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ENERGY & ENVIRONMENT DIVISION

Energy Use in Sweden: An International Perspective

L. Schipper, F. Johnson, R. Howarth, B. Andersson,
B. G. Andersson, and L. Price

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Energy Use in Sweden: An International Perspective

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December 1993

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PREFACE

Energy Use in Sweden: An International Perspective analyzes the evolution of energy use in Sweden since the early 1970s. The purpose of the study, which is sponsored by *NUTEK*, Department of Energy Efficiency, the Swedish Agency for Technical and Industrial Development, is to shed light on the future path of energy use in Sweden by quantifying and understanding changes in past energy use.

Energy efficiency has been identified by Swedish authorities in countless official studies as a key element in Sweden's efforts to restrain oil imports, reduce reliance on nuclear power, reduce environmental impacts of energy use, and reduce CO_2 emissions. To understand the role or performance of energy efficiency in the 1970s and 1980s in Sweden, and what this performance means about the future, we seek answers to three broad questions:

• How has the structure and efficiency of energy use in Sweden evolved since the early 1970s, and where data permit, since even earlier? What caused these changes?

• How does the structure of energy use in Sweden differ from that of other countries, and how has the evolution of energy use in Sweden differed from developments in other countries?

• How much energy has Sweden saved, and why? Are these savings permanent? To what extent were they offset by changes in the structure of energy use? And to what extent is the magnitude of these savings dependent upon the way we measure energy use?

Our report reviews the long-term evolution of Swedish energy use, focusing on developments in five sectors of the economy: residential, service, industrial (manufacturing and "other industry" defined as mining, agriculture, forestry and fisheries, and construction), travel, and freight. We then examine Swedish energy use in a broader perspective, drawing detailed comparisons to other nations. Finally, we discuss a series of issues that hover over the future of energy demand in Sweden: Will energy savings in Sweden persist? Will changes in the lifestyles of Swedes offset or reinforce energy savings? Can the momentum of energy savings be maintained?

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Energy Use in Sweden: An International Perspective

EXECUTIVE SUMMARY

In 1990, NUTEK's Department of Energy Efficiency (then Statens Energiverk) asked the International Energy Studies (IES) Group at the Lawrence Berkeley Laboratory in California[1] *to analyze trends in the structure and efficiency of energy use in Sweden since 1970 and compare them with those in other countries. Work was carried out with assistance from Statistiska Centralbyrån and leading authorities on manufacturing, transportation, housing, and energy. The study, which took one year to complete, analyzed virtually all existing official and unofficial data on the structure of Sweden's energy-economy, building on previous IES studies of Sweden and other countries. Our results are summarized below.*

Between 1973 and 1989, improved energy efficiency saved 24% of Swedish final energy use and 8% of Sweden's energy use if the losses for making electricity and district heat are counted. These savings were concentrated in the manufacturing and household sectors, but important savings also occurred in air travel and the heating of commercial buildings. Savings in auto travel were small and savings for trucks were negative. Since the crash in the price of oil in 1986 the rate of savings has slowed markedly, consistent with trends in other major industrialized countries. Changes in the mix of goods produced by Swedish manufacturing *increased* energy use only slightly, but changes in how consumers lived increased energy use significantly.

How do these results compare with those in other countries? IES analyzed developments in Denmark, the U.S., W. Germany, Japan, and Norway over the same time period. We found that Sweden placed fifth in energy savings, ahead of Norway but well behind the other countries. The reasons included the relatively efficient starting point for Swedish buildings in 1973 (which are still the most effectively heated in the OECD) and the enormous increase in the use of low-cost electricity use (in place of oil).

The shift towards slightly more energy-intensive production in Swedish industry also occurred in France and above all in Norway, in strong contrast to the decline in the role of heavy industry in W. Germany, Japan, and the U.S. The increase in energy use led by changes in consumers' lifestyles—home comforts and travel—occurred in most other OECD countries as well.

Three factors "caused" the improvements in energy efficiency in Sweden. Higher fuel prices were the most important cause, as can be seen by the increases that occurred in the efficiency of oil use or substitution away from oil towards electricity or biomass in buildings and industry. Where prices changed less dramatically (electricity) or where price changes reversed (gasoline), savings were less dramatic. Long-term technological change that was already causing energy savings before the first oil crises of 1973 continued to contribute to energy saving in industry and heat savings in homes and buildings. The two most important policies underlying these long-term improvements were Sweden's open industrial policy oriented towards exports and unique policies for housing and buildings, which needed little change after 1973 in order to continue their contributions to energy efficiency. Energy-saving policies in place between 1973 and 1985, which were focused principally on heating and oil savings, were effective but overall had a smaller effect that the first two "causes" of improved efficiency. Lack of good data about energy use in Sweden in the 1970s hampered the effectiveness of energy saving policies somewhat, but the system has improved considerably, although major gaps still remain, mainly in transportation.

In the beginning of the 1990s, Sweden exhibits one of the most energy-intensive economic structures in the OECD (after the U.S. and Canada). Sweden maintains a slight edge in efficiency of space heating and trucking, shows average performance for industry and electric appliances, but has one of the most fuel-intensive auto fleets in Europe. Important new developments may change these rankings in the future, however. First, devaluation and new taxation policies, including so-called "green taxes", promise to raise the price of oil significantly. Second, a variety of programs to stimulate improvements in electricity use, particularly *Teknikupphandling* and Vattenfall's *Uppdrag*, have the potential to affect electricity efficiency dramatically in the coming decade. Finally, the current fiscal crisis may force authorities to wind down some traditions that have boosted energy use, such as company car tax subsidies, subsidies for commuting to work, and housing subsidies.

[1] The Lawrence Berkeley Laboratory is a federally-owned facility operated by the University of California, and has had nine Nobel Laureates. The present work was carried out under contract to NUTEK, with indirect support from the Stockholm Environment Institute. Similar efforts were carried out for the Danish and Norwegian governments. The full study, by Schipper, F. Johnson, R. Howarth, B. G. Andersson, B. E. Andersson (both of Handelshögskolan, Stockholm), and L. Price, is available from *NUTEK* or IES.

Environmental and climate concerns now drive much energy policy, but many other forces control the overall level of economic activity: What is made, how it is made, and how it is consumed in Sweden. In this respect, Sweden faces many dilemmas: the future of nuclear power, the future of subsidies for housing and travel, the choice to clean up further emissions from industry in Sweden or industries across the Baltic, pricing and taxation policies for fuels and electricity, the role of Sweden's energy-intensive exports of paper and steel products, and indeed the lifestyles of the Swedes. As outsiders, we only point out that these choices may be as important as energy-efficient technologies in determining future energy use in Sweden and the future level of pollution as well. Above all, public and private authorities in Sweden need to redouble their efforts to quantify the link between their choices and the resulting changes in economic activity, energy use, and pollution, lest they make the right choices but get the wrong results!

1. INTRODUCTION

The purpose of the study, which is sponsored by *NUTEK*, Department of Energy Efficiency, the Swedish Agency for Technical and Industrial Development, is to shed light on the future path of energy use in Sweden by quantifying and understanding changes in past energy use. In particular, our goal is to quantify the impact on energy use of improvements in energy efficiency and other changes in the structure of energy use after 1973. Where possible, we identify the causes of these changes. After comparing Sweden's performance with that of other countries, we discuss implications of our findings for future energy use and policies in Sweden.

1.1. Background

Twenty years ago, Swedish policy makers and the public at large were confronted by unwelcome and unanticipated increases in oil prices. While world oil markets previously had been marked by relative stability, the Arab oil embargo of 1973 sent fossil fuel prices to record highs. In 1979, oil prices jumped once again, spurred by the Iranian Revolution and ensuing Iran-Iraq War. The impacts of these events on the Swedish economy should not be underestimated.

Sweden was particularly vulnerable to the oil price shocks of the 1970s because the nation depended so highly on imported oil to provide the bulk of fuel for homes, buildings, and manufacturing (see Figure I-1). Also Sweden's export-oriented industry was critically dependent upon energy-intensive metals and paper products for both direct exports and as inputs to finished goods. Lastly, the oil crisis occurred just as Sweden was beginning to question the role nuclear power would play in its electricity system, which up until the 1970s was based almost entirely on hydroelectric power. In fact, the first oil crises occurred as oil-fired capacity for electric power and combined district heat and power was starting to spread. Thus the first oil crisis struck Sweden when attention was already focusing on energy problems.

Not surprisingly, the energy shocks garnered the attention of public and private authorities on the both the conflicts and complementarities of these issues. On the one hand, higher oil prices could spark a wave of efficiency improvements that might affect all energy use; on the other hand, electricity from nuclear power offered both an alternative to expansion of oil-fired capacity, and to a significant extent, a direct alternative to oil for both space or water heating in homes and buildings. Additionally, electricity could offer an indirect alternative to oil by stimulating growth in electro-processes, such as thermo-mechanical pulping or electro-steel, or by permitting a shift in chemicals output towards electricity-intensive chemicals such as chlorine.

The Swedish debate over nuclear power and oil raged on through the 1970s and continued well after the second oil shock. The accident at Three Mile Island renewed concerns over nuclear power, leading to the 1980 Nuclear Referendum. Far from putting the issue aside, the decision in 1980 to phase out nuclear power—maybe—rekindled a rash of electricity-saving studies, as oil saving concerns faded as the real price of oil continued to fall. The crash in the price of oil in early 1986 would have dissolved remaining interest completely, had not the accident at Chernobyl once again fanned public opinion in Sweden against nuclear power. After another round of studies illustrating the potentials for saving electricity, Sweden embarked anew on a major conservation campaign.

In the 1990s, the "energy problem" has been refined further in light of concerns over the relationship between energy use and environmental degradation. Fossil fuels are recognized as a major source of urban air pollution and contributor to the acid deposition that threatens terrestrial and aquatic ecosystems in Northern Europe and Scandinavia. Perhaps most importantly, carboniferous fuels such as coal, oil, and natural gas have been linked to the greenhouse effect, which threatens to bring about highly uncertain but potentially devastating changes in the earth's climate.

The energy-saving successes of the 1970s and 1980s had both positive and negative impacts on the environment. Certainly, enhanced energy efficiency reduced the environmental burdens associated with energy use. Increased reliance on nuclear power, however, furthered the challenges to future Swedish energy policy: How could Sweden turn off nuclear power yet reduce the problems associated with burning fossil fuels at the same time, particularly if carbon-laden fuels would have to substitute directly or indirectly for some of the nuclear power?

Whatever the answer, it is clear that any proposals to modify future energy supplies in Sweden will depend on the evolution of energy demand. Indeed, Swedish energy policies recognized the importance of understanding the demand side in the 1960s, a time when little was known—or asked—about the intricacies of energy demand in most other countries' energy-policy circles. Yet in many ways the analyses of Swedish energy demand connected to these policies was sometimes deficient, lacking both critical data and a historical perspective balanced among all major consuming sectors.

For example, the 1967 report, *Sveriges Energiförsörjning* (EK 1967), could not disaggregate fuel consumption by major modes of transportation. Yet the same study showed a remarkable sensitivity to the breakdown of household energy use by home type, fuel, and heating system. By contrast, the 1974 report, *Energi 1985 2000* (EPU 1974) was rich in the details of the 1970 structure of energy use in transportation, but lost much of detail in the residential sector. Yet energy efficiency policies developed in the wake of EPU focused so much on saving oil from space heating. The lack of information on the structure and energy use in heating had wide repercussions, since it was difficult to measure the impact of energy efficiency improvements, or the success of policies, aimed at particular sectors or uses. Only in 1978 did a new bill aim at improving energy efficiency in buildings with a clearly stated quantitative goal of a certain reduction in energy use in buildings built before 1978. Successive energy policy documents focused on different sectors, yet there was never a comprehensive review of trends in the structure of energy use in all sectors covering the entire period of turmoil from 1973 onward.

1.2. Goals and Scope of This Study

This report reviews the long-term evolution of Swedish energy use, focusing on developments in five sectors of the economy: residential, service, industrial (manufacturing and other industry), travel, and freight. Although we had intended to start our analysis in 1960, lack of data constrained our ability to construct a detailed history of the nation's energy use prior to the 1970s. We examine trends in both the activities that drive energy use and their corresponding energy uses, seeking to understand not only the technical efficiency of energy utilization but also the human context in which energy is used.

This report also examines Swedish energy use in a broader perspective, drawing detailed comparisons to developments in other nations. First we compare energy use in Sweden to that in other OECD countries (Denmark, Norway, Italy, France, the U.K., West Germany, Japan and the U.S.) on a sectoral basis. Then we assess Sweden's overall standing among five of these countries (Norway, Denmark, West Germany, Japan and the U.S.) in terms of sectoral activity levels, the structure of energy use, and energy intensities.

With this in mind, the specific goals of this study are to:

- Quantify the development of energy use and its underlying structural determinants;
- Quantify components of changes in energy-use that occurred between 1970 and 1990: sectoral activity, sectoral structure, the intensities of individual energy uses, and fuel switching;
- Compare these findings with those from other major countries;
- Comment on causes of change, the short- or long- term nature of these changes, and whether such changes might reverse in the near future;
- Address the apparent slow-down in the improvement of energy-use efficiency in Sweden;
- Comment on implications the findings have for future energy use patterns in Sweden.

We examine the major uses of energy in five end-use sectors in detail, and in a sixth sector (agriculture, mining, and construction) briefly. We also note important developments in the energy sector itself.

1.2.1. Definitions, Conventions

In this study, *activity* (also called *volume* or *output* in our other work) represents the gross measure of output in each sector, the population, or the total level of passenger or freight transportation. *Structure* refers to the mix of activities for which energy is used. Energy *intensity* measures energy consumed per unit of activity. Intensity may be measured as an aggregate across one or many sectors or be narrowly defined as the ratio of a use of a single fuel to a measure of activity for a single purpose. Efficiency, properly defined, is the ratio of activity to energy use. *Energy conservation* in its broadest sense means the act of decreasing energy intensities or increasing energy efficiencies. With respect to the energy sector, we adopt the convention of considering primary fuel inputs to electricity production by counting hydropower at 85%, nuclear power at 34% and other fuels such as oil and gas at 40%. The SCB energy balances use similar conventions in reporting the fuel content of electricity inputs.

In this study, we report on energy use using three methods of accounting:

- Delivered energy (*slutliga användning, köpt energi, bruttoenergi, osv*), the energy delivered to a building, factory, or fuel tank and converted ultimately to heat, light, motion, and other energy services. No accounting of losses in transformation is made.
- Useful energy (*nettoenergi*), defined as delivered energy minus the losses in combustion in boilers. This definition is used to estimate the heat provided in space- and water-heating and cooking applications. In this report, we assume that the efficiency of conversion of gases and liquids is 66%, solids 55%, and electricity and district heat 100%. This eliminates most of the apparent conservation that occurs solely because of fuel substitution. Carlsson, of *PREDECO*, (1992) presents a more detailed analysis with somewhat different coefficients that vary over time. Useful energy is employed when

significant substitution of energy sources with few local transformation losses, *i.e.*, electricity or district heat, are substituted for fossil fuels.

• Primary energy (*primärenergi*) represents the delivered energy consumed plus the losses in transformation and distribution of district heating and electric power, but not other losses from the energy sector (which tend to be much smaller). *The primary energy figures referred to in the sectoral analysis in each chapter count nuclear and hydroelectric power at their "thermal" equivalents in common with OECD practice, as discussed in the yearly energy balances published by Statistiska Centralbyrån (SCB)* (Statistics Sweden).

There are many conventions we adopt that permit a more ready comparison of Sweden with other countries. Some of these conventions are at considerable variance with Swedish ones. These are explained at the outset of each section.

In Figure I-1, primary electricity denotes the primary equivalent of hydroelectric power and nuclear power. These by definition have losses associated with production. Other "losses" arise in oil refining, city gas production, production of electric power using conventional thermal power or combined heat and power, transmission of electricity, gas, and heat, and other small losses in the energy sector. The largest of these are shown in Figure I-2 which gives some perspective on the relationship between primary energy consumed in Sweden, losses in conversion, and fuels delivered to various final demand sectors. Figure I-3 shows the *SCB* accounting of energy sources available to final demand, as well as the total losses by their accounting.

Once energy is converted to its delivered form, it is "consumed" in the main sectors of final demand: residential (*bostäder, hushåll*); services (*tjänster*, often referred to as *lokalsektorn* because virtually all energy in this sector is consumed in buildings); industrial, which is made up of manufacturing (*tillverkning*) and other industry (mining, agriculture, forestry, fisheries, construction; *gruvor, jordbruk, skogsbruk, fiske, byggverksamhet*), travel (*persontransporter*); and freight (*frakt, godstransporter*). In "Other Industry", agriculture represents the largest share, accounting for somewhat less than half of the total. As can be seen, however, the overall role of any of these parts of "Other industry" in total energy use is small. Figure I-4 shows the shares of delivered energy consumed by each of the major sectors we study. Energy consumption data for other industry are uncertain, because all but mining are lost in the combined sector "Households, services, etc." (*hushåll, service, m. fl.*) before 1983. *SCB* provide estimates of oil and electricity use for most of these missing sectors for the years 1970-1983, but the sector is still incomplete for those years. Figure I-5 shows the shares of fuels meeting the final demands studied in this work. Here the losses are counted as an aggregate. Additionally, there is a residual calculated as the difference between the final demand sectors we have constructed sector by sector, and the final demand as listed by *SCB* in the official energy balances.

1.2.2. The Main Data Sources

While a full accounting of our data sources and derivations will be provided in a set of appendices, we will describe key data sources in the section summarizing each sector. Wherever practical we rely on data from *SCB*. The sources are both publications and, where noted, special tabulations of data provided by *SCB* in Stockholm or in Örebro (Sahlberg 1992). Key secondary sources of data include *NUTEK*, the former *Transportrådet* (many of whose functions are being assumed by *Väg- och Trafik- Institut*). Key data for the residential and service sectors were provided by Carlsson, of *PREDECO, Vattenfall*, and by a multitude of sources used and described in previous LBL studies of Sweden (Schipper 1984a; Schipper 1984b; Schipper, Meyers, and Kelly 1985; Schipper, Meyers, and Ketoff 1986; Schipper and Hawk 1991; Schipper and Tyler 1989).

Our sources for international data are many. Our recent analysis of energy use in Denmark (Schipper, Howarth, Andersson, and Price 1992) details a number of these. Schipper, Howarth, and Geller (1990) applied the present methods to the U.S. situation, while Schipper, Howarth, and Carlesarle (1991) analyzed developments in Norway. Additionally, the reader should consult Howarth and Schipper (1992) for our comparison of energy use in manufacturing; Schipper, Meyers, *et al.* (1992), Schipper, Steiner, Duerr, An, and Strøm (1992), Schipper, Steiner, Figueroa, and Dolan (1993), and Schipper, Figueroa, Price, and Espey, (1993) for our analyses of transportation energy use; Schipper, Meyers, and Ketoff (1986) for our analysis of the service sector; and Schipper (1984a), Schipper, Ketoff, and Kahane (1985), and Ketoff and Schipper (1990) for further background on the residential sector.

1.3. The Structural Approach: Methodology

The development of Swedish energy use between 1970 and the present is characterized by two fundamental breaks in trends clear from the aggregate view of energy consumption presented above. The first break was the sharp drop in oil use caused as much by improved efficiency as by substitution by other delivered energy carriers, notably biomass and electricity. Some of this change is clear from Figure I-1 or Figure I-5. The second was steady reduction in energy intensities in sectors where intensities had been growing, namely in buildings and travel, or an acceleration of the decline in intensities in manufacturing. To understand the *causes* of these important changes requires disentangling the underlying components of the structure of energy use.

Trends in aggregate energy use and economic activity are often used as indicators to gauge improvements in the efficiency of energy utilization over time, explain major shifts in the mix of fuels, or to anticipate future developments. While broad-based measures are indispensable because they convey facts in simple and hence digestible terms, they often hide information that is crucial in understanding the nature of energy use. Energy, after all, is not used in the abstract to produce abstract units of GDP. Instead, it is used to carry out numerous specific activities such as maintaining comfortable indoor temperatures; providing mobility in automobiles and other vehicles; and producing chemicals, steel, and other raw materials.

Previous research has shown that the structure of energy use—its disposition among different activities—changes substantially over time in response to demographic trends and changes in lifestyles and technologies (Schipper, Bartlett, Hawk, and Vine 1989; Schipper, Howarth, and Geller 1990; Schipper, Howarth, Andersson, and Price 1992; Schipper, Meyers, *et al.* 1992). To see that this is true, it is useful to break delivered energy use down into five end-use sectors: residential, service, industrial (manufacturing and other industry), travel, and freight.

As Figure I-4 shows, the residential and manufacturing sectors are the most important end-use sectors in Sweden, accounting respectively for 28% and 42% of delivered energy use in 1973. The share in the residential sector fell to 25% by 1990, and the manufacturing share fell as well, to 38%. The shares of service, travel, and freight gained. Agriculture, construction, and mining, which are small, are aggregated into "Other Industry". For each of these end-use sectors, it is possible to define an indicator of aggregate sectoral activity that represents in broad terms the factors that drive energy use, as noted above. In travel, for example, aggregate activity is defined as personal mobility measured in passenger-km. Within particular end-use sectors, it is possible to obtain more detailed information regarding *structural change*, or the disposition of energy use between specific activities. In the residential sector, it is interesting to consider developments in space heating, water heating, cooking, lighting, and appliance energy use. In manufacturing one may divide energy use among different subsectors that produce fundamentally different kinds of *products. To each specific activity corresponds a measure of energy intensity*, or energy use per unit of specific activity.

According to this formulation, changes in the level of energy use in a given sector may be attributed to three factors: growth in aggregate activity; structural change (changes in the ratio of specific activities to aggregate activity); and changes in energy intensities. In formal terms, let A_{it} represent the aggregate activity level in sector i in year t, S_{ijt} $(j = 1,2,...,n)$ be the level of specific activity j per unit of aggregate activity, and I_{ijt} be the energy intensity of specific activity j. Then the energy use of sector i is:

$$E_{it} = A_{it} \sum_{j=1}^{n} S_{ijt} I_{ijt} .$$

While this formula is simply an accounting identity, it provides the basis for constructing meaningful indicators of the determinants of energy use in a given end-use sector.

To measure the relative change in energy use that would have occurred over time if sectoral structure and energy intensities had remained fixed at base year ($t = 0$) values while aggregate activity had followed its actual development, we calculate the *activity effect* as:

$$\%\Delta E_{Ai} = (A_{it} \sum_{j=1}^{n} S_{ij0} I_{ij0} - E_{i0})/E_{i0} .$$

Similarly, the hypothetical change in energy use given constant aggregate activity and energy intensities but varying sectoral structure (the *structure effect*) is:

$$\%\Delta E_{Si} = (A_{i0} \sum_{j=1}^{n} S_{ijt} I_{ij0} - E_{i0})/E_{i0}$$

and the proportional change in energy use given constant *activity and structure but varying energy intensities (the intensity effect)* is:

$$\%\Delta E_{Ii} = (A_{i0} \sum_{j=1}^{n} S_{ij0} I_{ijt} - E_{i0})/E_{i0} .$$

The specific numbers attached to each effect depend on the definitional framework used in the analysis, determined by the analyst based on theoretical considerations, data availability, and professional judgement; the specific definitions we use in each sector are summarized in Table 1-1 and discussed in the main body of the paper. This approach gives us a means of understanding the complex realities that lie behind energy-use trends. In particular, the methodology shows the importance of considering not only the efficiency but also the structure of energy use. To understand energy use one must focus therefore not only on the technical characteristics of energy-using equipment but also on the level of energy-using activities and the human context in which energy use occurs. The indices defined above are known as Laspeyres indices (Howarth *et al.* 1991).

Combining the changes in activity level and structure, we obtain a measure of *energy services*. This measures the overall output derived from energy use in any sector, much like GDP measures changes in economic activity. Using changes in energy services weighted by energy use in each sector in a base year, we can estimate how much changes in energy services alone affected overall energy use. This result can be compared to changes in energy use that would have occurred had only GDP changed; conversely, changes in the ratio of energy services to GDP affect the energy/GDP ratio independently from the effects of evolving energy intensities.

Decomposition of changes in energy use using the Laspeyres indices yields indices or growth rates of change in energy use arising from changes in each of the named factors. These indices may be multiplied to give the total change in energy use, to first order, between the base year and the final year caused by simultaneous application of all three factors. Because these changes are multiplicative when applied to energy use in the base year, the total change in energy use is *not* equal to the sum of the changes caused by each factor, but rather the product of each of the indices times the base year energy use. One can, however, compare the change in energy use, relative to the base year, arising from the effects of one factor alone changing, with those that arise if two factors act or if all three acted. These results can be compared to the actual development in energy use as well.

We define conservation as the difference between actual energy use and the amount of energy that would have been used in a given year if energy intensities in each sector were frozen at a base year level, but the activity and structure of each sector had evolved as they actually did. We measure this as:

$$\%E\ savings\ in\ sector = A_{it} \sum_{j=1}^{n} S_{ijt} (I_{ij0} - I_{ijt})/E_{it}\ .$$

1.4. The Energy Sector

The energy sector includes those industries associated with the production of district heating, electric power, finished petroleum products, town gas and other energy-related activities. The structure of energy consumption in the energy sector has changed substantially since 1970. The two oil shocks of the 1970s coupled with the introduction of nuclear power in Sweden irreversibly changed the nature of the energy sector. The shares of oil, hydroelectric, and nuclear in the production of heat and power, changed dramatically, for example, as nuclear absorbed most of the growth in electricity production while oil disappeared. In terms of delivered electricity, the share of oil decreased from 17% in 1973 to 1% in 1990, while hydropower decreased from 79% in 1973 to 51% in 1990. Nuclear power has made up the difference resulting from these changes, increasing in share from 3% in 1973 to 47% in 1990. We can also think of these changes in terms of primary fuel inputs to electricity production by adopting the convention used in the SCB energy balances which counts hydropower at 85% and nuclear power at 34%. We count other fuels such as oil and gas at 40%, which is approximately the average conversion factor for thermal power plants. By this accounting, as shown in Figure ES-1, the share of primary energy use to produce electricity by oil dropped from 30% in 1973 to almost zero in 1990, hydropower dropped from 63% in 1973 to 29% in 1990, while nuclear power increased from 6% in 1973 to 68% in 1990.

The reduction in the share of oil at district heating plants was even more dramatic (Figure ES-2). In 1973, oil provided nearly all of the fuel input at district heating plants, roughly 96%. By 1990, this share decreased to 11%, although this is partially due to the warm winters of 1989-90. The share of solid fuels such as coal and biomass increased substantially, from 6% in 1973 to 39% in 1990. Gas has also gained a small but not insignificant share at district heating plants. Finally, there is a significant input of electricity. At the same time, waste heat from industrial activities has been used in district heating systems more frequently and reduced the need for primary energy inputs. The contributions from electric boilers, heat-pumps, and waste heat from industry, in combination with more efficient fuel burning (heat recovery from stack-gas condensing) are important reasons why there has been considerable improvement in the thermal efficiency of the district heating system, from 79% in 1973 to 91% in 1990. Since much of the equipment has turned over since the time of the first oil shock, the trends in fuel choices for the production of district heating are likely to continue even as oil prices remain low, although the use of interruptible electricity in place of oil is extremely sensitive to relative prices.

Other energy sector consumption includes energy used in refineries, gasworks and non-energy consumption of oil for feedstocks and asphalts. We included these activities along with district heating and power production in a summary of the disposition of gross energy use shown in Figure I-3. The only significant change beyond those mentioned above has been more efficient conversion of crude oil to products. Refinery consumption of oil was 61% greater in 1990 than in 1973 while oil losses increased by only 17% over this period. Other energy sector consumption is rather small by comparison.

We will not analyze the energy sector in greater detail in this report because we are focused on end-use consumption. However, it is clear that important changes in the composition of primary energy use had many impacts on end-use consumption. These impacts included a significant reduction in the role of oil in the Swedish economy, an increase in the importance of biomass and of course, the substitution of nuclear power for oil in both the electric power system and through end-use substitution from oil heating to electricity.

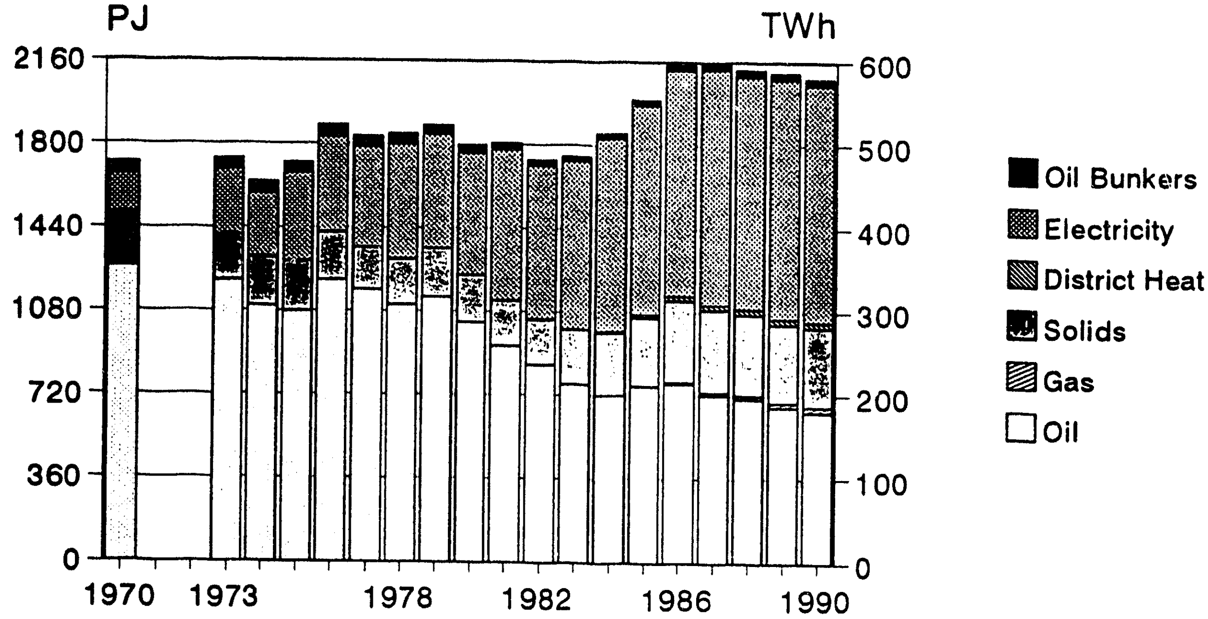
1.5. Further Analysis of Swedish Energy Use

The following sections present an analysis of energy use in each sector in Sweden. Our results are then integrated and we provide conclusions based on the Swedish observations. After these first conclusions, we compare the evolution of energy use in Sweden with that in other OECD countries. New conclusions, particularly those that may be at odds with those found in considering Sweden alone, are highlighted. In the final chapter, we discuss the implications of our findings for future developments of energy use in Sweden. The appendices detail sources for the sector analyses as well as describe important data needs for future energy analysis and policy development in Sweden.

Table 1-1. Definition of Factors for Impacts of Changing Activity Levels, Sectoral Structure, and Structure-Adjusted Energy Intensity on Sectoral Energy Use.

Sector/indicator	Definition/description of factors
RESIDENTIAL	
Activity	Population
Intensity	Space heat energy per unit of home floor area, electricity per appliance, energy per capita for cooking and hot water adjusted for home occupancy, lighting energy use per unit of floor area
Structure	Household floor area per capita, persons per household, appliance ownership per capita
MANUFACTURING	
Activity	Manufacturing value added
Intensity	Industry-group energy use/value added
Structure	Industry-group value added shares
OTHER INDUSTRY	
Activity	Value added in agriculture, forestry, fishing, mining, and construction
Intensity	Energy use/value added
Structure	Not applicable (activity not disaggregated)
SERVICES	
Activity	Service sector value added
Intensity	Energy use/value added
Structure	Share of value added in sub-sectors
PASSENGER TRANSPORT	
Activity	Passenger-km/year
Intensity	Modal energy use/passenger-km
Structure	Modal mix
FREIGHT TRANSPORT	
Activity	Tonne-km/year
Intensity	Modal energy use/tonne-km
Structure	Modal mix

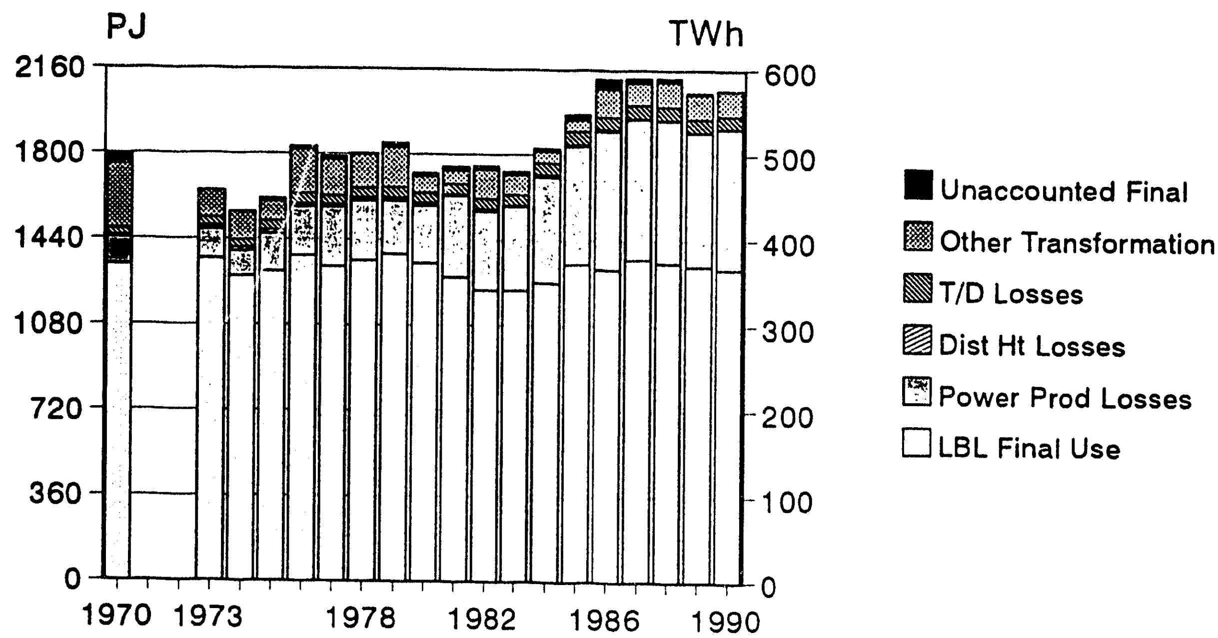
Energy Use In Sweden
Primary Use and Bunkers



Total primary inputs, from SCB, with nuclear electricity counted at thermal production and hydro at SCB accounting.

Figure I-1

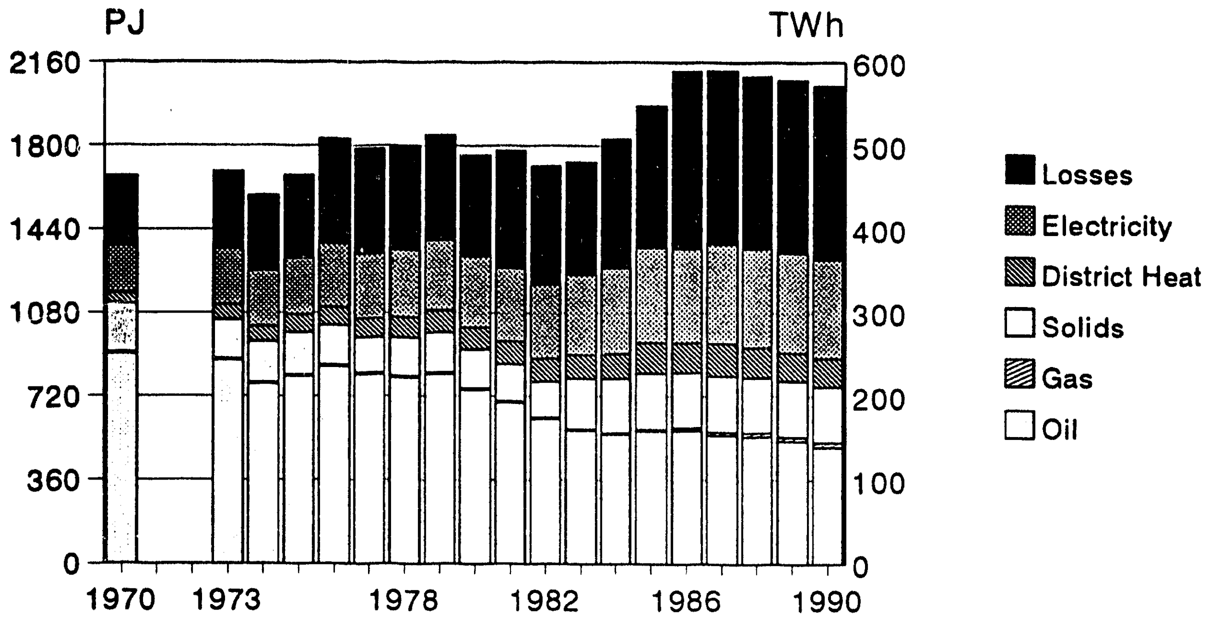
Energy Use In Sweden
Delivered Energy and Losses



Total primary inputs using SCB conventions.

Figure I-2

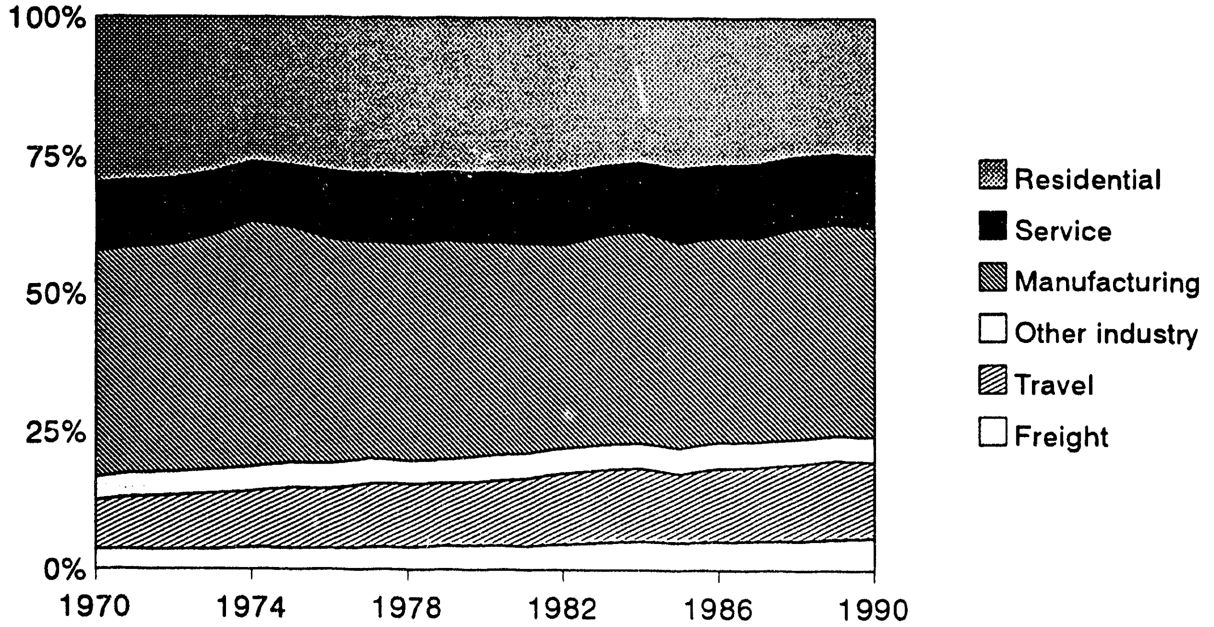
Energy Use In Sweden
Delivered Energy, by Fuel, with Losses



Total primary inputs, from SCB, showing aggregate losses, and final demand for energy by source.

Figure I-3

Energy Use in Sweden
Delivered Energy By End-Use Sector



Agriculture included in "Other Industry". Figures corrected to normal climate
Source: LBL calculations by sector

Figure I-4

Energy Use in Sweden
Delivered Energy by Fuel

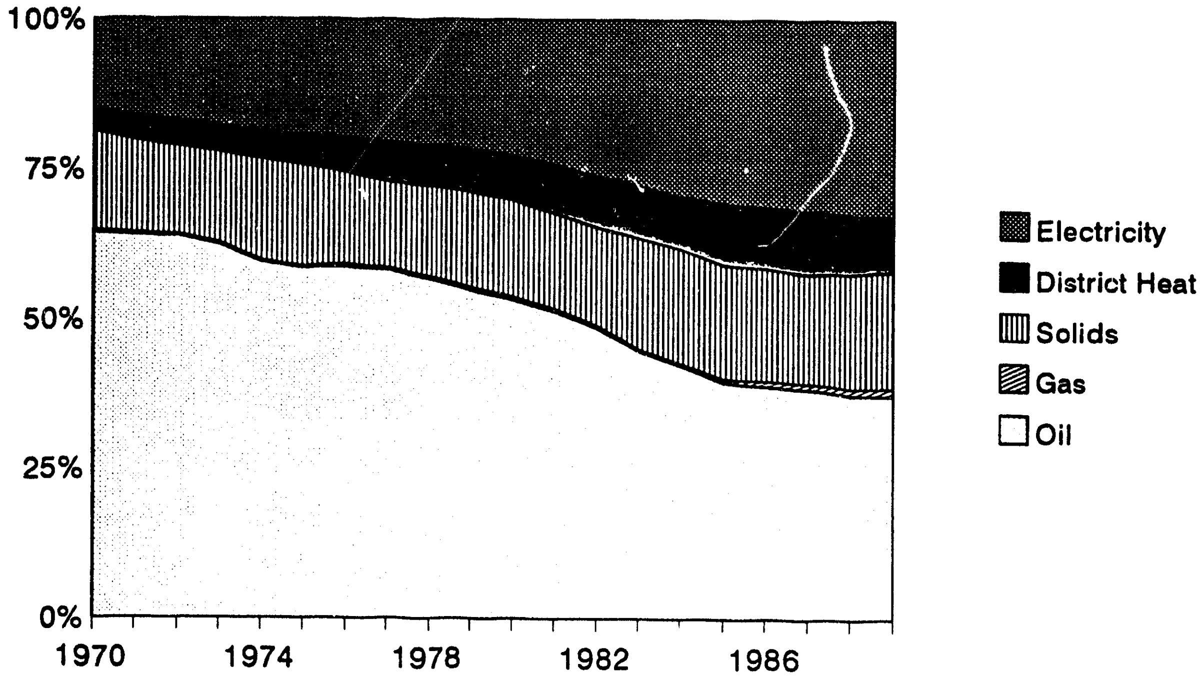


Figure I-5

Primary Energy Input for Electricity Production

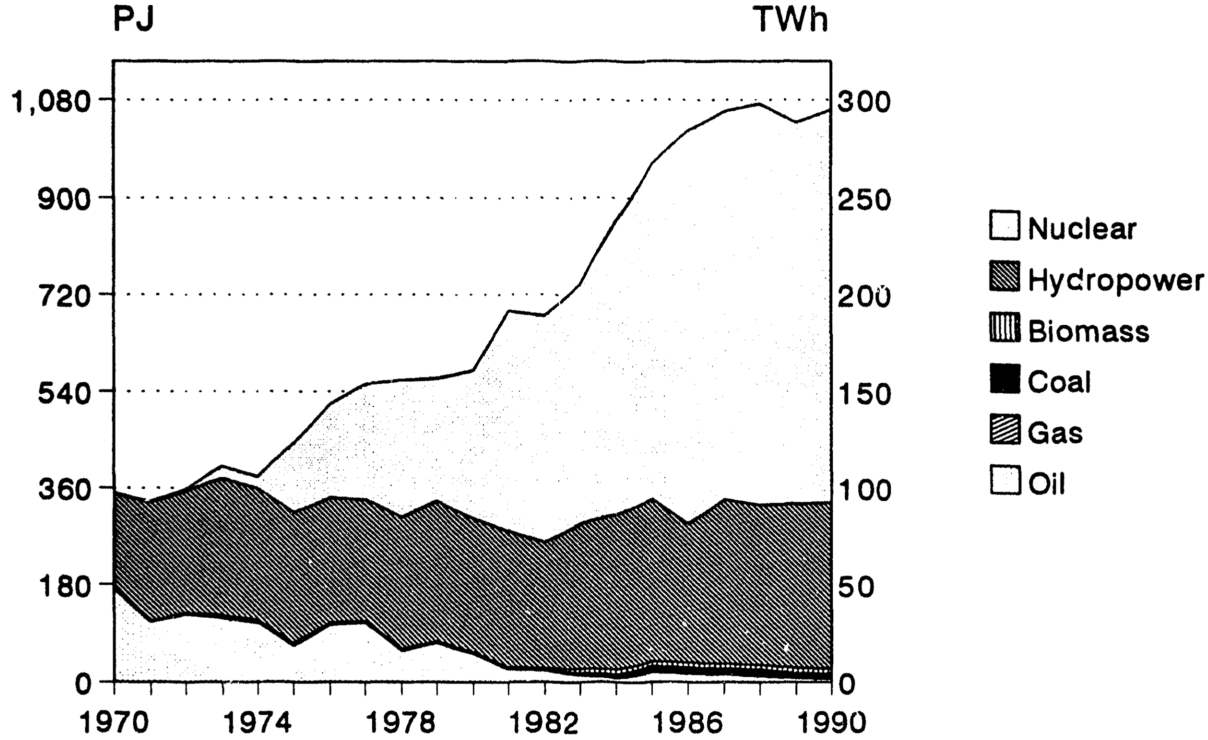


Figure ES-1

Primary Energy Input at District Heating Plants

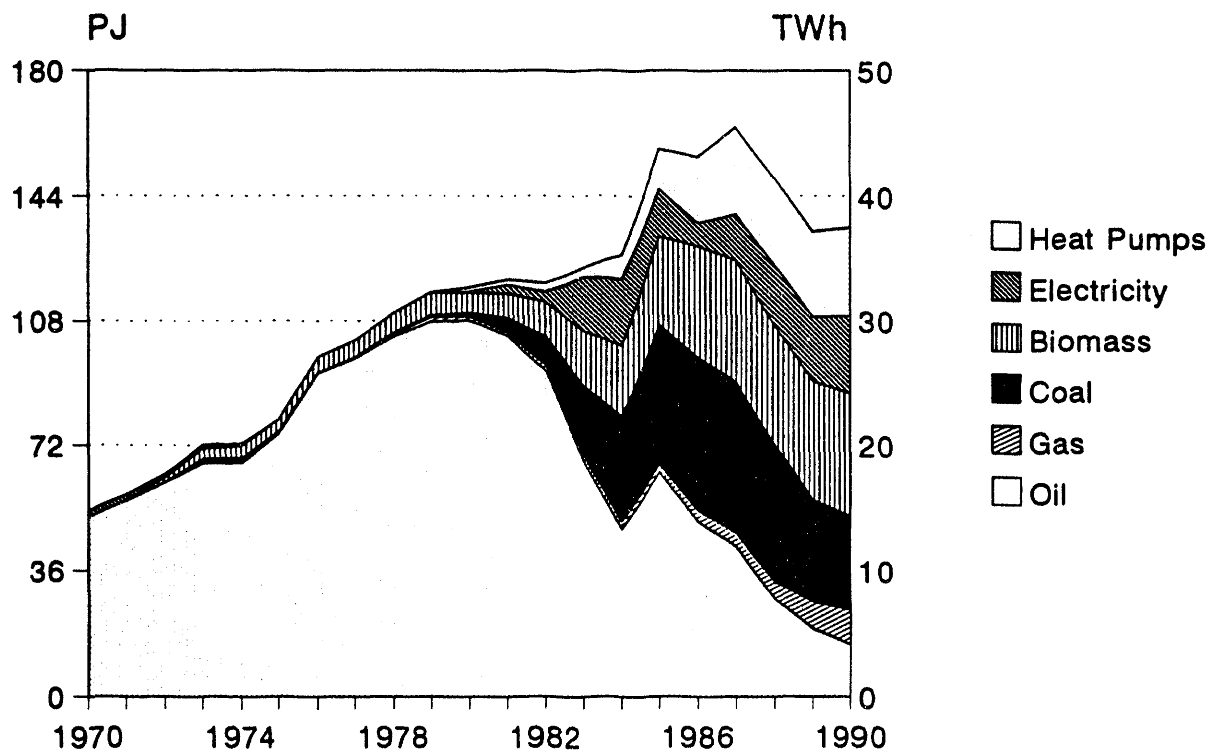


Figure ES-2

2. THE RESIDENTIAL SECTOR

Residential energy use is important in Sweden. The climate is cold, with over 4000 heating degree days (base 18°C) and the homes are large and well-furnished. In 1970, Swedish homes had a central heating penetration of over 90% and the occupants enjoyed at least 35 square meters of heated space per person. Also, few of the individual apartments in multi-family dwellings, which made up over 50% of the sector in 1970, are directly metered for heat. As a result, Sweden had high per capita energy use for households in the 1970-1973 period.

By 1990 central heating reached virtually every home, heated area per capita had increased to around 50 square meters, and the number of single-family dwellings reached nearly 49% of the stock. In addition, stocks of household appliances expanded significantly. These changes, by themselves, would seem to indicate increases in household energy use in Sweden. Yet delivered energy use in this sector was lower in 1990 than it was in 1973 and useful energy use virtually the same; only primary energy use increased, largely as a result of increased use of electricity. This section explains these many apparently contradictory trends.

Our analysis is based on conventions that differ from those in Sweden, which are explained below:

• Single-family dwellings (SFDs) include *småhus (en- och tvåfamiljshus, radhus, kedjehus)* and farmhouses *jordbruksfastigheter*. Multi-family dwellings (MFDs) include all homes in apartment buildings (*flerfamiljshus*) or in buildings otherwise predominantly occupied by businesses (*lokaler*).

• Primary, useful, and delivered energy are counted according to our conventions outlined in the introduction to this report.

• Degree days are counted as the difference between 18°C and the average outdoor temperature during the period January-June and October-December. This is derived from monthly figures from the *Överstyrelsen för Ekonomiskt Försvar* (ÖEF 1970-1985) and *VVS Tekniska Förening*, as well as yearly figures published by *SCB* in *Energistatistik för småhus* (SCB 1978-1991a). To convert from 17°C, the standard base used in Sweden, to 18°C, we add 250 degree-days, or 1 degree x 250 days (the average length of the season). An index of actual/normal is derived from this procedure. We divide the estimate use of each fuel for space heating *only* by this index to correct to "normal year".

• Central Heating (*CH*) means full house heating from hot air or circulating hot water heated by any fuel or electricity (or by hot water from a central grid), as well as heating from fixed electric radiators in virtually every room. The few homes in Sweden with no central heating have wood, coke, gas, or kerosene stoves, usually in combination with a few fixed or portable electric heaters.

• The counting of heating systems by "principal fuel" proceeds by first assigning all homes using only one fuel to that fuel. For those SFDs using oil plus another fuel, we assign them to oil. For those SFDs using electricity and wood, we assign 80% of them to electricity and 20% to wood, based on the distribution of wood and electricity use given in *Energistatistik för Småhus*. We assign those homes using three fuels to oil. District heating and gas are assigned to those fuels. Where electric heat pumps are indicated as a second source (for MFDs), we assign these to oil as the main source.

• Water heating is counted separately from space heating by estimates of system ownership and unit consumption. Water and space heating assignments are the from the early 1970s until the mid-1980s, when we begin to assign electric water heating to some SFDs using oil for space heating. The numbers are estimated knowing the number of homes using both fuels and the number of "loose" electric water heaters in homes *not* using electricity for space heating.

• Electric cooking and lighting are separated from "*hushållsel*".

• Fuel use for cooking is counted as such.

• Secondary electric heat (*dold elvärme*) is counted as such, consistent with Swedish practices, using information from *Vattenfall* and *Energistatistik för småhus*.

• "Useful" energy (*nettoenergi*) is counted as if oil and gas were coverted with 66% efficiency and solids with 55% efficiency, while electricity and district heat are 100% efficient. The purpose of this assumption is attempt to equalize the different space and water heating fuels when they are aggregated. Carlsson, of *PREDECO* (1992) presents reasonable estimates that differ from these and vary over time. Carlsson's assumptions mean that the changes in "useful energy" as they measure them are less than ours, because the loss of energy in combustion improves by their measure. Experience in our previous study of Denmark suggest this effect is small, about 10%.

2.1. Structure of the Residential Sector

2.1.1. Housing, Space and Water Heating

When the 1970s began there were slightly more than 3.2 million occupied homes in Sweden, and almost 59% of these were apartments, a result of the *million program* of the 1960s. By the mid-1970s the building rate for apartments began to fall, while that for detached housing remained strong. As a result, the share of apartments fell to 51% of the dwelling stock by 1989. Put another way, SFDs comprised only 41% of the stock and housed a bare majority of the population in 1970 and had about 55% the total floor area; by 1990 more than 60% of all Swedes lived in detached housing, whose share of total floor area had skyrocketed to 63%. This shift accounted for most of the increase in heated area available to Swedes.

Figure R-1 shows the distribution of main heating fuels used in all homes in Sweden. In 1970, oil heated 70% of all homes in Sweden. Electricity, wood, and even coal and district heating accounted for the remaining homes. Before the first oil shock, the oil share was already falling slowly, prodded by district heating for new apartments and electric heating for new detached homes. The first oil shock accelerated the decline markedly, and the share of oil heated homes fell to 55% in 1979, then crashed to 31% by 1986, settling at a slightly lower level thereafter. Over the same period, the share of district heating trebled while that for electric heating increased nearly seven fold.

Accompanying these shifts in heating fuels was the achievement of virtual saturation of central heating (including fixed electric radiators), running hot water, and electric or gas cooking. Differences in the standards of SFDs and MFDs were great in the early 1970s: MFDs had a higher penetration of central heating and running hot water than SFDs, while SFDs housed more heated area per person than MFDs. By 1990 these differences had narrowed. The rise in the importance of SFDs meant that increasing numbers of Swedes paid directly for their heat according to actual consumption, an important stimulus to energy efficiency.

Several other changes occurred in the heating system that affected energy use. According to early SIFO surveys (Schipper 1984b), only a small share of SFDs used more than one fuel for heating in 1970; by the late 1990s, a majority of the SFDs used combinations of oil, wood, and electricity. This switch indicated greater interest among occupants in reducing their heating costs by playing off one source against another. Particularly impressive in this mix is the presence of wood, used in roughly 1/3 of the single-family dwelling stock. Wood made an important comeback as a key complement for both oil and electricity in SFDs, as well as the principal heat source in over 100 000 SFDs by the 1980s. This wood is almost always self-gathered, and represents (since 1976) a form of untaxed income.

A second important shift is that from direct electric heating to hydronic heating, stimulated by the *ELAK* rules of the mid-1980s (Schipper, Meyers, and Kelly 1985 [SMK 1985]). This shift protected those using electric heat from possible shortages or price increases, since they could switch their electric boilers to other fuels or even connect to a district heating system.

The majority of occupants of MFDs still get their heat from water-borne systems, now fueled principally by district heat in place of oil. Few efforts to advance direct metering of individual apartments succeeded. Not surprisingly, the intensity of MFDs space heating (per square meter or per capita) is virtually the same, for a given fuel and building vintage, as for SFDs. That is, few occupants in MFDs have an incentive to control their heating actively with their thermostats and valves. Apartments are warm. As a side effect, secondary heat is only used by those in apartments whose indoor temperatures cannot easily be maintained at the usual 21°C during cold periods. Natural gas moved in slowly in the late 1990s to MFDs, but appears stalled because nearly all of the MFDs in dense areas are served by district heat. Thus, while enormous changes took place to heating in SFDs that were directly evident to occupants, little happened to the indoor heating environment for those Swedes still in MFDs.

Water heating in Sweden usually followed the energy source of central space heating, prepared in the same system. When oil prices increased and multi-fuel boilers became more popular, however, increasing numbers of those in SFDs turned to electricity for water heating in the summer or indeed year-round. We estimate that this began in 1980, leveling at about 100 000 SFDs by the late 1980s. About 3% of the apartment stock appears to rely on electric heat-pumps for water heating, but most of the rest use the same fuel as for space heating. Individual boilers are only common for those in MFDs (and SFDs) with electric resistance heating.

Cooking was based primarily on electricity in 1970 (85% of homes had an electric oven and cooker), with 11% used gas and the rest used wood or small electric rings. Wood all but disappeared in the 1970s, and the role of gas fell to approximately 3% of all homes; furthermore, city gas yielded to natural gas in many of these homes. As with space and water heating, the result of this fuel substitution was to reduce delivered energy for water heating more than was accounted for by energy conservation.

2.1.2. Electric Appliances

Figure R-2 shows the developments in appliance ownership during the period 1970-1990.[1] In 1970, Swedish homes had many electric appliances, including refri-

[1] The jump in ownership of clothes washers is a result of including access to collective washers in "*tvättstugor*" in some surveys.

gerators, freezers, televisions, and washing machines, boosted by the rapid entry of dishwashers, clothes dryers, car heaters, saunas, and other important equipment. Apartments often had collective rooms (*tvättstugor*) used for washing, something unusual in much of the rest of Europe.

2.2. Fuel Mix and Energy Intensities

Figure R-3 shows the development of energy use by source in the residential sector. Included are the losses in producing electricity and district heating, as we count them in our study. The increase in these losses reflects the enormous increase in electricity use, mostly for space and water heating rather than for purposes that can only be met by electricity, such as lights, motors and electronics. In this sense, fuel substitution lead to a decline in delivered energy use.

The substitution of district heating for oil lead to very little change in primary energy use for heating and hot water. The substitution of electricity, however, has a profound effect depending on which accounting convention is used. If we adopt the old way of accounting in Sweden (nuclear power and hydro power counted at the rate of electricity produced), substitution of electricity for oil heating reduces primary energy use; if we count nuclear power at equivalent of the thermal energy expended (nuclear fuel consumed) in power stations and hydro power counted at 85% production efficiency, primary energy consumed for heating remains about the same. If we adopt this convention for nuclear power and count hydro as if it were also provided by thermal powerplants, the most common OECD convention, energy use for heating in Sweden increases substantially. Figure R-3 follows the latter convention, which is why primary energy use for households in Sweden is considerably higher in 1990 than it was in 1973.

If we examine delivered fuels, we see how oil dominated delivered residential energy use in 1970, accounting for a full 71% of delivered energy use (after climate correction). By 1990, the oil share had plummeted to only 25%. By contrast, electricity's share rose from 12% to 39% and that of district heating from 7% to 20%. These shifts alone accounted for a marked decline in delivered energy, since the losses in using electricity or hot water for heating are minimal compared to those involved in burning oil. Wood, which was disappearing in the late 1960s, made an important comeback as a key complement for both oil and electricity in SFDs, as well as in over 100 000 SFDs by the 1980s as the principal heat source. City gas yielded to natural gas, but remained unimportant overall. Coal and coke had already been drive from the market by oil in the late 1960s.

Fuel prices showed mixed developments. Oil prices shot up in 1973 and again in 1979, and remained high in the 1980s as taxes were added. District heating generally followed oil with a lag. Electricity prices moved up only moderately; during the 1980-1984 period electricity was virtually cheaper than oil as a source of heat (if oil was converted at 70% efficiency), certainly one factor causing the landslide of oil use in favor of electricity. As Carlsson (1992) of *PREDECO* shows, the real cost of heating a square meter in Sweden in 1990 was higher than in 1970, mainly because of the higher cost of oil and district heating.

2.2.1. Space and Water Heating Intensities

Measuring individual intensities back to 1970 for space and water heating is difficult. From *Energistatistik för Småhus* and other sources (Schipper 1984b), we assembled estimates of the specific consumption of oil, district heat, and electricity for space heating, as shown in Figure R-4. Figure R-5 shows the assumed consumption for water heating that was removed from the combined total of water and space heating.

The contrasts are dramatic. In spite of uncertainties, it is clear that oil heating intensities fell the most. Even correcting for the use of second and third fuels, the "only oil" SFDs reduced their heating intensities by 30% between 1973 and 1986. We believe this is reflected both in hot water use and space heating use. Part of this decline occurred because so many older homes coverted from oil heat, leaving newer, better insulated homes to use this heat. Similar trends occurred in oil-heated MFDs. The drop in the intensity of district heated MFDs was less dramatic, both because there were no gains made in improving boilers on site *and* because so many older oil-heated MFDs were converted to district heating.[2]

The same problem affects the interpretation of electric heating intensities in SFDs. On the one hand, there are ample data showing that more recently built SFDs use less electricity per square meter than older ones (SMK 1985; *Energistatistik för Småhus* various years). Yet the aggregate picture does not show a clear decline in electricity use per square meter for main space heating. Some of the uncertainty rests with the assumptions that have to be made about total electricity used for space heating, but there are ample data from the early 1970s and late 1960s characterizing the housing stock of that period (SMK 1985; Schipper 1984b). We have no doubt that electric heating intensity fell in SFDs, but

[2] It is well known from *Energistatistik* that heating intensity in older dwellings is higher than in newer ones. Some of this difference has been reduced through retrofits since 1973.

hesitate to attach too much significance to that decline because of the influence of these uncertainties and the use of secondary fuels, as well as the use of electricity for other purposes. Our best estimate is that the electricity intensity of heating in homes built before 1973 declined by 15% and that in newer homes it was a full 30% below the 1973 values. These "gains", however, were offset by an increase in the number of leakier homes built before 1970 or even 1960 that converted to full or partial electric heating. As a result, *average* electricity use per square meter of homes heated entirely by electricity does not appear to have declined significantly.

2.2.2. Electric Appliances

There are few good measurements of actual consumption of electricity for individual appliances. Using models built by *Vattenfall* (Malinen 1989) and estimates from various CDL and Kraftsam forecasts (see Schipper 1984b; Tyler and Schipper 1990), we assembled the best estimates of actual unit consumption for household appliances in 1973, 1978, 1982, and 1987 (Figure R-6). These estimates indicate a significant potential savings in the actual stock of appliances. We caution that by 1987 the six major appliances only account for about 50% of the electricity not allocated to heating, lighting, cooking, or water heating. Clearly there are important uncertainties about present use that may be resolved by experiments underway.

In spite of these uncertainties, we believe real improvements occurred. Data from Electrolux (Schipper 1984b; Tyler and Schipper 1990) indicate important reductions in energy use in new appliances. Since the number of combination refrigerator-freezers, dishwashers, and clothes dryers more than doubled in the period we have studied, the UECs for these three appliances could easily have fallen by more than a third, as is suggested. For freezers and washing machines, the turnover has probably been slow. But electricity savings in washing machines also reflects changes in washing practices that have occurred in many countries, particularly colder water temperatures and lower water use in general (Tyler and Schipper 1990; Schipper and Hawk 1991).

2.3. Evolution of Energy Efficiency and Energy Savings

Since energy intensities are the key indicator of energy savings, it is important to assemble the information available to see what happened in Sweden. Many of the uncertainties in the evolution of the intensity of any given fuel cancel when these are aggregated using useful energy. Figure R-7 shows the evolution of delivered energy and primary energy per capita (from Figure R-3) as well as useful energy per capita. The decline in delivered energy intensity is not matched by a decline in useful energy intensity, while primary energy intensity increases. These divergences suggest that while efficiency may have improved, it is both masked by the impact of structural changes and fuel substitution, and to a certain extent mimiced by fuel substitution as well.

To examine this problem further we show the main components of energy intensity stacked in Figure R-8. We see that useful energy per capita for most purposes shows no dramatic savings. This is because the amounts of energy service (heating and area heated or numbers of appliances) have increased over the period we have studied.

To see beyond this, we tabulated useful energy per square meter for space heating. This indicator showed a dramatic decline of over 33%, in spite of a slight increase in penetration of central heating. Also, the energy intensities of individual electric appliances declined. Water heating energy intensity declined too, even beyond the decline we might expect from the shrinking size of households. Clearly, Swedish households saved energy.

To better understand these changes, we measured the evolution of energy intensities holding other effects constant which indicates whether energy conservation has occurred.

- For space heating, we hold floor area and central heating penetration constant. Experience shows that homes with central heating use about twice as much fuel as those without. Therefore, we construct an index $(1 + CH)/2$ that takes the value of 0.5 if no home has central heating and 1 when all have central heating. We divide useful space heating by this index in any two years to compare changes between the two years. If space heating intensity (i.e., per square meter) fails to keep up with the increase in this index, conservation is indicated.
- We normalize useful energy for water heating and cooking by the square root of the number of people in a household, because of the observation that energy use for these two functions scales with the square root of the number of people in a homes. The size of households in Sweden fell by nearly 12% between 1973 and 1990, an effect which by itself reduced energy needs for water heating and cooking. Thus any decline in useful energy per capita for water heating or cooking beyond that suggested by shrinking household size is measured as conservation.
- We measure changes in lighting energy use by dividing by house area.
- We measure changes in electricity use for the six major appliances by forming an index of use in any year, and multiplying actual appliance electricity intensities by the base-year ownership data of electric appliances.

From these calculations we form indices of energy intensities. These indices, when multiplied by 1973 base year energy use for each purpose, yield changes caused by changes in intensity. The converse procedure, holding 1973 intensities constant and varying only the structural parameters (home size and central heating in each year, the square root of household size, appliance ownership for each year weighted by the 1973 intensities of each appliance) yields estimates of changes in per capita household energy use arising because only the structure of energy use changed.

The results of these two calculations are shown in Figures R-9 for delivered energy and in Figure R-10 for primary energy. The same calculation carried out for the major electric appliances alone are given in Figure R-11. All three figures indicate a clear drop in intensity. The difference between the primary and secondary intensities arises primarily because of substitution towards electricity. Since electricity is weighted 3 times more in "primary" than in "delivered" energy, about half of the apparent drop in intensity measured as delivered energy arose from fuel substitution. If we hold everything but the shares of fuels used for space and water heating constant, we see roughly the same results.

Note in Figures R-9 through R-11 that the structure effect is important. That is, increased home area and appliance ownership per capita, and falling household size all contributed to driving up household energy use by some 33%.

2.4. Causes for Changes

What caused changes in energy use in Swedish households? Higher incomes and falling household size contributed to increased per capita area and equipment ownership, the main causes of *structural* change. As Carlsson points out, however, stagnation in incomes or related measures in the mid-1970s and again in the mid-1980s also depressed household energy use in ways that were easily reversed when hard times passed. Higher oil prices (Figure R-12) encouraged a great deal of conservation of oil and fuel switching as well. Indeed, the price of heat from electricity was lower than that from oil in the early 1980s, as comparison of the two prices suggests.[3] Subsidies for conversion to electricity played a role as well. Not surprisingly, the rush away from oil slowed considerably after the price of heating oil fell in 1986.

[3] In the figure the price of oil is about 80% of the price of electricity. Unless an oil system is more than 80% efficient, the cost of the heat delivered to a room from resistance heat in each room is less than that from the oil furnace.

What about energy conservation programs? In earlier work (SMK 1985; Schipper 1984b) we noted that energy saving occurred in homes where public funds were used for retrofit measures, but that similar savings occurred in homes not taking public funds. Looking back on the years of energy efficiency programs, it is hard not to credit these programs with provoking important conservation investments in MFDs, where individual incentives to save through either changed behavior or investment have always been small. But it is also difficult to quantify how much investment in measures by occupants of SFDs, and subsequent energy savings, occurred solely because grants and loans were available (Wilson *et al.*, 1989). The precipitous fall in oil heating intensities when prices shot up is difficult to trace to programs that took several years to be developed. On the other hand, the combination of higher oil heating prices *and* efficiency programs probably reinforced the results of each stimulus itself.

The fact that oil intensities fell so greatly, while electricity intensities fell so much less is consistent with the radically different behavior in the real prices of these two heating sources in Sweden. By contrast, in countries where prices for *both* increased (Denmark, France, and the U.S.), electricity intensities fell along with those for oil. Energy efficiency subsidies for existing homes were present in some form or another in all three of these countries as well as in Sweden. This suggests that prices changes have been an important stimulus to changes in space heating.

The entry of new homes into the stock reduced average energy intensity for heating in Swedish homes. This was primarily an effect of the rapid expansion of the SFDs stock, which had significantly lower heating intensity than did older SFDs. This lowered intensity was supported by the financing system, which assured that any reasonable effort to exceed the regulations in the building requirements was financed (SMK 1985). To be sure, the building codes were strengthened in 1977 and again in the early 1980s. The changes in 1977 (SBN 1975) were clearly weaker than what was already occurring in practice (SMK 1985). Those proposed for 1985 (ELAK 1980) were widely debated. Our earlier study (SMK 1985) suggested that *ELAK* requirements, which affected homes heated with electric resistance heat, were somewhat beyond common practices then, and probably did provoke changes in the average practices for these homes.

What provoked the improvements in electric appliances? The most important factor named by manufacturers was the pressure from international markets, particularly Germany (Schipper and Hawk 1991), where both programs and higher prices heightened manufacturer and consumer interest in more efficient appliances. Swedish authorities called for improvements, but no mandatory standards were put in place. Increased testing and information in Sweden helped consumers make better informed choices, but conversations with manufactures throughout Scandinavia always raise doubts about the overall importance of this information. Certainly no consumers ignore the energy-use characteristics of new appliances, and no consumers are wholly insensitive to the role of electricity prices and total consumption. But it is also hard to credit most of the change in new-appliance characteristics to changes in consumer buying habits. Since electricity prices did not change very much, we believe that international pressures on Sweden's multinational appliance suppliers, bolstered somewhat by more information and heightened consumer interest, "caused" manufacturers to improve their product and consumers to buy these products.

Were the reductions in energy intensities achieved by 1990 permanent? Certainly the two periods of extremely higher prices and depressed incomes (1975 and 1979-82) led to small temporary drops in energy use for almost all purposes. But there was no precipitous drop in space heating intensities as observed in many other countries. This happened for two reasons. First, Swedish homes were well insulated in the physical sense, and therefore in the economic sense, when heating prices shot up. Second, the large number of apartments without metering meant that there were few direct incentives for occupants to change their behavior. As a result, the real changes in heating intensity occurred slowly, mostly through technology. Indoor temperatures in the early 1980s lay over 20°C (Schipper 1984b), hardly an indication of ongoing sacrifice. The other side of this development, however, is that there is very little unsatisfied heating demand waiting to spring back if prices fall or incomes to skyrocket. Similarly, the changes in electricity use for appliances came about through gradual turnover in the stock, with the new products always less electricity intensive than those that were replaced. This evolution also leaves little to be "reversed". Consequently we judge that virtually all of the difference between 1990 and 1973 household energy intensities is permanent.

2.5. Prospects

There have been significant changes in the level and structure of residential energy consumption in Sweden over the last two decades. These changes have led to a 28% decline in useful delivered energy intensity since 1973 and a 35% decrease in the intensity of electricity consumption. At the same time, decreased household size and heated floor area have worked against this trend to keep total energy consumption from falling significantly. Among the significant changes was the large-scale shift away from oil heating in the wake of the two oil shocks of the 1970s. Another important change has been the improvements in building practices driven by stricter building codes and increased energy prices, resulting in better-insulated and more comfortable homes. A third and more recent change has been the improvement in the efficiency of electrical appliances used in the household. Improvements on the supply-side through decreased losses at district heating plants and in electric power plants have also benefitted the overall energy efficiency of the residential sector.

The level of amenities in homes in Sweden is nearly saturated. Central heating is virtually universal. Homes are near the largest of any OECD country (in spite of the high share of apartments), while household size is the lowest of virtually any OECD country. Per capita house area is unlikely to grow strongly because of expected slow down in long-term economic growth. The *Vattenfall* studies (quoted in Appendix 4 of *Elanvändningsdelegation* [1987]) expect only a small impact on household electricity use of increases in appliance ownership. Also, population is growing very slowly. Thus, we expect very little change in energy use for homes through structural or activity changes. The only major changes in the structure of household energy use could be a shift to natural gas.

What do these changes mean for the future trends in the energy efficiency of the residential sector? We can consider first the fact that the efficiency of most residential appliances will continue to improve, especially since they are a number of incentive programs in place on the manufacturing end. For appliances that are already saturated, such as refrigerators, this will result in a continuing decline in total end-use consumption. However, for appliances whose ownership profile is changing, such as dishwashers and dryers, there is the potential for slight increases in total end-use consumption in the next decade. Overall, we can thus expect slight increases in appliance energy consumption as the saturation of most appliances begins to level off.

In space heating and water heating, however, we see a different pattern emerging. As discussed above, the decreases in household energy intensities can be regarded as "permanent" in the sense that these changes came about on the technology side rather than through behavioral changes that may have been temporary. However, much of the savings in final energy are the result of fuel-switching to electricity and district heating. Unlike direct heating with fuels such as gas or oil, there is no possibility to improve electric heating-equipment efficiency without changing to a new technology, such as a heat pump. This means that much of the savings are tapped out in existing homes that have resistance heating and relatively good insulation. To be sure, *Uppdrag 2000* (Hedenström 1992) found some potential for improving such homes, through some additional insulation and improving windows to those with three panes. The main future improvements, however, appear to lie in the thermal standards of new homes, which will gradually raise the old ones. The widespread use of electric resistance heating and district heating locks out many future improvements in the individual heating system in the same sense that these improvements were locked in by their proliferation. While Sweden has backed out of oil successfully, Sweden has not moved to other fuels, such as natural gas, with the result that their overall residential energy system might be considered less diverse and more inflexible in the face of uncertainty. Fortunately, the popularity of low temperature hot-water as the medium for electric heating, sparked by *ELAK*, adds an important degree of flexibility to electric heating, as does the spread of two- or even three-fueled boilers. And the same can be said for district heating, which can use fuels like woodchips or other forms of biomass that are difficult to handle in small boilers. And the fact that the majority of single-family homes using oil or wood for the main heating source also have a second or third source adds diversity.

The outlook for energy intensity and energy use is thus varied. The current recession will likely lead to a temporary down turn in household energy use and a slowdown in investment in efficiency or new equipment as well. In the longer term (i.e., towards 2000 and beyond), intensities should continue to move downward. New homes in Sweden have very low heat losses already, so little further improvement is expected in this small sector, but their entry into the housing stock pushes down average intensities. No one doubts that there is a potential for continued, if slow, heat saving in existing homes through home replacement, retrofit, and renovation. What is uncertain is the pace of this decline, both for fuels or district heat and for electricity. That is, consumers appear satisfied with their present level of energy costs. But electricity intensity for appliances and lighting may fall more rapidly, prodded by *Teknikupphandling* and price increases as well.

