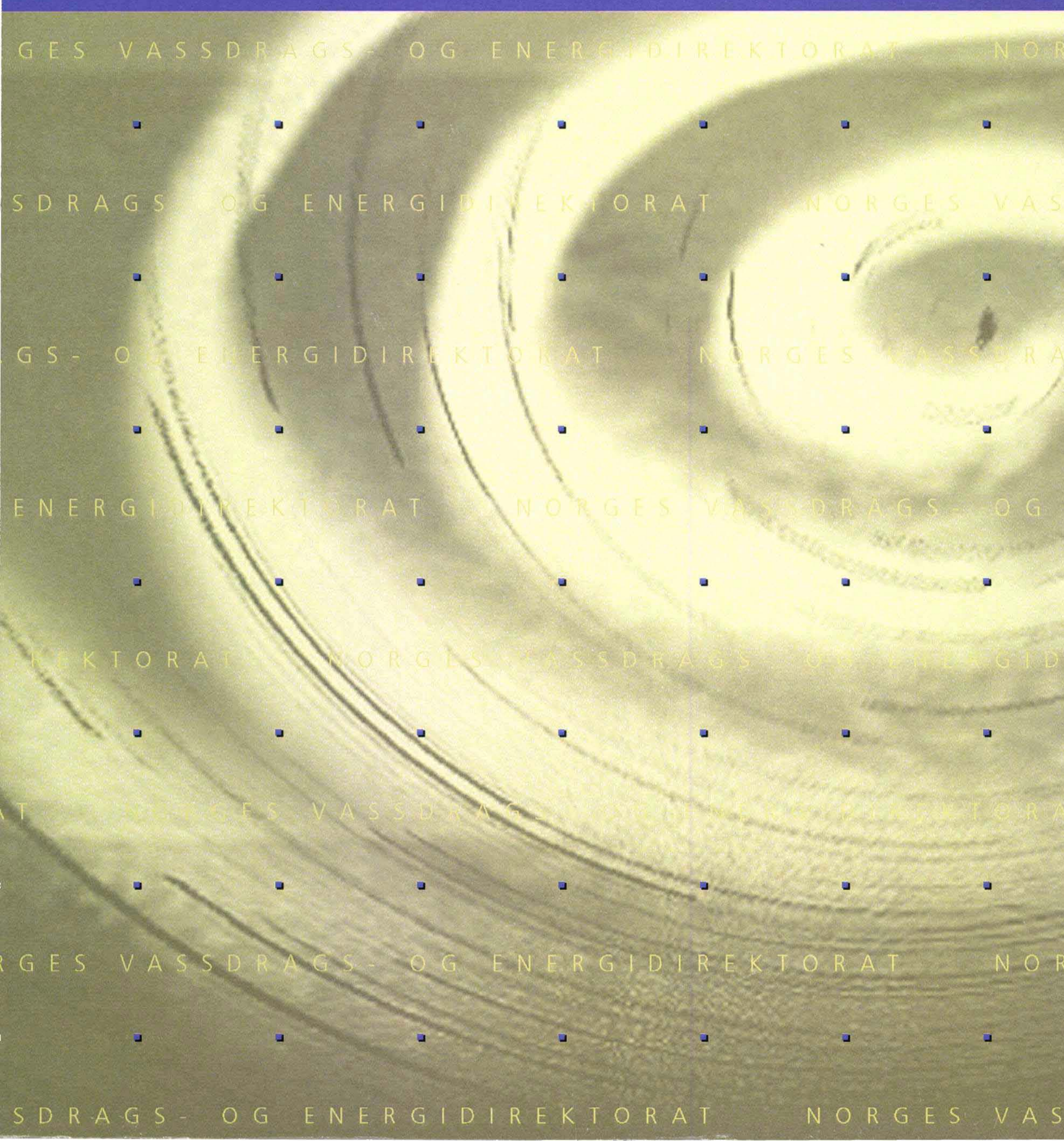
NVE

Trends in Norwegian Stationary Energy Use

An International Perspective

2
2000

REPORT



Report no. 2-2000

TRENDS IN NORWEGIAN STATIONARY ENERGY USE:

Published by: Norwegian Water Resources and Energy Directorate, NVE

NVE contact: Harald Birkeland

Authors: Fridtjof Unander and Lee Schipper, International Energy Agency

Printed by: NVE
Copies: 250
Front Cover: Rune Stubrud, NVE
ISSN: 1502-3664
ISBN: 82-410-0423-0

Summary : This report presents the results of a study comparing trends in stationary energy use in Norway with selected other Member countries of the International Energy Agency (IEA).

Key findings show that considering the cold climate and the energy intensive industry structure, stationary energy use per capita in Norway is not significantly higher than the average of the other countries in the study. However, the per capita electricity use is much higher in Norway.

Per capita stationary energy use has increased in Norway since 1973, contrary to the trend in most other IEA countries. This is partly because the industrial structure has become more energy intensive, homes have become larger and the use of electric appliances has increased. The analysis shows that energy savings in Norway were lagging other countries in the 1970s and 1980s. However, since 1990 savings in the stationary sector in Norway appear to have had a higher rate than in most other countries studied. Measured according to the method in this report savings of about 10 TWh of stationary energy use occurred in Norway between 1990-1997.

The opinions expressed in this report are those of the authors and do not necessarily reflect the opinions of the IEA, NVE or OED.

Subjects: Energy Use, Energy Intensities, Domestic Sector, Commercial and Service Sector, Manufacturing Sector

Norwegian Water Resources and Energy Directorate
Middelthuns gate 29
P.O.Box 5091 Majorstua
N-0301 OSLO

Telephone: + 47 22 95 95 95
Telefax: + 47 22 95 90 00
Internet: www.nve.no

October 2000

TRENDS IN NORWEGIAN STATIONARY ENERGY USE: AN INTERNATIONAL PERSPECTIVE

Fridtjof Unander and Lee Schipper
International Energy Agency
Paris, May 2000

INTERNATIONAL ENERGY AGENCY
9, RUE DE LA FÉDÉRATION, 75739 PARIS CEDEX 15, FRANCE

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-four* of the OECD's twenty-nine Member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions;
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations;
- To operate a permanent information system on the international oil market;
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- To assist in the integration of environmental and energy policies.

**IEA Member countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States. The European Commission also takes part in the work of the IEA.*

FOREWORD

This report presents the results of a study comparing stationary energy use trends in Norway with selected other countries of the International Energy Agency (IEA).[1] 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).

Principal authors of this report are Fridtjof Unander and Lee Schipper of the IEA Secretariat, assisted within the IEA by Celine Marie-Lilliu and Sohbet Karbuz. Debra Justus helped the authors with the final editing of the report. The authors are indebted to Ann Christin Bøeng and Karin Snesrud from Statistics Norway and to Leif Alm, Institute for Energy Technology, Norway, for providing crucial help with the Norwegian data. Marta Khrushch, Mike Ting, Scott Murtishaw and Tom Krackler from Lawrence Berkeley National Laboratory, Berkeley, California, all deserve thanks for assisting in preparing data for the international comparisons.

The opinions expressed in this report are those of the authors and do not necessarily reflect the opinions of the IEA, NVE or OED.

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

TABLE OF CONTENTS

List of Figures

Trends in Norwegian Stationary Energy Use: An International Perspective

SUMMARY

This study provides an analysis and international comparison of stationary energy use in Norway and selected other International Energy Agency (IEA) Member countries.[2] Stationary energy use in this study is defined as energy use in manufacturing, residential and commercial/service sectors, excluding energy use for transportation. The methodology applied is based on the disaggregated indicator approach that the IEA is using to analyse trends in energy use in its Member countries.

Overall Results

Considering the cold climate and its industry structure, energy use in Norway is *not significantly higher* than the average of countries in this study

Energy use in the manufacturing, residential, commercial/service sectors (i.e. stationary energy) in Norway is relatively high compared to most other IEA countries. Measured on a per capita basis, 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 levels of stationary energy use are just above average for the thirteen IEA Member countries included in this analysis.

But *electricity* use is higher than anywhere....

Electricity use in Norway is very high; no other IEA country comes close to the levels consumed per capita in Norway. This can partly be explained by the high share of electricity-intensive industries in Norwegian manufacturing, and partly by the high penetration of electricity to heat homes and service buildings and to produce industrial process steam. The considerable amounts of electricity used for thermal purposes in Norway is not surprising given its vast hydropower resources, which have traditionally provided Norwegian industries and homes with cheap electricity. But as further development of hydropower is limited and other alternatives are likely to be more costly and/or emit CO_2 emissions, controlling demand growth via energy efficiency measures has become ever more important.

Contrary to most other countries stationary energy use has *increased* since 1973....

..but how much of the increase is due to structural changes and activity growth, and what has happen to efficiency?

Though the climate and structure-adjusted level of stationary energy use in Norway is not higher than the IEA-average, per capita energy use has increased in Norway since 1973, contrary to trends in most other IEA countries. This is because Norway's manufacturing structure has become more energy intensive (higher share of energy-intensive products in total manufacturing production), homes have became bigger, and Norwegians today own and use more electric appliances. 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 also can be expected that energy savings in Norway have not been as significant as in IEA countries where prices have been higher.

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

IEA's method for estimating energy savings

To estimate the effects of energy savings this study attempts to isolate changes in energy use resulting from changes in the demand for energy service (driven by sectoral activity levels and structure) and changes in energy intensities (energy use per unit of activity). Changes in energy intensities, e.g. changes in space heating per house area, electricity use per appliance, energy use per value-added in manufacturing, etc., are related to energy efficiency and hence important to track in order to evaluate energy savings over time.

Savings Before 1990

Small savings in Norway during the 1970s

The results 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.

1981-1990: Savings in manufacturing, less in residential and services

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.

Savings After 1990

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:

Significant savings in residential

Norway's reductions in *residential* sector intensities led those in most other countries. According to the calculation method used in this study, the reduction of intensities in the residential sector corresponds to savings on the order of magnitude of 4 TWh between 1990 and 1997. 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.

Service sector savings through 1995, but...

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. In total the reductions of energy per value-added between 1990 and 1997 correspond to savings of about 2.5 TWh. 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.

Slow-down in manufacturing, but still more savings than in most other countries

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 or even an increase in intensities after 1990. This development can be explained by the recessions that many countries went through during the early 1990s. The reductions in Norway indicate savings of energy use per value-added in manufacturing of about 4 TWh between 1990 and 1997.

Total savings of stationary energy use

In total the energy savings for all three sectors add up to about 10 TWh, relatively equally divided among the sectors in terms of percentage savings of 1990 energy use. Although this estimate is subject to many uncertainties, there is little doubt, that measured according to the method used here, significant savings of Norwegian stationary energy use occurred between 1990 and 1997.

CHAPTER 1: OVERVIEW

1.1 Norway's Energy Situation

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.

Yet, the significance of the electricity-intensive industries to the economy became less pronounced when Norway started to export oil in 1973 just as the rest of the industrial world faced recessions induced by dramatic increases in oil prices and demand restrictions. Since then, Norwegian oil exports, and subsequently natural gas production, have grown steadily. In 1997 the petroleum sector contributed almost 20 percent to the national GDP. Oil revenues have made Norway rich. Today Norway enjoys one of the highest standards of living in the world. But the expansion of the capital-intensive petroleum sector has had its consequences; measured as a share of GDP, Norway has the lowest manufacturing production of all IEA countries. In fact outside the electricity-intensive industries, Norwegian manufacturing does not produce much more today (in 1990 Norwegian kroner) than it did three decades ago. This leaves Norway with an economy very dependent on the production of raw materials.

The expansion of energy-intensive industrial production together with increased energy demand in the residential, and commercial/service sectors - related to higher disposable incomes - has led to a rise in stationary energy use per capita over the last twenty years. This is contrary to the development in most other IEA countries. Furthermore, as a large and increasing share of the stationary energy consumption is based on electricity, Norway has higher electricity consumption per capita than any other country in the world. In fact, electricity use in commercial/service and residential buildings alone is higher than total per capita electricity use in almost any other country.

Traditionally, electricity demand growth has been met by developing more hydropower. This has provided Norwegian industry with low-priced, long-term electricity contracts and private consumers with cheap electricity for both space heating and electrical equipment. Today, however, Norway has more or less reached the limit of how much hydropower that can be developed at a competitive cost without unacceptable environmental consequences. As an alternative, natural gas-fired power generation has been debated at regular intervals over the past decade. But this issue is now highly controversial as conventional gas-fired power stations will increase domestic CO_2 emissions, all else being equal, and thus put additional pressure on meeting Norway's Kyoto commitment.

In the meantime, Norway increasingly relies on imported electricity from primarily fossil fuel-based generation in Denmark to meet demand above the capacity in the national power system. This in turn increases Denmark's CO_2 emissions. A key issue in the Norwegian debate is whether new gas-fired power generation will displace the more carbon intensive generation in Denmark and hence lead to reduced global emissions, or if the added capacity will contribute to lower prices in the northern European electricity market and thus inject a upward force on demand and emissions.

