain in their own neighborhoods where they know their neighbors and can obtain trusted services. Similarly, "producing" services with inexpensive equipment, rather than paying for these services (e.g. using a video recorder instead of going to the movies) also represents a significant shift in the way goods and services are produced in most countries (54). Thus, the very notion of how and where individuals "produce" in society is changing, and with this, the amount, type, and location of energy use.

National policies can have a major impact on personal energy use. For example, tax relief on mortgage interest stimulates the construction or purchase of single-family dwellings. In the United States, tax rules permit unlimited deduction of mortgage interest payments from taxable income, while this benefit is limited in most European countries. On the other hand, US authorities permit essentially no deduction for commuting costs, while these are directly deductible in some countries (Sweden), or indirectly subsidized through light tax treatment of company-provided cars or company-subsidized transit tickets (United Kingdom). Changes in these types of rules demonstrably and rapidly alter the type and location of homes built (e.g. the size and share of single-family dwellings) and the types of cars purchased and how they are used.

Similarly, national policies toward the social security system and care for the elderly have important energy implications. For example, in Scandinavia, liberal pensions permit retirees to travel and lead otherwise active lives on their own, while concerns about retirement force Japanese families to save more and live together longer.

Changes in the leisure time that societies formalize through paid vacation and holidays could have important impacts on energy demand. If people want to work fewer hours, they could find themselves with significantly more free time. Scandinavians, for example have as much as six weeks' paid vacation, and more paid holidays than US workers.

We have not considered explicitly the potential impact of new technologies in stimulating changes in personal activities. The question is whether such developments provide goods that substitute for services otherwise obtained outside the home, or whether they provide new incentives for people to leave the home. Where cheap goods that substitute for services are the result of new technology, we expect that people will find new things to do in their homes instead of going out for services: home dry cleaning is a good example. Or technology may create new kinds of activities. Since TV watching often acts as the source or sink for time in the home (J. Robinson, private communication, 1988), there is no real shortage of time in the home. Technical change that creates new in-home activities need not lead to a reduction of out-of-home activities.

Another issue is whether new technologies act to remove other constraints on where people go and what they do. "Smart cars," which sense other cars, thereby allowing cars to be driven more closely to each other, would allow traffic to flow faster, thus permitting or even encouraging more driving and allowing people to move further in a given time; improved air-traffic control systems could relieve congestion in air traffic above airports and allow this energy-intensive activity to increase.

The evolution of customs and policies has changed how and where money is earned and spent. On balance, governmental policies have encouraged more ownership of dispersed, detached homes, and more automobile travel. New technologies have permitted greater use of energy-intensive travel modes, but have also created a variety of activities that can be brought back into homes. With these thoughts in mind, we once again discuss the main energy-using sectors, focusing on how changes in what people do might change energy use in these sectors.

Energy Use by Sector: The Impact of Changing Life-styles

Now that we have reviewed measures of human activity, as well as constraints on the mix of activities that characterize life-styles, we return to a description of each energy use sector. This time, we focus on changes in life-styles that may have significant impacts on future energy use in each sector.

RESIDENTIAL SECTOR In general, the key factors that pushed up household energy use in the major industrialized countries—central heating, hot water equipment, increased appliance ownership, increased size of appliances, and greater house area—are currently saturated or growing slowly, compared to the 1960s and 1970s. The shrinking of household size is expected to continue, as is the continued aging of the population. These factors will push up per capita household energy use. Currently, for example, the elderly spend more time watching TV than others. Energy use for the TV itself is not important, but energy to keep the heat or air-conditioning on while people are sedentary is significant, particularly if these people would otherwise have been away from home. Beyond these relatively certain changes, however, lies the main uncertainty in home energy use—the amount of time that will be spent in the home and how that time will be spent.

In the future, many expect that the home will increasingly be used as a place of work. Almost 10% of the US population does some work at home (either telecommuting or self-employment) (55). By the year 2000, this share is predicted to grow to 15% (55), excluding paid work performed in someone else's home [e.g. private personal services (domestic work), child care, and home health care]. More paid work in the home will cause the amount of time spent in the home to increase. This shift will be fostered by the introduction of new information technology, the continuing decrease in the cost of office equipment, and increased commuting costs. This shift will increase energy use in the home for office equipment (not a particularly energy-intensive use) and for heating and cooling (that would not be required if the home were unoccupied). But women's participation in the labor force is expected to grow from 55% in 1985 to 62% in the year 2000 (23). If the consequences of this shift follow those observed from 1975 to 1985, this shift will result in a decrease in the time spent in the home.