Can efficiency programs be designed that will truly stimulate individuals and organizations controlling homes to undertake large investments to reduce heating needs? The evidence from Sweden's past is ambiguous. The programs of the late 1970s and early 1980s led to much activity, but some investments were barely profitable (SMK 1985), and some could have occurred anyway (the so-called "free rider" problem). And the flurry of installation of heat pumps is still to be validated as an *energy* saving measure, although few doubt this measure effectively promoted electricity in place of oil.

Whether state and local authorities will continue to have enough resources to offer generous subsidies is unclear, and so therefore is the pace of any stimulated retrofit or renovation program. *Vattenfall*'s ambitious *Uppdrag 2000* demonstrated that the potential savings in electricity use in homes and buildings are modest. Nevertheless, this program has still not moved beyond the (successful) experiment stage to a full scale program of retrofits, particularly in the relatively well-insulated homes heated with electricity.

Residential Energy Use in Sweden
Space Heating Fuel Choice

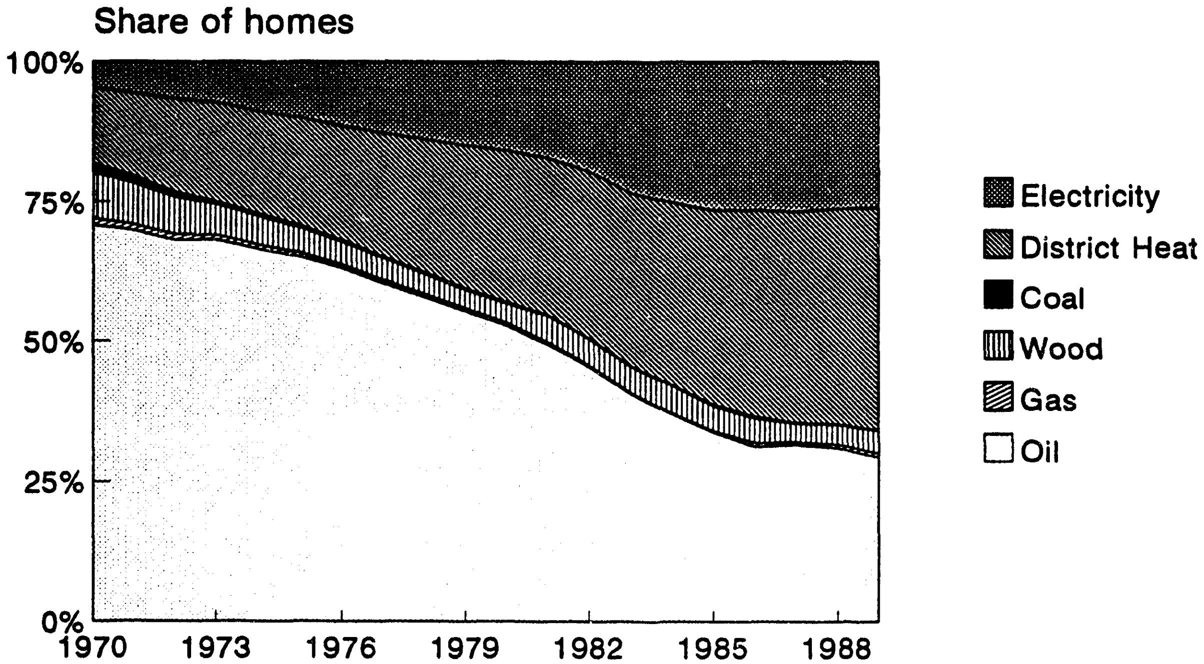


Figure R-1

Residential Energy Use in Sweden
Diffusion of Appliances

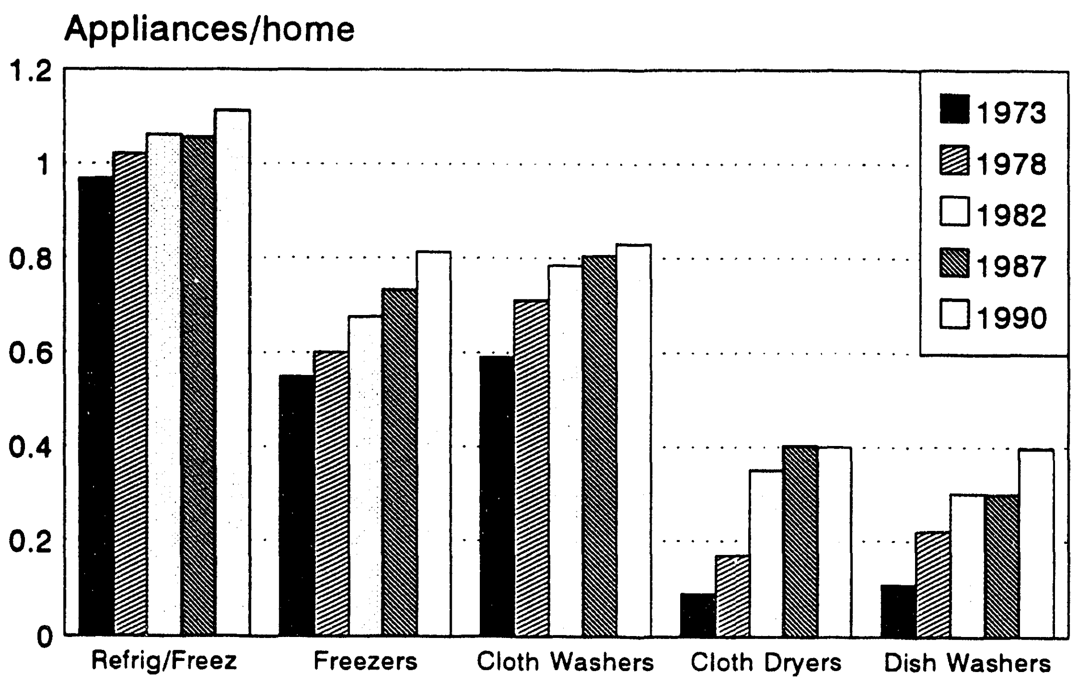
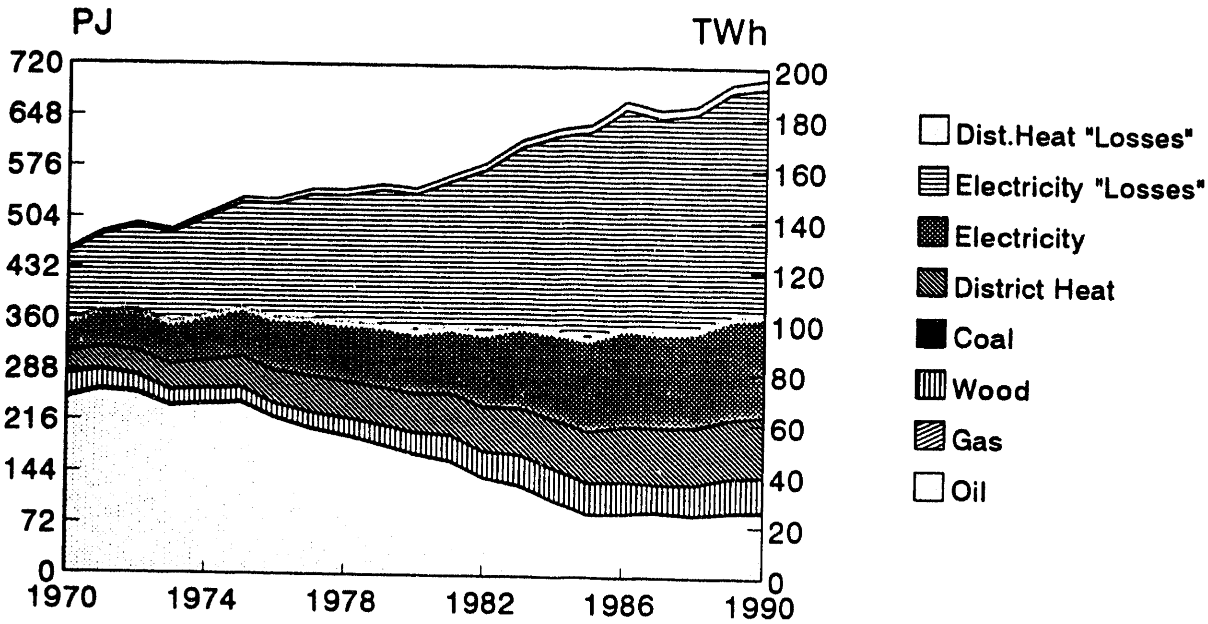


Figure R-2

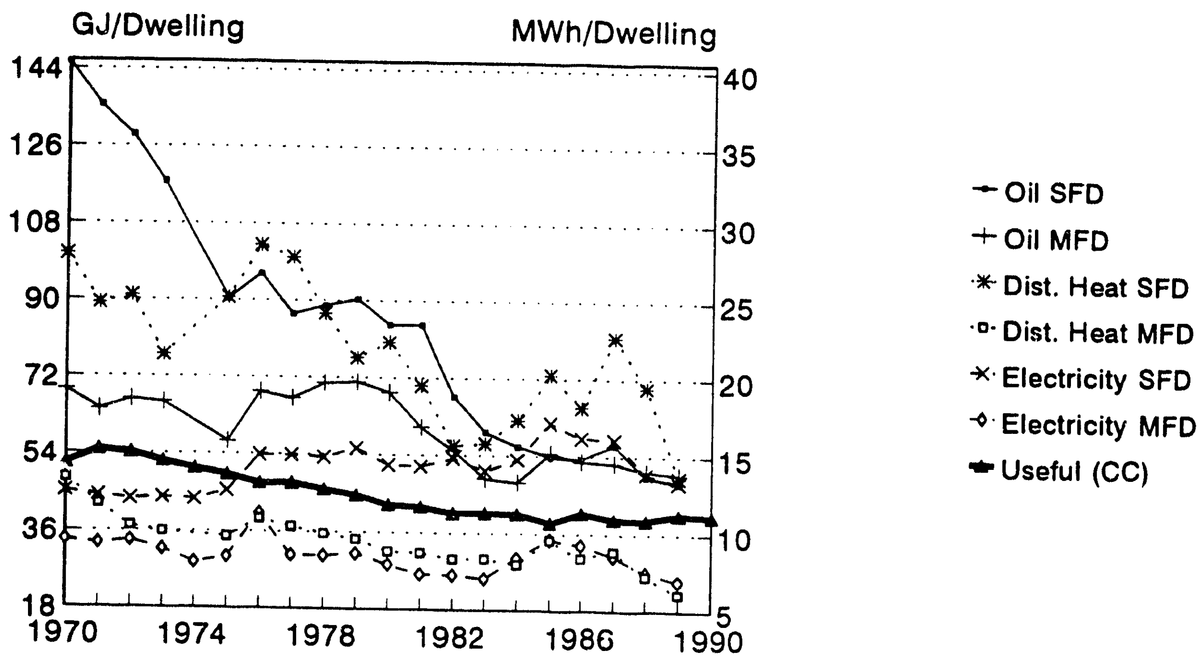
Residential Energy Use in Sweden
Delivered Energy, Climate Corrected



"Losses"= production & distribution losses using LBL convention.

Figure R-3

Residential Energy Use in Sweden
Space Heating Intensities by Fuel



Uncorrected for climate except useful average

Figure R-4

Residential Energy Use in Sweden
Delivered Water Heating Intensities by Fuel

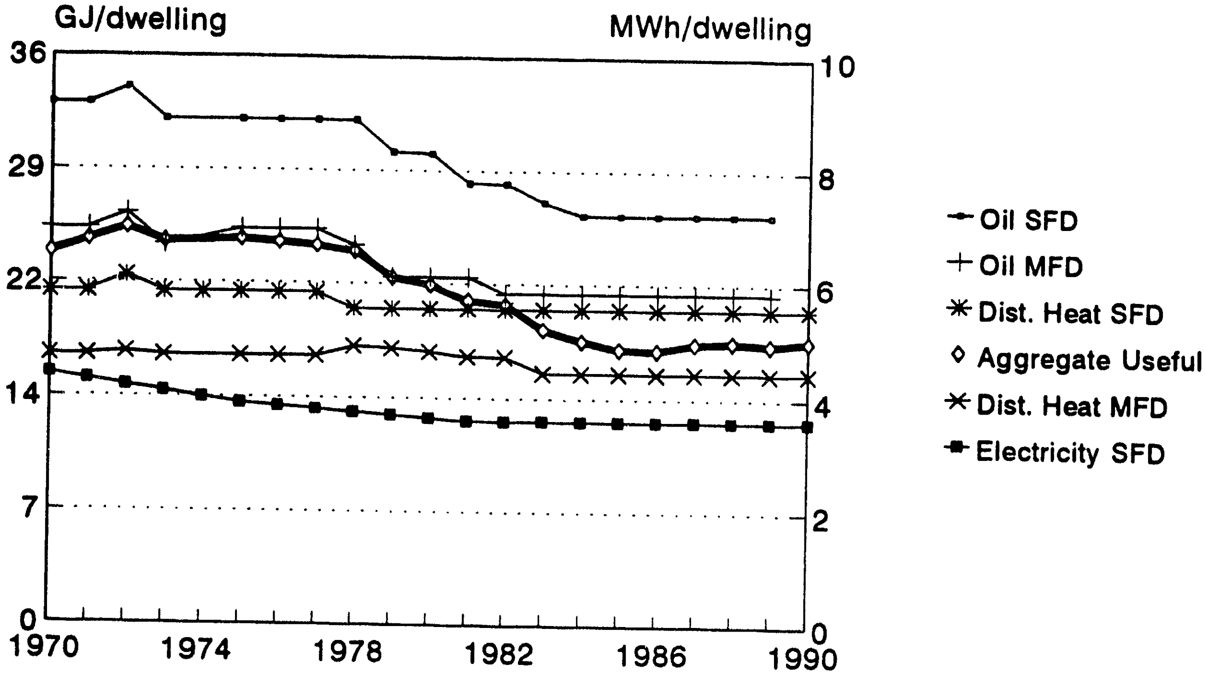


Figure R-5

Residential Energy Use in Sweden
Appliance Unit Consumption

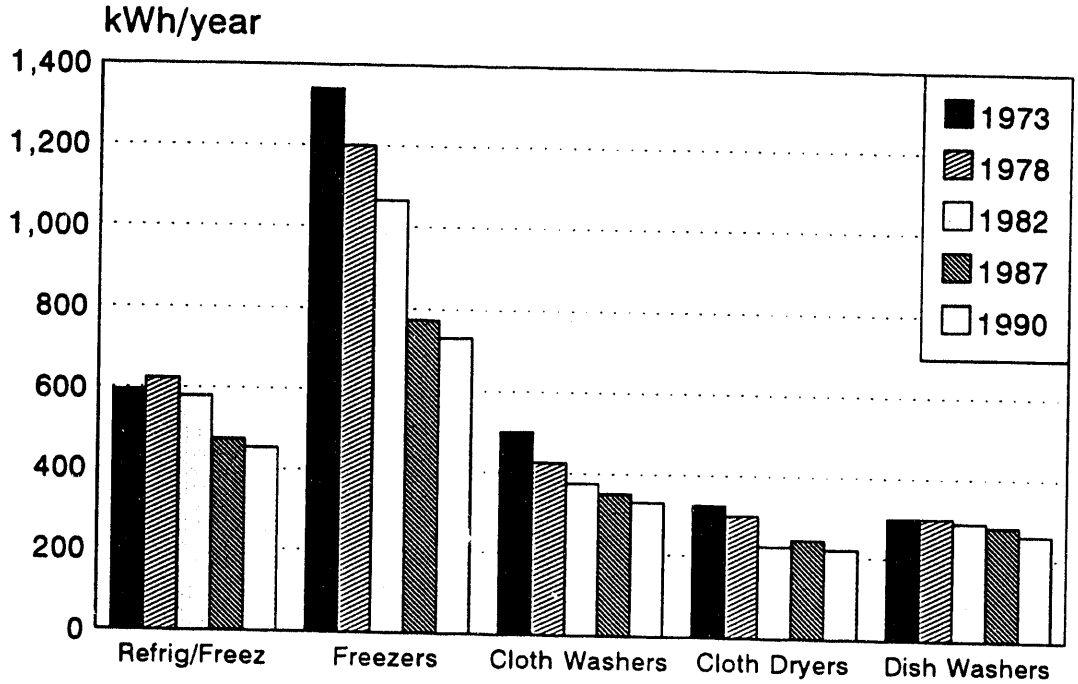
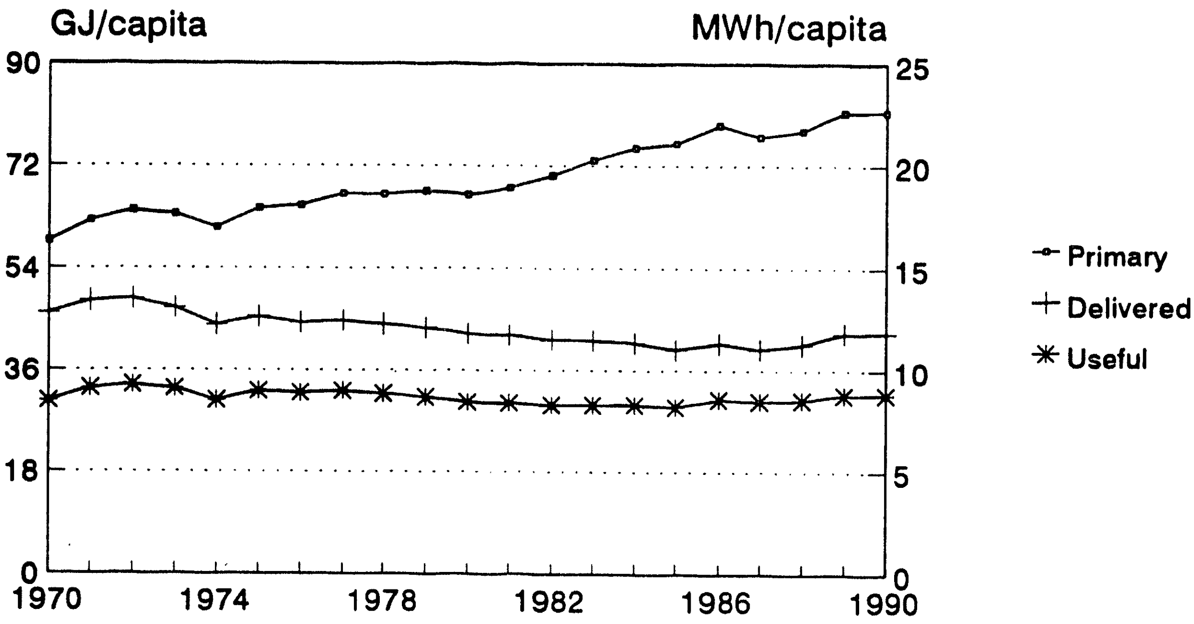


Figure R-6

Residential Energy Use in Sweden
Three Measures (Climate Corrected)



For definitions of measures, see text

Figure R-7

Residential Energy Use in Sweden
Useful Energy per Capita, Climate Corrected

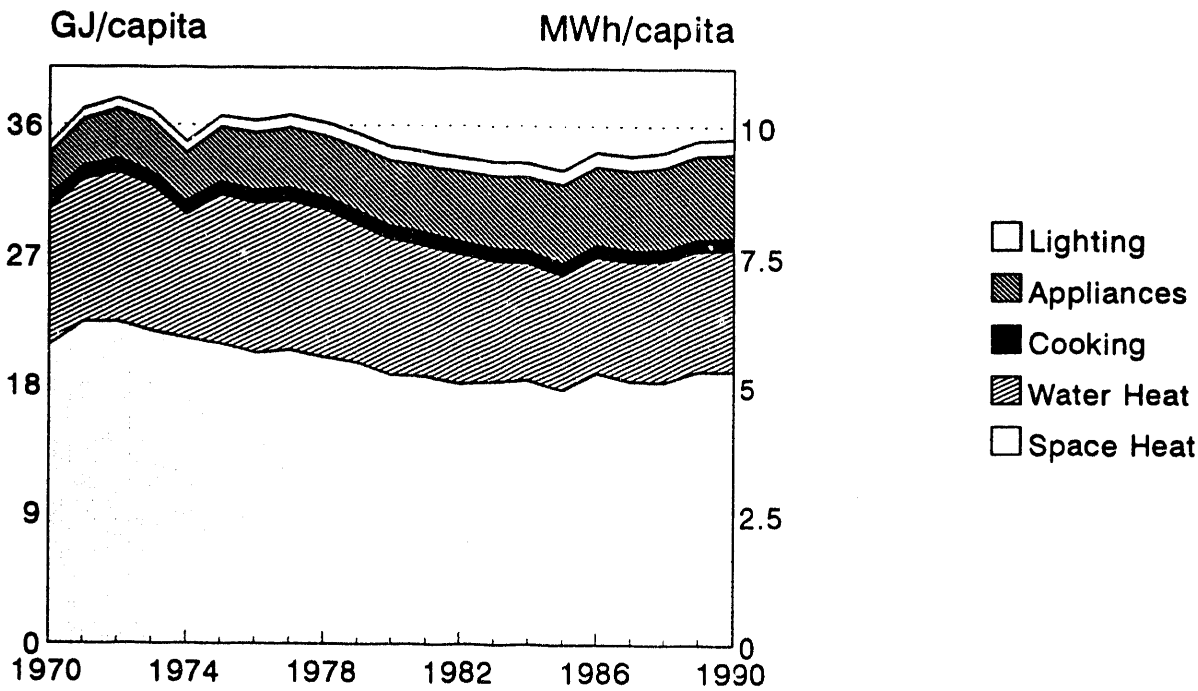


Figure R-8

Residential Energy Use in Sweden
Activity, Structure, Intensity Effects
Delivered Energy

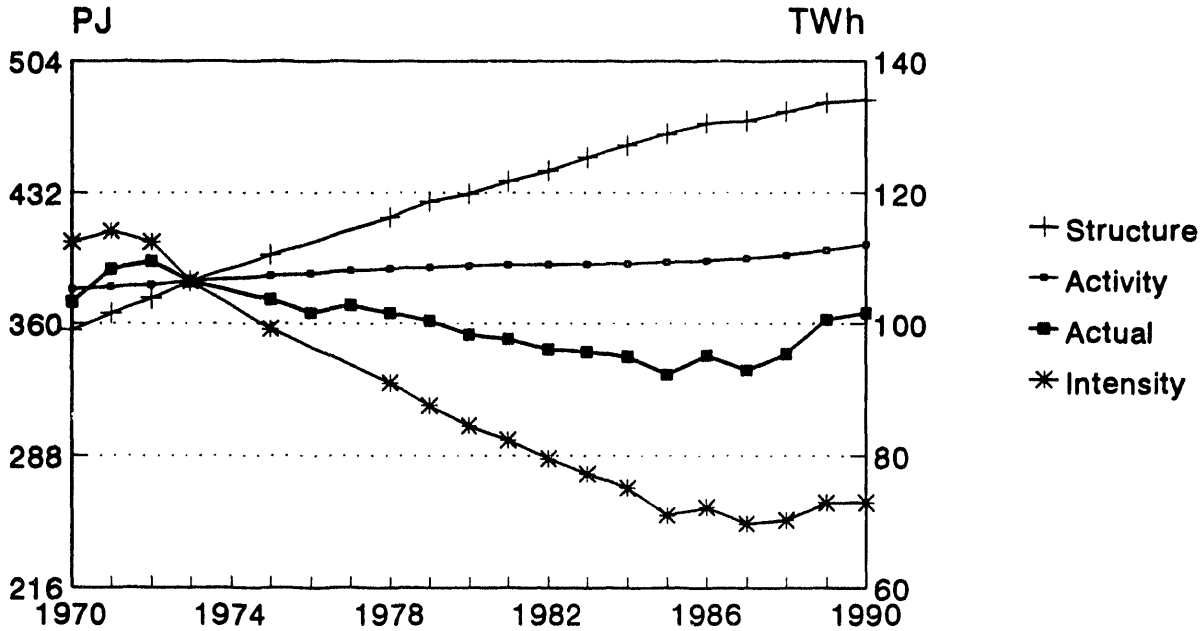


Figure R-9

Residential Energy Use in Sweden
Activity, Structure, Intensity Effects
Primary Energy

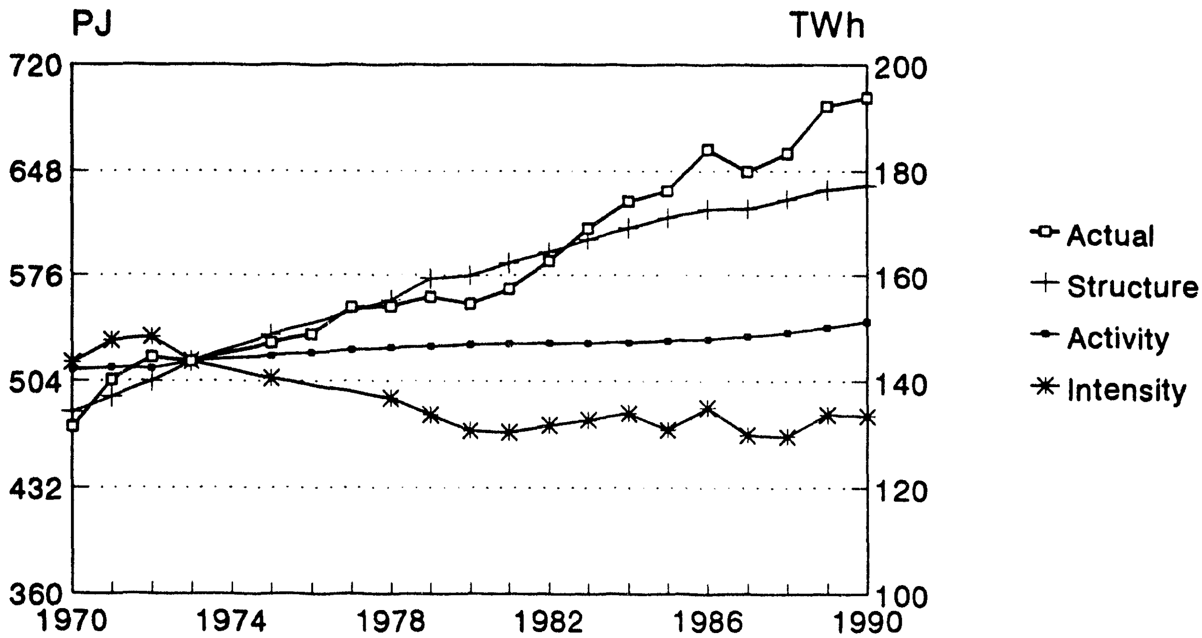


Figure R-10

Energy Use for Appliances in Sweden
Activity, Structure, Intensity Effects
Delivered Electricity

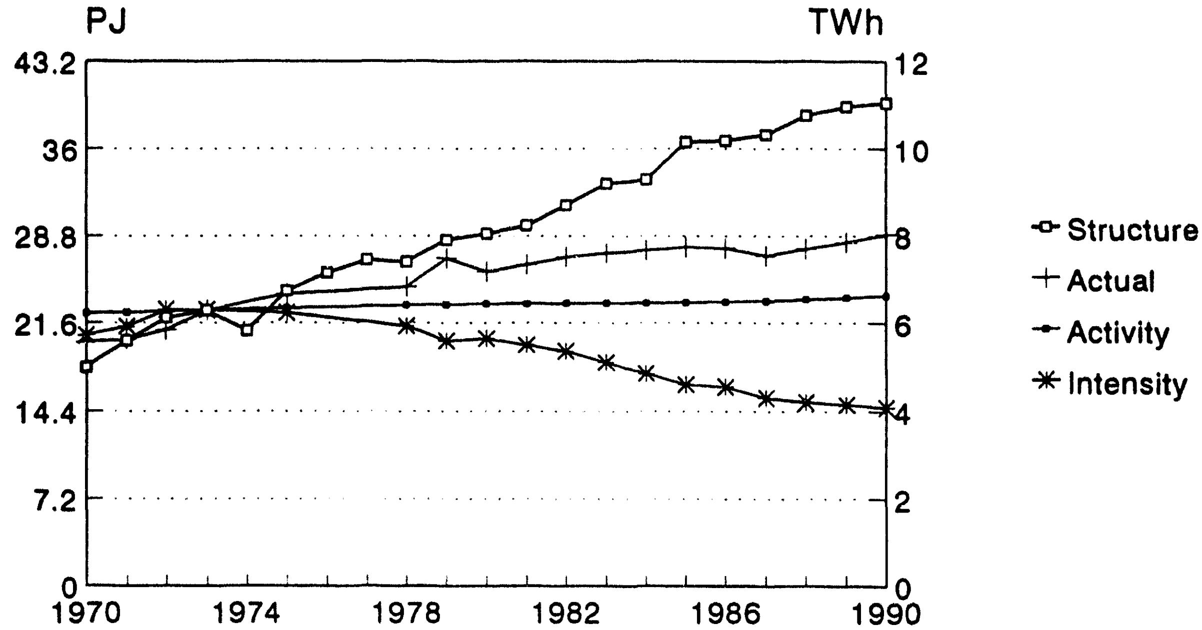
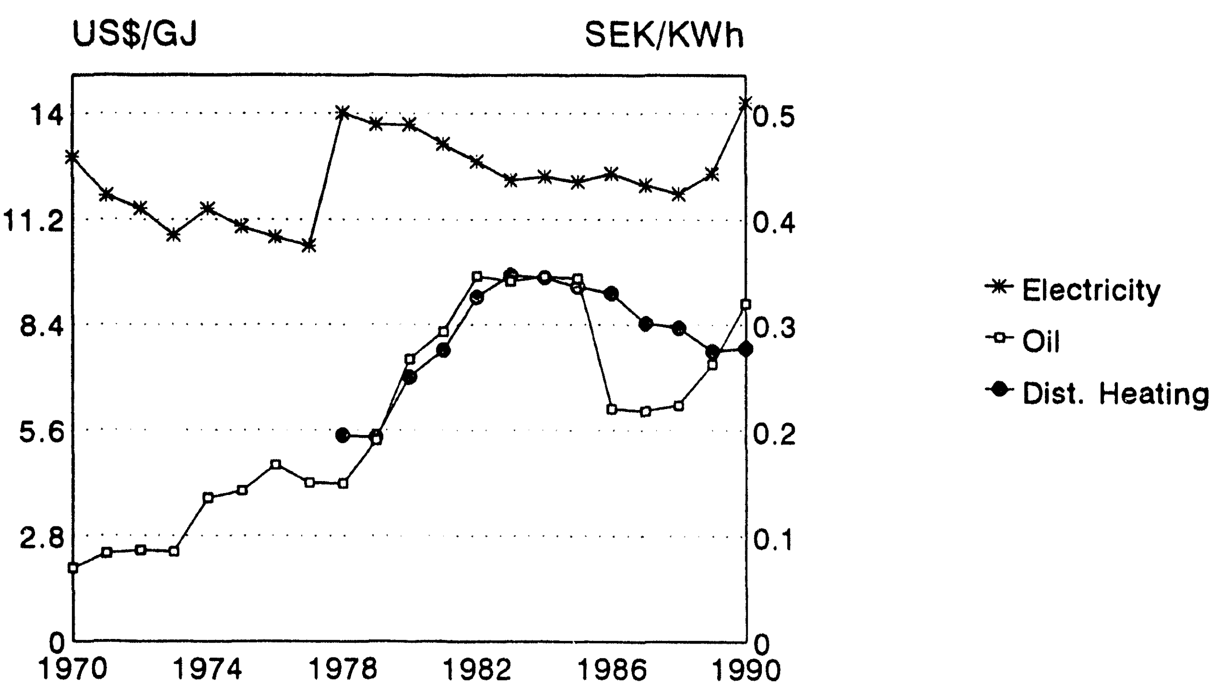


Figure R-11

Residential Energy Prices in Sweden



Source: International Energy Agency and U.S. DOE
Converted to US$ at 1985 Purchasing Power Parities

Figure R-12

3. THE SERVICE SECTOR

The service sector (ISIC 6-9) encompasses a wide range of activities associated with the provision of services rather than the production of goods. Energy consumption in the service sector represents a small but growing proportion of total energy consumption in Sweden. The service sector's share of delivered energy increased from 11.7% in 1973 to 13.2% in 1990 while its share of primary energy increased from 12.7% in 1973 to 16.8% in 1990. The increase in the share of primary energy is due to the rapid growth of electricity in the service sector. The service sector's share of electricity consumption in Sweden has increased from 15% in 1973 to 21% in 1990. As we shall see, part of this growth is due to substitution of electric heating for oil heating, just as in the residential sector. However, a larger part of this growth is due to increased penetration and use of electric appliances and equipment in the service sector. It is this rapid growth in electricity consumption for such equipment as computers, lighting, and motors, which may represent the largest source of potential energy savings in the service sector.

In spite of what appears to be a large potential for energy savings in the service sector, surveys and end-use data for this sector have not reached the level of detail available in the residential and industrial sectors. As in many countries, energy analysts have only recently begun to focus attention on the service sector. A recent survey and report by *Vattenfall* (1990) provides the first comprehensive look at the end-use structure of energy consumption in the Swedish service sector. With data for only a single year (1989) available at the end-use level, we determined that it was not yet possible to break down the service sector into end-uses. We do have data from *PREDECO* (Carlsson 1992) with which to break out heating and water heating (*uppvärmning och varmvatten*) from other non-heating uses of electricity (*driftel*). Consequently our analysis here is confined to the level of fuel intensities and two categories of electricity consumption--heating/water heating and other electricity use.

3.1. Structure of the Service Sector

The service sector includes many commercial activities such as finance, insurance, retail businesses, and personal services. For this reason, it is sometimes called the "commercial" sector. However, we prefer the term "service" because it also includes many activities which are not commercial in nature, such as education, social services and religious facilities. The service sector also includes activities such as communications and public utilities, as well as some of the financial and administrative aspects of transportation industries.

We measure economic activity in the services sector by value-added or GDP, just as we do later in the manufacturing sector. Figure S-1 shows service sector GDP in constant (1980) SEK from 1970-1990 for the five major groupings used in the National Accounts (SCB 1992a). The service sector has been responsible for most of the growth in the Swedish economy, with its GDP increasing by 52% from 1973-1990, while total GDP increased by only 36% over the same period.

Since nearly all of the energy consumption in the service sector takes place in buildings, another measure of service sector structure is floor area or heated floor area. Figure S-2 shows the floor area by building type in 1981 and 1990 according to data gathered by the *SCB*. Each type of building carries with it a rather different pattern of occupancy characteristics and consumption. Offices and retail businesses have consumption patterns based on the working day. Theaters and concert halls have low occupancy for much of the time and high occupancy for a few hours per day. Hospitals and restaurants are rather energy-intensive, due both to longer hours of occupancy and to the special types of equipment which tend to be used there.

Unfortunately, there is no way to draw a correspondence between the economic measure of activity (GDP) and the physical measure (floor area) for the given types of buildings and their associated economic activities. Furthermore, the lack of end-use detail makes it difficult and inappropriate to address distinctions among the wide variety of economic activities and their associated level of energy consumption. Consequently, we consider changes in energy consumption only at the aggregate level, using data from the National Accounts for GDP and a time series developed by *PREDECO* (Carlsson 1992) for service sector floor area from 1970-1990. At this level, GDP and floor area are rather closely related, as suggested by Figure S-3. Total floor area in the service sector increased by 41% from 1973-1990 while GDP increased by 52% as previously discussed. Consequently, we present the results for energy intensity in terms of energy consumption per unit of GDP.

3.2. Fuel Mix and Energy Intensities

Over the period from 1970 to 1990, fuel choices in the service sector were basically limited to oil, district heating and electricity. Wood, kerosene, and coal have played a small role and until recently, gas (city gas in the past) was negligible. Figure S-4 shows fuel consumption in the service sector from 1970 to 1990. It is interesting to note that service sector delivered energy consumption in 1990, which stands at 173 PJ, is not much different than it was in 1970, at 167 PJ. However, the differences in the fuel mix are quite dramatic. Oil consumption was cut dramatically over this period to less than a third of its pre-oil shock level. At the same time, district heating has more than doubled and electricity has more than tripled. In terms of delivered energy, this has meant only a modest increase of 10% from 1973-1990, but primary energy has increased strongly by 61%. However, the warm winters of 1989 and 1990 have masked some of the increases in energy consumption. In order to correct for climate, we apply the same method used in the residential sector to fuels and to the heating/water heating portion of electricity consumption, resulting in the smoother time series shown in Figure S-5. The climate corrected energy consumption totals show an increase in delivered energy of 21% from 1973-1990 and an increase in primary energy of 72%. Thus Swedes should expect higher energy bills in the future compared to those they faced in 1989-90.

It is no surprise that the major change in fuel shares in the service sector in the wake of the 1973 oil shock was substitution away from oil to district heating and electricity. The share of oil in service sector delivered energy use dropped from 63% in 1973 to 20% in 1990. Over the same period, electricity's share grew from 23% in 1973 to 54% in 1990 while the share of district heating in service sector delivered energy grew from 14% to 25%.

These changes do not quite convey the effects of substitution for oil because of the substantial increase in electricity use for appliances and other equipment (*driftel*) over this period. If we include only electricity used for heating and water heating, we gain a better estimate of the substitution for oil. In Figure S-6 we give the fuel shares after discounting *driftel*. The share of oil was 76% in 1973 and 36% in 1990. Electricity's share went from 4% in 1973 to 17% in 1990 while district heating's share increased from 20% in 1973 to 45% in 1990. Much of the increase in district heating arose as existing buildings were converted. The use of electricity portrayed for space heating in Figure S-6 probably underestimates its real role, as the bulge in the ratio of *driftel* to floor area suggests a significant amount of secondary or hidden heating as well. Still, district heating became the main replacement for oil as the primary source of heating/water heating in the service sector over this period.

Figure S-7 shows the breakdown of service sector floor area by type of main heating equipment. As in the previous figures, it shows the declining importance of oil heating and the increasing importance of district heating. However it also shows a dramatic increase in the number of combination heating systems or secondary heating systems in the service sector. Such systems show up in the "Other" category and grew from only 3% in 1970 to nearly 20% of floor area in 1990. This category includes heat pumps, dual-fuel boilers, use of secondary electric heat, and miscellaneous other heating combinations. This proliferation of heating systems was a response to higher oil prices as well as an indication of the increased cost-consciousness of energy consumers. The reliance on a more diverse set of fuels and equipment also makes the overall heating portfolio more robust in the face of uncertainty about fuel prices, especially in the cold Swedish climate.

3.3. Evolution of Energy Efficiency and Energy Savings

Changes in energy intensity in the service sector, measured as changes in energy consumption per unit of GDP, are closely related to the changes in the fuel mix discussed above. Energy intensity is measured as energy consumption per unit of service sector GDP. Delivered energy intensity decreased by 27% from 1973-1990. Electricity intensity increased by 71%, contributing to the resulting increase in primary energy intensity of 6%. In Figure S-8, we show the trends in energy intensity after correcting for climate. Since 1989 and 1990 were warm winters, the graph reveals that the effective energy intensity increases were higher than the uncorrected data suggests. Delivered or final energy intensity decreased by 20%, while electricity intensity increased by 77% and the resulting primary intensity showed an increase of 13%. The increase in electricity intensity for heating/water heating, at 68%, was only slightly lower than the electricity intensity for non-heating electricity or *driftel*, which was 76%. Useful energy intensity, calculated by assuming a conversion efficiency for fuels, decreased 6% from 1973 to 1990.

When it is available, energy intensity based on floor area, or specific energy consumption, provides a more useful measure of structural changes in energy consumption over time because it is based on the physical characteristics of buildings. We used the *SCB lokaler* statistics for 1977-1990 (SCB 1978-1991b) to determine the specific energy consumption by heating system. We then used the *SCB* estimates of specific energy consumption for different vintages to estimate the specific energy consumption from 1970 to 1976. Figure S-9 shows the specific energy consumption by main heating system. Also shown in the figure are the aggregate useful energy intensity and the intensity of electricity use for all buildings. We do not show the specific energy consumption for buildings with other heating systems or combination heating systems as this data is only available for a few recent years.

The trends in Figure S-9 indicate that buildings heated with oil and district heat have experienced fairly steady declines in real energy intensity while electrically heated buildings have not. There are several reasons for these trends. One is that the efficiency of oil boilers improved over this period whereas electric heating has no combustion losses on which to improve. A second reason is that the use of temporary heating to supplement main heating systems. A third reason is the fact that our climate correction probably over-corrects to some extent. This is because service sector buildings are occupied at different times and periods than in the residential sector, are more varied in their occupancy patterns, and are also more dominated by internal loads. A final, but perhaps the most significant reason, is that the building upgrades and retrofits of the 1970s and 1980s were often applied to the older buildings heated by oil and district heat rather than to newer buildings heated by electricity.

3.4. Causes for Changes

Two main trends dominated changes in the structure of service sector energy consumption between 1970 and 1990. The first was the large-scale substitution of district heating and electricity for oil in heating. The second is the rapid growth in other end-uses of electricity in the service sector, such as lighting and office equipment. Substitution for oil had the effect of decreasing delivered energy intensity and increasing primary energy intensity. If we separate changes between 1973-1980 and changes from 1981-1990, we discover that most of the improvement in delivered energy intensity occurred in the first period while remaining flat in the second period. Furthermore, after correcting for yearly variations in winter climate, oil use was fairly constant in the second half of the 1980s, while district heat gained slightly. The incentive to switch away from oil decreased after the 1986 oil price collapse. At the same time, most of the increase in electricity consumption occurred in the second period. The plateau in oil consumption and the flat curve for delivered energy intensity suggest that Sweden will not find energy savings in the service sector in the ways it has previously been doing so—that is to say, Sweden must now look for electricity savings rather than switching away from oil to achieve its savings in this sector.

3.5. Prospects

Did Sweden become sloppy in the 1980s after achieving some notable gains in the 1970s or did the service sector simply grow faster than energy policies can keep up with? The aggregate nature of our analysis of the service sector prevents us from answering this question properly. However, we suspect that a lack of attention to potential energy savings in the booming 1980s, fostered in part by relatively low electricity prices, is the root cause. In any case, the structure of service sector electricity demand needs to be better understood in order to begin to reverse the trends of the 1980s. Figure S-10 shows the breakdown by end-use for the service sector according to the *Vattenfall* study (1990). Lighting represents roughly 29% of service sector electricity use, heating accounts for about 16%, and other space conditioning such as motors, ventilation and air conditioning account for 29%. Computers, food preparation, and "other" roughly split the remaining usage. Lighting and space conditioning probably represent the best opportunities for savings in the near-term. As more end-use data become available for the service sector in Sweden, we can better gauge the relative changes in the structure of energy consumption.

The *STIL-project* (Statistical Investigation in Commercial Sector) within *Uppdrag 2000* included energy audits and interviews at 900 commercial sector buildings. The technical and economic potential was estimated using a customer perspective based on 1991 prices and a 4-year payback limit for private building owners, and a 7-year payback limit for official or public building owners. The study showed that roughly 80% of commercial buildings have cost-effective potential under these conditions with an average payback of two years. The average energy cost savings was 12% (Hedenström 1991, Kruse 1992, Hedenström 1992).

The *STIL-project* has also pointed to the important behavioral and organizational aspects of energy conservation programs in the commercial sector. The motivation for energy conservation was found to be correlated with some expected characteristics such as buildings in which the owner is responsible for activities and operations in the building. But the degree of motivation was also connected to the presence of "fiery spirits," people who are actively interested in energy conservation. Furthermore, there were other organizational attributes which made some groups much more active than others in promoting energy conservation measures, even when the economic incentives and physical constraints were the same. It seems clear than these motivational aspects must be taken into consideration when pushing conservation programs in the service sector. Ignoring such characteristics can result in pushing programs where they may mot be implemented or conversely, providing incentives where none were necessary in the first place.

Sweden Service Sector
GDP

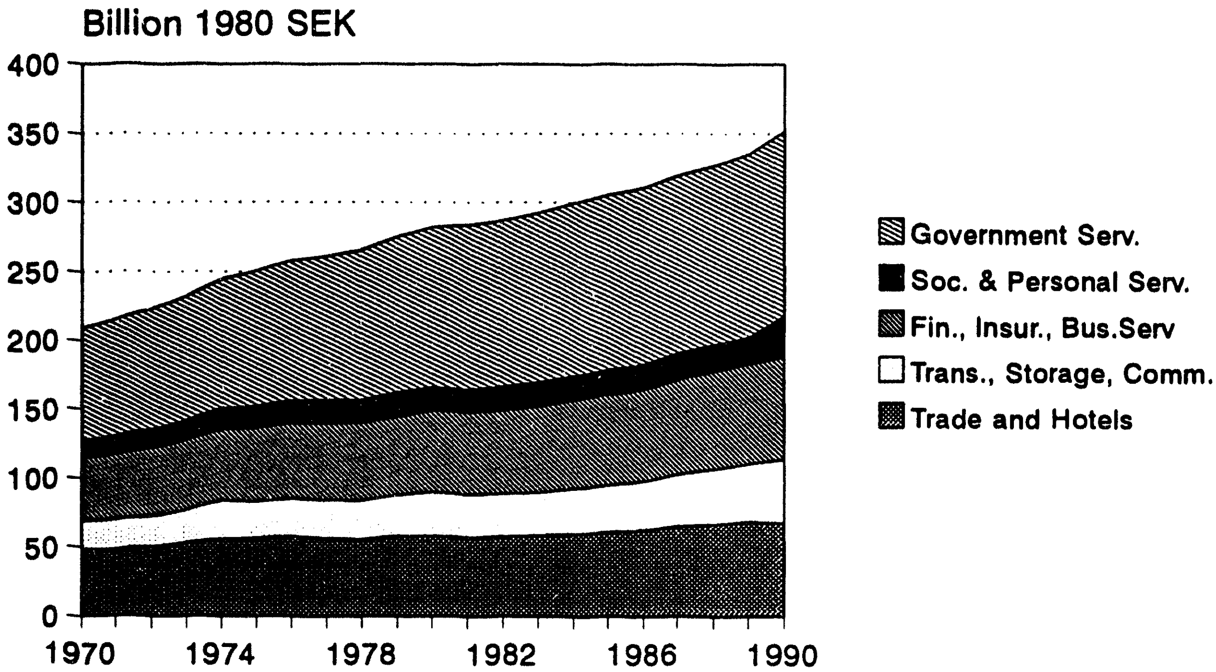


Figure S-1

Sweden Service Sector
Floor Area by Building Type

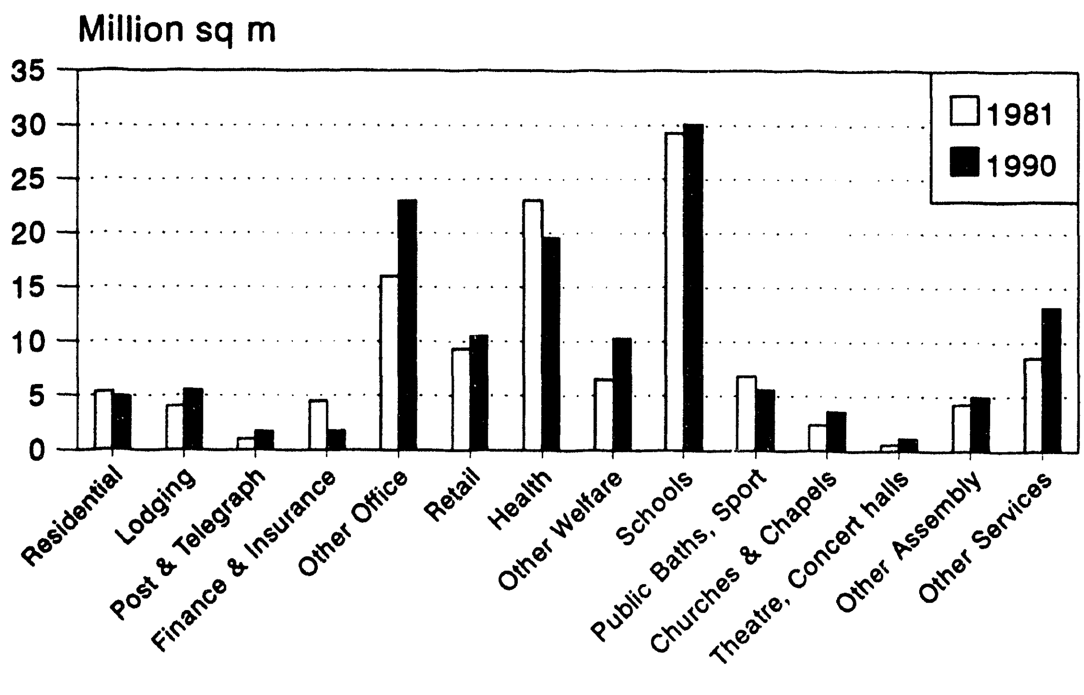


Figure S-2

Sweden Service Sector
Floor Area and GDP

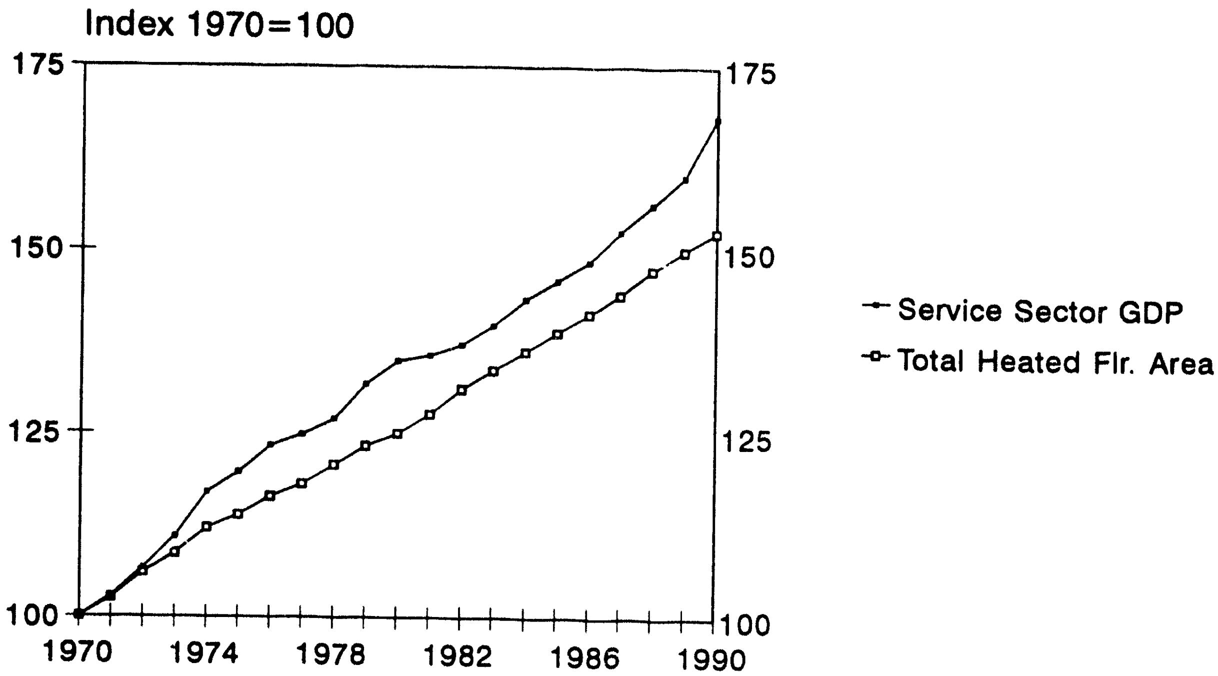
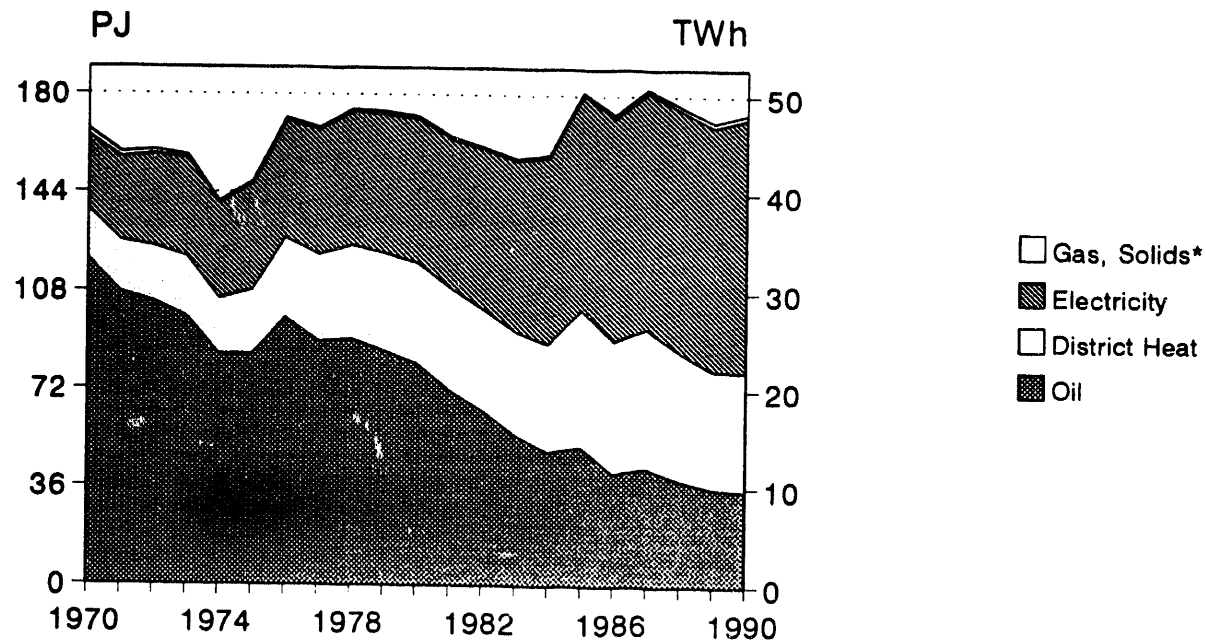


Figure S-3

Service Sector Energy Use in Sweden
Delivered Energy



* Gas, Solids includes biomass

Figure S-4

Service Sector Energy Use in Sweden
Delivered Energy: Climate-Corrected

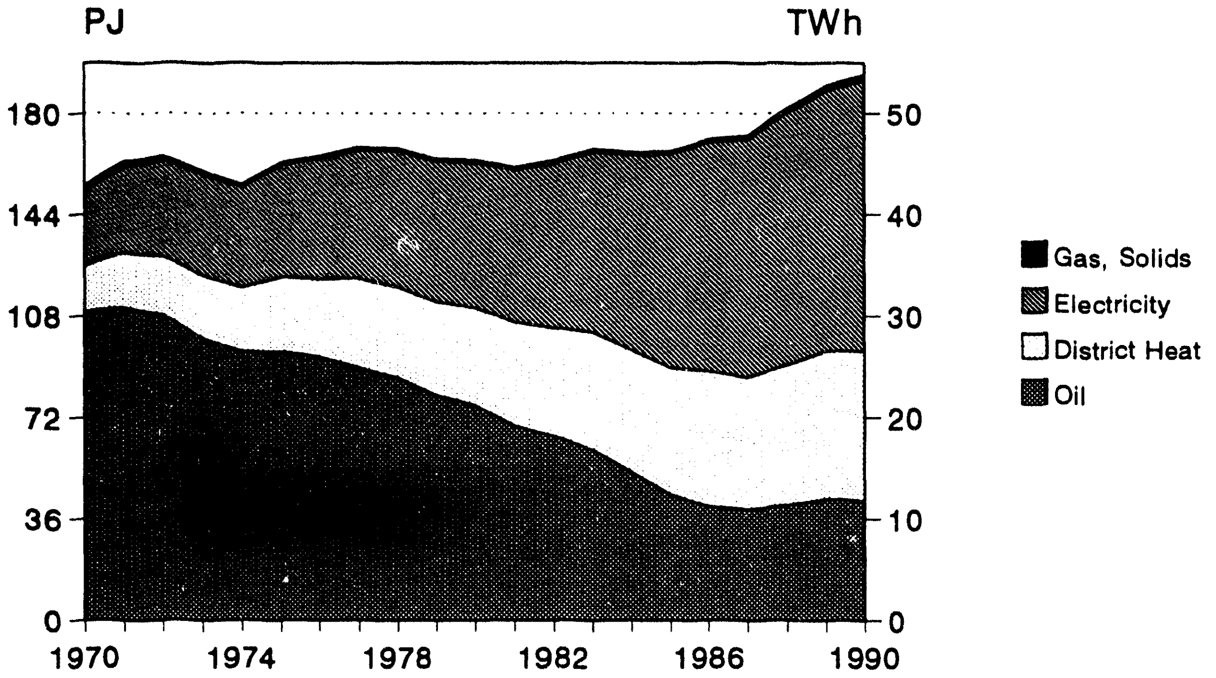


Figure S-5

Service Sector Energy Use in Sweden
Space Heating Fuel Shares

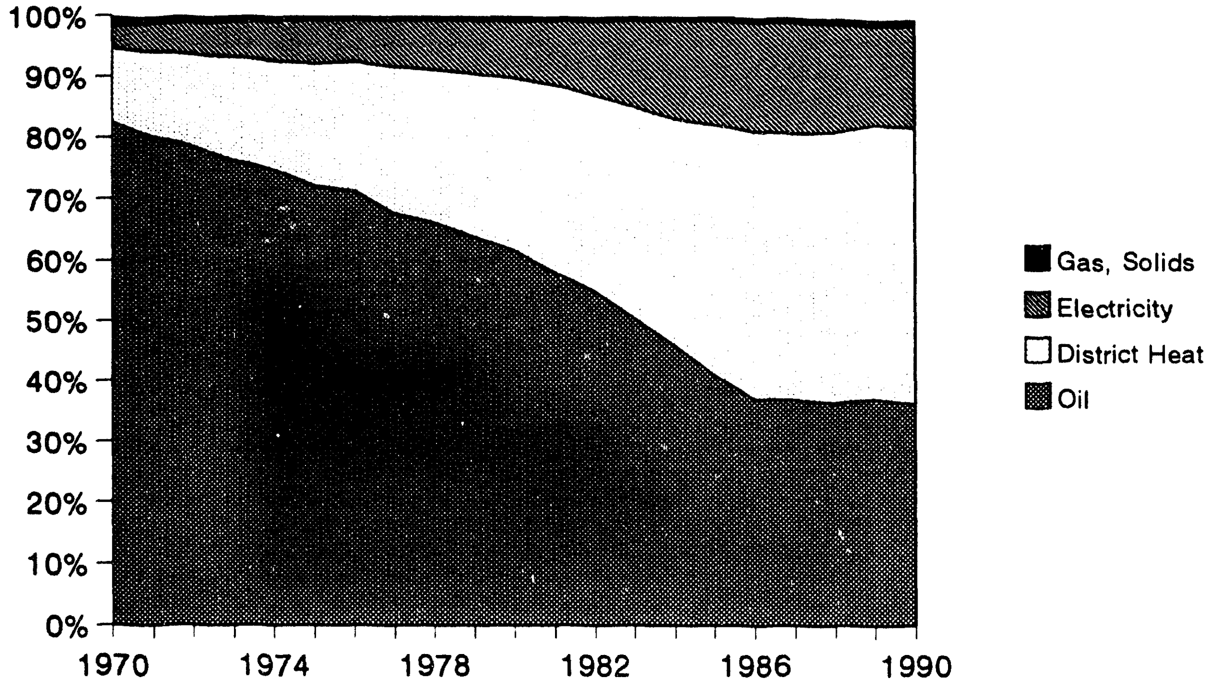


Figure S-6

Sweden Service Sector
Floor Area by Main Heating System

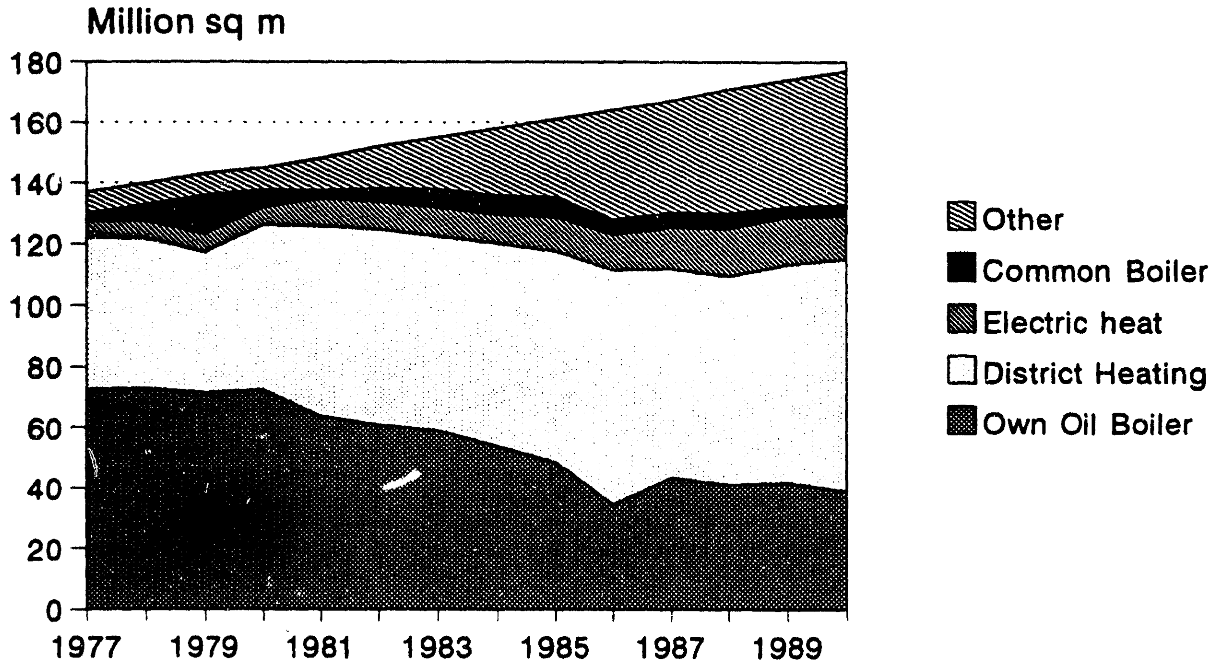


Figure S-7

Service Sector Energy Use in Sweden
Energy Intensity Trends

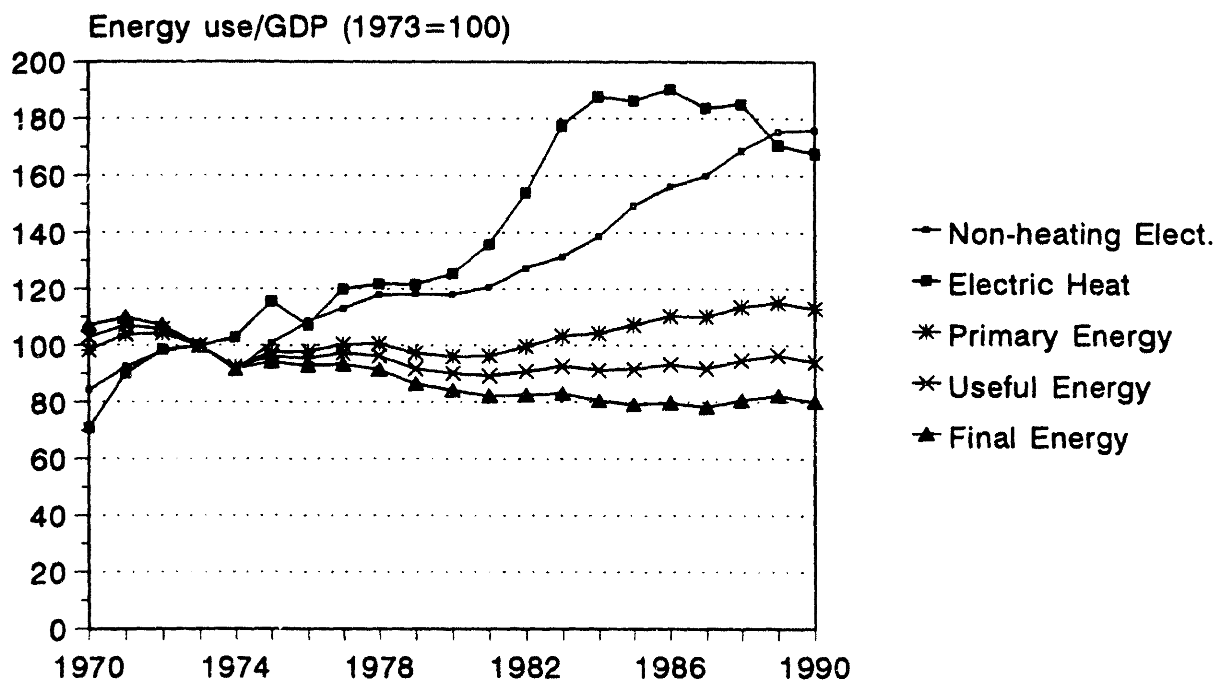


Figure S-8

Service Sector Energy Use in Sweden
Delivered Intensities By Fuel Type

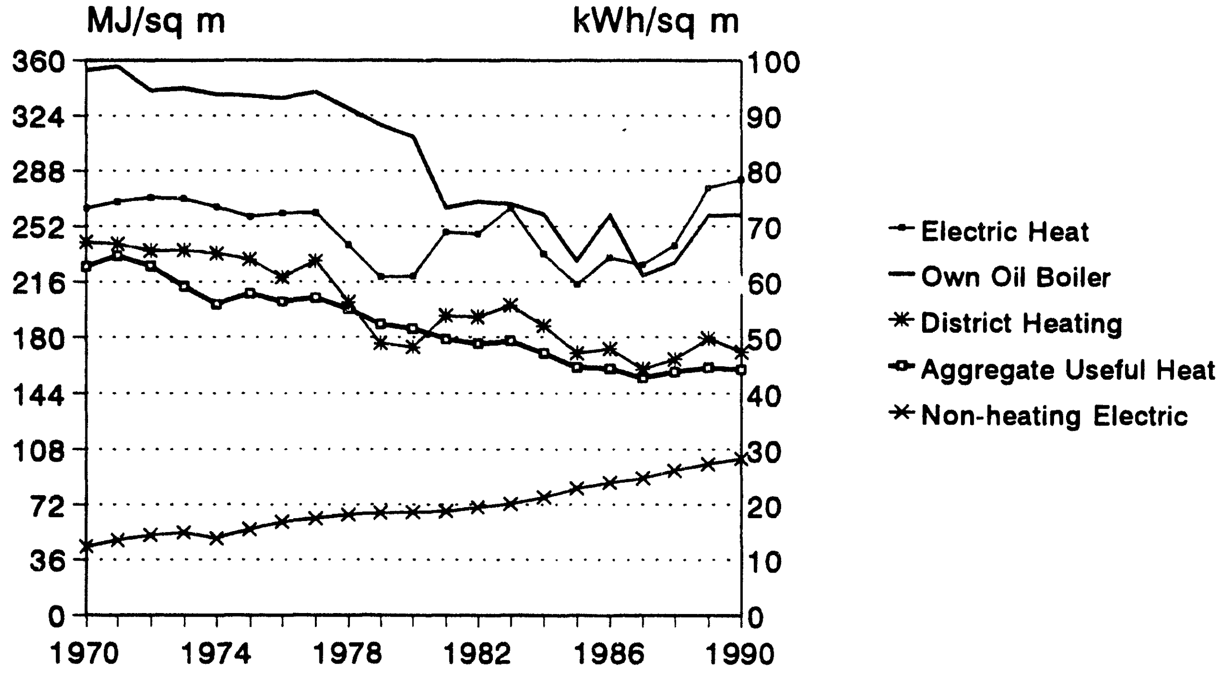


Figure S-9

Sweden Service Sector
1989 Services End-Use Shares

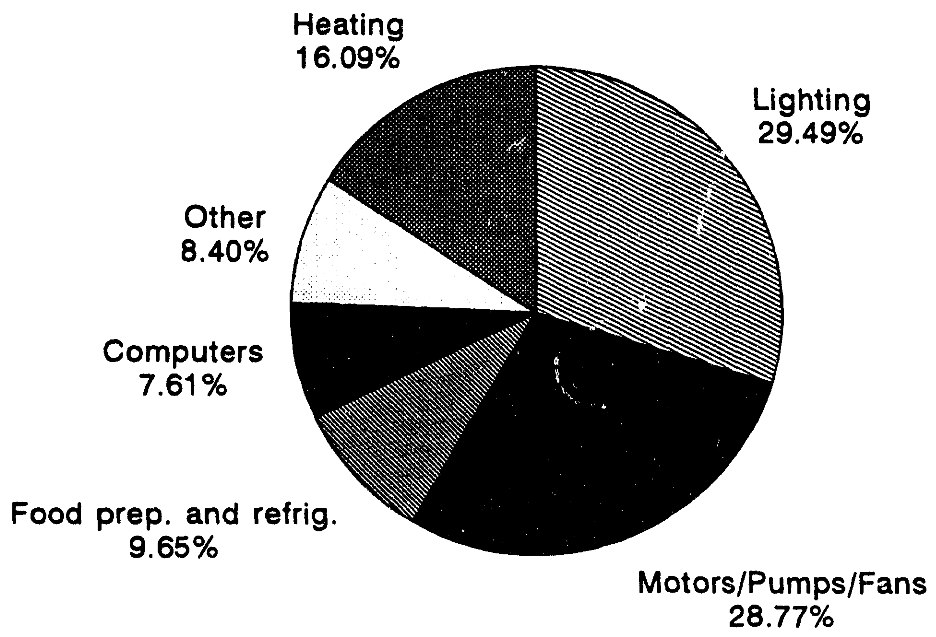


Figure S-10

(Source: Uppdrag 2000)

4. THE INDUSTRIAL SECTOR

With its rich endowment of forest and mineral resources, Sweden has been a leader in heavy industry for centuries. As Sweden's economy was transformed from rural to urban industries in the twentieth century, however, an increasing share of the raw materials were transformed into finished products, first quality steels and paper, then vehicles, tools, complete houses, and electronics. This transformation has had an important impact on energy use in manufacturing and other industry, as this section will show.

In our work we adopt several conventions to permit ready comparison of trends in Sweden with those in other countries. These conventions, which are not always the same as those used in Sweden, are explained below:

• **Manufacturing** (*tillverkning*) includes all industries in ISIC 3 (International Standard Industrial Code, for most industries the same as *Svenska Näringsgren Indelning*, or *SNI* 3). Our study surveys trends from 1970 to 1990, and we have examined trends starting in 1960. Our study breaks manufacturing in to ISIC categories 341 (Pulp and paper [*papper och massa*]), 351/2 (Chemicals [*Kemikaler*]), 36 (Non-Metallic Minerals [*Sten och Jord*], 371 (Iron and Steel [*Järn och Stål*], 372 (Non Ferrous Metals [*Icke Järnhaltiga Metaller*]), lumping all the remaining branches into "other manufacturing".[1]

• **Other Industry** includes mining (ISIC and *SNI* 2), primary industries (agriculture, forestry, and fisheries, ISIC 1 [*jordbruk, skogsbruk, och fiske, SNI 1*]), and construction (ISIC 5 [*byggverksamhet, SNI 5*]). But lack of precise data on fuels used outside of the mining subsector before 1983, or indeed in the entire group of subsectors, precludes any more careful analysis of these industries. Instead, they are treated primarily as a residual from manufacturing.[2]

• We have attempted to count correctly the use of biomass in the paper and other industries, and to distribute district heating consumption by 2 or 3 digit ISIC category using estimates made by *SCB* and *NUTEK*.

[1] Previous experience (Howarth *et al.* 1990, 1991) suggests that this breakdown may cover most, but not all of the important trends in energy intensities and structural change that can be found without going to a 4- or 5-digit level of classification. This is because of the important role of paper and pulp, and some other parts of manufacturing in Sweden and Norway. Making this level of analysis would be very time consuming, and, difficult for Sweden, because of the problems of assigning use of biomass fuels in the paper industry. We did find that aggregating chemical sectors 351 and 352 for compatibility with other countries only hides a small shift between the former and latter of these subsectors that produced effects only 5% as large as those measured when the sectors were combined.

[2] Mining is carefully documented, but the other industries disappear into "*Hushåll, Service, mm*" before 1983.

Production is measured in real value-added, in 1980 or 1985 real SEK. Where data were available only in 1985 currency, these were chained by industry back to 1980 using the overlapping year of 1980. The data source is *Nationalräkenskaper*. Energy consumption data come from *Industristatstik* published by *SCB* and provided by Hans Berglund of *SCB*. These include his unpublished estimates of the use of district heat by two- and three-digit industry. The important exception is that of biomass data, which come from *SCB*'s *Bränslestatistik*. These covered the years 1970-1990. Additionally, Stefan Kornerud provided *NUTEK*'s own processing of these data for the years 1980-1990. For *SCB* data we built worksheets in which we entered each kind of fuel in its physical units, then converted these to energy units (at conversion rates provided by *SCB*), then aggregated to liquid fuels (including LPG), gaseous fuels (city and oven gas, natural gas), biomass, solids (coal, coke, etc.), electricity, and district heating. These worksheets matched the format of those provided by *NUTEK*. By comparing both sets we resolved minor discrepancies. We also compared our work with a recent analysis by *Prognoskonsult* (1993) and found little disagreement, except that we estimated biomass use for the years 1970-1975 using information provided by *NUTEK*, which they did not use.

Three important adjustments have been made. Since estimates of district heating consumption by 2- or 3-digit ISIC branch, in thermal units, are not published, *SCB* provided re-estimates of district heating use for each industry, based on the published data on district heating expenditures. Second, after consultation with *SCB* and *NUTEK*, we agreed to use *NUTEK*'s data on biomass, which agree with *Bränslestatistik* but go back to 1970. Finally, blast furnace gas is excluded from "consumption" in industry, since it is produced through use of coke that is already counted.