Further discussion of supply-side issues and the emission consequences of building conventional gas-fired power stations in Norway is not in the scope of this report. Instead the report focuses on explaining factors behind changes in energy demand patterns in Norway and other IEA countries for manufacturing, residential and commercial/service sectors. Particular attention is given to the analysis of how well rates of energy savings are keeping up with demand pressure from increasing human and economic activity levels.

1.2 Scope

The report provides an analysis and international comparison of stationary energy use in Norway and selected International Energy Agency (IEA) Member countries.[3,4] Not all countries are included in every comparison, but those selected are representative of both the key trends and the extremes. Moreover, a special effort has been made to select countries whose manufacturing mix, climate, or geography are similar to those in Norway, while pointing out differences in key characteristics.

The analysis is introduced in chapter 3 with a brief summary of aggregate trends in energy use through 1997.[5] Details on the evolution of energy use in the residential, commercial/service and manufacturing sectors are presented in chapters 4, 5 and 6. They focus on comparing the structure and intensity of energy use in each sector across countries. Due to data limitations for some countries, the period covered by this analysis is 1973 to 1995. Chapter 7 focuses on recent trends in Norwegian stationary energy use between 1990 and 1997, drawing on the lessons learned from the international comparisons in the previous chapters.

The methodology used in the study is based on the IEA indicator approach. A brief overview is provided in chapter 2.[6] 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[7]; Bartlett (1993) for energy use to 1990[8]; and Unander, Alm and Schipper (1997), who extended the analysis to 1993.[9]

1.3 Objectives

Through detailed analysis of long-term trends in Norway and comparisons with other countries, this study aims to explain several elements of Norwegian energy use:

- how and why energy use patterns in Norway differ from other IEA countries;
- how sectoral trends in the structure of energy use differ;
- how key energy intensities compare;
- how long-term energy savings compare across countries.

With a special emphasis on the most recent developments in Norway, the study also addresses:

- what are the impacts of energy savings since 1990;
- which end-uses and sectors contributed to the savings.

Further, the study evaluates the available data for describing stationary energy use in Norway. The availability of consistent annual data at a level disaggregated enough to describe important end-uses and the activities driving their energy demand is important for several reasons. First, it facilitates a better understanding what has caused changes in the past. This, in turn, is important when assessing future developments and evaluating energy efficiency and climate policies. The availability of such data is also necessary when measuring how existing policies are progressing. Additionally, ensuring

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

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

[5] As only preliminary Norwegian data were available for 1998 at the time of this analysis, the discussions on Norway focus primarily on trends through 1997.

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

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

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

[9] 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.

that the data are internationally consistent allows for transparent comparisons across countries. This is important when explaining why countries at similar stages of economic development differ widely in their energy use.

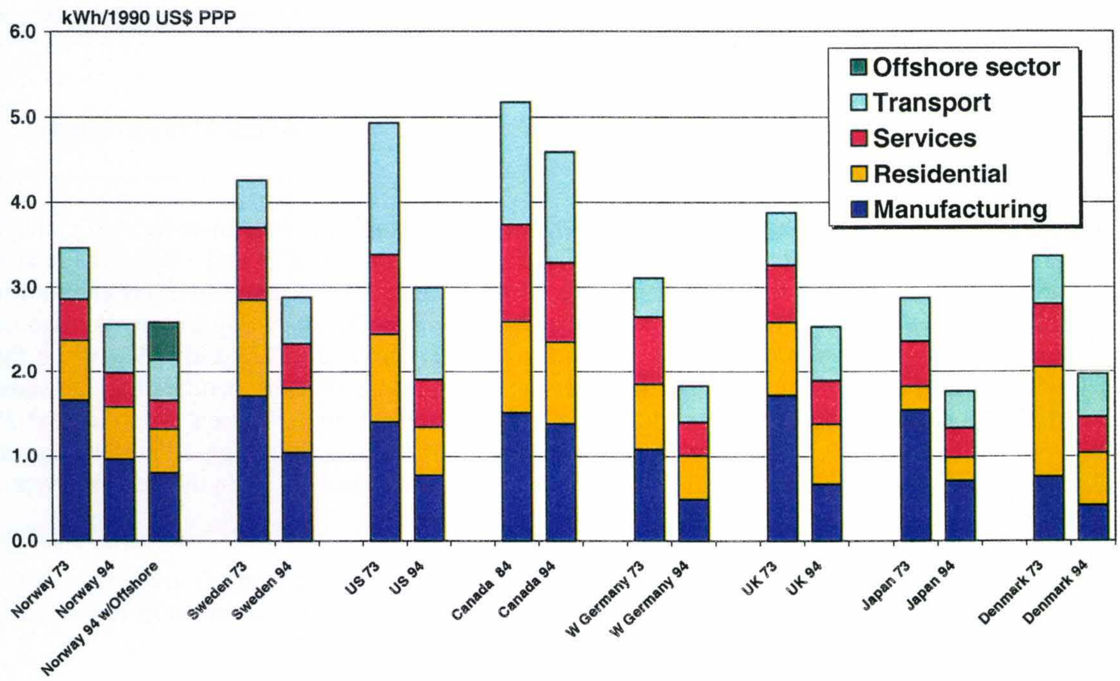
The following chapter illustrates how the disaggregated IEA approach can be used to better understand these differences better and how it can be applied to study trends in energy use. Those trends are the focus of the subsequent chapters.

CHAPTER 2: HOW TO MEASURE ENERGY USE DEVELOPMENTS

2.1 *Energy per GDP*

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 2.1 shows this ratio for a selection of IEA countries for 1973 and 1994.[10] Energy use (excluding mining, agriculture, and construction) is grouped by main sectors: manufacturing, residential, commercial/service, and transport and divided by total GDP.[11] Clearly countries use very different levels of energy to fuel their economies. The figure includes two bars for Norway in 1994: one shows "on-shore" energy use divided by "on-shore" GDP; the second bar is total energy and total GDP, including energy and GDP generated by the off-shore petroleum sector. The figure shows that including the off-shore sector only has a small impact on the energy to GDP ratio, i.e. the off-shore sector consumed approximately the same amount of energy per GDP generated in that sector as the land-based part of the Norwegian economy.

Figure 2.1
Total Final Energy per GDP for Selected IEA Countries



In 1994 Canada used about 2.5 times as much energy per GDP as Japan, Denmark and west Germany. 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. Table 2.1 shows the

[10] The conversion to US dollars is made using Purchasing Power Parities (PPP). In 1990 the conversion rate was 9.73 NOK.
[11] Transport is included in the figure as it is an important component of the energy used to produce a unit of GDP. Careful comparison of 1973 and 1994 shows that in virtually all countries, the significance of transportation increased because more energy was saved in other sectors, and because in most countries transport activity levels such as car ownership and freight volumes grew more than activity levels in other sectors. The rest of this report only addresses developments in the stationary energy use sectors. For more detailed discussion of transport trends in IEA countries, refer to Schipper, L. and Lilliu, C., "*Carbon Dioxide Emissions from Transport in IEA Countries: Recent Lessons and Long-term Challenges*". Kommunikations Forsknings Beredning, Stockholm, 1999.

variations in some of the factors that have an important influence on energy use, but are not directly related to energy, or are not areas to which energy policies are primarily directed. Differences in energy prices are also shown, as these often reflect non-energy factors, e.g. resource base, industrial policy, distributional policies, fiscal reasons.

Table 2.1

Variations Across IEA Member Countries

Primary energy per GDP:	Varies by a factor of 2.5
CO_2 per GDP:	Varies by a factor of 2.5
Climate:	Heating degree-days varies by a factor of 5
Car use:	Distance driven per capita varies by a factor of 3.5
Freight:	Tonnes hauled varies by more than a factor of 2
Home size:	Area per capita varies by a factor of 2
Household size:	Numbers of persons per household varies by a factor of 1.5
Service buildings:	Service building area to service GDP varies by almost a factor of 2
Manufacturing structure:	The share of energy-intensive raw materials in total GDP varies by a factor of 2.5
Energy prices:	Road fuel varies by a factor of 3 Heating fuel by a factor of 2 Electricity by as much as a factor of 3 The difference between coal and natural gas prices within a country varies by a factor of 3

To what extent do changes in energy per GDP over time reflect improvements in energy efficiency? Figure 2.1 indicates big differences in how much this ratio fell between 1973 and 1994. This is also evident from Figure 2.2, where stationary energy per GDP is shown for the same countries and for the IEA average.[12] 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 (Figure 2.2). 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.

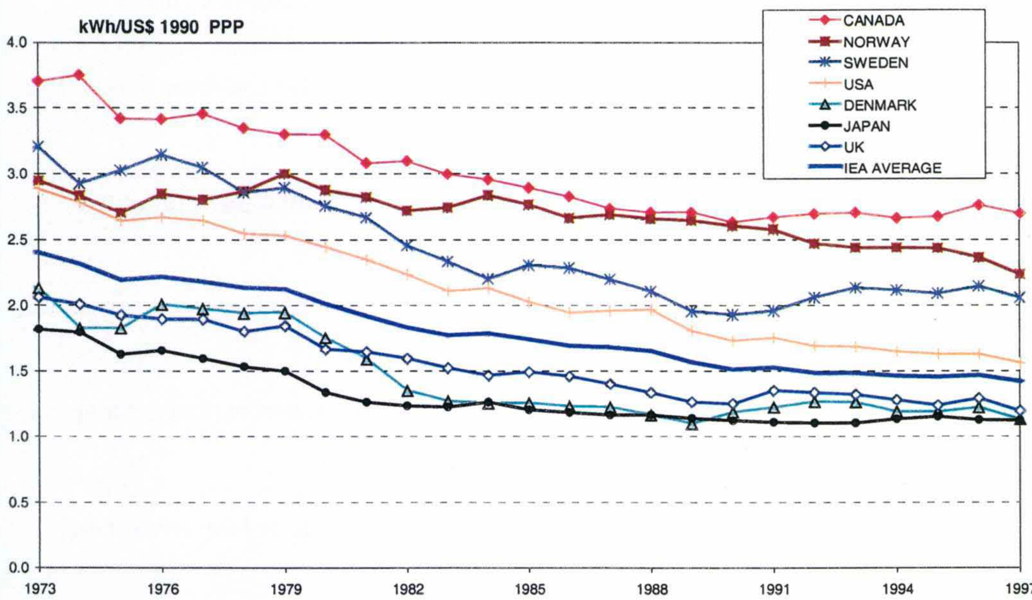
Does this mean that the rate of efficiency improvements in Norway was that much lower than in the United States and until 1990 in Sweden? And has the rate of efficiency improvement in recent years really been so notably better in Norway compared to many other countries?

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. This has been the case in several IEA countries, e.g. the United States. In Norway, on the other hand, the share of raw materials production in total value-added from manufacturing has increased. This has moved the sector towards a more energy-intensive

[12] Energy data for this figure are taken from the IEA energy balances database. These data differ slightly from the IEA indicator databases used in most of the analysis in this report. The latter database has a more detailed sectoral breakdown, which is needed for the sector trend analysis, but does not cover all countries. Hence to allow for calculating IEA average the more aggregated database is used in Figure 2.2.

structure, injecting an upward force on the energy per GDP ratio, all else being equal. These structural shifts alone would then imply that the development of energy per GDP shown in Figure 2.2 underestimates the energy savings rate of the Norwegian economy compared to, for example, the United States. To better isolate factors that affect energy efficiency developments more disaggregated measures than energy per GDP are clearly needed.

Figure 2.2
Stationary Energy per GDP Over Time *



*GDP for Norway excludes GDP generated in the off-shore petroleum sector.

2.2 A Disaggregated View of Energy Use Developments: The IEA Indicator Approach

The IEA and many of its Member countries are increasingly using a disaggregated method to analyse energy use. This *indicator approach* is a useful tool to provide more insights on energy use developments than can be read from the broad energy per GDP trends. An *indicator* is a factor relating energy or emissions to the activity that drives the demand and results in emissions. For example, the amount of energy used to heat a house to a certain temperature is not just related to the size of the house, but also to climate, insulation level and the choice of heating equipment. An indicator for household heating can thus be defined as the delivered energy to the house per unit of area, corrected for climate. Changes in this indicator give an indication of how the residential space heating efficiency is developing, i.e. how changes in insulation standards and equipment efficiency is affecting space heating demand. To further exclude impacts from changes in heating equipment the same indicator can be expressed as useful energy per area, indicating how much energy is actually used to heat a certain space. (See box "Key Terms").

Key Terms

Delivered energy or final consumption ***("Bruttoenergi" or "tilført energi" in Norwegian):***
Energy delivered, for example, to a building, factory or fuel tank and ultimately converted to heat, light, motion or other energy services, i.e. energy the consumer actually purchases. Transformation and distribution losses are not included.

Primary energy:
Delivered energy plus losses incurred in converting energy resources into purchased heat and electricity. Primary energy figures are not included in this study as no considerations of energy supply are made.

