Trends in Norwegian stationary energy use: An international perspective

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1. SYNOPSIS

Analysis of end-use trends in residential, service/commercial and manufacturing sectors in Norway and a selection of other IEA countries. Comparison of energy savings from 1973 to the mid-1990s.

2. ABSTRACT

Energy use in the manufacturing, residential, service sectors (i.e. stationary energy) in Norway is relatively high compared to most other IEA countries. A cold climate and an energy intensive structure can partly explain this; adjusted for these two factors, Norway's levels of stationary energy use are just above average for the thirteen IEA countries included in this analysis.
Stationary energy use has increased in Norway since 1973, contrary to trends in most other IEA countries. This is partly because the manufacturing structure has become more energy intensive, homes have became bigger, and Norwegians today own and use more electric appliances than two or three decades ago. But as electricity and, to some extent, oil prices have been low in Norway compared to other countries over the entire period since 1973, it can also be expected that energy savings in Norway have not been as significant as in IEA countries where prices have been higher.
To estimate the effects of energy savings, changes in energy use resulting from changes in the demand for energy service are isolated from changes in energy intensities. Changes in end-use energy intensities are related to energy efficiency and hence important to track in order to evaluate energy savings over time.
The results show that savings in Norway for all sectors were lagging behind other IEA countries during the 1970s. During the 1980s the rate of savings increased primarily due to reductions in manufacturing intensities. After 1990, however, energy savings in all stationary end-uses appear to have taken place at a higher rate than in most other counties.

3. INTRODUCTION

This paper presents the results of a study comparing stationary energy use trends in Norway with other selected countries of the International Energy Agency (IEA)[1,2]. The study was undertaken by the IEA Secretariat in Paris, in collaboration with the Norwegian Water Resources and Energy Directorate (NVE) and Norwegian Petroleum and Energy Ministry (OED). This paper builds on the full report from the study, Unander and Schipper (2000)[3].

The methodology used in the study is based on the IEA indicator approach[4]. This study also draws on the data and analysis developed in three previous studies of Norwegian energy use: Schipper, Howarth, and Wilson (1990) for energy use in Norway through 1986[5]; Bartlett (1993) for energy use to 1990[6]; and Unander, Alm and Schipper (1997), who extended the analysis to 1993[7].

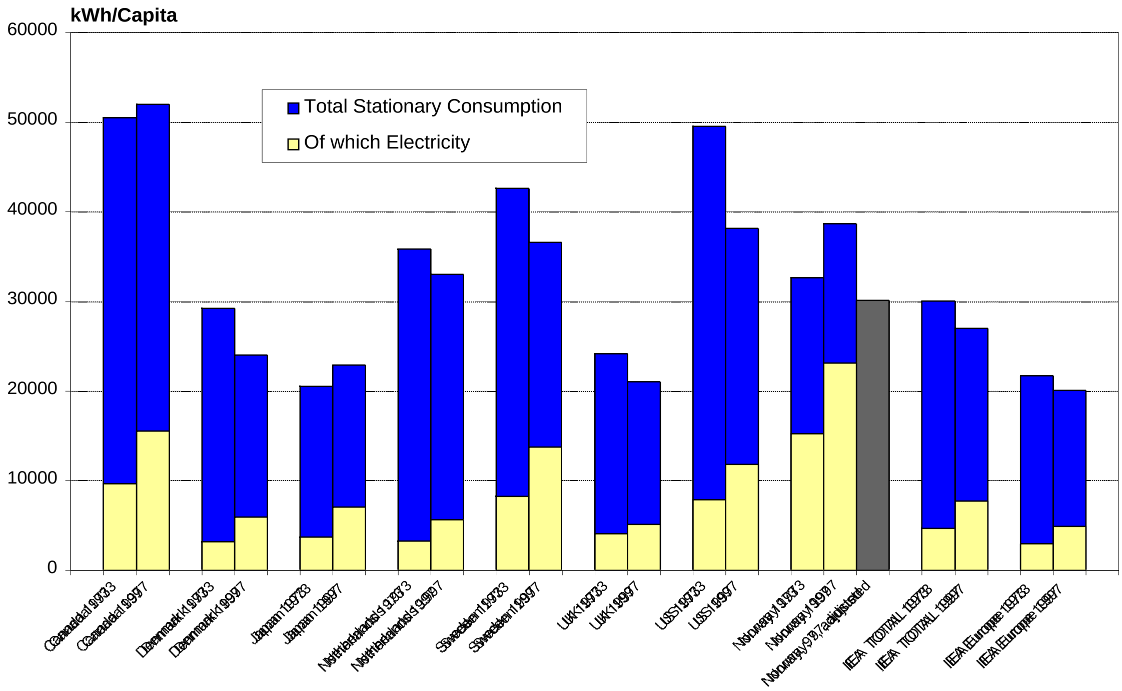
The paper starts out with a brief overview of stationary energy use in Norway and other IEA countries and the methodology used in the study. In the following chapters results for the residential, services and manufacturing sectors are presented before the paper concludes with a summary of the developments in all three sectors.

4. STATIONARY ENERGY USE IN NORWAY AND OTHER IEA COUNTRIES

Norway is in a unique energy situation among IEA Member countries. It is the second largest oil exporter in the world after Saudi Arabia and has vast resources of natural gas. Norway is also well endowed with hydropower resources that traditionally have supplied almost all domestic electricity demand. The availability of inexpensive hydropower has led to the development of a very electricity- intensive industry structure in Norway and to widespread use of electricity for space heating.

Stationary energy use in Norway is relatively high compared to most other IEA countries, as seen in Figure 1, where final consumption for total stationary use per capita are shown for selected countries and the average for all IEA countries and for IEA Europe. However, Norway's stationary energy use is only marginally higher than in Sweden or the United States. And it is far lower than in Canada, a country like Norway with a cold climate and an energy-intensive industry structure. By adjusting for differences in outdoor temperatures and industry structure, Norway's level of stationary energy use falls towards a level just above the IEA average, but still significantly higher than the average for IEA Europe. (This calculation is done only for Norway's total stationary energy use and is shown in the third bar for Norway in Figure 1)[8, 9,10].

Figure 1. Stationary energy use and electricity per capita for selected IEA countries



However, as Figure 1 also indicates, Norwegian electricity consumption levels are very high in comparison with other IEA counties. Electricity consumption in Norway grew from about 15 000 kWh per capita in 1973 to more than 23 000 kWh per capita in 1997. In all other countries shown and for the IEA-average, electricity use also increased. But no other country is even close to the consumption levels in Norway. Canada and Sweden, the two other big consumers of electricity among IEA countries, both had consumption levels more than 35 percent lower than Norway in 1997. A high share of electricity-intensive industries in Norwegian manufacturing partly explains the high consumption. But only partly, since even when subtracting electricity use in manufacturing, Norway would have ranked high in electricity use per capita, almost at the same level as Sweden's total electricity consumption. The other important explanation for Norway's high consumption levels is the broad penetration of electric heating in residential and commercial/service buildings.