4.1. Structure of the Manufacturing Sector

In 1970 industry contributed 36% of Sweden's GDP, of which manufacturing was responsible for 23% and "other industry" for 13%. By 1989, these shares had diminished by two points each. Overall activity in manufacturing grew unsteadily, rising 6% above 1973 levels in 1976, then falling back to virtually the same level as 1973 in 1981-82. Spurred by a 1982 devaluation of the *krona*, however, activity grew steadily until reaching a peak in 1989, then fell back 3% in 1990. **Output in 1989 lay at only 20% above its 1973 level, a somewhat lackluster performance for a major manufacturing nation.**

These developments were spread unevenly among manufacturing's subsectors (Figure M-1). The share of activity in 1981 from paper and pulp was virtually unchanged from that in 1973, while chemicals grew significantly and non-metallic minerals, ferrous and non-ferrous metals fell back somewhat. By 1989 ferrous metals had actual risen to a higher share of activity than in 1973, paper and pulp expanded as well, and chemicals continued its upward trend, while the two other heavy branches continued to lose share slowly. **Taken together, these five energy-intensive subsectors increased their share of manufacturing value-added, from 23.7% in 1973 (in 1980 prices) to 24.0 % in 1989. This small change may seem unimportant, but it is unusual for OECD countries, most of which experienced declines in the share of energy-intensive manufacturing.**

4.2. Fuel Mix and Energy Intensities

The manufacturing fuel mix in Sweden underwent an important transformation in the period we have studied, as Figure M-2 suggests. Whereas oil provided nearly 47% of the delivered energy in 1973, its share shrank dramatically in the 1980s from 37% in 1980 to 15.5% in 1989. The fuels with the largest increases were biomass and coal, but district heating also increased to 3% of delivered energy. Electricity use also rose dramatically, from slightly over 21% of delivered energy in 1973 to 37% in 1989. While the trend towards electricity existed before 1973, the trend away from oil was a break with the past.

Sweden experienced an important phenomena, growth in the use of electric boilers (*avkopplingsbara pannor*). This appears to have been a factor in reducing oil use in later years. By 1990, these were responsible for 9.5 PJ of delivered consumption of electricity (out of 185 PJ), up from 4.5 PJ in 1983 and only 1 PJ in 1981. If they replaced oil in oil-fired boilers that had provided heat at 85% efficiency, implying a savings in fuel of about 11 PJ in 1990 through this electric substitution. If we compare these "savings" with the total use of fuel (including wood wastes), we find they amount to 1.5% in 1983, rising to over 3% by 1989. But if we compare only with oil use, we find the heat supplied could have replaced 4% of oil consumed in industry in 1983, close to 7% in 1988, and nearly 16% in 1990. This substitution is not negligible, but still small compared with the total reduction in oil use. Similarly, the use of electricity for boilers is never more than 5% of total electricity consumed in industry. Thus direct substitution of electricity for fuel in interruptible boilers, while not negligible, is neither a major use of electricity nor accounts for a major portion of the decline in fuel intensity.

Indirect substitution of electricity for fuels, mostly oil, also took place. The rise of electric steel making and mechanical or thermo-mechanical pulping processes in Swedish industry, electric paint drying in automobile manufacturing, and other processes led to an indirect substitution of an electricity-intensive process for one that was based on fuels for heating.

Manufacturing energy intensities declined in Sweden. Measured as delivered energy per SEK (1980) of real value added, the intensities of four of the five "heavy" branches declined precipitously between 1973 and 1989, as Figure M-3 shows. The intensity of remaining industry declined by only 10%. (The upturn in some branches in 1990 appears to be an effect of the decline in activity and capacity utilization.) In primary energy, the declines were smaller; non-ferrous metals and non energy-intensive industry actually saw an increase in energy. The difference between primary and delivered intensities arose because electricity intensities increased in two branches and fell less in the other four than did fuel intensities, as Figure M-4 shows.

4.3. Evolution of Energy Efficiency and Energy Savings

4.3.1. Aggregate Measures

Aggregate energy intensity in manufacturing in Sweden fell 28% between 1973 and 1990, while that for primary energy fell by 11%. As suggested above, the fact that electricity intensities fell only slightly or even increased (Figure M-5) lay behind this important difference. Aggregate electricity intensity increased.

Since reducing dependence on oil was an important goal of Swedish energy policies expressed throughout the 1970s and early 1980s, it is interesting to see how well this goal was achieved. Oil use in Swedish industry fell by 74% between 1973 and 1990. Oil *intensity* fell 78%.

4.3.2. Decomposing Changes

We can explore the changes in manufacturing energy use with Laspeyres indices. Holding the mix of fuels and activity and individual energy intensities constant at their 1973 levels, we find that manufacturing energy use rose 22.5% because of changes in activity alone between 1973 and 1989 (Figure M-6). Changes in the individual energy intensities decreased delivered energy use by 22% (Figure M-6) and primary energy use by 12%. A sharp decline in delivered energy intensities in 1974 was reversed when manufacturing activity fell in the mid-1970s, but intensities began to fall again in 1979, and the pace quickened. This decline was centered on oil use, the intensity of which declined by 77% (holding the mix of activity constant at 1973 shares).

Structural change, which increased slightly the role of the five energy-intensive industries in the mix of manufacturing, also boosted energy use in Swedish manufacturing. Holding energy intensities constant, structural change left delivered energy use at virtually the same level in 1989 or 1990 as in 1973 (Figure M-6), and boosted primary energy use by only 1% over the same period. Oil use fell 1% because of structural change. The "winners" in this shift were wood and electricity, representing the important gains made by industries relying on these energy sources.

The 1989 or 1990 values for all energy hide much larger fluctuations, however. Contraction of energy intensive industries reduced manufacturing energy use in 1975 by a full 8% over 1973 levels. The 1978 devaluation led to a recovery in heavy industry, however, by the early 1980s.

The structure of Swedish industry is complex, particularly in the branches of paper and pulp and forest products. Aggregation of certain subsectors may cloak some structural change in the form of changes in intensities. The production of paper (ISIC 3412) in 1987 was 50% higher, in tonnes, than it was in 1973, while the production of all kinds of pulp (ISIC 3411) rose by only 7%. Since paper has a higher value added than pulp, this change itself reduced energy intensities, in MJ/SEK, in the combined paper and pulp sector, ISIC 341. Problems measuring energy use in these four digit sectors, however, precludes an exact calculation of this effect. The aggregation of basic chemicals (ISIC 351) and finished chemicals (ISIC 352), which was done to make Swedish data compatible with those from other countries, might also hide important structural change. In this case, however, we found that the slight increase in the share of ISIC 352 in the combined total for this industry itself decreased the energy intensity of the aggregate by only 7%, while the intensities of the two components decreased by 35% and 69%, respectively, and the aggregate intensity declined by 35%. Thus the effects of aggregating two branches of chemicals, while not negligible, were still small compared with changes in all other energy intensities.

Energy prices for Swedish manufacturing behaved in different ways. Heavy and light oil prices shot up and lay significantly higher in 1990 than in 1973, mostly because of taxes. For example, in 1990 heavy oil lay at nearly 3 times its 1973 real value. Prices for coal lay at nearly 1.5 times their 1973 value in the late 1980s, but this fuel was only important in steel and a few other industries. "Prices" for other solid fuels are not defined, since they are comprised mainly of wastes gathered in the paper making process. Prices for electricity increased by only 15% over this period, fluctuating both above and below the 1973 level before rising permanently in 1983. This stimulated some of the substitution of electricity for oil, particularly in temporary boilers (*avkopplingsbara pannor*). Thus, while Swedish industry bore a particularly heavy burden of higher oil prices, the large reduction in the use of oil, combined with the increase in the share of low-priced electricity moderated and almost offset the overall price increase.

4.4. Causes for Changes

The structural changes that increased slightly the importance of energy-intensive materials in Swedish industry were rooted in continual growth in exports of these materials, particularly forest products. At the same time Swedish firms succeeded in increasing the share of pulp turned into paper for export, rather than being first dried and exported as raw pulp. Indeed, the government promoted two important devaluations of the *krona* (1978 and 1982) to foster these exports. On the other hand, these devaluations could not totally compensate for Sweden's high wages. As a result, Sweden has attempted to boost its high-tech manufacturing. Should this strategy succeed in the future, we might expect the mix of industrial activity in Sweden to shift away from raw materials.

What caused the decline in energy intensities in Swedish industry? Higher oil prices certainly stimulated both the overall decline in fuel intensity in general and the backout in particular (Figure M-7). Comparison of our study with EK (1967) and EPU (1974) as well as private calculations from *Vattenfall* show a long-term decline in energy intensities, using either physical or monetary units to measure activity. But electricity intensity was not declining, and indeed was rising slowly in some industries. The oil crises of 1973 and 1979 should best be seen as accelerating these long-term trends. But the pressure from higher oil prices was offset by flat electricity prices and access to biomass.

Other forces contributed to the accelerated decline in manufacturing energy intensity. Government efforts to foster improved efficiency focused on aiding smaller sized firms in the short term (in the late 1970s), and on increasing R&D into new processes into the longer term. Additionally, funds were available for switching away from oil. Finally, there was increased pressure in Sweden to remain competitive in the markets for energy intensive steel and paper products, in part by cutting energy costs. Certainly these forces all contributed to the drop in energy intensities.

4.5. Prospects for Energy Use

The prospects for energy use and efficiency in the manufacturing sector are clouded by the deep recession of the 1990s. This recession was accompanied by a slow down in the rate of decline of energy intensity, due both to low capacity utilization and a slow down in investment in new technology, much of which reduces intensity. The industrial downturn of the 1990s is very deep, and may have profound affects on the structure of

Swedish industry. We believe that the present recession will affect heavy industry (steel, chemicals) where Sweden has less of a natural advantage more than other branches (paper and pulp) where the advantage is clear. At the same time, the de facto devaluation of the SEK in 1992 and 1993 against the US Dollar and DMARK mean that Swedish engineering products, plagued by high labor costs, will gain significant advantage over those of other countries. The overall effect could be to both boost the demand for Swedish finished products over that for raw materials and to boost domestic demand for domestically made products, by raising the cost of imports of finished products. This change will reduce the importance of energy intensive industry in Sweden, thereby reducing the aggregate energy intensity of industry.

Recent relaxation of the higher energy taxes on industrial fuels, particularly oil, should further the rate of decline in energy intensity, although the decline should accelerate at the end of the recession. Introduction of competition and trade into the electricity markets may have a downward affect on electricity prices in the short term, but increased interest in trade with countries where prices are higher (i.e., in the EEC) might lead to higher electricity prices. These changes may ultimately ease pressure for increased substitution of electricity for oil and lead to more pressure to improve efficiency of electricity use.

Manufacturing Energy Use in Sweden
Real Value Added by Sub-Sector

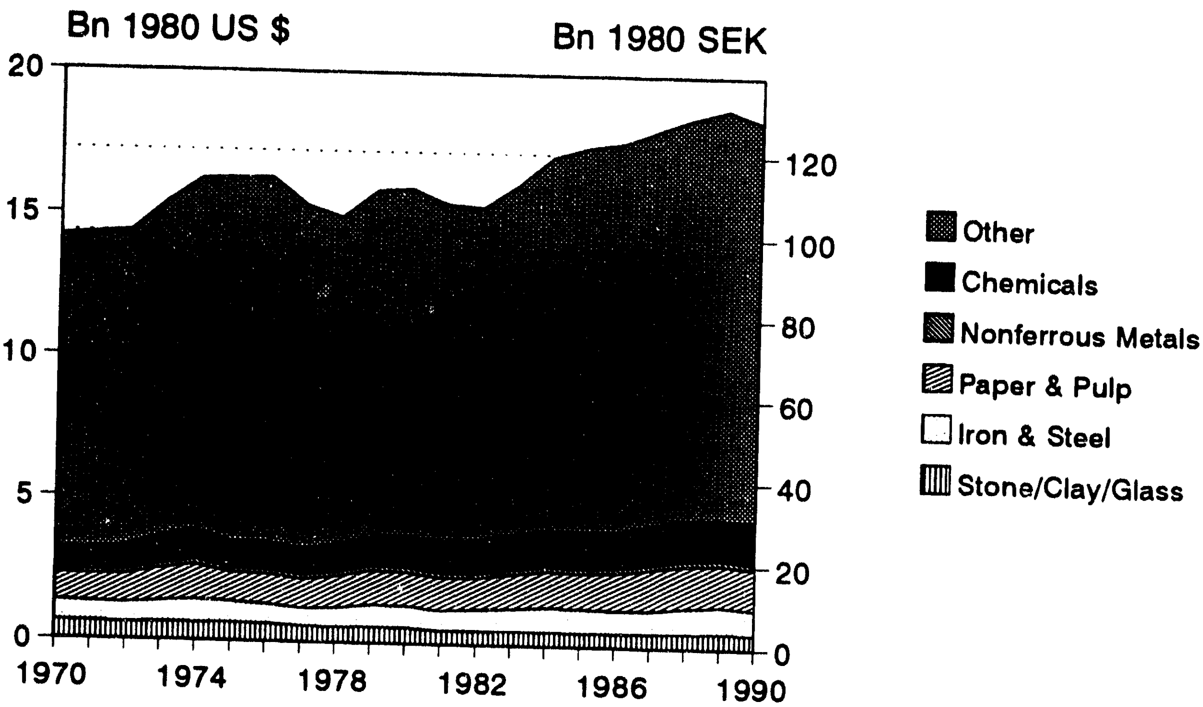


Figure M-1

Manufacturing Energy Use in Sweden
Fuel Mix, Delivered Energy

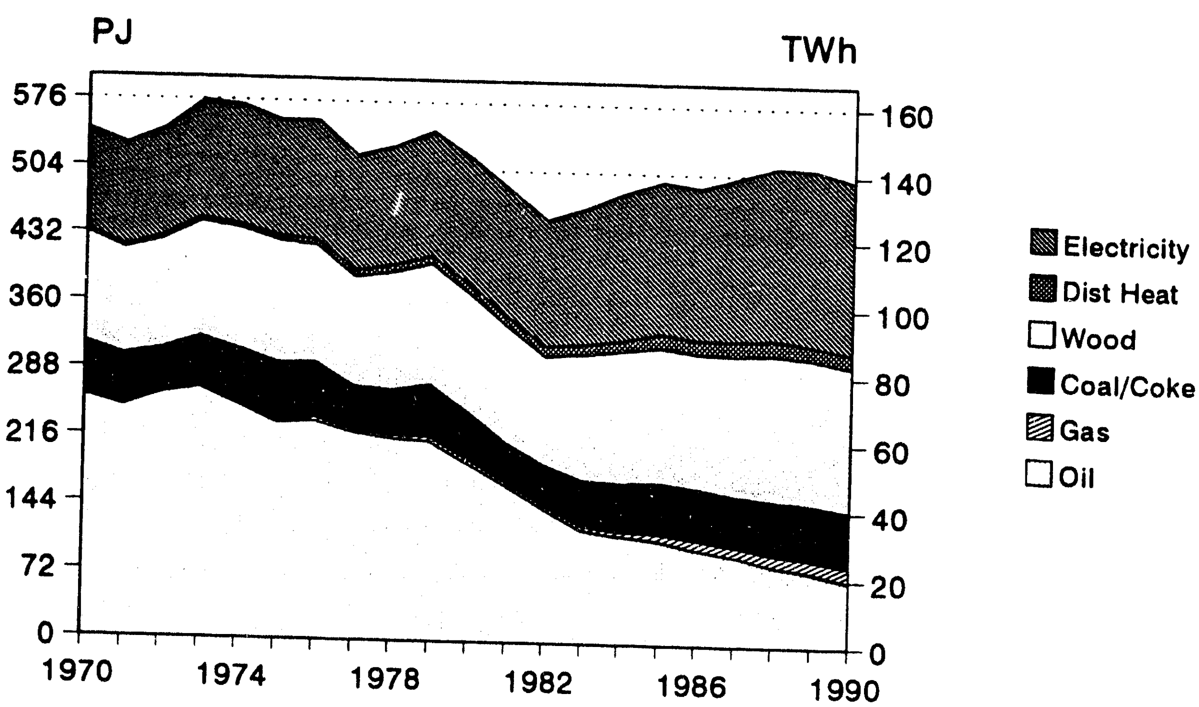


Figure M-2

Manufacturing Energy Use in Sweden
By Industry Group

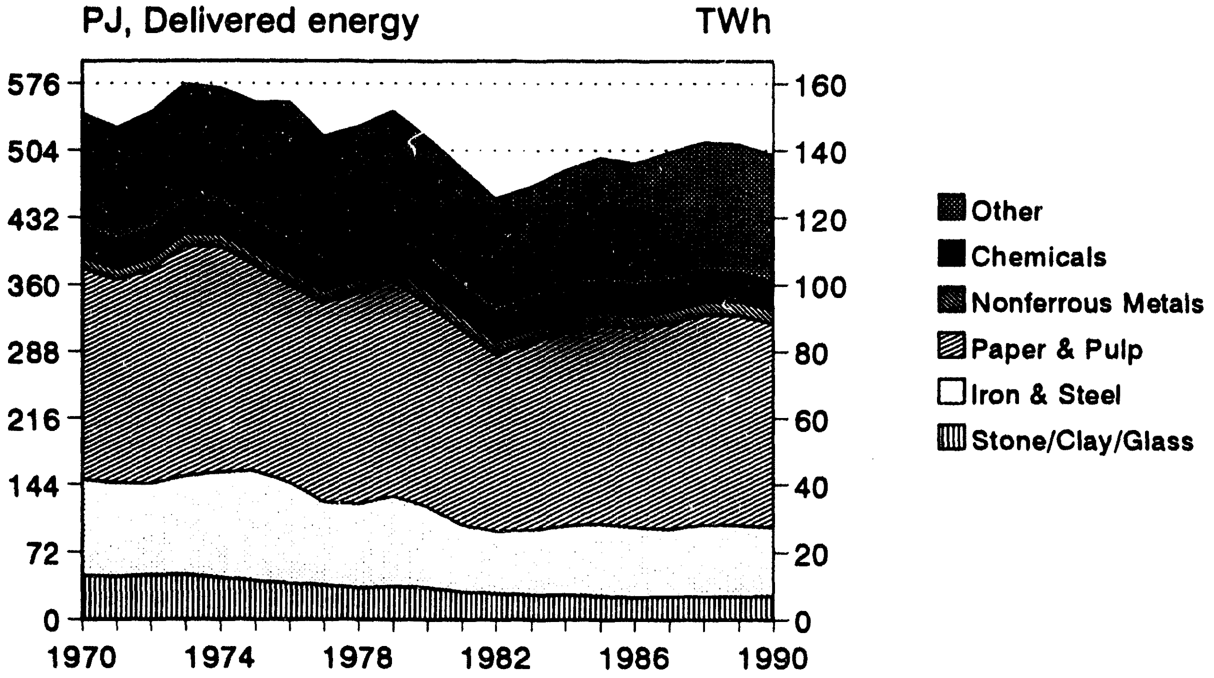


Figure M-3

Manufacturing Energy Intensity in Sweden
Delivered Energy by Industry Group

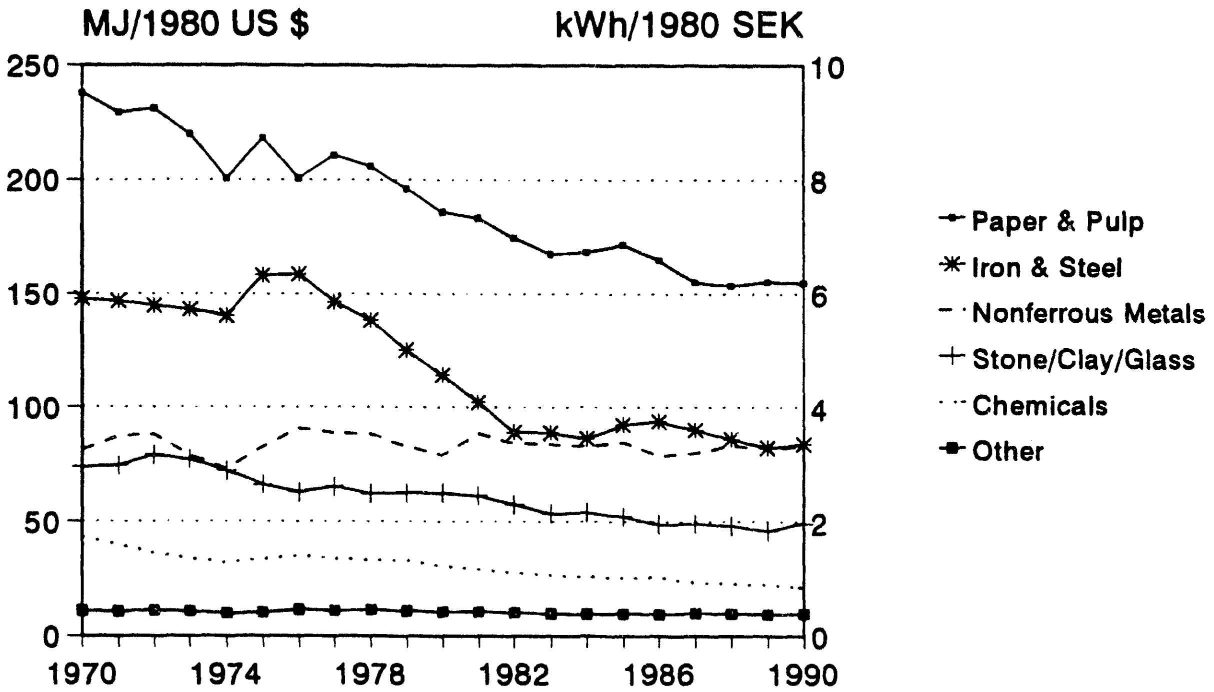


Figure M-4

Manufacturing Electricity Intensity in Sweden
By Major Industry Group

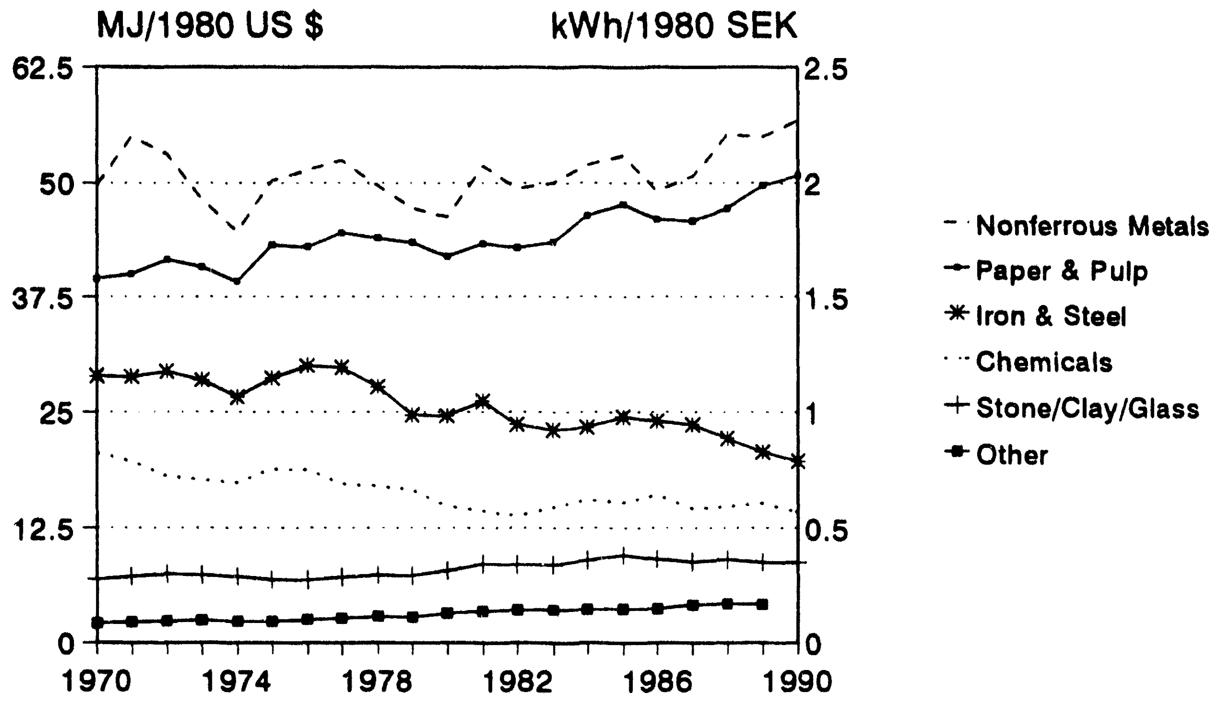


Figure M-5

Manufacturing Delivered Energy Use in Sweden
Activity, Structure, Intensity Effects

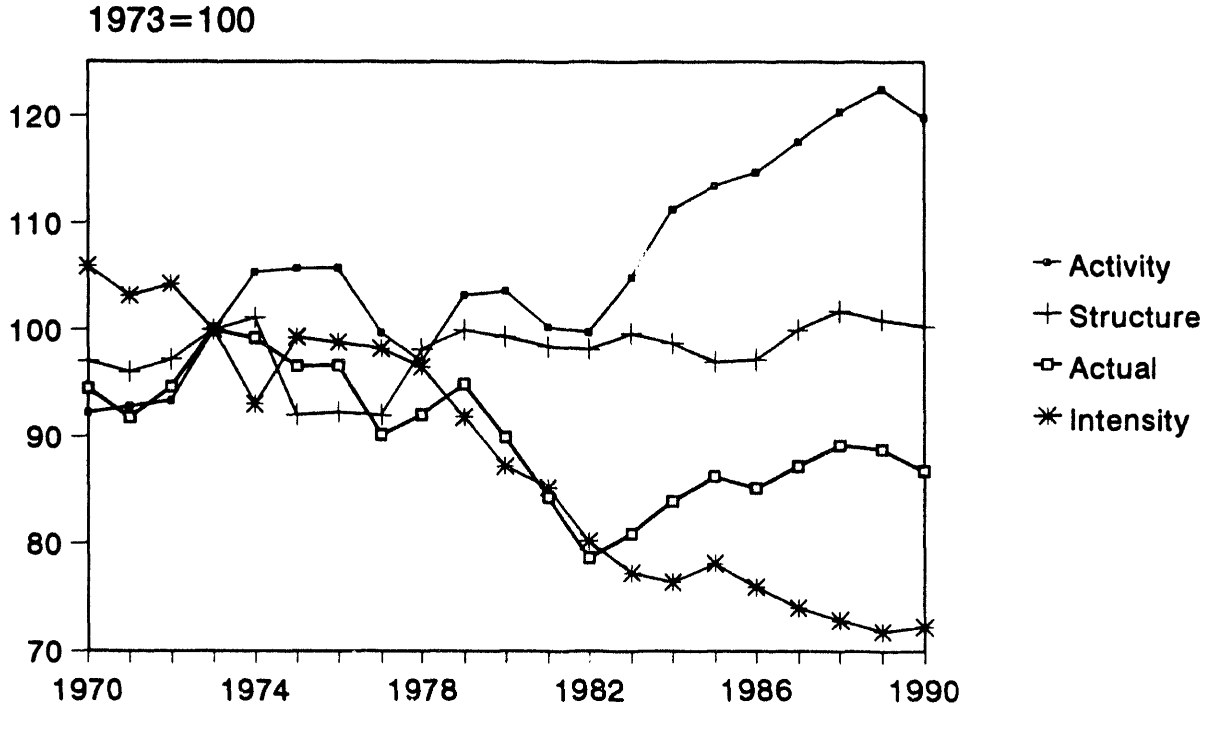
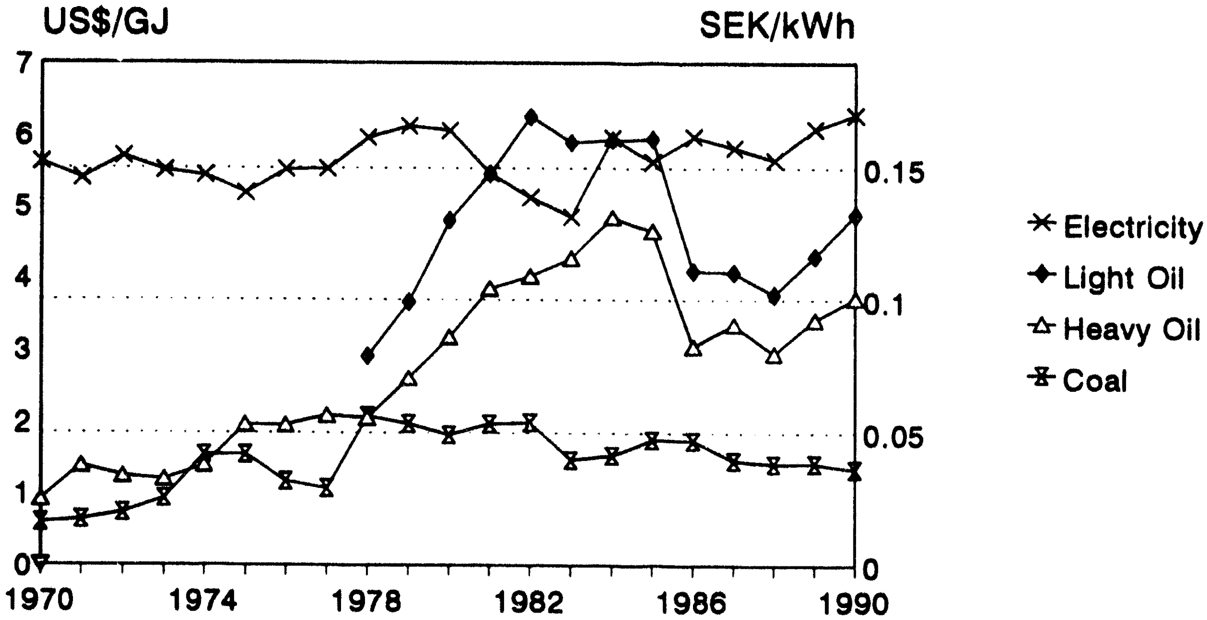


Figure M-6

Real Energy Prices in Sweden
Manufacturing Sector



Source: International Energy Agency & US DOE
Converted to US$ at 1985 PPP

Figure M-7

4.6. Other Industry: Agriculture, Mining and Construction

Among the more significant non-manufacturing industries are three sectors which we consider under the category of other industry: agriculture, mining and construction.[3] Other industry accounted for about 11% of GDP and 6% of delivered energy use in Sweden in 1990. The breakdown of this contribution itself is shown in Figure O-1, which reveals the dominate role of construction. The delivered energy consumption of this sector totaled 61 PJ in 1990, as shown in Figure O-2, up from 59.2 PJ in 1973. Primary Energy use lay at 88 PJ in 1990. Uses for agriculture dominate the picture, but, with reference to Figure I-4, still only makes up less than 3% of final energy use. Over two-thirds of delivered energy in other industry is for oil and petroleum-based fuels, as shown in Figure O-3. Unlike many manufacturing industries, the demand for oil in these sectors is rather inelastic because much of the equipment consists of heavy mobile machinery like tractors and construction equipment which can use only fuels. Consequently the trend towards electrification found in manufacturing did not occur here.

The agricultural sector consists of ISIC 11-13 and includes forestry and fishing in addition to farming. Value-added in agriculture has not increased significantly in the last two decades, with its 1990 level only 14% higher than its level in 1973. Consequently, energy consumption has exhibited only a slight upward trend with a 1990 level that is 22% higher than in 1973. Delivered energy consumption was 32 PJ in 1990.

The delivered energy intensity of the agricultural sector has not changed significantly over the entire period of our analysis. One of the reasons for the flat curve of energy intensity is the low rate of economic growth in the sector. There was a slight decrease of 12% in the energy intensity of oil in the sector and considerable growth in electricity intensity over this period. The normal turnover of equipment likely contributed to the decrease in fuel intensity. At the same time, substitution tended to be among fuels, with gas and biomass gaining fuel shares between 1973-1990. We expect this trend to continue in the near future, given the structure of energy consumption in the agricultural sector.

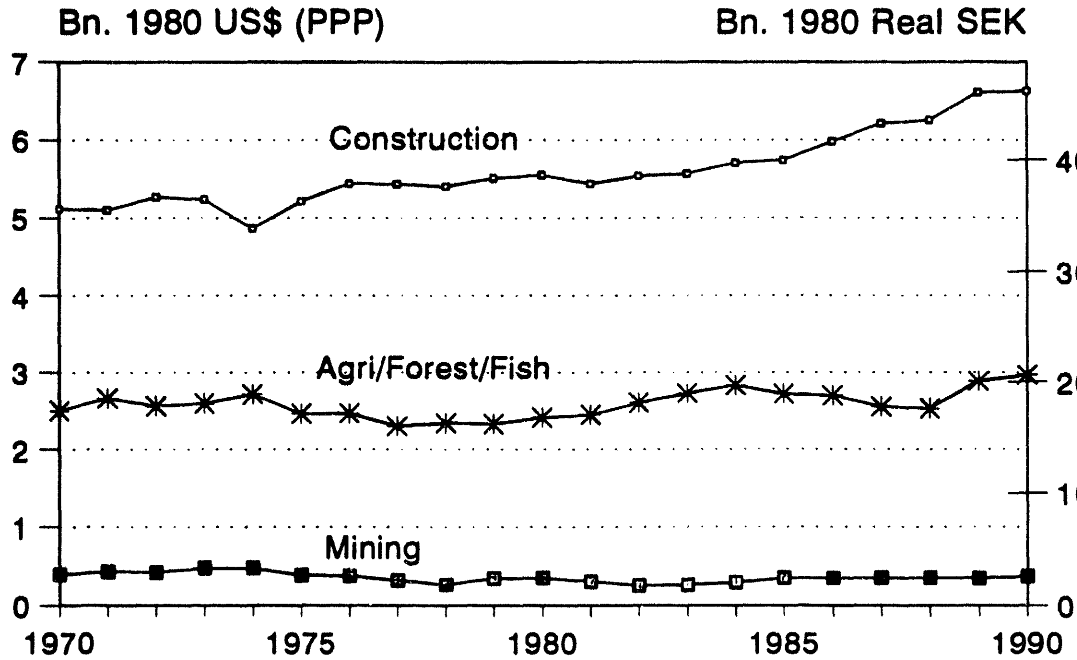
The mining sector accounted for 13.4 PJ of delivered energy in 1990, representing a 35% drop since 1973. Much of this drop is due to the declining economic activity of the mining sector, whose GDP has fallen 22% relative to 1973. Given the energy intensive and oil-intensive nature of the mining sector, these trends are not surprising. Oil consumption dropped over 50% from 1973 while electricity consumption increased by 12%. This has resulted in a drop of 17% in delivered energy intensity. We do not expect mining to decline much further in the near-term, however, given the rapid decline already experienced in a country which has a substantial endowment of important minerals such as iron ore.

The construction industry poses some difficulties because of the lack of data on the consumption of fuels in the 1970s. Noting that the level of oil use lay close to 3.33 times the level of electricity use for each year after 1983, we estimated oil use before 1983 using this coupling with electricity use. Using this approximation, oil rose slowly from 8.5 PJ in 1970 to 10.3 PJ in 1982. Based on these rough estimates, delivered energy consumption was about 15 PJ in 1990, an increase of 30% relative to 1973. Oil consumption drove this increase, since it represents 80% of delivered energy in the construction sector. Value-added grew by 27%, so that energy intensity actually increased slightly over this period.

Figure O-4 summarizes the main trends in the other industry sector. We show the impact on energy use of changes in activity, changes in energy intensities of the three subsectors, and changes in the shares of the three subsectors, which varied significantly. It can be seen that activity changes increased energy use after 1982. Changes in delivered intensities first increased overall intensity significantly, but this changed reversed in the late 1980s, leaving a small decline in sectoral energy use. The effect of changes in intensities on primary energy was more marked, and resulted in a slight increase in energy use. Changes in the structure of the other sector reduced delivered energy use by 15% between 1973 and 1990.

[3] Agriculture includes forestry and fisheries (ISIC 11-13).

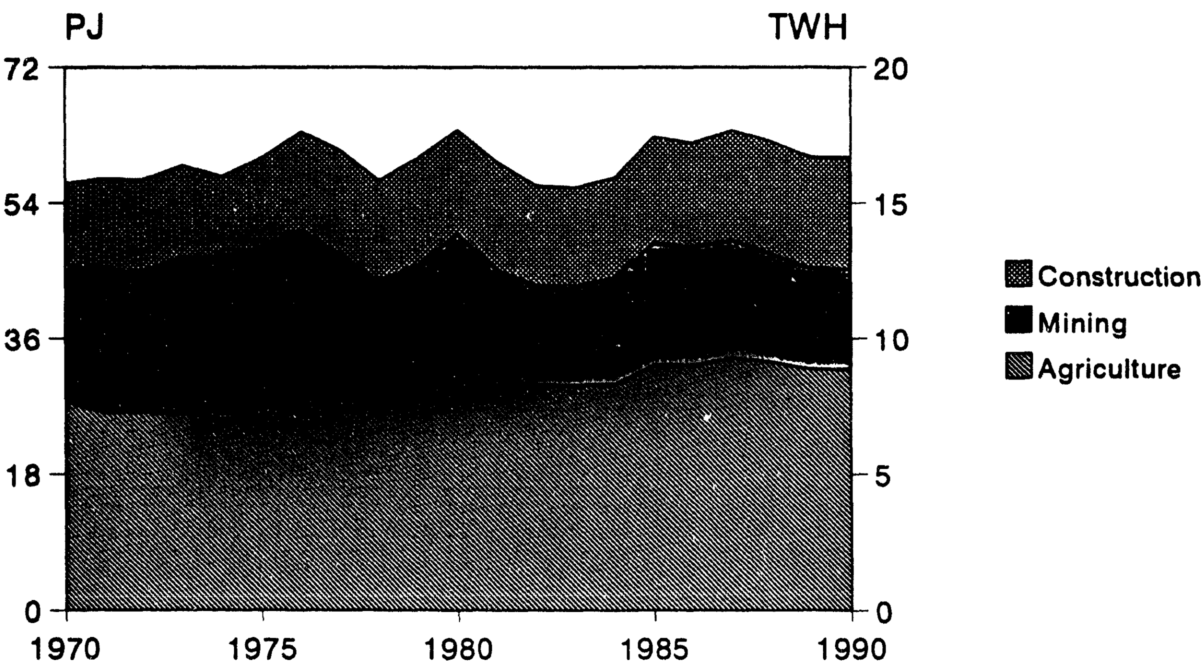
Other Industry Energy Use in Sweden
Real Value-Added



US dollars converted at 1980 PPP

Figure O-1

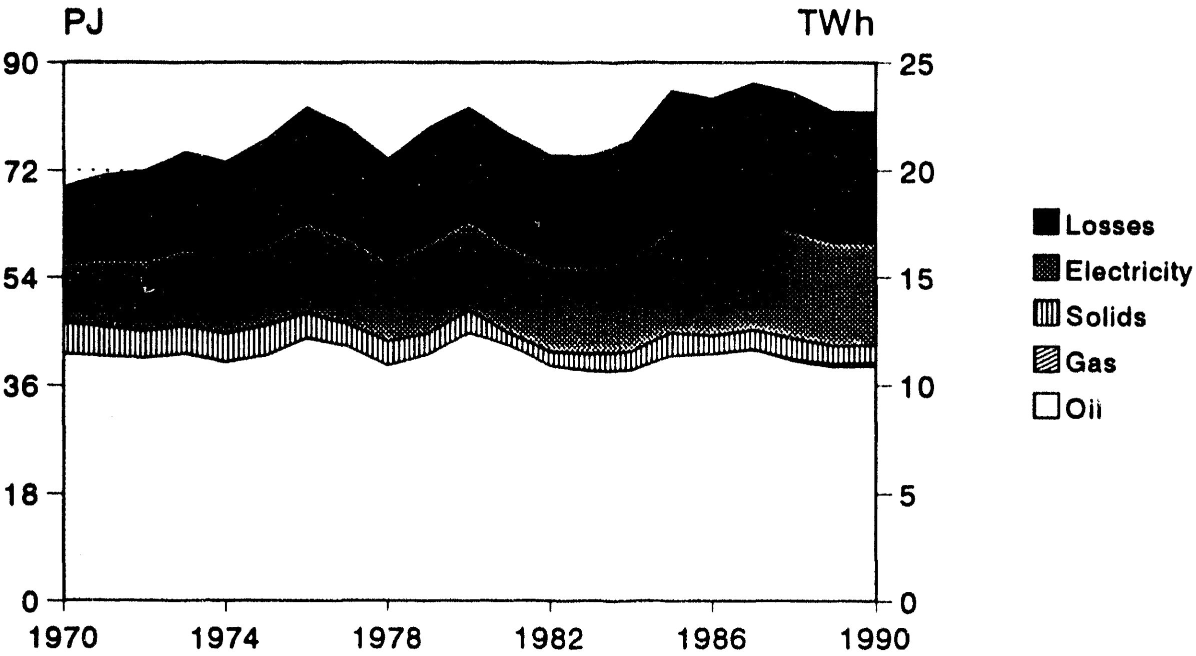
Other Industry Energy Use in Sweden
Delivered Energy



Source: 1970-82: unpublished SCB data; 1983-90: pub. and unpub; Construction use of oil estimated, 1970-82 (10 PJ/yr)

Figure O-2

Other Industry Energy Use in Sweden
Delivered Energy, By Fuel



Source: 1970-82: unpublished SCB data; 1983-90: pub. and unpub. SCB data
Contruction use of oil est. 1970-82 (10 PJ/yr)

Figure O-3

Other Industry Energy Use in Sweden
Impact of Activity, Structure, and Intensity Changes

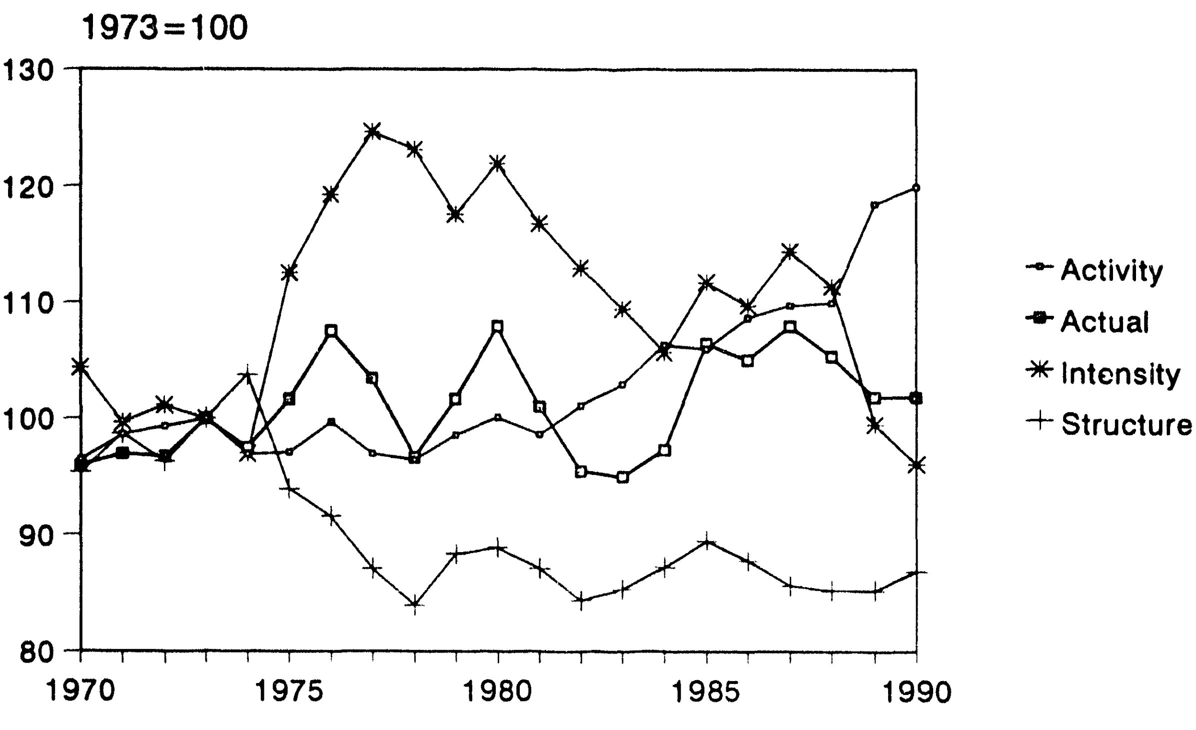


Figure O-4

5. ENERGY USE FOR TRANSPORTATION: THE TRAVEL SECTOR

Analyzing energy use for transportation is difficult because the data are so poor: Fuels used for transportation are not always singled out by either the oil industry or *SCB* as transportation fuels. That is, non-road use of gasoline and diesel fuels are included in the historical data from 1970. Also, marine and rail fuels are not separated as such. But more difficult is the important split of gasoline and diesel fuel into use in automobiles, light trucks, heavy trucks, buses, and other vehicles. Work done in the 1970s (SIND 1977) made important advances in disaggregating this data, but was then only carried out for certain years in the 1980s (Wajsman 1989), and never really published. Official energy studies, by that time preoccupied with issues surrounding electricity (EK 1978, etc.), simply glossed over important details of the use of fuels for transportation. Consequently, we were forced to piece together information on energy use for transportation in Sweden. The appendix explains the tortuous procedures we followed and assumptions we made.

One set of control figures are available from *NUTEK* (1970-90) and *SCB* (1973-1990). These account for fuels by type, not by main transport mode, and include more than just transportation fuels. Moreover, they are not disaggregated by mode, *i.e.*, automobile, bus, truck, passenger rail, etc. The more detailed balances from *SCB* after 1983 permit better disaggregation of gasoline, diesel and heating oil into transportation and other sectors, but not by mode. Nevertheless, these provide a useful check on our calculations. Figure T-1 shows our tentative division of transportation energy use into its main components: travel, freight, international ship bunkers, and a residual. Bunkers, shown in Figure T-1, are counted separately and excluded from our analysis. The residual is the difference between those uses we have assigned and the total quantity of gasoline, road diesel, heating oil, and marine diesel delivered to transportation. This residual consists of three main components: fuel for the military (both air and land-vehicles), aviation gas and jet fuel for civil aviation and international air travel, and small amounts of diesel and gasoline that we could not account for in ground transportation, water transportation, or pleasure boating. Given that most of the residual is military fuel or fuel for international air travel, we believe that the residual shown is acceptably small.

In this work, the main activity data for travel (in vehicle-km and passenger-km) come from the former *Transportrådet, (TPR)* (Wajsman 1989; TPR 1990; Eriksson 1991; hereafter referred to collectively as TPR 1989-1991), for rail activity from *TPR* (1989-1991) and *SCB*, and for air activity from *TPR*, *SCB*, and both SAS and Linjeflyg (LIN) directly (Olemyr 1990-1992).

Sources for data on energy use by mode are *SIND* 1977 (actually carried out by *Vägverket*) covering 1970-1976, and *TPR* (1989-1991) for the years 1980 and 1983-1989. Some partial information was also provided by *Väg- och Trafik- Institutet (VTI)* (Swahn 1991, 1992a, 1992b; Jönson 1993; hereafter referred to collectively as VTI 1991-1993). Because there are no time series splitting electricity use into that for freight trains, passenger trains, and local transit/metro, we used the split provided by *SIND* 1977 to estimate the freight/non-freight breakdown for the entire period under study. But we did not attempt to split the non-freight consumption into a part for transit and one for rail. Electricity is separated from fuel use for railroads. In aggregation with fuel, we count electricity both at its delivered and primary values.

For all modes, we made our own estimates for years not covered by data provided. These were usually estimated by multiplying published activity levels by our interpolations of energy intensities. For air travel energy use, we obtained data from SAS and LIN directly, which was matched to the *SIND* 1977 data and used for the latter part of the 1980s. *SIND* 1977 and *TPR* (1989-1991) provide some information on fuel use for shipping, recreational boats, and a variety of other vehicles (snowmobiles, etc.). After assigning diesel and gasoline to the major modes, we calculated the residual for each fuel. For gasoline, the residual lay at around 5% of use, but for diesel this figure was higher. We suspect that *SIND* 1977 underestimated the use of diesel by trucks (covering the early period).

The following analysis discusses travel-related energy use only. Energy use for freight is covered in a subsequent section. In this section, ***traffic*** is measured in vehicle-km, and ***travel*** in passenger-km. Fuels are converted from volumetric to energy units at rates given by *SCB*: 32.2 mJ/l for gasoline and 35.58 mJ/l for diesel fuel. *Vehicle intensity* means fuel per kilometer of traffic, while ***modal intensity*** means energy use per passenger-km. The number of cars is "***antal bilar i trafik***" as defined by *SCB* and discussed in Jansson, Cardebring, and Junghard (1986). Air travel includes domestic scheduled flights, and excludes civil aviation.

5.1. Structure of the Travel Sector

Travel in Sweden is dominated by cars. Car ownership passed 250/1000 in 1970 and climbed for most of the period we studied, although there were periods of stagnation, as Figure T-2 shows. Also clear from Figure T-2 is that increased car ownership drove increased travel. Cars in Sweden are heavy by international standards, and their weight (and horsepower) increased slowly during the 1970s and 1980s. Over 80% of individuals have access to at least one car, and 20% have two or more (*Bilindustriföreningen-AB Bilstatistik* 1991). In other words, Sweden is a motorized and mobile country.

To understand how the rise in per capita travel by mode (Figure T-2) is distributed, we show the shares in Figure T-3. The car's dominance is clear. The figure for total travel by car presented by *TPR* (1989-1991) agrees with that indicated in the major travel surveys (RVU 1978; RVU 1984/85), after the 1984/5 survey is adjusted to remove activity by bus and truck drivers and include travel by those under 15 or over 74 (Wajsman 1993). Yet this figure depends on both the total traffic (in veh-km) and the load factor, or number of people per car. The former is uncertain, as new estimates of travel per car developed by *VTI* (1991-1993) lie well over the figure we use herein, about 14 500 km/year. Additionally, the load factor, or number of people per car, must be estimated. The ratio of trips or travel by both drivers and car passengers to trips or travel by drivers yields an estimate of the load factor of only 1.35, very low by any standards. This figure was assumed to be much higher by *TPR*, closer to 1.7. Moreover, *TPR* assumes only a slight decline in developing their automobile travel estimates for the 1970-1989 period. Other observers (VTI 1991-1993) suggest that load factor may have fallen from as much as 2 in 1970 to below 1.6 in 1990. If VTI's assumptions were correct, then automobile travel would start at a higher level than we indicated for 1970 but grow less rapidly. This issue is important for both historical analysis and for considering future directions in mobility. But we cannot resolve the issue at this stage. Until these uncertainties are cleared up, we will use the long-standing figures of *TPR* (1989-1991) for both automobile traffic and automobile travel.

Complementing travel by cars is that by collective land modes (rail, local transit, and bus, and domestic air). The role of rail or transit and buses changed little during the period we studied. These shares rose briefly in the wake of the two oil price hikes (1974-75 and 1979-82), but fell back in the late 1980s, although buses still carried a larger share of total traffic in 1988-89 than they did in 1990. One reason may be the abandonment of a number of local rail lines, particularly those with diesel *rälsbuss*, that cut across or branch out from the main north-south lines in Sweden. But while the role of collective land travel stagnated, that for domestic air travel rose, and total domestic travel rose nearly five-fold between 1973 and 1990. Sweden's great distances explain in part why air travel is popular. Incentive fares (*röda avgangar*) and higher incomes also stimulated this increase. As a result of all of these changes, although automobile travel increased on a per capita basis, its percentage share of the total travel dropped by 2% while the percent of the total contributed by air travel increased by the same amount.

5.2. Fuel Mix and Energy Intensities

The fuel mix in the travel sector changed very little between 1970 and 1990. Diesel played a very small role in automobiles, comprising approximately 4% of automobile fuel (by energy content) in 1973, rising during the early 1980s as fuel prices rose in general, then falling back. Diesel fuel dominated that for buses, but played a very small and diminishing role for rail. Aviation gasoline was significant in the early 1970s, but by the late 1980s, virtually all scheduled air travel was based on jet fuel, with aviation gasoline used primarily for private aviation. Since cars and jets rose in overall importance, this meant that gasoline and jet fuel made up an increasing share of total oil use. Ethanol and other alternative fuels only began to appear in the late 1980s or early 1990s and are not significant.

Figure T-4 shows the modal intensities of four modes, and the vehicle intensity of automobiles. Energy intensities for all modes except air changed little in Sweden. This in and of itself is surprising, given the two significant oil price shocks. The vehicle intensity of automobiles rose in the late 1970s, because the momentum of increasing car size, weight, and performance was not slowed in the first years after oil prices skyrocketed.

The Swedish fleet of gasoline automobiles required 10.6 liters/100km in 1973 (SIND 1977), a figure that rose slowly to a high of 10.8 liters/100km in 1980 (TPR 1989-1991). We used the same values for 1978 and 1979, surmising that during these years the intensity of new cars began to drop. From 1980, then, fleet vehicle intensity declined, to slightly over 10 liters/100km in 1989 (TPR). The intensity of diesel vehicles lay at around 8.7 liters/100 km in 1973 (SIND 1977), drifting downward slowly to 8.2 liters/100 km, where it lay stagnant (TPR). The combined fuel intensity of automobiles, expressed in energy units, moved from 10.6 liters/100 km in 1973 to 10.8 liters/km in 1980 and fell back to 10.06 liters/100km by 1989, an overall decline between 1973 and 1990 of only 6% but a fall of around 10% from the peak years of 1978-1980. Combined with a slowly falling load factor, this change caused the modal intensity of automobiles to rise until the early 1980s, then fall slightly, showing a decline of 3% in 1990 over 1973.

Modal intensities for bus and rail showed the converse behavior, falling during the high price years (early 1980s) as ridership was up, then rising slowly in the late 1980s. Still, the energy intensities of these modes in 1990 lay slightly below their levels of the early 1970s.

The most surprising performer among the travel modes was air transport. Using data from *SIND* 1977 as well as from SAS/LIN (Olemyr 1990-92), we estimate that the intensity of passenger air travel lay around 4.2 mJ/pass-km in 1973. In spite of phasing out most propeller traffic in favor of jets, the intensity of air travel sank to 3.5 mJ/pass km in 1980 and continued downward, reaching a low of 2.80 mJ/pass-km in 1990 for the combined efforts of SAS and LIN.

From the intensities and levels of activity we can estimate total energy use for each mode of travel. Figure T-5 shows our results. Automobile fuel use in 1990 lay about 25% above its 1970 value. Increases in traffic or travel were far greater than the small reductions in respective intensities. Total use of energy for buses or rail travel was also higher than 1973 values, because of increases in traffic on these modes as well. Total fuel used by air travel was up sharply by the late 1990s over its value in 1973, but the growth was cut sharply by the decline in modal intensity of nearly 50%.

5.3. Evolution of Energy Efficiency and Energy Savings

5.3.1. Aggregate Measures

The ratio of domestic travel to GDP, shown in Figure T-6, indicates that travel kept pace with the growth in the economy.[1] Aggregate travel energy intensity fell by only 4% between 1973 and 1990. This reflects the very small gains made in the dominant mode, automobile travel. The large decline in air travel intensity is almost invisible in this aggregate statistic, because of the small share of air travel. To understand the components of this aggregate behavior, we turn to our structural/intensity analysis.

5.3.2. Decomposing Changes

Three factors drive changes in energy use for travel: Total activity (passenger-km), the mix of modes, and the energy intensities of each mode. We tested these changes in travel-related energy use in Sweden between 1970 and 1987 using both the divisia and Laspeyres indices (Schipper, Steiner, Duerr, An, and Strøm 1992). Both techniques give the same result, showing how much change in one factor results in change in total energy use. The three components of change represent growth factors; they can be compared with base-year energy use to calculate the absolute change that occurred from any one factor alone.[2]

Applying the Laspeyres indices to the structure of energy use for travel in Sweden yields the results shown in Figure T-7. Changes in activity alone caused a 30% increase in energy use. Changes in the share of modes, holding the level of travel and modal intensities constant at 1973 values, caused an increase of 5% in energy use by 1989. Changes in the intensities of the individual modes caused a very small decline in energy use of 3% between 1973 and 1989. If we counted primary energy use, this decline is the same, because the share of electricity, which affects the primary/delivered energy ratio, changed very little from its low value.

Thus we see that very little energy was saved in the travel sector in Sweden. To be sure, vehicles became more efficient. But most of the improvements in automobile efficiency were offset by increases in power or weight. Figure T-8, for example, shows the six-fold increase in the share of cars in the two largest weight classes. Small improvements in the efficiency of rail probably occurred as well, as with buses, but load factors did not show major improvements, hence there was little change in overall modal intensities.

The dramatic improvements in air travel were caused by a variety of factors. First, load factors increased. There were more seats per aircraft and, more importantly, a large share of these were occupied. Our data indicate that seats/aircraft increased from 33.5 in 1973 to over 60 by the end of the 1980s. The share occupied rose steadily from 54% in 1973 to nearly 64% in 1989, alone permitting nearly an 18% decline in modal energy intensity. Thus, while load factors (and power or size) acted to offset energy savings of automobiles, and had very little net impact on energy use for bus or rail travel, these factors permitted an increase in aircraft performance (through substitution of jet for propeller aircraft) and resulted in a significant energy savings. Additionally, actual aircraft engines and other features that influence energy use improved significantly (Schipper, Meyers *et al.* 1992; Greene 1992), leading to even greater savings than from operations.

5.4. Causes for Changes

Why are Swedes more mobile in 1990 than in the early 1970s? Certainly higher incomes permitted greater automobile ownership and more travel. Increase in the number of women in the workforce increased both travel and car ownership and use. The shrinking household size, led by a dramatic increase in the number of single-person households, had an indirect effect on the load factor in cars, since more trips that might have been

[1] Since overseas travel increased more rapidly, this means that Figure T-6 underestimates growth in total mobility of Swedes.

[2] It is important to realize that the estimates of changes in energy use arising from each component do not add. Because of some uncertainties in the 1990 structure of travel-related energy use, we perform the analysis here through 1989.

taken by couples were taken by two individuals. This meant that more traffic was required to provide a given amount of travel. And much anecdotal evidence supports the proposition that Swedes became increasingly suburbanized in the 1970s and 1980s. Even if transit systems such as that in Stockholm continued to carry nearly half of all trips to work, expansion in travel for other trips led to increases in car use (*Resvaneundersökningen (RVU)* 1978, 1984/85). Finally, the extension of paid vacation time to around six weeks and liberalization of shopping hours in the evenings and on weekends certainly permitted, if not encouraged, more activities requiring transport modes that were traditionally served by the automobile.

Opposing this trend were higher fuel prices. In the year following the first oil shock, travel fell, particularly that in cars, but it sprung back by 1975. The same thing occurred after the oil shock in 1979; this time the drop was small but lasted four years. Since that time, travel has increased steadily until 1990, when prices skyrocketed again as a major tax shift raised the price of fuel in Sweden. However, the overall price changes were small during the 1970-1990 period. By 1982 real gasoline prices had reached their highest point, 4.89 SEK/liter in 1985 SEK, about 50% higher than their 1973 value, and higher than even the 1990 value after the tax increase. Overall, prices in the late 1980s had declined. By 1989, just before the fuel tax increase, it cost about 20% more for the fuel required to travel one kilometer, in real terms, than in 1973. This was the lowest in a decade, but still substantially higher than before 1973. Why didn't the vehicle intensity of cars improve more?

The answer may lie with company car traditions. Car ownership, use, and power was boosted by company car policies that permit employers to provide cars as compensation, often with all fuel and sometimes even insurance provided as well. The employees pay a nominal tax on this "income" that is indirectly related to the size and features of the car but not related to its use. Essentially company cars are "zero marginal cost" cars. The company car policies in Sweden encouraged both greater ownership and travel and permitted those with company cars to own larger, more powerful cars (Carlén 1991; Wall 1991).

Figure T-9 shows indicators of new car weight and power for the study period. The increases in both indicators are clear. Weight has increased steadily, and even increased after the fuel tax increases in 1990. The ratio of fuel intensity to weight in the stock fell 21% between 1981 and 1990, and the ratio of fuel intensity to power fell by more, indicating a true improvement in fleet efficiency. But power grew faster than weight, yielding greater performance.

What lay behind these increases in car weight and power, which seem to belie the increase in fuel prices? Tabulation of *Bilregistret* (SCB 1992b) shows that the average power of a company-owned car in 1981 was approximately 69 KW, while that for cars owned by "physical persons" (including private personal companies such as consultants' own companies) was only 59 KW. Since company cars are much newer than those in the stock in general, this comparison is a bit distorted. But comparisons for new cars, as shown in Figure T-9, are revealing. Between 1981 and 1991 the power level in new cars increased, with that for company cars increasing by a greater amount than that for private cars. By 1991 the average *new* company car was 8 KW more powerful than a "private" car, a gap that had widened from only 6 KW in 1988. Since company cars represented approximately 33% of the new cars in 1991 (and 10% of the entire stock), their effect is not negligible. Moreover, the fact that the company car share of new cars is more than twice the share in the whole stock means that company car policies lead to a "flooding" of the used car market, a private car market, with cars larger than those normally purchased by private persons.[3] The share of company cars in the stock lay at 8% in 1976 (excluding those owned by private companies), and about 17% in 1985 (including private companies), decreasing slightly thereafter. It appears that the popularity of company cars in the new-car market kept the average fuel intensity from falling more than it did until the mid-1980s, while the stagnation in fuel prices in the late 1980s then provided a "floor" for new car fuel economy. But new company and private cars sold in 1990 and 1991 were more powerful than those in previous years. Reversing the momentum of the trend to more powerful cars in the new car market will take time!

The changes in the characteristics of new cars have an important interpretation. Since the ratio of power to weight increased, the performance and acceleration of Swedish cars increased. More important, the ratio of test fuel consumption to power (in KW) fell 26% between 1981 and 1991. This is a sign of improved "efficiency". What happened is clear: the improvements in automobile technology were directed primary at fueling heavier and more powerful cars. The overall efficiency improvements nevertheless permitted a small decline in the fuel intensity of new cars, which in turn was reflected in a decline across the entire fleet.

[3] As of this writing *SCB* has not yet disaggregated the horsepower of "private cars" into those truly private vehicles and those registered to "privata företag" or private companies. Therefore the figures shown here may underestimate the company car/private car gap.

While the company car effect was certainly a prominent influence on the ownership and characteristics of cars, the government did encourage lower fuel intensity through its 0.85 Program, which took effect with the 1978 model year. This program had as its goal the voluntary achievement of a sales-weighted average fuel intensity for new cars of 8.5 liters/100 km, starting at a level of 9.3 in 1978. The goal was achieved, according to figures tabulated by the automobile industry and Ministry of Commerce and published in *Bilismen i Sverige* (Bilindustriföreningen-AB Bilstatistik 1992), although the low point, 8.2 liters/100 km, was reached only in 1987, after which the average moved back to 8.3 liters/100 km. As we note above, however, our best estimate of "real" (*i.e.*, on the road) fuel intensity lies at around 10 liters/100 km in 1990. Since independent surveys (KOV 1988 and earlier years) confirm that the actual fuel intensity of new cars is close to that which is "declared" as the basis for the 0.85 Program (Schipper, Steiner, Duerr, An, and Strøm 1992), this means that either our estimates of fleet fuel intensity are very far off, that the impact of new cars in the stock is simply delayed, or that the mix of cars used in the "weightings" for the 0.85 Program do not reflect extra equipment or more powerful motors taken as options. The quantitative issue of real fuel economy must be resolved before a judgment can be passed as to the effectiveness and impact of the 0.85 Program, higher fuel prices, or other stimuli in encouraging or discouraging lower fuel intensity.

Other policies also encouraged travel in Sweden. Tax deductions for commuting were introduced to promote labor mobility without forcing individuals to move their homes to cut costs of travelling to work. Vigorous support for transit in a few key cities like Stockholm has certainly meant that a high share of this traffic is on public transport, but the *level* of travel increased. Likewise, expansion of the airport network supported a great expansion of SAS and LIN domestic flying. There is nothing surprising in these policies, but they led to increases in travel that offset the energy savings won from new technology.

5.5. Prospects for Energy Use.

The prospects for energy use for travel are mixed. The gradual shift towards more automobile (and air) travel continues, interrupted only by recession and periods of higher fuel prices. The preliminary data for 1990 and 1991 indicate a clear drop in automobile use. But between 1988 and early 1993, the real price of gasoline has been raised by roughly 33%. As our data show, this increase is significant, and could slow the move toward heavier and more powerful vehicles and slow the shift toward car travel, although the sales data for 1989-1991 indicate that both weight and horsepower continued to increase. Moreover, value-added tax was added to domestic travel in 1990, adding to the effects of recession in ushering in a slowdown and then downturn in air travel in particular. Because this came at a time when competition was being introduced into the domestic air market, it is likely that load factors the individual airlines achieve will fall until traffic volumes pick up. This means that the ratio of energy use to travel in Sweden may not drop in the very near term.

In the longer term, however, higher fuel prices, increased intercity bus service and recent introduction and subsequent popularity of high speed rail, the *X-2000*, should lead to a recovery of the share of intercity traffic carried by rail and bus. Transportation infrastructure programs, such as the Dennis-Paket, should also relieve some of the strain on local traffic arising from automobiles, another factor promoting use of rail and bus. If tax subsidies to commuting are eliminated, the way people commute to work, and, in the longer run, where they live, could be affected.

Coupled with these likely shifts are the real possibilities that Sweden's car buyers will assume a larger share of their costs of motoring if company car schemes are restricted. This will most certainly mean that cars bought in coming years will be lighter and less powerful, challenging Sweden's domestic producers to make safe and efficient cars that are smaller and lighter than today's flagships. That is, the market for more energy efficient cars will be strengthened. Consideration of new registration taxation schemes that reward environmentally friendly cars (and, significantly, trucks as well) over those that pollute more also encourages this trend. These rules may not change intensities directly, but they may indirectly favor less energy-intensive vehicles because these fulfill stringent environmental requirements more easily than do more energy intensive vehicles.

Moreover, Volvo has forged an alliance with Renault, a maker of small cars, and is building its own smaller cars in Holland, while Saab is now owned in part by General Motors, whose Opel line produces many successful small cars in Europe. This could lessen political pressures to keep company car schemes in place, since Volvo and Saab now profit indirectly from imports of smaller cars from these two continental manufacturers. Finally, there is the possibility that concerns over both energy and carbon-dioxide leads other auto producers to develop new energy-efficient technology. These factors, combined with the potential removing of company car subsidies, could mean that the first meaningful drop in the energy intensity of automobiles in Sweden will occur in the next few years.

In other sectors, the energy outlook points towards greater efficiency. Various schemes have helped *Statens Järnväger* and *Stockholms Lokaltrafik* maintain reasonable load factors; more funding and more passengers seem to be on the way. Linjeflyg (now a part of SAS) has ordered even more modern 737s and other, new airlines are using modern plane as well. SAS has almost phased out its DC9s. In all, we expect a continued decline in the energy intensity of air travel in Sweden. For its intercontinental traffic, SAS has moved to long-range 767s, with energy efficiency playing a prominent role in their decision (Abrahamsson 1990). As the economic situation picks up for all airlines, load factors will likely rise, reducing energy intensities further. And in the long run, it is likely that SAS will consider the Boeing 777 or, if developed, a prop fan jet, both of which reduce energy intensities even further (Schipper, Meyers *et al.* 1992). Of course, international traffic is not counted in our analysis, but the trends cited here are indicative of the continued pressure on air carriers to improve energy efficiency. Since intensities, and therefore fuel costs, are higher in short haul markets, and competition from other modes most intense in these markets, it is likely we will see improvements in domestic energy use as well.