It is also possible that more services and family business will be produced inside the home than previously. The increased ownership of inexpensive and sophisticated consumer goods will be substituting for services previously purchased outside the home (e.g. dry cleaning, video recording, repairs, food processing). The increasing cost of these services outside the home—which includes the time, energy, and money cost of getting to and from services—will promote the use of these services in the home. Gershuny (54) identified this substitution as a significant factor in the entire postwar period. More recently, electronic and catalog shopping, as well as take-home food, have risen in popularity. These activities all directly replace activities that used to take place outside of the home.

For leisure time, the trends may be different. Gershuny & Jones (28) indicate that people are going out more for leisure-related activities (e.g. dining, entertainment, and sports). However, certain out-of-home activities (e.g. movies) have lost popularity to their in-home substitutes (e.g. television and video). In addition, it appears that cooking itself has gained popularity as a leisure activity, a trend reflected in the popularity of cooking shows on television and the number of cookbooks sold. On balance, however, the time surveys indicate an increase in time spent for leisure out of the home.

These opposing trends in home activity cannot be easily weighed against each other. In the very long run, even more uncertainty over use of the home arises because the living patterns of the increasingly important older generations depend on whether private and public savings will allow older couples and singles to live apart, allow them to live collectively, or force them to live with their children.

SERVICES SECTOR Future service sector energy use depends on the number and types of service enterprises. Service buildings that consumers visit as customers tend to be slightly more energy- and electricity-intensive than those where employees dominate the use of space. How much more will the sector expand? As in the previous section, we examine future service energy use by examining the related activities of work, family business, and leisure.

In general, the total space available in buildings for work and services increases as the Gross Domestic Product (GDP) increases. However, the current trend toward longer business hours could slow down the growth of space in the service sector by allowing existing buildings to be used for more hours. This change increases energy use per unit of building area. But whether this change increases or decreases energy use relative to the number of people visiting the building depends both on the occupancy during extended hours and the nature of the climate, lighting requirements, etc. In addition, increased awareness by workers and customers of the problems of indoor air quality (e.g. cigarette smoke) has led to laws promoting better indoor air quality. In many cases this has meant increased ventilation, which requires increased electricity use for motors, heating, and cooling, unless heat recovery technologies are used. On the other hand, bans on smoking can reduce the need for ventilation.

We reviewed a variety of ways in which consumers are substituting work in the home for services, or substituting communication for visiting places of business. Additionally, the importance of informal work as a source of services means that more "services" will be performed by mutual friends, etc, without formal transactions taking place in places of business. These trends reduce the need for commercial building space. The aging of society will give further growth to the need for health and elderly care facilities, which are relatively energy-intensive. Alternatively, the elderly might be cared for in their own homes, or in the homes of their children; either of these possibilities would reduce service sector energy use but increase energy use in the home slightly.

We also noted that the trend toward greater out-of-home leisure, including vacation travel, is clear in almost every industrialized country. In the past, people spent an increasing share of their growing incomes on leisure activities outside the home (e.g. restaurants and vacation resorts), particularly for leisure activities. This trend increases the need for commercial building space. The trend toward smaller families, e.g. fewer children, indicates that people are now able to spend more time away from home. However, the trend of spending an increasing share of leisure out of the home could slow if people attach more value to leisure activities inside the home, owing to home electronics and other new technologies that increase the variety of entertainment and leisure activities in the home. In addition, as the population ages, leisure activities outside the home may become less popular. But in the near term, we believe that more leisure time will be spent in the services sector, causing an overall increase in energy demand there. In the longer term, however, it is difficult to predict which changes in the need for overall built space, and therefore energy, will dominate.

TRANSPORTATION SECTOR Travel can increase as more people gain access to cars, as people with cars drive farther, or as people switch to modes that allow them to travel farther, i.e. air. There are many factors pointing to both more and less travel. Consider first access to cars. We noted that access to cars (i.e. cars per licensed driver) in European countries is still growing, while this access lies near saturation in the United States. In other words, increased car ownership will push up travel in Europe and Japan, but not in the United States. Beyond the growth in the number of drivers, future levels of travel will be most heavily influenced by growth in total miles traveled per driver. We see no immediate limit to this growth because of income or time constraints.