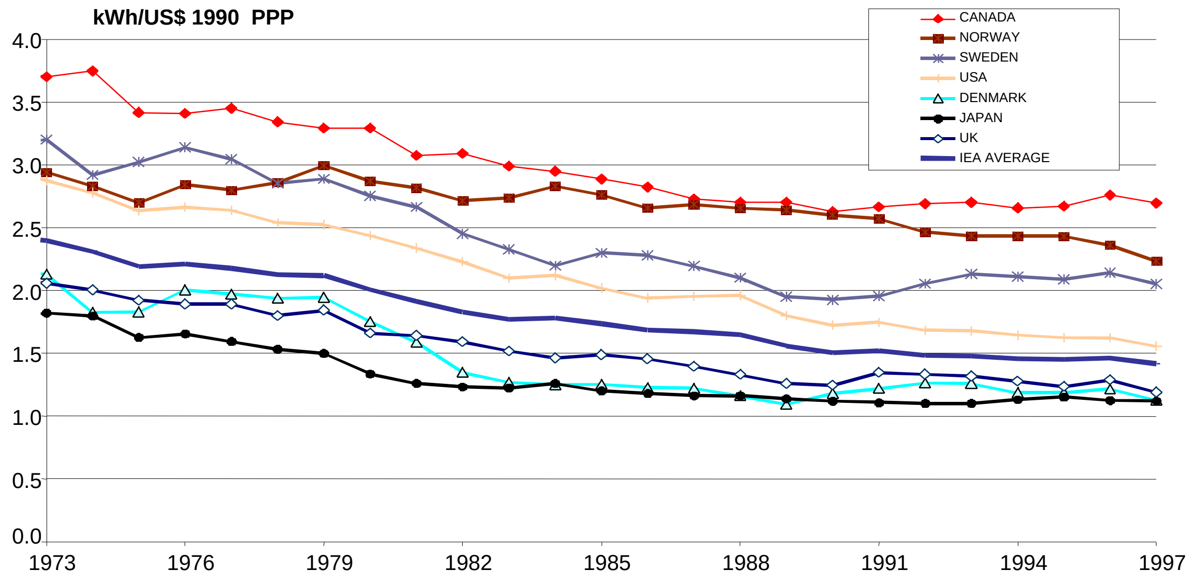
Though the climate and structure-adjusted level of per capita stationary energy use in Norway today is not much higher than the IEA-average, energy use has increased in Norway since 1973, contrary to trends in most other IEA countries. (Figure 1). As discussed in the next sections, this is at least partly due to a more energy-intensive manufacturing structure (higher share of energy-intensive products in total production), bigger homes, and increased ownership and use of more electric appliances. But as electricity and, to some extent, oil prices have been lower in Norway than in other countries over the entire period since 1973; it can also be expected that energy savings in Norway have not been as significant as in IEA countries with higher energy prices. This paper aims at exploring if this has indeed been the case, by examining trends in Norway and other countries from 1973 through the mid 1990s.

5. HOW TO MEASURE ENERGY SAVINGS?

The ratio of energy per GDP ratio is often used to study energy developments in a country and even more often when comparing countries to one another. Figure 2 shows this ratio for a selection of IEA countries between 1973 and 1997[11]. In 1997 Canada used about 2.5 times as much energy per GDP as Japan and Denmark. Norway is also higher than the IEA average, but significantly lower than Canada. Why are countries' energy per GDP levels so different? IEA analysis indicates that as much as half of the country-to-country variations in the ratio of energy to GDP may be due to non-energy factors such as weather and climate, geography, travel distance, home size and manufacturing structure, Unander and Schipper (1999)[12].

To what extent do changes in energy per GDP over time reflect improvements in energy efficiency? Figure 2 indicates big differences in how much this ratio fell between 1973 and 1997. For example, if the energy to GDP ratio did reflect efficiency improvements it would imply that relatively small improvements took place in Norway between 1973 and 1997, while the United States achieved significant savings over the same period. In fact both countries had the same ratio in 1973. Yet while the ratio in the United States fell by 50 percent over the next 25 years it only fell by some 25 percent in Norway. Sweden started out a little higher than Norway in 1973, but by 1990 the ratio had fallen almost 40 percent before it climbed up again the next few years, yet it was still lower than in Norway in 1997.

Figure 2. Stationary energy per GDP over time



Does this mean that the rate of efficiency improvements in Norway was that much lower than in the United States and until 1990 in Sweden? And has the rate of efficiency improvement in recent years really been so notably better in Norway compared to many other countries?

To answer these questions more information is needed. Changes in the energy per GDP ratio can be explained by shifts in both energy intensities (related to energy efficiency improvements) and structural changes. GDP represents economic activities that require energy services in varying degrees. For example, generating one unit of GDP from producing electronics requires much less energy than if the same unit of GDP is generated from producing steel. Thus, a shift away from heavy industries (e.g. steel) to less energy-intensive production (e.g. electronics) could drive down a country's energy demand, all else being equal.

The IEA's method for analysing end-use developments is based on much more disaggregated measures than energy per GDP. Using this method, observed changes in the end-use of energy can be separated into changes in activity, structure and energy intensities. Hence, changes related to improved end-use energy efficiency (reductions in energy intensity) can be isolated from changes derived from shifts in other factors. For example, a reduction in total manufacturing energy use to manufacturing value-added does not necessarily mean that the energy efficiency of production has improved. A more disaggregated investigation may reveal that during the same period the industry structure itself became less energy intensive, e.g. that relatively less of the manufacturing production came from energy-intensive raw materials. To better understand the changes that are due to improvements in efficiency, these structural changes need to be taken into account.

Using this approach the decomposition of changes in energy use in a *sector* can be summarised in the following equation:

$$\mathbf{E = A * \_ S_{\mathit{i}} * I_{\mathit{i}}}$$

In this decomposition,

E represents total energy use in a sector
A represents the activity level in the sector (e.g. value-added in manufacturing),
S represents sectoral structure (e.g. shares of output by manufacturing sub-sector *i*), and
I represents the energy intensity of each sub-sector or end-use *i* (e.g. energy use/real US$ value-added)
In addition the method adjusts for changes in energy use due to yearly variations in outdoor temperature, based on degree-days for each country.

If indices for the changes in each of these components over time are established, they can be thought of as "all else being equal" indices. This paper uses the index method defined as Laspeyres indices[13]. The indices describe the evolution of energy use that would have taken place if all but one factor remained constant. Table 1 gives an overview of the various measures used for activity, structure and energy intensities in each sector.

This study defines energy savings 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, while the activity and structure of each sector had evolved as they actually did. The activity and structure components can be combined to a measure of demand for energy services. Hence energy savings can also be defined as the difference between energy service demand and actual energy use.

It is important to separate between the different components described in the equation above, since they change for different reasons and in response to different stimuli, e.g. energy prices. Demand for energy service (i.e. the activity and structure components) is related to welfare and economic development, e.g. industrial production, travel activity, appliance ownership, etc. Affecting energy service levels are seldom targets for energy policies. Energy intensities on the other hand are closely related to energy efficiency, and thus the component to which energy efficiency policies are primarily directed.