Transport Energy Use in Sweden

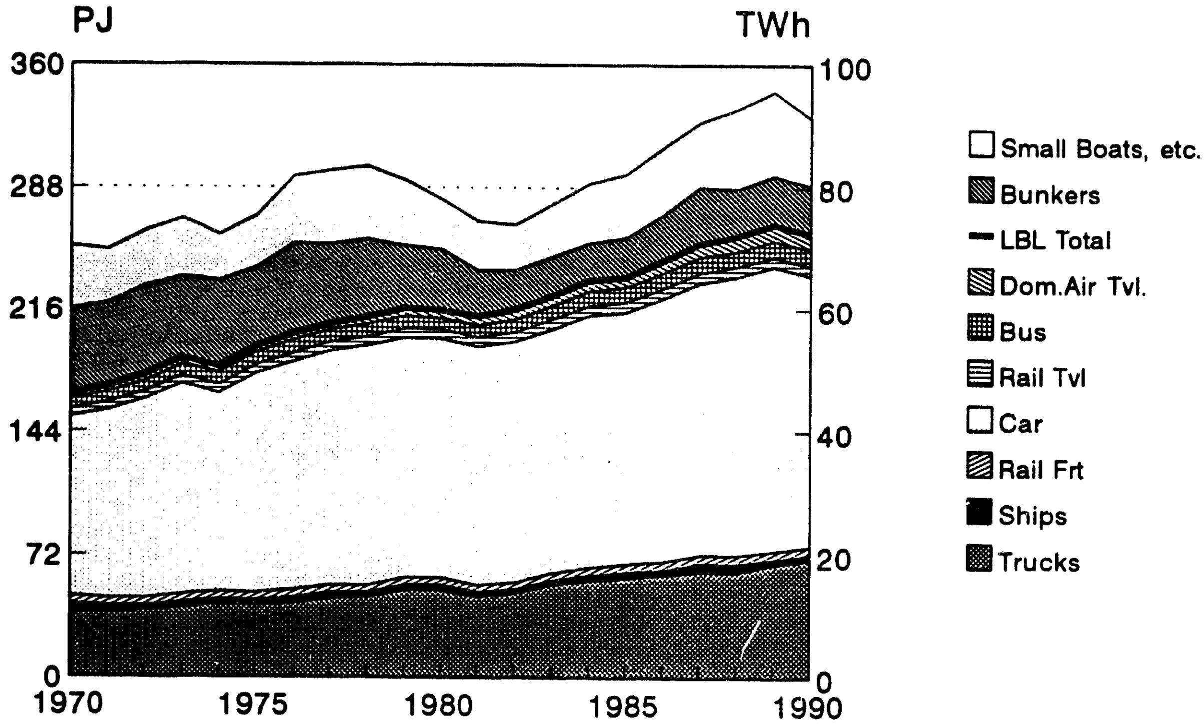


Figure T-1

Travel Energy Use in Sweden
Car Ownership and Total Travel

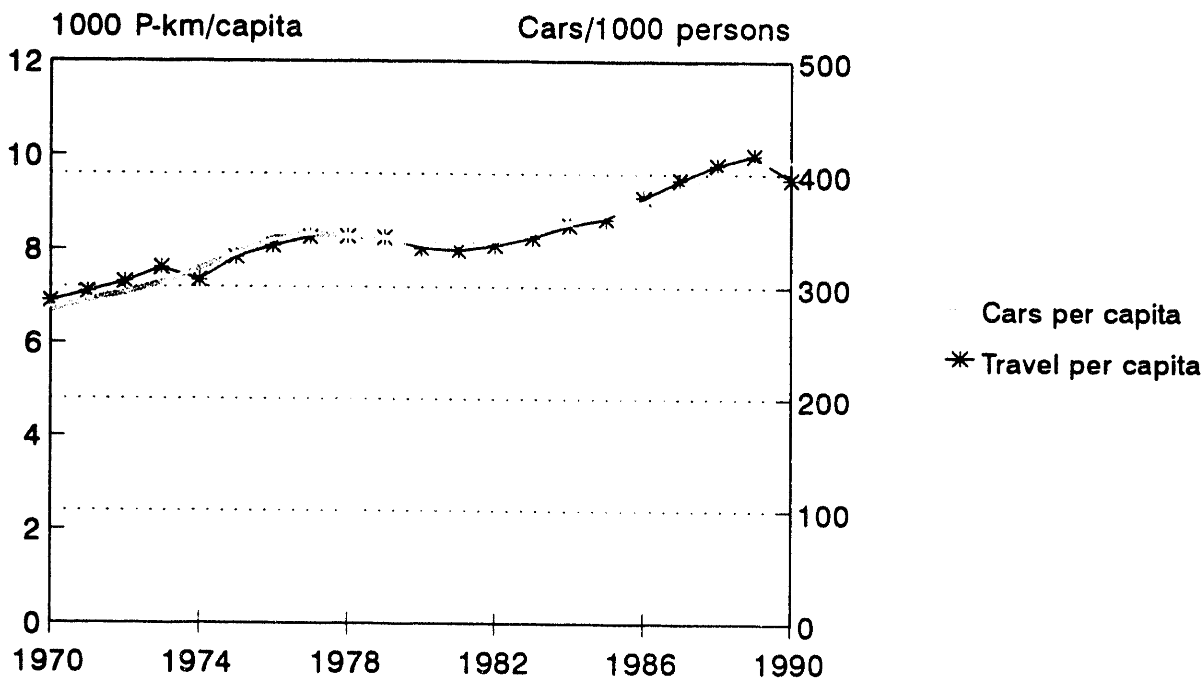


Figure T-2

Travel Energy Use in Sweden
Sectoral Shares

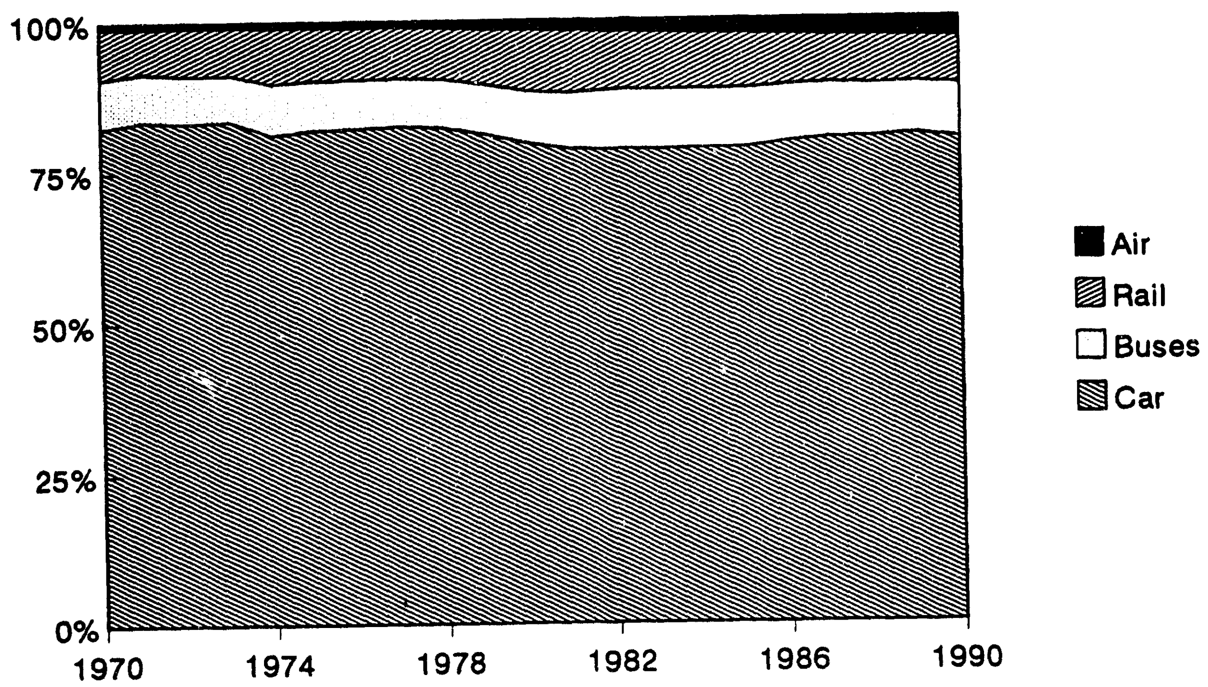


Figure T-3

Travel Energy Use in Sweden
Travel Energy Intensities

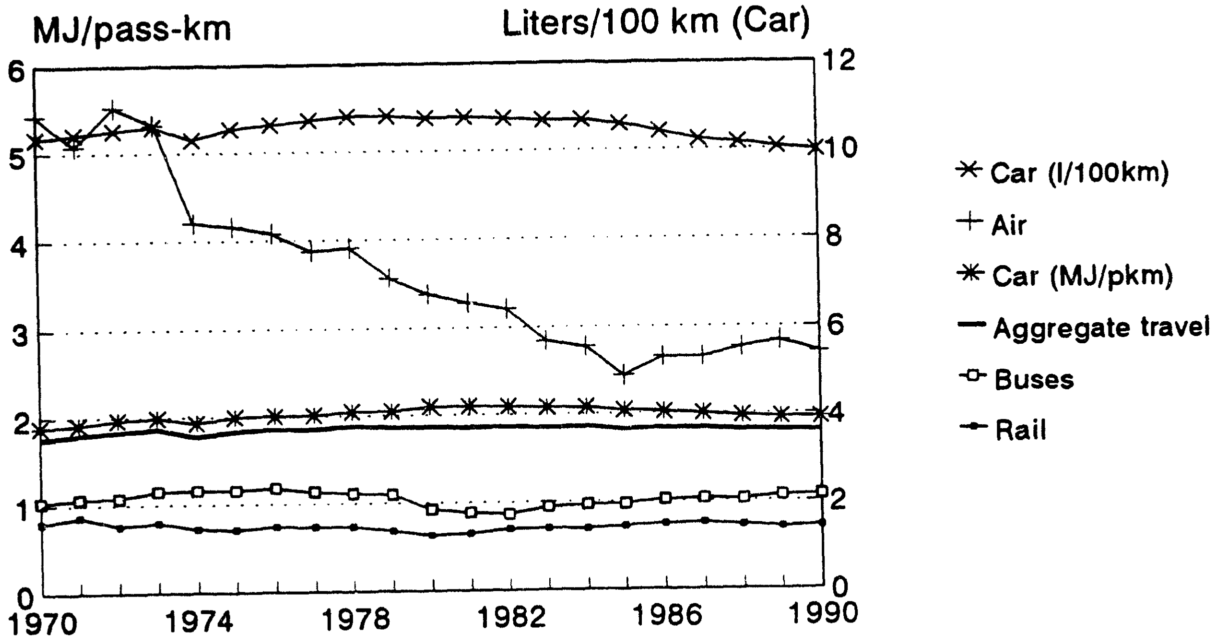


Figure T-4

Travel Energy Use in Sweden
By Mode

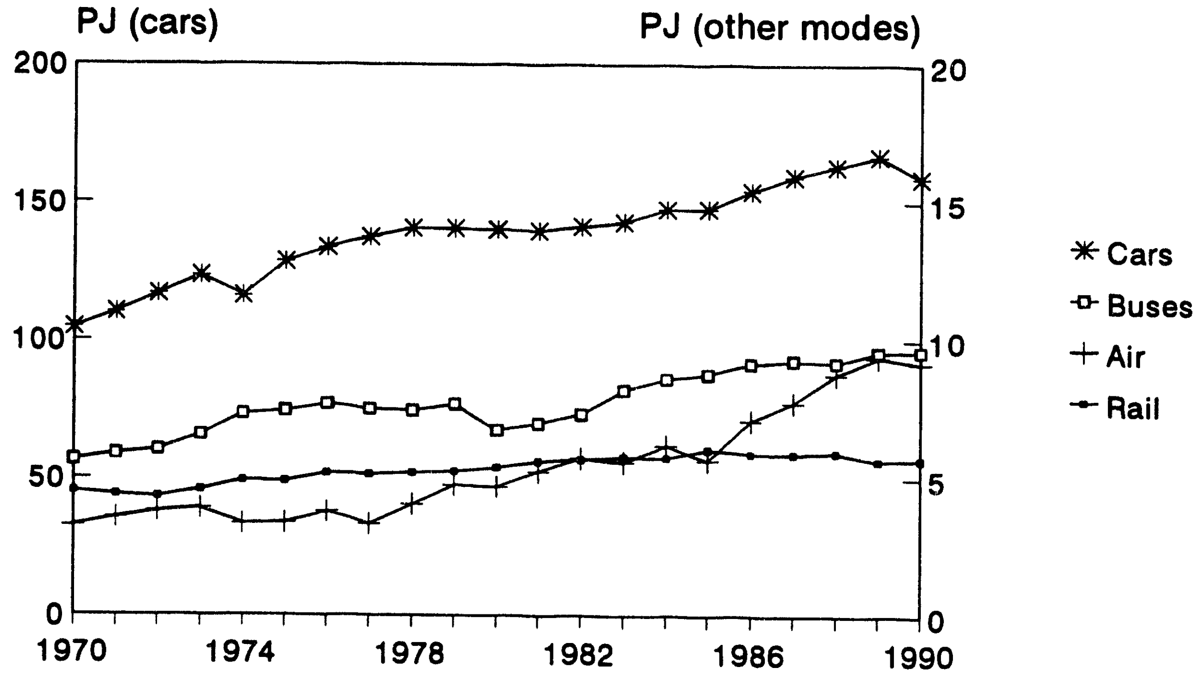


Figure T-5

Travel And Freight Energy Use In Sweden
GDP Intensity

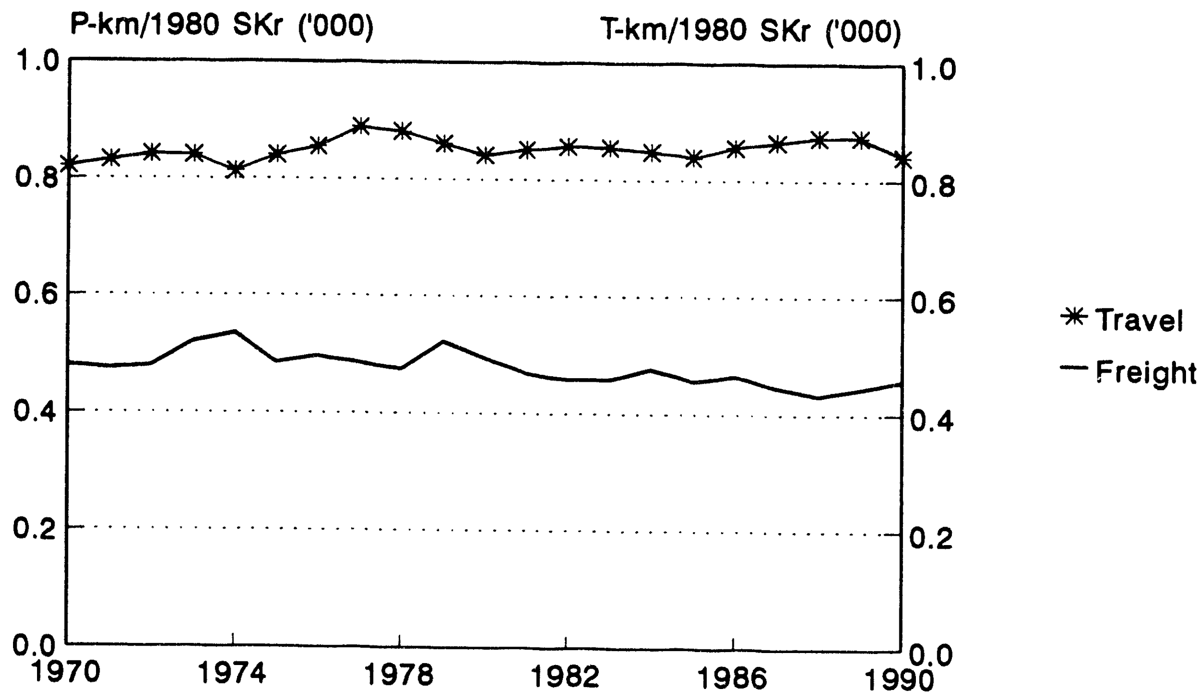


Figure T-6

Travel Energy Use in Sweden
Effects of Activity, Structure, Intensity

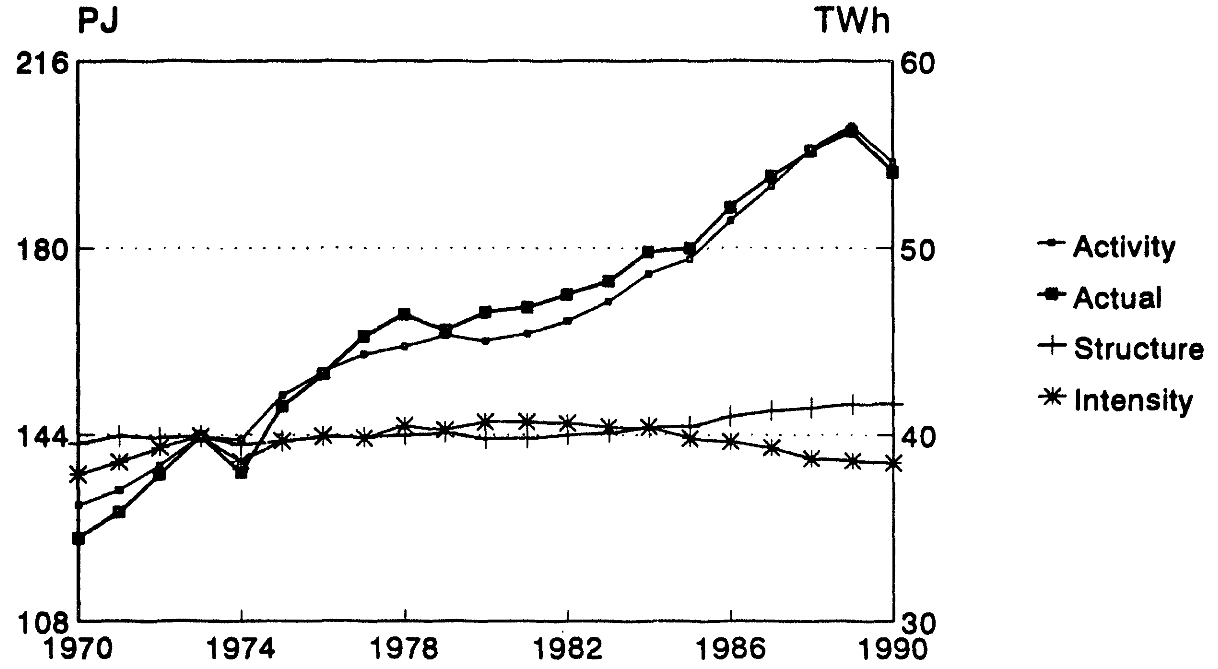


Figure T-7

Automobile Stock in Sweden
Distribution by Weight

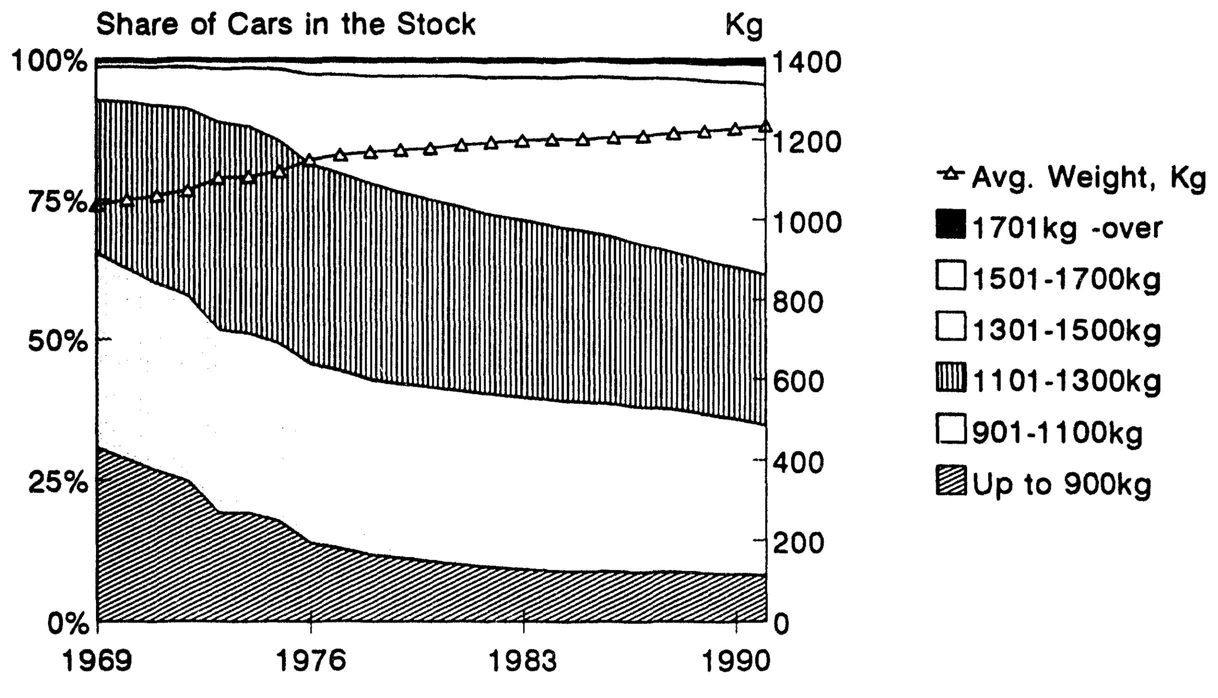


Figure T-8

Sweden: New Cars by Power and Weight
Effects of Company Cars

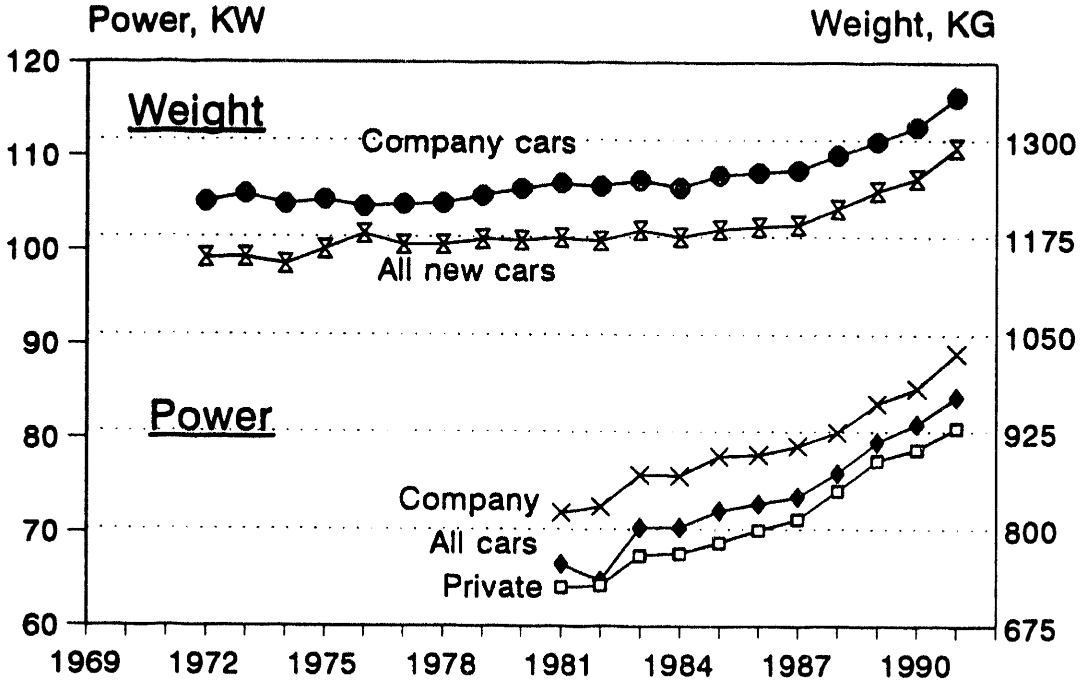


Figure T-9

6. ENERGY USE FOR TRANSPORTATION: THE FREIGHT SECTOR

The split of transportation energy use into components was shown in Figure T-1 in the previous section. The share of freight-related energy use in total transportation fluctuated, driven principally by changes in the level of industrial activity in the near term. Yet the use of fuel for truck freight increased at a faster rate than for any other major mode except air travel. Energy use for truck freight in 1990 lay at nearly 8.5 times the level of that for air travel (the other rapidly growing component of energy use for transportation), and approached 45% of the amount used for cars. Thus, energy use for freight has become an increasing source of concern because of the pollution generated and traffic it represents.

The calculations in this section are based on the same data sets used for those for travel. Activity data are from *TPR* and *SCB*. The use of fuel for light trucks is counted explicitly as such by *TPR*, but not by *SIND*, although these were less important in the early 1970s than in the 1980s. There are great uncertainties in the data for energy use for water transport which will become apparent, too. The split of energy use for rail freight from that for travel follows the trends from *SIND* 1977, where explicit breakdowns were provided by SJ. Energy use for air freight is calculated from that for air travel by assuming that one tonne-km is the equivalent of seven passenger-km (by weight) and therefore draws seven times as much energy as that of a passenger-km.

6.1. Structure of the Freight Sector

Sweden has a raw-materials intensive economy. Forest products, ore, and bulk shipments of steel and steel products are important as feedstocks to the engineering economy and as exports. Nevertheless, the ratio of freight hauled to GDP has fallen slightly between 1970 and 1990, as Figure T-1 showed. This position is reflected in the importance of both rail and ship in total domestic freight.

Trucks also figure in the shipment of raw materials, particularly for forest products. Overall, trucks dominate freight, and their share increased slowly during the 1970s and 1980s, as seen in Figure F-1. Average load shrunk as smaller trucks grew in popularity and "just-in-time" production and distribution made speed more important than capacity utilization. Air freight (including mail) grew but was still small relative to the other modes. Timber floating disappeared.

6.2. Fuel Mix and Energy Intensities

As with transportation, oil use dominates the freight market. Electricity dominates the railroad, but its share is small compared to the total energy use for trucks. Energy use for trucks is dominated by diesel, although the proliferation of light trucks has kept gasoline consumption important as well. Figure F-2 shows the energy intensities of the major freight modes.

The energy intensities of truck freight were calculated for diesel and gasoline vehicles for 1970-1976 by *SIND* (1977), and for each fuel by size of vehicle for 1980 and 1983-89 by *TPR*. It is hard to judge the accuracy of these estimates, since, unlike the case for gasoline, there is no readily available control total for road diesel with which to compare these estimates. However, the distances which diesel vehicles are driven each year is reported for tax purposes and published by *SCB*. When the fuel data are compared with freight hauled (measured in tonne-km), however, there appears a steady increase in the intensity of trucks. At first this may seem strange. Yet data from *SCB* (Swahn 1992a, 1992b) show a great increase in the number of light trucks, including some for private use. These vehicles carry far less freight, per unit of energy use, than do heavier trucks, and far more of the light trucks run on more energy-intensive gasoline engines than on diesel ones. This may explain the apparent increase in the ratio of aggregate energy use for trucks to tonne-km hauled. At the same time, data provided by Volvo show very little improvement in the rated fuel use per tonne-km of large trucks built in the 1980s over those built in the late 1960s. The average load per truck appears to have declined (seen by dividing total tonne-km by total km driven), confirming the suspicion that shifts in the way trucks are being used has led to an increase in fuel use per tonne-km hauled. In all, these change led to steady increases in energy use for trucking.

The energy intensities of rail and ship freight varied with the strength of the economy and loadings. Uncertainties in energy consumed for shipping may explain the jumps seen in the data in Figure F-2. When activity levels and energy intensities are combined, we obtain total energy use for trucking as shown in Figure F-3. The domination by trucks is evident.

6.3. Evolution of Energy Efficiency and Energy Savings

6.3.1. Aggregate Measures

As was shown in Figure T-6 in the previous section, total freight volume kept pace with GDP in Sweden, losing only two points between 1973 and 1990 (from 48 tonne-km/1000SEK to 46). Since the share of industrial GDP in total GDP fell slightly, this implies that the ratio of freight hauled to industrial GDP actually increased. Aggregate energy intensity for freight *increased* by around 30% between 1973 and 1990, in spite of significant increases in energy costs for trucking and shipping.

6.3.2. Decomposing Changes

We can disaggregate changes in freight energy use using the same technique used to understand energy use for travel, again using 1973 as the base year (Figure F-4). Doing this we find that increases in the volume of freight alone raised energy use for freight by 17% between 1973 and 1989. Changes in the mix of modes pushed up energy use for freight by 6%. Changes in the individual intensities of the three main modes raised energy use for freight by nearly 23%. As we saw, truck freight was responsible for both the shift to more energy intensive modes and the increase in the energy intensity of freight. In sum, freight was the only sector in the Swedish economy where all three factors changed in ways that *increased* sectoral energy use. Clearly energy use for freight deserves further study if it is to be restrained in the future.

6.4. Causes for Changes

Why did energy use for freight increase so much? As we noted, it can hardly be said that vehicles themselves became less efficient. What did happen, however, is that the utilization of the entire system changed markedly, towards smaller loads and smaller vehicles. This must have occurred because of the high capital cost of holding goods, i.e., in response to "just-in-time" production and distribution. Officials at Volvo's *Kalmarverken*, for example, explained how most of the parts they used (except for chassis) arrive by truck, and most cars are hauled away by truck. This reduces the time that either parts or finished products sit in Kalmar, and increases the flexibility of routing. The trend towards "just-in-time" also means smaller loads on trucks, as the data for Sweden imply. An additional factor that applies to Swedish freight is the gradual disassembly of the smaller, feeder-type rail routes, most of which were designed for diesel traction. As these were removed, trucks became the only practical freight mode available.

6.5. Prospects for Energy Use

The prospects for energy use for freight are mixed. The current economic slowdown will reduce freight volume and thereby energy use for freight. In the longer term, the slow shift towards greater use of trucks for freight and the continual shift towards smaller loads have more than offset the impact of small technical improvements to motors that would lower energy use for trucking. Sweden's alignment with the EEC promises to increase the importance of trade, particularly trade in consumer goods. Unless new rail systems are developed for international traffic, trucks are likely to absorb most of this trade.

There are many technical measures that could reduce greatly the fuel requirements of various sizes of trucks (Schipper, Meyers *et al.* 1992). With the new emphasis on fuel taxation in Sweden, particularly the shift from kilometer taxation of diesel vehicles to heavier taxation of the fuel itself, investments in significant improvements in the fuel economy of trucks, will become increasingly attractive. The recognized need to raise revenue from vehicle use to pay for transportation infrastructure will likely encourage the carrying of fuller loads and filling up trucks on return trips. Lower interest rates generally will shift the trade off between inventory size and "just-in-time" shipping towards larger inventories, by lowering the cost of inventories, and this will permit or encourage shippers to form larger loads.

The dilemma for Sweden is that both the kinds of freight shipped (or modes used) and truck market are international. Sweden alone cannot influence radically the choice of modes used for freight. Of course, much of the move towards smaller loads is a local phenomenon, driven by "just-in-time" considerations (Engström *et al.* 1991). This trend can be influenced somewhat by local planning. This means using zoning or fees and permits to segregate trucks from other traffic in congested areas or simply raise the cost of using trucks in congested areas. This would shift the balance somewhat from "just-in-time" shipments with smaller loads to larger loads.

The potential for improving vehicles should not be overlooked. Volvo and Saab-Scania are world leaders in trucks, but they cannot bring vehicles to market for only the Swedish market when most of their business is overseas. Nevertheless, the trends in Central Europe, North America, and most of the rest of the world point towards the same traffic, energy, and environment pressures perceived in Sweden. If other nations raise taxes on diesel fuel or vehicle use and emission, we foresee that new energy-efficient trucks and trucking systems will begin to appear in Sweden and elsewhere.

Freight Energy Use in Sweden
Freight Per Capita, By Mode

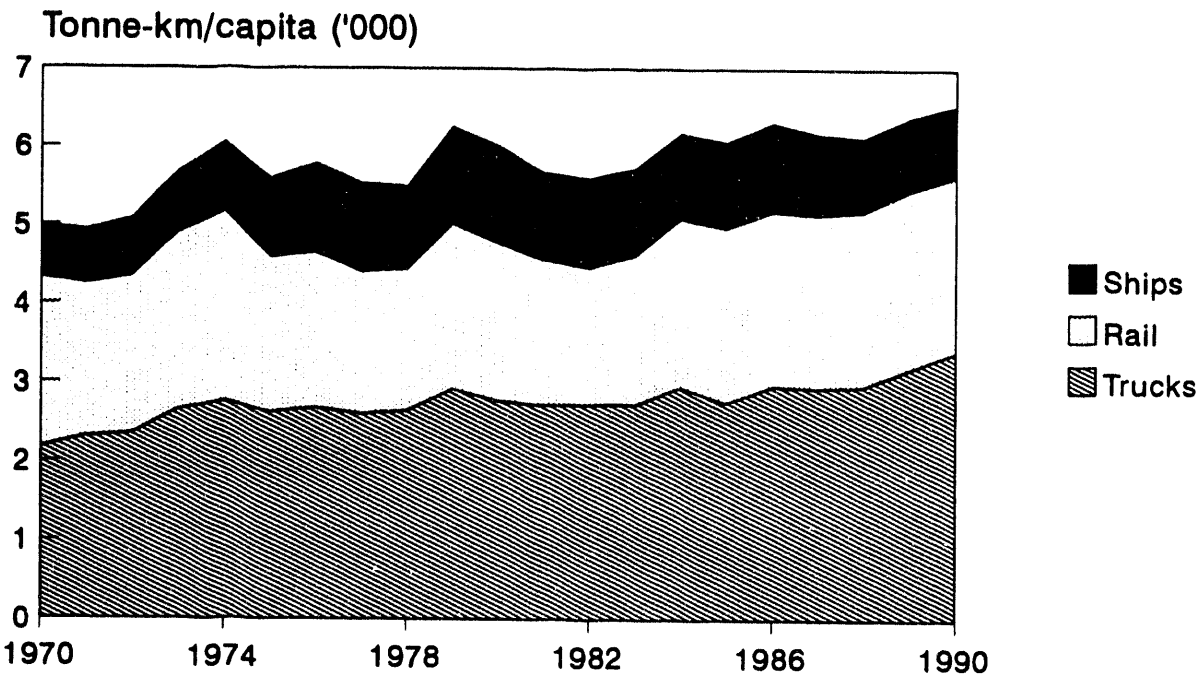


Figure F-1

Freight Energy Use in Sweden
Energy Intensities

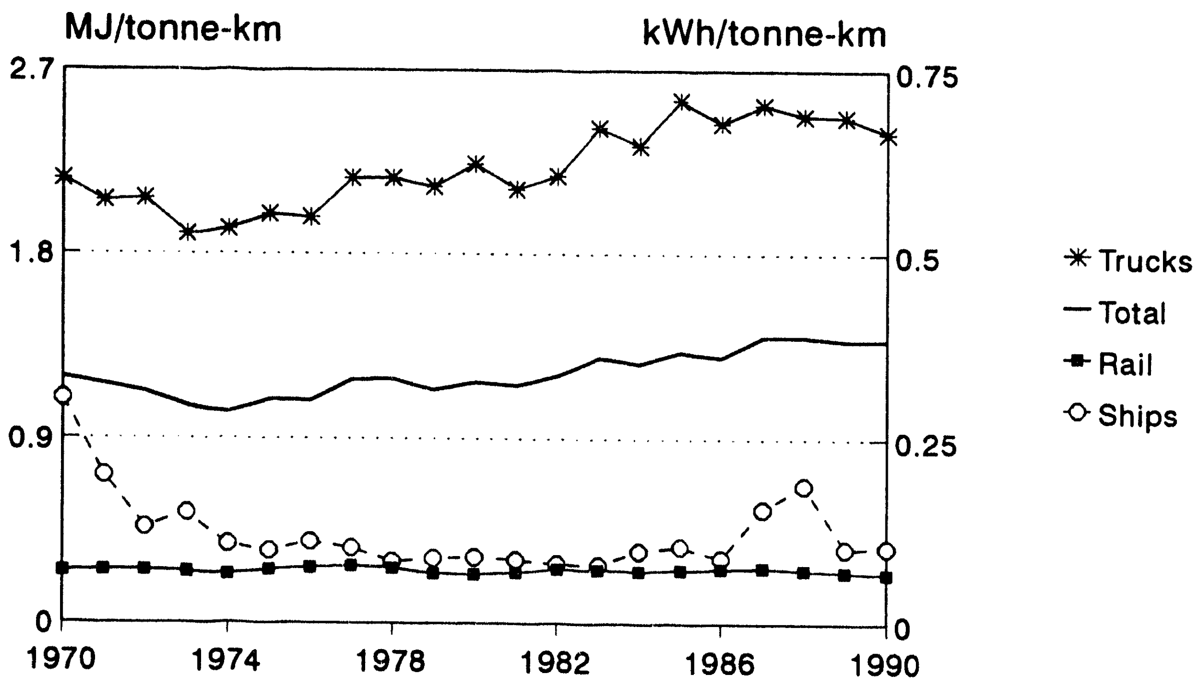


Figure F-2

Freight Energy Use in Sweden
Total Energy By Mode

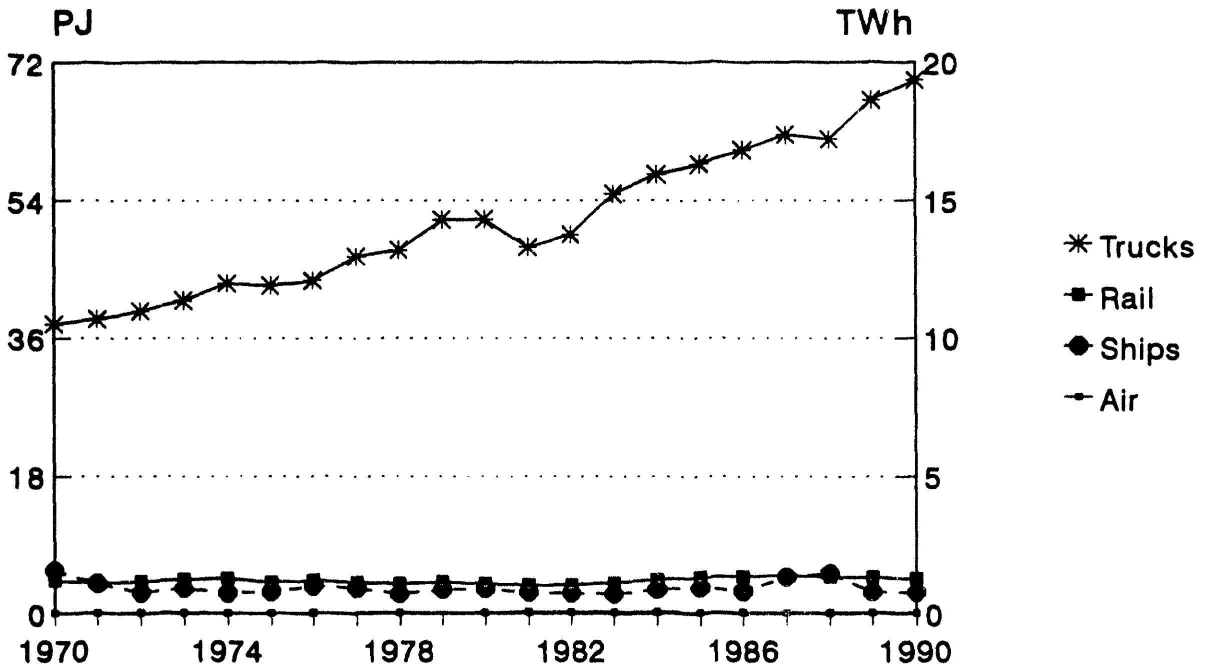


Figure F-3

Freight Energy Use in Sweden
Activity, Structure, Intensity Effects

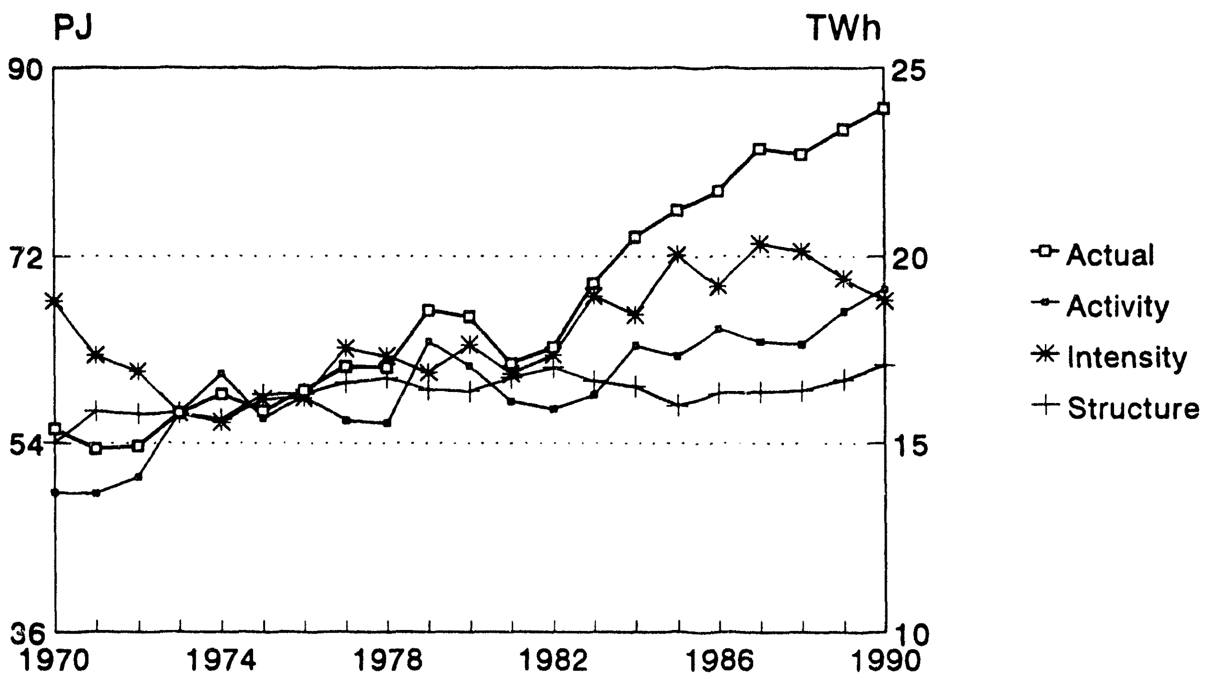


Figure F-4

7. SUMMARY: INTEGRATING THE RESULTS

Policy-makers in every country have asked: what are the quantitative results of improved energy efficiency? This question cannot be answered by examining a country's overall energy/GDP ratio because this ratio is clouded by effects not related to changes in individual energy intensities (Schipper and Meyers *et al.* 1992; Schipper 1991a; Schipper 1991b). Certainly, per capita energy use in Sweden was lower in the 1980s than in 1973. However, for a complete understanding, we must quantify the impact of changes in individual energy intensities on sectoral energy use, as well as gauge the impact of structural change itself on sectoral energy use. To do this, we turn first to a review of the sectoral findings. Then, we present more detailed calculations that separate most of the effects of changes in structure and activity from those that arise principally from improved energy utilization. The first calculation uses the sectoral findings that show how much changes in energy intensities alone reduced (or in some cases, increased) energy use. The second method estimates how much energy use would have been in 1989 had energy intensities *not* decreased (or increased).[1] Since downward changes in energy intensities are related to "energy conservation", both of these calculations offer a useful measure that can be evaluated over different time periods or compared with results from other countries. Despite their imperfections, these calculations illustrate the impact of reduced energy intensities on total energy demand far better than the aggregate numbers.

7.1. Activity and Economic Background

Swedish GDP growth in the 1970s and 1980s was intermittent, with periods of downturn in the mid-1970s and early 1980s. Indeed, real GDP in 1981 was only 4% higher than it was in 1976, suggesting that the entire period from 1975 through 1982 was plagued with economic stagnation. This situation certainly suppressed consumer expenditures on energy for heating and travel, and restrained growth in industrial energy use. But the same slowdown retarded energy efficiency investments and the turnover of industrial capital and the building stock. When the economy finally improved after 1983, much of the repressed consumer demand returned, but industrial efficiency investment was still behind. Consequently, we judge that the slow growth in the Swedish economy restrained energy *use* but also restrained efficiency improvements.

In the introduction we noted that sectoral activities are driven by different factors. We chose GDP arising in the manufacturing, service, and other industry sectors as the major activity drivers, noting that service sector activity rose more than did activity in the other sectors. The structure of manufacturing shifted slightly towards more energy intensive sub-sectors, while that of other industry moved in the other direction. True measures of structural change in the service sector are absent, but increases in lighting, ventilation, and information technology led to "structural" changes that increased electricity use. The major driving factor for the household sector is population, which increased slowly. But household size shrunk, driving increases in both the number of homes and the number of private vehicles. These subtle structural changes lead in turn to increases in energy use for households and travel. And while industrial activity only increased by 20%, overall freight kept pace and evolved towards greater reliance on trucks, indeed on smaller trucks (or at least smaller loads). All of these factors *increased* energy use within each respective sector. Most of these changes occurred relatively independent of changes in energy prices, but in response to economic growth and demographic change.

Overall energy prices in Sweden evolved in different ways. Real electricity prices did not increase by more than 15% for industry or 30% for households, in both cases peaking in the early 1980s and again after price and tax reform in 1990. Diesel fuel prices crashed from 130% of their 1973 value in 1984 to less than their 1973 value by 1986. Gasoline only exceeded 125% of its 1973 level between 1979 and 1986, but shot up again in 1990. Heating oil prices, and with them prices for heating in apartments and the service sector, increased several-fold, and reached more than 300% of their 1973 value in 1989. Industrial heavy oil prices were also very high in the 1980s. But in all, the Swedish economy was not exposed to large price changes for *all* fuels, as was the case in many other countries.

7.2. Fuel Substitution

Fuel substitution played a key role in reducing oil use in Sweden. While it is difficult to make an exact calculation, we estimated that fully half of the oil savings in households and services, and likely 20% of the oil reduction in manufacturing, arose because consumers and businesses switched from oil to electricity, wood, and district heating. Moreover, oil use for producing electricity and district heating itself was reduced drastically. The flight from oil slowed somewhat after the price fell in 1985, particularly in the residential sector, suggesting that price differences drove these substitutions.

[1] Since there are still major uncertainties in the data for travel and freight for 1990, we limit our integrated analysis to 1989.

7.3. Energy Intensities: Stars and Laggards

Figure SU-1 shows the intensities of key energy uses in the Swedish economy over time. The intensities of home space heating fell by more than 20%. The intensity of fuel heating in the service sector also fell by nearly this amount. The intensity of oil heating in homes using only oil appears to have fallen by 30% between 1973 and 1989, and the intensity of oil heating in commercial buildings fell nearly as much, supporting these aggregate findings. Intensities for air travel, and most sectors of manufacturing also fell by more than 25%. (The structure-corrected aggregate is shown in Figure SU-1; Figure M-4 in the manufacturing section shows changes by industry branch.) The importance of oil or energy costs to space heating, manufacturing, and air travel are clear.

What is surprising is the sluggish behavior of the intensities of automobiles and trucks. The vehicle intensities of automobiles and trucks fell by very small amounts (10% for cars and less than 10% for trucks). The intensity of automobile *travel* fell by only 2%, while that for truck freight increased significantly. What is not obvious is that fuel represents only a small part of the total cost of transportation. In the short term, little can be done to reduce vehicle intensities, but changes in utilization could increase modal intensities. However, over the 20 year period of observation, important changes in how cars and trucks have been utilized acted to increase modal intensities for these vehicles. Increased income, boosted by company car policies, permitted drivers to own or use larger and more powerful cars. Also, the overall change in real fuel prices for diesel fuel and gasoline were smaller than the changes in real prices for space heating or process heating fuels or airline fuel.

7.4. Integration and Comparison of Sectoral Findings

Using the methodology outlined in the introduction and applied to each sector, we can review the evolution of energy use in the Swedish economy between 1973 and 1989. Figure SU-2 shows the impacts of changes in activity, structure, and primary energy intensity between 1973 and 1989 on each sector. Services and travel showed the greatest increases in activity, while residential and freight lagged. Manufacturing activity increased 20%, close to the average across all sectors. That is, other things being equal, shifts between sectors favored energy use in services and travel over energy use in other sectors. Overall, changes in sectoral activity alone boosted primary energy use in Sweden by nearly 20%, and increased delivered energy by virtually the same amount.

Figure SU-2 also shows the changes in primary energy use in each sector that occurred because of structural changes within each sector. While structural change increased energy use in *all* sectors, the impact was strongest in the residential and transportation sectors. (Structural change had a small but negative impact on energy use in "other industry", not shown.) Overall, structural change itself increased energy use in Sweden by nearly 10%.

The combined effects of activity and structural change on sectoral primary energy use, which measure energy services, are also shown in Figure SU-2. These are normalized to overall growth in GDP. It can be seen that this measure for the services and travel sector raced ahead of GDP growth, as indicated by the positive result, while the same measure affected the residential sector by the same amount as GDP grew, while the effect for freight and manufacturing lagged behind GDP. On balance energy services lagged GDP growth, as evidenced by the small (2%) decline in the "average" figure.

Figure SU-2 shows the strong decline in manufacturing and the residential structure-corrected intensities. Equally strong is the increase in intensity in freight and services. Increases in energy use from activity and from structural change (for freight; structural change is not defined for the services sector) acted together to boost energy use strongly in these sectors. Energy use for travel lay between these extremes, rising from increased activity and structural change, but falling from reductions in intensities.

Significant reductions in intensity were achieved in the Swedish residential, services, and manufacturing sectors between 1973 and 1990, although electricity intensity rose rapidly. The intensity for freight increased, while that for travel fell slightly, and then only in the later 1980s. On balance, delivered intensity in Sweden fell 26%, and primary energy intensity 8% between 1973 and 1989.

Figure SU-3 shows year-to-year behavior of the delivered energy intensities in all sectors. As shown in Figure SU-4, when measured in primary energy terms, the decline in intensity in manufacturing or the residential sector was smaller than when measured by delivered energy, while that for services was reversed into an increase. The rise in electricity use intensities, of course, which lay behind the different behavior of primary energy intensities need not imply reduced efficiency in end-use technologies; instead, the growth may be due to fuel switching and the increased penetration of electrical equipment.

Figures SU-5 and SU-6 integrate these results, scaling them to 1973 (base year) energy use. The provision of energy services—the combined effects of activity and structural changes—grew substantially in all of these sectors with the affluence afforded by economic growth. Figures SU-5 and SU-6 show the impact on energy use of this growth in energy services. This growth lifted delivered energy use 33% and raised primary energy use by 32% between 1973 and 1989. At the same time, the parallel evolution of the intensity effect and the ratio of primary energy use to GDP is important, and will be discussed further below.

7.5. Detailed Intensity Calculations

The first of our calculations shows what Swedish energy use would have been if energy intensities had matched their 1989 levels but the level and structure of energy-using activities were in their 1973 configuration. This is done by summing the effects of changes in energy intensities, sector by sector, on total energy use. By comparing this hypothetical level of energy use against the actual 1973 level, the impacts of intensity changes between 1973 and 1989 become apparent. Figures SU-5 and SU-6 show the results of this calculation over time applied to delivered energy use and primary energy use as well. This quantifies the overall impact of lower energy intensities on Swedish energy use, with structure and activity measures in each sector remaining constant.

Using this method, we start by noting that in 1973 primary energy demand in Sweden for the sectors we studied totaled 1900 PJ (including the other industry sector). Recalculating this demand using the lower 1989 energy intensities for each sector yields a demand of 1769 PJ. As shown in Table SU-1, this is a 7% reduction in primary energy. We also calculated that between 1973 and 1989, energy intensity reductions would have reduced delivered energy use in 1973 by 26%.

The second calculation estimates how much energy would have been used in Sweden given 1989 activity and structure but 1973 energy intensities. By comparing the result with actual 1989 energy use, one obtains a gauge of the energy savings achieved by reductions in energy intensity over the period. This second calculation takes into account the fact that changes in the level and structure of energy-using activities on balance raised energy use between 1973 and 1989. Using this calculation, primary energy use in the six sectors (industrial sector is divided into manufacturing and other industry) would have reached 2502 PJ, about 6% higher than it actually was, in 1989. Equivalently, intensity reductions over the period reduced the level of primary energy use by 5% (Table SU-1). Note that for freight and services, there were no savings, i.e., with actual energy intensities, *more* energy was used in 1989 than would have been used at 1973 intensities.

Figure SU-7 shows the behavior of this indicator for each sector over time, using 1973 as the base. It can be seen that in primary terms, the savings in the residential sector "peaked" in the early 1980s, and that the negative savings in the service sector appeared in the early 1980s. Both of these changes occurred because of the massive substitution of electricity for oil, which in primary terms leads to an *increase* in energy intensities (or decrease of savings) in both sectors. This effect arises because of the nature of our calculations, not necessarily because there was no energy savings in the service sector or because electricity substitution erased energy savings. But as we noted in our sectoral chapters, the evidence of significant savings of electricity where it was used for heating was slender. Using useful energy (or following the work of Carlsson, of *PREDECO*, [1992]) shows that savings did accumulate, but they are not fully measured here.

Neither of these calculations is perfect for other reasons, as well. These methods ignore the interactions among intensity, structure, and activity that took place in the real world. For example, had Swedes not reduced their use of energy for space heating markedly, they would have had to reduce expenditures for other goods and services in order to pay for space heating. And if Swedes had not bought automobiles in the 1980-1989 period that were less fuel-intensive than those they drove in 1973, the cars they drove in 1989 would have used more fuel per kilometer. It is likely they would have driven less than they actually did in 1989 with such cars, in order to reduce their expenditures for fuel. These effects should be borne in mind when interpreting our results.

In spite of these shortcomings, however, the overall findings of our study should be clear. First, significant energy savings occurred in both the residential and in manufacturing sectors, as well as in the air travel sector. Heat savings likely occurred in the service sector. Small savings occurred in automobile travel. But only in the manufacturing and household sectors were the savings greater than any uncertainties arising from the procedure we used to aggregate fuels and activities. This fuzzy picture should itself be cause for some concern by authorities.

7.6. Swedish Energy/GDP Ratio

Between 1973 and 1989, the Swedish energy/GDP ratio declined by 25.6% in terms of delivered energy and 6.9% in terms of primary energy as measured in this study. Surprisingly, these decreases are close to the energy intensity declines we calculate above, indicating that the energy/GDP ratio for Sweden *could* be construed as an indicator of changes in energy intensities. The reason for the close agreement in the case of Sweden is straightforward: real GDP grew by 35% over the period, close to the growth in energy services (Figure SU-6 shows the growth in energy services). Put another way, the ratio of energy use to GDP in Sweden fell only 2% because growth in energy services was only slightly slower than growth in GDP. The rest of the decline was caused by reductions in individual energy intensities.

7.7. Sweden's Energy Efficiency Plateau

The development of energy-using activities and energy intensities was not consistent over time. The growth in energy services, for example, slumped during the sharp recession that fell on the Swedish economy after the 1979 oil price shock. More striking, however, is the development of energy intensity. The decline after the first oil shock reached a hiatus in 1979, then accelerated again between 1979 and 1983, when it reversed for one year but fell again through 1988, before settling into an apparently trough or plateau. In primary energy terms this trough is clear, but there is little decline after 1983, suggesting that most of the decline in delivered intensity after that time was caused by substitution of oil by electricity. This means, in effect, that although Sweden managed important improvements in energy efficiency in the 1970s and early 1980s, this progress came to a standstill as energy prices eased in the mid-1980s (Figure SU-5 and SU-6).

Overall, these detailed calculations show that the impact of lower energy intensities reached a maximum in the mid-1980s and then fell back somewhat. Energy efficiency in Sweden, to the broad extent it is related to energy intensities, seems to have hit a plateau.

Table SU-1: Energy Savings in Sweden 1973-1989

Method One

Sector	Actual 1973 Energy Use (PJ)	Energy Use (PJ) 1973 Activity & Structure 1989 Energy Intensities	% Difference
Residential	517	456	-12%
Manufacturing	858	757	-12%
Other Industry	78	82	+5%
Services	241	261	+8%
Travel	147	142	-3%
Freight	59	71	+20%
Total Primary Energy	1900	1769	-7%

Method Two

Sector	Energy Use (PJ) 1989 Activity & Structure 1973 Energy Intensities	Actual 1989 Energy Use (PJ)	% Difference
Residential	696	692	-1%
Manufacturing	1066	935	-12%
Other Industry	102	99	-3%
Services	348	377	+8%
Travel	218	203	-7%
Freight	72	84	+18%
Total Primary Energy	2502	2390	-5%

Method One: Energy demand with the structure and activity levels of 1973 but energy intensities of 1989. The difference shows the impact of changes in energy intensities between 1973 and 1989, other factors held constant.

Method Two: Energy demand with the structure and activity levels of 1989 but the energy intensities of 1973. The difference shows how much energy was saved relative to the level that would have prevailed in the absence of intensity reductions.

Swedish Energy Intensities
Relative Changes since 1973

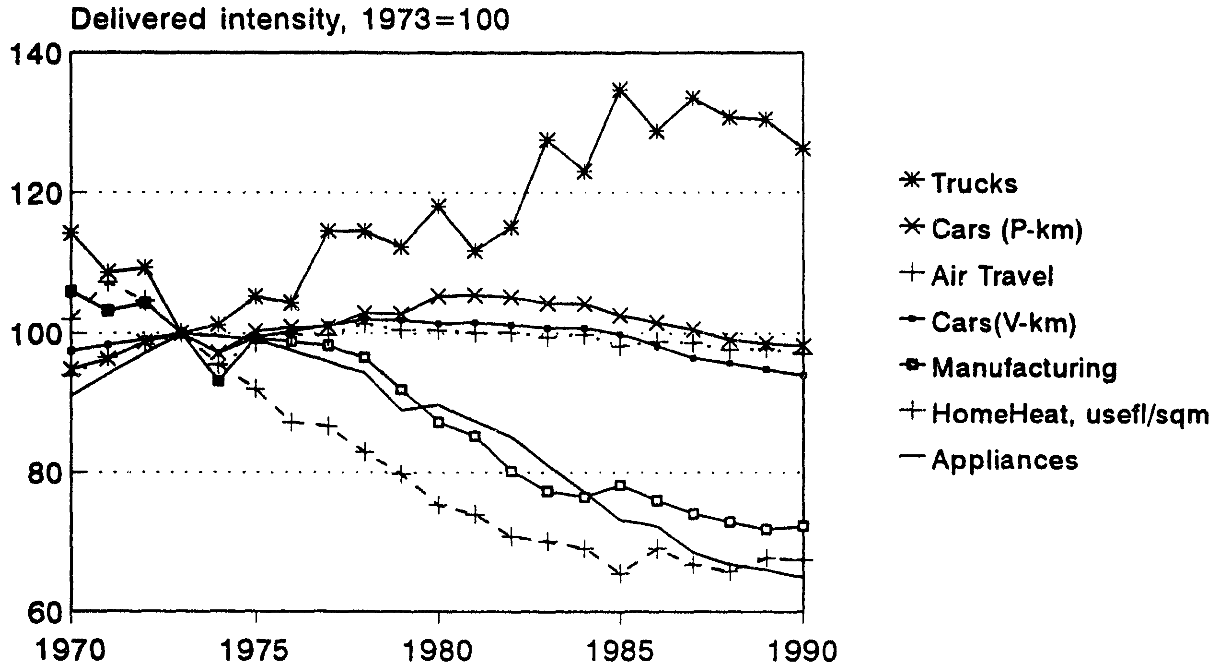
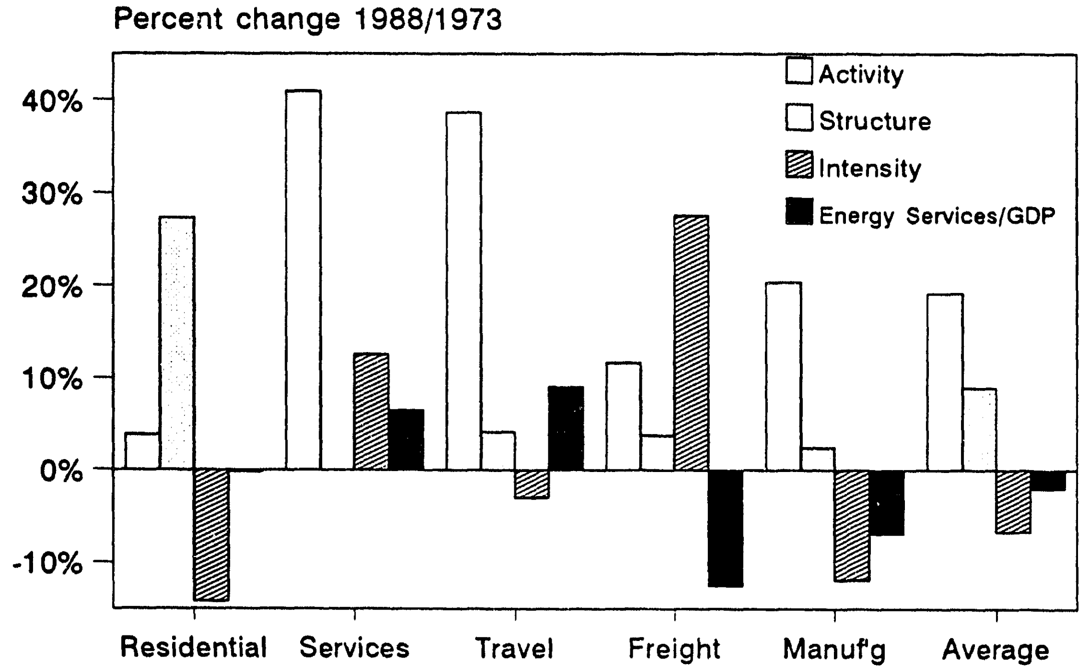


Figure SU-1

Sectoral Primary Energy Use in Sweden
Components of Change



Note: Energy Services is the combined effect of activity and structure in each sector.

Figure SU-2

Delivered Energy Intensity in Sweden
Activity and Structure Constant

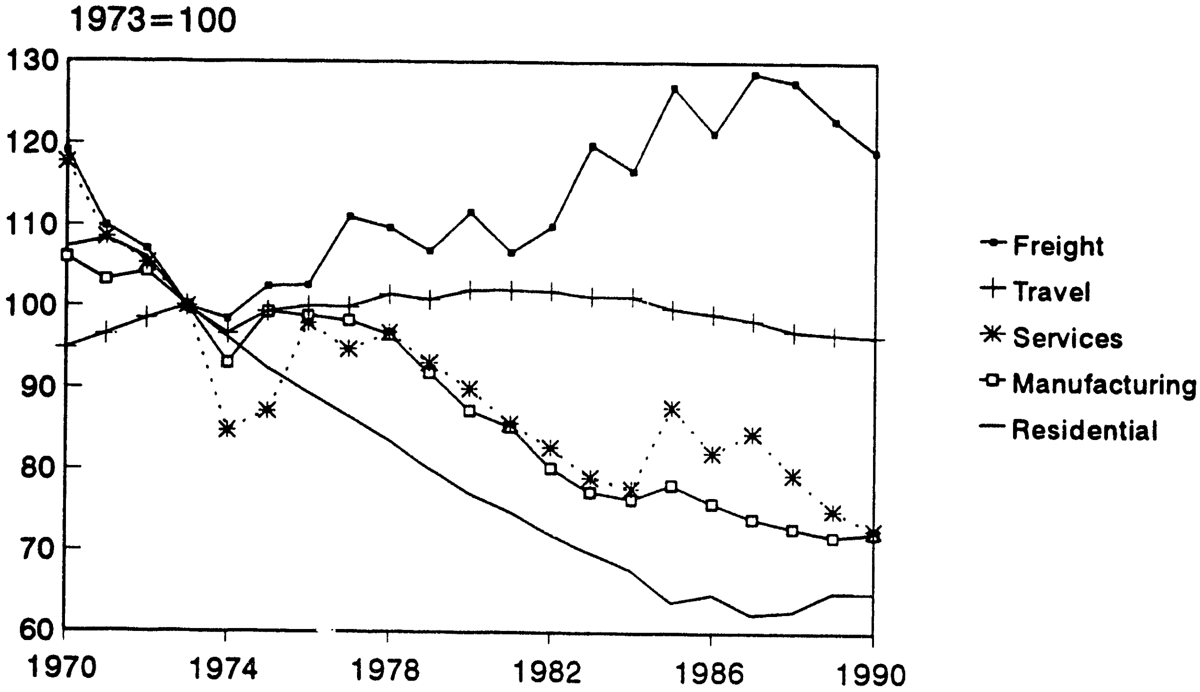


Figure SU-3

Primary Energy Intensity in Sweden
Activity and Structure Constant

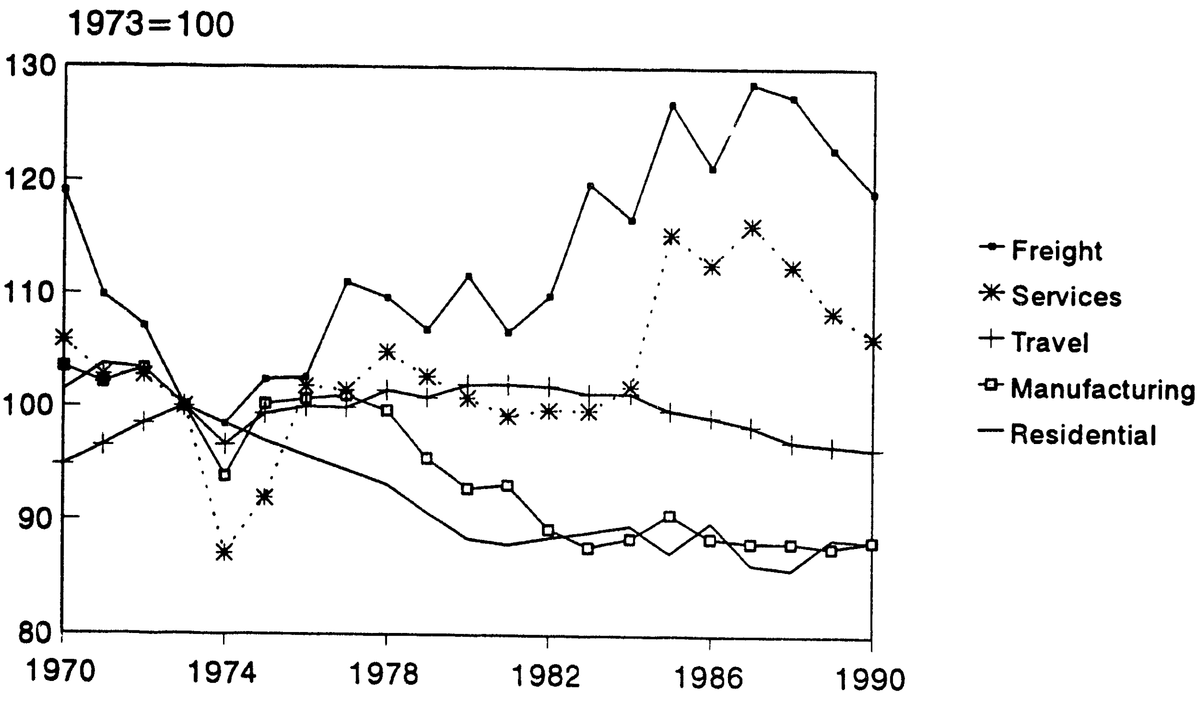


Figure SU-4

Energy Use in Sweden
Changes in Delivered Energy

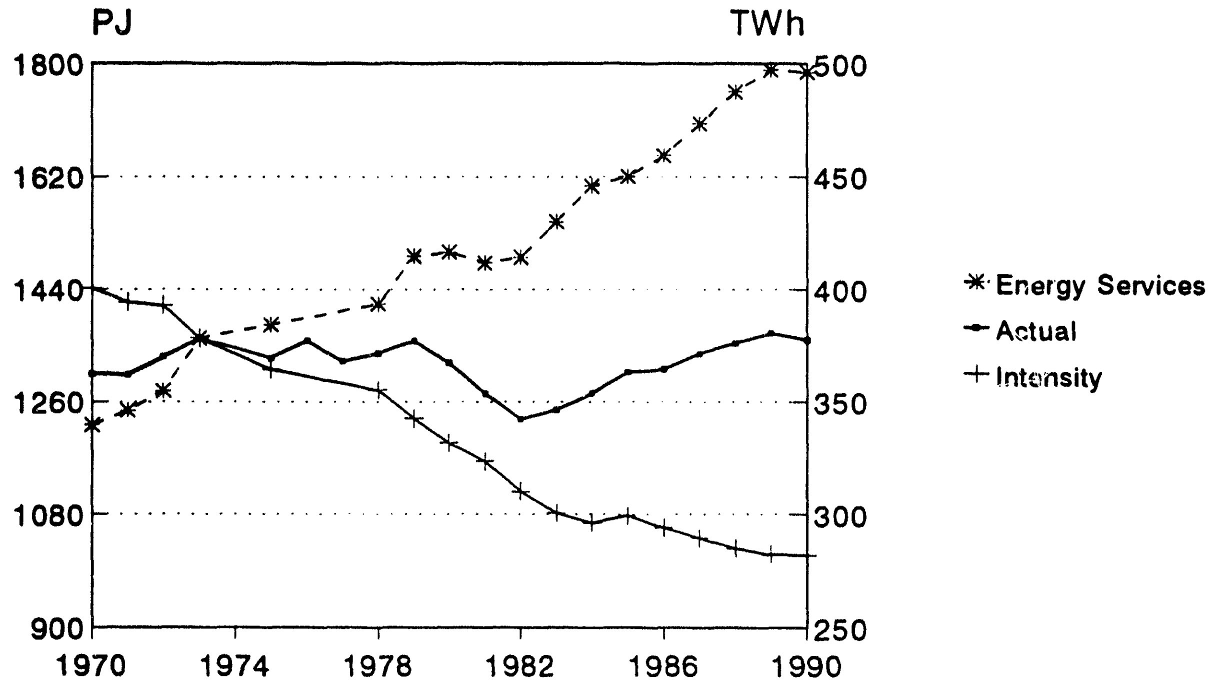


Figure SU-5

Primary Energy Use in Sweden
Structure, Activity, Intensity Impacts

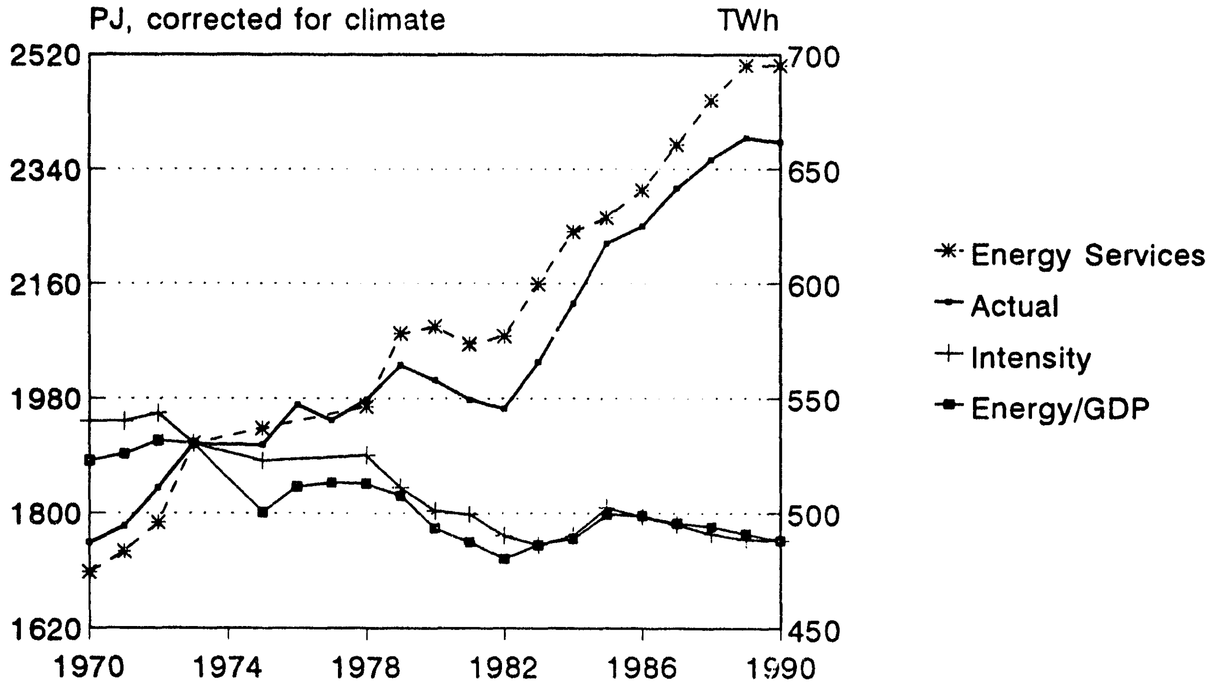
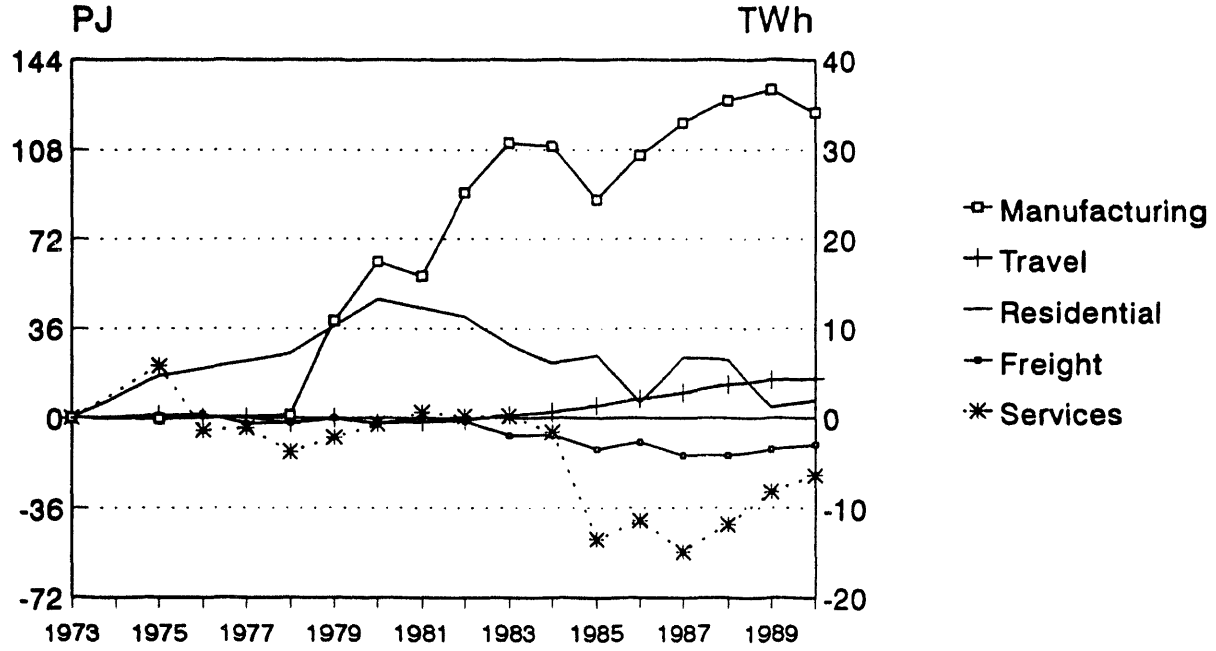


Figure SU-6

Primary Energy Use in Sweden
Energy Saved in Each Sector



* Energy at actual energy services, 1973 intensities minus actual energy.

Figure SU-7

8. INTERNATIONAL COMPARISONS[1]

There are many important reasons for comparing the structure and efficiency of energy use in Sweden with that of other industrialized countries. One obvious reason is political. The recent United Nations Conference on Environment and Development (UNCED) highlighted the importance of international energy issues. Points of competition among nations are both the present state of energy efficiency as well as future plans for improvements. Each nation needs to know where the others stand.

There is also a very practical reason for understanding differences between energy use in one's own nation and elsewhere. Certain energy use patterns in another country may resemble those that form the goals at home. Understanding how the other country arrived at a particular pattern may provide insights on how to steer one's own course. For example, careful study of the efficient state of housing in Sweden led to many ideas for promoting efficiency in the U.S. (Schipper, Meyers, and Kelly 1985). Such international study may reveal important technologies that save energy as well as key policies that promote energy saving.

The final reason for undertaking cross-country comparisons of energy use and efficiency is to identify boundary conditions in highly efficient countries. The inter-country differences in some particular policy parameter are often great enough to permit policy analysts to isolate the effects of that parameter on a particular energy use. For example, Sweden has relatively low taxes on automobiles relative to Norway and Denmark. Comparison of Sweden with these countries might reveal how changes in the taxation of automobiles in Sweden would affect their characteristics or use.

The following comparison of energy use in Sweden and other countries aims to satisfy all of these purposes. We will show how energy use patterns in Sweden differ from those in other industrialized countries. We will briefly compare the sectoral trends in the structure of energy use in Sweden and other countries. We will also compare key energy intensities in Sweden with those in other countries.[2] We shall see that Sweden was a relatively energy-intensive country in 1973. Energy saving, as well as some structural change, has reduced energy use in Sweden somewhat, but other countries we have studied achieved far more.

[1] In this section, "EU-7" refers to Sweden, Norway, Denmark, former W. Germany, France, Italy, and the United Kingdom. In the manufacturing section, Italy is missing because of serious data deficiencies. "EU-4" refers to the non-Scandinavian countries. We often aggregate these four countries to simplify the figures or present a meaningful average where the differences among them are small. Wherever possible we present all three Scandinavian countries separately, in order to facilitate comparisons in the future.

[2] The comparison in the manufacturing sector extends only to 1988. For other sectors the comparison is complete through 1989, and in some cases individual countries are compared through 1990.

8.1. The Residential Sector

Swedes enjoyed Europe's largest and most well-outfitted homes in 1973. These were also the most efficiently heated. After two oil crises and much conservation activity, Swedish space heating intensity continued to reflect the most efficient space heating in the OECD. While families in other countries narrowed the gap somewhat, the comfort in Swedish homes in 1990 lay at the highest level among OECD countries. This section explores how household energy use in Swedish compares with that in other countries.

8.1.1. Equipment and Fuel Mix

In 1973, Swedish households had a relatively high standard of comfort, as measured by house area per capita (Figure RI-1). Penetration of central heating was over 90%. Electric appliance ownership reflected the highest levels in Europe (Tyler and Schipper 1990). Although the gap with Norway, Denmark, and the rest of Europe narrowed somewhat, Sweden still claimed the highest indoor standard of living in 1990 among European countries.

In 1973, Swedish homes had the highest share of oil heating among major OECD countries, although homes in France, Denmark, and W. Germany were also critically dependent upon oil as a space heating fuel, as Figure RI-2 shows. Additionally, most of the district heating systems indicated in the figure were fired with oil. By the late 1980s Sweden's oil dependence had fallen drastically, more so than in any other country in Europe. But unlike other countries in Europe, substitution away from oil accounted for more of the decline than did reductions in the intensity of oil-heated homes. This distinction is important, for it lies behind much of the success of oil-saving in Sweden. The actual decline in oil-heating intensity in Swedish homes heated only with oil was modest, around 20-25% (if we exclude the impact of increased use of wood and electricity in homes still using oil), less than in France, W. Germany, or Denmark. Also, wood or electricity played only a minor role in the decline in oil intensity in homes in these countries, in contrast to the development in Sweden.

In 1973, Sweden had, after Denmark, the highest share of homes in the OECD heated with district heat. By 1990, the role of district heating in Sweden almost surpassed that in Denmark, largely a consequence of the fact that Sweden has a higher share of apartments in densely populated areas than Denmark. Moreover, district heating in Sweden felt no real competition from natural gas used in individual apartments or their boilers, at least through the early 1990s. By contrast, gas won significant market share in Britain, Italy, W. Germany, France, and later Denmark, and was already found in half of the homes in the U.S. The enormous success of district heat among Swedish apartments makes it unlikely that natural gas will be attractive as a fuel for direct use, but could spur interest in gas to provide heat at the district stations.

Electric heating in Sweden became a distinguishing feature of that country's housing stock. Over 33% of homes in Sweden, as opposed to 30% in France, and 20% in the U.S., relied on electricity for their principal heating source in the late 1980s. Additionally, at least 20% of all homes, principally those in SFDs, used electricity in combination with oil and wood for heating. While the use of small electric room heaters was common in every country, the secondary electric heating in Sweden was far more prominent than almost everywhere else. The main exception was Norway. And at least 40% of homes used electricity for water heating. Among the countries we have studied, only in Norway was this penetration exceeded. Low electricity prices in the 1980s, which fell to below the cost of oil for providing heat, were one important reason why electricity penetrated so far in Sweden (Tyler and Schipper 1990). But the very low heat losses of Swedish homes encouraged electric heating in the 1960s, since the net costs of using electricity rather than oil were usually small or even negative when the full cost of boilers and other equipment was considered.

In conclusion, fuel use in Swedish homes moved rapidly away from oil, towards high shares of electricity and district heat. These changes alone reduced *delivered* energy consumed by homes in Sweden, relative to the situation in Denmark, central Europe, and the U.S. The share of oil in delivered energy consumed in homes in Sweden fell drastically, as Figure RI-3 shows, from the highest share among the European countries shown (after Denmark) to one of the lowest shares. The expansion of solids, district heating, and electricity in Sweden outpaced the evolution of those fuels in the other countries, but conspicuous in its absence is gas, which is significant in all the countries outside of Scandinavia and making inroads in Denmark. Were all countries' consumption measured in the same primary units, however, Sweden's energy use would be very high, as we shall see below.

8.1.2. Energy Use, Energy Intensities, and Efficiency

By international standards household energy use in Sweden was high in 1973. Figure RI-4 shows each major end use for Sweden and other OECD countries.[3] Sweden's residential consumption ranked third, after Denmark and the U.S., in 1973. Given the large size of Swedish homes, its position *vis-a-vis* other countries in Europe is not surprising.