Indeed, there are signs that travel will increase. Even though there is one car for every licensed driver in the United States, there is a significant potential for increased driving as more women enter the work force. Moreover, a continued substitution of air travel for the automobile for vacation would increase distances traveled in a given time, and increase energy/distance as well. In either case, transportation energy use would increase. Although older people (i.e. above 60) presently drive less than younger ones, the distance older people travel has been increasing (50). Therefore, it is likely that travel per capita will increase somewhat in the future.

Demographic changes will have an important impact on travel. Smaller families and household sizes reduce time needed for child care, leaving more time available for work or leisure. Smaller families also means lower load factors in cars. Increased numbers of women working increase the importance of trips to work, which have lower load factors than family travel and take place during peak periods. Location and family size also influence the choice of travel mode. Modal choice could be affected by the increased numbers of the elderly, who may not be able to drive, and the growing number of singles who may choose to live near city centers and use public transportation.

Social constraints and habits are also changing. We noted above that men drive almost twice as far as women. Some of this difference arises out of the patterns of sharing driving when families travel together; the rest is caused by difference between the actual daily routines of men and women, reflected in part, in time use. If women's driving reaches three fourths of the level of men's, total miles traveled would increase by 13%, with significant consequences for gasoline demand.

There are also many possible changes in the level of travel that are related to the way people connect their homes, their place of work, and their places of leisure and family business. As noted previously, there are many trade-offs between activities conducted in the home and those in the services sector (workplace). The cost of travel, in time and money (including the energy cost), is an important factor used in calculating the trade-offs. Accordingly, we examine future transportation energy use by examining the related activities of work, family business, and leisure as they relate to the cost of travel.

In the United States, about one third of the energy used for personal transportation is related to work. Participation in the work force has increased in most industrialized countries as more women work, and as more liberal rules on retirement allow more older people to retain some kind of jobs. The increased employment of women and the elderly produces a growing need for transportation. But congestion makes it harder to get to work at rush hour, which may discourage more commuting, and encourage telecommuting, which is becoming more popular. Moreover, shorter work weeks (with longer hours) would reduce transportation energy demands for getting to and from work. On the other hand, we expect greater transportation energy use if work days are shortened and more people work, or if part-time work increases, because more commuting trips will be required for a given number of total hours worked.

About one third of the energy demand for personal transportation in the United States goes for family business. If people visit services less, energy needs for transportation could fall. The use of electronic shopping and banking, instead of visiting stores and banks, will lead to reduced transportation energy use. Also, the decentralization of services into residential and working areas will reduce traveling time. Similarly, the increased use of delivering services to the home (e.g. food and videotapes) reduces the number of household trips. Also, an increase in the "grey" (informal) economy could lead to reduction in distances to services, since people only trade services with those they know, who tend to live or work nearby. On balance, we expect travel for services to decrease. Since the areas where services are concentrated are often congested, travel to and from these areas is inefficient: the energy savings from these changes could be significant.

Out-of-home leisure activities, and associated travel, have increased in the United States and other countries. Time-budget data show that Americans and Europeans still spend more free time at home than away, so increases in the out-of-home component of leisure are plausible even if total leisure is limited. Such increases would increase the energy demand for transportation. If at-home leisure increases, on the other hand, then the number of trips could be reduced, along with transportation energy use. Similarly, if leisure-related services are located closer to home, then trip distance is reduced (although the number of trips may increase). On the other hand, if the amount of free time increases as a result of working less, or working four-day weeks, then transportation energy use could increase because (J. Gershuny, 1987, private communication) people have enough time to travel long distances for leisure. In all, we believe that increased leisure activities out of the home will be a driving force in increasing travel. Because these activities tend to avoid the most congested times and places, the travel associated with leisure will probably not face the same constraints from congestion as does work and family-business-related travel.