The distinction between factors affecting energy service demand and energy intensities is crucial when setting energy policy targets. For example, the Select Committee on Energy and Electricity Balance towards 2020 (*Energiutvalget*) in Norway discussed how stationary energy use in Norway could be stabilised by 2020[14]. However, it is difficult to design energy efficiency measures that will meet a target like this as long as growth in energy service levels results from activities and policies outside the normal mandate area for energy policy-makers. Hence to establish targets for energy efficiency policies it is essential to disentangle the factors that are affected by these policies from those that result from, for example, economic development. The approach used in this study examines trends at a disaggregated level, allowing for decomposition of the various components that have shaped and will shape energy developments.

6. TRENDS IN RESIDENTIAL ENERGY USE

Residential energy use in Norway has grown by more than 50 percent over the last 25 years. This is an average growth rate of 1.7 percent per year. The most rapid growth was between 1973 and 1986 at an average rate of 2.45 percent per year. This compares to 0.61 percent per year from 1986 to 1997. Increased use of electricity for space heating is the dominant factor behind the growth. As well, more lighting and use of appliances have driven up energy use, increasing their share of total residential energy consumption from about 15 percent in 1973 to 20 percent in 1997[15]. Even if the share of space heating has fallen since 1973, Norwegians still use about 60 percent of residential energy to heat their homes. The share of electricity in total residential energy use grew from about 50 percent in 1973 to around 80 percent in 1997.

Table 1. Measures of Activity, Sectoral Structure and Energy Intensities

Sector	Sub-sector (I)	Activity (A)	Structure (S_i)	Intensity ($I_i = E_i/A_i$)
Residential		Population		
	Space Heat		Floor area/capita	Heat[1]/floor area
	Water Heat		Person/household	Energy/capita[2]
	Cooking		Person/household	Energy/capita[2]
	Lighting		Floor area/capita	Electricity/floor area
	Appliances		Ownership[3]/capita	Energy/appliance[3]
Commercial/Service				
	Services total	Floor area or Value-added	(not defined)	Energy/floor area or Value-added
Manufacturing		Value-added		
	Paper and Pulp		Share total value-added	Energy/Value-Added
	Chemicals		"	"
	Non-metallic Minerals		"	"
	Iron & Steel		"	"
	Non-Ferrous Metals		"	"
	Food and Beverages		"	"
	Other		"	"

[1] Adjusted for climate variations and for changes in the share of homes with central heating systems.

[2] Adjusted for home occupancy (number of persons per household).

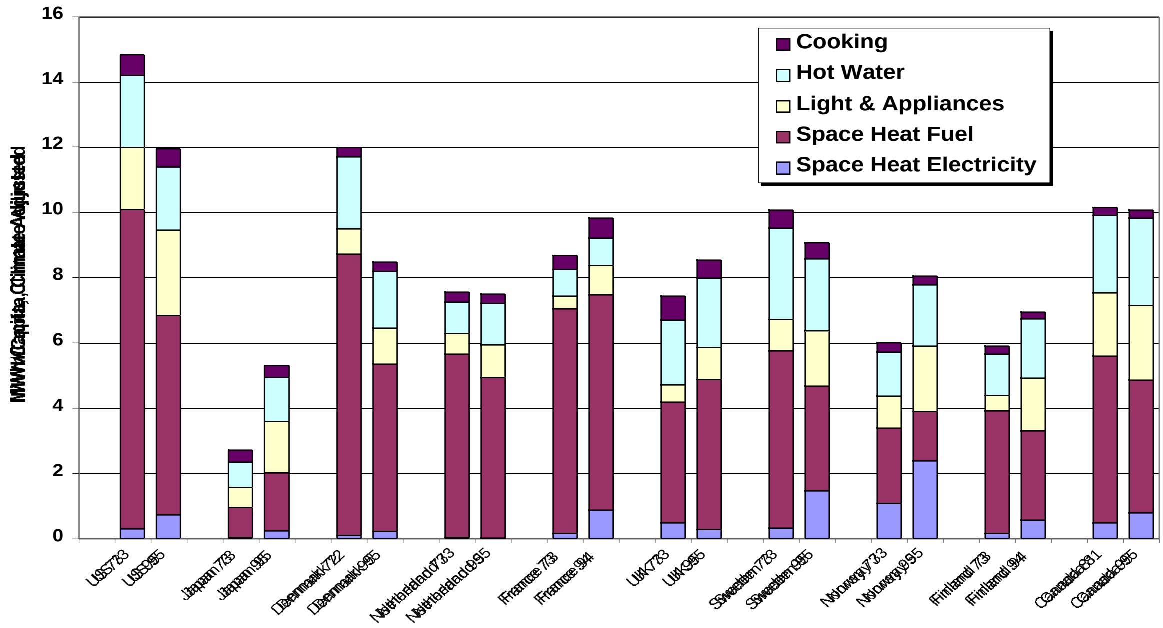
[3] Includes ownership and electricity use for six major appliances.

Even if income levels were relatively low in the early 1970s, Norwegians clearly had above average floor space as measured per capita. Yet, Norwegian homes were smaller than in Sweden and Denmark, where income levels were higher. As incomes rose for Norwegians, house sizes grew bigger. Today Norwegians have the same per capita size residences as in Denmark. The United States is the only country besides Sweden where homes are bigger than in Norway.

Despite the relatively big homes residential energy use in Norway was low in 1973 compared to many other countries, if the cold climate is accounted for. Figure 3 shows each major end-use for Norway and selected IEA countries, with space heating adjusted linearly to 2 700-degree days[16]. Norway's residential consumption in 1973 was well below Sweden and Denmark, and at about the same level as Finland. By 1995 per capita household energy use in Norway had risen significantly compared to other countries. Although residential energy use fell in both Sweden and Denmark, in 1995 Norway still used less energy per capita than its two neighbouring countries.