By 1990, however, the picture had changed somewhat. Per capita household energy use in Sweden fell because of conservation and because of substitution away from oil. The high penetration of equipment in Sweden meant space heating was close to saturation in 1973. Mostly through conservation, household energy use also fell in the U.S. and Denmark, two countries where indoor heating comfort was very high in 1973. Use increased in Norway, Japan, and the four European countries, because of the increased in the penetration of central heating and appliances ownership in the EU-4 and of all energy-based amenities in Japan. In other words, the gap in indoor standards between Sweden and Central Europe or Japan narrowed, and this important change reduced the difference in energy use per capita in homes.

Examining space heating (Figure RI-5), we find that Sweden in 1973 had the lowest intensity in the OECD after Norway and Japan. Lower indoor temperatures accounted for the lower positions of these two countries, particularly Japan. By the early 1980s, comfort in Norway caught up to that in Sweden, and heating intensity in Sweden became the lowest in the "cold" OECD. If we only compare SFDs centrally heated with oil, then the intensity of oil use in Sweden lies far below those of most other countries (Schipper and Meyers, *et al.* 1992). The reason is that so many oil-heated SFDs in Sweden also use secondary fuels, use of which does not appear in the oil statistics. If homes using only oil, but no secondary fuels, for heating are compared, the Swedish lead is slightly smaller. Even after a reaching a trough in the late 1980s, and perhaps even showing a slight rebound, space heating intensity in Sweden is still the lowest among those of European countries.

Household electricity use per capita is high in Sweden, after Norway and the U.S. (Figure RI-6). After Norway, Sweden had the second highest shares of electric cooking, water heating and space heating. Swedish households also have more and larger appliances than

[3] In our international data base, Sweden has 4071 degree days (DD) to base 18C in a normal year. For comparison, W. Germany has 3116DD, Norway slightly over 4000DD, Denmark 3114DD, the U.S. 2600DD, and the EU-4 (Italy, France, U.K., and W. Germany, weighted by population) 2700 DD. For this comparison, we have scaled energy use for space heating to 2700 DD Celsius, the average of the EU-4 and close to that of the U.S. This adjustment lowers the figures for Norway and Sweden by some 40%, lowers those of Denmark by about 10%, and increases those for Japan by 50%.

do those in other European countries. This explains the high total consumption of electricity in Swedish homes. But as Figure RI-5 implies, the intensity of electric space heating in Sweden is low. This is because homes are so well insulated. On the other hand, the unit consumption of electricity for water heating appears as high as in Norway or the U.S.

Electric heating intensity declined by 20% or more in the U.S., France, and Denmark, but not in Sweden (or Norway). We ascribe this difference in evolution to price effects; electricity prices were higher (and increased more) in the former countries than in the latter countries. Moreover, households in Sweden and Norway used wood effectively to reduce electric heating costs, rather than cut back on electricity.[4]

Electricity use for appliances in Sweden is high by European standards, and has increased (Figure RI-7). Yet unit consumption for most household appliances fell. The increase shown in Figure RI-7 is due to both the increases in ownership levels of the main appliances (refrigerators, refrigerator-freezers, dryers, and dishwashers) as well as a proliferation of smaller uses, such as circulation pumps. Weighted by 1973 ownership levels, the decrease in average consumption of the six major appliances (refrigerator, combination refrigerator/freezer ["combi"], freezer, washer, dryer, dishwasher) in Sweden was somewhat higher than in other countries in Europe (except for Denmark), about 26%. One reason was the high unit consumption of appliances in the stock in 1973. A second reason was the relatively strong growth and turnover in those appliances compared to the situation in other countries. The third reason was the important savings of hot water in dish- and clothes-washing, two uses where energy and water may have been used more sparingly in other countries. Of course, the unit consumption of new appliances fell in all countries, because of the multinational nature of manufacturers and similarity of models produced for the Europe-wide market. The Electrolux refrigerator that is appearing in Sweden as a result of *NUTEK*'s *Teknikupphandling* ranks as a breakthrough for both technology and marketing, and will appear in other countries as well.

8.1.3. The Residential Sector: Sweden in an International Context

Three factors help explain the path that residential energy use has taken in Sweden since 1973 relative to the course elsewhere in Europe. First, energy uses in Swedish homes were relatively saturated in 1973, while these were still growing significantly elsewhere. This restrained overall growth. Second, fuel switching itself led to a decline in delivered energy. Third, energy intensities of heating and appliances in Sweden fell significantly, although not as much as was the case in the other countries we studied.

Important stimuli provoked these changes in Sweden. Oil prices were raised to high levels through taxes. But electricity prices remained low in comparison with those in other countries. Together, this pushed Swedes away from oil, forced those still using oil to use far less, and stimulated massive *conversions* of existing homes from oil to electricity. Norway saw the same evolution.

The aggressive conservation policies, which we have reviewed in a comparative light elsewhere (Wilson *et al*. 1989), certainly contributed too. Danish and French policies were arguably as far reaching as those in Sweden, yet when all three countries are compared, heat savings appear greater in the first two countries than in Sweden. What may distinguish Sweden, however, is the system of loans for new-homes and its strong building codes (Schipper, Meyers, and Kelly 1985) as we noted in the residential section. As a result, Swedens' homes were extremely efficient in 1973, while those in Denmark, France, and other countries played "catch up". Yet indoor temperatures in Sweden were probably the highest in Europe before 1973. Why were the savings after that year not greater?

The low price of electricity and the relatively modest price increases seen for oil in Sweden *vis a vis* most other countries in Europe could account for some of the difference in the depth of conservation after 1973. Using 1985 purchasing power parities to convert prices from 1985 real local currency into U.S. dollars (or SEK),[5] we compared residential oil and electricity prices in Figures RI-8 and RI-9. Because of very high taxes imposed on both heating oil in the late 1970s and thereafter, Swedes faced significant increases in residential heating prices, led by those for oil. Still, oil prices did not surpass those in the majority of the other countries (in purchasing power units) in Sweden until 1986, when the crash in the price of crude oil sent the price of heating oil in countries with light taxes down sharply. And unlike Denmark, France, W. Germany, Italy, or the U.S., Sweden offered relatively low cost electricity for the entire

[4] In this comparison we have attempted to remove the effects of both wood (or oil) used in homes with electricity as their principal source, as well as the use of electricity itself as a secondary source of space heating.

[5] The conversion rate tends to lower the value of the *krona*, making Swedish household energy prices appear relatively low. Recall that purchasing power parities take into account that fact that other goods and services in Sweden, and not just energy, are expensive. The conversion factor we use, 6.97 SEK/$ in 1980 money, or 7.8 SEK in 1985 money, reflects these relative prices. The market exchange rate was closer to 6.0 SEK/$ in 1980 and 9 SEK in 1985.

period and significant quantities of wood as well. Availability of these two sources limited the increase in the average price of heating in 1990 in real terms over its 1973 value. (The gradual shift to significant quantities of electricity for heating, however, alone raised the consumption-weighted average price paid for energy.) Hence, Swedes, unlike most other Europeans, did have two alternative fuels whose prices did *not* increase as sharply as that of oil. This, combined with the relative low heating intensity of Swedish homes in 1973, and the lack of direct metering of apartments for heat actually consumed, meant Swedes were by and large spared the blunt impact of higher residential energy prices felt by most others in Europe, U.S., and Japan. In light of this fundamental difference, energy conservation in Swedish homes earns high marks for its achievements.

Thus, in an international context, Sweden started the 1970s with a low residential heating intensity and moderate intensities for appliances. By the end of the 1980s Swedish heating intensity had fallen somewhat and was the lowest in Europe, while those for appliances improved as well. Other countries narrowed the gap with Swedish heating intensity. An energy-efficiency policy that combined high oil prices with building retrofit programs, thermal codes for new structures, research and development, and an active role of government as coordinator of much of the effort contributed to the improvements in Sweden.

OECD Residential Energy Use
Living Area in Homes

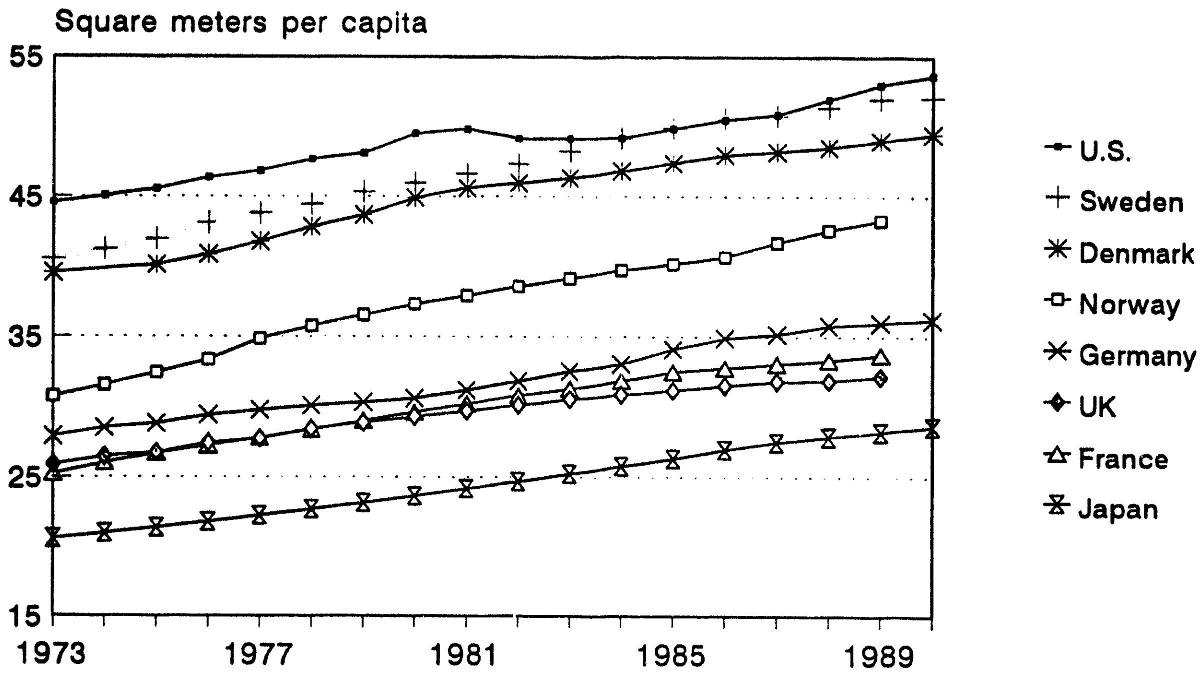


Figure RI-1

OECD Residential Energy Use
Principal Space-Heating Fuel, 1973-1990

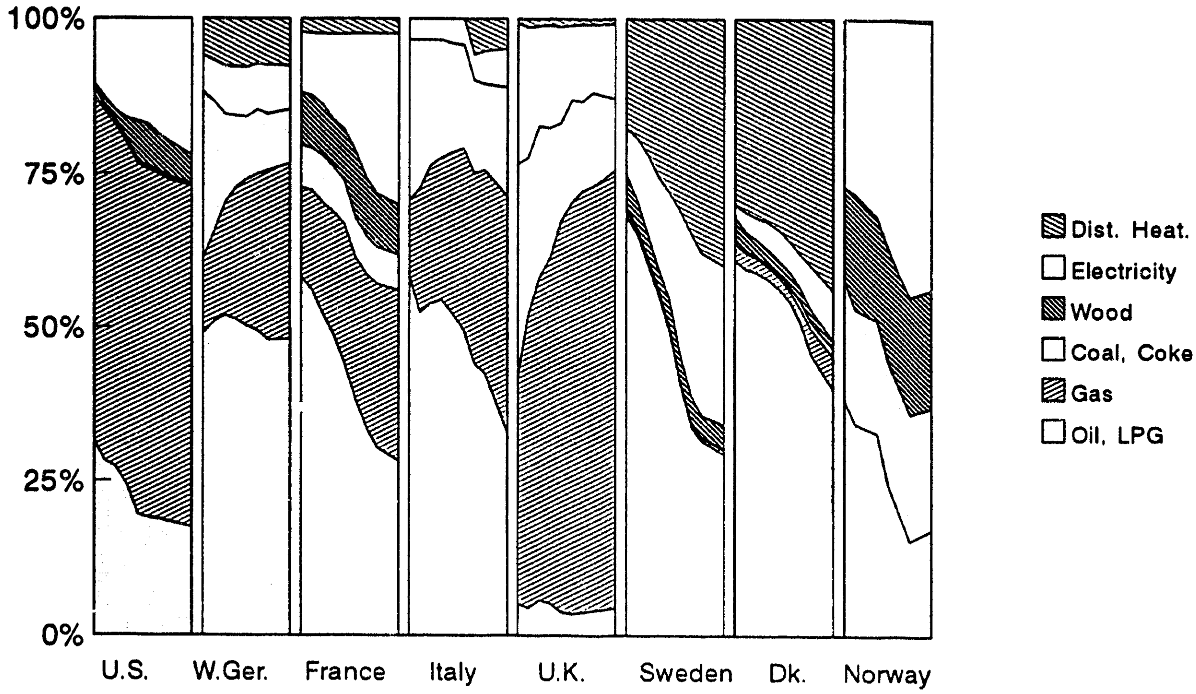


Figure RI-2

OECD Residential Energy Use
Delivered Energy, 1973-1989

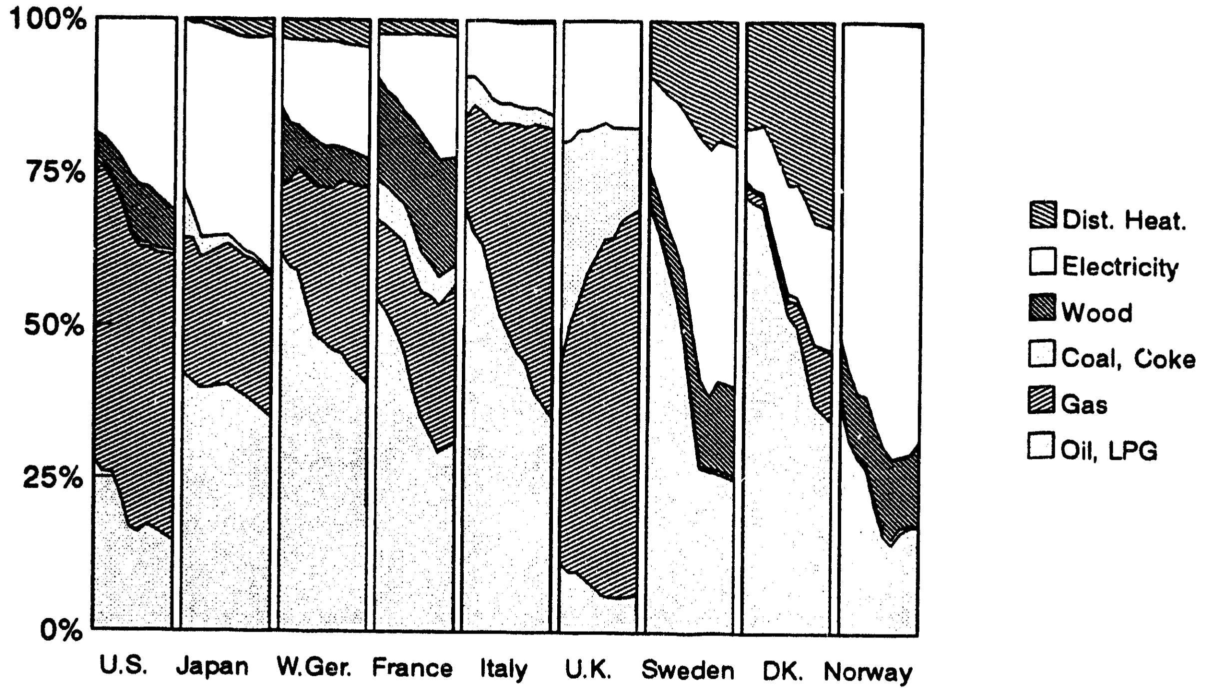
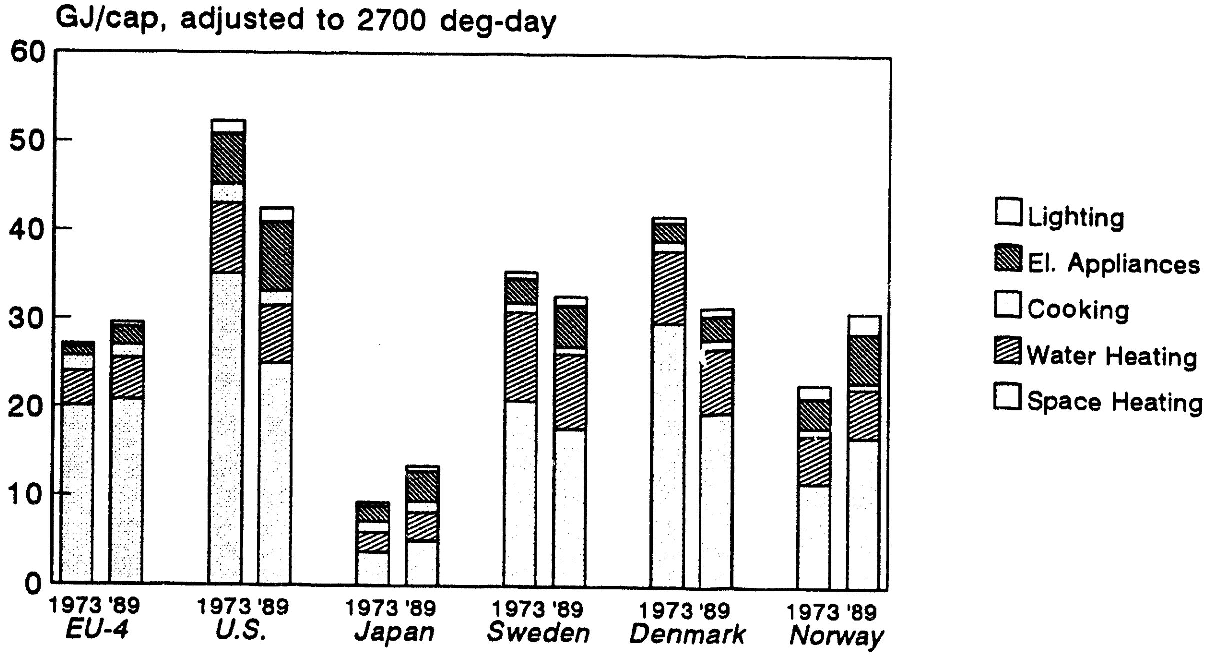


Figure RI-3

OECD Residential Energy Use
Delivered Energy



EU-4: France, W. Germany, Italy, UK

Figure RI-4

OECD Residential Energy Use
Space Heating Intensity (Useful Energy)

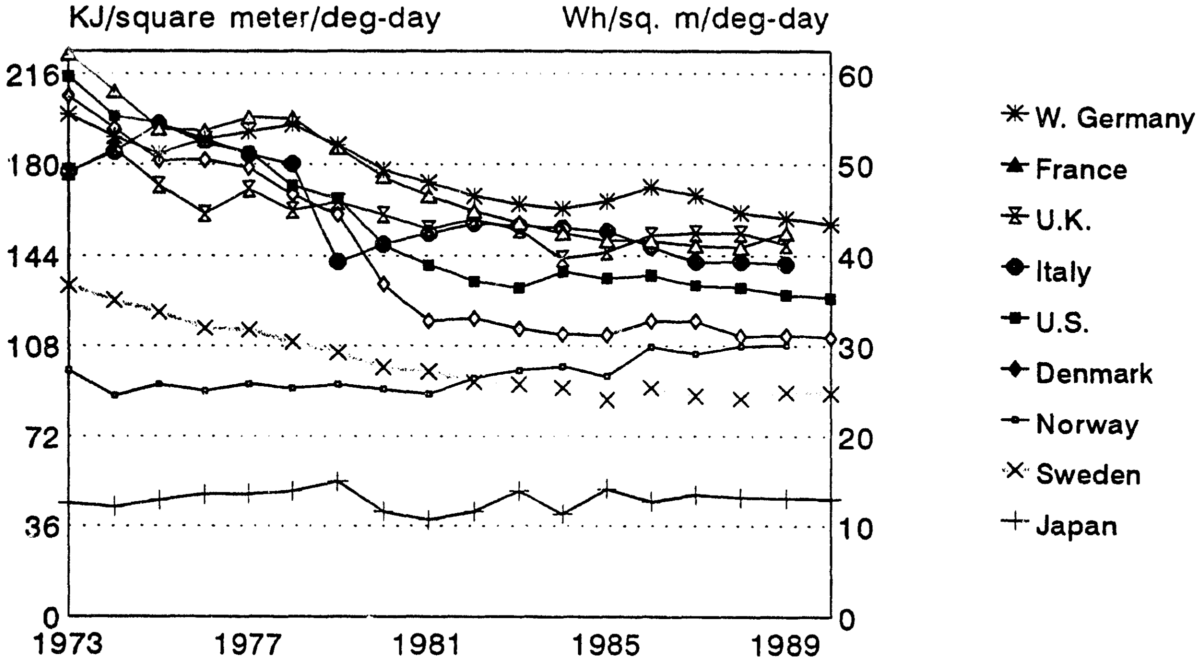
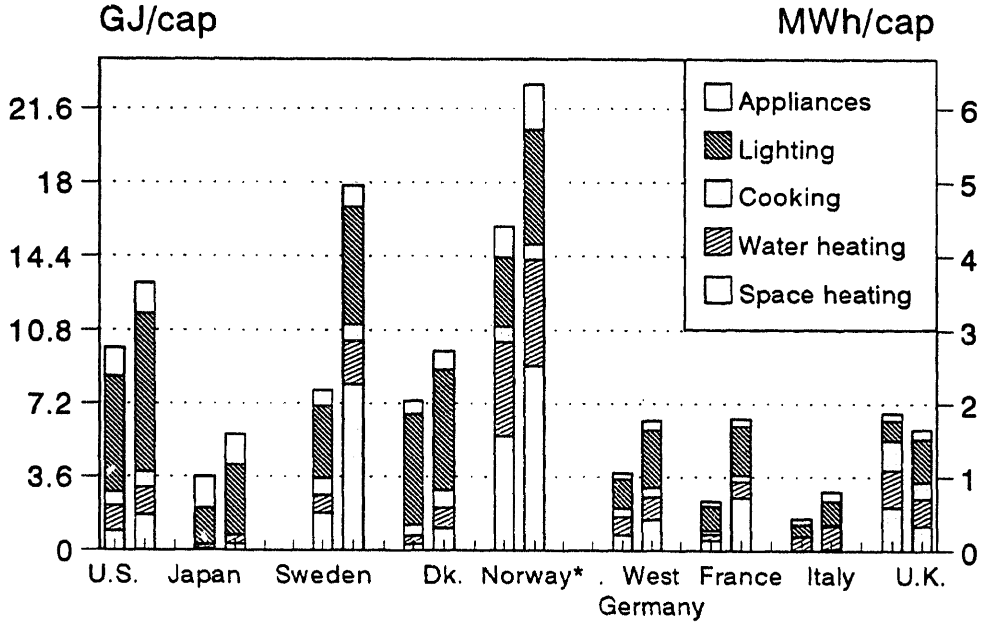


Figure RI-5

OECD Residential Electricity Use
1973 and 1989



*1989 Norway space heating reduced by 6.0 MWh.

Figure RI-6

OECD Residential Energy Use
Electricity Use for Appliances

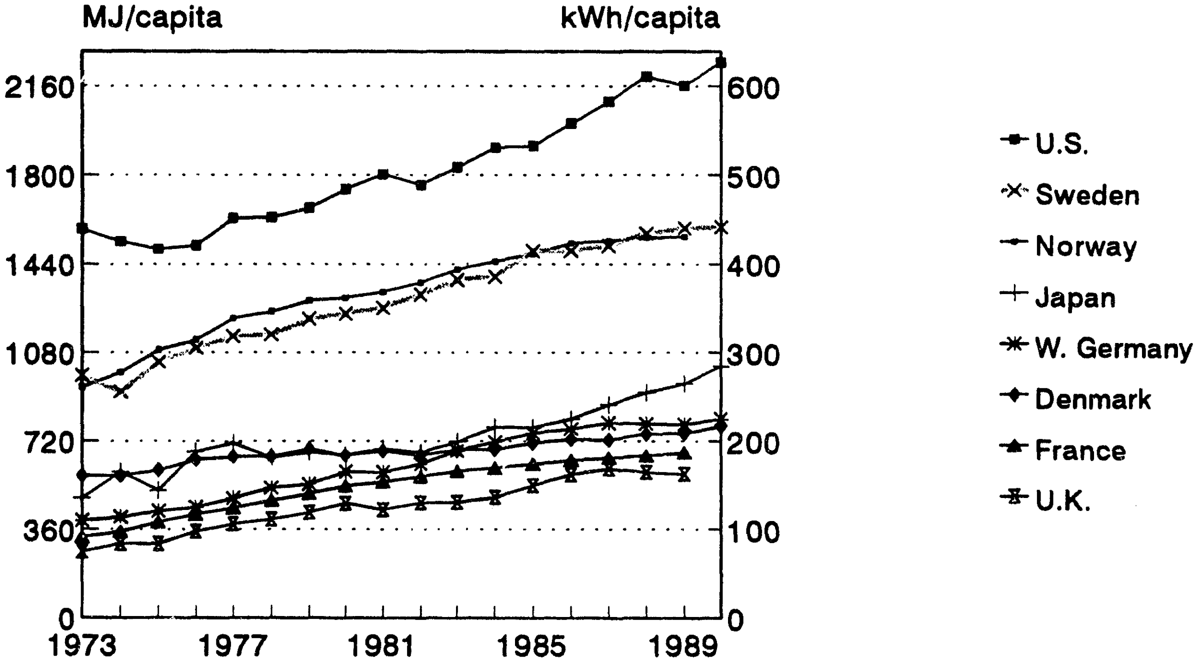


Figure RI-7

OECD Residential Oil Prices
Real Prices

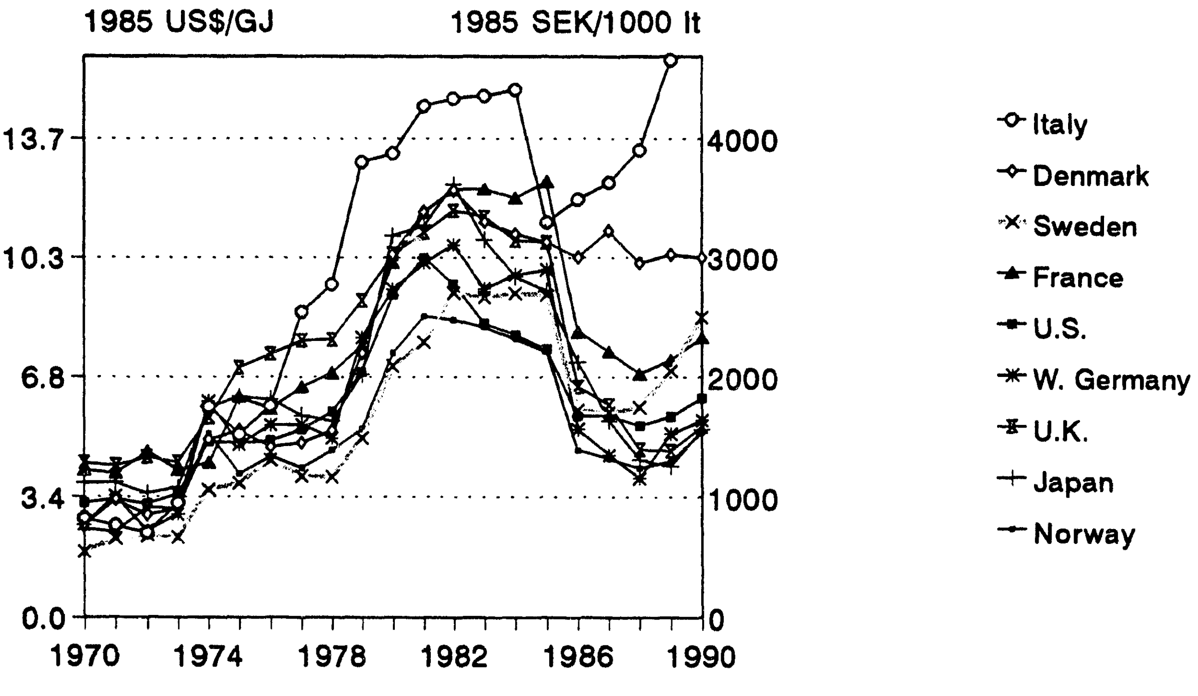


Figure RI-8

OECD Residential Energy Use
Real Electricity Prices (1985 US Dollars)

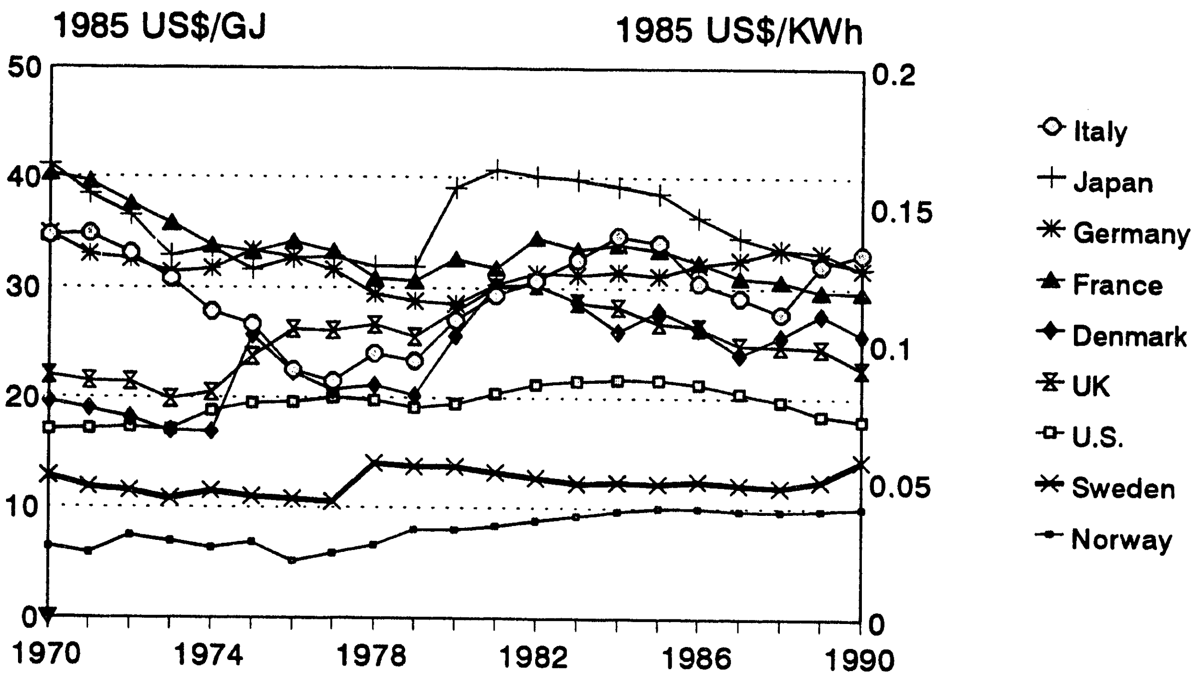


Figure RI-9

8.2. The Manufacturing Sector

We carried out a detailed comparison of Denmark, Norway, Sweden, W. Germany, France, the U.K., the U.S., and Japan (the OECD-8) (Howarth and Schipper, 1992). The new data on Swedish manufacturing energy use developed in this project revealed some small but important changes in the evolution of energy use for manufacturing in Sweden *vis a vis* that in other countries. Overall, delivered energy use in manufacturing fell by an average of 18% across these nations between 1973 and 1988. The decline in Sweden was sharp until the mid-1980s, when strong growth resumed. Delivered energy use in manufacturing reached 90% of its 1973 level by 1988, more than any other country we studied except Norway and just ahead of the growth seen in Japan. This suggests that Swedish manufacturing energy trends have been different in many respects from developments in other OECD nations. The analysis below untangles the differences.

The role of manufacturing in the Swedish economy contracted slightly during the study period. The decline of the share of manufacturing was larger than in all other countries studied except Denmark (-0.6% points), and the U.S., which showed an increase. Thus Sweden was not "de-industrializing" more than most other countries. The 20% actual increase in manufacturing activity in Sweden between 1973 and 1988 lay intermediate between the increases in Japan (64%) or the U.S. (52%) and those in W. Germany and France (18%) and the U.K. (2%). And while shifts in product mix in the U.S., Japan, and W. Germany alone cut manufacturing energy use by more than 10%, these shifts actually boosted manufacturing energy use in Sweden by 1%. Norway showed the largest increased in energy use from this shift, a surprising 25%, as the development of electricity-intensive industries placed strong pressure on sectoral energy use (Figure MI-1).

If we combine the effects of both activity growth and structural change on manufacturing energy use, Sweden's increase of 22% over the 1973 level of use is median, close to the average of all eight countries of 25%, but well below Japan or the U.S. (37% and 32% increases, respectively) and above those of W. Germany and the U.K. (5% increases and 1% decrease, respectively). By this combined measure of the change in both mix and activity, Sweden's changes were average.

The mix of fuels changed greatly in every country we studied. Since oil saving was a primary goal in virtually all of these countries, it is worth comparing the 1988 share of oil with that in 1973, correcting for changes in the structure of manufacturing. By this measure, Sweden had the largest decline, a full 68%, while Japan had the smallest drop, a "mere" 42%. The boost in the use of biomass in the paper industry and the slight increase in the importance of that industry in the overall mix of activity in Sweden led the increases in the use of this fuel that were also evident in Norway and the U.S., the two other important paper producers. Coal use and intensity in most countries declined; while coal picked up some share from oil, it lost share because of the decline in cement and steel production, as well as because of environmental pressures. Electricity intensity behaved the other way, rising 20% in Sweden after correcting for structural changes. Indeed, the electricity intensity of Swedish industry in 1970 was second only to that of Norway (Figure MI-2), and actually increased during the 1970s and 1980s. (Note that Sweden and Norway are shown on a separate scale.) Use of electricity for heat and steam explain some of this boost. Only Denmark exceeded this rate of increase, but from a far lower level. Swedish industry's position as the second most electricity-intensive after that of Norway makes this result surprising.

This last finding leads to an important feature of Swedish manufacturing, its very high concentration of energy-intensive industries. Yet even this arguably underestimates the true disparity between Sweden or Norway and the other OECD countries we have studied. Figure MI-3 shows the aggregate energy intensity of manufacturing in each country we studied in 1988.[6] The very high values for Sweden and Norway might reflect the high share of energy-intensive manufacturing in those countries' activity mix. Accordingly, we calculated aggregate energy intensity in each country's manufacturing as if all had the same mix of activity (the average for all eight countries) but the actual energy intensities of each of the six industrial branches we consider. By this measure, the intensities for Sweden (and Norway) fall considerably, showing that the structure of manufacturing in these countries is more energy-intensive than in the others. Still a significant gap remains between Sweden (and Norway) and the average for the European countries.

Much of this remaining gap arises because of differences in structure *within* the energy-intensive industries. These industries are not homogeneous, but produce many different products with varying degrees of energy intensity. In particular, the production of paper and pulp and chemicals in Sweden is weighted towards more raw materials than in most other countries shown, with Norway an even greater extreme.

Another goal all countries shared was to save energy in manufacturing. Reductions in energy inten-

[6] National currencies were converted to USD using 1980 purchasing power parities.

sity, measured in MJ/$, is indicative of these savings. Adjusted for structural change, delivered energy intensity fell by 20% to 35% in every nation (Figure MI-4). The Swedish decline of 28% was close to the 29% achieved in Denmark, greater than the 20% in Norway, but far below the declines seen in the U.S., U.K., Japan, or France. The drop in primary energy intensity in Sweden was only 12%, the smallest of any of the countries we considered. This shift in Sweden's relative position is explained by the large boost in the role of electricity noted above.

The trend towards increasing electricity intensity in Swedish manufacturing is of special significance, given the high electricity share there before 1970, when electricity comprised nearly 20% of delivered energy. The share of electricity in Swedish manufacturing energy use approached 40% by 1990, highest after Norway among the countries we studied. This comparison shows how reliant upon electricity- and energy-intensive processes Swedish manufacturing really is, compared with all other countries except Norway, giving some weight to concerns voiced over the impact of higher electricity prices there.

An examination of international trends in industrial energy prices provides interesting insights into the determination of energy use. Electricity prices in Sweden were low and remained relatively low (Figure MI-5), while those for oil (Figure MI-6) rose to among the highest in the countries studied. These developments explain part of the evolution in fuel mix discussed here. After the oil price crash, however, Swedish oil prices did not fall with those in much of Europe or the U.S., because of high taxes. After 1988 Swedish heavy oil prices heated upward again, a result of new taxes that were only reduced in 1992. Not surprising, the trends towards reduced oil intensity in Swedish manufacturing persisted in the mid- to late-1980s.

Thus we see that many of the changes we observed in Sweden appear "average" for the countries we studied. But the increase in electrification stands out when measured against Sweden's already high electricity intensity in 1973. And the relatively modest reduction in energy intensities compared with those in other countries is surprising, given the very energy-intensive nature of Sweden's industry. Low electricity prices, which did not increase very much in the period we studied, explain part of this behavior. But the very high oil prices lead us to expect that Sweden's overall reduction in manufacturing energy intensities would have been greater, unless the availability of cheap electricity and biomass offered the same relief in Sweden as these two fuels did in the residential sector.

OECD Manufacturing Energy Use
Impact of Structural Change
1973 Activity and Intensities

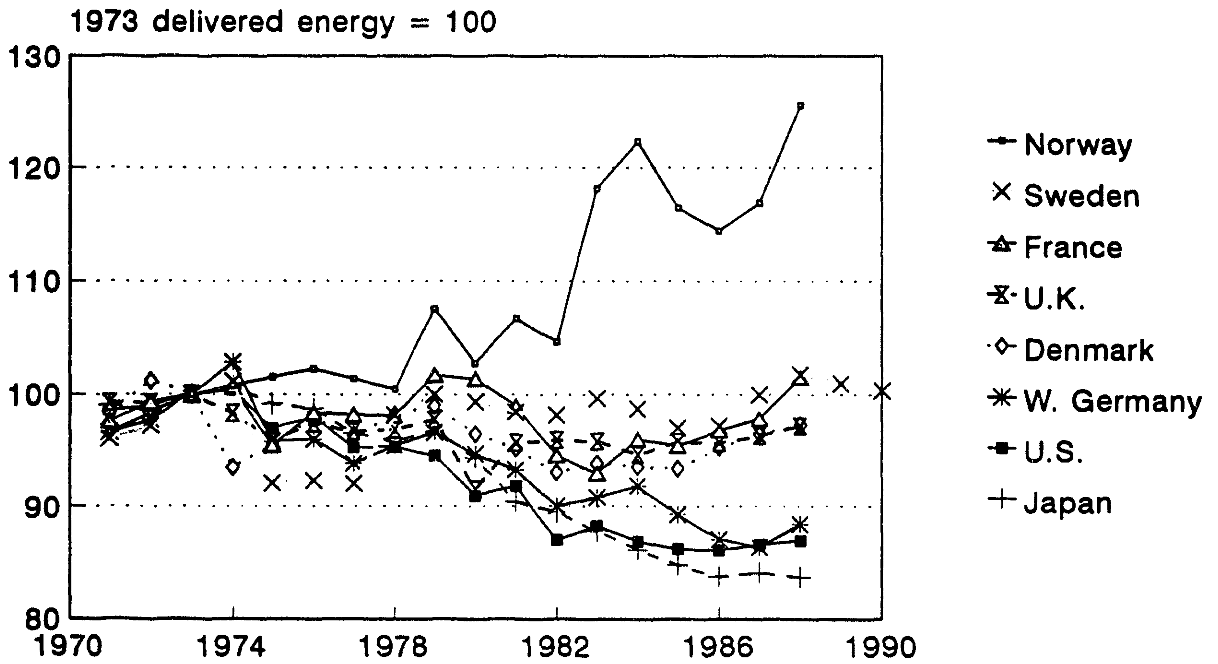


Figure MI-1

OECD Manufacturing Energy Use
Electricity Intensities
1973 Activity and Structure

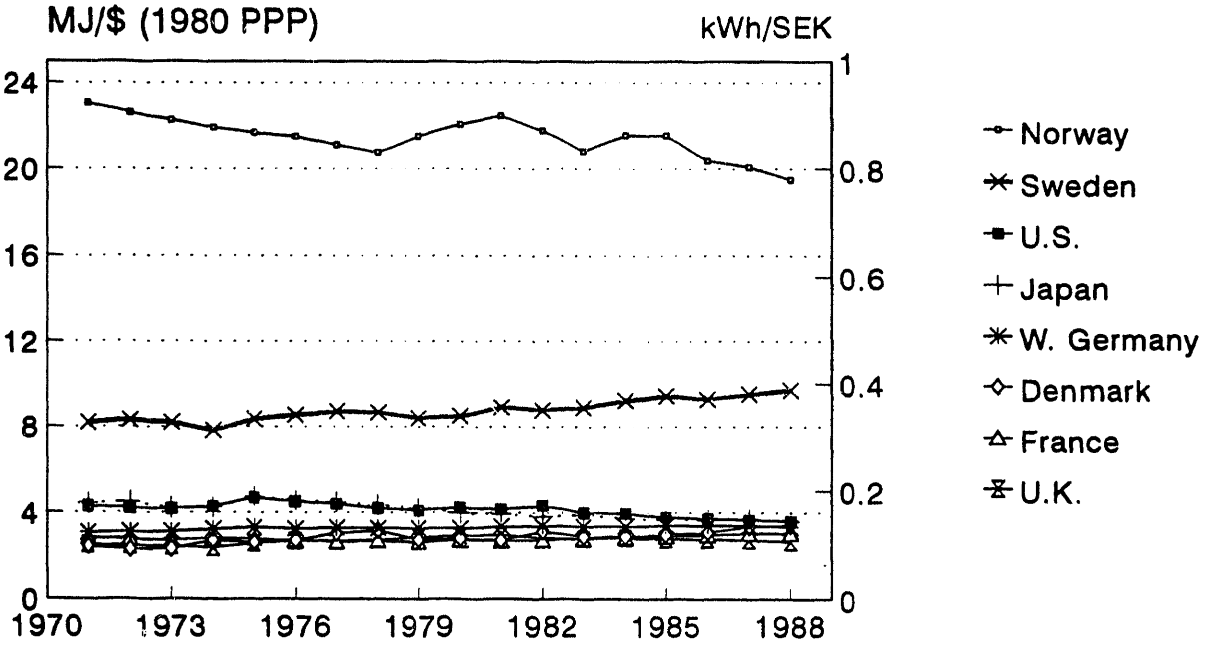


Figure MI-2

OECD Manufacturing Energy Use

Delivered Intensity, 1988

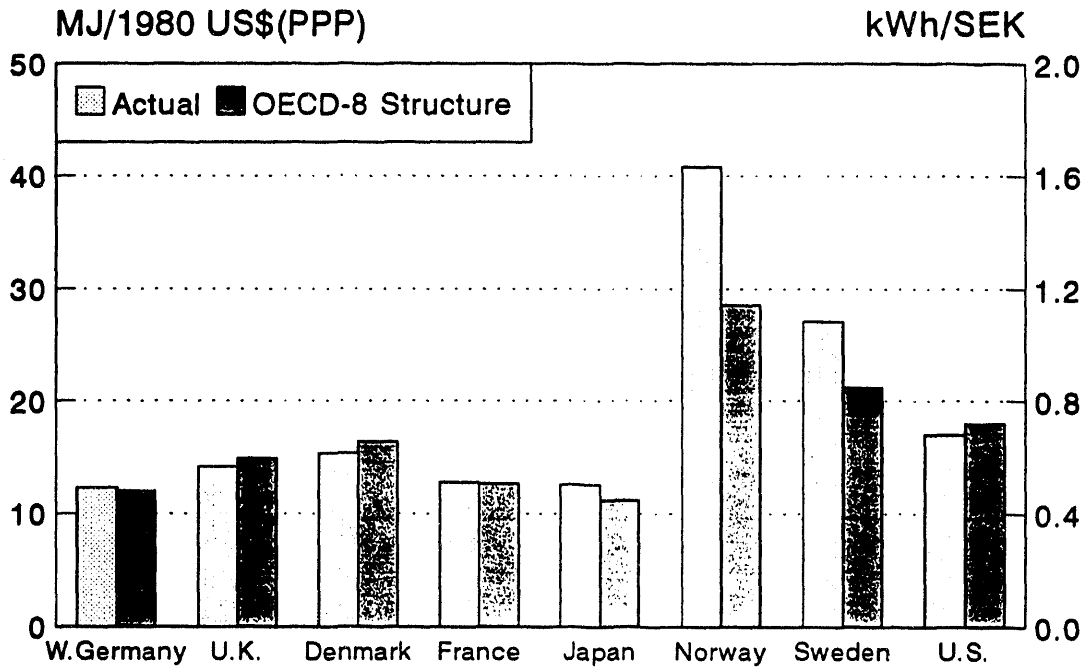


Figure MI-3

OECD Manufacturing Energy Use

Impact of Changing Intensities

Constant 1973 Activity and Structure

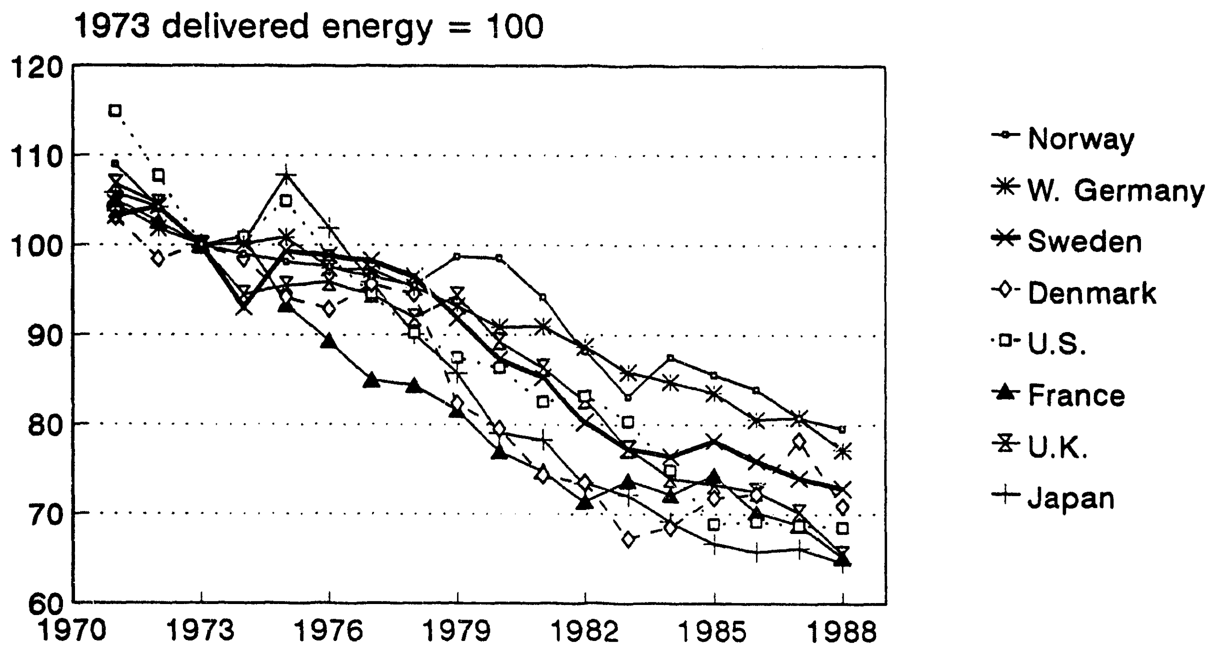
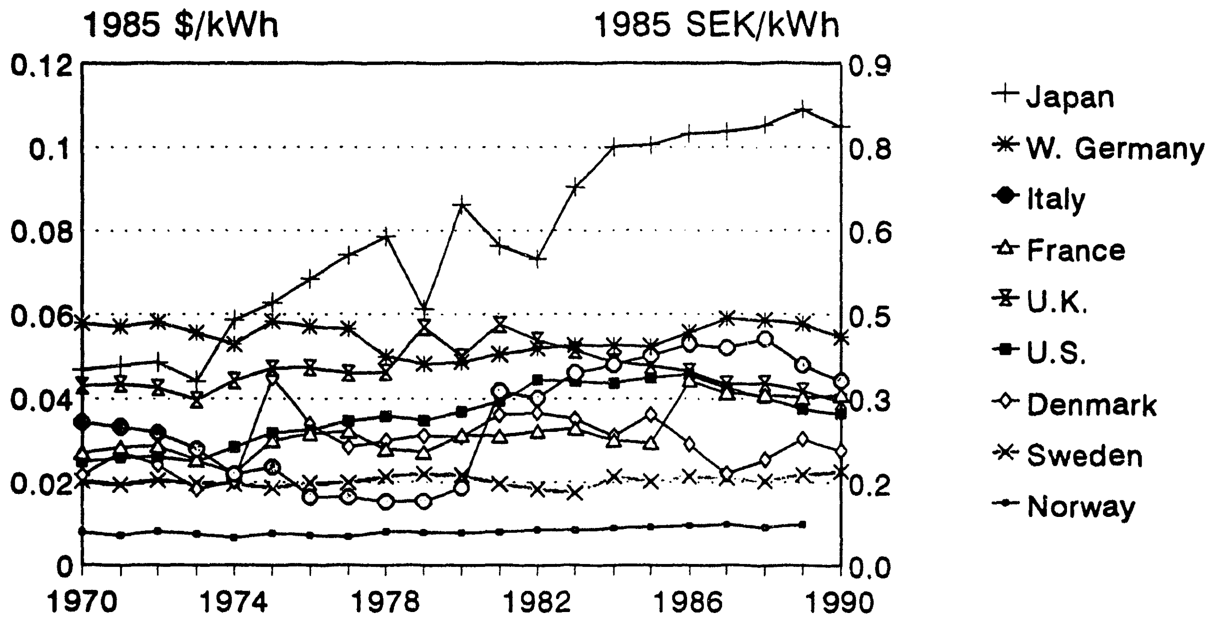


Figure MI-4

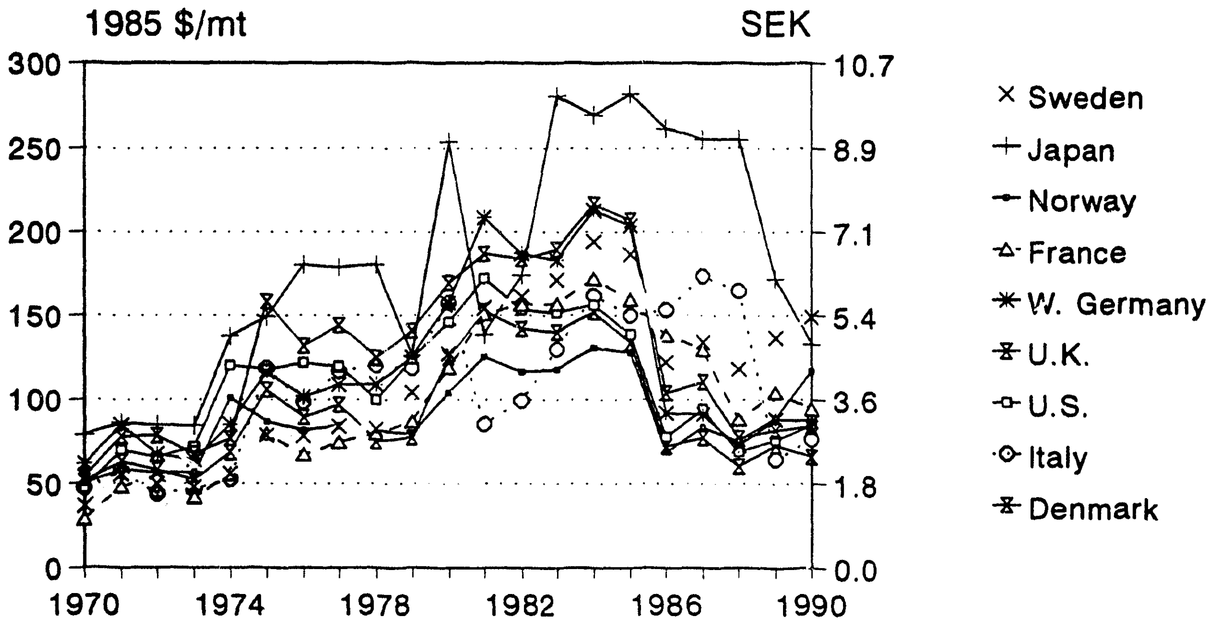
OECD Industrial Electricity Prices
Real 1985 Values



Using PPP

Figure MI-5

OECD Industrial Oil Prices
Real Values using Purchasing Power



Using PPP

Figure MI-6

8.3. The Service Sector

In 1973, the share of delivered energy consumed in the service sector was rising in every nation we have studied. As in the residential sector, the Swedish service sector was highly dependent upon oil heating in the early 1970s. Oil also dominated this sector in France, W. Germany, Italy, and even the U.K., a consequence of the availability of this fuel in the 1960s for central heating systems. Natural gas was not available in Sweden or much of Europe then, so oil (or oil-fired district heating) provided the most convenient source of heating. Electricity was used principally for lighting, machines, and some heating in Norway, Sweden, and the U.S. Total per capita space in the sector in Sweden was the highest in Europe throughout the entire period.

Figures S-1 and S-2 in the service sector chapter show fuel and electricity intensity in Sweden and other OECD countries from 1970 to 1988. The high fuel intensity in Sweden and Denmark in before 1973 reflects a high penetration of central heating in cold climates, compared with other countries shown. Values for the U.S. the EU-4, and Japan lie below these colder countries, almost in proportion to the lower number of heating degree days in these countries.[7] The lower value of fuel intensity in Norway reflects the already widespread use of electric heating in that country. Not surprisingly, this high share of electric heating meant that Norway had the highest *electricity* intensity of the countries we have seen. The high electricity intensity in Sweden in 1970 lay below that for Norway because of the lower penetration of electricity heating in Sweden; the high value for the U.S. reflects high lighting and air conditioning levels that existed at the time in that country.

[7] See the section above on residential energy use.

By 1990, the picture had changed everywhere. The share of oil fell in every country, yielding principally to gas outside of Scandinavia. Electricity and district heating gained in Sweden and Denmark (to more than 35% of heated space), as well as to some extent in France and W. Germany (less than 5% of heated space). Significant reductions in the combined fuel/district heating intensity occurred in almost every country, as Figure SI-1 shows. Improved heating efficiency was the chief reason in most countries. Greater penetration of electricity and district heating (counted as "fuel") in Figure SI-1 caused more than 1/3 of the decline in "fuel" intensity in Sweden, however. By 1990, Norway and Japan still had the lowest levels of fuel intensity, for the same reasons as in 1973, and Denmark and Sweden remained on top.

Even after removing the estimated impact of electricity used for heating, the electricity intensity of this sector increased in Sweden as in most other countries (Figure SI-2). This increase represents electrification, the purposeful increase in the number of electricity-using devices per m^2 of building space. Some of this electricity provided indirect heating for buildings, too.

An active effort to save non-heating electricity in Swedish buildings appears to have begun late, while efforts in other countries have been underway for some time. One reason may be the large difference in the price of electricity. While there are few data from any country giving the price of electricity in the service sector, these tend to be intermediate between residential and industrial sector prices. As both the residential and industrial comparisons shown earlier reveal, Sweden had the second lowest electricity prices among the countries we studied in these two sectors. The same can be assumed for the service sector.

OECD Service Sector Fuel Intensity

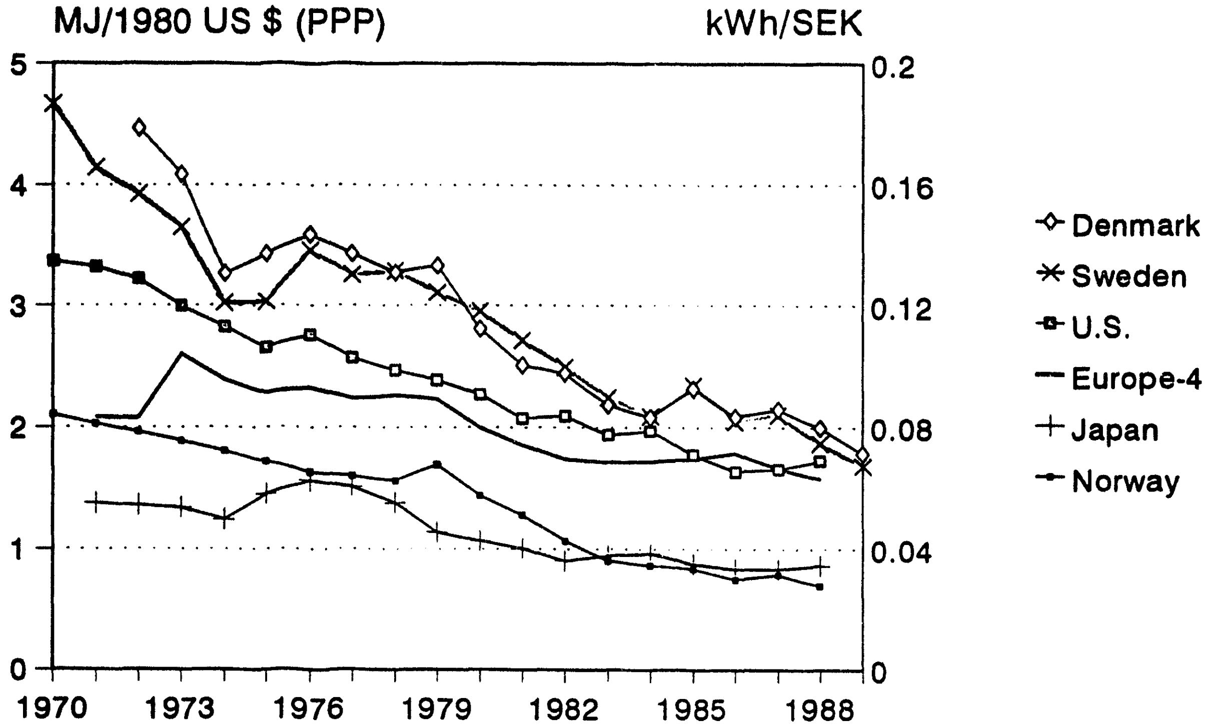


Figure SI-1

OECD Service Sector Electricity Intensity

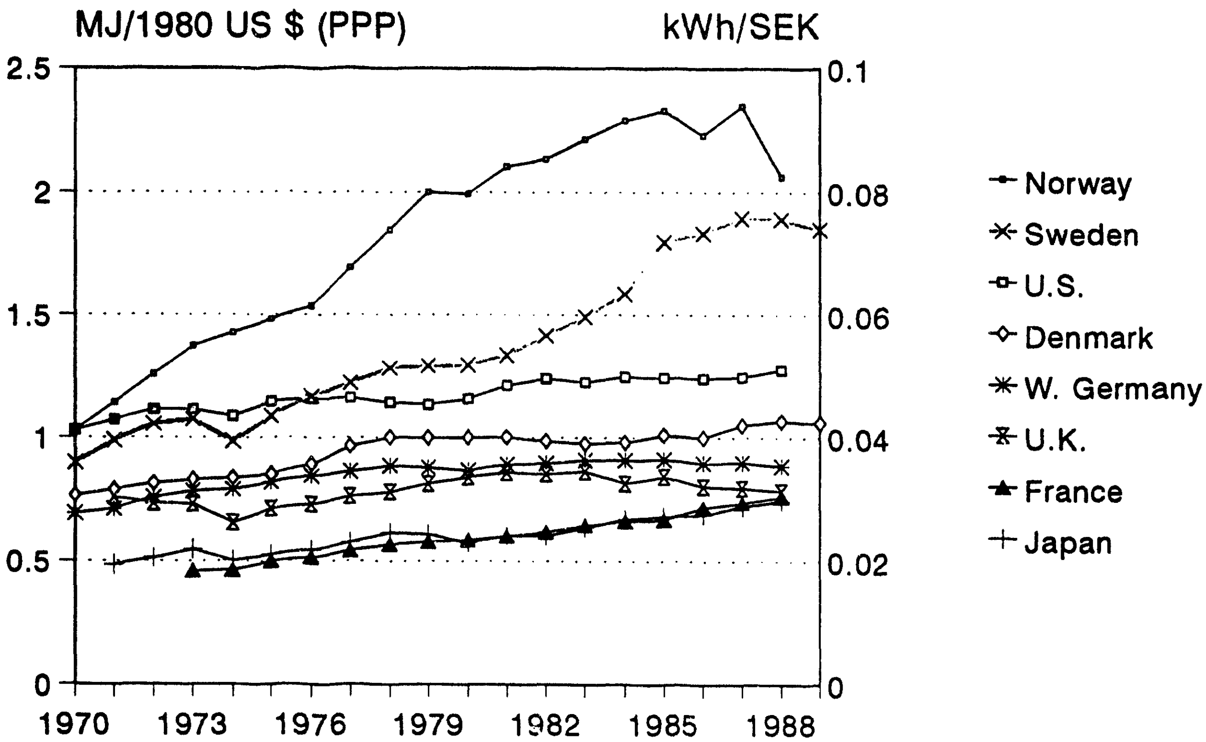


Figure SI-2

8.4. The Transportation Sector: Travel

Sweden has the highest per-capita energy use for travel of the major countries in Europe, and Swedes have a relatively high level of domestic travel using motorized vehicles. One reason for this is Sweden's size and low density, but other factors are important, as we shall see.

The ownership of cars in Sweden (cars in use) lies at 410 per 1000 people, one of the highest levels in northern Europe (Figure TI-1). Swedish cars are driven more than cars in continental northern Europe, nearly 15,000 km/year in 1989 (Figure TI-2). The high number of cars, combined with a load factor that is close to the European average, means that per capita domestic travel in automobiles in Sweden is about average among the EU-7.[8] But total travel in Sweden is *high* for Europe (Figure TI-3). The large geographical size of Sweden might be one reason that Swedes travel significantly less in cars and more in airplanes than other Europeans.

In spite of the high number of cars in Sweden, the share of travel provided by rail and bus is relatively high. The large share of travel in these modes (16.5% in 1990) helped boost total per capita travel in Sweden to above the average level of the other countries in Europe (Figure TI-4).[9] Note that Sweden is one of the only countries where travel on trains and buses in 1990 was actually higher, however slightly, than it was in 1973.

The vehicle energy intensities of cars in Sweden—3.2 mJ/vehicle-km or 10 liters/100 km—ranks with W. Germany as the highest in Europe among countries we have studied (Figure TI-5). Sweden's neighbor Norway lies approximately 10% lower, and neighbor Denmark near the lowest in Europe (tied with Italy). The improvement in Sweden between 1980 and 1990, a reduction of nearly 10%, is typical for Europe. The small reduction in the value of sales-weighted *test* fuel intensities of new cars in Sweden, is less than the decline apparent from other countries in Europe (Figure TI-6). But the published test figures for Sweden are very close to the "real" ones (Schipper, Figueroa, Price, and Espey, 1993), while the real figures for W. Germany, France, the U.K., the U.S., and Japan diverge significantly from test figures. Hence the modest reduction in Sweden reflected in Figure TI-6 was probably no less than the real decline experienced in other countries.

Most observers agree that fuel prices are an important determinant of fuel use and fuel economy in the long term. Figure TI-7 shows the prices for automobile fuel in real terms, weighting the prices of gasoline and diesel fuels by actual consumption for automobiles. In this regard, prices in Sweden ranked relatively low for Europe until the tax reform of 1990.[10] Gasoline was taxed heavily, while taxes for diesel fuel were shifted to actual distance travelled. But Sweden has shifted its pricing strategies and the price in 1990 appears to lie above those in all other countries shown except Italy.

If we compare the price of gasoline and the fuel intensity of cars in the fleets of major countries, we obtain a relationship that approximates a straight line (Figure TI-8).[11] Similarly, there is a relationship between the price of fuel and automobile fuel consumption per capita (Figure TI-9), a relationship that takes into account driving distances and car ownership as well. Since Sweden has high ownership and high driving distances, per capita fuel consumption for cars is not surprisingly the highest in Europe, as this figure shows. (In the figure the most recent years are those with the highest consumption. Sweden "noses out" W. Germany by a small amount. This high consumption of automobile fuel explains the high value of total travel energy use in Sweden.)

This position should not be surprising: Sweden has had relatively low fuel prices for Europe. Moreover, the tax burden on driving in Sweden, compared with that on other goods and services, is relatively light (compared with most other countries), and the Swedish company car policies have boosted both ownership and size or power, a factor not negligible in W. Germany or Britain either. The tax burden was increased in 1990 in Sweden, but the reaction is yet to be seen. To call Swedish cars "inefficient" is misleading, however. But they are large, heavy, and powerful, apparently the heaviest in Europe and among the most powerful, as measured in kW.

The remaining travel energy sectors in Sweden are hardly important to the overall comparison of travel energy use.[12] The share of travel on rail and bus is inter-

[8] The EU-7 are Norway, Sweden, W. Germany, France, Italy, and the U.K. This average is overwhelmingly dominated by the U.K., France, W. Germany, and Italy.

[9] These figures exclude the small contributions of motorcycles, boats, and non-motorized modes.

[10] Recall that the currency exchange in the figure takes into account purchasing power parities, by which the price of gasoline is evaluated relative to the prices of other goods and services sold in Sweden. This helps explain why Swedish automobile fuel prices appear so low.

[11] In this figure, the U.S. is seen in the upper left, then W. Germany and the U.K., then Japan, then Sweden and Norway, then France and Italy.

[12] This ignores indirect effects. People in built-up areas with good public transit facilities may find themselves travelling fewer kilometers to get to jobs, services, and leisure activities. Of course, they may find that they do not get as far using public transport as if they were to live in less dense areas and use cars. The exact relationship between density and travel is uncertain, but the concentration of the Swedish population into several large and medium-sized cities with good transit is an important characteristic of Sweden.

mediate to that of the rest of the EU-7 (Figure TI-4). Because the intensities of these modes are so low relative to those for autos, however, energy use is insignificant. However, domestic air travel per capita is the highest in the EU-7 after Norway, making energy use for domestic air travel significant, but still a small part of all energy use for travel.

Swedish modal energy intensities behaved differently from those in most other European countries. The 2% decline in the modal intensity of automobile travel may seem small, but in most other countries, the energy intensity of automobile travel *increased* because the fuel intensity of automobiles only improved marginally while load factors decreased.

The energy intensity of bus travel in Sweden is high for Europe, which may reflect the number of inter-city and suburban lines that connect regions of relatively low density. The intensity for rail travel is also very high, whether measured counting the electricity component as delivered energy or primary energy. Differences among countries reflect load factors and operations as much as intrinsic differences in vehicle intensity. The dip of modal intensities for Swedish buses and rail in the early 1980s is not unusual. During the early 1980s, high fuel prices and a depressed economy boosted bus travel, increasing load factors and reducing modal energy intensity in most European countries. Air travel intensity in Sweden is one of the lowest in Europe. The downward trend in the energy intensity of Swedish air travel is typical for every country we studied. In virtually every OECD country, the energy intensity of domestic air travel declined steadily because of improved aircraft design and increased proportion of seats filled. Energy use per passenger-km thus fell by as much as 40% in Europe and 50% in the U.S.

Figure TI-10 summarizes the difference between travel energy intensities in Sweden and other OECD countries. The first bar for each country shows actual aggregate travel energy intensity in 1988, measured in MJ/passenger-km. Sweden lies with the other Scandinavian countries, intermediate among the OECD nations, but high for Europe. The second bar shows the figure that would have prevailed in Sweden given the nation's own modal energy intensities but the average modal mix for the OECD. Sweden's position is hardly changed. The position for Japan changes because the role of cars is boosted when the OECD average mix is used to calculate the aggregate intensity. That Sweden's figure changes so little suggests that it is indeed high individual intensities and not the modal mix per se that contributes to the high intensity of travel in Sweden.

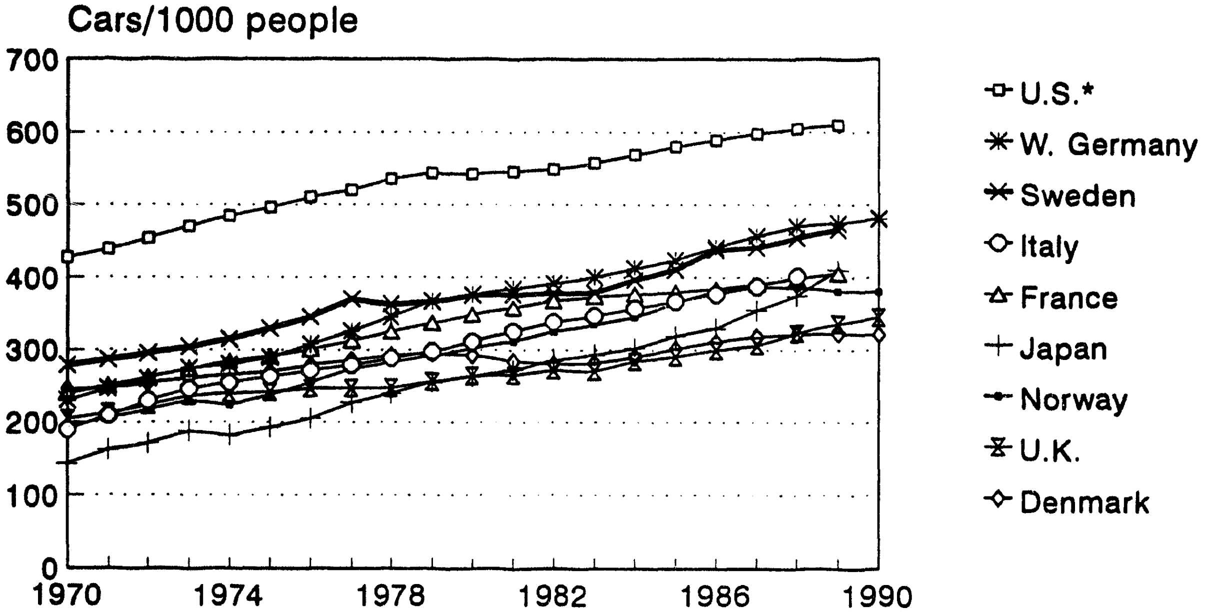
How do these differences look in a time perspective? If we decompose the overall changes in energy use for travel in Sweden into components due to changes in sectoral activity, structure, and intensity, we find results that are rather unusual for the OECD. The increase in per capita travel in Sweden was average for the countries we studied. On the other hand, the change in energy use driven by modal shifts, a 4% increase, was high for Europe (Figure TI-11). This is surprising, since the share of rail and bus traffic in Sweden in the late 1980s was higher than in the early 1970s. The emergence of domestic air travel is the chief reason for this shift.

Energy efficiency in Swedish travel showed a slight improvement between 1973 and 1989. Corrected for modal shifts, travel in Sweden experienced a small decline in intensity of 4% (Figure TI-12). Most other European countries experienced an *increase* in this important indicator, largely because of the increase in energy use per passenger-km for automobiles (Schipper, Steiner, Duerr, An, and Strøm, 1992). Thus the relatively minor improvement in energy efficiency of travel in Sweden is actually rather good for Europe.

These findings can be illustrated in another way. Figure TI-13 shows the evolution of *per capita* energy use for travel in Sweden and in other countries we have studied. The strong decline in the fuel intensity of autos led to a drop in this indicator for the U.S between 1973 and 1989. In Japan and the EU-7, by contrast, per capita energy use for travel increased strongly. The increase in Sweden was much less, and driven almost only by the increase in the total volume.

What happened in Sweden? Sweden saved more energy than did other countries, in spite of relatively low fuel prices, a low tax burden on private vehicles, and a geography favoring auto and air travel. The reasons seem to be similar to those behind the savings in energy in the household and service sectors: relative to other countries in Europe, Sweden's structure was well-developed and relatively energy-intensive in 1973. While others "caught up" (particularly in terms of total travel, car ownership, and car muscle), Sweden's growth was moderated. Only in the U.S., Denmark, Norway, and Italy did automobile vehicle intensity fall as much as in Sweden. Norway, Denmark, and Italy experienced very high taxes on automobile use, while the U.S., starting with a very energy-intensive system, was prompted by CAFE fuel economy standards until its fleet came closer in line with those in Europe (Figures TI-5 and TI-8). Indeed, examination of Figure TI-8 does not suggest that energy use for automobiles in Sweden is much out of line from the general relationship suggested in that picture, and Sweden's position in Figure TI-9 also looks "correct".