Useful Energy ***("Nettoenergi"or" nyttiggjort energi" in Norwegian)*****:**
Delivered energy minus losses estimated for boilers, furnaces, water heaters and other equipment in buildings; used for estimates of heat provided in space and water heating.

Energy Units:
This report uses primarily kWh or TWh as units for energy. In some figures MJ or PJ is used instead. The conversion between these units is: 1 kWh = 3.6 MJ.

Energy intensity:
Energy "consumed" per unit of activity or output.

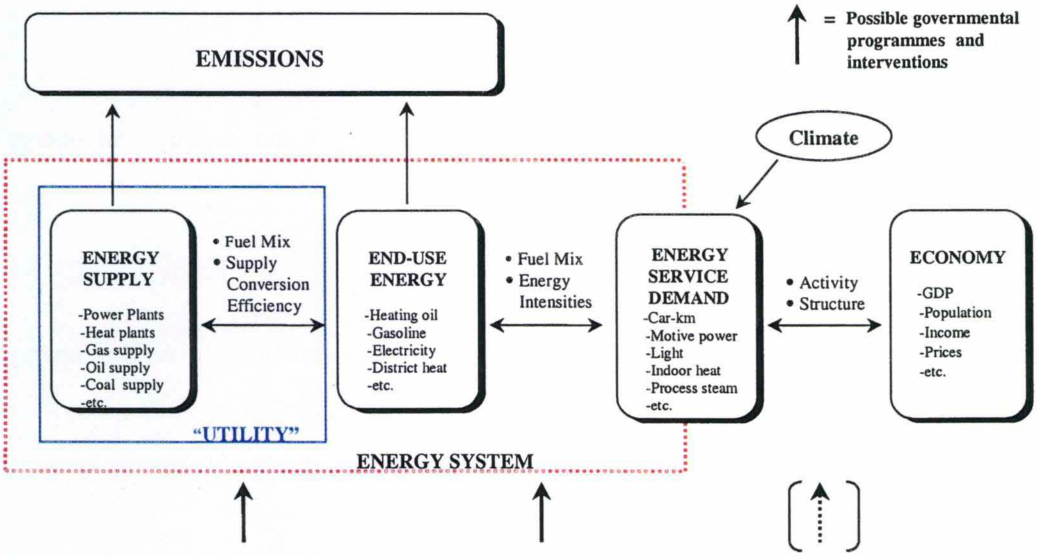
Activity or output:
Basic unit of accounting for which energy is used, e.g. in space heating, it is house area; in manufacturing, it is the production measured as value-added in real terms.

Structure:
Refers to the activity mix, e.g. a measure of different energy end-uses in households, and the shares of each branch to total manufacturing value-added.

Energy services:
Implies actual services for which energy is used: heating a given amount of space to a standard temperature for a period of time, etc. In this study, energy services combine activity and structure.

Figure 2.3 illustrates how the indicator approach can be used to break down changes in energy use and CO_2 emissions into different components. It illustrates the links between the general economy and consumers' demand for different kinds of energy service, the energy system to supply these services and the resulting emissions. The demand for energy service is driven both by the activity levels in the different sectors of the economy, and the structure within each of these sectors. Examples of *activity levels* are value-added in manufacturing branches and house area for space heating. Examples of the *structure* component are the mix of branches in manufacturing and the mix of different end-uses for residential. Furthermore, the evolution of activities and structure within the economy is dependent on factors like GDP, population, income distribution and prices, as well as geographic aspects like climate. The end-use energy required to satisfy the demand for energy service is expressed as delivered, or final, energy per unit of activity, which is termed energy intensity. By including supply-side losses for each energy carrier and multiplying all fuels by their emission factor, the emissions resulting from each of the activities in the sectors can be calculated.

Figure 2.3
Model of Energy/Emission Indicators



Using the indicator approach, observed changes in the end-use of energy can be separated into changes in activity, structure and energy intensities. The approach can be extended to consider CO_2, emissions through decomposing emissions into changes in fuel mix and in supply-conversion efficiency and the above mentioned factors affecting end-use. 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 overall sectoral activity (e.g. value-added in manufacturing),

S represents sectoral structure (e.g. shares of output by manufacturing sub-sector *i*),

I represents the energy intensity of each sub-sector or end-use *i* (e.g. energy use/real US$ value-added)

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. They describe the evolution of energy use that would have taken place if all but one factor remained constant. Table 2.2 gives an overview of the various measures used for activity, structure and energy intensities in each sector.

While the formula above 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, the ***activity effect*** can be calculated as:

$$\%\Delta E_A = (A_t \sum_{i=1}^{n} S_{i0} I_{i0} - E_0) / E_0$$

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

$$\%\Delta E_S = (A_0 \sum_{i=1}^{n} S_{it} I_{i0} - E_0) / E_0$$

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

$$\%\Delta E_I = (A_0 \sum_{i=1}^{n} S_{i0} I_{it} - E_0) / E_0$$

The indices defined above are known as Laspeyres indices.[13]

Energy savings can be defined 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. This can be measured as:

$$\%Esavings = (A_t \sum_{i=1}^{n} S_{it} (I_{i0} - I_{it}) / E_0$$

Combining the two equation components for activity, ΔE_A, and structure, ΔE_S, gives a measure of demand for *"**energy service**"* in a given year. Energy savings as defined by the equation above are then simply the difference between energy service demand and actual energy use.

It is important to separate the energy intensity component from those related to individual and companies' demand for energy service, since they change for different reasons and in response to different stimuli, e.g. energy prices. Demand for energy service 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

[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)

trends at a disaggregated level, allowing for decomposition of the various components that have shaped and will shape energy developments.

Table 2.2

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.

CHAPTER 3: STATIONARY ENERGY USE IN NORWAY AND OTHER IEA COUNTRIES

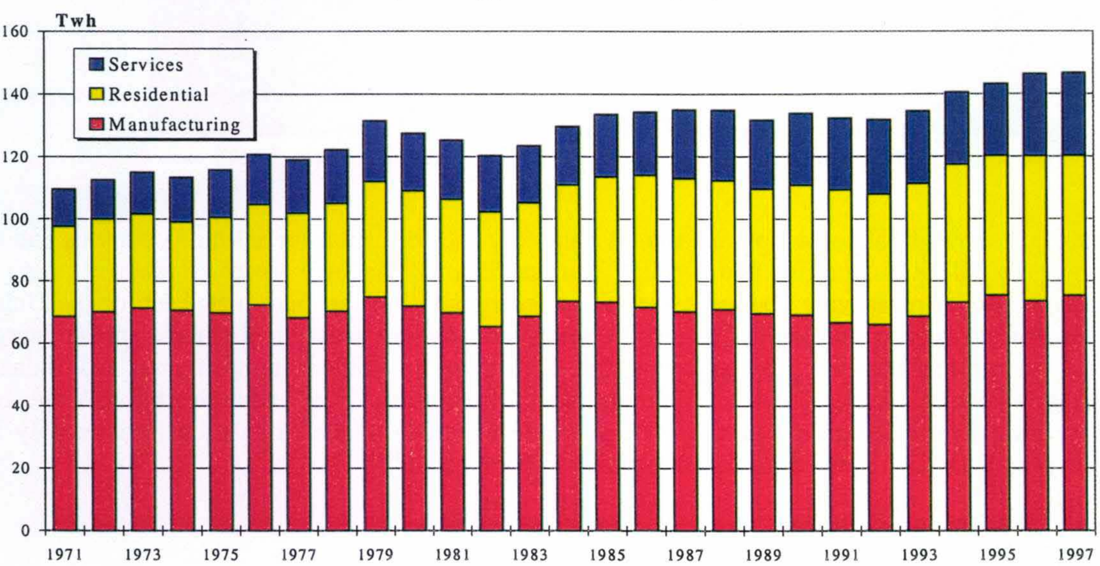
3.1 Trends In Aggregate Energy Use

As discussed in Chapter 2, total energy use per unit of GDP declined in Norway and in almost every other IEA country over the last decades. In most countries, including Norway, *total* energy use itself increased, primarily driven by growing demand in transport. In Norway also stationary energy uses have grown since 1973, contrary to the development in most other IEA nations. Figure 3.1 shows that in Norway stationary energy use peaked in 1979, at a level that was again reached in 1985. After a few years at that level, energy use declined a little around 1990 and then started climbing again in 1993.

The drop in the early 1980s is to some extent due to a shift from oil to electricity for space heating and industrial process heat. Electricity has a higher efficiency in conversion from final energy to useful energy than oil. Thus final energy demand goes down, all else being equal, for example, when an oil boiler is replaced with an electric boiler or a resistance heater for space heating. This does not mean that the energy end-use has become more efficient: heating a room or producing one unit of steam for pulp manufacturing still require the same amount of useful energy.

Figure 3.1 illustrates that manufacturing energy use fluctuated, although the variations are fairly small: the minimum levels in 1982 and 1992 were about 10 percent less than the maximum levels in 1979 and 1995. Energy use in the commercial/service and residential sectors has been climbing steadily as private income and services production increased. As a result, the manufacturing share of total stationary energy use fell from 62 percent in 1973 to 50 percent in 1992.

Figure 3.1
Stationary Energy Use in Norway by Sector*



* Residential heating is adjusted for year-to-year climate variations that affect space heating, (see Chapter 4).

Total stationary energy use increased by 16 percent totally between 1973 and 1990, and by 10 percent between 1990 and 1997, in which all the growth was in the last 4 years. Increased electricity use clearly has driven up total energy use in all three sectors. Figure 3.2 shows how the use of the main fuels and electricity in the stationary sectors has developed between 1970 and 1997. Electricity use grew steadily until 1990 with an average annual growth rate of 3.1 percent between 1970 and 1990. It then levelled off until 1997 after which energy use grew by 4 percent in 1997.

Oil use has been significantly reduced over the period, most notably between 1979 and 1984 when stationary oil consumption declined from 37 TWh to 18 TWh. Increasing oil prices and access to cheap electricity as an alternative for space heating and production of process steam are the main reasons for the decline. Note, however, that oil use increased somewhat after 1993.

Coal and coke are primarily used in heavy industries. Their use has remained relatively constant over the period. The use of biomass has increased both for space heating and in manufacturing, especially as an alternative to oil in the paper and pulp industry.

Figure 3.2
Stationary Energy Use in Norway by Fuel
1970-1997

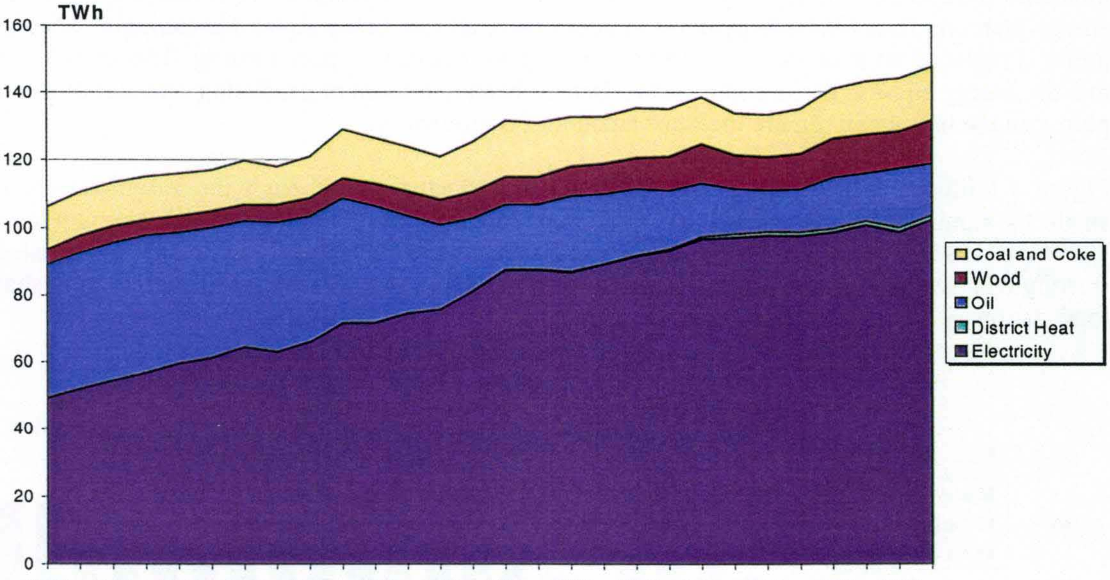
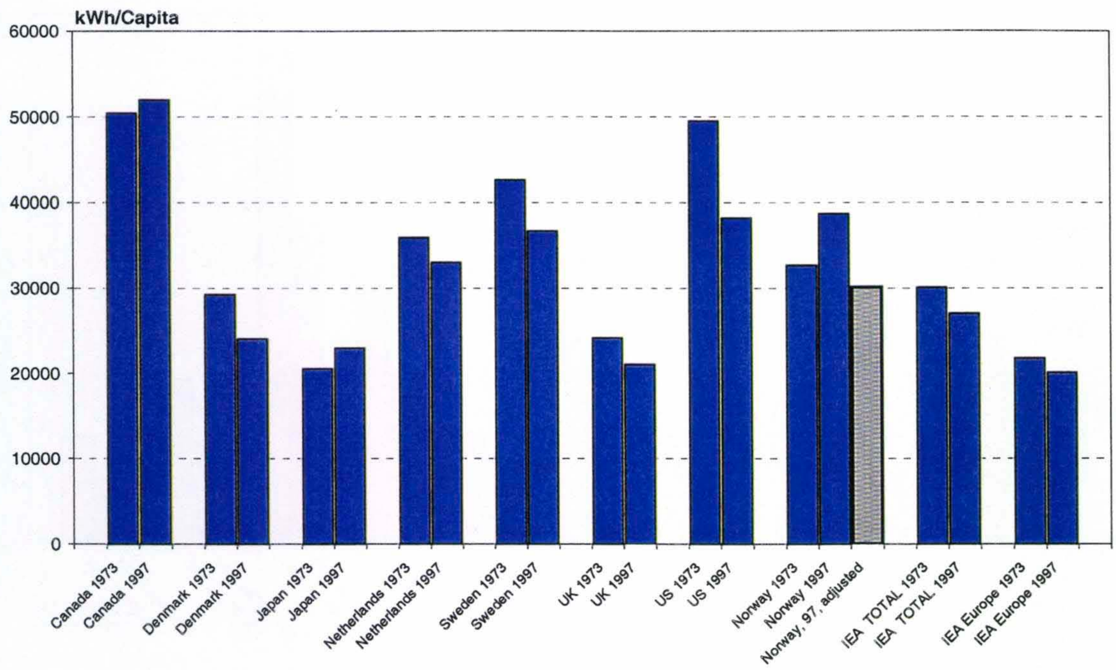