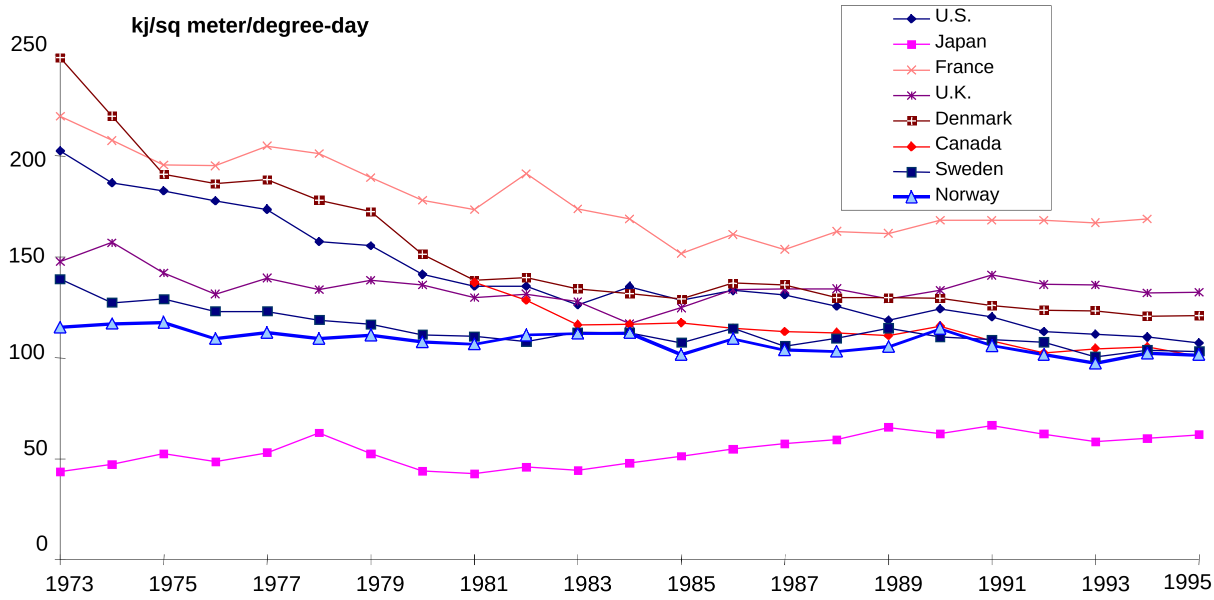
Measured as space heat per square meter per degree-days the space heating intensity in Norway has been among the lowest of the countries shown in Figure 4 throughout the 1973-1995 period. Since heat is expressed in terms of useful energy, the high penetration of electric resistance heaters in Norway does not explain the low intensity. Lower heating levels (heating comfort) in Norwegian homes in the early years shown in the figure may be an important reason for the low intensity. Throughout the 1970s and early 1980s the heating comfort in Norwegian households expanded with a rise in indoor temperatures and the heating of more of the total area[17]. This increase in heating comfort levelled out savings by higher insulation levels as new homes (built with tighter codes) replaced older residences. This helps to explain why the space heating energy intensity in Norway did not decline as much as in other countries in this period. After Norway reached similar income levels as in other "cold" countries in the mid 1980s, heating intensity has fallen at about the same rate as e.g. Sweden, Denmark, and Canada.

Figure 3. Residential energy use (Climate adjusted to 2 700 DD base 18_C)



Today Swedish, Canadian and US homes use about the same amount of heat per area per degree-days as homes in Norway, despite that Norwegian consumers have been endowed with significantly lower prices than in the other "cold" countries[18]. Though residential electricity prices (including taxes) in real terms have increased since the early 1970s prices in Norway are still the lowest among all IEA countries. Danish consumers, for example, pay on the order 2.5 times more. Also residential oil prices in Norway have been among the lowest, and are significantly lower than in Sweden and Denmark.

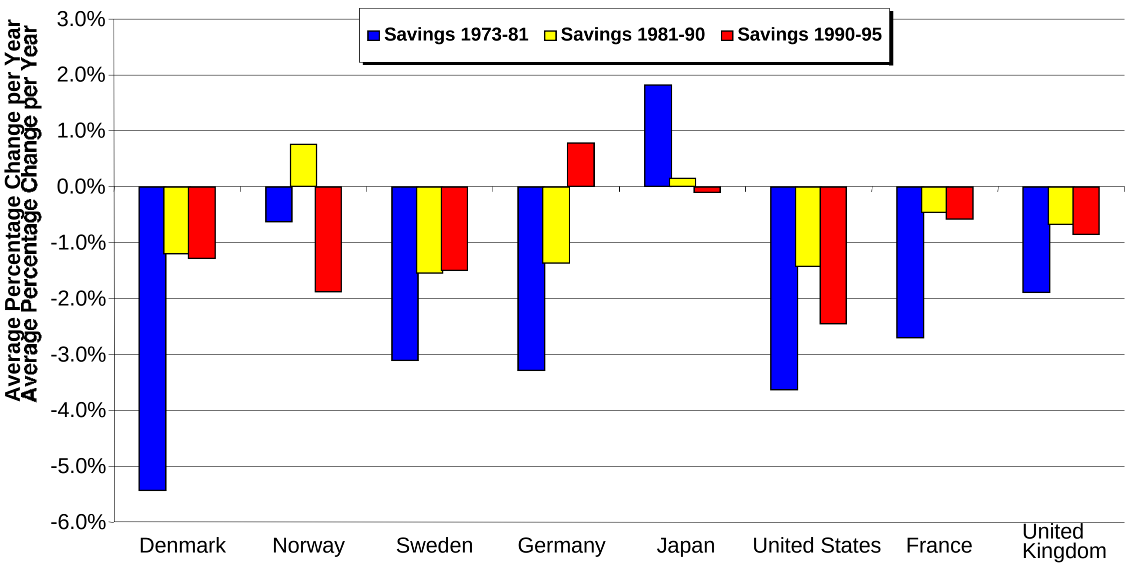
Figure 4. Residential space heating intensity (Useful energy for heating per square metre per degree-day)



As mentioned above energy savings are in this paper calculated as the impact changes in energy intensities have on energy use over time. Figure 5 shows the results for Norway and selected other IEA countries for three time periods. Before 1990 falling energy intensities lead to savings in all countries, except for Japan and Norway (between 1981 and 1990). In both these countries the development can be explained by increasing heating comfort levels through higher indoor temperatures and heating of a larger part of the homes as incomes grew. The small decline in Norway before 1981 more or less neutralised the small increase between 1981 and 1990 so that the total change in energy use between 1973 and 1990 due to intensity changes were zero.

Between 1990 and 1995, however, Norway had the most rapid decrease among all countries, except the United States, at almost 2 percent on average per year. This development may indicate continued improvements in space heating, but this time without loosing the savings through increases in heating comfort. Given that Norwegian electricity prices are among the lowest within the IEA, it may seem surprising that the energy savings rate in Norway in recent years is high relative to most other countries. But price is not the only factor. For example, a cold climate makes it attractive to invest in better insulated houses for comfort reasons. On the other hand, the price per delivered unit of heat is not much lower in Norway than in many other countries, e.g. the price per unit of gas for heating in many places in Europe is comparable to the Norwegian electricity price level.