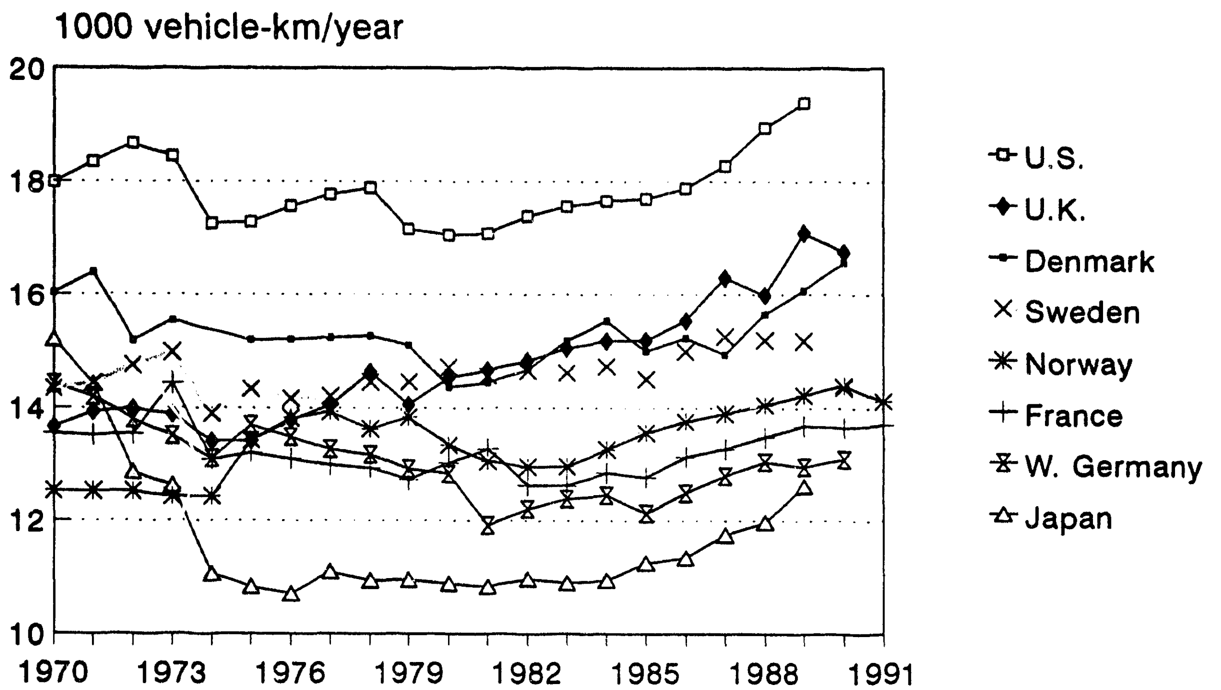
Automobile Fleet in OECD Countries
1970 - 1990



* Includes personal light trucks
Source: LBL-IES Transport Study

Figure TI-1

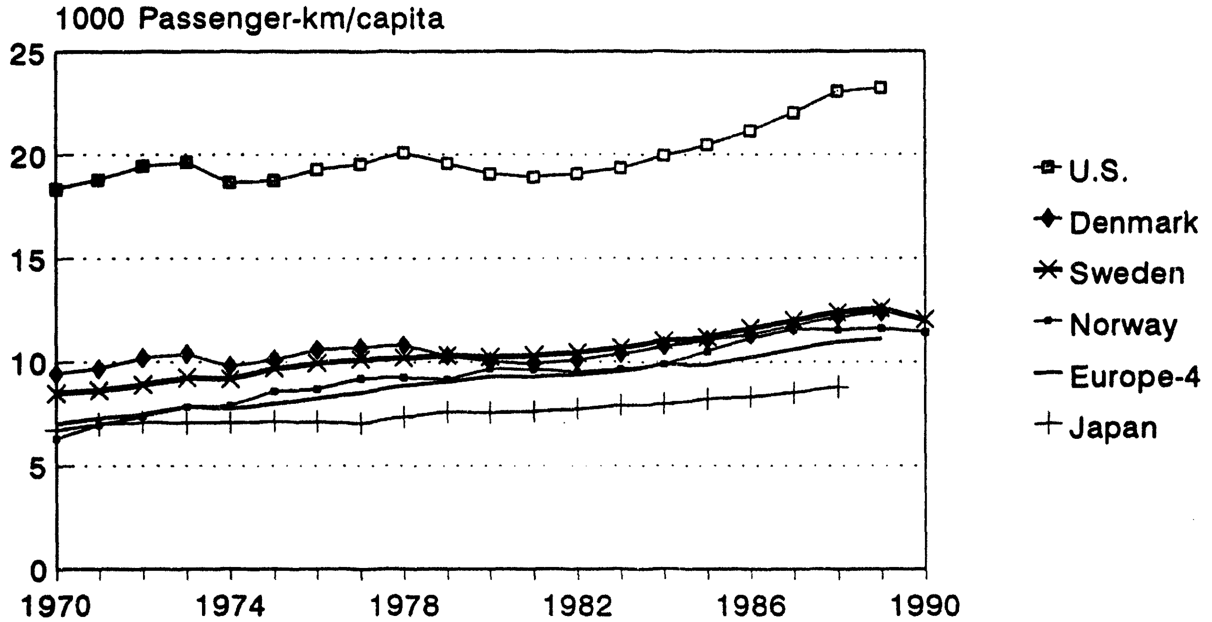
Distance Travelled per Automobile



Sources: National Authorities

Figure TI-2

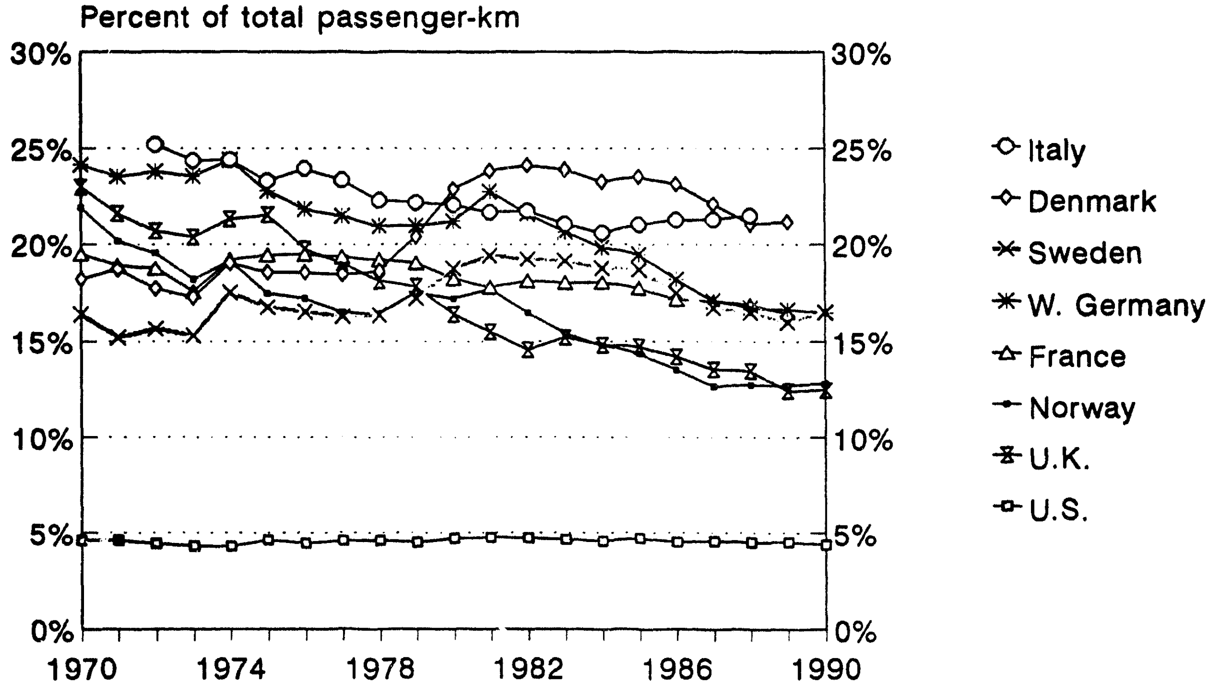
OECD Per Capita Travel 1970-1989
All Modes



US and Europe 1989 preliminary

Figure TI-3

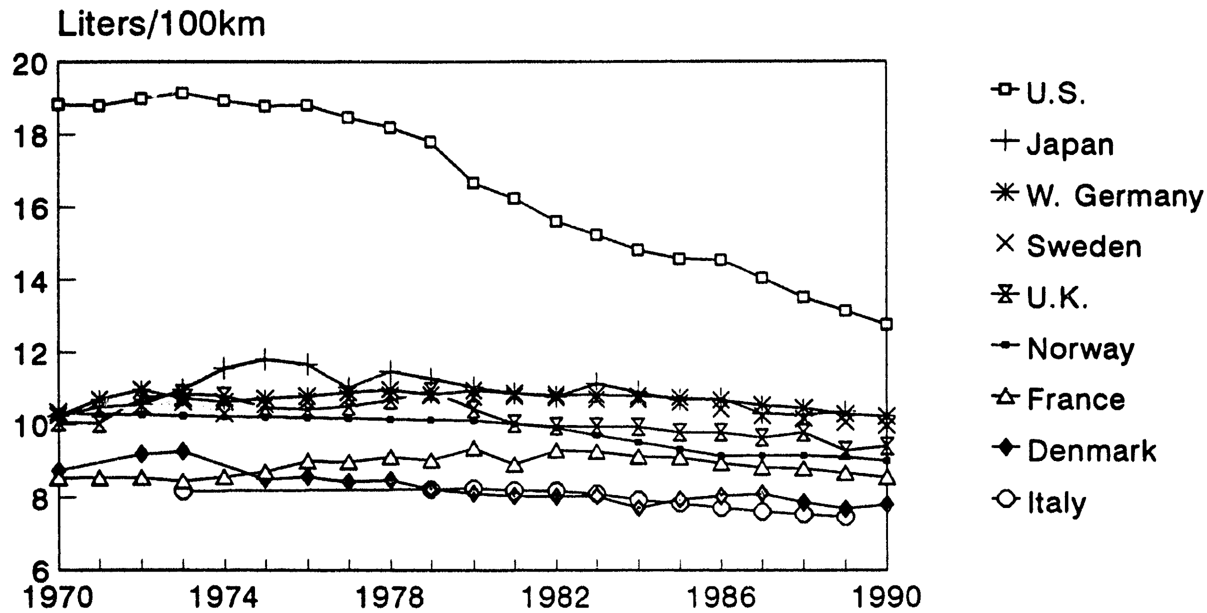
Rail and Bus Travel



Japan share of rail & bus in 1988 was 39.5 %, down from 55.8% in 1970.

Figure TI-4

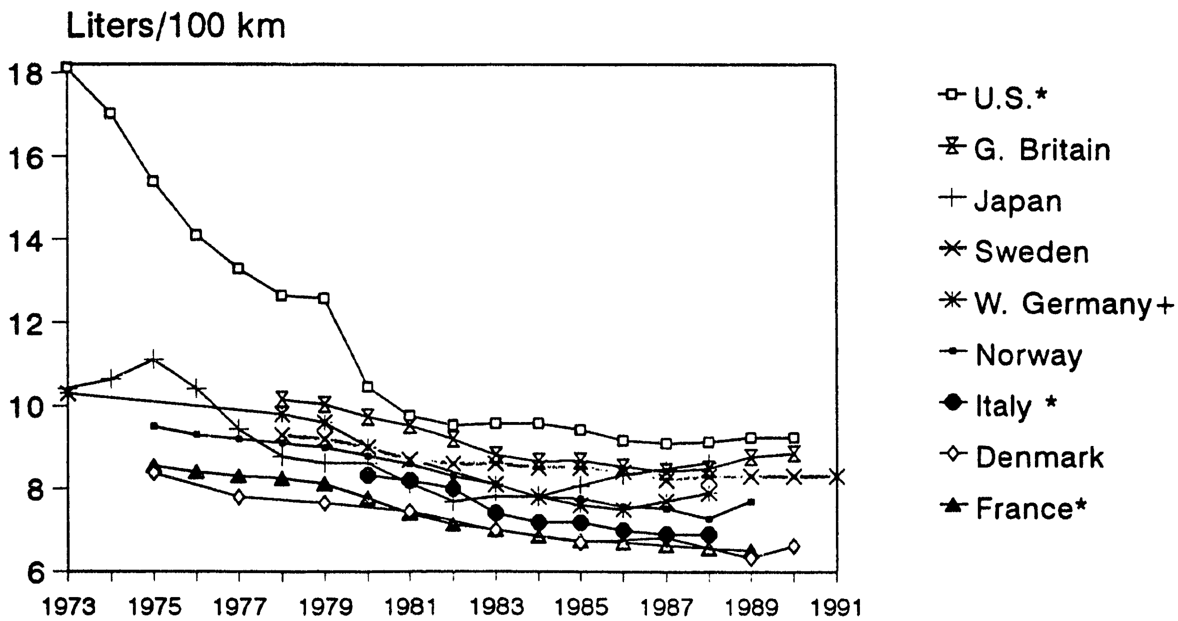
Automobile Fuel Intensities
On Road (Actual) Fleet Averages



Includes diesels, personal light trucks; liters of gasoline equivalent.
Source: LBL-IES Transport Study

Figure TI-5

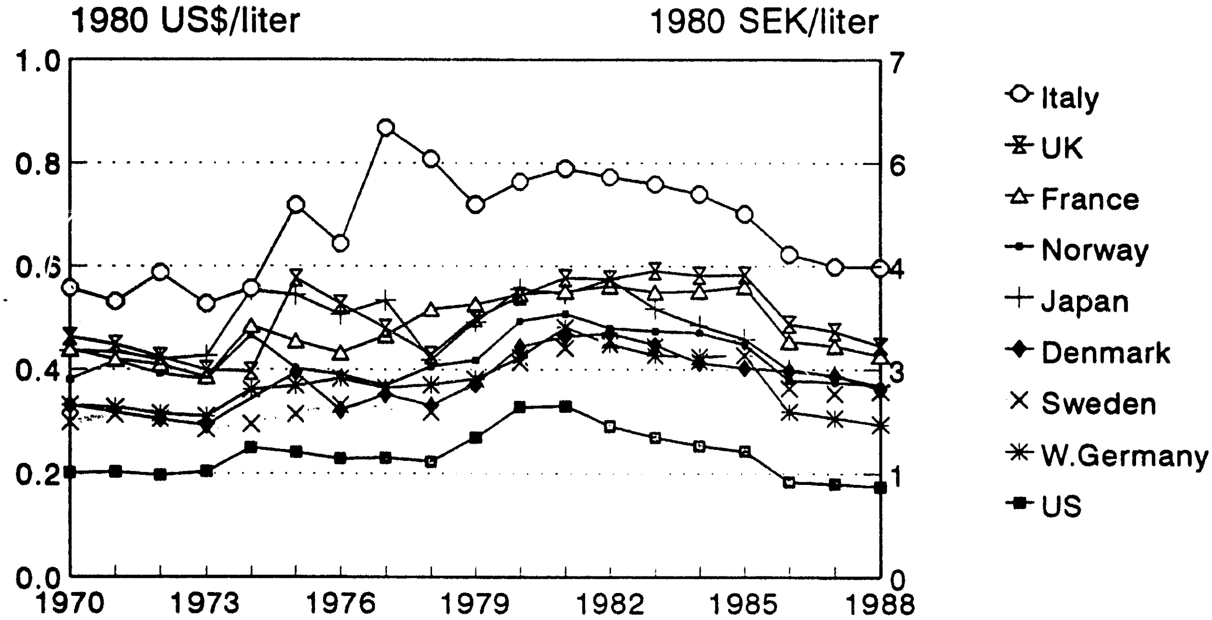
New Car Fuel Intensity
Sales-weighted Test Values



* U.S., Italy, France include diesel; W. Germany excludes diesel.
U.S. includes light trucks

Figure TI-6

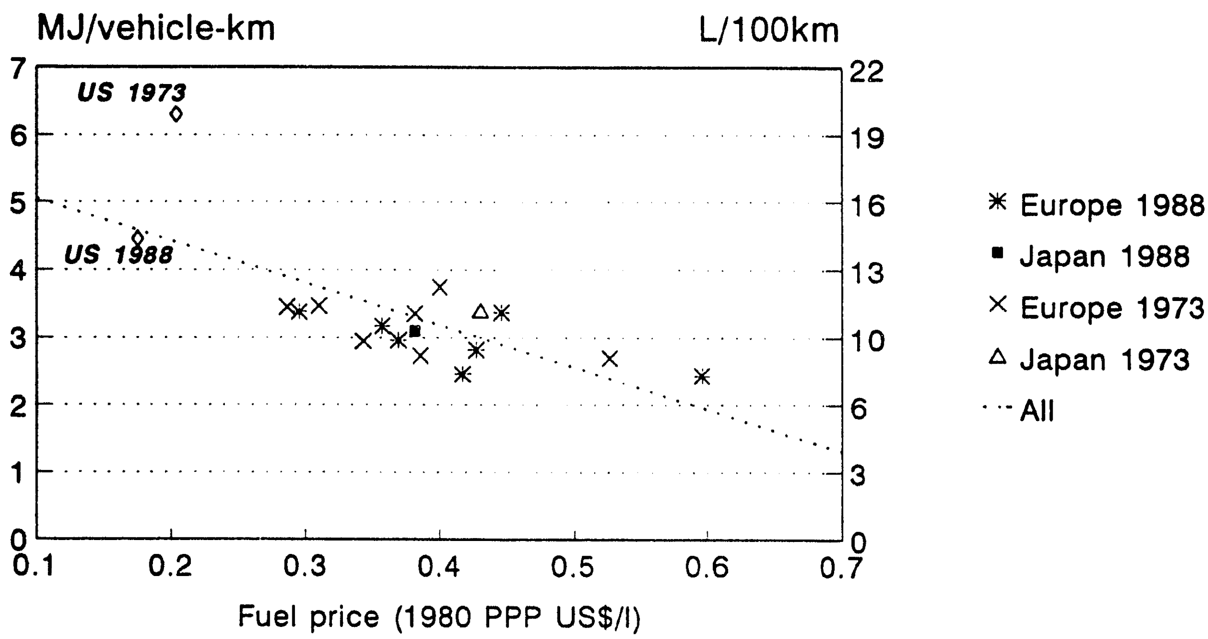
Real Automobile Fuel Prices
Weighted By Auto Gasoline and Diesel Use



Converted using 1980 real currency and PPP

Figure TI-7

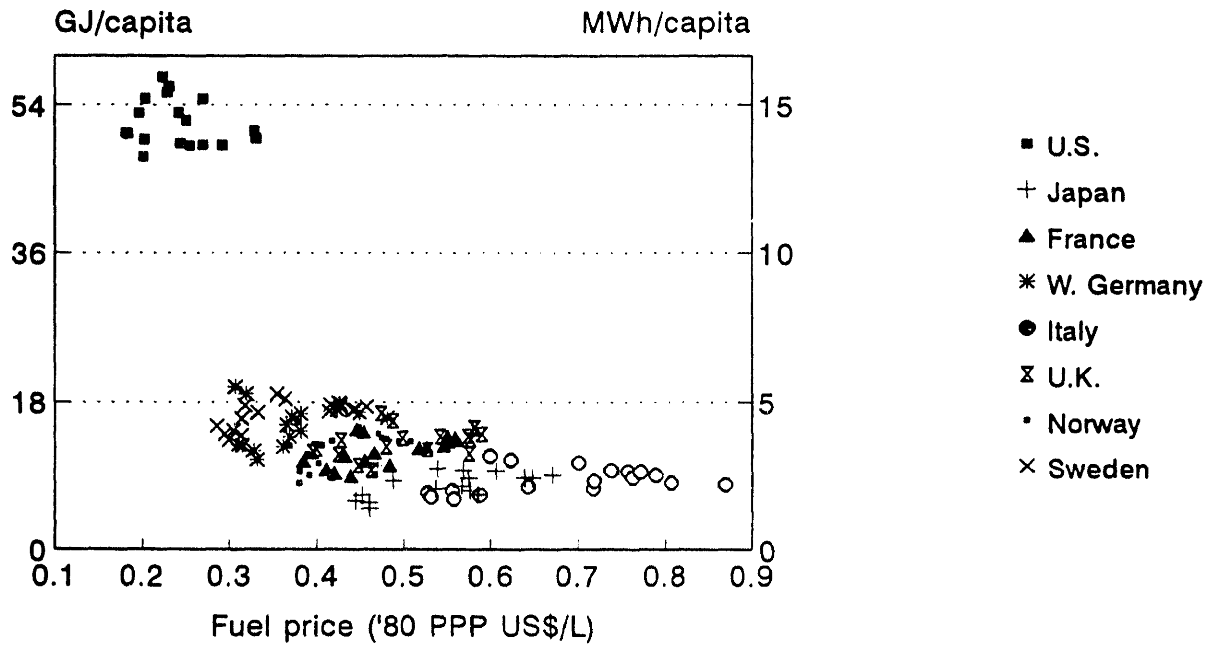
Auto Fleet Fuel Intensity
vs Real Fuel Price



U.S. & Denmark include light trucks.
Diesel and gasoline weighted by actual use.

Figure TI-8

Per Capita Fuel Use vs. Real Fuel Price
1970 - 1988



Auto diesel and gasoline prices are weighted by use.

Figure TI-9

1988 Travel Energy Intensity
Actual and OECD-9 Structure

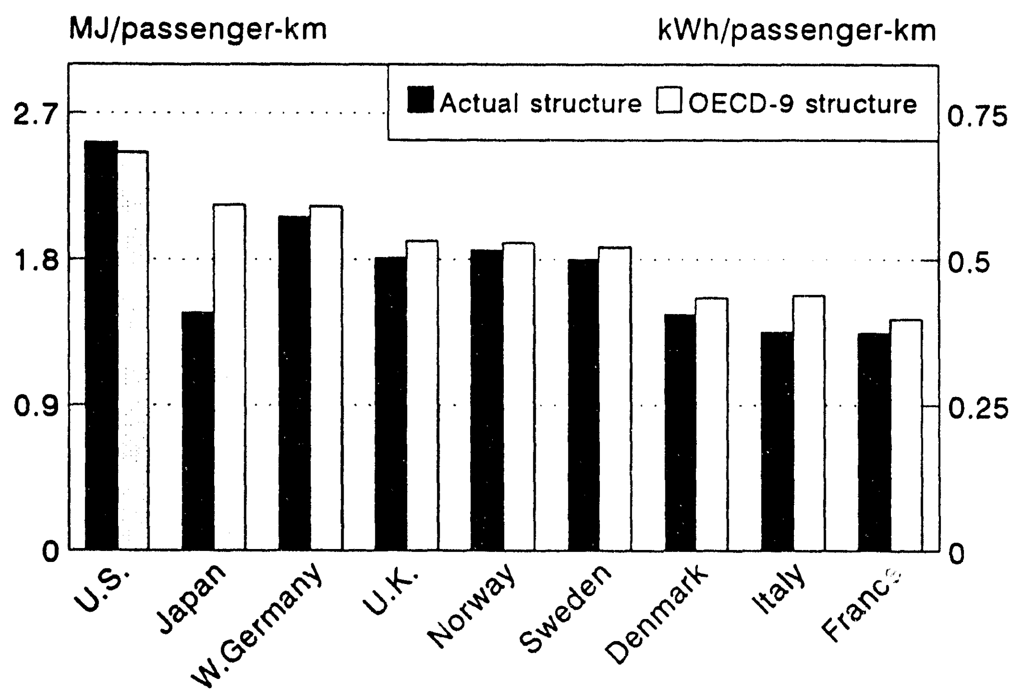


Figure TI-10

Energy Use for Travel
Impact of Changing Intensities
Constant 1973 Modal Structure

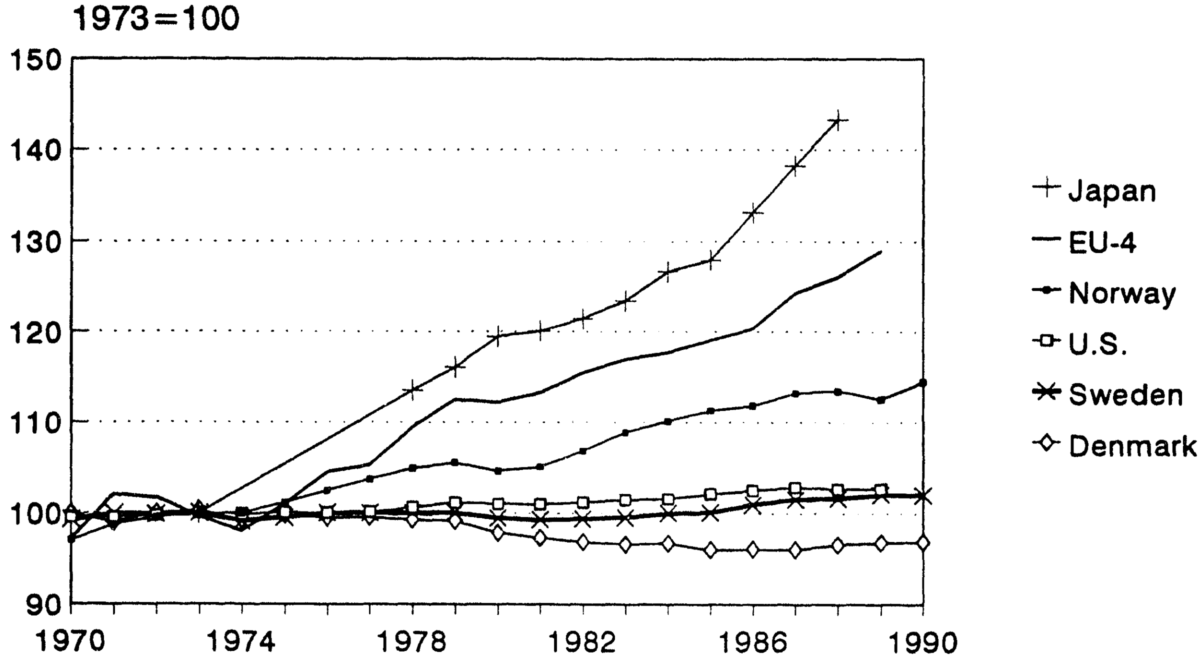


Figure TI-11

Energy Use for Travel
Impact of Intensity Changes
Constant Modal Shares

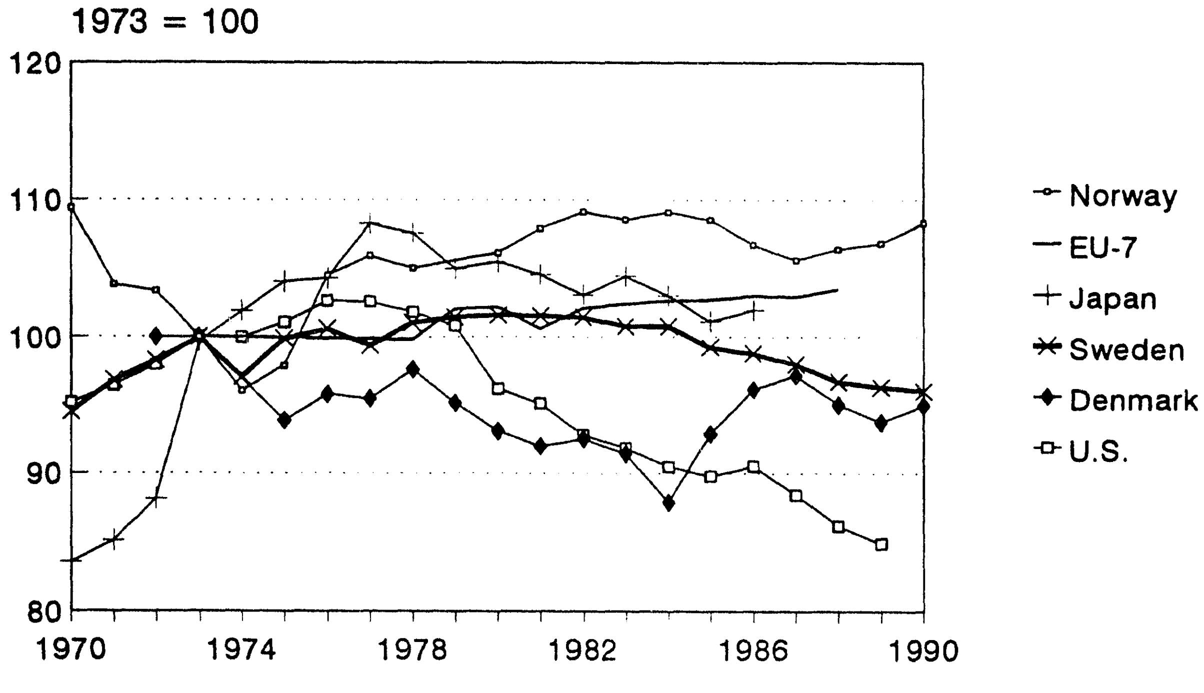


Figure TI-12

Energy Use for Travel

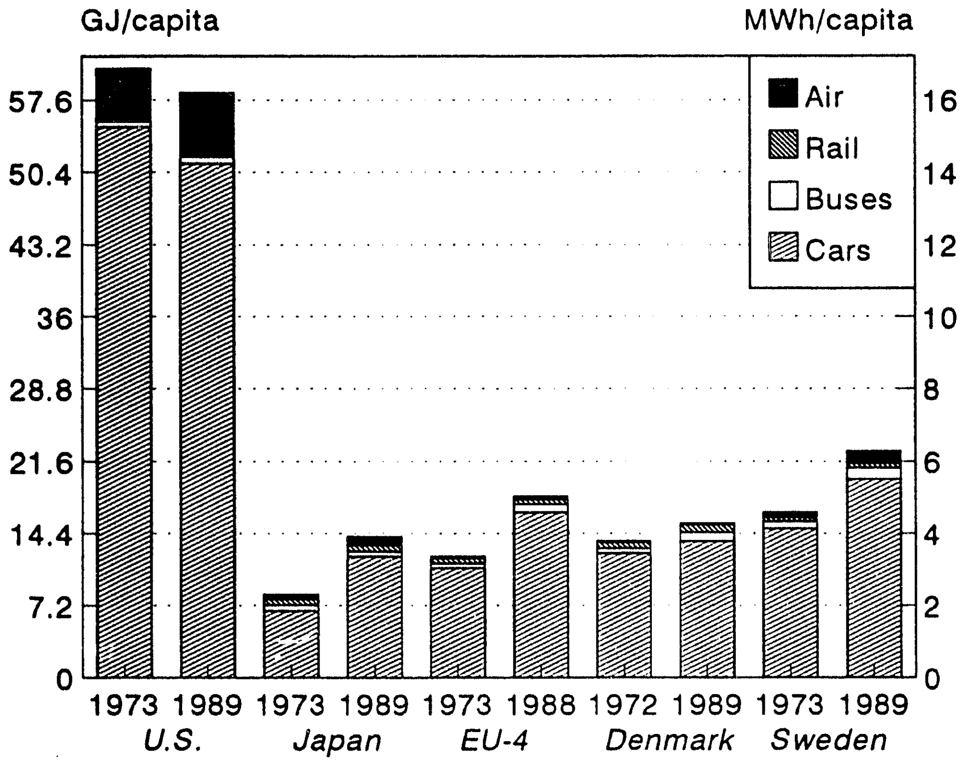


Figure TI-13

8.5. The Transportation Sector: Freight

Freight has played a minor role in driving fuel demand in most OECD countries. But the increasing role of trucks and the increase in the fuel intensity of truck freight in North America and many European countries, coupled with expectations of greater freight activity after the Single Market, means that energy use for freight is on the rise.

In Sweden, domestic freight activity per unit of GDP is high compared to other OECD countries in Europe (Figure FI-1).[13] The importance of raw materials processing in Sweden increases the natural role of inland or coastal shipping and rail freight, which also explains why the share of these two modes is so high in Norway and the U.S. compared with the EU-4. Significantly, the ratio of domestic freight carried to GDP fell in Sweden, a trend observed in all the countries we studied.

The energy intensities of each freight mode in Sweden differ significantly from those in other countries. The most important of these is that for truck freight, which is very low, although it has increased in the 1980s (Figure FI-2). The low level may be explained by the importance of raw materials, particularly forest products, which are shipped around Sweden by truck. Also, Sweden's laws permit larger single-unit trailers than do those of most other European countries. Finally, traffic on Sweden's main trunk roads is considerably less congested than traffic on the Continent or in the U.K. But the rising intensity in Sweden is shared by the fleets of most countries, caused principally by the drop in the typical size of the load and the increased number of light trucks. The same effect has been observed in Norway and Denmark, driven in part by tax loopholes that encourage both use of light trucks as passenger vehicles as well as inefficient use of trucks for small loads.

Sweden's other modes of freight transportation have energy intensities that are low compared with other countries in Europe, the U.S., or Japan. Since these modes are together more important in Sweden than in most of the other European countries, the aggregate energy intensity of freight in Sweden is low. This offsets Sweden's somewhat higher ratio of domestic freight to GDP. As a result, the ratio of freight energy use to GDP in Sweden is slightly lower than the EU-4 average or that of any of the other countries shown in Figure FI-3.

The impacts of modal shifts and changes in modal energy intensities on freight energy use are similar to what occurred in most OECD countries. The shift in mix towards trucks increased energy use for freight in Sweden by less than in Norway, Denmark, or the EU-4 (Figure FI-4). Changes in individual modal intensities, by contrast, raised energy use for freight in Sweden more than the increase in other countries (Figure FI-5). Indeed, a slight decline in intensity is indicated for the EU-4, Norway, and the U.S. Recall, however, that individual and aggregate intensities in Sweden in 1973 were the virtually the lowest of the countries studied. In this light, the increases over the succeeding 17 years do not seem unreasonable.

The contrasts in energy use for freight in Sweden and other countries are best illustrated in Figure FI-6. While per capita energy use in Sweden is close to that in the EU-4, it lies below the values for the U.S., Japan, and remaining Scandinavian countries shown. The increase was fueled by all three forces: higher modal intensities, more trucks, and a slight increase in the ratio of freight to GDP.

[13] Transit traffic between continental Europe and Scandinavia plays a small role in the total freight shipments of Sweden. We have counted this freight in the total, since we are unable to separate energy use for this freight from that for domestic freight.

Domestic Freight Activity and GDP

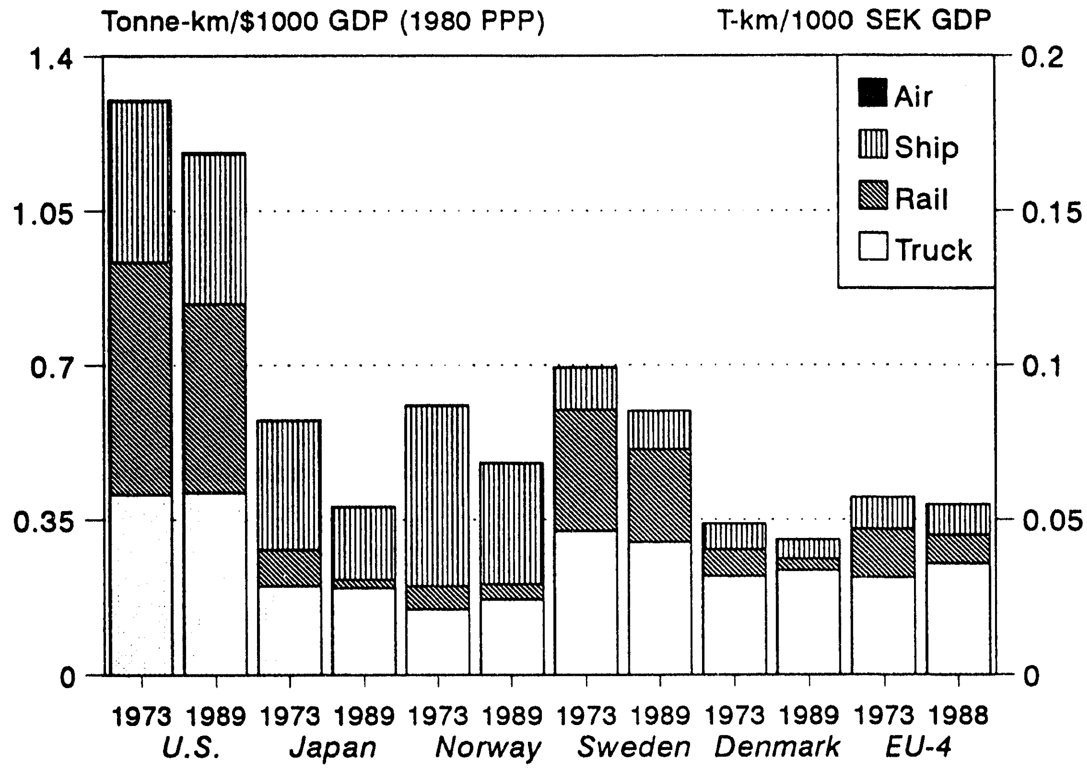


Figure FI-1

Truck Freight Energy Intensity

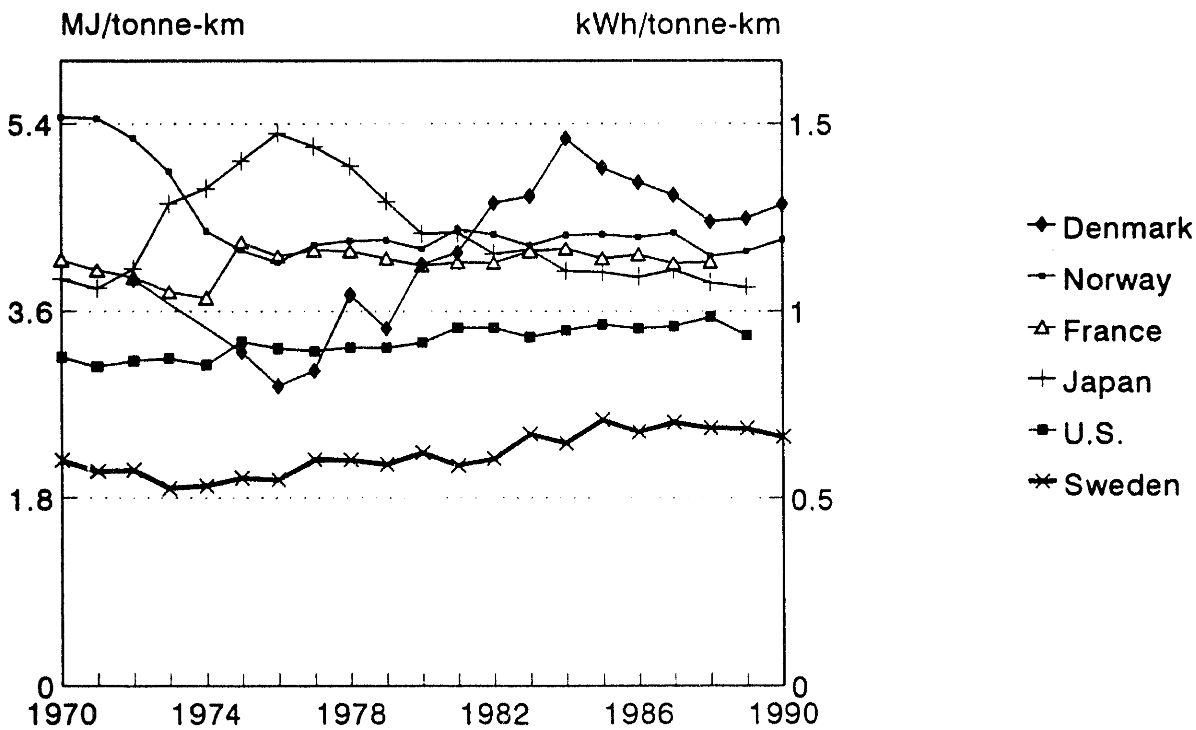


Figure FI-2

Domestic Freight Energy Use
GDP Intensity of Freight

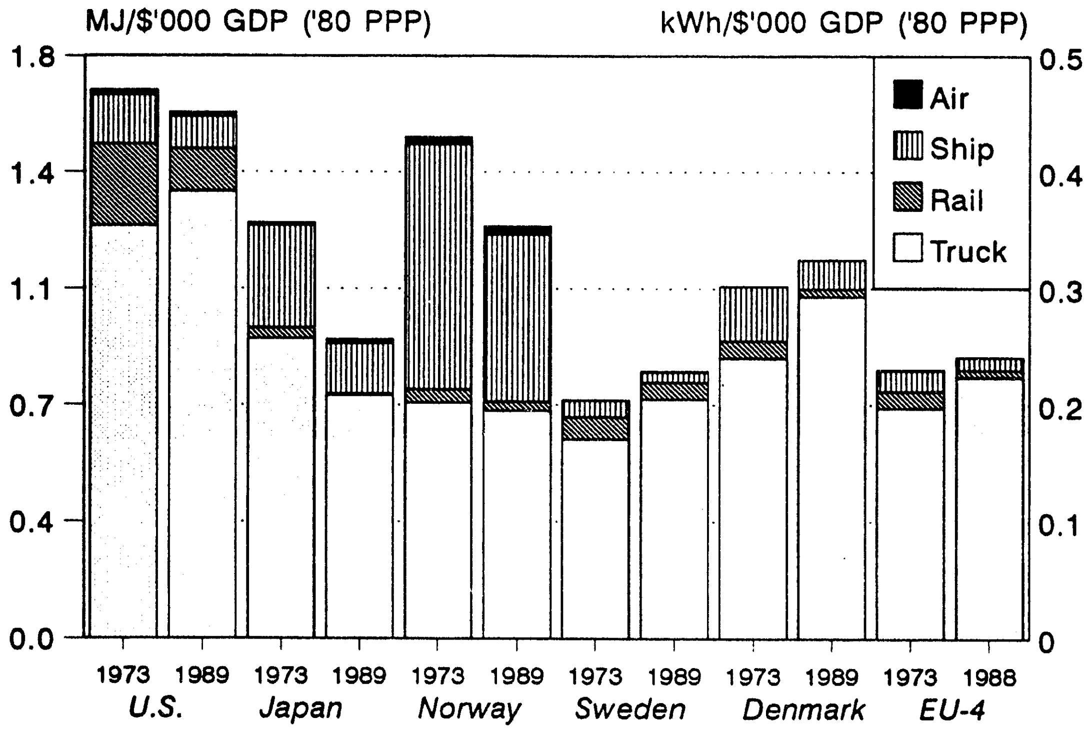


Figure FI-3

Energy Use for Freight
Impact of Changes in Modal Mix

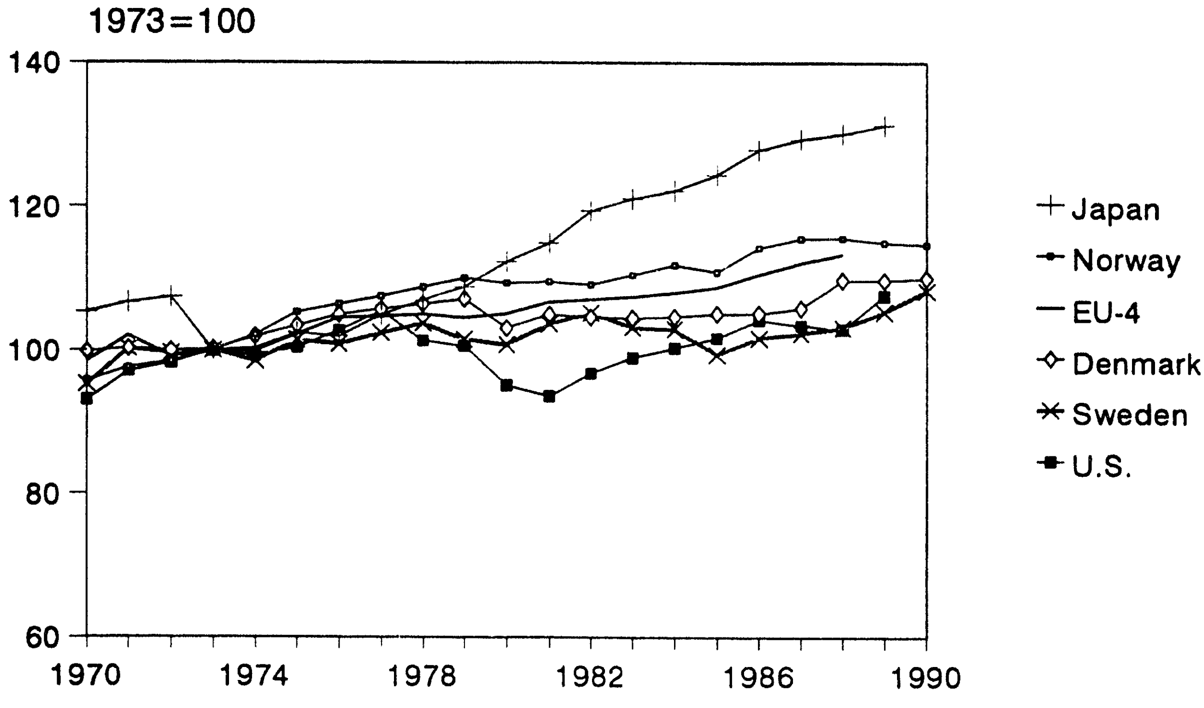


Figure FI-4

Energy Use for Freight
Impact of Changes in Modal Intensities

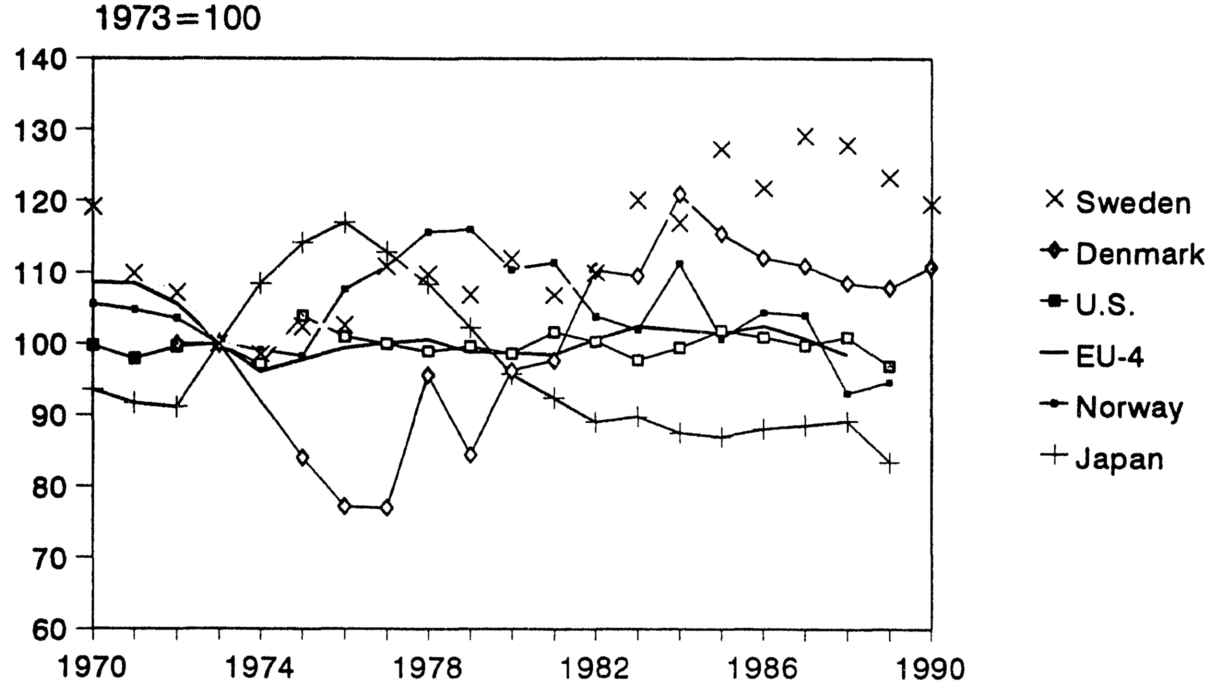


Figure FI-5

Energy Use for Freight

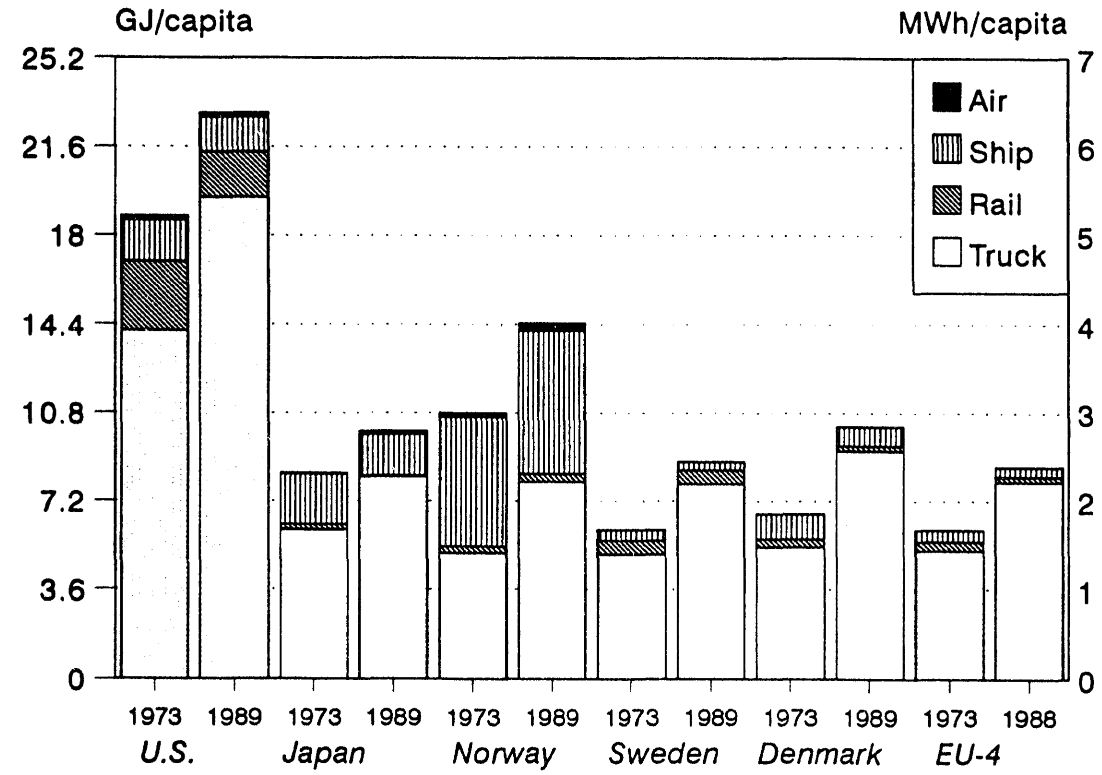


Figure FI-6

8.6. SUMMARY: ENERGY USE IN SWEDEN AND OTHER INDUSTRIALIZED COUNTRIES

The structure of energy use in Sweden is more energy-intensive than in other important OECD countries. Individual intensities of energy use in Sweden, on balance, are higher than in many other countries (except for the U.S.). Intensities dropped somewhat less in Sweden than in most of the other countries we studied. Thus, while Sweden was already relatively energy-intensive country in 1973, the changes intended to reduce energy use during the period up to 1989, while significant, still left the economy relatively energy intensive.

8.6.1. Is Sweden Different?

Figure IS-1 shows per capita delivered energy use by sector in six countries (Sweden, Denmark, Norway, the U.S., West Germany, and Japan) in 1988 or 1989. Figure IS-2 shows the same measure as primary energy use. The obvious variations arise out of differences in the levels of sectoral activity, the structure of activity in each sector, and the energy intensities of each activity, all of which shape each country's energy use. Differences in fuel mix, which we have not analyzed in detail, play some role as well. The most obvious of these is the role of electricity, which changes Sweden's per capita energy ranking.

The aggregate figures presented in Figure IS-1 or IS-2 hint at some of the most important differences in energy use we encountered. Per capita delivered energy use in Sweden lies near the middle for the five countries shown, well below that of the U.S. or Norway, but close to that of Japan or West Germany. Per capita primary energy use ranks high, with Norway and the U.S., because of the important role of electricity in Sweden's residential, service, and manufacturing sectors. By contrast, travel and freight boost the U.S. position compared with the other countries dramatically in either formulation.

8.6.2. Energy Savings Achievements Since 1973: International Comparison

In the aggregate, energy savings in Sweden, compared with 1973 or 1989 consumption, rank low compared with the achievements of most of the other countries we studied. And these savings were focused in only a few sectors, which is cause for some concern. In other countries, savings were distributed more evenly among many sectors. Finally, the rate of savings in Sweden has slowed markedly. This observation is consistent with an international trend that reflects changes in both the kinds of energy-using equipment being designed and sold in the largely international market, as well as conditions in each country that affect the adoption of energy-using—and energy-saving—equipment.

We summarize the impact of energy savings on energy use in several other countries, including Norway, the U.S., West Germany, and Japan using the same measures discussed in Section 7. Figure IS-3 shows the impact of changes in delivered energy intensities on delivered energy use over time in each of these countries between 1973 and 1989, all other factors held constant. Figure IS-4 shows the same affect applied to primary energy use. (This is the first method of measuring energy savings discussed in Section 7.) For comparison, energy use in 1973 is set to 100. It can be seen that the intensity effect in Sweden lay among the largest if only delivered energy were considered, but fell behind those for the other countries (except Norway) when primary energy is analyzed. Note that Japan, which is often credited with leading energy savings achievements, lies in fourth place by either measure, while Norway shows almost no energy savings by either measure. Note, too, the slowdown in the rate of decline of the intensity indicator after 1985 in every country.

Rankings of these changes by sector explain the position Sweden attained. Figure IS-5 compares the primary energy intensities in 1988 with their 1973 values on a sector by sector basis. It can be seen that in the countries with the deepest savings, Denmark, the U.S., and Germany, almost all sectoral intensities declined, while in the remaining countries, including Sweden, two more sectors experienced increases in energy intensities.

For each country, Figure IS-6 portrays energy saved, *i.e.*, the amount by which total primary energy use would have differed in any given year had not energy intensities fallen. For Sweden, almost 5% more energy would have been required in 1989 (4% in 1988) without energy savings, well below Denmark, the U.S., W. Germany, and Japan, but ahead of Norway. The position of Japan may seem odd, given Japan's reputation for energy efficiency. In effect, the improvements in Japan were concentrated into two sectors: manufacturing (with other industry) and freight, that are tied to international competition. Other sectors performed poorly by our measures, hence the overall results for Japan fall behind those for Denmark, the U.S., and West Germany.

We can also compare the importance to the evolution of total energy use of both intensity changes and structural or activity changes in Sweden with developments in other countries. Figure IS-7 shows these effects in the six countries. The activity effect in Sweden had a significant impact on energy use, less than only that in Japan or the U.S. The structural effect was median; structural changes boosted energy use in Norway, Denmark, and West Germany far more than in Sweden, but had a smaller effect in Japan and the U.S. This difference arose primarily because the contraction of energy use in manufacturing in these two countries from structural changes was so large.

Figure IS-8 shows the impact of changes in activity and sectoral structure in a different light. We calculate the changes in energy services for each country and compare then with growth in GDP. By this measure, Sweden experienced a small decline in this indicator, which was even smaller in the U.S. and positive in West Germany but significantly larger (and negative) elsewhere. Note that the decline in energy intensities and in the ratio of primary energy to GDP in Sweden were nearly equal, while these diverged significantly in Norway and Japan. This helps explain the difference between the intensity effect and the change in the actual ratio of energy use to GDP that we have measured in each country. In other words, the ratio of energy/GDP overstates considerably the decline in energy intensities, and therefore the improvements in energy efficiency, achieved in Denmark, Japan, and especially Norway, gives a mild overstatement for the U.S. and a small one for West Germany, but is accurate for Sweden.

These international comparisons reinforce an important lesson: The ratio of energy use to GDP is a poor measure of energy efficiency and comparisons among countries should be made without references to it because changes in that ratio over time give a poor measure of improvements in efficiency over time. The distortions that arise when this simplistic ratio is used for Sweden are small, but much larger among the other countries we have studied.

8.6.3. Sweden Is Different

The structure of energy use in Sweden differs considerably from that in the other countries studied, although patterns in Norway come closest to those in Sweden. The most important factors are:

- Sweden is the coldest country, with the largest homes in Europe and the most residential and service-sector space per person in Europe. These factors raise heating energy use significantly;
- Sweden has the highest per capita travel in Europe and very high domestic freight per unit of GDP, a median share of automobile travel and truck freight in each sector's respective mix;
- After Norway, Sweden has the most energy-intensive industrial structure of any high-income OECD country;
- After Norway, Sweden has the highest penetration of electricity in all sectors of any country in Europe.

These factors all raise energy use in Sweden relative to the other countries portrayed in Figure IS-1, except the U.S., and for a few sectors, Norway. That is, Sweden is more energy intensive than virtually any country in continental Europe, including Great Britain. The high level of electrification also raises Sweden's *primary* energy use to high levels.

Changes in energy use between 1973 and 1989 tended to reinforce all of these features of the Swedish economy, and almost kept pace with overall GDP growth in propelling upward energy use. The total area of built space, the mix of output in manufacturing, and the levels of both freight and travel increased. Only the decline in the share of manufacturing in total GDP tended to reduce the energy intensity of the Swedish economy.

The relative position of energy intensities in Sweden is mixed. Space heating intensity is the lowest among the major OECD countries. The intensity of truck freight and freight in the aggregate is also very low. By contrast, the energy intensity of travel is one of the highest in Europe, and the intensities of individual branches of industry are moderate to high by European standards. Declines in these intensities were for the most part average for Europe, but less than average in a few cases. As a result, energy efficiency gains in Sweden were somewhat less than those that occurred in many of her neighbors, particularly if we measure these gains in terms of primary energy use.

Delivered Energy Use in OECD Countries
Major End-Use Sectors, 1988

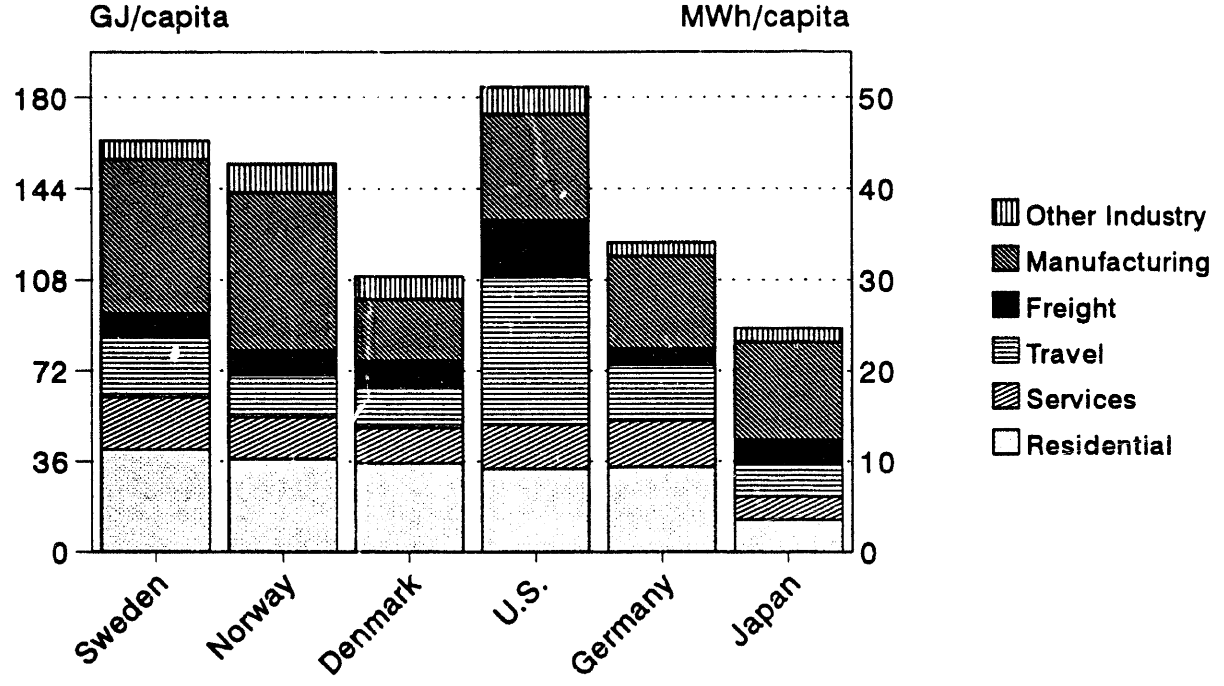


Figure IS-1

Primary Energy Use in OECD Countries
Major End-Use Sectors, 1988

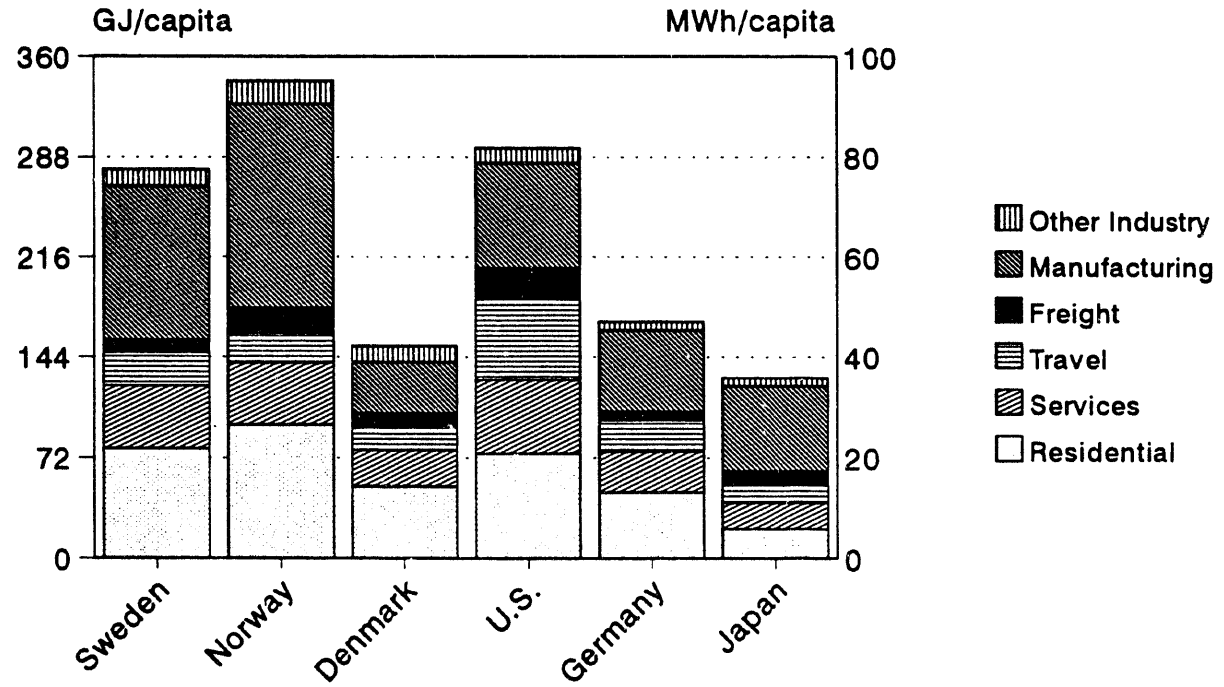


Figure IS-2

Delivered Energy Intensities 1973-1989
All Sectors, Constant 1973 Structure

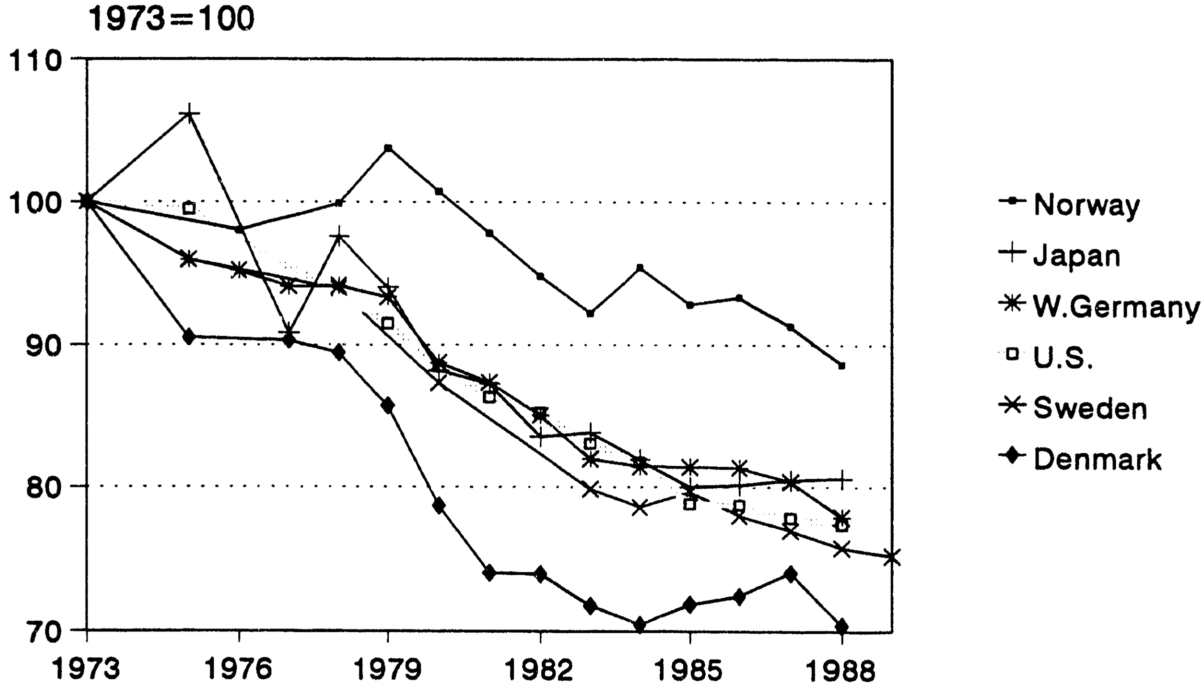


Figure IS-3

Primary Energy Intensities 1973-1989
All Sectors, Constant 1973 Structure

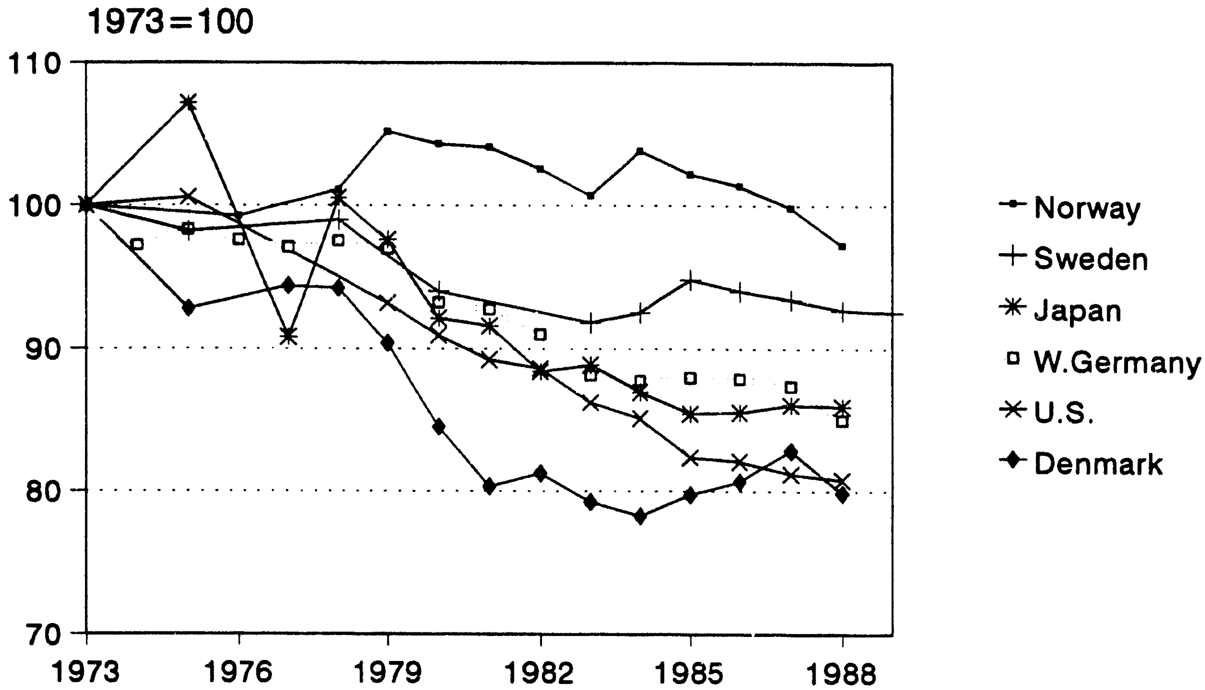


Figure IS-4

Changes in Energy Uses
Primary Sectoral Intensities

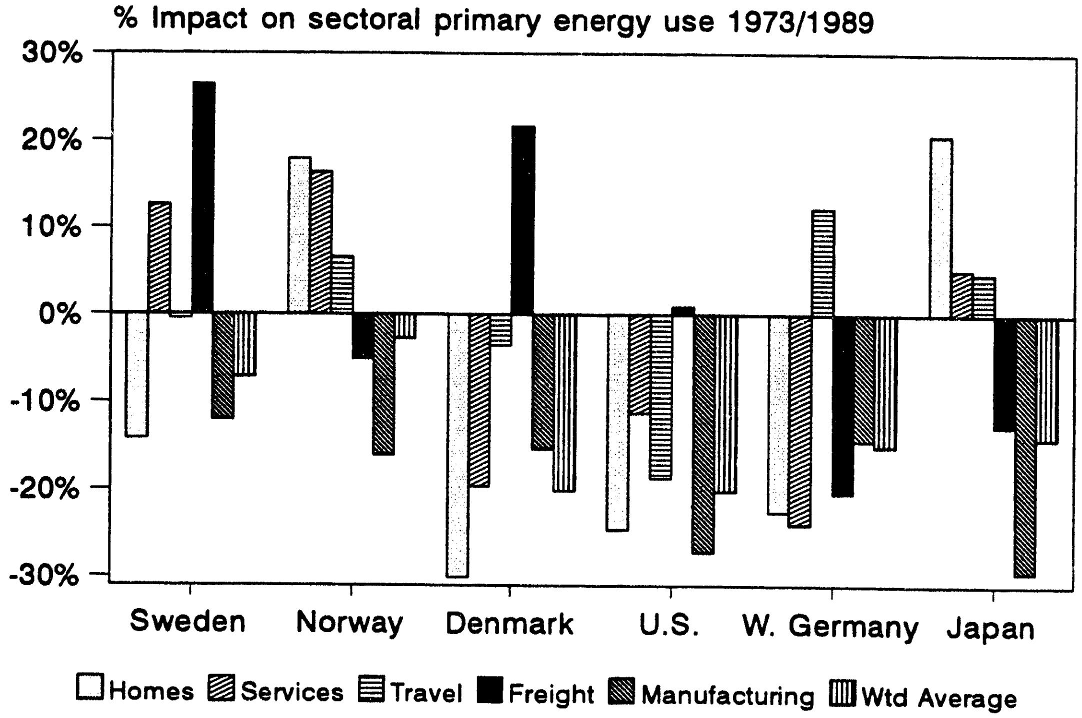


Figure IS-5

Primary Energy Saved Relative to Actual

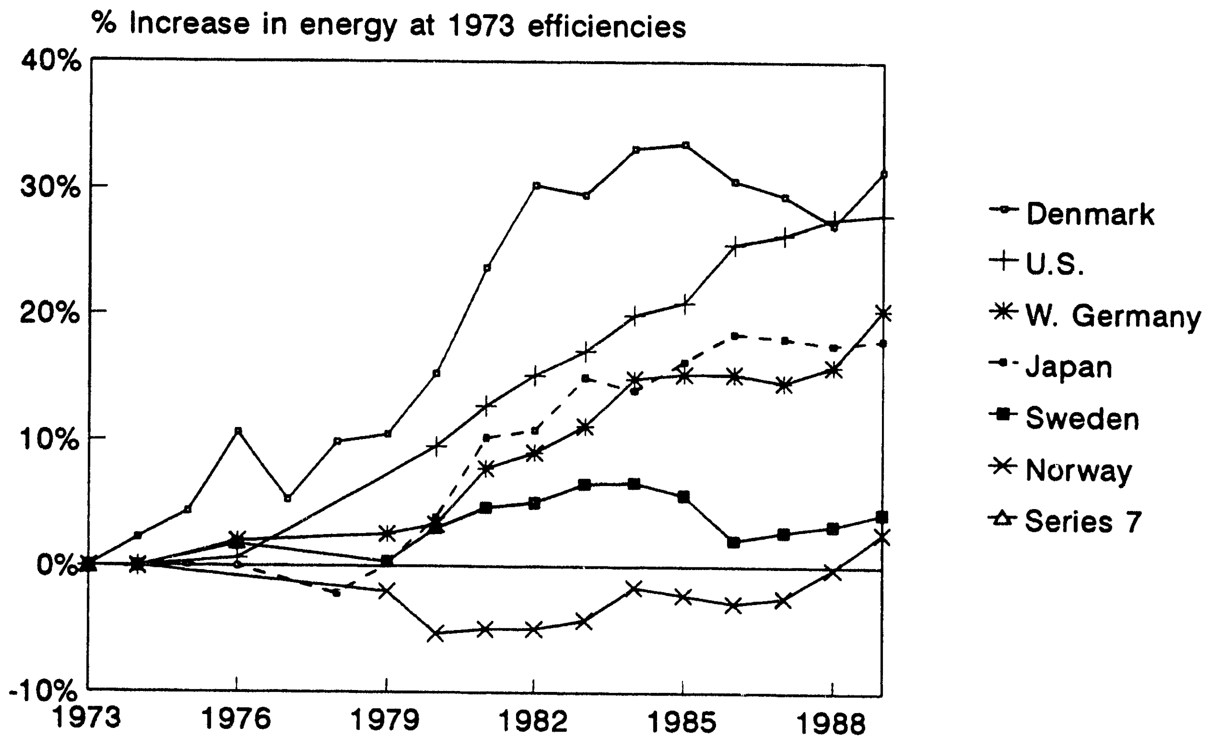


Figure IS-6

Changes in Energy Uses
Aggregation of Subsectoral Change

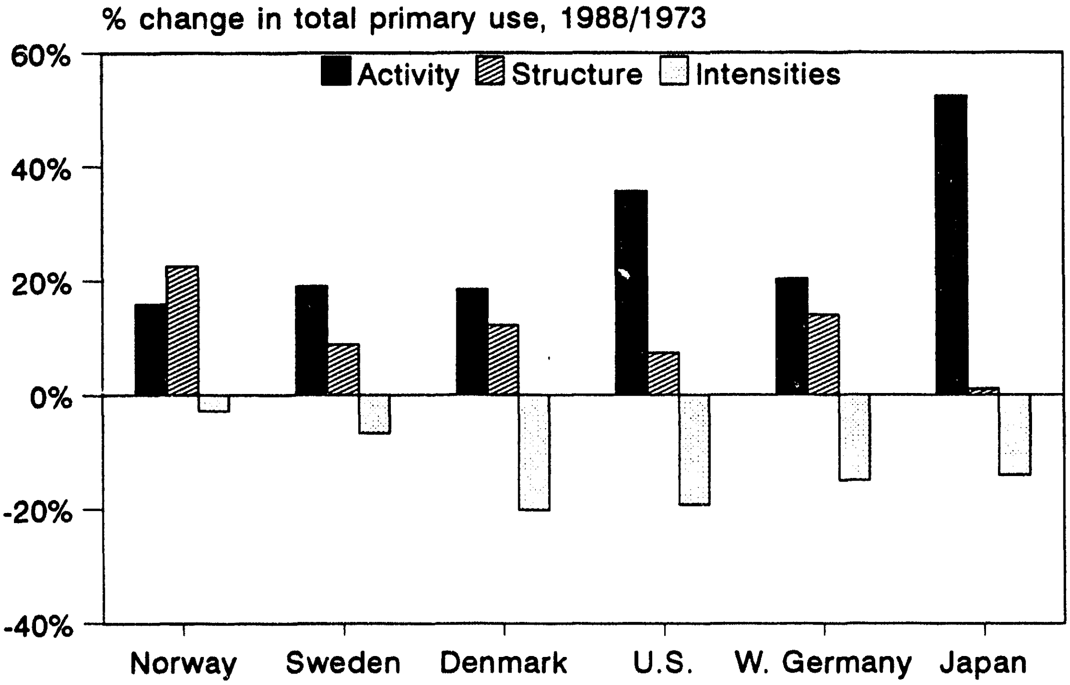


Figure IS-7

Changes in Primary Energy Uses
Comparison of Indicators of Change

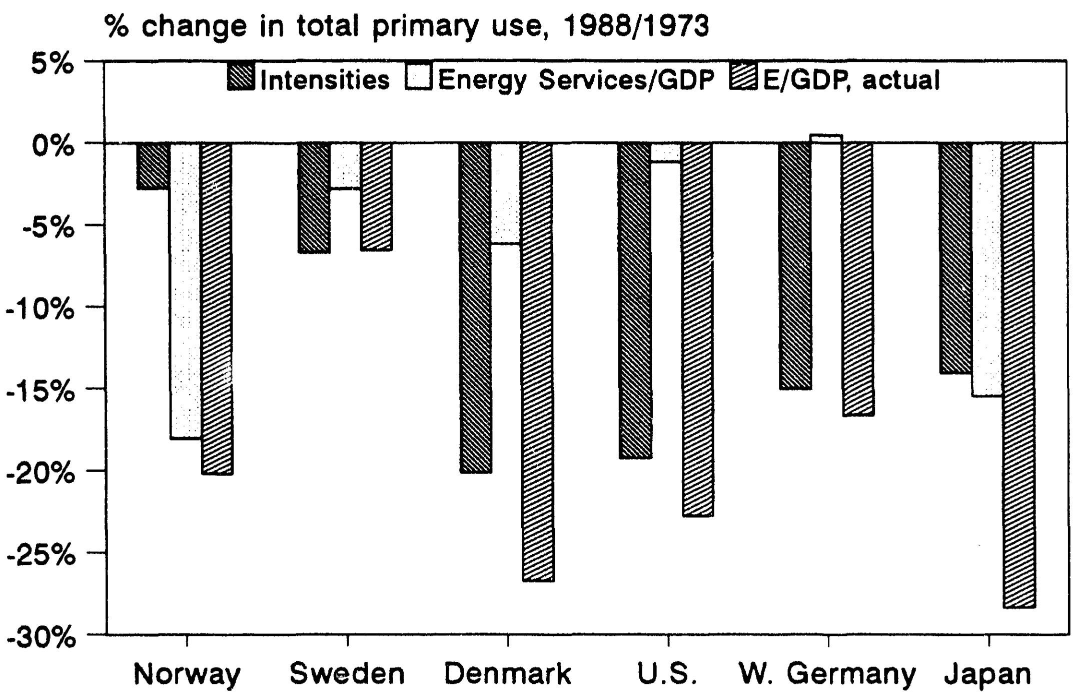


Figure IS-8

9. ISSUES FOR THE FUTURE: WHAT WE LEARNED FROM THE PAST

Our analysis of energy use in Sweden since 1970 has revealed that both evolution in the structure of energy use and improvements in efficiency caused fundamental changes in total energy requirements. We suggested that the overall level of energy savings in Sweden was only modest, considerably behind the savings we measured elsewhere. This would not in itself be controversial, except that a long series of Swedish energy policy proposals from the 1970s and 1980s focused on improving the efficiency of first energy use, then electricity use. Present interest in energy saving arises from environmental concerns, although there is still a lingering malaise over the future of nuclear power in Sweden. Whether the rate of efficiency improvement in Sweden will be re-ignited, however, depends on several issues that we raised in our sectoral analyses and international comparisons. We will address these issues here.[1]

9.1. The Nature of Improvements to Efficiency Between 1970 and 1990

It is important to summarize the nature of improvements in energy utilization that occurred up to 1990. Understanding these improvements is crucial to judging whether we can expect similar developments in the future.