Figure 3.3 shows final consumption for total stationary use per capita for selected countries and the average for all IEA countries and for IEA Europe. Energy use in Norway is relatively high in comparison with most other countries, but is only marginally higher than in Sweden or the United States. And 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 and is shown in the third bar for Norway in Figure 3.3).[15, 16]

[15] Differences in manufacturing structure are calculated as for Figure 6.7. 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 (see Chapter 4).

[16] Figure 3.3 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.

Figure 3.3
Stationary Energy Use per Capita for Selected IEA Countries

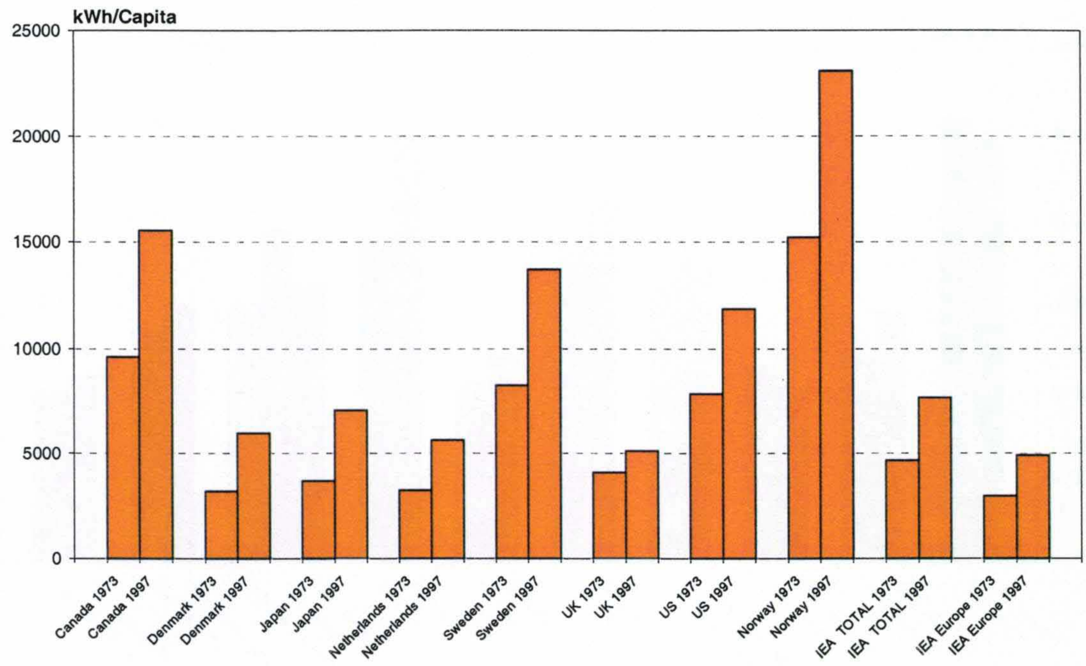


Norwegian electricity consumption levels, however, are very high in comparison with other IEA counties. (Figure 3.4). Electricity consumption in Norway grew from about 15 000 kWh per capita in 1973 to more than 23 000 kWh per capita in 1997. In all other countries shown and for the IEA-average, electricity 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.

Even if 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 3.3). As discussed in the next chapters, 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.

Since 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. The following chapters examine if energy savings in Norway have in fact been lower than other places, or if the growth in energy use is primarily a result of increasing energy service demand through activity growth and structural changes.

Figure 3.4
Electricity Use per Capita for Selected IEA Countries



3.2 Development of Demand for Energy Services and Intensities

Data on energy consumption alone reveal little about the underlying forces that shape it, or how energy savings have developed. Consequently, as described in Chapter 2, this study uses indicators that relate consumption to measures of activity to assess developments in each sector. A more detailed discussion of this analysis for residential, commercial/service and manufacturing sectors is given in the following chapters. Here the focus is to summarise the impact that energy intensities have had on energy use for the three sectors together, through weighting the impact of the intensity factor for each sector according to that sector's share of total energy use in 1990.

In Figure 3.5 the development of the intensity factor is indexed to 1973 energy use and compared to the impact of changes in energy service demand and an index of actual energy use. For illustration, energy per GDP and GDP are also shown as indices. Here GDP excludes the GDP component related to off-shore petroleum production. The energy per GDP ratio is calculated as in Figure 2.2, i.e. as total stationary energy in manufacturing, commercial/service and residential, divided by "on-shore" GDP.

Growth in the energy service component corresponds to an increase in energy use of almost 55 percent from 1973 to 1997, as shown in Figure 3.5. This component combines the effect of changes in structure and activity levels in the three sectors. The demand for energy service has grown due to:

- rapid growth in commercial/service sector value-added,
- some growth in manufacturing value-added,
- moves to a more energy-intensive manufacturing structure,
- larger homes, and
- more use of electric appliances.

All of these components drive up energy use, but none of them have anything to do with energy efficiency.

So what happened to energy efficiency? There clearly seems to have been some effect from energy savings as energy use did not grow as much as energy service demand over this period. The decoupling between the 55 percent increase in energy service demand and the 30 percent growth in actual stationary consumption between 1973 and 1997 is due to falling energy intensities in the seven manufacturing branches, commercial/service sector and for a number of different end-uses in residential. Although these intensities are also affected by structural changes at a level of disaggregation not captured by the data used in this study, they are related to how efficient people and enterprises use energy.[17]

Figure 3.5 shows that energy intensities have driven down energy use over the entire period, almost a 20 percent reduction in 1997 from the level in 1973. The rate of decline has not been constant, intensities fell most rapidly during the first half of the 1980s, a period when oil prices were increasing. As mentioned, this decline is partly due to substitution of some oil consumption by electricity with higher end-use conversion efficiency. Note also that after increasing somewhat in the late 1980s intensities fell in the early 1990s. This trend halted in the two last years, yet the figure still indicates savings between 1990 and 1997.

Figure 3.5

Impact on Energy Use of Changes in Energy Services, Energy Intensities, GDP and Energy per GDP for Stationary Sectors of "On-shore" Norway

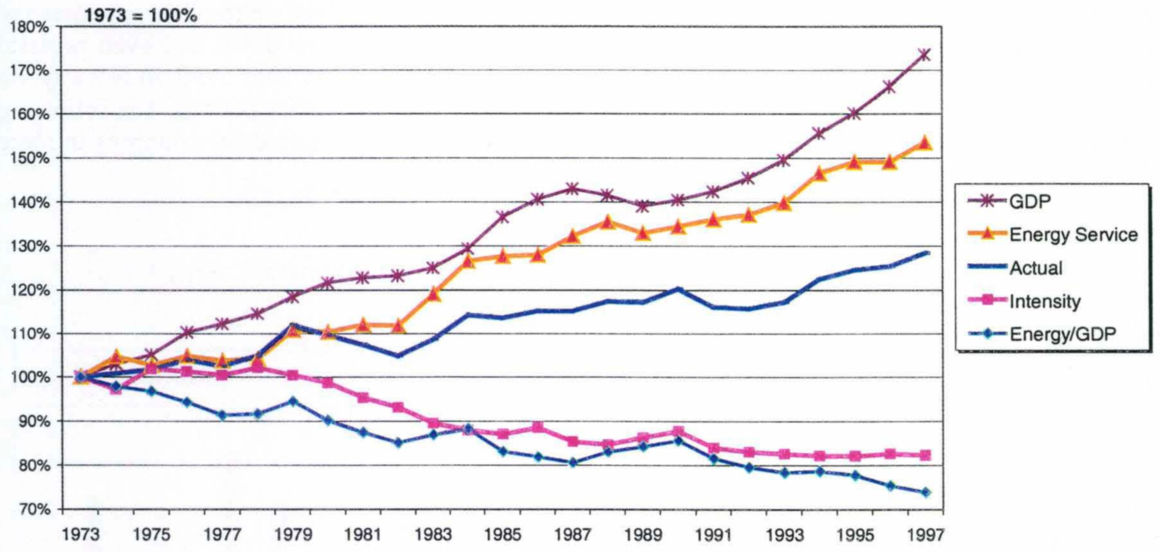


Figure 3.5 also shows how the energy to on-shore-GDP ratio fell far more than the intensity effect until the early 1980s. This is due to faster growth in on-shore GDP than in energy services, because value-added in the less energy-intensive commercial/service sector increased much more than did value-added from manufacturing. This structural change alone led to a decline in energy per GDP that is not related to energy efficiency. The commercial/service sector kept growing relative to total manufacturing value-added during the rest of the period, but the intensity effect still declined faster than energy per GDP between 1981 and 1990. The reason is that energy service levels rose faster than GDP in this period due to a more energy-intensive structure within manufacturing, more than compensating for the effect of the "macro-structural" change towards the commercial/service sector. After 1990 energy per GDP again fell faster than intensities due to less effect from structural change in manufacturing and a slow-down in the growth of house area per capita in the 1990s. Both effects slowed the increase in energy services relative to GDP.

[17] For example, energy use per value-added in the paper and pulp industry is dependent on the structure within this industry itself, e.g. if the value-added share of energy intensive pulp production is increasing relative to paper, the energy intensity will increase.

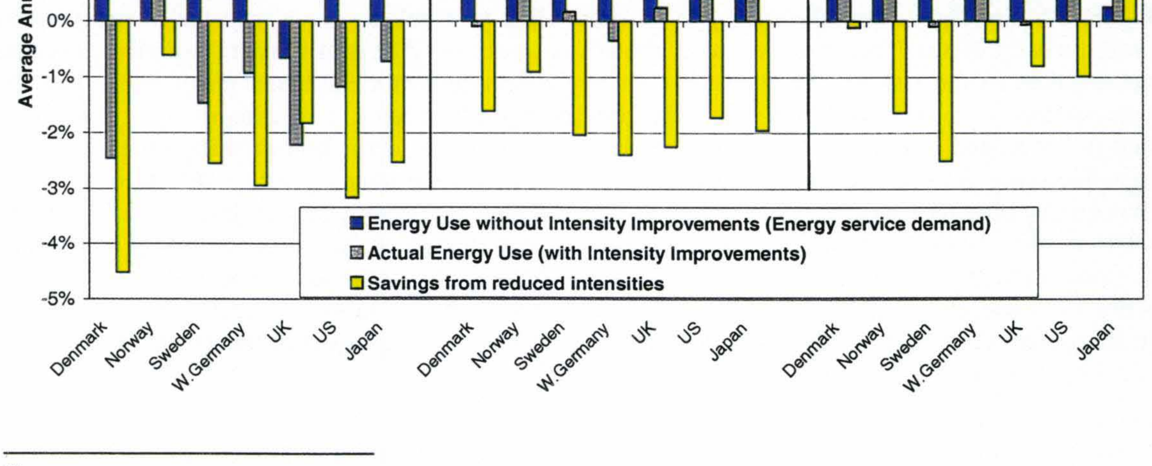
The changes in energy service levels, actual energy use and intensities in Norway compared to other IEA countries for the periods 1973-1981, 1981-1990 and 1990-1994 are shown in Figure 3.6. The changes are expressed as average annual percentage change in each factor.