Figure 5. Energy savings in residential due to changes in intensities



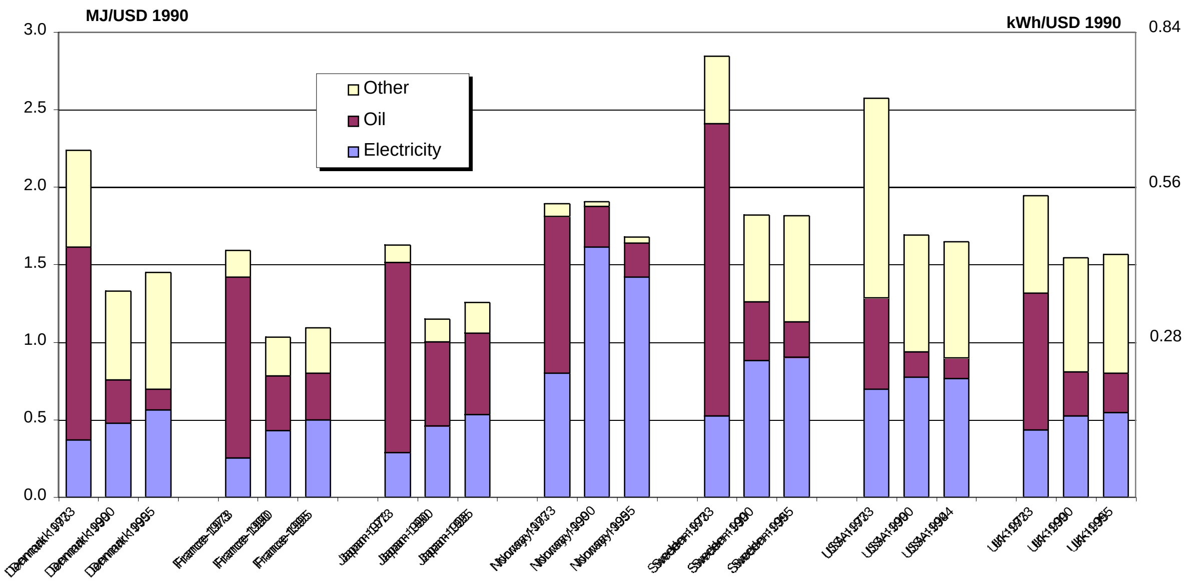
7. COMMERCIAL AND SERVICES SECTOR

Energy use in Norway's commercial/service sector increased steadily from 1973 through 1990, on average 3.5 percent per year. Electricity use grew at an average rate of 7.5 percent, while oil declined at 4.3 percent. From 1990 to 1995 energy use fell on average 1 percent per year through decreased use of both electricity and oil. In the next two years, it rose drastically, averaging about 8 percent per year, led by growing electricity use, though also oil increased somewhat.

Dividing total energy use by value-added yields a measure of aggregate energy intensity in the service sector (Figure 6). Norway is the only country where this intensity did not fall between 1973 and 1990. Over the next five years, however, the intensity in Norway did decline, while it remained stable or rose in most other countries. The values in Figure 6 are not climate-corrected. This makes the development in Norway even more notable since 1990 was a relatively warm year while 1995 was about average. But as mentioned above energy use increased significantly after 1995.

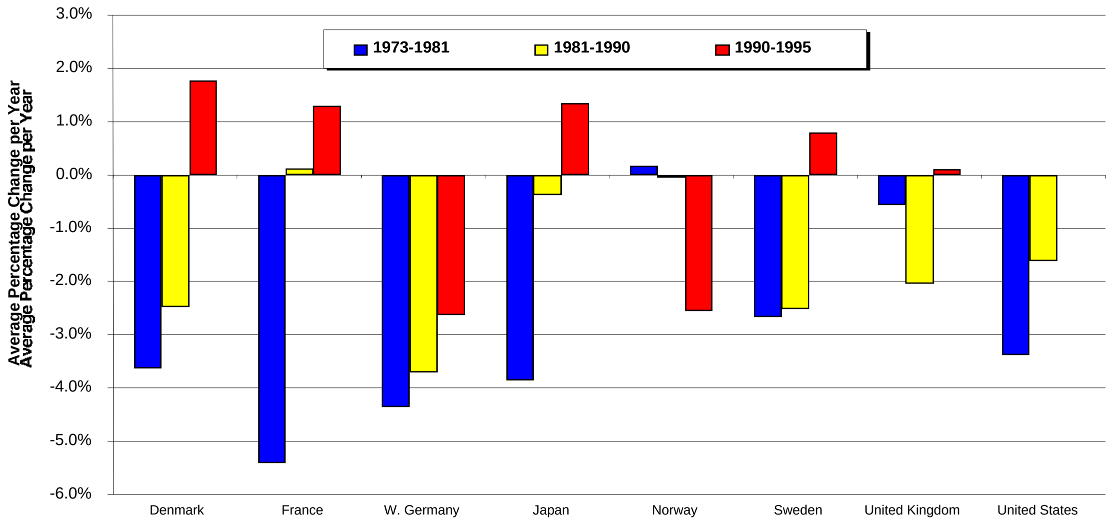
Despite the decline after 1990, energy per value-added in 1995 was among the highest in Norway, along with Sweden and the United States. The differences across all countries are not large, especially considering that the energy consumption data are not climate-corrected. In terms of electricity per unit value-added, however, Norway is undoubtedly highest of all. This can be explained by the widespread use of electricity to heat Norwegian commercial and service buildings, a result of the very low electricity prices compared to most other countries.

Figure 6. Energy per unit of commercial/service sector value-added



Before 1990 falling energy intensities lead to savings in all countries, except for Norway (Figure 7). As for the residential sector there was no net change in the Norwegian intensity between 1973 and 1990. Between 1990 and 1995, however, Norway had the most rapid decrease among all countries, except former West Germany. This development is also consistent with the trend seen in the residential sector.

Figure 7. Energy Savings in Commercial/Service sector due to Changes in Intensities



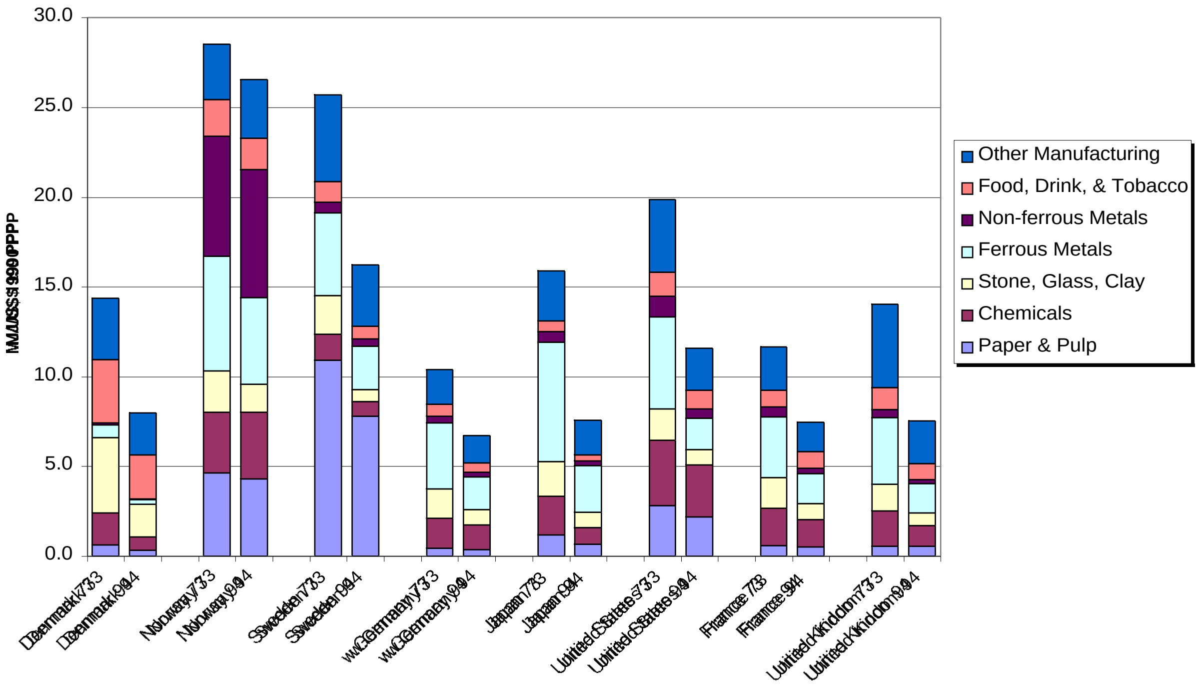
8. MANUFACTURING

Norwegian manufacturing energy use was fairly stable between 1970 to 1992. After 1992, however, energy use increased notably, from about 66 TWh in 1992 to 74 TWh five years later. The use of oil has fallen significantly since the mid 1970s; in 1973 oil accounted for 32 percent of total manufacturing energy use, while it was down to only 9 percent in 1997. Electricity use has increased steadily and accounts today for about 60 percent of total energy use.