9.1.1. Technical or Behavioral Changes?

It is possible to estimate the components of energy savings that are related to either technical changes or to changes in behavior. Technical changes are those involving how energy is used and are carried out slowly as technology is modified or replaced. In contrast, changes caused by behavior are carried out very rapidly. Technical changes have little impact on comfort, behavior, or productivity and output, and may enhance these qualities of life or work. By contrast, some behavior changes can involve "sacrifices" of comfort or mobility. These "sacrifices", such as those related to lower indoor temperatures or more careful use of hot water, may become routine as individuals become accustomed to more energy-frugal behavior. However, they can reverse with lower energy prices or higher incomes, or simply because of a sense that the crisis has passed. An intermediate change occurs if energy users manage their consumption more carefully and energy use falls: Little comfort is lost. Who would argue that Swedes living at 21C today are living with sacrifice compared to those who sweated through 24C before 1973? This change is reversible too, if users begin to ignore management procedures.

Turnover of industrial equipment, buildings and their equipment, and the gradual renewal of the transportation fleet has clearly led to energy savings that can be ascribed to technology. Persistent actions to improve existing heating systems by outfitting them with various controls also count as technical change. These kinds of changes pervade every sector of energy use in Sweden, and appear to have made the largest contribution to energy savings by 1990.

By contrast, the decline in space heating that occurred rapidly in both 1974/75 and 1980/81 was short lived, in part because the efficiency of Swedish heating practices meant that the marginal savings from decreasing temperatures one or two degrees were small. By 1990 there seemed very little residual "sacrifice" from uncomfortable indoor conditions. And while there may have been increased vigilance by energy managers in industry and buildings in the mid-1970s and again the 1980s, these effects seem to have worn off. This means that the short-term, behavior component of reduced energy intensities is small, probably less than 10% of the total savings we have measured.

9.1.2. Permanent or Reversible Improvements in Energy Efficiency?

When we consider all factors, it appears that well over 90% of the total savings we measured in homes, transportation, and industry, are *permanent* because they arose through the application of technology. Reductions in energy intensities so gained will likely never be reversed. In a few activities (production of energy-intensive materials, space heating, driving), reduced energy intensities permit the very activity for which energy was saved. This "rebound effect", however, is small by most estimates (Schipper and Meyers *et al.* 1992).

Energy savings gained through behavior change, by contrast, are by no means permanent. From all the surveys we reviewed, we did not find a significant component of the Swedish population that had (or has) made important changes in their indoor heating habits (Schipper, Meyers, and Kelly 1985). Indeed, indoor temperatures of 20-21 degrees reported to the 1981/82 SIB survey appear to have been the highest of any cold country in Europe. This is not to castigate Swedes for enjoying well-engineered comfort, but to emphasize that little of this comfort was sacrificed to save energy. In that sense, there is little comfort sacrifice that we expect will reverse in the coming years.

There is clearly a small potential for further reversal of energy savings in large buildings gained through

[1] This chapter (and the one that follows) draw heavily on similar chapters in our report on Danish energy use.

behavior and management change, however. Our perception is that Swedish buildings, while slightly cooler than before 1973, are slightly warmer today than in the 1980s, a situation not restricted to Sweden alone. Lower energy costs relative to the early 1980s, particularly during the extremely mild winters that have become "normal" since 1989, permit building owners, operators, or occupants to pay less attention to their heating costs. But at some point, such inattention leads to overheating. In the past, Swedes opened the windows to deal with this problem! Hopefully renewed interest in energy saving spurred by higher fuel prices (in turn a result of the lower *krona*) will stimulate energy management in large buildings that will provoke operators to continue to pay attention to energy costs. And a continued proliferation of heating controls for homes and buildings even if slower than in the past, might stem the rise in indoor temperatures in homes that could occur if winters stay mild and prices low.

Another important behavior change affecting energy use is the choice of cars over buses or trains for short- and medium-distance travel. The share of cars in total travel appears to have stabilized in the last few years, reinforced by the large increases in automobile fuel prices, after rising through the late 1980s. Much of this rise was a consequence of *both* stagnation in real energy prices and growth in incomes in the 1980s. If the real price of gasoline remains high, in real terms, we might expect an end to the constantly rising share of automobiles in total traffic.

The trends in the freight system, by contrast, reflect much more fundamental forces at play than merely energy costs, as we noted in our analysis of this sector. Quite simply, there are no energy savings that can reverse with lower energy prices! The shift to smaller trucks and lighter loads was driven by "just-in-time" (materials administration). The same trends have appeared in many countries. In addition to measures that might reverse this trend (discussed in the chapter on freight), the rising cost of road fuels may set off a careful re-evaluation of the kinds of trucks used in Sweden and of use itself.

9.1.3. Savings That Occurred After 1973: Trend or Break?

We noted that the behavior of energy intensities after 1973 resembled developments in the previous decade in some sectors, but took a new course in others. In manufacturing, the rate of decline of energy intensities increased somewhat after 1973, but the decline had been evident for many years previously. This is consistent with what we have observed in many countries.

By contrast, energy intensities in other sectors were rising before 1973. Part of this rise really reflects structural changes, such as increases in automobile size, home appliance size (or number of features), and comfort levels in homes and buildings. However, the standard of comfort in Sweden, as measured by house size, indoor temperature, and central heating penetration, was clearly the highest in Europe in 1973; much of the rapid growth was slowing. And the trend towards electricity or district heat for heating had already begun and was merely accelerated by higher oil prices. Thus these structural changes may have slowed as saturation approached. .

Not surprisingly, the post-1973 reductions in energy intensities for these end-uses represented marked, but not dramatic, changes from the pre-1973 period. Part of the reason was that trends towards improved insulation levels were already well-established, as was the rising share of homes using electric or district heating. Clearly, energy prices and energy conservation policies together had an important impact on energy use, particularly in buildings.

9.1.4. Fuel Switching

We have not expressly dealt with fuel switching in this report. The fuel switching that occurred in Sweden included conversion of many oil boilers to a mixture of oil, wood, and electricity, both in buildings and in industry; outright conversion of more than one half million apartments to district heat, initially oil fired but now produced mostly from other sources; and increase in the share of new buildings with equipment for heating with only district heating or electricity. Clearly, a significant part of "what happened" to energy use in Sweden was led by fuel switching of various sorts, mostly with the effect of reducing oil use.

The effect of these changes was to reduce *delivered* energy to homes and buildings as well as industry by substituting electricity and district heating, with very small losses at the point of use, for oil, with important combustion losses. Using the previous Swedish method of counting on nuclear or hydro as a source for electricity, these substitutions led to an apparent energy saving. The switch to wood or biomass for home heating probably entails greater combustion losses than use of oil, but this switch was not really recognized by policymakers until the 1980s, hence there was an apparent energy savings created by the absence of estimates of wood use in statistics.

One effect of this substitution bears mention again. The availability of relatively low cost electricity and virtually zero-cost wood signaled many energy users to switch to these sources in place of oil rather than bear down harder on actual uses of oil. In this case, fuel switching substituted for conservation. In Denmark, W. Germany, and the U.S., less wood was available to homes using oil, so the conservation effect dominated (Schipper and Ketoff 1985). Sweden was very successful at saving oil, which was one important policy goal that was achieved. Clearly much of the oil saving was through substitution.

A study by Aspén shows the importance of the conventions (Aspén 1988). He suggests that if delivered energy is counted backward to its primary source (as we do here), 207 units were required in 1986 to accomplish what 187 units did in 1976. He measured "accomplish tasks" using useful energy, which we relied on principally for our residential and services sector work. Counting only delivered energy, Aspén shows 140 units used in 1986 for what was done by 155 units in 1976. Aspén correctly identifies one of the main problems here: there is no "right" way to count energy.

What his important paper really underlines, however, is the fact that the impact of changes in Swedish energy end-use efficiency and intensity were not so great as to overshadow changes caused by fuel switching alone. That is, the measurement of energy saving in the other countries we studied was robust against changes in measurement from delivered to primary energy. In Sweden (as in Norway), massive increases in electricity use make a clear measurement of energy efficiency improvement difficult, particularly at the aggregate level. Indeed, the original policy goals of *Energihushållning mm*, expressed as a total energy use goal for 1985 rather than targets for improving efficiency, could easily be met predominantly by switching to nuclear and hydro-based electricity and using the accounting system in place in Sweden in the early 1970s. *It is vital that future energy policy makers take the effects of accounting for fuel substitution on energy use into account in formulating their goals.*

9.2. Causes: Trends, Energy Prices, or Programs?

What were the underlying causes of the changes in energy use efficiency in Sweden? We cannot divide the aggregate energy savings in Sweden into exact portions permitted by technological or other trends or caused solely by higher energy prices or imposition of energy policies. Clearly all three factors— influenced energy use. This section discusses the interplay of the underlying causes of improved energy use.

9.2.1. Technological Change

The preceding remarks suggest that some of the energy savings that occurred in Sweden after 1973 would have occurred anyway, as part of long-term trends in technological progress. These trends in manufacturing and other industry are universal. Higher prices for fuels and district heat accelerated what was already underway in an open, competitive economy like that in Sweden. (The same is true for the substitution of district heat or electricity for oil for space heating that started in the 1960s). We count the impact of these long-term changes on energy use as improved efficiency, in part because it is almost impossible to separate them from other changes.

9.2.2. The Effects of Changes in Energy Prices

Although we have not formally modelled the impact of price changes on the evolution of energy use in Sweden, we have alluded to the importance of energy prices in the discussion of each sector. No one discounts the importance of energy price changes in causing changes in energy use and efficiency. Higher oil prices provoked changes in energy efficiency and massive substitution away from oil, as we noted above. Prices for other energy forms increased significantly, with the notable exception of prices for electricity. The price shocks of 1973/74 and 1979/80 provoked energy saving in general, and, in the latter case, a recession as well. The fact that energy intensities fell far more than electricity intensities, even after correcting for substitution, indicates the importance of higher prices in shaping energy-use efficiency in Sweden. That prices signaled "off oil" more than "energy conservation" may be viewed as a blessing by some.

More analysis of the impact of energy prices on past changes in consumption in Sweden is justified. Certainly the building surveys permit a far better analysis of how consumers use energy than has been done in the past. Careful analysis of the impact of fuel price changes on choice and use of automobiles, or on the choice of mode for freight, is also called for if environmental policies, particularly taxes, are to be designed correctly to affect fuel choice and fuel consumption. Finally, the rapid substitution for oil by both biomass and electricity were driven mostly by higher oil prices, but we have not counted this change as "energy conservation." Yet there has been almost no disaggregated economic analysis of the impacts of changes in energy prices on use and efficiency in Sween.

9.2.3. The Effects of Energy Efficiency Programs

The third cause of improvements in energy efficiency is efficiency programs. By "cause" we hypothesize that a program or policy (other than higher energy taxes) caused improvements to occur that would not have occurred otherwise, or would not have occurred as rapidly. While it is almost impossible to measure the impact of most energy efficiency policies, a few observations are in order here.

In the 1970s, *Statens Industriverk* fostered a modest energy efficiency program that provided grants and loans to small and medium sized concerns (SIND 1979).

But the total savings from this program are small compared with the overall savings we measured in our study. This point is important: the program was successful, but its overall results were small compared with manufacturing energy savings at large. And the savings in manufacturing represent, in part, a continuation of long-term technological trends. Therefore, it is hard to ascribe much of the energy savings that arose in Swedish industry to conservation programs per se and even tougher to divide the savings we observed into a long-term component and one stimulated by energy prices.

While international competition was the real driving force behind energy saving in Swedish industry, Swedish building owners, operators, or occupants are not really "competing" with anyone for low energy costs. The drop in oil intensity after both price increases certainly had an important relation to the price increases themselves. Nevertheless, technology has made more and more efficient heating systems (and building systems) available in Sweden even without the provocation of higher energy prices. If energy prices were falling, why was this the case?

To answer that question, just compare Sweden with Denmark or Norway. Until recently, Danish buildings were far more energy-intensive than those in Sweden. The reason was that there was no institutional pressure or encouragement for far reaching investment in energy savings in Danish buildings. And Norwegian homes in 1973 were heated with a mixture of small stoves using kerosene and wood as well as a large number of small electric heaters. Comfort levels were low. In Sweden, by contrast, homes were both efficient and very well heated. The reason for the difference was that Sweden had a fundamentally different way of financing new construction that favored adoption of many energy-saving technologies, and space heating efficiencies were improving at a rapid pace even before 1972 (Schipper, Meyers, and Kelly 1985). The changes in energy use in homes and buildings in Sweden had been gradually introduced through technological developments, the pace of which was stepped up after 1973. By contrast, the changes in Denmark and Norway occurred abruptly when energy prices increased. In all these countries, however, prices were an important cause of the savings in the short term. But this merely accelerated the long-term trend in Sweden, rather than causing a break.

Certainly programs designed after 1973 to encourage savings in homes and buildings contributed to some of these savings that actually occurred, although we argued in Chapter 2 that programs could not be the major reason for improvements in energy efficiency in existing buildings in Sweden that occurred after 1973 (see also Schipper, Meyers, and Kelly 1985). Similarly, the imposition of energy-saving provisions standards in *SBN-75* does not appear to have forced improvements in the thermal characteristics of *new* buildings beyond what might have occurred with only pressures from higher energy prices and the existing policy mechanisms that financed these improvements. Indeed, we showed in Schipper, Meyers, and Kelly (1985) that *SBN-75* requirements as stated in 1975 were already behind current practices at that time. It was not until *ELAK* was announced in the early 1980s that requirements moved beyond average practices. Thus only in new electrically heated single-family dwellings built after 1980 could one detect a forcing element in the thermal requirements, one whose cost effectiveness was debated vigorously but then generally accepted. Not surprisingly, new homes in Sweden are still the most efficiently heated in all of Northern Europe. Thus the predominant reason for improvements in heating in Sweden was policies already in existence before 1973, reinforced by higher energy prices.

In the transportation sector it is hard to identify concrete energy-saving policies in Sweden. The "0.85 program" encouraged *manufacturers* to sell less fuel-intensive cars than otherwise, but other Swedish policies stimulated *Swedes* to acquire vehicles that are heavier and more fuel-intensive than those used in Europe as a whole. Clearly a small reduction in fuel intensity resulted, but it is almost impossible to apportion this change between higher prices or the "0.85" policy. It is certainly evident that taxation of motor fuels for private transportation had an important impact on restraining both travel and fuel use, as well as reducing fuel intensity. But the motivation for such taxation is ages old—fiscal considerations related to both the balance of payments and raising revenue—so it would be unfair to ascribe the savings Sweden experienced in travel-related energy use to "energy policies" per se.

Technology did provide important energy savings in manufacturing. Sweden also expanded her comprehensive policies promoting energy efficiency in buildings to push energy savings, and this effort has now been extended, saving electricity through *Teknik Upphandling* and *Uppdrag 2000*. At the same time, the Swedish government presented its citizens with increases in the prices of heating fuels without similar increases in prices for household electricity. As a result, the message was mixed. Given the relatively efficient state of Swedish buildings, savings in heating were not as dramatic as in Denmark, W. Germany, or even the U.S. This does not mean that the various energy saving programs for buildings were ineffective or inefficient, only that their overall impact was modest. Unlike Denmark, the largest contribution to total energy savings in Sweden came from improvements in manufacturing, with these driven mainly by higher oil prices. And while the 0.85 program stimulated auto manufacturers and importers to market fuel efficient cars, the results were only a modest decline in real world fuel intensity. For this reason, it is tempting to attribute most of the savings of energy in that country that arose between 1973 and the late 1980s to long-term technological trends and to higher fuel prices, bolstered by certain energy-saving programs.

Energy-saving programs have not faded from Sweden entirely. In particular, there has been a great deal of focus on electricity savings in all major sectors of stationary energy use. These appear to be effective, if the efforts towards improving home appliances (particularly the low-energy refrigerator) or increasing sales of low-energy compact fluorescent bulbs is any indication. *Nordnorm* is likely to lead to adoption of efficiency standards at least for home refrigeration equipment. *Teknik Upphandling* could lead to rapid improvements in many other technologies used in homes or buildings. And *Teknik Upphandling* could lead to technological developments among industries important in Sweden (steel, paper and pulp, and for all industries, heat recovery) that might even be exported to other countries. This means that even with stagnant energy prices, we could expect electricity intensities in industry, homes and the service sector to fall gradually, yielding economic gains to users.

Thus, the efficiency of energy and electricity use in Sweden can be expected to continue to improve, even if at a slower rate than in the 1980s, because of both energy-saving programs and technological progress. This means that the contribution of energy efficiency policies and programs to savings will slowly increase as more homes and buildings are affected by the programs and standards of the 1980s and 1990s.

The key question is how rapidly policies (including energy taxes) can increase that rate of savings. The hidden question is whether individuals and companies are prepared to pay higher energy taxes as part of a package to stimulate the improvement of efficiency. That is, higher prices reinforce the effects of policies.

This is particularly true for transportation. However, the price question appears moot: Road fuel prices in 1993 were almost 33% higher, in real terms, than they were in 1988 (Eriksson 1993). Restraint of CO_2 output in this sector to the 1990 level in the year 2000 means that this price hike must be maintained in real terms, which appears likely given the present fiscal imbalance in the Swedish budget. Thus we expect price driven energy savings in the 1990s in Sweden to be substantial, but the components driven by policy (transportation, buildings) will increase in relative importance.

9.2.4. The Plateau of Energy Intensity

The plateau of energy intensity is evident in both the building sectors and in industry. Part of the reason for this plateau is the stagnation in most energy prices. While there is still a difference in average energy intensities between new homes, new cars, or new machines and older ones, this difference is smaller now than that which was evident from the fall that occurred during the first half of the 1980s.[2] Intensities are falling, but much more slowly than before 1985.

To be sure, "stagnation in energy prices" is somewhat misleading. The real cost of heating is higher today than in 1973, so the marginal cost of keeping homes or buildings to a given temperature is also higher. The improvements in energy utilization in industry, by contrast, appear to have overcome much of the impact of the increase in real fuel prices, particularly after taxes were reduced in 1992. And Swedish drivers in 1988 paid only slightly more for fuel to drive one kilometer than they did in 1973, once the taxes on gasoline were lowered. Significantly, that changed dramatically in the following four years. Indications of a small drop in driving in 1990 and 1991 suggest that a permanent change in the use of motor fuels may be in the wind.

Thus in Sweden the plateau of energy efficiency may be short lived. Higher prices for transportation fuels, pressure to raise electricity prices closer to levels in other countries, and, most recently, the weakened *krona* leading to higher oil prices suggest that Sweden in the early 1990s will feel much more pressure to save energy than will many other countries. Fortunately, there appears to be a significant potential for reducing heating needs in existing buildings, the most long-lived part of the energy-use system. And the potential for great changes in transportation and in the use of electricity in homes and buildings for purposes other than heating is well documented. Perhaps Sweden will "catch up" with many of her competitors in the energy efficiency race in the next few years?

9.3. Conclusion: Sweden is Different

The foregoing comparison has revealed many important characteristics of Sweden's energy use:

1. Sweden has the most energy-intensive structure of any of the OECD European countries we have stu-

[2] The fall in industrial production from 1990 onwards also contributed to this slowdown, as capacity utilization fell, which tends to raise energy intensities.

died.[3]

2. Sweden achieved moderate energy savings, compared both with the savings we measured in other countries and against the depth of Sweden's public energy efficiency efforts and policies.

3. The judgment of the degree and success of Sweden's energy efficiency efforts is clouded, and to a certain extent overstated, by the issue of how to count the hydro power and nuclear power that directly or indirectly substituted for fuel use, principally oil, in buildings, industry, and power generation.

4. Outstanding for Sweden (and Norway) is the one-sided development of prices. Great increases for oil and oil products were not matched by anything more than moderate changes for those for electricity. These low electricity prices were natural, because both nuclear and hydro have been ostensibly cheap electricity sources. Nevertheless, the effect of low electricity prices is clear: the incentive to improve efficiency is weaker than in Denmark, W. Germany, or even the U.S.

5. Energy efficiency policies, which were focused on buildings and then on heating, while in large part successful in their own right, only accounted for a small part of the total energy saved in Sweden as we measure savings. (The Swedish government probably spent more money in subsidies or low-interest loans, per capita, than any other national government with the possible exception of Denmark's. See Schipper 1984a or Schipper, Meyers, and Kelly 1985) Most of the savings between 1973 and 1990 were either caused by long-term technological trends (reinforced somewhat by policies or prices) and by higher energy prices.

6. As *Uppdrag 2000* has pointed out, factors other than changes in energy prices can contribute to changes in energy efficiency. For industry, there are few lasting examples anywhere of major changes in energy use not supported by energy prices, except for those changes caused by long-term technological change. Where non-price factors are crucial, however, is when efficiency standards or procurement (*Teknik Upphandling*) is applied to push technology in the real market closer to levels of efficiency that pay in principle, or when efforts are undertaken to market energy efficiency opportunities.

7. The plateau of energy efficiency that characterizes energy intensities since 1988 is widespread among wealthy countries. Only a concerted effort focusing *both* prices *and* efficiency policies will reignite serious investments in energy savings and exploit those possibilities largely passed over during the 1980s, particularly where electricity is used.

8. With the debate over nuclear power now relatively quiet, a much more fundamental debate about sustainable development has taken much of the attention in the energy and environmental debate. Sweden's recognition of both local environmental problems (SO_2, NO_x, emissions from motor vehicles - including NO_2, water pollution, etc., and global environmental problems like CO_2) has clearly raised interest in energy use, one of the major sources of pollution, and energy efficiency, one of the tools that would restrain use and therefore pollution. Sweden's acceptance of so-called green taxes as part of a broad effort towards dealing with environmental problems is in the vanguard among industrialized nations.

Thus Sweden is poised to realized significant energy savings in the coming years, because: 1) energy costs are likely to rise through internalization and the devaluation of the currency 2) efficiency programs have brought forth new technology for using—and saving—electricity, and 3) concern for environment is forcing even more energy savings as a byproduct of environmental improvement.

9.4. Future Prospects

Immediate concerns in Sweden hover over the current recession. During previous periods of recession (1975-76 and 1980-82), energy intensities in industry normally increase or at least fail to decline at historical rates because capacity utilization falls. Declining output overall reduces industrial energy use. At the same time, energy use for travel and freight often falls with declining travel and freight, while energy use in homes falls as households reduce as many of their variable expenditures as possible. The economy presents a false picture of energy saving.

Presuming Sweden's economic problems are resolved soon, energy efficiency concerns may surface as part of the process of improving economic efficiency. Indeed, the most rapid improvements in efficiency in U.S. manufacturing took place after the great recession of 1981/82 (Schipper, Meyers *et al.* 1992). At this time, several old issues will surface again, issues that must be resolved if Sweden is to confront energy use in the future.

[3] When compared with Norway, the impact on energy use of the lifestyles of Swedes more than outweighs the differences in the structure of Swedish and Norwegian industry.

First, the decades old controversy over nuclear power must be resolved. The earliest plants will face natural retirement early in the next decade (and century). What will fuel electricity production after that? Next, the present energy and electricity saving programs must be carefully evaluated. Which ones clearly promote economic efficiency *and* energy savings? Sweden's sectoral authorities (ministries, *nämnd*, *verk*) can no longer afford to support every effort and subsidize so many small initiatives. Third, Swedish authorities will have to invest to improve their own ability to monitor the relation between economic and personal activity, energy use, and energy efficiency (which we treat in a separate chapter, below). Finally, Swedish authorities and the Swedish people must make important decisions about the non-energy policies, stated or implied, that have held sway over Swedish energy use.

The most obvious policy addresses energy and electricity pricing. Sweden has an intrinsically low-cost electricity system but must import most of its liquid fuels. Pressures to raise electricity prices from the internationalization of electricity markets are counterbalanced by privatization and the potential entry of new producers into the system, with the subsequent competition reducing prices. The outcome is uncertain. Equally as important, oil is seen as an increasingly important source of environmental problems and at the same time revenues. Eventually, however, high taxation could lead to falling demand and diminished revenues. Sweden has probably not passed that point yet, but the limits could be reached soon. Most of these issues are tied not to energy per se but to larger economic issues about the structure of Sweden's economy in the future.

The second important policy relates to transportation. Sweden supports an energy-intensive truck and automobile oriented system through taxes and other policies. Certainly there are also counter-incentives in place that reduce automobile use somewhat. But this tension should be resolved, at least by adopting a neutral stance—removing subsidies—towards company cars and commuting expenses.

Third, the Swedish economy has given rather lavish support, by international standards, to homes and to construction of both public and private buildings. If we include second homes, of which Sweden has more, per capita, than any other country we know, we can say that Sweden has the best indoor standard of living in Europe, and possibly in the world. But every square meter of this space is heated at some time, much of it for most of the year. Shall these volumes continue to grow with economy output, spurred on by policies, or will growth be more restrained as such a high level of per capita space is reached?

And will the mobility of the average Swede, like that of the Dane and the Norwegian and German, continue to rise towards that of the North American? The large volume of the built environment means that Swedes move from one place to another with increasing frequency. And Swedes have more paid vacation than most other citizens in the industrialized world, permitting and even stimulating travel, as do the many holidays and long-weekends during the year. In short, personal mobility in Sweden is still on the rise. And mobility of goods is also rising as well. Both of these trends mean rising energy use.

Finally, let us not forget that Sweden lives very much from exports, both those of raw materials and those from high engineering products. But what is Sweden's real long-run niche in manufacturing, raw materials or engineering? Raw materials are not so labor-intensive, and make sense if other factor inputs (including energy) are cheap because of a country's natural endowment. Engineering products can be capital- and knowledge-intensive, two other resources Sweden commands. But simple, labor-intensive products are not important to Sweden's economy any more. If the economy continues to embrace raw materials for strength, energy use will be considerably higher than if engineering products expand their importance, at least for exports. The fall of the *krona* could favor differentially the engineering products, which have a higher labor content and lower energy content than the raw materials. If this is the case, the energy intensity of Sweden's export-driven industry will fall.

These four basic issues are tied to the long-range reshuffling of priorities that began with the first major tax reforms of 1990. Changes in taxes and tax treatment of mortgages, commuting, company car use, etc., could all affect energy use more than policies related directly to energy use. Changes in energy pricing, whether motivated by restructuring in the power and heat industries or by fiscal and environmental policies, could also profoundly affect energy use. If energy efficiency policies are keyed to these potential changes, following them rather than striking their own course, the impact on Sweden's energy use could be profound: Sweden might well rank among the less energy-intensive countries twenty years hence, yet still be one of the most prosperous.

The other outcome, however, is not unreasonable. If the present endowment of hydro and nuclear power is combined with the ample biomass resources, Sweden might sustain a level of energy-intensive production close to, but not much higher than today's. In this case, a vigorous effort to improve energy efficiency could reduce the overall energy use in the economy, even if the energy-intensive structure were more or less maintained. In fact, the more energy-intensive the structure (i.e., the more square meters are heated, kilometers driven, tonnes produce), the more that individual efforts to improve energy efficiency tend to pay.

This irony leads us to believe that Sweden' s energy future may lie along a course that represents a mixture of diminished importance of energy-intensive production, travel, freight, and heated area (*relative to GDP*), and reduced energy use for a unit of each of these activities. But sketching out such a scenario, or the one implied in the previous paragraph, is the goal of future work.

10. RECOMMENDATIONS: ANALYSIS AND INFORMATION FOR BETTER POLICIES

In this study,[1] we have examined many sets of energy data for Sweden, and confronted at least three sets of "official" energy demand data for industry in the process. We uncovered many key uncertainties that cloud both our analysis and, to a certain extent, our conclusions. In this section we set forth three important recommendations for research and data collection that could rectify some of the problems we encountered.

The first recommendation addresses the need for basic energy data as well as information on the sectors where energy is used. The second recommendation addresses uncertainties over how much energy has been saved by individual energy-saving measures. The third recommendation focuses on the poor understanding we have of how individual lifestyles affect energy use.

10.1. Demand-Side Energy Data

In spite of its rich information, Sweden needs an improved demand-side energy data system. This is particularly true for the transportation sector. Understanding energy use in each sector is not the only important step in providing better information on trends in energy demand. It is important that good information on the characteristics of equipment and activity in each sector is coupled to energy data.

Several major uncertainties we uncovered show why better energy use data is important. The first is the separation of fuel consumption between the residential and service sectors. Fortunately, this is now done quite well by *SCB*, through surveys of each component (*småhus, flerbostadshus, lokaler*). Uncertainties in dividing up fuels between apartment buildings and service sector buildings are small, and even the uncertainty between residential energy uses in farm houses and process energy for farming have been reduced.

Swedish authorities made an important step in this direction with the establishment of *Energistastik* in the mid-1970s. However, some key data are lacking from this data base, data we have found available in similar investigations in other countries. These include:

- Reliable information, ie., details on the kind of equipment and fuel used, on water heating, cooking equipment, and electric appliance ownership from the residential sector;

- An occasional expansion of *Småhusstatistik* to give more detail on farm use of electricity, on use of electric water heaters, and on use of electric cookers;

- Reliable data on electricity consumption in homes and buildings that do not use electricity for heating;

- More detail in the structure of fuel and electricity use in service sector buildings. Even if the massive *STIL* survey cannot be repeated, enough extra information can be gained from slight expansion of the existing surveys to better outline energy use for space heating, water heating, cooking, and a few of the major functions satisfied only by electricity.[2]

A final, and very important task, is to study the relationship between fuel switching and energy use in buildings. How much natural gas or district heating is required in homes or buildings formerly using oil? How do oil, wood, and electricity complement each other? Despite the best data base in the world (*Energistatistik för smähus*), virtually no one besides *PREDECO* has really utilized this information. Results from these surveys are important if authorities are to judge the progress being made towards the heat-saving goals implicit in both the 1978 Bill and subsequent initiatives. While the authoritative *PREDECO* studies have proven suitable for most purposes, there is much more that can be learned about how households use energy. Influencing these households will be important if the kinds of goals expressed in *Uppdrag 2000* are to be carried out for both electrically-heated homes and for homes using other fuels.

An important result of such detailed information will be a clearer view of how energy use changes *after* important policy measures are implemented or conservation actions are taken. For example, energy use in buildings where retrofit subsidies or rehabilitation loans have been granted could be examined to see how much was really saved. Energy use in these buildings could be compared to that in buildings where no such measures were carried out, too. The same information could be used to monitor energy use in recently built homes, particularly *lågenergihus*.

Buildings are not the only sector where energy conservation strategies are being pursued. Present data covering modes of travel or freight are too uncertain to permit judgment of the effectiveness of measures to restrain energy use in these sectors, except after several years have passed. To better understand trends in tran-

[1] The material in this chapter is based on Schipper, Howarth, Andersson, and Price, *Energy Use in Denmark: An International Perspective*, 1992 (LBL-32362).

[2] In the U.S., the Household Survey (*Residential Energy Consumption Survey*, carried out every three years by the Energy Information Administration of the U.S. Department of Energy) asks respondents to give the survey company permission to contact energy suppliers directly to get accurate billing records. The *Commercial Building Energy Consumption Survey* fulfills a similar role for that sector.

sportation, authorities should extend the *Resevanorundersökning (RVU)* to cover more detail on the use of cars and light trucks, and consider monitoring fuel consumption in a subset of households interviewed for *RVU*. Similarly, information gathered from private truckers and trucking companies by *SCB* and other authorities should be extended to reflect distances and fuel use, particularly for gasoline-driven light trucks. The same is true of rail and transit companies, and above all airline companies. In the U.S., these data are either collected directly by the Federal Government or through the major branch associations. In Germany, France, and Holland, the same data are available. By contrast, the transportation data in Denmark, Norway, Canada, and Britain are fraught with uncertainty. In Japan efforts by different ministries are often contradictory, but a generally good picture of the structure of energy use in transportation emerges. Yet many of these data will be vital if authorities are to monitor the ambitious plans for improving air quality in cities by improving motor vehicles. Sweden's information about energy use in transportation must be improved soon.

By contrast, industrial energy use data, as reported to *SCB*, are quite good. Unfortunately, there is little information on energy use and physical production of materials, except that which is produced occasionally by Branch organizations or coughed up in response to government commissions. Given the rising electricity intensity seen in Swedish industry and the clear role of electricity in substituting for oil, it would be useful to understand both the economic and physical nature of this substitution.

10.2. Energy and Lifestyles

Enhanced energy-use information will also shed more light on the link between lifestyles and energy use. Do those Swedes who have low energy use at home use more energy use for transportation? Do Swedes who live in apartments in town centers travel more frequently to summer homes (or Mallorca) than those living in villas in the suburbs? Can we specify better the relationship between energy use for homes and personal transportation and a family's demographic characteristics? These relationships will become more important as household size falls and the average age of the Swedish population increases, two factors that will influence future lifestyles in significant ways. Similarly, car ownership in Sweden is expected to increase somewhat, mostly as more women acquire cars. With this increase will likely come more personal travel. Understanding now how these changes affect energy use will provide useful information for policy makers trying to estimate the impacts of changing Swedish lifestyles on future energy use in Sweden.

10.3. What Other Countries Do about Energy-Use Data

The level and quality of energy use data varies among OECD countries.[3] Detailed energy-use surveys covering major sectors of demand are regularly carried out in the U.S., for the Department of Energy's Energy Information Administration, and in France for the *Agence Francaise pour la Matrise d'Energie*. These surveys include information on equipment characteristics, changes in energy use, and energy conservation measures carried out.

Household energy use is carefully studied by regular surveys in France and the U.S. Partial surveys of energy use in homes (focusing on gas use only) are carried out regularly in Holland. Ad-hoc surveys of household energy use have been out in Japan and Norway. Very little information on actual consumption is available for Canada or Germany. Almost no surveying is carried out in Denmark. Surveys in Britain have been carried out by the electricity and gas industries separately, but there has never been a full survey of both consumption and structural characteristics.

Energy use in the service sector is poorly documented in most countries. Part of the reason is that the service sector, together with the residential sector, form a residual of energy consumption once transportation and industrial fuel and electricity use has been accounted for. Complicating the picture for the service sector is the heterogeneity of the building stock and the uses of energy in service-sector buildings, particularly uses of electricity. Only the U.S. carries out a complete survey of building characteristics, actual fuel use, and conservation activities in the service sector. The *STIL* survey rates as one of the most ambitious, and, in our view, one of the most successful anywhere, but it is unlikely to be repeated. Smaller surveys have been carried out on an ad hoc basis in Japan, Norway, France, and Holland. In some countries (Canada, Germany, Holland) the total area of service sector buildings is not even well known.

Energy use in industry is recorded in almost every country, but few countries carry out detailed surveys that add information on processes, fuel substitution, energy conservation measures. The U.S. and France are important exceptions.

Transportation energy use is also poorly understood in most countries, where rules of thumb have provided some information on both utilization of vehicles

[3] In the course of research over the past dozen years, LBL's International Energy Studies Group has examined energy data from Japan, the U.S., Canada, Holland, France, Norway, Denmark, Italy, West Germany, and, to a lesser extent, Switzerland, Austria, Finland, and Belgium.

and travel behavior as well as fuel efficiency and fuel use. Almost every country undertakes travel behavior surveys, or freight activity surveys, but none of these are combined with energy use surveys as well. Energy and Transportation authorities in France survey almost every mode and gather very good data on vehicle characteristics and use, as well as on energy use. The U.S. asks respondents to its household energy use survey about characteristics of private vehicles, their utilization, and their fuel use. Because of the relationship between transportation and air pollution, we expect that authorities in most countries will strengthen their surveying efforts, in order to monitor the relationship between transportation activity and emissions.

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APPENDIX A: AUTOMOBILE UTILIZATION AND ENERGY USE

During the initial phase of this work, we contacted *Väg- och Trafik- Institutet* (*VTI*), Linköping, (Swahn 1991, 1992a, 1992b; Jönson 1993) to compare estimates of automobile traffic, travel, freight and energy use. Our comparison revealed uncertainties regarding driving distance per car per year, specific fuel use, and total fuel use for cars. We discuss these uncertainties in this appendix.[1]

Automobiles and Energy Use: The Vicious Circle

In theory, the basic description of automobile use and fuel consumption is simple: total annual fuel use equals number of automobiles times average vehicle kilometers driven times average intensity. With knowledge about average vehicle occupancy, you can also easily calculate total person-kilometer travelled. However, in practice it has shown to be a complex question (Schipper *et al.* 1992). Transport energy statistics are generally poor and Sweden is no exception. Only two (not fully comparable) national travel surveys have been carried out during the last two decades (*RVU* 1978, 1984/85). One of these relied on surveys that focus on special segments of the market, often produced with other primary purposes.

Following the energy crisis in 1973/74, more interest was paid to the transportation sector's energy use. In 1976, *Transportnämnden* at *Staten Vägverk* (Swedish Highway Administration) published an analysis meant to be a starting point for future work in the field (Sjöberg and Almquist 1976). However, not until the 1980s was work of this kind institutionalized. *Transportrådet* (*TPR*, The Swedish Board of Transport)—given the responsibility for traffic forecasting and preparedness for transportation security in case of an energy crisis—analyzed and described the situation. They also presented a consistent description of relevant factors. However, the methods used and background statistics were never fully documented in writing. When *TPR* was phased out of existence, the Swedish government delegated the responsibility for traffic forecasting to *VTI*. *VTI*'s first reported forecast was prepared in draft in 1992 (Swahn 1992b).

The *TPR* estimate of intensity was questioned. For instance, for the *TFB* (The Swedish Transportation Research Board) project "A Transportation System Adapted to the Environment" (Eriksson and Hesselborn 1990), *TPR* reported an average intensity at 1.03 l/10 km (Wajsman 1989), while *VTI* reported an intensity of 0.9 l/10 km (Hammarström 1990). In contrast to *TPR*, (Wajsman 1989; Eriksson 1991) *VTI* based their estimate on a bottom-up approach. On the basis of knowledge about single vehicles' performance, they did a theoretical calculation of fuel use. But the *VTI* work is not fully documented, and does not cover the entire period. With these problems in mind, we review the key factors.

Number of Vehicles

VTI used number of vehicles in use (registered and taxed) on the first day of each year according to the national vehicle register, published by *SCB*. On the other hand, *TPR* used "number of autos used during the year". In other words, *TPR* included all newly registered, de-registered, and scrapped cars that had been driving during the year, but *VTI* did not. ("De-registered" (*avställda*) cars includes those used only in the summer, for example.) From 1972 to 1989 the *VTI* estimate of the number of cars typically is about 5% lower than *TPR*'s. The difference for 1983 is only 1% while it was as much as 8% in 1986. Definition of number of vehicles is not a determining factor per se, but to make the total picture correct it has to be consistent with definitions of other factors.

Total Driving Distance

The first uncertainty involves traffic, or the total distance driven by private cars. There are several ways of measuring this traffic. The first method uses traffic counts, based on the number of vehicles passing a number of checkpoints around the country. Wall's (1990) review explains with some skepticism how authorities use various factors to convert the counts (registered as axle pairs) into vehicles, thence into car traffic, and then into car traffic for all of Sweden. It is not clear that this procedure is either accurate at any point in time, or over time, as Wall pointed out privately. Particularly unsatisfactory is the implicit assumption in many analyses that traffic on the main intercity roads (*riksnätet*) is a good indicator of total traffic. Similarly, authorities often use changes in gasoline sales from year to year to "calibrate" changes in traffic. But this method relies on assumptions about changes in figures of specific fuel use (liters/km) as well as the share of gasoline for cars vs. other vehicles, particularly light trucks. Since both specific fuel consumption of cars *and* the numbers of light trucks (and likely their own use and specific consumption) are changing, gasoline sales only provide a zero-order approximation to changes in automobile traffic. Unfortunately, the effects we are searching for in this work are both first-order (driving distance, fuel intensity) and second-order (changes in these quantities).

[1] This section was written by Lee Schipper and Gunnar Eriksson, *Nordplan*, on leave to LBL.

An alternative exists, namely, the use of *RVU* (1984/85) to estimate total driving. This is done by tabulating distance travelled as driver. *RVU* gives several alternative modes of travel, including "car as driver", so this method appears to reasonably separate cars, motor cycles, and other vehicles, although Thulin (1993) points out that there is probably some light truck traffic including in the *RVU* figures, and Wajsman (1993), who studied *RVU* 1984/85, feels that driving of other vehicles may also be included. Thulin uses the *RVU* figure of 51.9 bn "automobile" vehicle-km in 1984/5 as a starting point, to which he adds 0.6 bn veh-km for foreign cars driven in Sweden, but suggests an additional downward adjustment of 0.5 - 0.8 bn veh-km/year for light trucks counted as private cars in the *RVU* response.

Annual Driving Distance

As another alternative, consider in greater detail the bottom-up surveys of driving distance by car. There are various sources of this information—*SIND* 1977, *Konsumentverkets (KOV)* (The National Swedish Board for Consumer Policies) surveys, *Bilunderhåll och Reparationer*, and other data sources (Borgstrand 1974; Borgstrand 1979). These indicate that private cars (i.e., not company cars) were driven distances of roughly 14 000 - 15 000 km/year, values which declined somewhat after the first and second oil shocks. If these figures are multiplied by the number of cars in traffic, the result gives total distance driven. (If the substantial number of cars used only during part of the year were included in these averages, the distance per car would fall.)

KOVs calculations of annual driving distance are based on respondents' answers to the question: "Approximately, how many kilometers is the vehicle driven per year?" They answer by marking one of eleven distance intervals. The surveys cover private owners of automobiles from the last 16 model years, registered as in use at a certain date during spring of each year. At first sight, the survey population is comparable with *VTI*'s definition of number of vehicles, as summer automobiles and some other seasonal vehicles are presumably not included. *KOV* and *VTI* feel that the reliability of these answers is high, and we agree. And *KOV*, unlike *AB Svensk Bilprovning*, does include cars less than two years old. If some adjustment is made for cars less than one year old to obtain a yearly driving distance, then *KOV* could cover the right population of private cars. This means that we can multiply the number of private cars by the distance private cars are driven to get total driving *for that population*.

Unfortunately, the *number* of cars used in this calculation may not be correct, given the nature of the population surveyed by *KOV* or *AB Bilprovning*. *KOV* does not take into account that vehicles older than 16 years are excluded from this survey—cars known to have comparatively low driving distances. If those cars' share of total stock is very low, this would not be a problem. However, statistics for January 1, 1990, show that the share of vehicles older than the 1975 model year was as large as 11.4% and as much as 5.4% of the automobiles belonged to model year 1971 and earlier (*Bilindustriföreningen-AB Bilstatistik* 1990). If we assume an average driving distance for those older automobiles of 5 000 to 7 000 km—everything else being equal— this method seems to overestimate average distance by 6 to 8% for 1990. If older data from the *KOV* survey are used, this problem seems to be less important. In 1979 the share of older automobiles was only 3.9%, corresponding to an overestimation of 1.5 to 2.5% (*Bilindustriföreningen-AB Bilstatistik* 1979). Finally, we cannot control for the inclusion of "part time cars". It is important to take the entire structure of the automobile fleet into account when using the *KOV* survey, both for point estimates of average distance, and also for estimating time series. The same is true for using Borgstrand's data, based on car inspections. The inspections do not apply to cars less than two years old, and thereby miss most of the company cars (which are usually less than three years old) as well as new private cars, which are almost always driven significantly farther than older cars.

Nevertheless, the results for total automobile traffic from the bottom-up estimate agree well with those estimates provided regularly by *TPR* for the 1980-1989 period for total traffic and, with a slight correction, with those adopted by Rickard Wall, who studied company car usage (Wall, 1990). Wall uses a slightly higher figure for total traffic, derived from traffic counts. He also estimates the yearly distance driven by both private cars and company cars, which are driven farther than privately-owned cars.

In *VTI*'s forecast, a substantially higher average driving distance was reported compared to *TPR*'s previous estimates. As mentioned above, *VTI* based their figures for private cars on a special analysis of *KOV*'s recurrent survey *Bilunderhåll* to determine the driving of private cars. They calculated the total traffic estimates from their extrapolations of *RVU*. They thoughtfully reduced this figure by a small amount of traffic by individuals in "private" light trucks, which they estimate at 0.5-0.8 bn vehicle-km.[2] They then use the yearly driving distances reported by *KOV*, multiplied by the number of private gasoline cars in traffic, to obtain the component of traffic for private cars. After subtracting a reasonable figure for diesel cars, they attribute the residual distance

[2] This is consistent with 60-70 000 private light trucks driven about 11 000 km/year.

driven to company cars. This works out to around 30 000 km/year, a figure that strikes us as very high. If the average distance for private cars used in the *VTI* calculation is somewhat too high (as we suggested above), then the average distance driven by company cars must be even higher in order to account for total traffic as indicated by *RVU*. If the multiplication of private cars in traffic times the *KOV* driving distance underestimates private vehicle use by ignoring the cars driven for only part of the year, (and not counted in "cars in traffic", which is based on a single point in time), then they overestimate the residual applied to company cars, although the *total* traffic figure they use for gasoline-powered vehicles remains the same.

How far are company cars driven? While true work vehicles (those for travelling salespeople, etc.) are often driven enormous distances, it is hard to believe that the entire fleet of company cars (16% of all cars) follows these patterns, which double the distance a car is driven. Recall that most of these cars are provided to employees in lieu of income, not necessarily as service vehicles. In the UK, for example, company cars are driven only about 25% more than non-company cars (Hughes 1992). In Norway, they are driven about 15% more (TØI 1992). In this respect, we find the estimates Wall made (approximately 10% greater driving distance for company cars) more credible. Wall uses a somewhat higher number of cars ("*verkligt antal*", "actual number", a quantity that includes some of the cars not registered for the entire year), and together with the traffic counts of *Statens Vägverk*, obtains a yearly driving distance slightly higher than ours.

What is particularly troubling about this high level of total traffic is that we find no reference to the much larger company-car distances in the large body of transportation and energy literature we have reviewed. Surely a level of traffic this high would have been confronted by one or more of these studies. That is, the problem as we see it is *not* one of estimating company car use per se but of total traffic.

When these three methods are compared, the results leave a significant gap. The traditional bottom-up estimates and the traffic counts we relied upon, as well as Wall's own estimates, give figures about 10% lower than those obtained from *RVU* for 1984. *RVU* measures the driving of people, not cars: these two measures should match, but, as noted above, people drive vehicles other than cars. However, if any difference between these two measures is roughly constant over time, then the *changes* in activity by either measure are consistent, because *VTI* 'updates' the *RVU* figures for succeeding years using essentially the same growth rates as our sources do. This means the *differences* in total driving are roughly constant for every year.

We suspect *VTI* overestimates average distance driven, especially during the last years, because of uncertainties in the interpretation of *RVU* (1984/85) and subsequent extrapolations. Ideally, several methods should be used to provide yearly figures on the use of automobiles in Sweden. It would be useful to make a full comparison of all the estimates of traffic and car use we have encountered, both published and unpublished.

Specific Fuel Consumption

Bilunderhåll, quoted by *VTI*, suggests that average intensity for private cars in Sweden is 9.53 l/100 km in 1987 and 9.12 in 1991. These figures are not inconsistent with the test figures for new cars sold since 1978, which are known to agree quite well with figures from actual traffic. *KOV* claims that respondents' answers are reliable because a majority of them state that their answers are based on actual calculations of fuel use and mileage driven. Lack of data about old cars is less important from this point of view. Driving distances for old automobiles are low and therefore have a limited influence on average intensity. It could mean about 0.1 l/100 km in 1990.

However, the specific consumption of company cars is likely to be significantly higher than that of private cars for three reasons. First, this study found that the average company car in the *fleet* is 20% more powerful and 13% heavier than the average private car in the fleet. Second, company car rules permit the beneficiary to select extra equipment on a base model without affecting his/her taxation, which often means turbo charging or other features that increase fuel consumption even more. Finally, company cars privileges usually include free fuel, which means that drivers need not pay attention to how carefully they drive. We estimate these conditions mean that company cars require 15% more fuel/km than private cars. If they are driven 30 000 km, as *VTI* suggests, than the "average" consumption for the stock should be

$$P * 9.12 * 13750\text{km/year} + C * 10.7 * 30000\text{km/year } 9.51\text{l}/100\text{km}.$$

where P and Q are the shares of private and company cars in the stock, 84% and 16% respectively. If the company car distance is 20 000 km/year (a figure we would favor), the average falls slightly, to 9.4 l/100 km. For 1983, the *KOV* figure of 9.69 l/100 km becomes 10.12 l/100km using 30 000 km/year for company cars; for 1987, the *KOV* intensity of 9.53 l/100 km becomes 9.95 l/100km. Clearly, our figure for the fuel intensity of the entire fleet depends on our assumptions about the characteristics and number of company cars. Since the share of company cars in the stock has not varied greatly, and their size and power have exceeded those of private cars by roughly constant amounts, this means that the relative *changes* in the fuel intensity of the stock do not vary among the sets of estimates, only the absolute level.

Total Gasoline Use For Automobiles

Total gasoline use consists of several components. The largest (over 90%) is for automobiles. The next largest is for light trucks. Much less is used for busses, snowmobiles, lawn motors, boats, and other miscellaneous vehicles. Our estimates of use for light trucks, following Wajsman, is about 16 PJ/year in the late 1980s. The calculation of total gasoline use for automobiles, given *VTI* data, suggests that during 1987-1991 automobiles consumed 95% to 93% of total gasoline. *TPR* estimated the corresponding share to be between 87% to 88% during the 1980s. In working papers, *TPR* also claimed that the bulk of the rest, about 10% in 1989, was used by light trucks. Given the rise in the importance (and number) of gasoline-fueled light trucks and vans, the *TPR* estimate is not implausible, while that from *VTI* implies either very efficient vans and light trucks or unusually low yearly use.

VTI suggests fuel use by light trucks is two-thirds of that estimated by *TPR*, both because *VTI* assume lower driving distances for light trucks and because they assume only 15 L/100 km. The lower driving distance is based on a 1991 survey, and seems reasonable. The specific fuel consumption, on the other hand, strikes us as far too low, given the tax incentives that encourage purchasing vans weighing over 3000 kg and the key role of light trucks as delivery vehicles facing city traffic. That is, these business vehicles are not driven by those who are responsible for fuel consumption.[3] Using the lower driving distance but the higher intensity yields gasoline consumption for light trucks of about 475 tn cubic meters of fuel, or 15 PJ in 1990, slightly less than our original estimate. This leaves about 4975 tn cubic meters or 154 PJ for private automobiles. Since our original estimate was 152 PJ, this change implies a small upward adjustment in either automobile fuel intensity (which we would reject, based on *VTI*'s reasonable contention that our original estimates were somewhat too high, or that our driving distance must be increased by 2%, consistent with Wall's estimates.

Conclusions: Uncertainty

Comparing our approach with that of *VTI*'s reveals both similarities and differences. We use the same *number* of gasoline cars as *VTI*. But *VTI*'s total gasoline consumption for automobiles is about 10% higher than ours and *VTI*'s total traffic is almost 15% higher than ours (taken from Wajsman 1989 and Eriksson 1991), which means that *VTI* has a 5% lower fuel intensity than we do. Unfortunately, the *VTI* calculations are only available for a few recent years. *VTI* used the 1984/85 *RVU* to obtain a figure for total distance driven, which is obtainable directly from the survey, but figures from the 1978 *RVU* are not available.

It is the company cars where the greatest uncertainty lies, preventing us from making a bottom-up determination of total distance driven. Starting from the *RVU* distance driven, with small adjustments for diesel cars and light trucks, *VTI* finds a higher level of traffic and thereby a significantly higher average driving distance per car that we do. This leads to a lower specific fuel consumption for gasoline-fueled cars.

If the *VTI* assumptions are correct, then the fuel intensity of the Swedish fleet is somewhat lower than we have estimated. However, both their specific consumption and ours decline at the same slow rate in the late 1980s. Thus, the changes *VTI* estimates are the same as those we estimate. But the *VTI* figures would also imply that total gasoline consumption for automobiles was about 8% higher in 1989 than Wajsman from *TPR* calculated. The problem is that this extra gasoline consumption must be taken from gasoline-driven light trucks, a substantial consumer of gasoline. By Wajsman's estimate, these used 540 000 cubic meters of gasoline in 1989. To make the *VTI* gasoline consumption for cars work out, the consumption of light trucks must be halved. An alternative, and tempting compromise, is to assume that the light trucks actually provide travel for individuals that is recorded as such by *RVU* (1984/85), which leads *VTI* to find more traffic.

Finally, *VTI* presents some evidence (noted in the text) that the load factor in cars in Sweden has fallen considerably, from near 1.9 in the early 1970s to below 1.6 in 1990. This is not inconsistent with experience in other countries. If this finding is correct, then the growth in passenger travel in cars is slower than we (and *TPR*) estimate, unless *VTI* figures ultimately show a more rapid growth in automobile traffic. If that were true, then the growth in passenger kilometers in automobiles in Sweden may have grown as we stated, while vehicle-km grew even faster. However, Wajsman (1993) points out that *RVU* excludes children and older people from its estimates of travel, from which load factor can be determined. This would raise values somewhat,

[3] Rutger Friberg, Volvo, Gothenburg, made these important points in a private communication, (Friberg 1993). According to the same survey, 68 000 of these vehicles are for personal use, but we expect almost all are large vans.

perhaps for the entire period. The *VTI* proposal is not implausible, but until we can obtain a complete picture, we cannot manipulate our figures for travel.

The implications of the *VTI* findings for our work are uncertain. If the rate of decline of automobile fuel intensity is similar in each calculation, and the rate of increase in traffic is the same, then there is essentially no difference in our conclusions about energy savings. But if the *VTI* parameters behave differently (for example, fuel intensity declines more rapidly in their model than in ours, while distance/car increases more rapidly as well) then they will measure a greater *saving* of fuel than we. Similarly, if the rate of growth of passenger-km in cars is lower than we assumed, then the changes in shares of travel between cars and other modes will be quite different, more heavily weighted towards collective modes. But the same decline in the load factor means that the modal intensity of automobile travel, in energy/passenger-km, may not have declined at all, in which case the overall energy savings in Swedish travel could be nullified.

Confusing? We think so. In the end, the problem revolves around the estimate of *total* distance driven, since this is what must be compared with total fuel use, which is related to fuel intensity. Unfortunately, we cannot resolve these discrepancies at this time in a way that provides a complete picture of the 1970s and 1980s. The problem is quite simply that the fuel use per kilometer and total kilometers driven are more or less circularly determined. *VTI* have chosen a higher level of kilometers and lower level of fuel use/kilometer than we have. Our re-analysis suggests that the "truth" is somewhere in between, i.e., that the correct fuel intensity for gasoline cars was about 9.5 l/100 km in the late 1980s. If *VTI*'s average driving distance for gasoline-powered cars is reduced by 8%, total gasoline use for automobiles approximately equals the *TPR* level for the end of the 1980s. After adjustment for the slightly lower use of gasoline by light trucks, the two calculations are reconciled. But there still remains differences in fuel intensity and driving distances of vehicles. Since we cannot yet extrapolate back *VTI*'s interesting approach to 1970, we cannot adjust all of the figures in our study. The vicious circle has not yet been closed! However, it appears that the differences in the absolute level of fuel intensity in 1973 and 1990 would be small were we to recalibrate the entire period using their assumptions. This recalibration would increase the small savings we have found for energy use for travel, but not affect the overall results of our study very much. Therefore, we leave the matter unresolved, pending further study by various authorities, and, we hope, ourselves.

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APPENDIX B: SUMMARY OF DATA USED IN THIS REPORT

We attach as a statistical appendix a summary of the data used in this study, Table B-1. Most figures were derived in this work from official data sources; a few were used with no further processing. The analyses of developments in each sector in the text explain our main assumptions. Readers are referred to the Chapters or Appendices for detailed references.

The units are petajoules (10^{15} joules) and other multiplies of the joule.

Many details for 1974 are omitted because of the influence of the first Oil Embargo and resulting distortions from stockage and hoarding.

B.1. Summary Energy Balance

This section presents an overview of the production and conversion of energy carriers in Sweden, as shown on the first two pages of Table B-1. All data are based on statistics provided by *Statistiska Centralbyrån* (*SCB*).

The first category, "Gross Energy Use", provides information on the total use of energy, including conversion and distribution losses. "Gross energy" use is equal to the sum of domestic production and net imports of energy products. Data for 1971 and 1972 are missing. Energy from hydro and nuclear power are included under "primary electricity" counted at their theoretical thermal equivalent, at variance with Swedish practices but consistent with OECD practice.

"Net Use of Oil in Refineries" accounts for the energy used to produce refined petroleum products. "Non-Energy Use of Oil" measures the use of oil products as construction materials, chemical feedstocks, and related items.

The next items give the net use of energy in four types of energy conversion facilities—central heat and power stations, gasworks, district heat plants, and "private producers" (e.g., industrial facilities that produce by-product heat and power). Negative values indicate negative consumption or positive net production of a given energy carrier. The losses from each stage are shown as "Net losses".

"Net Distribution Losses" represent the quantities of energy lost in the transfer of energy from the point of conversion to the point of end use. The "Efficiency Coefficients" give the total amount of primary energy required to provide one unit of district heat or electricity to end users. The difference between "primary" and "delivered" coefficients reflects the difference between *production* efficiency (i.e., at the powerplant) and the overall efficiency, counting transmission and distribution losses with generation losses.

"Final Energy Use" is the amount of energy at the point of end use, and is equal to gross energy use minus non-energy uses and conversion and distribution losses. This category is taken from *SCB*. "Apparent total losses" is the difference between "gross" and "final" energy use, with "unaccounted" the losses we have not explicitly observed or calculated.

The final category ("Difference, Balances - LBL") gives the statistical difference between the levels of final energy use calculated by adding up final demand across sectors and the "gross energy minus losses" approach. The large residuals for solids reflects our inclusion of wood in the residential and industrial sector not counted by *SCB* before 1983. The residual of oil reflects our exclusion of international air bunkers and some other residual oil use in transportation. As can be seen, the overall residual is small, particularly if we exclude residential wood use.

B.2. End-Use Summary Indicators

This section presents an overview of the structure of energy use and energy-using activities across end-use sectors. Included is information on total energy use, Gross Domestic Product, and population. The figures for primary energy use are calculated by multiplying the use of district heat and electricity by factors of 1.15 and 3.24 to approximate upstream conversion and distribution losses in a manner comparable with other OECD nations.

The section reports figures on actual energy use as well as the so-called "Activity/Structure" and "Intensity" effects. The activity/structure indicators shows the evolution of total energy use that would have occurred if energy intensities in each sector had remained fixed at their 1973 values while energy services followed their actual path. The intensity indicator holds energy services constant at the 1973 levels while energy intensities follow their historical development.

B.3. Residential Sector

The data we used follow closely, but not exactly, those provided by *NUTEK*. Chapter 2 explains how the end-use estimates were derived. "Population" is from *SCB*, a mid-year average. Dwellings and the numbers heated by different fuels are taken from *PREDECO*. "Fuel heated" includes oil, gas, coal, and various renewable solid fuels. Floor area for homes area), is taken from *PREDECO* from 1970 onward. Our degree day figures are derived from those provided by *PREDECO*.

Energy use for space heating (and total residential energy use) is corrected for climate variations. The space heat indicators are energy (delivered, useful, or primary using the LBL convention) divided by both floor area and yearly degree days. For electricity, actual consumption for space heat is divided by the entire area of the dwelling stock. Similar conventions are used for hot water and cooking.

The ownership of appliances are taken from the various references cited in the text. Unit consumption refers to stock averages. Figures for refrigerators and combis (combined refrigerator-freezers) are added, and unit consumption averaged.

The various effects (activity, structure, intensity) are calculated as explained in the text.

B.4. Service Sector

This section gives data on service-sector energy use and economic activity (real value-added). Chapter 3 describes how the energy consumption data were separated from those for the residential sector. No correction for climate is made.

B.4. Manufacturing Sector

This section gives energy use and economic activity (real value-added) in six subsectors: paper and pulp, chemicals, nonmetallic minerals, ferrous metals, nonferrous metals, and "other". All statistics are from *SCB* or *NUTEK*, as referred to in Chapter 4.

B.5. Other Industry

This section gives summary information on energy use and real value-added in the agriculture, fishing, mineral extraction, and construction industries. All data are from *SCB*, with approximations and interpolations as we explained in Chapter 4.

B.6. Travel

Energy use for travel by mode is derived from several references and this work. These are used to calculate the intensities (MJ/PKM) from the activity levels of each mode, data for which come from *Transporträdet*. Stocks of cars (and light trucks) and vehicle-km of car (and light truck) travel come from *SCB*, as modified in this work. The total stock of cars and light trucks was divided by population to calculate the indicator shown.

B.7. Freight

Energy use for freight by mode is from references in the text, as modified by this study. These are used to calculate the intensities (MJ/PKM) from the activity levels provided by *Transporträdet* and *SCB*. Some uncertainties arise over the use of gasoline in light trucks.