There are other important, but uncertain, changes in the geographical relationship among the places where people work, live, and play that could radically alter the personal energy demands in all sectors. For example, changes in the sizes, types, and locations of new homes, reactions to aging, the changing labor market, and smaller families would certainly affect the need to travel between these places. The future financial and health situation of the elderly could have an important influence on future travel patterns. Changes in tax treatment of homes, or changes in land-use policies, could also influence spatial layout of society, and thereby affect the need to travel.

Certain aspects of car use have an impact on energy use. CONAES noted that fuel economy is poor in a short trip because a car engine is not warmed up for the first few miles of a trip from a cold start. Therefore, changes in the average length of trip alone could influence overall fuel economy. Fuel use per year could change for the same total distance driven. And trips to and from work and shopping tend to take place in peak hours, in the most congested traffic. This congestion reduces fuel-efficiency. Finally, more families are acquiring specialty cars, from sports cars to heavy-duty recreational vehicles, as extra vehicles. These have a wide variation in fuel economy. Consumers may choose which vehicle to drive according to the nature of the activity in which they will engage. These choices can have an important impact on fuel-efficiency and therefore use.

CONCLUSIONS

In industrialized countries, about 45–55% of total energy use is influenced by consumers' activities for personal transportation, personal services, and homes. This share has grown steadily over the past decades owing to increases in the ownership of cars, electrical appliances, and central heating and expansion of the service sector. We found that, for most industrialized countries, increases in the ownership or availability of equipment and infrastructure will no longer drive significant changes in energy demand. Instead, changes in use of this equipment will be the dominant source of changes in energy demand. Such changes will be driven by many factors besides energy prices and incomes. We have shown that the most important factors are those that influence the mix of personal activities and their locations.

We also showed that understanding how the spectrum of human activities changes may be the key to a better understanding of future energy use. This is because in most industrialized countries, an increasing number of the activities people engage in are not directly related to providing themselves with food, clothing, and shelter. Moreover, higher incomes broaden the ranges of what people can do and how they do it. Models of future activity based on traditional economic analysis of expenditures, or estimation of energy demand as a function of prices and incomes alone, will miss this expanding range of "what and how." Instead, with a firm understanding of the infrastructure of energy-using equipment, buildings, and vehicles, which tells us how people do things, we propose models of activities that use time (and location), which provide the best insights into what people are doing, as well as where and for how long. Since the number of hours in the day is limited, the time-based activity approach forces the analyst to consider both what people might do in the future that is different from what they do today, as well as what they will not do as a consequence of their new activities.

We demonstrated that the most energy-intensive activities people engage in are those involving travel. That is, energy use per person per unit of time is far higher when people travel than when they are in their homes or service establishments. Based on moderate variations in the present use of time by people in industrialized countries, we estimate that individual energy use could vary up or down by 15% as a result of changes in the mix of activities, particularly travel, at roughly today's level of incomes, without changes in energy prices. Greater changes in the future are possible as the relation between work, home, and free time and the technologies that support these activities evolve. Research concerned with understanding plausible levels of future energy demand should turn to understanding what people will do and where they will do it as keys to how much energy will be used in the future.

ACKNOWLEDGMENTS

This work was supported by funds from the Electric Power Research Institute (EPRI), Palo Alto, California, under contract RP 2927-3. We acknowledge the guidance of our project manager at EPRI, Larry Lewis. We are grateful for the support of Shell International Petroleum Co., London, where Dr. Schipper was a guest when the initial ideas for this paper were developed. Also, we thank Antonella Marucco for her guidance in structuring the ideas presented in this paper. Bonnie Morrison contributed ideas and guidance during early stages of this project, and organized two workshops on Energy and Lifestyle at Michigan State University. Steve Meyers and Rick Diamond of LBL provided helpful comments on the manuscript. We also acknowledge the assistance of Phil Patterson and David Greene of the US Dept. of Energy, J. Gershuny of the University of Bath, John Robinson of the University of Maryland, and Oliver Yu of EPRI.