Norwegian manufacturing production is low in terms of the relative importance to the economy. In 1995 only 12 percent of the Norwegian GDP originated from manufacturing industries, compared to more than 25 percent in Japan and west Germany. The Norwegian situation can be explained by the rapid expansion of off-shore petroleum production that drained labour and capital resources from the development of new land-based manufacturing industries.

On the other hand, total manufacturing energy use per value-added is higher compared with all the studied countries, see Figure 8. This is not surprising given the high share of energy-intensive raw materials in Norway's manufacturing production. Looking at the absolute values of energy intensities in each of the manufacturing sub-sectors, most Norwegian intensities rank above average. This does not necessarily imply lower energy efficiency than other countries, as there are significant country differences in the product mix within each sub-sector. For example, in Norway the non-ferrous metals sector is dominated by the very energy-intensive production of aluminium and the paper and pulp sector has a higher share of the more energy-intensive pulp production than in most other countries.

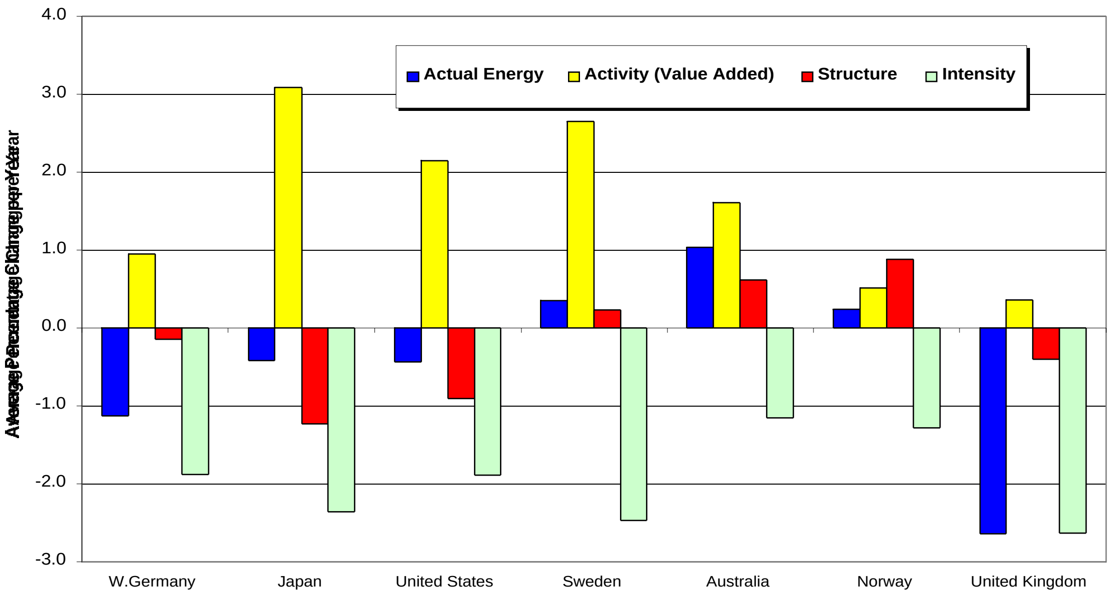
Figure 8. Manufacturing energy use per value added (Aggregate energy intensity)



The expansion of energy-intensive industries has pushed up Norwegian manufacturing energy use. Norway is one of the few countries in this study where structural changes have had an upward effect on energy use. Between 1973 and 1995 structural changes alone would have increased manufacturing energy use by 22 percent, while, for example, structural changes led to a 24 percent decline in Japan over the same period. The third bar in Figure 9 shows the impact that changes in structure, expressed as annual average percentages, had on manufacturing energy use if intensities for each sub-sector are held constant. The structural changes can explain why Norway is one of the few countries studied where aggregate energy intensity (total manufacturing energy per value-added) has not declined much since 1973.

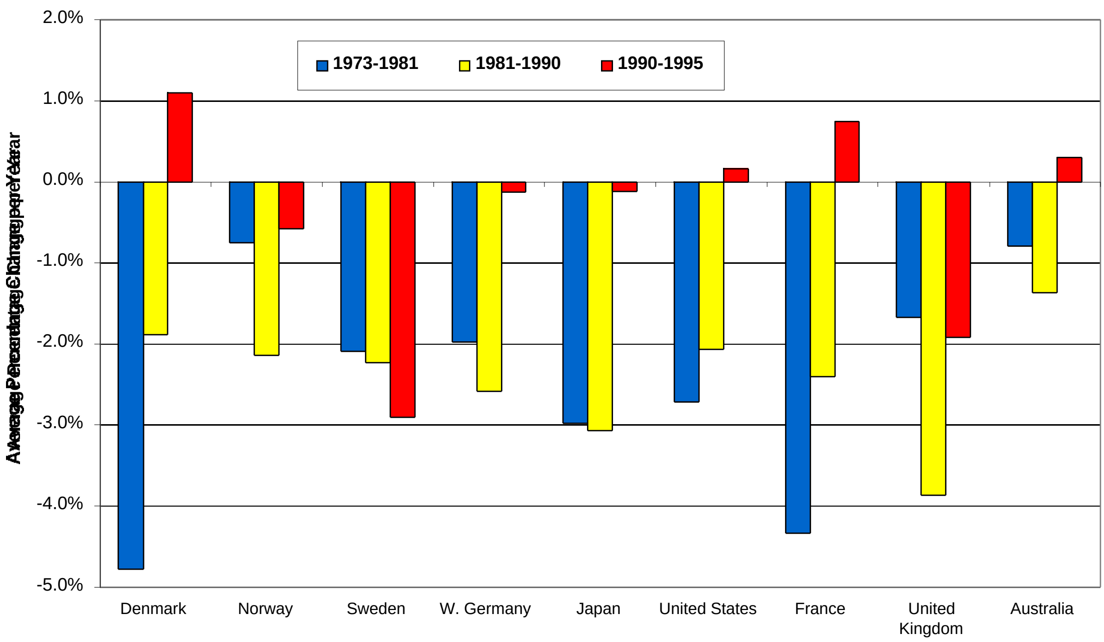
Similarly as for the calculation of the structure effect, the impact of changes in energy intensities can be isolated from the impacts of structural changes by looking at how energy use would have evolved if the aggregate level and the structure of manufacturing production were held constant. The variations in energy use induced by changes in energy intensities alone are shown in the fourth bar in Figure 9. For comparison changes in total energy use (first bar) and activity (second bar) are also shown. All the countries included in this study experienced reductions of energy intensities between 1973 and 1995. The overall reductions led to savings between 1973 and 1995 ranging from only 15 percent in Australia, to about 40 percent in Japan, the United Kingdom, France and Sweden. Norway achieved a 25 percent reduction or somewhat below the average for this group of countries. This reduction was almost enough to compensate for the growth induced by structural changes and increased value added.