Energy service demand reflects the energy use that would have been if intensities had not changed. The growth in energy service demand to 1990 was relatively modest in Norway, but between 1990 and 1994 energy services in Norway grew faster than most other countries. As seen from Figure 3.5 the Norwegian on-shore GDP grew even faster than energy services, indicating that the recession that hit most other IEA economies in this period affected Norway relatively less. Note the very high growth in the Swedish energy service component between 1990 and 1994, driven by a strong recovery in some of its heavy industry branches which pushed up both the structure and activity component (Figure 3.6).

The second bar shows actual energy use including the savings that falling intensities induced. The third bar shows the change in intensities. These changes are equal to the difference between the first and the second bar.[18] Negative values for intensities indicate a decline, although the savings from this decline are "positive". Over the 1973 to 1990 period, intensities fell less in Norway than in the other countries included in Figure 3.6. 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. Note the slow-down and even reversal (Japan) of the trend of declining intensities that most countries experienced after 1990. In Norway, on the other hand, intensities kept falling, even at a higher rate than in the earlier periods. The following chapters discuss the underlining factors shaping these trends in Norway and other countries in more detail for each of the three stationary energy use sectors.

Figure 3.6

Changes in Energy Service and Energy Intensities for Stationary Energy Use
Selected IEA Countries



---

[18] In some cases energy service demand less actual energy use diverges somewhat from the changes in energy intensities. This is due to a small interaction term that occurs when using the Laspeyres indexing method.

CHAPTER 4: RESIDENTIAL SECTOR

Highlights

- *Norwegian homes are relatively large, and due to a cold climate, they use more energy per capita than in most other countries included in this study. When adjusted for differences in climate, however, residential energy use is about the same level as in most European countries and lower than in the United States and Canada. Contrary to the developments in Denmark and Sweden, residential per capita energy use in Norway has increased since 1973, but the level is still lower than in its two neighbouring countries.*
- *Norway has efficient space heating practices, primarily because of good insulation: heating per floor area is low compared to other countries. Yet it declined little between 1973 and the mid-1980s. This is partly because Norwegian homes increased the indoor comfort as income grew, a phenomenon that also occurred in Japan and the United Kingdom. In recent years, however, the space heating intensity in Norway appears to have fallen at the same, or higher, rate than in most other countries.*
- *Electricity use for lighting is high in Norway, not necessarily because of inefficiencies, but because lighting levels and hours of use are high. Today Norway also enjoys above average ownership levels of electric appliances compared to western Europe as a whole. While there are few real data on electricity use by appliance in Norway, there is reason to believe that trends in appliance efficiency have followed trends elsewhere in Europe.*
- *Overall savings of residential energy use in Norway between 1973 and 1990 were among the lowest of all countries examined. Between 1990 and 1995, however, there was a strong decline in energy intensities and thus a high rate of energy savings compared to other countries. The development in the first period can to a large extent be explained by increased heating comfort and appliance ownership up to the levels of its Scandinavian neighbours that took place in Norway through the 1970s and 1980s. The decline in the most recent years may indicate continued positive effects from improved heating practices, but this time without loosing the savings through increases in heating comfort.*

Definitions

End-uses: 1) Residential space heating, 2) water heating, 3) cooking, 4) six major appliances (refrigerators, freezers, dishwashers, clothes-washers and dryers, air conditioning) and miscellaneous appliances, and 5) lighting.

Activity: Population.

Structure: Per capita house area for space heating, index of square root of family size for cooking and water heating, per capita appliance ownership (with miscellaneous appliances extrapolated at the same rate of change of major appliances), per capita floor area for lighting.

Intensity: Useful energy and delivered energy use per square metre per degree-day for space heating. Energy per capita for water heating and cooking; energy per appliance for appliances; lighting energy per square metre of floor area.

Useful energy: Delivered energy in electricity and district heat plus 66 percent of delivered energy of gases and liquids and 55 percent of delivered energy in coal and wood or other solids.

Climate correction: Space heating is corrected for year-by-year variations in climate by dividing by a climate index defined as the ratio of actual number of degree-days to the number of degree-days in a year with normal climate. The number of degree-days are calculated as the difference between average outdoor temperature and 18C and summed up over all months except June, July and August.

Data

Norway: Total energy use by fuel is taken from Statistics Norway's (SSB) energy statistics. It should be noted that data for 1998 are preliminary and thus uncertain. The report therefore pays little attention to the development between 1997 and 1998. Data for wood use from 1976 are updated with new estimates from SSB. Data for household area are from SSB's *Survey of Housing Conditions 1995* (Boforholdsundersøkelsen, 1995), with data for 1973, 1981, 1988, and 1995. Data for number of households for 1970, 1980 and 1990 are from SSB's *Folke- og boligtelling*, while the *Building Statistics* (Byggearealstatistikk) provided annual figures for the construction of new buildings. These figures were used to calculate the number of households for other years, based on an average retirement rate of old buildings calculated from the 1970, 1980 and 1990 data points. *Building Statistics* also contains area figures for new buildings that were used to establish trends in household area between the years given by the Housing Condition Survey.

Data separating electricity consumption between space heating and other end-uses are generally not available for Norway. This adds uncertainty to the analysis. One reference for separating end-uses is the *Energy Survey 1990* (SSB 92/2) where some estimations were done based on a selected number of households. Data for other years are estimated through detailed "bottom-up" assumptions drawing on work documented *in "The Evolution of Norwegian Energy Use from 1950 to 1991*" (SSB 93/21) and in "*A Long Term Perspective on Norwegian Energy Use*", (Schipper et. al, 1990). Some modifications to the previous documented work have been done for this study. For example, electricity uses for appliances are now described using available data for stock efficiencies of various electric appliances based on surveys in Sweden and other EU countries. Data for ownership levels for the same appliances are based on SSB's regular *Survey of Consumer Expenditure* (Forbruksundersøkelsen).

Other Countries: Data are primarily developed through Lawrence Berkeley National Laboratory's long-standing analysis of each country's official housing, equipment, household, and energy statistics, and updated for recent years in collaboration with the IEA.

4.1 Trends in Residential Energy Use

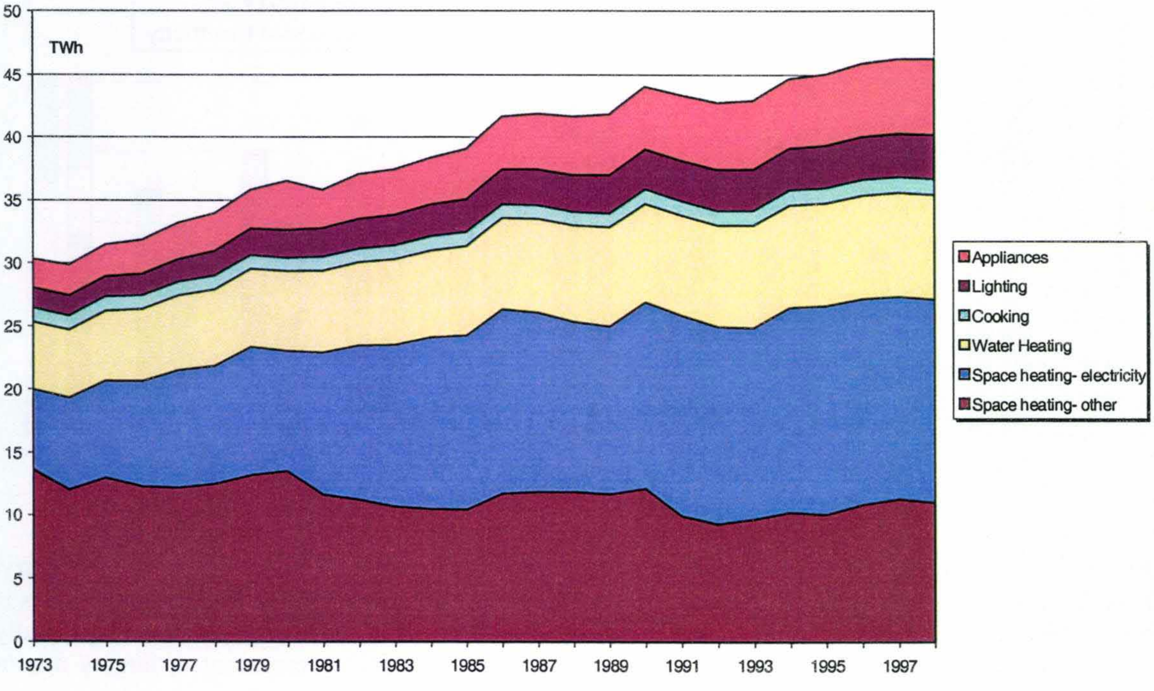
Residential energy use in Norway has grown by more than 50 percent over the last 25 years. (See Figure 4.1) This is an average growth rate of 1.7 percent per year. The most rapid growth was between 1973 and 1986 at an average rate of 2.45 percent per year. This compares to 0.61 percent per year from 1986 to 1998. (Table 4.1). 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 1998.[19] Even if the share of space heating has fallen since 1973, Norwegians still use about 60 percent of residential energy to heat their homes.

[19] 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, as described in the Data section.

Table 4.1
Average Annual Percentage Growth in Residential Energy Use in Norway

	1973-1986	1986-1998
Space heating –electricity	6.38 %	1.06 %
Space heating –other	-1.14 %	-1.16 %
Water Heating	2.42 %	0.73 %
Cooking	-0.09 %	0.80 %
Lighting	4.03 %	1.30 %
Appliances	4.82 %	2.43 %
Total	**2.45 %**	**0.61 %**

Figure 4.1
Residential Energy Use in Norway by Type of End-Use*



*Space heating corrected for variations in degree-days.[20]

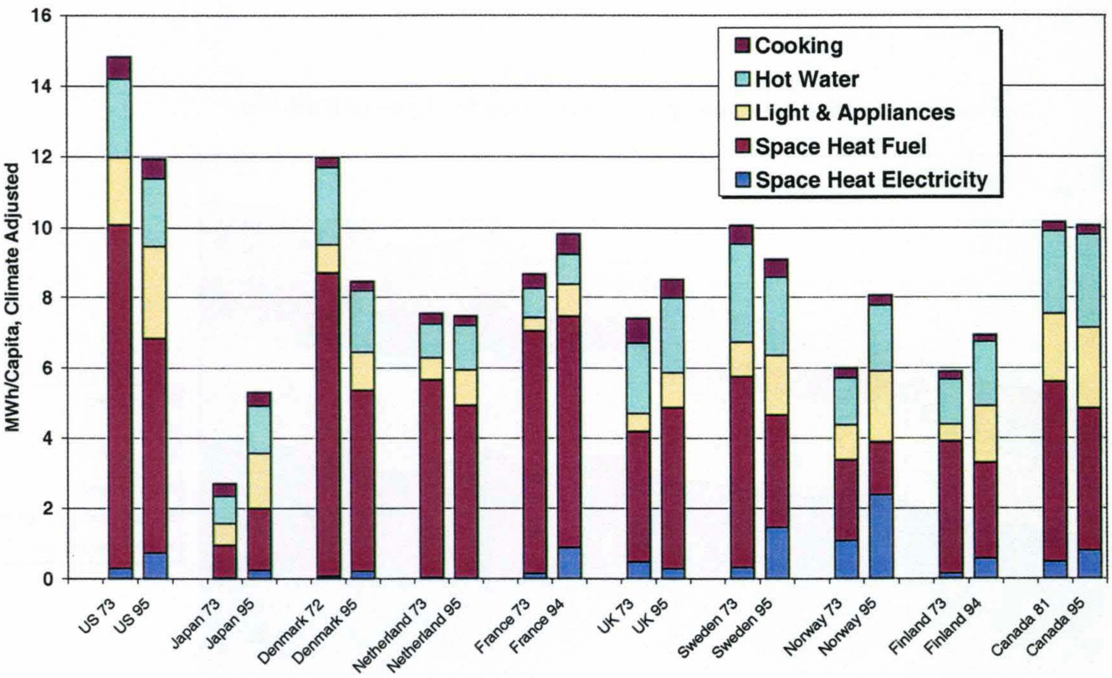
In international comparisons, household energy use in Norway was low in 1973 given the cold climate. Figure 4.2 shows each major end-use for Norway and selected IEA countries, with space

[20] This analysis adjusts electricity and other fuels used for space heating for year-to-year variations in degree-days. However, since it is difficult to estimate exactly the functional relationship between space heating and degree-days, some of the dynamics seen in Figure 4.1 may still be due to variations in climate, especially in extreme years. For example, 1990 was an extreme with a very mild winter and hence the climate correction had the effect of moving up energy use. Judging from Figure 4.1 it may seem like this year has been somewhat over-corrected.

heating adjusted linearly to 2 700-degree days.[21] 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. Despite reductions in residential energy use in both Sweden and Denmark, in 1995 Norway still used less energy per capita than its two neighbouring countries.

Energy use rose in the United Kingdom and France as central heating became more widespread and appliance ownership expanded. More residential appliances also drove up energy use in all the other countries. It was most significant in countries where ownership levels were low to start with in the 1970s. As a result, residential per capita energy use differs less among the countries in 1995 than in 1973.