Table B-1

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
SUMMARY OF ENERGY SECTOR																						
GROSS ENERGY USE (PJ)																						
Oil	1271			1210	1098	1077	1211	1170	1105	1139	1031	931	850	766	719	758	771	722	706	671	649	
Gas	0			0	0	0	0	0	0	0	0	0	0	0	0	3	8	11	14	19	24	
Solids	232			198	212	217	209	185	198	213	204	195	197	238	272	297	351	358	350	340	342	
District Heat				0	0	0	0	0	0	0	0	0	0	0	6	11	18	21	24	23	24	
Primary Electricity	166			281	276	378	409	434	497	493	525	653	666	727	831	903	974	1013	1005	1031	1022	
Total	1669			1689	1586	1673	1829	1789	1801	1845	1760	1779	1713	1730	1828	1972	2123	2125	2099	2084	2060	
BUNKERING	50			47.9	51.0	46.7	53.3	47.1	46.2	37.0	35.9	27.2	23.4	23.4	22.1	23.7	27.4	33.6	28.1	28.7	28.5	
NET OIL USE IN REFINERIES (PJ)	337			460	449	484	615	629	662	687	749	592	559	622	614	592	651	676	651	726	741	
Net Losses of Oil & Products	114			102.8	99.8	91.2	114.3	110.4	101.9	98.3	142.2	24.1	74.4	48.4	52.6	58.3	74.4	62.9	68.4	64.9	61.4	
NON-ENERGY USE OF OIL (PJ)	33			38.5	42.0	30.8	43.5	32.7	34.9	39.2	33.4	30.3	32.9	62.2	53.3	48.4	58.8	50.0	56.8	51.2	65.6	
CENTRAL HEAT & POWER (PJ)																						
Oil	172.0	110.7	124.8	118.5	109.6	67.8	106.2	109.5	57.9	72.9		76.1	21.9	11.4	5.6	16.1	14.4	12.0	6.0	6.6	4.7	
Gas	0.5	0.5	0.6	1.5	1.4	1.1	0.9	0.5	0.4	0.3		0.0	0.4	2.0	2.9	3.0	3.6	2.8	3.1	4.2	5.2	
Solids	1.6	0.5	1.7	3.0	3.3	1.8	2.0	1.4	1.7	0.6		3.4	3.9	6.8	13.4	16.9	17.5	18.2	18.6	15.1	14.5	
District Heat				0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Electricity	177.1	223.5	245.0	278.7	266.6	378.0	401.6	441.0	501.2	481.3		664.9	657.0	711.9	832.4	912.2	993.8	1030.3	1017.7	1034.0	1031.1	
Total	351.2			401.6	380.9	448.7	510.7	552.4	561.2	555.1		744.4	683.3	732.2	854.2	948.2	1029.3	1063.3	1045.4	1059.8	1055.5	
Net Losses	117.2			131.5	117.1	178.1	202.7	246.6	241.9	220.0		398.7	331.1	352.1	446.8	498.7	582.9	593.3	576.7	586.1	588.6	
GASWORKS (PJ)																						
Oil				3.7	3.8	2.9	3.9	3.6	3.4	3.3		2.7	2.4	2.2	1.9	1.5	1.4	1.3	1.1	1.1	1.1	
Gas				1.0	1.0	1.0	1.1	1.2	1.1	1.2		1.2	1.1	1.0	1.3	1.3	0.9	0.9	0.8	0.7	0.6	
Solids				0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	
District Heat				0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	
Electricity				0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	
Total	0			4.7	4.7	4.0	5.0	4.7	4.5	4.5		3.8	0.0	3.2	0.0	0.0	0.0	2.2	1.9	1.8	1.8	
Net Losses				-2.3	-1.9	-3.2	-3.3	-2.8	-3.0	-3.1		-3.2	-6.5	-3.0	-6.4	-9.6	-13.1	-12.5	-13.9	-16.2	-18.4	
DISTRICT HEAT PLANTS (PJ)																						
Oil	51.3	55.9	61.2	66.7	66.8	75.0	92.7	96.9	103.4	107.8	108.2	103.8	93.5	66.0	46.8	62.4	48.3	41.3	24.3	17.2	12.3	
Gas	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.8	1.2	1.0	1.0	1.6	2.3	6.2	2.6	3.4	4.2	6.4	9.2	11.3	
Solids	0.0	0.0	1.6	4.3	4.9	7.6	8.8	9.8	10.3	12.0	11.9	11.1	18.2	33.2	48.0	64.4	73.4	77.1	72.0	62.5	63.6	
District Heat				0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0	6.5	11.1	18.5	21.0	23.5	23.2	23.7	
Electricity				0.0	0.1	0.1	0.1	0.1	0.1	0.1			5.5	15.3	19.2	13.1	6.3	13.0	17.6	18.7	22.4	
Total	51.3			71.0	71.8	82.8	101.6	106.8	114.7	121.2	121.1	116.0	118.7	116.8	126.7	153.7	149.9	156.6	143.9	130.9	133.4	
Net Losses	-1.0			2.3	-0.7	-1.3	15.5	17.1	17.7	18.3	15.9	7.0	9.4	5.0	9.3	7.9	8.0	2.5	2.2	-1.3	-0.8	
PRIVATE PRODUCERS																						
Oil																						
Gas																						
Solids																						
District Heat																						
Electricity	11.0			10.0						11.0	11.0								8.0	7.0	7.0	
Total	11.0			10.0	0.0	0.0	0.0	0.0	0.0	11.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	7.0	7.0	
Net Losses																						
NET DISTRIBUTION LOSSES (PJ)																						
Oil				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Gas				1.6	3.0	4.3	5.7	4.1	3.2	4.5	4.1	3.2	3.1	1.8	1.9	2.0	2.3	1.9	2.0	2.4	2.8	
Solids				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
District Heat	4.2	4.5	4.2	5.3	6.0	6.8	8.5	8.2	8.7	8.6	9.1	9.4	9.6	9.6	10.3	13.2	12.2	13.4	12.4	12.1	11.7	
Electricity	29.0			27.6	23.8	27.1	30.0	25.2	29.5	30.3	29.6	30.5	30.6	35.1	37.8	40.1	38.3	40.8	40.7	43.5	38.6	
Total	33.2			34.5	32.8	38.2	44.2	37.5	41.4	43.4	42.8	43.1	43.3	46.5	50.0	55.3	52.8	56.1	55.1	58.0	53.1	

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
EFFICIENCY COEFFICIENTS																						
District Heat																						
Gross Eff. (Prod./Fuel Used)	0.92			0.92	0.92	0.92	0.90	0.91	0.91	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	
Net Eff. (DH Cons/Fuel Used)	0.94			0.89	0.93	0.93	0.76	0.76	0.77	0.78	0.79	0.86	0.84	0.87	0.85	0.86	0.87	0.90	0.90	0.92	0.92	
Electricity Delivered	0.88			0.90	0.91	0.90	0.90	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.92	
Electricity Primary	0.58			0.60	0.63	0.54	0.54	0.51	0.52	0.55	0.41	0.42	0.47	0.47	0.43	0.43	0.40	0.40	0.41	0.41	0.41	
FINAL ENERGY USE (PJ)																						
Oil	901			876	772	806	847	813	800	815	747	691	623	573	557	569	572	553	548	529	503	
Gas	8			7.0	6.6	7.2	8.3	7.5	7.5	7.6	7.4	7.0	6.5	6.2	6.4	9.6	13.1	14.7	15.9	18.0	20.2	
Solids	212			169	177	182	171	154	166	174	167	159	154	218	233	240	236	241	237	241	238	
District Heat	48			63	67	77	78	82	88	94	96	100	100	102	107	133	130	141	129	120	123	
Electricity	205			243	240	244	278	281	290	305	307	315	322	345	370	409	408	429	428	430	428	
Total	1374			1357	1262	1316	1381	1337	1352	1395	1325	1272	1204	1245	1273	1360	1359	1378	1359	1338	1312	
Apparent Total Losses	295			331	324	356	448	452	449	450	436	507	509	485	555	612	764	747	741	746	748	
Losses Unaccounted For Herein	111.5			129.1	133.9	112.4	161.0	137.9	134.0	150.8		37.8	108.1	27.7	11.6	18.9	82.1	60.2	65.8	67.0	59.3	
BALANCES- LBL	146			163	175	141	186	151	148	169	377	58	125	82	49	50	120	95	107	103	107	
Oil	41			25	4	37	36	37	29	52	29	31	24	26	26	43	62	32	47	35	24	58%
Gas	2			3	3	4	1	2	1	0	0	0	0	0	0	1	1	1	1	1	1	433%
Solids	-5			-34	-38	-35	-36	-34	-35	-44	-47	-44	-47	-11	-9	-17	-14	-10	-23	-21	-23	129%
District Heat	-1			5	10	13	0	-2	-2	0	-2	-2	-3	-2	-2	-4	-4	-2	-3	-2	-2	210%
Electricity	9			4	0	-5	11	9	8	9	5	6	2	4	-1	1	-4	-2	-7	-5	-8	183%
Total	45			3	-21	13	11	12	1	18	-15	-9	-23	18	15	23	42	19	15	7	-8	98%
Share of Total	3.3%			0.2%	-1.6%	1.0%	0.8%	0.9%	0.1%	1.3%	-1.1%	-0.7%	-2.0%	1.4%	1.2%	1.7%	3.1%	1.4%	1.1%	0.6%	-0.6%	
-- ex res wood to 1982	25			-16	-18	-19	-18	-14	-13	-16	-15	-10	-9	30	36	35	33	33	19	23	21	-110%
Differene ex res wood to 1982	70.6			-12.4	-38.4	-5.7	-7.1	-1.5	-11.4	2.0	-29.4	-18.1	-32.9	48.1	50.6	58.4	74.2	52.1	34.6	30.2	13.1	-12%
GENERAL INDICATORS																						
POPULATION (10e6)	8.04	8.07	8.09	8.13	8.17	8.19	8.22	8.25	8.28	8.29	8.31	8.32	8.33	8.33	8.34	8.35	8.37	8.40	8.44	8.49	8.56	104%
Dwellings, (10e6)	3.04	3.11	3.16	3.21	3.26	3.32	3.37	3.40	3.43	3.46	3.50	3.52	3.54	3.56	3.59	3.62	3.61	3.61	3.63	3.66	3.70	114%
Single Family Dwelling, %	41.4%	41.6%	41.8%	42.3%	42.9%	43.5%	43.9%	44.4%	44.9%	45.5%	46.0%	46.5%	47.0%	47.4%	47.7%	47.9%	48.2%	48.3%	48.5%	48.7%	48.8%	
Central Heating, %	91.4%	92.4%	93.0%	93.5%	0.0%	95.2%	95.8%	96.9%	96.9%	97.1%	97.5%	98.4%	98.5%	98.6%	98.6%	98.6%	98.9%	99.1%	99.2%	99.2%	99.3%	
Dwelling Area, m2 TOTAL area	93.7	94.8	95.9	97.5	98.3	99.1	100.7	101.6	102.4	103.5	104.3	105.1	106.1	107.4	108.3	108.9	109.4	109.3	109.9	110.5	110.3	113%
Privat.Cons.Expen/Cap	3958	3928	4093	4228	4341	4517	4677	4535	4562	4710	4616	4598	4719	4708	4776	4834	5101	5389	5545			
Persons/Dwelling	2.65	2.60	2.56	2.53	2.50	2.47	2.44	2.43	2.41	2.39	2.37	2.36	2.35	2.34	2.32	2.31	2.32	2.33	2.32	2.32	2.31	92%
Area/Capita	35.4	36.5	37.5	38.5	39.3	40.2	41.2	41.9	42.5	43.2	43.9	44.5	45.1	45.9	46.6	47.2	47.3	47.0	47.3	47.6	47.7	124%
Degree Days (18C Basis)	4483	3955	3932	4020	3644	3639	4299	4088	4309	4419	4377	4234	4016	3732	3804	4654	4182	4509	3895	3410	3380	
Normal = 1.00	1.10	0.97	0.96	0.98	0.89	0.89	1.05	1.00	1.05	1.08	1.07	1.03	0.98	0.91	0.93	1.14	1.02	1.10	0.95	0.83	0.83	
GDP (10e9 '80 US$)	62.1	62.7	64.1	66.6	68.8	70.5	71.3	70.1	71.4	74.1	75.3	75.1	75.7	77.6	80.6	82.4	83.5	86.2	88.2	90.1	90.3	
Shares: Manufacturing	23%	23%	22%	23%	24%	23%	23%	22%	21%	21%	21%	21%	20%	21%	21%	21%	21%	21%	21%	21%		
AgForFi, Constr, Mining	13%	13%	13%	12%	12%	11%	12%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	10%	11%		
Services, Energy, other	64%	64%	65%	64%	65%	65%	66%	67%	68%	68%	68%	69%	69%	68%	68%	68%	68%	68%	69%	68%		

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
END-USE SUMMARY INDICATORS																						
ENERGY USE BY TYPE (PJ)	NOT CLIMATE CORRECTED, INCLUDES OTHER INDUSTRY																					
Oil	860	833	848	851	768	769	811	776	771	763	718	660	599	547	531	527	510	521	502	494	478	58%
Gas	5.5	4.8	4.7	4.0	3.6	3.4	7.1	5.6	6.3	7.3	7.1	6.6	6.0	5.9	6.0	8.5	12.5	13.5	15.0	17.4	19.6	433%
Solids	217	198	192	203	215	217	207	188	201	218	214	204	201	229	241	257	250	251	260	262	262	129%
District Heat	49	51	54	58	56	64	78	83	90	95	98	101	103	104	109	137	133	143	132	122	125	210%
Electricity	196	207	221	238	240	249	267	271	281	295	302	309	319	341	370	409	412	431	435	435	436	183%
Final Energy	1329	1294	1320	1354	1283	1303	1370	1325	1350	1378	1339	1281	1228	1227	1258	1337	1318	1359	1343	1330	1320	98%
Primary Energy	1776	1765	1823	1896	1827	1869	1980	1944	1993	2052	2029	1987	1956	2005	2103	2271	2258	2344	2335	2321	2313	122%
Primary Losses	447	471	503	542	544	566	610	620	643	674	690	706	728	778	845	934	940	985	991	991	993	183%
ENERGY/GDP (MJ/'80USD), Climate Corrected, excludes other industry																						
Electricity	3.2	3.3	3.5	3.6		3.6	3.7	3.9	3.9	4.0	4.0	4.1	4.2	4.5	4.6	4.9	4.9	4.9	5.0	5.0	5.0	138%
Final Energy	21.0	20.8	20.8	20.4		18.9	19.1	18.9	18.7	18.3	17.6	16.9	16.3	16.1	15.8	15.9	15.7	15.5	15.3	15.2	15.1	74%
Primary Energy	28.2	28.3	28.6	28.6		27.0	27.6	27.7	27.7	27.4	26.7	26.3	25.9	26.3	26.4	27.0	27.0	26.8	26.7	26.5	26.4	93%
Del E/GDP Effect	1399	1385	1384	1361		1257	1270	1259	1249	1221	1170	1129	1084	1071	1052	1057	1047	1033	1022	1012	1004	74%
GDP Effect	1267	1279	1309	1361	1404	1440	1455	1432	1457	1513	1538	1534	1546	1583	1646	1682	1705	1761	1801	1840	1845	135%
Primary E/GDP Eff	1877	1888	1909	1904		1796	1838	1848	1847	1823	1776	1754	1728	1750	1760	1798	1796	1784	1778	1767	1758	93%
ENERGY/CAPITA (GJ/Capita) (Climate Corrected, excludes other industry																						
Electricity	24	26	27	29	29.3	31	32	33	34	35	36	37	38	41	45	48	49	51	52	53	52	179%
Final Energy	162	162	165	167	157	162	165	161	162	164	159	153	148	150	153	157	157	159	160	161	159	96%
Primary Energy	217	220	227	234	224	232	239	236	239	244	242	238	236	245	255	266	269	275	279	281	279	120%
ACTUAL ENERGY USE (PJ, Climate Corrected for Residential Sector), X OTHER IND																						
Electricity	196	207	222	239		251	266	271	280	293	300	308	320	346	375	400	410	425	438	447	448	187%
Final Energy	1304	1303	1331	1361		1330	1358	1325	1338	1358	1322	1273	1231	1246	1273	1307	1312	1337	1353	1369	1361	101%
Primary Energy	1749	1775	1836	1904		1903	1966	1945	1978	2028	2008	1977	1963	2037	2129	2223	2250	2309	2354	2389	2384	125%
ACTIVITY/STRUCTURE EFFECT (PJ, Climate Corrected for Residential Sector), X OTHER IND																						
Electricity	202	208	219	239		250			270	292	299	302	318	348	372	389	399	416	430	442	461	185%
Final Energy	1221	1245	1276	1361		1382			1415	1491	1497	1480	1488	1544	1601	1616	1649	1699	1750	1788	1789	131%
Primary Energy	1703	1735	1781	1904		1927			1961	2075	2086	2058	2070	2151	2232	2254	2296	2367	2438	2495	2501	131%
INTENSITY EFFECT (PJ, Climate Corrected for Residential Sector) X OTHER IND																						
Electricity	218	228	236	239		250			267	265	265	276	285	293	311	324	335	330	332	338	332	142%
Final Energy	1440	1418	1413	1361		1311			1278	1233	1194	1165	1116	1082	1066	1078	1059	1042	1024	1012	1009	74%
Primary Energy	1939	1939	1951	1904		1878			1887	1837	1800	1794	1761	1746	1761	1805	1791	1778	1762	1751	1747	92%

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
SECTORAL BREAKDOWNS			1.15			3.24																
Total Final	165.3	160.4	163.2	166.6	157.1	159.0	166.7	160.5	163.2	166.1	183.0	176.4	169.7	169.9	173.0	178.2	177.7	179.9	179.0	179.2	176.7	108%
Residential	49.4	47.2	47.4	46.4	40.7	42.2	46.0	44.8	45.8	46.0	44.6	43.2	41.1	39.1	39.2	43.4	41.6	42.5	39.5	38.1	38.0	82%
Services	20.8	19.6	19.7	19.4	17.2	18.1	20.8	20.3	21.1	21.0	42.6	42.3	41.5	41.4	41.0	39.8	40.9	39.8	40.7	42.7	42.8	220%
Manufacturing	67.6	65.4	67.3	70.7	69.8	67.8	67.6	62.8	63.9	65.8	62.2	58.3	54.3	55.9	57.9	59.4	58.5	59.7	60.8	60.1	58.3	85%
Other Industry	7.0	7.1	7.1	7.3	7.0	7.3	7.7	7.4	6.9	7.2	7.7	7.2	6.8	6.7	6.9	7.5	7.4	7.6	7.4	7.1	7.0	98%
Travel	14.5	15.3	16.0	16.9	16.1	17.6	18.2	18.6	19.0	19.0	18.9	18.9	19.2	19.5	20.1	20.1	21.1	21.7	22.1	22.5	21.7	133%
Freight	6.0	5.8	5.7	6.0	6.2	6.1	6.3	6.6	6.5	7.1	7.1	6.6	6.7	7.4	7.8	8.0	8.2	8.6	8.6	8.8	9.0	146%
Primary, LBL																						
Residential	62.3	61.3	62.8	62.7	57.1	60.6	67.0	67.1	69.0	70.8	69.6	69.5	69.8	69.5	72.3	82.0	80.3	81.6	76.2	73.8	73.5	118%
Services	28.6	28.5	29.4	29.6	27.1	29.2	33.2	33.3	34.9	35.4	35.5	35.1	35.7	36.3	38.0	43.8	43.5	45.8	45.3	44.4	45.3	150%
Manufacturing	97.7	96.1	99.3	105.4	105.1	101.9	102.6	96.4	98.6	101.9	99.0	95.3	90.6	95.0	100.4	103.2	102.1	106.5	109.9	109.8	106.8	104%
Other Industry	9.9	10.2	10.4	10.8	10.6	11.1	11.9	11.4	10.6	11.4	11.7	11.2	10.7	10.7	11.1	12.3	12.1	12.5	12.2	11.7	11.6	108%
Travel	15.3	15.9	16.7	17.5	16.7	18.2	18.9	19.8	20.2	19.8	20.2	20.3	20.5	20.9	21.5	21.5	22.5	23.0	23.5	23.8	23.0	136%
Freight	7.1	6.8	6.8	7.1	7.2	7.1	7.3	7.5	7.5	8.1	8.0	7.5	7.7	8.4	8.9	9.2	9.3	9.8	9.7	9.9	10.1	139%
Electricity Use	24.9	25.0	26.2	28.0	27.8	28.1	30.1	30.1	31.1	32.4	33.1	33.3	33.0	34.8	37.2	41.1	40.6	43.1	42.7	41.7	41.2	149%
Residential	3.57	3.67	3.83	3.97	3.93	4.40	5.13	5.42	5.78	6.05	6.19	6.37	6.53	6.71	6.99	8.46	8.31	8.97	8.09	7.52	7.76	189%
Services	2.21	2.32	2.48	2.71	2.48	2.87	3.55	3.84	4.12	4.32	4.46	4.56	4.50	4.56	4.78	6.09	5.85	6.13	5.61	5.13	5.12	189%
Manufacturing	13.47	13.69	14.28	15.50	15.73	15.22	15.62	15.01	15.47	16.15	16.43	16.52	16.21	17.49	19.00	19.54	19.47	20.87	21.92	22.18	21.65	143%
Other Industry	1.26	1.40	1.48	1.60	1.57	1.69	1.86	1.79	1.65	1.85	1.81	1.79	1.76	1.77	1.88	2.15	2.10	2.17	2.15	2.04	2.03	128%
Travel	0.33	0.29	0.30	0.29	0.28	0.30	0.31	0.53	0.55	0.33	0.59	0.61	0.61	0.61	0.61	0.64	0.62	0.61	0.62	0.58	0.58	200%
Freight	4.03	3.65	3.84	3.96	3.83	3.63	3.64	3.55	3.50	3.73	3.61	3.44	3.42	3.62	3.99	4.24	4.26	4.34	4.31	4.21	4.05	106%
SECTORAL SHARES																						
Final Energy																						
Residential	29.9%	29.4%	29.1%	27.8%	25.9%	26.5%	27.6%	27.9%	28.0%	27.7%	27.7%	28.1%	27.9%	26.5%	26.0%	27.1%	26.4%	26.2%	24.8%	24.3%	24.6%	
Services	12.6%	12.2%	12.1%	11.6%	11.0%	11.4%	12.5%	12.7%	12.9%	12.6%	12.9%	12.9%	13.1%	12.8%	12.6%	13.6%	13.1%	13.5%	13.1%	12.8%	13.1%	
Manufacturing	40.9%	40.8%	41.2%	42.4%	44.5%	42.6%	40.5%	39.1%	39.2%	39.6%	38.6%	37.9%	36.8%	37.9%	38.4%	37.1%	37.2%	36.9%	38.2%	38.4%	37.8%	
Other Industry	4.3%	4.4%	4.3%	4.4%	4.5%	4.6%	4.6%	4.6%	4.2%	4.4%	4.8%	4.6%	4.6%	4.6%	4.6%	4.7%	4.7%	4.7%	4.6%	4.5%	4.5%	
Travel	8.8%	9.5%	9.8%	10.1%	10.2%	11.0%	10.9%	11.6%	11.6%	11.5%	11.7%	12.3%	13.0%	13.2%	13.3%	12.6%	13.4%	13.4%	13.9%	14.3%	14.1%	
Freight	3.6%	3.6%	3.5%	3.6%	3.9%	3.8%	3.8%	4.1%	4.0%	4.3%	4.4%	4.3%	4.6%	5.0%	5.2%	5.0%	5.2%	5.3%	5.4%	5.6%	5.8%	
Primary Energy																						
Residential	28.2%	28.0%	27.9%	26.9%	25.5%	26.6%	27.8%	28.5%	28.7%	28.6%	28.5%	29.1%	29.7%	28.9%	28.7%	30.1%	29.8%	29.2%	27.5%	27.0%	27.2%	
Services	12.9%	13.0%	13.0%	12.7%	12.1%	12.8%	13.8%	14.2%	14.5%	14.3%	14.6%	14.7%	15.2%	15.1%	15.1%	16.1%	16.1%	16.4%	16.4%	16.2%	16.8%	
Manufacturing	44.3%	43.9%	44.0%	45.2%	46.9%	44.7%	42.6%	40.9%	40.9%	41.2%	40.6%	39.9%	38.6%	39.5%	39.8%	37.9%	37.9%	38.1%	39.7%	40.2%	39.5%	
Other Industry	4.5%	4.7%	4.6%	4.6%	4.7%	4.9%	4.9%	4.8%	4.4%	4.6%	4.8%	4.7%	4.6%	4.4%	4.4%	4.5%	4.5%	4.5%	4.4%	4.3%	4.3%	
Travel	6.9%	7.3%	7.4%	7.5%	7.5%	8.0%	7.9%	8.4%	8.4%	8.0%	8.3%	8.5%	8.7%	8.7%	8.5%	7.9%	8.3%	8.3%	8.5%	8.7%	8.5%	
Freight	3.2%	3.1%	3.0%	3.0%	3.2%	3.1%	3.0%	3.2%	3.1%	3.3%	3.3%	3.1%	3.3%	3.5%	3.5%	3.4%	3.5%	3.5%	3.5%	3.6%	3.7%	

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
RESIDENTIAL SECTOR																						
ENERGY USE BY TYPE																						
Oil, PJ	283.6	274.7	273.6	264.4	218.8	225.4	240.8	223.4	222.8	211.6	195.3	175.8	145.7	117.3	104.2	98.4	90.8	94.9	87.6	82.9	79.9	31%
LPG, PJ	0	0	0	0		0		0	0	0	0	0	0	0	0	0	0	0				
Gas, PJ	4.6	4.0	3.9	3.2	2.9	2.6	2.6	2.5	2.3	2.2	2.0	1.8	1.5	1.3	1.1	1.2	1.6	1.9	2.0	2.0	2.2	63%
Coal, Coke, PJ	5.2	2.5	1.8	1.4	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2	12%
Wood, PJ	30.7	21.1	19.7	18.3	20.4	16.1	17.9	19.7	22.5	28.2	32.0	34.9	37.8	41.3	44.2	52.4	46.4	42.7	41.8	43.8	44.7	239%
Electricity, PJ	44.4	48.9	53.6	57.3	57.6	65.0	74.3	79.1	82.8	88.6	89.5	93.9	102.7	109.3	119.1	139.2	139.9	141.7	133.6	131.0	131.4	229%
District, PJ	28.7	29.6	31.0	32.3	32.1	36.0	42.2	44.7	47.8	50.2	51.4	53.0	54.3	55.9	58.3	70.7	69.6	75.3	68.2	63.9	66.4	198%
Total Final, PJ	397	381	384	377	333	346	378	370	379	381	371	360	342	325	327	362	348	357	333	324	325	86%
Total primary, PJ	501	495	508	510	466	497	551	554	571	587	579	578	581	579	603	684	672	685	643	627	629	123%
ENERGY USE BY TYPE, Climate Corrected																						
Oil, PJ	264	282	282	268	238	246	232	223	214	200	186	171	148	125	110	89.8	89.3	88.5	90.7	94.6	91.5	35%
Gas, PJ	3.1	2.9	2.9	2.3	2.2	1.9	1.8	1.8	1.6	1.5	1.3	1.2	1.0	0.9	0.7	0.7	1.2	1.3	1.6	1.7	1.9	76%
Coal, Coke, PJ	4.8	2.6	1.9	1.4	1.0	0.7	0.6	0.5	0.5	0.5	0.5	0.8	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2	13%
Wood, PJ	28.3	21.7	20.4	18.6	22.6	17.9	17.1	19.7	21.5	26.3	30.1	33.8	38.5	45.0	47.1	46.4	45.3	38.9	43.6	51.9	53.4	279%
Electricity, PJ	43.5	49.2	54.1	57.5	59.9	67.3	73.0	79.2	81.2	86.0	87.2	92.7	104	114	123	131	138	135	137	143	143	248%
District, PJ	26.9	30.4	31.9	34.6	36.0	39.1	40.7	44.7	46.2	47.0	48.6	51.4	54.4	59.0	60.6	64.0	67.8	70.2	70.0	70.8	74.9	205%
Primary Demand, CC, PJ	472	504	519	516	500	529	535	553	554	561	556	566	585	608	627	634	662	647	659	692	697	134%
Final Demand,CC, PJ	371	389	393	382	360	373	365	369	365	361	353	351	345	344	342	332	342	334	343	362	365	95%
Useful Demand, CC, PJ	245	264	270	266	250	264	262	266	263	259	252	251	248	248	249	246	258	256	259	268	271	101%
Final/Households, GJ	115.1	118.4	117.8	113.1	105.1	107.4	103.9	103.8	101.6	99.4	96.5	95.1	93.0	91.9	90.2	86.6	88.3	85.4	86.8	90.4	90.3	80%
Final/capita, GJ	46.1	48.2	48.6	47.0	44.1	45.5	44.4	44.8	44.1	43.5	42.5	42.2	41.5	41.3	41.0	39.7	40.9	39.8	40.6	42.6	42.7	91%
Useful/Households, GJ	76.0	80.4	80.9	78.6	72.9	76.1	74.5	74.8	73.1	71.2	68.8	67.9	66.9	66.3	65.8	64.3	66.6	65.6	65.7	67.1	67.1	85%
Useful/capita, GJ	30.4	32.7	33.4	32.7	30.6	32.3	31.9	32.3	31.8	31.2	30.3	30.1	29.8	29.8	29.9	29.5	30.8	30.5	30.7	31.6	31.7	97%
																						128%
SHARES OF FINAL, Climate Corrected																						
Oil, %	71.0%	72.3%	71.5%	69.9%	66.0%	65.8%	63.4%	60.4%	58.6%	55.2%	52.5%	48.7%	42.7%	36.4%	32.1%	27.0%	26.1%	26.5%	26.4%	26.1%	25.0%	
Gas, %	1.2%	1.0%	1.0%	0.9%	0.9%	0.7%	0.7%	0.7%	0.6%	0.6%	0.5%	0.5%	0.4%	0.4%	0.3%	0.3%	0.5%	0.5%	0.6%	0.6%	0.7%	
Coal, Coke, %	1.3%	0.7%	0.5%	0.4%	0.3%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	
Wood, %	8.9%	6.2%	5.6%	5.2%	6.5%	5.0%	4.8%	5.5%	6.0%	7.4%	8.6%	9.8%	11.2%	13.1%	13.8%	14.0%	13.3%	11.7%	12.7%	14.4%	14.7%	
Elec, %	11.7%	12.6%	13.7%	15.0%	16.6%	18.0%	20.0%	21.4%	22.2%	23.8%	24.6%	26.3%	29.9%	33.0%	36.0%	39.3%	40.4%	40.4%	39.8%	39.3%	39.2%	
District Htg, %	7.2%	7.8%	8.1%	9.0%	10.0%	10.5%	11.1%	12.1%	12.6%	13.0%	13.7%	14.6%	15.7%	17.1%	17.7%	19.3%	19.8%	21.0%	20.4%	19.6%	20.5%	

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
RESIDENTIAL SECTOR (continued)																						
END USES: SPACE HEATING																						
Oil, LPG PJ	203.5	219.0	216.8	205.7	178.0	182.6	170.1	163.1	156.8	148.4	137.1	127.4	106.4	91.0	79.5	63.0	64.3	62.7	65.0	69.9	66.5	34%
Gas, PJ	2.64	2.42	2.38	1.79	1.74	1.53	1.42	1.58	1.33	1.26	1.10	1.04	0.82	0.75	0.55	0.54	0.95	1.01	1.26	1.42	1.56	79%
Coal, Coke, PJ	4.1	2.1	1.4	1.1	0.7	0.5	0.4	0.3	0.3	0.3	0.3	0.7	0.1	0.0	0.0	-0.1	-0.1	0.0	0.0	0.1	0.2	9%
Wood, PJ	25.0	18.9	17.9	16.4	20.5	16.1	15.3	17.8	19.5	24.1	27.6	30.9	35.7	41.9	44.1	43.4	42.3	36.1	40.8	49.2	50.8	300%
Electricity, PJ	8.8	11.3	13.2	14.8	18.4	21.5	24.5	28.3	29.3	31.9	32.1	36.0	43.9	51.2	59.2	62.5	69.9	65.3	64.8	69.1	68.5	466%
District Htg, PJ	19.5	21.8	22.3	24.4	36.0	27.7	28.5	31.4	31.1	31.4	32.0	34.0	35.9	40.5	41.1	43.1	45.4	46.6	45.7	45.5	49.1	186%
Total, PJ																						
Primary	286	304	307	301	302	302	299	311	309	313	307	316	327	346	363	359	386	365	370	397	397	132%
Final	264	275	274	264	255	250	240	243	238	237	230	230	223	225	224	213	223	212	218	235	237	89%
Useful	167	180	181	177	173	171	166	169	165	162	155	155	151	152	153	148	158	154	154	162	163	92%
Intensities																						
Useful Sp.Htg/cap, GJ	20.7	22.4	22.4	21.7	21.2	20.9	20.2	20.4	19.9	19.6	18.7	18.6	18.1	18.3	18.4	17.7	18.9	18.3	18.3	19.0	19.0	88%
Useful Sp.Htg/Dw, GJ	51.7	54.9	54.2	52.3	50.6	49.3	47.3	47.4	45.9	44.6	42.4	42.0	40.6	40.7	40.4	38.6	40.8	39.4	39.1	40.4	40.2	77%
Useful Sp.Htg/Dw-DD, MJ	12.6	13.4	13.3	12.8	12 [illegible]	12.0	11.6	11.6	11.2	10.9	10.4	10.3	9.9	9.9	9.9	9.4	10.0	9.6	9.6	9.9	9.8	77%
Useful Sp.Htg/Dw-DD-m2, KJ	134.8	141.7	138.2	132.1	1[illegible].2	121.5	115.2	114.4	109.6	105.4	99.5	97.7	93.5	92.6	91.3	86.5	91.2	88.1	86.9	89.5	89.1	68%
Share of Homes with Main Fuel																						
Oil heated, %	70.9%	69.9%	68.2%	68.3%	0.0%	65.3%	63.2%	60.5%	57.9%	54.9%	52.4%	49.4%	45.3%	40.6%	37.1%	33.8%	31.3%	31.5%	31.0%	29.4%	27.8%	
Gas heated, %	1.1%	1.0%	1.0%	0.9%	0.0%	0.7%	0.7%	0.6%	0.6%	0.6%	0.5%	0.5%	0.4%	0.2%	0.2%	0.3%	0.7%	0.5%	0.6%	0.7%	0.8%	
Coal, Coke, %	1.8%	1.4%	1.0%	0.6%	0.0%	0.5%	0.4%	0.3%	0.3%	0.2%	0.2%	0.3%	0.3%	0.2%	0.2%	0.4%	0.4%	0.2%	0.1%	0.1%	0.1%	
Wood, %	8.2%	7.2%	6.6%	5.4%	0.0%	4.5%	4.1%	3.9%	3.7%	3.4%	3.4%	4.7%	4.7%	4.6%	4.8%	4.4%	4.4%	3.3%	3.5%	4.0%	4.0%	
Electric heated, %	4.7%	5.7%	6.6%	7.3%	8.8%	10.0%	11.4%	12.8%	13.9%	14.8%	15.7%	17.1%	19.6%	23.4%	25.0%	26.4%	26.5%	26.7%	26.2%	26.0%	28.0%	
District heated, %	13.4%	14.7%	16.6%	17.5%	0.0%	19.1%	20.3%	21.9%	23.7%	25.3%	26.9%	28.0%	29.8%	31.0%	32.7%	34.7%	36.8%	37.7%	38.5%	39.9%	39.3%	
END USES: WATER HEATING																						
Oil, LPG PJ	60.1	62.7	65.0	62.0	60.0	63.0	62.0	60.4	57.6	51.4	48.6	43.9	41.2	34.3	30.3	26.7	25.1	25.7	25.7	24.7	25.0	40%
Gas, PJ	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	65%
Coal, Coke, PJ	0.7	0.5	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	23%
Wood, PJ	2.3	2.1	2.1	1.8	1.8	1.5	1.5	1.6	1.7	2.0	2.3	2.7	2.6	3.0	3.0	3.0	3.0	2.8	2.8	2.7	2.6	150%
Electricity, PJ	4.7	5.3	6.2	7.0	7.4	8.1	8.8	9.5	10.1	10.5	10.9	11.6	12.9	14.1	15.1	16.1	16.8	17.4	17.7	18.2	19.0	261%
District Htg, PJ	7.4	8.6	9.6	10.2	0.0	11.4	12.3	13.4	15.1	15.6	16.6	17.4	18.4	18.5	19.5	20.8	22.4	23.6	24.3	25.3	25.9	249%
Total, PJ																						
Primary	87.4	93.0	99.0	98.9	86.5	104.4	106.8	108.6	109.8	105.7	105.8	104.4	107.0	104.4	104.9	106.3	108.5	112.3	114.4	115.8	119.3	117%
Final	75.7	79.7	83.7	81.8	69.9	84.5	85.2	85.3	85.0	79.9	78.8	75.8	75.4	70.1	68.2	67.1	67.6	69.8	71.0	71.2	72.9	87%
Useful	52.5	55.9	59.2	58.6	47.4	61.4	62.4	63.0	63.5	60.3	59.9	58.1	58.7	55.3	54.8	54.8	55.9	58.2	59.3	60.0	61.6	102%
Intensities																						
Useful Hot water/cap, GJ	9.4	9.9	10.4	10.1	8.6	10.3	10.4	10.3	10.3	9.6	9.5	9.1	9.1	8.4	8.2	8.0	8.1	8.3	8.4	8.4	8.5	83%
Useful Hot water/Dw, GJ	23.5	24.3	25.1	24.2	20.4	24.4	24.2	24.0	23.6	22.0	21.5	20.5	20.3	18.7	18.0	17.5	17.5	17.9	18.0	17.8	18.0	74%
Share of Homes with Main Fuel																						
Oil, %	66.0%	67.5%	66.2%	66.8%	0.0%	64.5%	62.5%	60.0%	57.6%	54.7%	51.9%	48.1%	45.8%	38.8%	34.4%	29.8%	27.4%	27.7%	27.2%	25.6%	0.0%	
Gas, %	1.5%	1.4%	1.4%	1.2%	0.0%	1.0%	0.9%	0.9%	0.8%	0.8%	0.7%	0.6%	0.5%	0.3%	0.3%	0.4%	0.8%	0.7%	0.8%	0.9%	1.0%	
Coal, Coke, %	1.1%	0.9%	0.6%	0.5%	0.0%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.3%	0.3%	0.2%	0.2%	0.4%	0.4%	0.2%	0.1%	0.1%	0.1%	
Wood, %	3.3%	2.8%	2.4%	1.9%	-0.6%	1.3%	1.3%	1.4%	1.5%	1.7%	2.0%	3.2%	3.2%	4.8%	4.8%	4.2%	3.9%	2.9%	2.7%	2.9%	0.0%	
Electric, %	5.5%	6.4%	7.5%	8.5%	9.7%	11.0%	12.4%	13.8%	14.9%	15.8%	16.8%	18.3%	20.9%	23.3%	25.3%	27.3%	28.3%	29.3%	29.9%	30.3%	31.5%	
Dist. Htg., %	13.4%	14.7%	16.6%	17.5%	0.0%	19.1%	20.3%	21.9%	23.7%	25.3%	26.9%	28.0%	29.8%	31.0%	32.7%	34.7%	36.8%	37.7%	38.5%	39.9%	39.3%	

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
RESIDENTIAL SECTOR (continued)																						
END USES: COOKING, PJ																						
Oil, LPG PJ	0.5	0.4	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Gas, PJ	1.2	1.1	1.1	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.6	0.6	55%
Coal, Coke, PJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Wood, PJ	1.0	0.8	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	25%
Electricity, PJ	6.6	6.7	6.8	6.9	7.1	7.0	7.2	7.3	7.4	7.3	7.1	7.3	7.3	7.3	7.2	7.0	6.8	6.5	6.6	6.8	6.8	98%
Total, PJ																						
Primary	23.9	23.8	23.8	23.9	24.5	23.9	24.4	24.6	24.8	24.6	24.0	24.4	24.3	24.2	24.1	23.3	22.4	21.7	21.9	22.6	22.7	94%
Final	9.3	8.9	8.6	8.5	8.6	8.2	8.3	8.3	8.3	8.2	8.0	8.1	8.0	7.9	7.8	7.5	7.3	7.1	7.2	7.4	7.5	87%
Useful	7.7	7.6	7.7	7.7	7.8	7.6	7.7	7.8	7.8	7.8	7.6	7.7	7.7	7.6	7.5	7.3	7.0	6.8	6.9	7.1	7.2	93%
Intensities																						
Useful Cooking/cap, GJ	0.96	0.95	0.95	0.94	0.96	0.92	0.94	0.94	0.94	0.93	0.91	0.92	0.92	0.91	0.91	0.87	0.84	0.81	0.82	0.84	0.84	89%
Useful Cooking/Dw, GJ	2.38	2.32	2.29	2.27	2.28	2.18	2.19	2.18	2.17	2.13	2.07	2.08	2.06	2.03	1.99	1.91	1.81	1.75	1.75	1.78	1.78	78%
Share of Homes with Main Fuel																						
Oil, %																						
Gas, %	11.0%	11.0%	11.0%	11.0%	0.0%	8.0%	7.3%	6.6%	6.0%	5.0%	4.0%	3.7%	3.3%	3.0%	3.0%	3.0%	3.0%	4.0%	4.0%	4.0%	4.0%	
Coal, Coke, %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
Wood, %	6.0%	6.0%	5.0%	4.0%	100.0%	6.0%	4.7%	3.4%	3.0%	3.0%	3.0%	2.8%	2.7%	2.7%	2.3%	2.0%	2.0%	0.0%	0.0%	0.0%	100.0%	
Electric, %	83.0%	83.0%	84.0%	85.0%	0.0%	86.0%	88.0%	90.0%	91.0%	92.0%	93.0%	93.5%	94.0%	94.3%	94.7%	95.0%	95.0%	96.0%	96.0%	96.0%	96.0%	
END USES: LIGHTING, PJ																						
Final	5.5	5.8	5.98	6.17	6.05	6.45	6.79	7.22	7.72	7.86	8.06	8.12	8.11	8.14	8.23	8.33	8.33	8.58	8.76	8.95	9.19	145%
Useful /total area, MJ	18.1	18.5	18.7	18.7	18.0	18.8	19.1	20.0	21.0	20.9	21.1	20.9	20.6	20.3	20.1	20.0	19.6	20.1	20.2	20.2	20.6	108%
	0.68	0.71	0.74	0.76	0.74	0.79	0.83	0.88	0.93	0.95	0.97	0.98	0.97	0.98	0.99	1.00	0.99	1.02	1.04	1.05	1.07	
END USES: APPLIANCES, PJ																						
Final, PJ	18.0	20.2	22.0	22.7	21.0	24.3	25.8	26.8	26.6	28.5	29.0	29.7	31.3	33.1	33.5	36.6	36.7	37.2	38.8	39.5	39.8	174%
Final/Capita, GJ	2.9	3.2	3.5	3.5	3.3	3.7	4.0	4.1	4.2	4.4	4.5	4.5	4.7	5.0	5.0	5.4	5.4	5.5	5.6	5.7	5.7	161%
Final/dwelling, GJ	7.3	7.9	8.4	8.5	7.9	8.8	9.3	9.6	9.6	10.0	10.1	10.2	10.6	11.0	11.0	11.7	11.6	11.7	12.0	12.1	12.1	142%
SEVEN MAJOR APPLIANCES																						
Final, PJ	14.9	16.2	18.8	20.3		23.1			23.0	24.2	23.7	23.9	24.0	23.6	23.1	22.6	22.7	21.5	21.8	22.3	22.7	110%
Share of Homes with, %																						
Refrigerators & Combis	94%	94%	94%	97%		100%			102%	93%	104%	105%	106%	107%	108%	109%	108%	106%	107%	109%	111%	
Freezers	46%	48%	53%	55%		65%			60%	76%	64%	66%	67%	70%	73%	75%	76%	73%	76%	79%	81%	
Clothes-washers	44%	47%	58%	59%		62%			71%	73%	75%	.77%	78%	78%	78%	78%	79%	80%	81%	82%	83%	
Clothes-Dryes	2%	2%	8%	9%		13%			17%	22%	26%	31%	35%	36%	37%	38%	40%	40%	40%	40%	40%	
Dish-washers	5%	5%	9%	11%		16%			22%	27%	27%	29%	30%	29%	29%	28%	30%	30%	33%	36%	40%	
Air Conditioner																						
Unit Consumption, Kwh/appliance																						
Refrigerators & Combis	519	545	570	594		618			623	559	602	590	580	551	522	494	488	473	464	461	453	
Freezers	1200	1250	1295	1340		1300			1200	1166	1133	1099	1065	1003	940	878	870	773	750	740	730	
Clothes-washers	500	500	500	500		475			425	413	400	388	375	368	361	354	350	350	340	335	330	
Clothes-Dryes	300	310	317.5	325		315			300	281	263	244	226	227	228	229	215	243	240	235	220	
Dish-washers	300	300	300	300		300			300	298	295	293	290	287	284	281	275	281	275	265	260	
Air Conditioner																						

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
RESIDENTIAL SECTOR (continued)																						
STRINT CALCULATION-total																						
Actual Energy Use, PJ CC																						
Electricity	43.5	49.2	54.1	57.5	27	67.3	73.0	79.2	81.2	86.0	87.2	92.7	103.6	113.8	123.3	130.6	138.4	135.0	136.7	142.5	143.3	248%
Final Energy	372	390	394	383	27	373	366	370	366	362	354	352	346	345	342	332	343	335	343	362	366	95%
Primary Energy	474	505	520	517	88	530	536	554	555	561	557	567	586	608	627	634	663	647	660	692	698	134%
Activity Effect, PJ, CC																						
Electricity	57	57	57	58	58	58	58	58	59	59	59	59	59	59	59	59	59	59	60	60	61	104%
Final Energy	379	380	381	383	355	386	388	389	390	391	392	392	392	393	393	394	395	396	398	400	403	104%
Primary Energy	512	513	513	517	490	521	523	525	527	528	529	529	530	530	530	531	533	534	537	540	545	104%
Structure effect, PJ, CC																						
Electricity	43	47	53	58		71			91	99	103	112	128	147	162	176	183	189	194	201	217	349%
Final Energy	351	362	373	383		402			427	437	443	452	459	468	476	484	491	492	498	505	506	132%
Primary Energy	475	488	505	517		543			571	588	591	603	612	623	633	642	650	650	659	667	670	129%
Intensity Effect, CC, PJ																						
Electricity	48	52	55	58		64			70	71	69	72	81	85	95	96	108	98	96	104	98	181%
Final Energy	411	415	406	383		354			320	307	295	287	276	267	259	244	248	239	240	249	249	65%
Primary Energy	525	537	535	517		502			482	470	458	455	458	461	464	451	465	446	444	458	457	88%

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
SERVICE SECTOR																						
ENERGY USE BY TYPE (PJ)																						
Oil	119.9	107.4	104.1	98.4	84.8	84.8	98.2	89.6	90.5	86.2	81.6	71.6	64.3	55.4	49.2	50.9	41.3	43.5	38.8	36.0	35.1	37%
Gas	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.4	0.6	0.7	1.0	1.0	319%
Solids	2.0	1.3	1.1	0.9	0.7	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	77%
District Heat	17.8	18.7	20.1	22.1	20.3	23.5	29.2	31.7	34.1	35.8	37.1	37.9	37.5	38.0	39.9	50.9	49.0	51.5	47.3	43.6	43.9	198%
Electricity	26.9	30.5	33.7	35.8	34.6	39.0	43.3	45.8	49.0	51.1	52.5	54.4	58.2	62.6	68.3	78.7	81.8	86.7	88.7	89.3	92.9	249%
Final Energy	167	158	159	157	141	148	171	168	174	174	172	165	161	157	158	181	173	183	176	171	173	108%
Primary Energy	230	229	238	241	221	239	273	275	289	294	295	292	297	303	317	365	364	385	382	377	388	157%
Useful Energy	125	121	123	123	111	119	138	137	143	144	144	140	139	138	141	164	159	168	162	158	161	128%
VALUE ADDED (10e9 '80 USD)	30.0	30.9	32.0	33.3	35.1	35.9	37.0	37.5	38.1	39.5	40.5	40.7	41.2	41.9	43.0	43.8	44.6	45.8	46.9	48.0	50.5	144%
	0.15	2.24																				
ENERGY/VALUE ADDED (MJ/'80 USD)																						
Electricity	0.9	1.0	1.1	1.1	1.0	1.1	1.2	1.2	1.3	1.3	1.3	1.3	1.4	1.5	1.6	1.8	1.8	1.9	1.9	1.9	1.8	173%
Final Energy	5.6	5.1	5.0	4.7	4.0	4.1	4.6	4.5	4.6	4.4	4.3	4.0	3.9	3.7	3.7	4.1	3.9	4.0	3.8	3.5	3.4	75%
Primary Energy	7.7	7.4	7.4	7.2	6.3	6.7	7.4	7.3	7.6	7.4	7.3	7.2	7.2	7.2	7.4	8.3	8.2	8.4	8.1	7.8	7.7	108%
Useful Energy	4.17	3.92	3.85	3.71	3.17	3.31	3.72	3.66	3.76	3.65	3.56	3.44	3.37	3.28	3.28	3.74	3.56	3.66	3.46	3.28	3.19	88%
FLOOR AREA (10E6 M2)	116	119	123	126	130	132	135	137	140	143	145	148	152	155	158	161	164	167	171	174	177	138%
ENERGY/M2 (GJ/M2)																						
Electricity	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	181%
Final Energy	1.4	1.3	1.3	1.2	1.1	1.1	1.3	1.2	1.2	1.2	1.2	1.1	1.1	1.0	1.0	1.1	1.1	1.1	1.0	1.0	1.0	78%
Primary Energy	2.0	1.9	1.9	1.9	1.7	1.8	2.0	2.0	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.3	2.2	2.3	2.2	2.2	2.2	113%
Useful Energy	1.08	1.02	1.00	0.98	0.86	0.90	1.02	1.00	1.02	1.01	0.99	0.95	0.91	0.89	0.89	1.02	0.97	1.00	0.95	0.91	0.91	92%
ACTUAL ENERGY USE (PJ)																						
Electricity	27	31	34	36	35	39	43	46	49	51	53	54	58	63	68	79	82	87	89	89	93	249%
Final Energy	167	158	159	157	141	148	171	168	174	174	172	165	161	157	158	181	173	183	176	171	173	108%
Primary Energy	230	229	238	241	221	239	273	275	289	294	295	292	297	303	317	365	364	385	382	377	388	157%
ACTIVITY EFFECT (PJ)																						
Electricity	32	33	34	36	38	39	40	40	41	42	44	44	44	45	46	47	48	49	50	52	54	144%
Final Energy	142	146	151	157	166	170	175	177	180	187	191	192	195	198	203	207	211	216	222	227	239	144%
Primary Energy	217	223	232	241	254	260	268	271	276	286	293	295	298	303	311	317	323	331	339	348	365	144%
STRUCTURE EFFECT (PJ)																						
Electricity	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	100%
Final Energy	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	100%
Primary Energy	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	100%
INTENSITY EFFECT (PJ)																						
Electricity	30	33	35	36	33	36	39	41	43	43	43	44	47	50	53	60	61	63	63	62	61	173%
Final Energy	185	171	166	157	133	137	154	149	152	146	142	135	130	124	122	138	129	133	125	118	114	75%
Primary Energy	255	247	247	241	210	221	245	244	253	247	243	239	240	240	245	278	271	280	271	261	256	108%

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
MANUFACTURING SECTOR																						
ENERGY USE BY TYPE (PJ)																						
Oil	258	246	260	267	249	230	233	221	216	213	190	167	142	121	115	111	102	96	86	79	71	30%
Gas	0.5	0.5	0.4	0.5	0.4	0.5	4.2	2.7	3.7	4.7	4.7	4.5	4.2	4.4	4.7	7.1	10.4	10.9	12.0	13.8	15.7	3001%
Solids	174	168	165	178	188	195	184	164	174	185	177	166	160	184	193	200	200	204	214	215	213	121%
District Heat	2.4	2.8	3.2	3.8	3.9	4.6	6.1	6.8	7.9	8.4	9.2	10.4	10.5	10.4	10.8	14.8	14.4	16.0	16.2	14.4	14.3	382%
Electricity	108	110	116	126	128	125	128	124	128	134	137	137	135	146	158	163	163	175	185	188	185	149%
Final Energy	543	528	544	575	570	555	556	518	529	546	517	485	452	465	483	496	490	502	513	511	499	89%
Primary Energy	786	775	803	857	858	835	843	796	816	845	823	793	755	791	837	862	855	894	927	932	914	109%
TOTAL RAW MATERIALS (PJ)																						
Oil	181	171	179	186	177	155	153	144	141	141	126	108	90	74	69	67	63	58	53	49	43	26%
Gas	0.0	0.0	0.0	0.0	0.1	0.1	3.8	2.4	3.4	3.4	3.4	2.9	2.9	3.1	3.4	4.5	6.1	5.7	5.3	5.6	5.9	
Solids	156	152	151	165	171	174	154	147	157	167	158	149	144	163	172	176	175	178	188	188	188	114%
District Heat	0.3	0.4	0.5	0.4	0.5	0.5	0.8	0.8	1.0	1.2	2.0	2.2	2.2	2.2	2.3	2.9	3.1	3.4	3.4	3.0	3.0	709%
Electricity	85	85	89	97	100	95	96	91	95	99	97	96	93	101	110	113	112	118	125	128	124	131%
Final Energy	422	408	419	448	448	424	407	385	397	411	387	358	331	344	357	364	359	364	375	373	364	83%
Primary Energy	611	600	619	666	671	637	622	589	610	634	604	574	539	571	604	617	610	627	654	659	642	99%
TOTAL NON-RAW MATERIALS (PJ)																						
Oil	76.7	75.6	80.9	81.3	72.3	74.8	80.5	77.8	75.1	72.7	63.1	59.2	52.8	46.3	46.4	44.3	39.4	37.1	33.3	30.5	27.8	37%
Gas	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	1.3	1.3	1.5	1.3	1.3	1.4	2.6	4.3	5.1	6.6	8.2	9.9	
Solids	18.5	15.8	14.3	12.6	17.9	21.5	30.0	17.0	16.5	18.4	18.7	16.6	16.6	21.0	21.7	23.6	24.6	25.4	25.2	26.2	25.5	209%
District Heat	2.1	2.4	2.8	3.3	3.5	4.1	5.3	6.0	6.9	7.2	7.3	8.2	8.3	8.2	8.5	11.9	11.4	12.6	12.8	11.3	11.3	340%
Electricity	24	25	26	29	29	30	32	33	33	35	40	41	42	44	48	50	51	58	60	61	61	210%
Final Energy	121	119	125	127	123	131	149	134	132	134	130	127	121	121	126	132	131	138	138	137	135	108%
Primary Energy	175	175	184	191	187	198	221	207	206	212	219	219	216	221	233	244	245	267	273	273	272	143%
VALUE ADDED (10e9 '80 USD)																						
Paper & Pulp	1.0	1.0	1.0	1.1	1.2	1.0	1.1	1.0	1.1	1.2	1.2	1.1	1.1	1.2	1.2	1.2	1.3	1.4	1.5	1.5	1.4	129%
Chemicals	0.8	0.8	0.9	1.0	1.0	0.9	0.9	0.9	0.9	1.0	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.4	1.5	144%
Nonmetallic Minerals	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	87%
Ferrous Metals	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.6	0.6	0.8	0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	125%
Nonferrous Metals	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	107%
Other	11.0	11.1	11.1	11.7	12.4	12.8	12.8	12.1	11.5	12.2	12.2	11.8	11.7	12.3	13.1	13.4	13.6	13.8	14.0	14.3	14.0	122%
Total	14.2	14.3	14.4	15.4	16.2	16.3	16.3	15.3	14.9	15.9	16.0	15.4	15.4	16.1	17.1	17.5	17.6	18.1	18.5	18.8	18.4	122%
ELECTRICITY (PJ)																						
Paper & Pulp	38.0	38.2	41.5	46.0	47.6	43.9	45.7	45.3	48.7	51.6	49.3	49.8	47.0	52.3	57.8	59.4	59.9	65.2	69.5	72.3	72.1	157%
Chemicals	15.7	15.7	15.8	17.5	18.1	17.5	17.8	15.7	16.1	16.6	16.6	16.0	15.9	18.2	19.3	19.5	20.1	20.1	21.2	21.6	20.7	123%
Nonmetallic Minerals	4.4	4.5	4.5	4.7	4.5	4.4	4.3	4.1	4.1	4.2	4.4	4.2	4.2	4.3	4.5	4.7	4.5	4.6	4.8	4.8	4.5	103%
Ferrous Metals	19.9	19.5	19.6	20.9	21.3	21.1	20.2	18.0	17.8	18.8	18.5	18.2	17.5	17.8	19.8	20.3	18.9	18.8	19.6	19.0	17.1	91%
Nonferrous Metals	6.6	7.5	7.7	8.0	8.1	7.8	8.2	8.1	8.2	8.1	8.1	8.1	8.2	8.6	9.0	9.2	8.5	8.9	9.7	9.8	9.8	122%
Other	23.7	25.0	26.4	28.9	28.8	29.9	32.3	32.6	33.1	34.5	39.7	41.2	42.2	44.5	47.9	50.0	50.9	57.7	60.3	60.8	61.0	210%
Total	108	110	116	126	128	125	128	124	128	134	137	137	135	146	158	163	163	175	185	188	185	149%

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
MANUFACTURING SECTOR (continued)																						
FINAL ENERGY (PJ)																						
Paper & Pulp	229	219	230	248	244	222	213	214	228	233	218	211	191	201	210	214	215	221	226	226	220	91%
Chemicals	33	32	32	34	33	31	33	31	32	33	34	33	32	33	32	33	32	32	33	32	31	95%
Nonmetallic Minerals	47	46	48	48	45	42	39	37	34	36	35	30	28	27	27	26	24	25	25	25	26	52%
Ferrous Metals	102	100	97	105	112	117	107	88	89	95	86	71	66	69	73	77	74	71	76	76	73	72%
Nonferrous Metals	11	12	13	13	13	13	14	14	15	14	14	14	14	14	14	15	14	14	15	15	14	111%
Other	121	119	125	127	123	131	149	134	132	134	130	127	121	121	126	132	131	138	138	137	135	108%
Total	543	528	544	575	570	555	556	518	529	546	517	485	452	465	483	496	490	502	513	511	499	89%
PRIMARY ENERGY (PJ)																						
Paper & Pulp	314	305	323	351	350	320	316	316	337	348	329	322	296	318	339	347	349	367	381	388	381	111%
Chemicals	68	67	67	73	74	71	73	66	68	70	71	68	67	74	76	76	77	77	80	80	77	110%
Nonmetallic Minerals	57	56	58	59	55	52	49	46	43	45	44	39	38	36	37	36	34	35	36	36	36	61%
Ferrous Metals	147	143	141	152	160	164	152	128	129	138	127	112	105	109	118	122	116	113	120	118	111	78%
Nonferrous Metals	26	29	30	31	31	30	33	32	33	32	32	32	32	34	34	35	33	34	36	37	36	118%
Other	175	175	184	191	187	198	221	207	206	212	219	219	216	221	233	244	245	267	273	273	272	143%
Total	786	775	803	857	858	835	843	796	816	845	823	793	755	791	837	862	855	894	927	932	914	109%
ELECTRICITY/VALUE ADDED (MJ/'80 USD)																						
Paper & Pulp	39.5	40.0	41.6	40.8	39.2	43.2	43.0	44.6	44.0	43.5	42.0	43.4	42.9	43.6	46.4	47.7	46.0	45.8	47.2	49.7	50.8	122%
Chemicals	20.6	19.7	18.1	17.7	17.4	18.9	18.8	17.3	17.0	16.7	14.9	14.4	13.8	14.8	15.6	15.3	16.1	14.6	14.8	15.2	14.2	86%
Nonmetallic Minerals	6.9	7.2	7.5	7.4	7.2	6.9	6.9	7.2	7.4	7.4	7.9	8.6	8.5	8.5	9.0	9.6	9.1	8.8	9.1	8.8	8.8	118%
Ferrous Metals	28.8	28.8	29.3	28.4	26.6	28.6	29.9	29.8	27.7	24.7	24.6	26.2	23.7	23.1	23.3	24.5	24.0	23.6	22.2	20.7	19.7	73%
Nonferrous Metals	49.7	55.0	53.2	48.2	44.7	50.2	51.4	52.4	49.6	47.3	46.3	51.8	49.4	50.0	51.9	53.0	49.1	50.7	55.2	55.0	56.8	114%
Other	2.2	2.3	2.4	2.5	2.3	2.3	2.5	2.7	2.9	2.8	3.3	3.5	3.6	3.6	3.7	3.7	3.7	4.2	4.3	4.2	4.4	172%
Total	7.6	7.7	8.0	8.2	7.9	7.7	7.9	8.1	8.6	8.4	8.6	8.9	8.8	9.0	9.3	9.3	9.2	9.7	10.0	10.0	10.1	122%
FINAL ENERGY/VALUE ADDED (MJ/'80 USD)																						
Paper & Pulp	238	229	231	220	201	218	201	211	206	196	186	183	175	168	168	172	165	155	154	155	155	71%
Chemicals	43	40	36	34	32	34	35	34	33	33	31	29	28	27	26	26	26	23	23	23	21	66%
Nonmetallic Minerals	74	74	79	77	72	66	63	65	62	62	62	61	57	53	54	52	49	49	48	46	49	60%
Ferrous Metals	148	147	145	143	140	158	158	146	138	125	114	102	89	89	86	92	94	90	86	82	84	58%
Nonferrous Metals	81	87	88	79	73	83	91	89	88	83	79	89	84	84	83	85	79	80	83	82	83	104%
Other	11	11	11	11	10	10	12	11	11	11	11	11	10	10	10	10	10	10	10	10	10	89%
Total	38	37	38	37	35	34	34	34	35	34	32	31	29	29	28	28	28	28	28	27	27	73%
PRIMARY ENERGY/VALUE ADDED (MJ/'80 USD)																						
Paper & Pulp	326	319	325	311	288	315	297	311	304	293	280	281	271	265	272	279	268	258	259	267	268	86%
Chemicals	89	84	77	74	71	76	77	73	71	70	64	61	59	60	61	60	62	56	56	57	53	77%
Nonmetallic Minerals	89	91	96	94	88	81	78	81	79	79	80	81	77	73	74	74	69	69	69	66	69	70%
Ferrous Metals	212	211	210	207	200	222	226	213	200	180	169	161	142	141	139	147	148	143	136	129	128	62%
Nonferrous Metals	193	210	207	187	173	195	206	206	199	189	183	205	195	196	199	203	189	194	207	205	210	110%
Other	16	16	17	16	15	15	17	17	18	17	18	19	18	18	18	18	18	19	19	19	19	117%
Total	55	54	56	56	53	51	52	52	55	53	52	51	49	49	49	49	48	49	50	49	50	89%
ACTUAL ENERGY USE (PJ)																						
Electricity	108	110	116	126	128	125	128	124	128	134	137	137	135	146	158	163	163	175	185	188	185	149%
Final Energy	543	528	544	575	570	555	556	518	529	546	517	485	452	465	483	496	490	502	513	511	499	89%
Primary Energy	786	776	803	858	859	835	844	797	817	847	824	794	756	793	839	864	857	896	929	935	916	109%

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
MANUFACTURING SECTOR (continued)																						
ACTIVITY EFFECT (PJ)																						
Electricity	116	117	118	126	133	133	133	126	122	130	131	126	126	132	140	143	144	148	152	154	151	122%
Final Energy	530	534	537	575	606	608	608	573	558	594	596	576	574	603	639	652	659	676	692	704	689	122%
Primary Energy	791	796	801	858	904	907	907	855	832	886	889	860	856	900	954	973	984	1008	1032	1050	1028	122%
STRUCTURE EFFECT (PJ)																						
Electricity	120	119	122	126	128	116	116	117	124	126	127	126	127	129	127	125	125	129	131	129	129	103%
Final Energy	558	552	559	575	581	529	531	529	564	575	571	566	564	573	567	558	559	575	585	580	577	101%
Primary Energy	827	820	832	858	868	789	792	790	843	858	856	849	849	861	852	839	839	863	878	871	867	102%
INTENSITY EFFECT (PJ)																						
Electricity	124	126	128	126	120	129	131	134	133	129	131	137	135	137	142	145	143	147	150	151	152	120%
Final Energy	609	593	599	575	535	571	568	565	555	528	502	490	461	444	439	449	437	426	419	413	415	72%
Primary Energy	887	876	887	858	805	860	863	866	855	819	796	799	766	753	759	777	759	756	756	752	757	88%

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
OTHER INDUSTRY	(Agriculture, Forestry, Fisheries, Construction, Mining)																					
ENERGY USE BY TYPE (PJ)																						
Oil	41.2	40.8	40.5	41.2	39.8	40.9	43.8	42.5	39.2	41.1	44.6	42.6	39.3	38.3	38.4	40.9	41.1	41.8	40.0	39.0	39.1	95%
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.6	
Solids	5.2	4.9	4.4	4.6	4.6	5.0	4.2	3.6	3.9	3.4	3.8	2.0	2.3	2.8	3.1	3.7	2.9	3.1	3.4	2.9	2.8	62%
District Heat	0.14	0.14	0.15	0.16	0.16	0.17	0.18	0.17	0.17	0.16	0.16	0.15	0.16	0.18	0.22	0.23	0.25	0.31	0.28	0.28	0.28	179%
Electricity	10.1	11.3	12.0	13.0	12.8	13.8	15.3	14.8	13.6	15.3	15.1	14.9	14.6	14.7	15.6	18.0	17.6	18.3	18.2	17.4	17.3	134%
Final Energy	56.6	57.2	57.1	59.0	57.5	59.9	63.4	61.0	57.0	59.9	63.6	59.6	56.3	56.0	57.4	62.8	61.9	63.6	62.1	60.1	60.1	102%
Primary Energy	79.3	82.5	83.9	88.1	86.3	91.0	97.6	94.1	87.6	94.3	97.4	92.9	89.1	89.1	92.5	103.0	101.3	104.6	102.9	99.0	98.9	112%
VALUE ADDED (10e9 '80 USD)	8.01	8.19	8.25	8.31	8.05	8.07	8.28	8.06	8.01	8.19	8.31	8.19	8.40	8.55	8.83	8.80	9.02	9.11	9.13	9.84	9.96	118%
ENERGY/VALUE ADDED (MJ/'80 USD)																						
Electricity	1.26	1.38	1.45	1.56	1.60	1.72	1.84	1.83	1.70	1.87	1.81	1.81	1.74	1.72	1.77	2.04	1.95	2.00	1.99	1.76	1.74	113%
Final Energy	7.07	6.98	6.92	7.10	7.14	7.43	7.65	7.57	7.11	7.32	7.65	7.27	6.70	6.55	6.50	7.13	6.86	6.98	6.80	6.10	6.03	86%
Primary Energy	9.9	10.1	10.2	10.6	10.7	11.3	11.8	11.7	10.9	11.5	11.7	11.3	10.6	10.4	10.5	11.7	11.2	11.5	11.3	10.1	9.9	95%
ACTUAL ENERGY USE (PJ)																						
Electricity	10	11	12	13	13	14	15	15	14	15	15	15	15	15	16	18	18	18	18	17	17	134%
Final Energy	57	57	57	59	57	60	63	61	57	60	64	60	56	56	57	63	62	64	62	60	60	102%
Primary Energy	79	83	84	88	86	91	98	94	88	94	97	93	89	89	92	103	101	105	103	99	99	112%
ACTIVITY EFFECT (PJ)																						
Electricity	13	13	13	13	13	13	13	13	13	13	13	13	13	13	14	14	14	14	14	15	16	118%
Final Energy	57	58	59	59	57	57	59	57	57	58	59	58	60	61	63	62	64	65	65	70	71	118%
Primary Energy	85	87	87	88	85	86	88	85	85	87	88	87	89	91	94	93	96	97	97	104	106	118%
STRUCTURE EFFECT (PJ)																						
Electricity	12	12	12	13	13	11	11	10	9	11	11	10	10	10	11	11	11	11	11	12	12	92%
Final Energy	56	58	57	59	61	55	54	51	49	52	52	51	50	50	51	53	52	50	50	50	51	85%
Primary Energy	80	85	84	88	88	79	79	73	69	76	77	74	72	74	78	81	82	81	81	86	89	98%
INTENSITY EFFECT (PJ)																						
Electricity	10	11	12	13	13	14	15	15	14	16	15	15	14	14	15	17	16	17	17	15	14	113%
Final Energy	59	58	57	59	59	62	64	63	59	61	64	60	56	54	54	59	57	58	57	51	50	86%
Primary Energy	82	84	84	88	89	94	98	97	91	96	97	94	88	87	87	97	93	95	94	84	82	95%
AGRICULTURE																						
Electricity, PJ	1.9	2.2	2.5	2.6	2.3	2.7	3.1	3.3	3.7	4.1	4.1	4.3	4.7	4.5	4.7	5.8	5.5	5.9	5.5	5.4	5.3	211.1%
Delivered, PJ	27.6	26.1	26.2	26.2	25.2	25.8	27.2	27.0	26.8	26.8	30.8	30.6	29.9	29.7	29.9	32.4	32.4	33.4	32.8	31.9	31.9	121.6%
Value Added (10e9 '80 USD)	2.5	2.7	2.6	2.6	2.7	2.5	2.5	2.3	2.3	2.3	2.4	2.4	2.6	2.7	2.8	2.7	2.7	2.6	2.5	2.9	3.0	111.1%
Intensity (MJ/USD)	11.0	9.8	10.2	10.1	9.3	10.4	11.0	11.7	11.5	11.5	12.8	12.5	11.5	10.9	10.6	11.9	12.0	13.1	13.0	11.1	10.7	109.5%
MINING																						
Electricity, PJ	5.7	6.4	6.7	7.7	8.1	8.5	9.1	8.2	6.9	8.0	7.9	7.2	6.9	7.3	7.8	8.9	9.0	9.2	8.9	8.6	8.6	112.0%
Delivered, PJ	18.0	19.1	18.6	20.6	21.7	22.3	23.2	20.1	16.8	19.1	19.1	14.6	13.1	13.2	14.2	16.3	15.7	15.7	14.4	13.4	13.4	64.8%
Value Added (10e9 '80 USD)	5.1	5.1	5.3	5.2	4.9	5.2	5.4	5.4	5.4	5.5	5.5	5.4	5.5	5.6	5.7	5.7	6.0	6.2	6.3	6.6	6.6	126.3%
Intensity (MJ/USD)	3.5	3.8	3.5	3.9	4.5	4.3	4.3	3.7	3.1	3.5	3.4	2.7	2.4	2.4	2.5	2.8	2.6	2.5	2.3	2.0	2.0	51.3%
CONSTRUCTION																						
Electricity, PJ	2.5	2.7	2.8	2.8	2.4	2.7	3.0	3.2	3.1	3.2	3.1	3.3	3.0	3.0	3.1	3.3	3.1	3.2	3.7	3.4	3.5	122.7%
Delivered, PJ	11.0	11.9	12.3	12.1	10.6	11.8	13.0	13.9	13.4	14.1	13.7	14.4	13.3	13.1	13.3	14.1	13.8	14.6	14.9	14.8	14.8	122.3%
Value Added (10e9 '80 USD)	5.1	5.1	5.3	5.2	4.9	5.2	5.4	5.4	5.4	5.5	5.5	5.4	5.5	5.6	5.7	5.7	6.0	6.2	6.3	6.6	6.6	126.3%
Intensity (MJ/USD)	2.2	2.3	2.3	2.3	2.2	2.3	2.4	2.6	2.5	2.6	2.5	2.6	2.4	2.4	2.3	2.5	2.3	2.4	2.4	2.2	2.2	96.9%

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
PASSENGER TRANSPORT SECTOR																						
ENERGY USE BY TYPE (PJ)																						
Oil	114	121	127	135	129	141	147	149	153	155	152	152	155	157	163	163	171	177	181	186	180	138%
Electricity	2.7	2.3	2.5	2.4	2.3	2.4	2.5	4.4	4.5	2.7	4.9	5.0	5.1	5.1	5.1	5.3	5.2	5.2	5.2	4.9	5.0	209%
Final Energy	117	123	130	137	131	144	150	153	157	158	157	157	160	162	168	168	176	182	187	191	185	139%
Primary Energy	123	128	135	143	136	149	156	163	167	164	168	169	171	174	179	180	188	194	198	202	197	142%
ENERGY USE FOR PASSENGER (PJ)																						
Autos	104.6	110.1	116.7	123.3	115.9	128.3	133.4	137.2	140.4	140.3	139.9	139.4	141.0	142.7	147.4	147.5	154.2	159.1	162.8	166.1	160.9	135%
Motorcycles	1.3	1.2	1.1	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.1	1.2	1.3	1.3	1.3	1.2	1.2	1.2	1.1	115%
Buses	5.0	5.3	5.4	5.9	6.5	6.7	6.9	7.0	7.1	7.5	6.7	7.0	7.3	8.2	8.6	8.8	9.2	9.3	9.2	9.6	9.6	163%
Rail	4.5	4.4	4.3	4.6	4.9	4.9	5.2	5.1	5.2	5.2	5.4	5.6	5.7	5.8	5.7	6.0	5.9	5.9	5.9	5.6	5.7	123%
Of which electricity	4.2	3.9	3.9	4.0	4.0	4.2	4.3	4.4	4.5	4.6	4.9	5.0	5.1	5.1	5.1	5.3	5.2	5.2	5.2	4.9	5.0	124%
Local transit																						
Water	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.4	3.3	3.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	125%
Air	2.1	2.7	2.5	2.8	3.1	3.3	3.7	3.3	4.0	4.7	4.7	5.2	5.7	5.6	6.2	5.6	7.1	7.7	8.8	9.6	9.2	339%
VEHICLE STOCK,(10e3) autos	2246	2327	2392	2470	2576	2700	2816	2865	2857	2856	2813	2829	2852	2907	2979	3052	3140	3250	3368	3476	3537	141%
VEHICLE-KM (10e9) autos	32.2	33.6	35.3	37.0	35.8	38.7	39.9	40.7	41.3	41.3	41.4	41.2	41.8	42.5	43.9	44.3	47.1	49.6	51.2	52.8	51.4	143%
PASSENGER-KM (10e9)																						
Autos, Light Trucks	55.4	57.4	59.3	61.9	59.9	64.2	66.4	68.2	68.5	68.5	66.7	66.4	67.3	68.7	71.0	72.2	76.2	79.6	83.3	87.4	86.4	141%
Motorcycles	1.00	1.00	0.90	1.00	1.00	1.00	0.80	0.80	0.90	0.80	0.80	0.90	1.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	110%
Buses	5.5	5.5	5.6	5.7	6.3	6.4	6.5	6.6	6.7	7.0	7.3	7.9	8.5	8.7	8.9	9.0	9.0	9.0	9.0	9.0	9.0	158%
Rail	4.6	4.0	4.5	4.6	5.5	5.6	5.6	5.6	5.6	6.2	7.0	7.1	6.6	6.7	6.7	6.8	6.4	6.2	6.3	6.2	6.2	135%
Local Transit	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.9	1.8	1.8	150%
Water																						
Air	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.3	1.4	1.6	1.8	2.0	2.2	2.3	2.7	2.9	3.2	3.3	3.4	452%
Total Pass-Km (10e9)	68.2	69.7	72.2	75.1	74.8	79.3	81.6	83.5	84.2	85.3	84.8	85.5	86.8	88.8	91.5	93.0	96.9	100.4	104.8	108.8	107.9	145%
ENERGY/PKM (MJ/PKM)																						
Automobiles & Light Trucks	1.89	1.92	1.97	1.99	1.94	2.00	2.01	2.01	2.05	2.05	2.10	2.10	2.10	2.08	2.08	2.04	2.02	2.00	1.95	1.90	1.86	95%
Motorcycles																						
Buses	0.92	0.96	0.97	1.03	1.03	1.05	1.06	1.05	1.06	1.07	0.92	0.88	0.86	0.94	0.97	0.97	1.02	1.03	1.02	1.06	1.07	103%
Rail	0.98	1.10	0.96	1.00	0.89	0.87	0.93	0.92	0.93	0.84	0.77	0.79	0.86	0.86	0.86	0.89	0.93	0.95	0.94	0.91	0.92	91%
Water																						
Air	3.47	3.80	3.68	3.86	3.95	4.05	4.01	3.84	3.91	3.56	3.38	3.28	3.21	2.84	2.77	2.44	2.65	2.65	2.76	2.89	2.70	75%
Total	1.71	1.76	1.79	1.83	1.75	1.81	1.84	1.83	1.86	1.85	1.85	1.84	1.84	1.83	1.83	1.81	1.82	1.81	1.78	1.75	1.72	96%
Autos, Energy/veh-km	3.25	3.28	3.30	3.33	3.24	3.31	3.34	3.37	3.40	3.40	3.38	3.38	3.37	3.36	3.36	3.33	3.27	3.21	3.18	3.15	3.13	94%
VEHICLE STOCK,CARS/(10e3)people	279	287	294	304	316	330	343	347	345	344	338	340	343	349	357	366	375	387	399	409	413	135%
ACTUAL ENERGY USE (PJ)																						
Electricity	2.7	2.3	2.5	2.4	2.3	2.4	2.5	4.4	4.5	2.7	4.9	5.0	5.1	5.1	5.1	5.3	5.2	5.2	5.2	4.9	5.0	209%
Final Energy	117	123	130	137	131	144	150	153	157	158	157	157	160	162	168	168	176	182	187	191	185	139%
Primary Energy	123	128	135	143	136	149	156	163	167	164	168	169	171	174	179	180	188	194	198	202	197	142%

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
PASSENGER TRANSPORT SECTOR (continued)																						
ACTIVITY EFFECT (PJ)																						
Electricity	2.1	2.2	2.3	2.4	2.3	2.5	2.6	2.6	2.6	2.7	2.7	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.3	3.4	3.4	145%
Final Energy	125	127	132	137	137	145	149	153	154	156	155	156	159	162	167	170	177	184	191	199	197	145%
Primary Energy	129	132	137	143	142	150	155	158	160	162	161	162	165	168	174	177	184	191	199	206	205	145%
STRUCTURE EFFECT (PJ)																						
Electricity	2.3	2.4	2.4	2.4	2.3	2.3	2.3	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	102%
Final Energy	136	137	137	137	136	136	137	137	137	137	136	136	136	136	137	137	138	139	140	140	140	102%
Primary Energy	141	143	142	143	141	142	142	142	142	142	141	141	141	141	142	142	144	144	145	146	146	102%
INTENSITY EFFECT (PJ)																						
Electricity	2.2	2.3	2.3	2.4	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.2	2.2	95%
Final Energy	130	133	135	137	133	137	138	138	140	140	141	141	141	140	140	138	137	136	133	130	128	95%
Primary Energy	135	138	140	143	139	143	144	143	146	145	146	146	146	145	145	143	143	141	138	135	132	95%

SWEDISH ENERGY SUMMARY 01/10/94	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989/1973
FREIGHT TRANSPORT SECTOR																						
ENERGY USE BY TYPE (PJ)																						
Oil	44	43	43	45	47	46	48	51	51	55	55	51	53	58	61	63	64	68	68	71	73	157%
Electricity	4.0	3.6	3.8	4.0	3.8	3.6	3.6	3.6	3.5	3.7	3.6	3.4	3.4	3.6	4.0	4.2	4.3	4.3	4.3	4.2	4.1	106%
Final Energy	48	47	47	49	51	50	52	54	54	59	59	55	56	62	65	67	68	72	72	75	77	153%
Primary Energy	57	55	55	58	59	58	60	62	62	67	67	62	64	70	74	76	78	82	82	84	86	146%
TRUCK STOCK (10^3)																						
Truck Stock	144	143	144	147	151	154	161	167	175	178	209	#N/A	#N/A	228	238	249	262	279	299	326	#N/A	222%
ENERGY USE BY MODE (PJ)																						
Trucks	37.9	38.5	39.5	40.9	43.2	42.9	43.5	46.7	47.5	51.5	51.5	47.9	49.5	54.9	57.4	58.7	60.5	62.5	61.9	67.0	69.7	164%
Rail	4.4	4.1	4.2	4.6	4.7	4.2	4.4	4.1	4.0	4.2	4.0	3.8	3.8	4.1	4.5	4.8	4.9	4.9	4.9	4.8	4.6	105%
Of Which Electricity	4.0	3.6	3.8	4.0	3.8	3.6	3.6	3.6	3.5	3.7	3.6	3.4	3.4	3.6	4.0	4.2	4.3	4.3	4.3	4.2	4.1	106%
Ship	5.7	4.0	2.8	3.4	2.8	2.9	3.7	3.4	2.6	3.2	3.3	2.8	2.7	2.6	3.2	3.5	3.0	4.9	5.3	2.9	2.8	85%
Pipeline, Floating																						
Air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37%
TONNE-KM (10e9)																						
Trucks	17.5	18.7	19.1	21.6	22.5	21.5	22.0	21.5	21.9	24.2	23.0	22.6	22.7	22.7	24.6	23.0	24.8	24.7	25.0	27.1	29.1	125%
Rail	17.3	15.7	16.2	18.3	19.6	16.1	16.2	14.8	14.8	17.4	16.6	15.3	14.4	15.7	17.8	18.4	18.6	18.4	18.7	19.2	19.1	105%
Ship	5.2	5.5	5.9	6.3	7.2	8.2	9.3	9.3	8.7	10.2	10.3	9.2	9.4	9.2	9.1	9.2	9.4	8.7	7.9	7.9	7.7	125%
Pipeline, Floating																						
Air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	79%
Total	40.0	39.9	41.2	46.2	49.3	45.8	47.5	45.6	45.4	51.8	49.9	47.1	46.5	47.6	51.5	50.6	52.8	51.8	51.6	54.2	55.9	117%
ENERGY/TKM (MJ/TKM)																						
Trucks	2.2	2.1	2.1	1.9	1.9	1.99	1.98	2.17	2.17	2.13	2.24	2.12	2.2	2.4	2.3	2.6	2.4	2.5	2.5	2.5	2.4	130%
Rail	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	101%
Ship	1.1	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.6	0.7	0.4	0.4	68%
Pipeline																						
Air	1.0	0.9	0.9	0.9	0.7	0.7	0.7	0.0	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.0	47%
Total	1.2	1.2	1.1	1.1	1.0	1.1	1.1	1.2	1.2	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4	130%
ACTUAL ENERGY USE (PJ)																						
Electricity	4.0	3.6	3.8	4.0	3.8	3.6	3.6	3.6	3.5	3.7	3.6	3.4	3.4	3.6	4.0	4.2	4.3	4.3	4.3	4.2	4.1	106%
Final Energy	48	47	47	49	51	50	52	54	54	59	59	55	56	62	65	67	68	72	72	75	77	153%
Primary Energy	57	55	55	58	59	58	60	62	62	67	67	62	64	70	74	76	78	82	82	84	86	146%
ACTIVITY EFFECT (PJ)																						
Electricity	3.4	3.4	3.5	4.0	4.2	3.9	4.1	3.9	3.9	4.4	4.3	4.0	4.0	4.1	4.4	4.3	4.5	4.4	4.4	4.6	4.8	117%
Final Energy	42	42	44	49	52	48	50	48	48	55	53	50	49	50	55	54	56	55	55	57	59	117%
Primary Energy	50	50	52	58	62	57	59	57	57	65	62	59	58	60	64	63	66	65	65	68	70	117%
STRUCTURE EFFECT (PJ)																						
Electricity	3.8	4.0	4.0	4.0	3.9	4.1	4.1	4.2	4.2	4.1	4.1	4.2	4.3	4.2	4.1	4.0	4.1	4.1	4.1	4.2	4.3	106%
Final Energy	46	49	49	49	48	50	51	51	52	51	51	52	53	51	51	49	50	51	51	52	53	106%
Primary Energy	55	58	58	58	57	60	60	61	61	60	60	61	62	61	60	58	60	60	60	61	62	106%
INTENSITY EFFECT (PJ)																						
Electricity	4.7	4.4	4.2	4.0	3.9	4.1	4.1	4.4	4.3	4.2	4.4	4.2	4.4	4.7	4.6	5.0	4.8	5.1	5.1	4.9	4.7	123%
Final Energy	58	54	52	49	48	50	50	54	54	52	55	52	54	59	57	62	59	63	62	60	58	123%
Primary Energy	69	63	62	58	57	59	59	64	63	62	65	62	64	69	67	73	70	74	74	71	69	123%

END

DATE FILMED

4/4/94