Figure 9. Changes in actual energy use, activity, structure and intensities for manufacturing (Percentage change between 1973 and 1995)



The intensity reduction in Norway was not constant over this period, however. Figure 10 shows that only small reductions were achieved up to 1981, during a period when intensities fell rapidly in most countries. Throughout the 1980s intensities in Norway fell at almost the same rate as in many other countries. After 1990 the reduction in intensity slowed in Norway, but still Norway achieved more savings than most countries. With the exception of Sweden, all countries experienced lower reductions than before, in some countries increasing intensities actually led to "negative" savings. This development can to some extent be attributed to the economic recessions many countries went through during the early 1990s. This may have reduced investment in energy efficiency and lowered utilisation of production capacity.

Figure 10. Energy savings in manufacturing due to changes in intensities

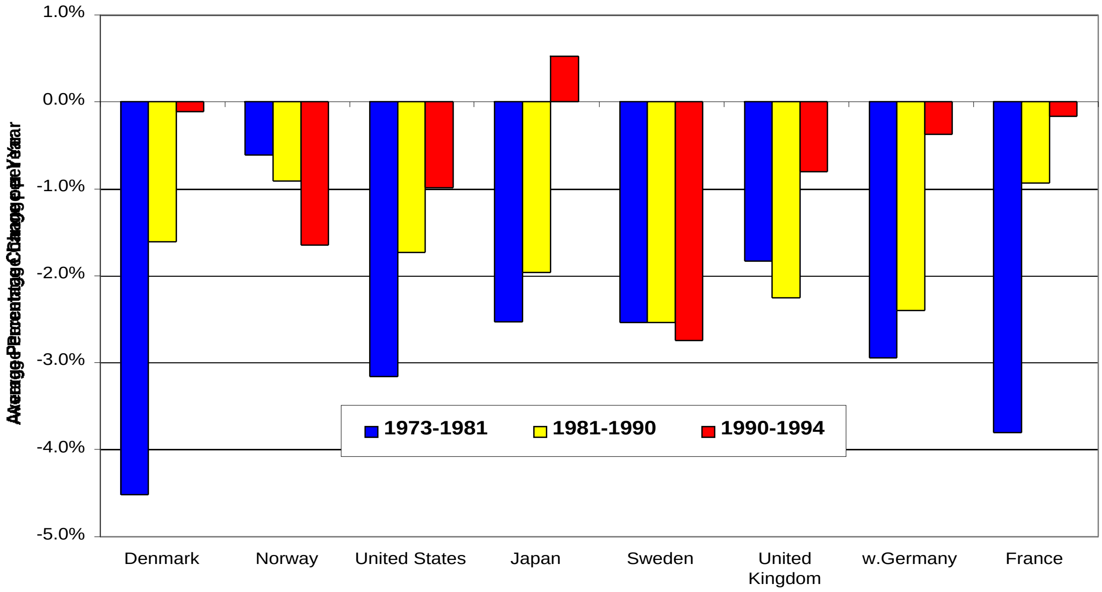


Presumably, the differences in energy savings among countries seen in Figure 10 are partly due to differences in energy prices. The relative importance of oil in the manufacturing industries may also play a role. For example, the relatively low savings after 1973 in Norway may signify that increases in oil prices had less impact on manufacturing energy use because inexpensive hydro power was available, while a higher reliance on oil is likely to have given countries such as Italy and Japan more incentive for improving energy efficiency.

9. SAVINGS OF TOTAL STATIONARY ENERGY USE

Figure 11 shows the energy savings that falling intensities in all three sectors together induced over three periods for selected IEA countries, i.e. adding up the results shown in Figures 5, 7 and 10, using 1990 energy consumption in each sector as weighting factors.

Figure 11. Changes in energy service and energy intensities for stationary energy use



Between 1973 and 1990 intensities fell less in Norway than in the other countries included in the figure. This is especially apparent in the 1970s when many countries achieved significant savings induced by the higher oil prices. As mentioned, Norway was less affected by the oil price increases as it had access to inexpensive hydropower. Relative to other countries the rate of savings in Norway picked up a little in the 1980s, primarily due to higher reductions of manufacturing intensities. After 1990 energy intensities for all three sectors together fell faster than all other countries, expect Sweden. Note the slow-down and even reversal (Japan) of the trend of declining intensities that most countries experienced after 1990. This development can be expected to be partly a result of the economic recessions many countries experienced in the early 1990s and that low oil prices gave little incentive for energy savings.

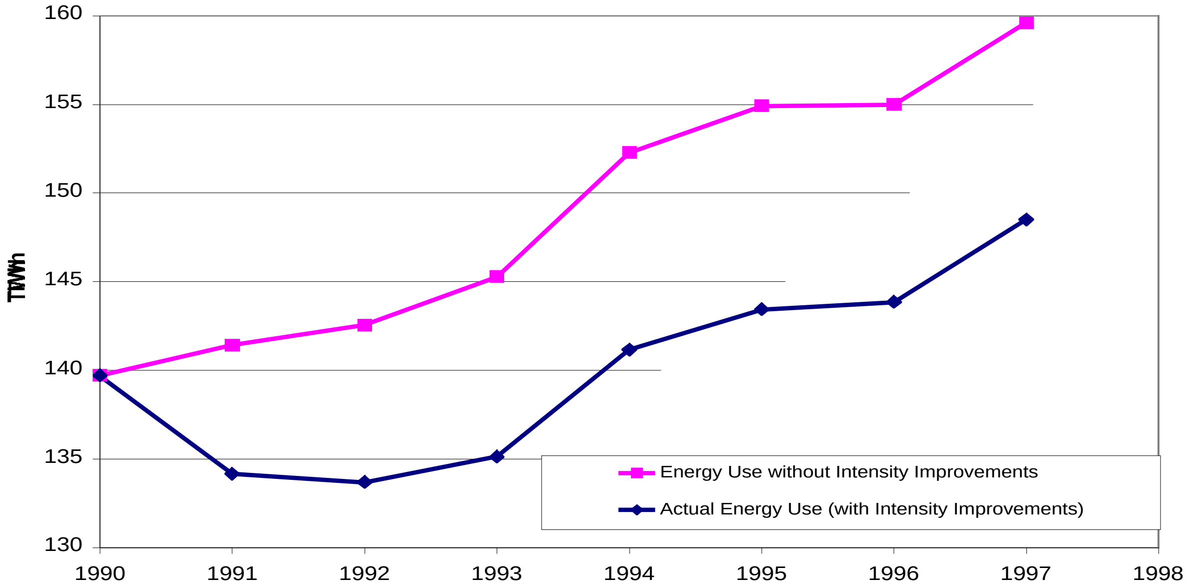
Figure 12 illustrates the development of savings of total stationary energy use in Norway after 1990. The upper line shows the growth in energy use that would have resulted from an increase in energy service demand had intensities remained at 1990 levels.