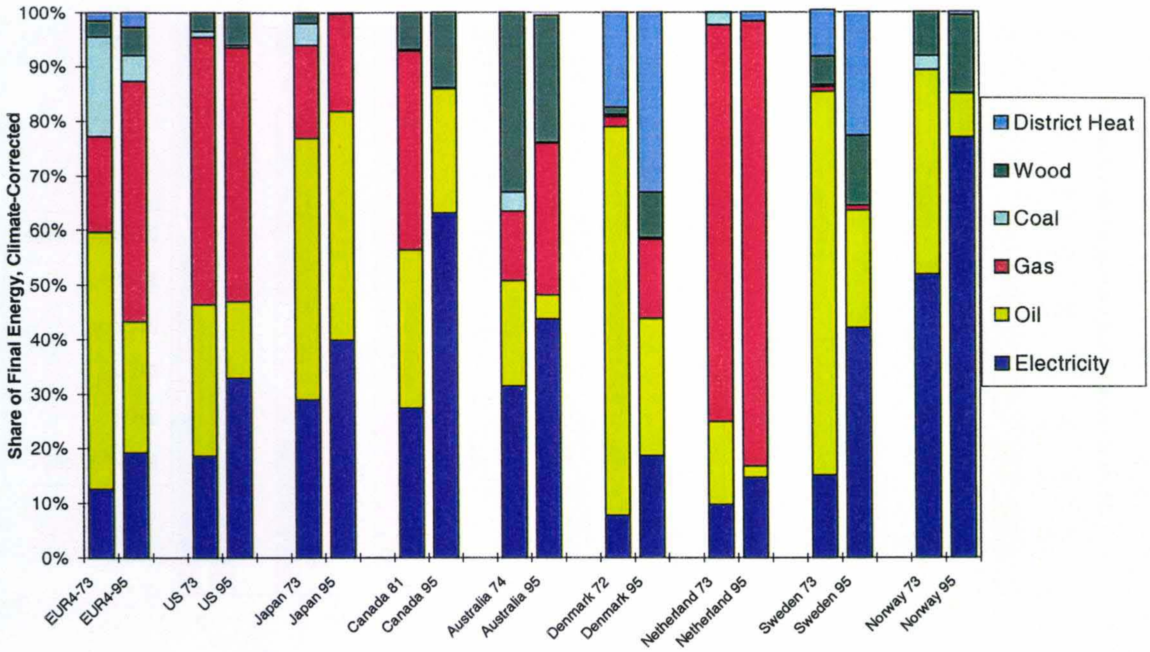
Figure 4.2
Residential Energy Use
(Climate Adjusted to 2 700 DD base 18°C)



Electricity accounts for almost 80 percent of residential energy use in Norway. In no other country, except Canada, is the share of electricity more than 50 percent. Figure 4.3 illustrates that natural gas is the dominant fuel choice in many countries in recent years, while the share of oil has generally decreased. The share of electricity has been increasing in the countries represented, largely due to more appliances.

[21] 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 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.

Figure 4.3
Residential Fuel Shares



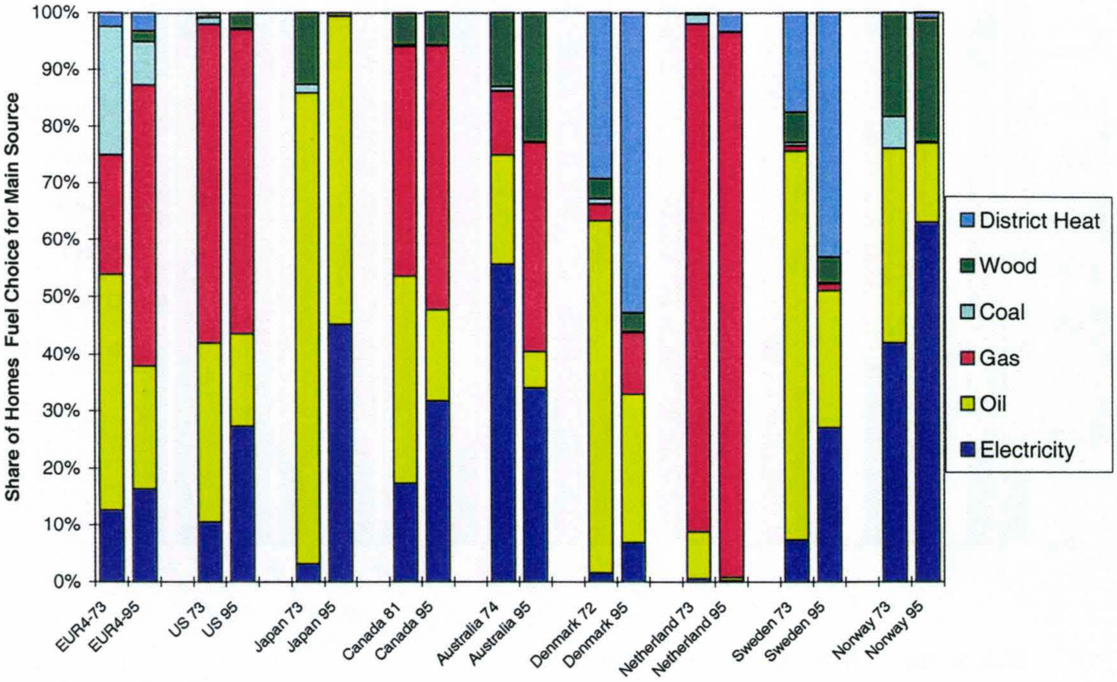
EUR-4= Italy, France, UK and west Germany

In Norway, Canada and Sweden the rapid expansion is also due to growing use of electricity for space heating, (Figure 4.4). Electricity is the main source for space heating in about 60 percent of Norwegian homes. Its share has been increasing steadily, primarily displacing oil, and is an important reason for the rapid overall growth in electricity demand.

Most of the electric space heating is provided via resistant heaters ("panelovner") in Norway. According to SSB's Consumer Expenditure Surveys, in 1995 almost 90 percent of Norwegian households had electric heaters. The survey indicates that about one-quarter of the households also had access to oil heaters as an alternative device and about three-quarters also had wood stoves. About one-third of the households had all three options. In about 20 percent of Norwegian households, electricity is the only heating source. The share of residences with oil heaters fell from 38 percent in 1983 to 23 percent in 1995. In most cases only homes with central heating systems can be fully heated without electricity. The share of such systems is low in Norway, 9 percent in 1995, down from 14 percent in 1980. By contrast, in Sweden and Denmark the shares of homes with central heating are approximately 80 percent and 90 percent, respectively. Installing the necessary pipes and radiators for central heating in existing buildings is expensive. Hence it is difficult for most Norwegian householders to shift away from electricity as the main heating source in response to increasing electricity prices.

Figure 4.4 also shows a high share of Norwegian homes with wood as the main heating source, much higher than Sweden, for example. On the other hand, biomass is an important fuel in district heating in Sweden, a source that has expanded significantly.

Figure 4.4
Residential Space Heating Choices



EUR-4= Italy, France, UK and west Germany

4.2 *Trends in Residential Energy Use Structure*

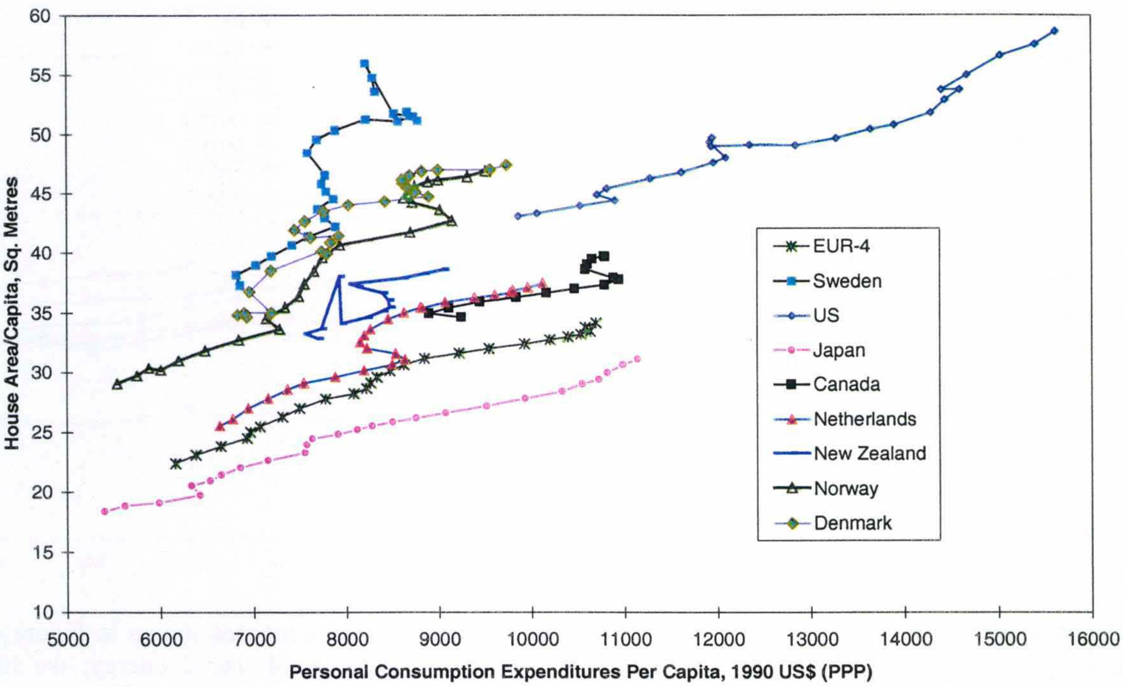
The most important structural component driving residential energy demand is the size of homes. Figure 4.5 shows house area per capita versus private consumption expenditures (a measure of private income[22]) for selected IEA countries. Note that each data point represents the combination of expenditures and area for a given year, if expenditures fall temporarily, successive values will move to the left temporarily. To illustrate the time development, a line is drawn through the data points year by year.

Despite having relatively low income levels 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. Interestingly, the two countries also had the same per capita personal expenditure levels in 1995. Swedish houses are larger than in Norway though income levels now are lower. The United States is the only country besides Sweden where homes are bigger than in Norway.

[22] The conversion to US dollars is as for all currency conversions in this report made using Purchasing Power Parities (PPP). In 1990 the conversion rate was 9.73 NOK.

Figure 4.5

Personal Consumption Expenditures and House Area
1970-1995



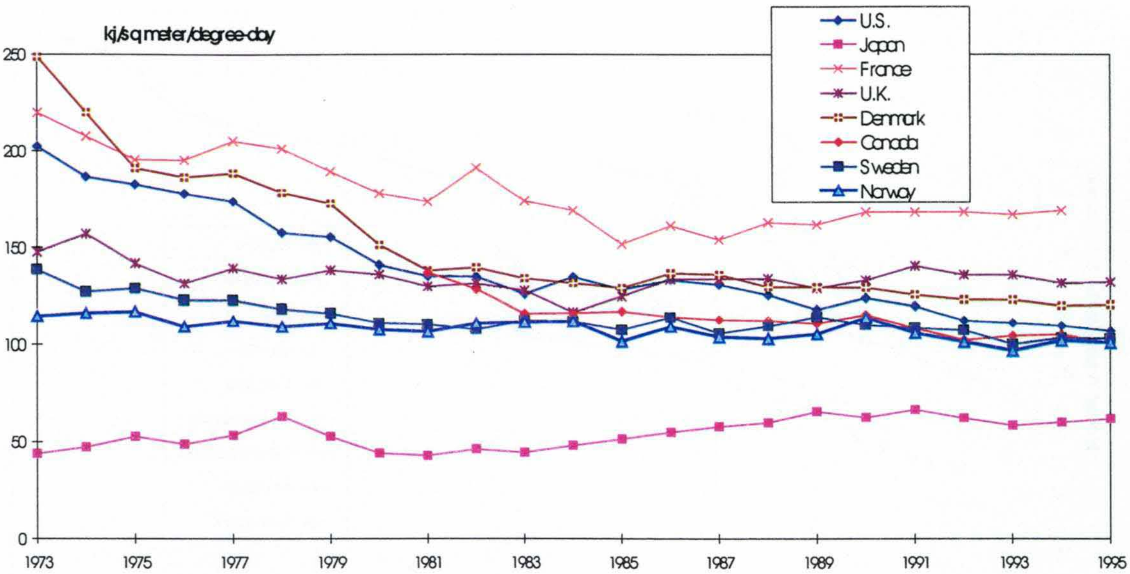
EUR-4= Italy, France, UK and west Germany

Another important determinant for residential energy use is household size, measured as persons per household. Energy use tends to rise with falling household size, all else being equal. The primary reason is that space heating, and to some extent lighting levels, in a given residence is relatively independent of how many people occupy the dwelling. In Norway, as in most other countries, household size has steadily declined since the 1970s, injecting an upward force on residential energy use.