Literature Cited

1. Gaunt, L. 1985. *Bostadsvanor och Energi*. M85:14. Gaevle, Sweden: Statens Inst. foer Byggnadsforskning (Building Research Institute) (in Swedish)
2. Gladhart, P., Morrison, B., Zuiches, J. 1986. *Energy and Families*. East Lansing, Mich: Inst. for Family and Child Study, Mich. State Univ. Press
3. Lundstroem, E. 1986. *Occupant Influence on Energy Consumption in Single Family Dwellings*. D5:1986. Stockholm: Swedish Counc. Building Res. (in English)
4. Schipper, L., Ketoff, A., Kahane, A. 1985. Explaining residential energy use with international bottom-up comparisons. *Annu. Rev. Energy* 10:341–405
5. Ketoff, A., Bartlett, S., Hawk, D., Meyers, S. 1987. *Residential Energy Demand in Six OECD Countries: Historic Trends and Future Directions*. LBL Report 22642. Berkeley: Lawrence Berkeley Lab.
6. Meyers, S. 1987. Energy consumption and structure of the US residential sector: changes between 1970 and 1985. *Annu. Rev. Energy* 12:81–97
7. Sonderegger, R. 1978. Movers and stayers: the resident's contribution to variation across houses in energy consumption for space heating. In *Saving Energy in the Home: Princeton's Experiments at Twin Rivers*, ed. R. Socolow. Cambridge, Mass: Ballinger
8. Kempton, W., Neiman, M., eds. 1987. *Energy Efficiency. Perspectives on Individual Behavior*. Washington, DC: Am. Council for an Energy-Efficient Economy
9. Lutzenheiser, L. 1988. *Energy, technology, and everyday life: a cultural theory of energy use*. PhD thesis. Univ. Calif., Davis
10. Schipper, L., Meyers, S. 1986. Energy use in the service sector: an international overview. *Energy Policy*. June
11. Energy Inf. Admin. 1981. *Non-residential Building Energy Consumption Survey 1979* (NBECS). US Dept. Energy. Washington, DC
12. Energy Inf. Admin. 1985. *Non-residential Building Energy Consumption Survey 1983* (NBECS). US Dept. Energy. Washington, DC
13. Energy Inf. Admin. 1988. *Non-residential Building Energy Consumption Survey 1986* (NBECS). US Dept. Energy. Washington, DC
14. Kitamura, R. 1988. *Lifestyle and Travel Demand*. Presented at *Conf. Long-Range Trends and Requirements for the Nation's Highway and Public Trans. Sys.* Washington, DC

15a. Marucco, A. L., Ketoff, A. N. 1988. *Energy and the Use of Time: Understanding Changes in Lifestyle*. Unpublished draft report. Berkeley: Lawrence Berkeley Lab.