The lower line shows actual climate-corrected energy use. The difference between the curves increased relatively rapidly in the first two years. It then continued to increase slowly but steadily year by year. In total the savings in 1997 add up to about 11 TWh, relatively equally divided among the sectors in terms of percentage savings of 1990 energy use. But this estimate is subject to many uncertainties, and thus an absolute figure for energy savings should be interpreted with care. There is little doubt, however, that measured according to the method used in this study, significant savings of Norwegian stationary energy use occurred between 1990 and 1997.

10. SUMMARY AND CONCLUSIONS

The results presented in this paper show that only very small levels of savings were achieved in Norway between 1973 and 1981 compared to other countries. This is a period when most other IEA countries saw significant reductions in energy intensities as energy prices increased in the aftermath of the 1973 oil crises. In Norway this development was different due to *inter alia* two reasons: First, the access to hydropower left Norwegian industries and private consumers relatively less affected by the rising oil prices and made room for further expansion of electricity-intensive industries. Secondly, Norwegian income levels were relatively low in the early 1970s compared to many other IEA countries. As income grew with growing revenues from oil exports, indoor heating comfort and ownership of electric appliances increased to the same levels as in e.g. Denmark and Sweden, injecting an upward force on residential energy use.

Figure 12. Norwegian stationary energy use: Impact of changes in energy intensities



In the 1981 to 1990 period the overall rate of energy savings in Norway was higher than during the 1970s. The savings in this period came primarily in manufacturing, where reductions in energy intensities were around the same level as in many other IEA countries. Only small reductions in energy intensities took place in the service and residential sectors. In the residential sector continued increases in heating comfort are expected to have outweighed improvements made in house insulation.

After 1990 total savings of stationary energy use in Norway appear to have taken place at a higher rate than in most other counties included in this study: In the *manufacturing* sector the intensity (corrected for changes in manufacturing structure) fell less after 1990 than during the 1980s. Still the reductions in Norway were more significant than in most other countries during this period as many countries experienced a significant slow-down in the rate of decline or even an increase in intensities after 1990.

In the *service* sector, energy intensity, measured as energy per value-added, also fell more in Norway than in most other countries between 1990 and 1995. However, energy use increased rapidly over the next two years. It is too early to say whether the growth in 1996 and 1997 indicates a longer term tendency in this sector, in which case the savings achieved in the first part of the 1990s soon will be outpaced by increasing energy use per value-added.

Norway's reductions in *residential* sector intensities led those in most other countries. However, it should be noted that there are many sources of uncertainty affecting this calculation. For example, the share of electricity for space heating is estimated and not measured, and there are no data on the development of stock efficiency for electric appliances. But the data analysed do clearly suggest that there has been an effect of de-coupling of energy service demand and energy use in the residential sector in recent years, which has led to energy savings.

Yet, as income levels and expenditures on housing are currently increasing, it can be expected that bigger houses will drive up energy service demand. Also new types of more luxury based energy services, such as the use of electricity for heating driveways, mountain cabins and vacation houses, etc., will have an impact on future electricity use.

11. END-NOTES

[1] Stationary energy use in this study is defined as energy use in manufacturing, residential and commercial/service sectors, excluding energy use for transportation

[2] The countries used in comparisons include Australia, Canada, Denmark, Finland, France, former West Germany, Italy, Japan, the Netherlands, Sweden, United Kingdom, and the United States.

[3] Unander, Fridtjof and Lee Schipper: Trends in Norwegian Stationary Energy Use: An International Perspective, NVE Report 2-2000, Oslo, 2000

[4] For more detail, refer to Indicators of Energy Use and Efficiency, IEA/OECD, Paris, 1997.

[5] Schipper, Howarth, and Wilson, A Long-Term Perspective on Norwegian Energy Use, Lawrence Berkeley National Laboratory, Berkeley, California, 1990.

[6] Barlett, Sarita, The Evolution of Norwegian Energy Use from 1950 to 1991, Statistics Norway, SSB/93/21, 1993.

[7] Unander, Fridtjof, Alm Leif, and Schipper, Lee, Energy Use in Norway, An International Perspective, Institute for Energy Technology, IFE/KR/E-97/006, Kjeller, Norway, 1997.

[8] Differences in manufacturing structure are corrected for by assuming that Norway has the same shares of output branch-by-branch as the IEA average. In the calculation for climate correction, space heating for residential and for service sector has been reduced according to the number of degree-days for Norway and for the IEA-average.

[9] Figure 1 shows final energy, and hence does not take into account the higher end-use efficiency of electric heating and district heat compared to other fuels. If Norway's energy consumption had been calculated assuming the IEA average space heating fuel mix and with assumed oil/gas efficiency of 66 percent and 55 percent for solids, including wood, the third bar for Norway would have been somewhat higher, around the 1973 level shown by the first bar.

[10] The corrections shown in the third bar for Norway in Figure 1 were only applied to total stationary energy use, and not for electricity separately.

[11] The conversion to US dollars in this study is made using Purchasing Power Parities (PPP). In 1990 the conversion rate was 9.73 NOK. GDP for Norway excludes GDP generated in the off-shore petroleum sector.

[12] Unander, F, and L. Schipper. 1999. Trends in Energy Use and Efficiency: On the Road from Kyoto? Published in "Energy Efficiency and CO2 Reductions: The Dimensions of the Social Challenge" ECEEE 1999 Summer Study

[13] Howarth, Richard B. , Lee Schipper, Peter A. Duerr and Steinar Strøm, "Manufacturing Energy Use in Eight OECD Countries", Energy Economics, Vol. 13, No. 2, April, 1991, pp.135-142.

[14] Energi- og kraftbalansen mot 2020, NOU 1998:11. (In Norwegian)

[15] Data separating electricity consumption by end-uses are not available on a regular basis in Norway. Hence the results presented here are partly based on assumptions between years where data are available.

[16] In the international database used for this analysis, Norway has 4 069 degree-days (DD) to base 18_C in a normal year. For comparison, west Germany has 3 116 DD, Sweden 4017 DD, and Canada 4 583, Denmark 3 141, Finland more than 4 800 DD, the United States 2 800 DD and the EUR-4 (Italy, France, UK and former West Germany, weighted by population) 2 700 DD. For this comparison, energy use for space heating has been scaled to 2 700 degree-days Celsius, the average of the EUR-4 and close to that of the United States. This adjustment lowers the space heating figures for Norway, Sweden, Canada and Finland by some 40 percent, lowers those of Denmark by about 10 percent, and increases those for Japan by 50 percent.

[17] This study uses measured total utility area for a building, as data on how much of the area is actually heated are difficult to obtain. According to Energiunders¢kelsen from 1990 (SSB report 92/2) 17 percent of the area in

single family houses is not heated. The area not heated in apartment buildings is much less. It can be expected that the share of unheated area was higher in earlier years when income levels were lower.

[18] The very low value for Japan in Figure 4 is readily explained by far lower indoor temperatures and only intermittent room heating.