4.3 Energy Use, Energy Intensities and Efficiency

Recall the relatively big differences in both levels and time development of various end-uses across countries (Figure 4.2). To what extent is this due to differences in energy efficiency developments and to what extent is it a result of structural differences? First, consider space heating. Obviously, levels of space heating are dependent on climate and house size, but also on the type of heating system. To correct for heating equipment, space heating can be expressed as *useful* energy. This approach allows a reasonable comparison among countries with different shares of electricity and district heating by calculating useful energy with solids counted at 55 percent conversion efficiency and oil and gas counted at 66 percent. A normalisation for climate variations is obtained by dividing by each country's yearly degree-days. The differences among countries and over time within a country are depicted by showing space intensity expressed as useful energy per square metre of floor area per degree-day (base 18C) in Figure 4.6.

Figure 4.6
Residential Space Heating Intensity
(Useful Energy for Heating per Square Metre per Degree-day)



Space heating intensity in Norway has been among the lowest in the countries shown in Figure 4.6 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.[23] 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.

Today Swedish, Canadian and US homes use about the same amount of heat per area as homes in Norway, despite that Norwegian consumers have been endowed with significantly lower prices than in the other "cold" countries.[24] 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 (Figure 4.7). Danish consumers, for example, pay on the order 2.5 times more. Also residential oil prices in Norway have been among the lowest (Figure 4.8), and are significantly lower than in Sweden and Denmark.

---

[23] 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 Energiundersøkelsen 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.
[24] The very low value for Japan in Figure 4.6 is readily explained by far lower indoor temperatures and only intermittent room heating.

Figure 4.7
Residential Electricity Prices[25]
(US$ 1990 (PPP) per GJ)

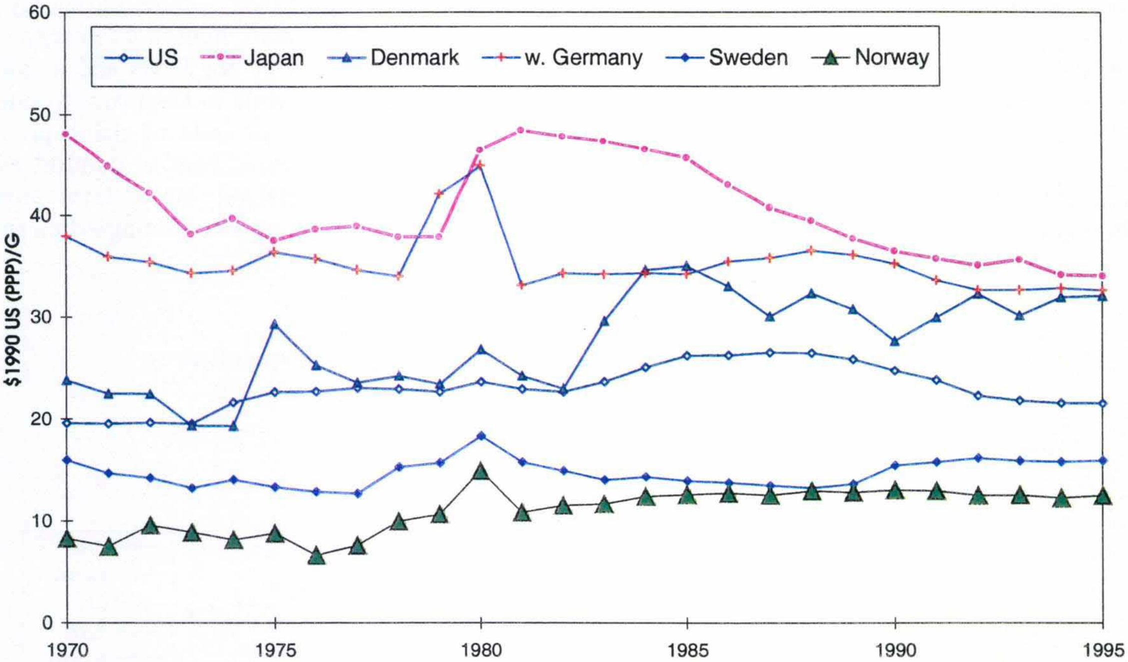
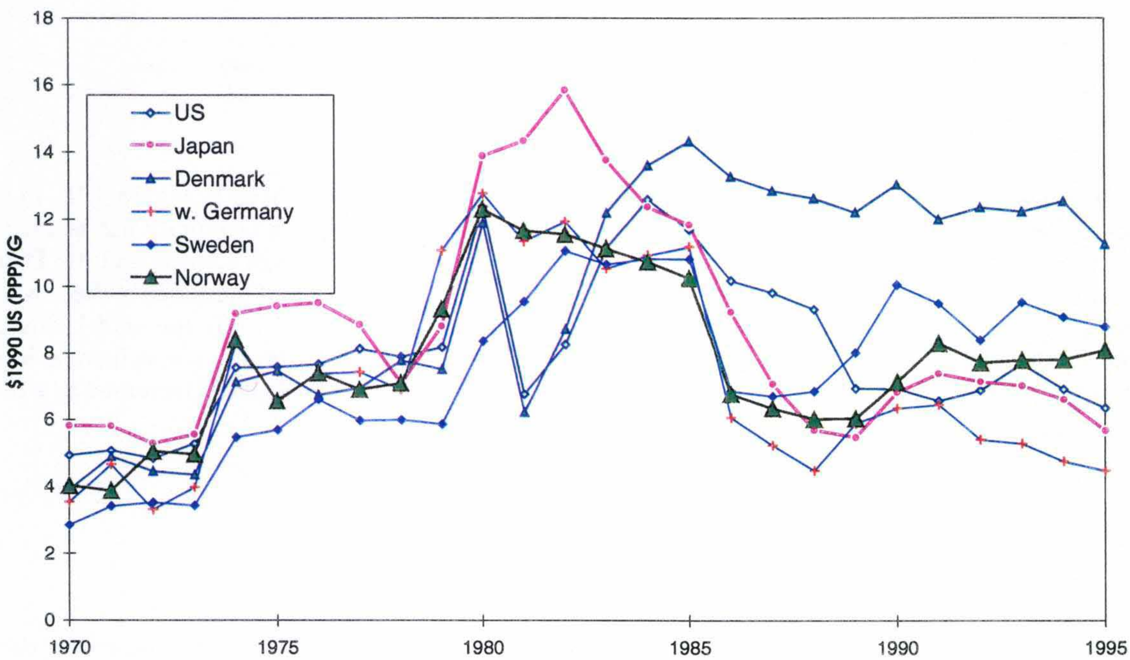


Figure 4.8
Residential Fuel Oil Prices
(US$ 1990 (PPP) per GJ)

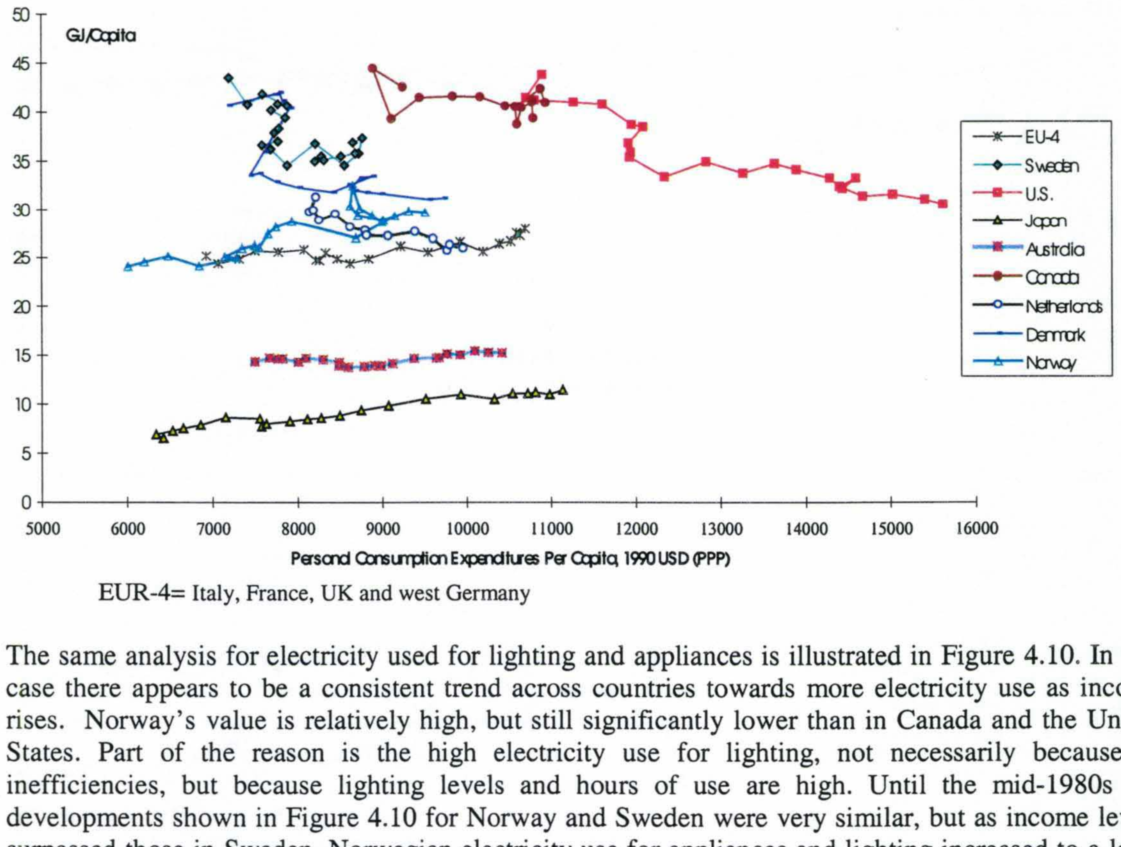


[25] For conversion: 10 US$/GJ is equal to 3.6 US cents/kWh, or approx. 0.35 NOK/kWh, based on 1990 PPP

Income growth seems to have had an important impact on the development of space heating intensity in Norway. To investigate the income effect on space heating, water heating and cooking, the total energy use for these three end-uses is shown as function of private consumption levels (Figure 4.9). The figures are not climate-corrected, as households will spend more of their income on energy in cold years and vice versa in warmer years. The figure shows that Norway's household energy use increased as private consumption grew. The same development can be seen for Japan and to some extent for the EUR-4 (w. Germany, France, United Kingdom and Italy), while in Denmark, Sweden, Canada and the United States the evolution led to reduced energy use in spite of rising private consumption. The results for Norway help confirm the notion that increased heating comfort as a function of income boosted this part of Norwegian energy use. Thus the relatively stable development of space heating intensity in Figure 4.6 should indicate real improvements in space heating efficiency.

Figure 4.9

Household Fuel and Electricity Use for Cooking, Space and Water Heat versus Personal Consumption Expenditures 1973-1995



EUR-4= Italy, France, UK and west Germany

The same analysis for electricity used for lighting and appliances is illustrated in Figure 4.10. In this case there appears to be a consistent trend across countries towards more electricity use as income rises. Norway's value is relatively high, but still significantly lower than in Canada and the United States. Part of the reason is the high electricity use for lighting, not necessarily because of inefficiencies, but because lighting levels and hours of use are high. Until the mid-1980s the developments shown in Figure 4.10 for Norway and Sweden were very similar, but as income levels surpassed those in Sweden, Norwegian electricity use for appliances and lighting increased to a level significantly above Sweden's.[26]

[26] Data separated by various end-uses in Norway are scarce; e.g. no information exists on the stock efficiency of electric appliances, (see description of data sources). However, as it is primarily increased ownership levels for appliances, for which regular data exist, that have driven up electricity use in Figure 4.10, the trend shown should be relatively robust. In fact, for this study the development of appliance efficiencies in Norway is based on Swedish data for the most recent years since the types of appliances sold in the two countries are relatively similar.