15b. Adler, A. 1931. *The Pattern of Life*. London: Kegan Paul

16. Mitchell, A. 1983. *The Nine American Lifestyles*. New York: Macmillan
17. Nader, L., Beckerman, S. 1978. Energy

as it relates to the quality and style of life. *Annu. Rev. Energy* 3:1–28
18. Weber, M. 1947. *The Theory of Social and Economic Organization*. Edinburgh: Hodge
19. Deutsch, D. 1967. Family therapy and family lifestyle. *J. Individual Psychol.* 23
20. Zablocki, B., Kanter, R. 1976. The differentiation of life-styles. *Annu. Rev. Sociology* 2:269–98
21. Sobel, M. 1981. *Lifestyle and Social Structure*. New York: Academic
22. Reagan, R. 1987. *Economic Report of the President*. Council of Economic Advisers. Washington, DC
23. US Bur. Census. 1987. *Statistical Abstract of the United States: 1988*. (108th ed.) Washington, DC
24. Wharton School of Finance and Commerce. 1957. *Study of Consumer Expenditures, Incomes and Savings, Statistical Tables Urban US—1950*. Univ. Penn. Vol. 18. Washington, DC: McGregor and Werner
25. Bur. Labor Stat. *Consumer Expenditure Survey, 1972–1973* (CES), US Dept. Labor. Washington, DC
26. Bur. Labor Stat. 1986. *Consumer Expenditure Survey, 1982–1983* (CES). Bulletin 2246. US Dept. Labor. Washington, DC
27. Schipper, L., Howarth, R. 1989. *Energy Demand and Economic Activity in a Very Long Time Perspective: The Case of Germany*. Unpublished report. Lawrence Berkeley Lab.
28. Gershuny, J., Jones, S. 1987. *Time Use in Seven Countries, 1961 to 1984*. Bath, England: Univ. Bath
29. Robinson, J. P. 1988. Who's doing the housework. *Am. Demographics*. Dec: 24–63
30. Szalai, S., ed. 1972. *The Use of Time*. The Hague: Mouton
31. Deutsches Institut fuer Wirtschaft (DIW). 1988. *Verkehr in Zahlen*. Federal Republic of Germany, Ministry of Transportation
32. Energy Inf. Admin. 1987. *Residential Energy Consumption Survey 1984/85* (RECS). US Dept. Energy. Washington, DC
33. Davis, S. C., Shonka, D. B., Hu, P. S. 1988. *1988 Automated Transportation Energy Data Book* (draft report). Oak Ridge: Oak Ridge Natl. Lab.
34. Office of Technol. Assess. 1988. *Technology and the American Economic Transition*. Congress of the United States. Washington, DC
35. Robinson, J. P. 1976. *Changes in Americans' Use of Time: 1965–1975*. Cleveland, Ohio: Communication Res. Cent.
36. Robinson, J. P. 1977. *How Americans Use Time: A Social-Psychological Analysis of Everyday Behavior*. New York: Praeger. Monograph Series
37. Natl. Acad. Sci. 1980. *Energy Choices in a Democratic Society*. Washington, DC
38. Armstrong, J. E., Harman, W. W. 1975. *Plausibility of a Restricted Energy Use Scenario*. Menlo Park, Calif: Stanford Res. Inst.
39. Edison Electric Inst. 1976. *Economic Growth in the Future*. New York: McGraw-Hill
40. Goldemberg, J., Johansson, T. B., Reddy, A. K. N., Williams, R. H. 1988. *Energy for a Sustainable World*. New Dehli: Wiley Eastern
41. Ministry of International Trade and Industry (Japan). 1986. *The Twenty-first Century Energy Vision—Entering the Multiple Era*. Tokyo: Japan Cooperation Cent. for Petroleum Industry
42. Diamond, R. C. 1987. *Energy Use in Housing for the Elderly: The Effects of Design, Construction and Occupancy*. Berkeley: Cent. Environ. Design Res.
43. Federal Highway Admin. 1972. *Nationwide Personal Transportation Study, Household Travel in the United States Report No. 7*. US Dept. Transportation. Washington, DC
44. Federal Highway Admin. 1973. *Nationwide Personal Transportation Study, Mode of Transportation and Personal Characteristics of Tripmakers Report No. 9*. US Dept. Transportation. Washington, DC
45. Federal Highway Admin. 1974. *Nationwide Personal Transportation Study, Purposes of Automobile Trips and Travel Report No. 10*. US Dept. Transportation. Washington, DC
46. Federal Highway Admin. 1981. *1977 Nationwide Personal Transportation Study, Vehicle Occupancy Report No. 6*. US Dept. Transportation. Washington, DC
47. Federal Highway Admin. 1982. *1977 Nationwide Personal Transportation Study, Household Travel Report No. 9*. US Dept. Transportation. Washington, DC
48. Federal Highway Admin. 1983. *1977 Nationwide Personal Transportation Study, Person Trip Characteristics Report No. 11*. US Dept. Transportation. Washington, DC
49. Federal Highway Admin. 1986. *Personal Travel in the US, Volume 1 &*

Volume 2: A Report on Findings From the 1983–1984 Nationwide Personal Transportation Study. US Dept. Transportation. Washington, DC

50. Greene, D. 1988. *Long-run Vehicle Travel Prediction from Demographic Trends*. Presented at *Annu. Meet. Transportation Research Board, 66th, Washington, DC*
51. Bonke, J. 1986. *Formellt og formellt Byggeri*. SBI Rapport 184. Hoersholm, Denmark: Statens Bygeforsknings Institut. See also Bonke, J., 1986. *Husholdningsoekonomi*. Memo Nr. 157. Copenhagen, Denmark: Oekonomisk Inst.
52. Bonke, J. 1986. *Aldrig mer Arbejde—oekonomi og verklighed!*. Copenhagen: Rosinante
53. Sanne, C. 1985. *Living People*. Stockholm: Swedish Counc. Building Res.
54. Gershuny, J., Miles, I. 1987. *The New Services Economy The Transformation of Employment in Industrial Societies*. London: Pinter
55. Ambry, M. 1988. At home in the office. *Am. Demographics*. Dec:30–61