Figure 4.10

Electricity Use for Appliances and Lighting versus Personal Consumption Expenditures 1973-1995

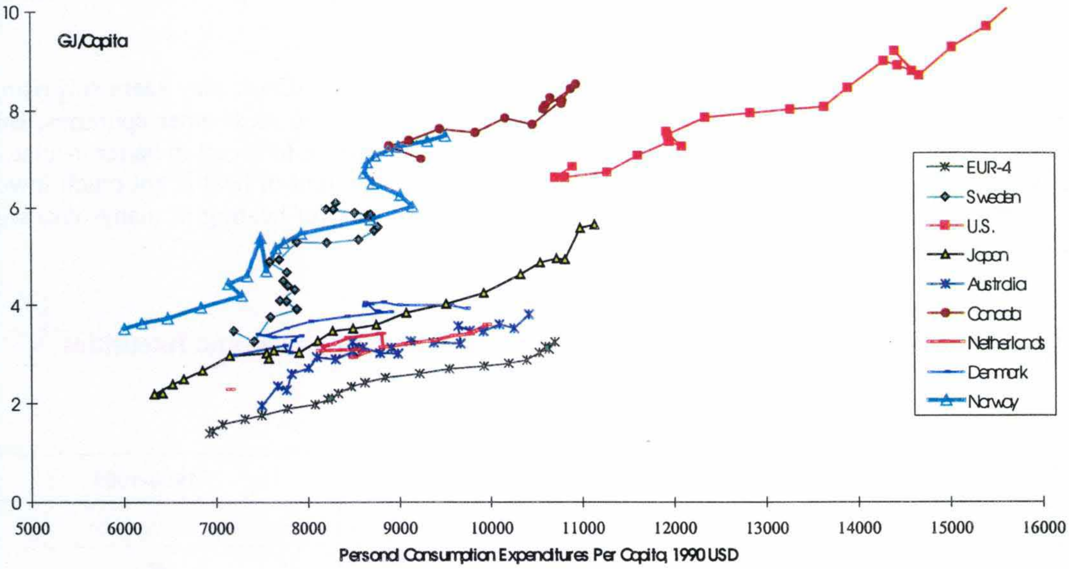


Figure 4.11 summarises the impact changes in structure and end-use intensities have had on per capita residential energy use in two periods. Recall that while the activity variable is simply population growth, structural changes include:

- home area per capita (for space heating and lighting);
- appliance ownership per capita;
- household size (for water heating and cooking).

These are measured as the impacts of changes in residential energy use with intensities for the same end-uses fixed at 1990 base-year values. Hence the structure component illustrates what residential energy use would have been in any given year if only these measures changed, (i.e. space heating and lighting per area, water heat and cooking per capita and electricity used in major appliances all remained constant). Conversely, the intensity effect illustrates the impact changes in all these intensities would have on energy use if the various structure components had been constant at 1990-levels. The combined effect of changes in the structural component and activity (population growth), yields a measure of energy service demand.

Figure 4.11 shows the changes in residential energy service levels, actual energy use and intensities in Norway compared to other IEA countries for three periods. To allow for comparison between the periods, the results are expressed as average annual percentage change in each factor.

Structural changes and population growth pushed up energy use in all three periods in all countries. The trend was stronger in the first two periods than after 1990 for most countries. Norway's lower increase in the structure component after 1990 is related to slower growth in house area due a slow-down in new construction, and in appliance ownership levels, due to saturation effects.

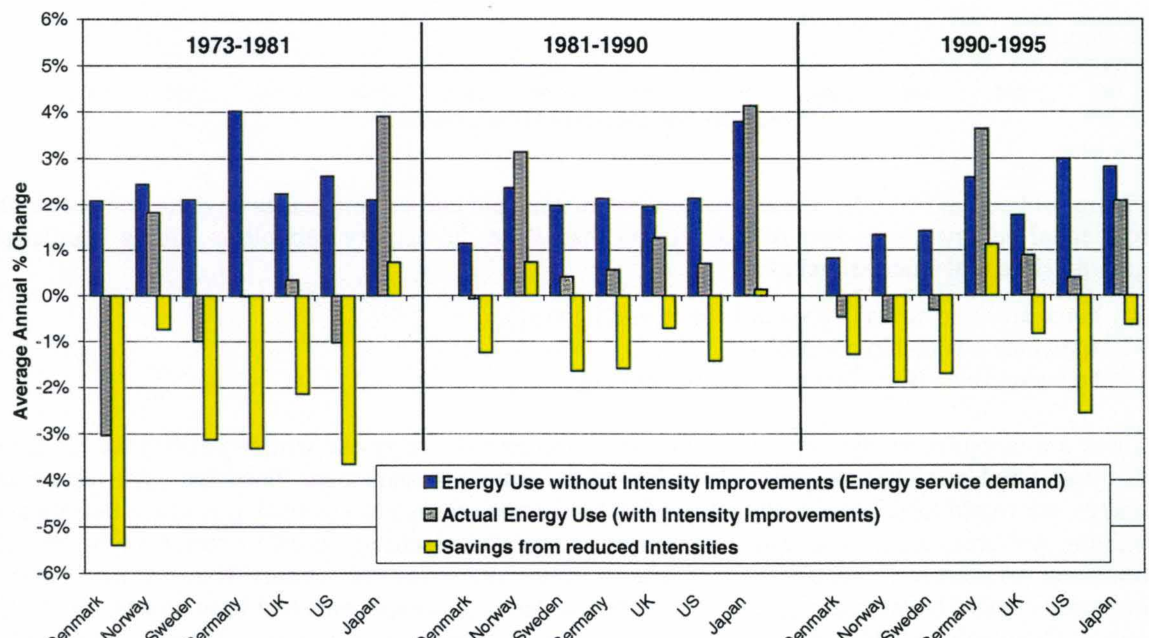
Before 1990 falling energy intensities lead to savings in all countries, except for Japan and Norway (1981-1990). In both these countries the development can be explained by increasing heating comfort levels through higher indoor temperatures and heating of a larger part of the homes as incomes grew.
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 the 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 4.11

Changes in Residential Energy Service Demand, Actual Energy Use and Intensities Selected IEA Countries



CHAPTER 5: COMMERCIAL AND SERVICES SECTOR

Highlights

- *Commercial/service sector energy use in Norway has grown significantly since 1973, mostly in demand for electricity. Part of the increased use of electricity is for space heating. Norway, and to some extent Sweden, the United States and Canada, are among the few IEA countries studied where electric heating of service and commercial buildings is significant.*
- *By far, Norway has the highest level of electricity use in the sector among the countries examined, measured both per floor area and value-added. Widespread use of electric space heating contributes significantly. Total energy use per value-added or floor area is not exceptionally high, however, especially considering the cold climate in Norway.*
- *A decline in total energy use per service sector value-added, a measure of intensity, is seen in all the study countries except Norway between 1973 and 1990. The reduction in most countries is driven by lower fuel use, which more than compensated for increased electricity consumption. Since 1990, however, this intensity fell more in Norway than in any other country. Data limitations make it difficult to assess to what extent the trend before 1990 is due to a lack of energy efficiency improvements, and whether the trend in recent years is related to significant progress in efficiency of space heating and other end-uses.*

Definitions

Sector: The service and commercial sector is defined as the ISIC 6-9 categories of national accounts. Throughout this report the term service sector is used to denote both service and commercial buildings.

Activity: Built area measured by square metre and also value-added measured in real terms (1990) and converted to US dollars, using purchasing power parities (PPP).

Structure: There is no structure variable since an internationally consistent disaggregation into further subsectors is not possible due to data limitations.

Intensity: Delivered (final) energy use per activity.

Data

Norway: Value-added data are taken from OECD National Accounts, energy data from Statistics Norway *Energy Statistics* and floor area data are from Statistics Norway annual *Building Area Statistics*.

Other countries: Energy data are primarily taken from official energy statistics and balances as described in (IEA 1997).[27] Value-added data are from OECD National Accounts.

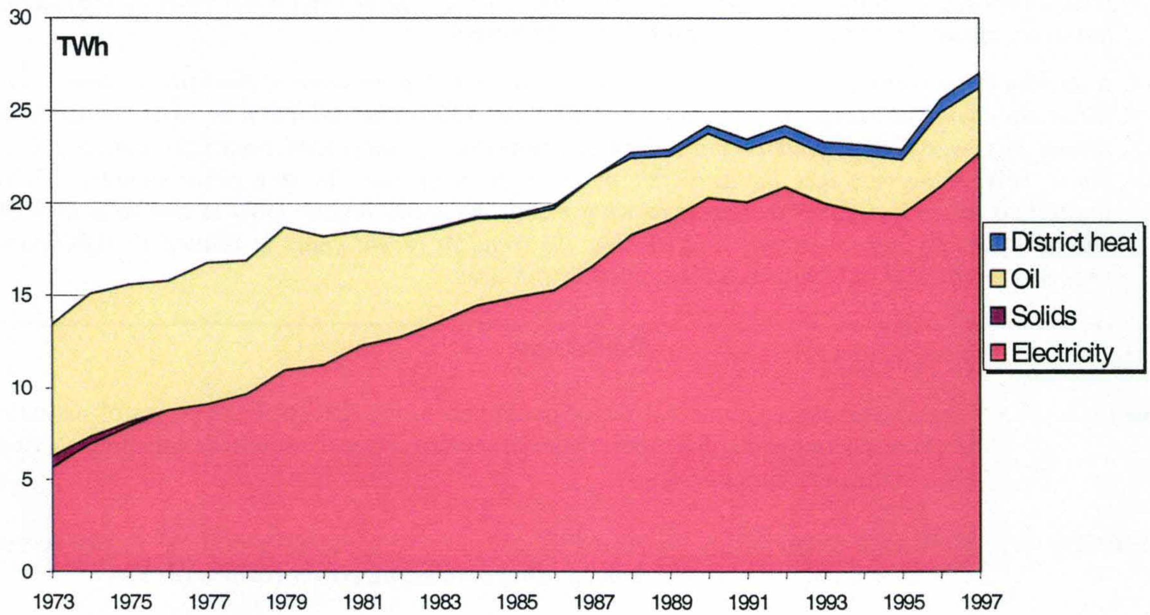
[27] *Indicators of Energy Use and Efficiency*, IEA/OECD, Paris, 1997.

5.1 *Trends in Energy Use*

Energy use in Norway's commercial/service sector increased steadily from 1973 through 1990, on average 3.5 percent per year (Figure 5.1). 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.

Figure 5.1

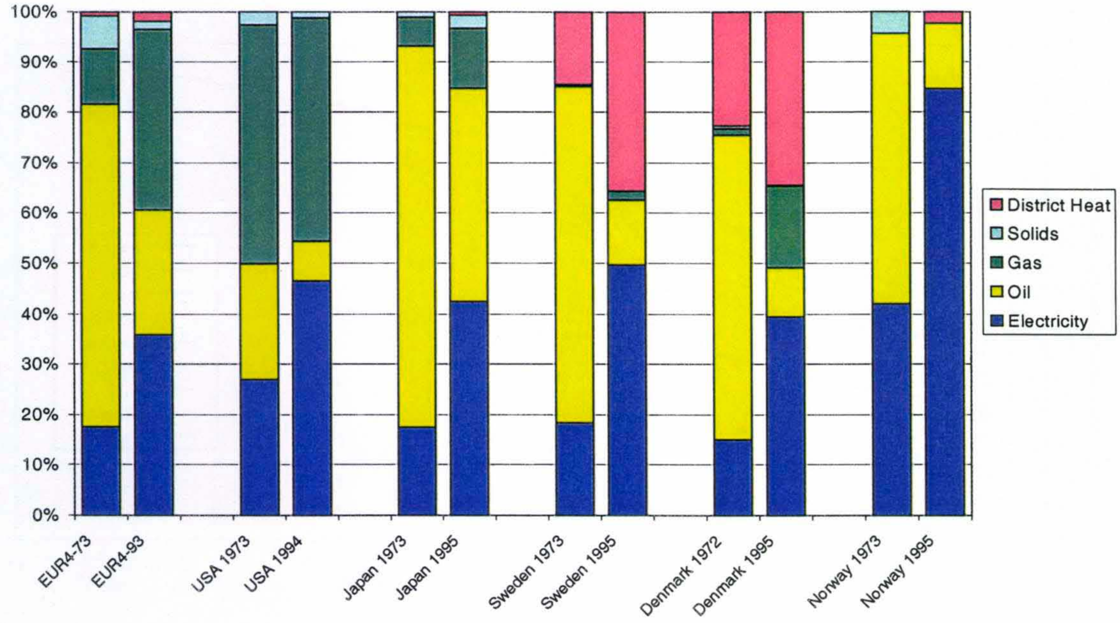
Norway: Energy Use in the Commercial/Service Sector[28]



Electricity's share of total energy use more than doubled between 1973 and 1995 (from 42 percent to 85 percent), while the share of oil declined from 54 percent to only 13 percent (Figure 5.2). Norway is the only country where electricity use constituted more than 50 percent of total energy use in the service sector in 1995. In many IEA countries, the share of natural gas has increased. In Sweden and Denmark, district heat has expanded and now accounts for a bit more than one-third of service sector energy use. All countries examined share a common trend of declining use of oil and increasing electricity use. Except in Norway, and to some extent Sweden and Canada, where electricity is also used for space heating, this is related to more demand for electricity to power various types of electrical equipment.

[28] In this figure energy use for all fuels has been climate-corrected. Little information exists on the share of electricity used for space heating, but to smooth out some of the yearly variations due to climate, 40 percent of electricity use is climate-corrected. The climate correction is obtained by dividing energy use assumed to be heating by the square root of the ratio of the number of degree-days in a given year to the number of degree-days in a normal year. Without this climate correction, energy use in 1990 would have been lower as it was a very warm year, while the jump in energy use between 1995 and 1996 would have been even more significant as 1995 had relatively normal temperatures while 1996 was significantly colder than average. In all remaining figures in this chapter, service sector energy use in Norway and other countries is **not** climate-corrected.

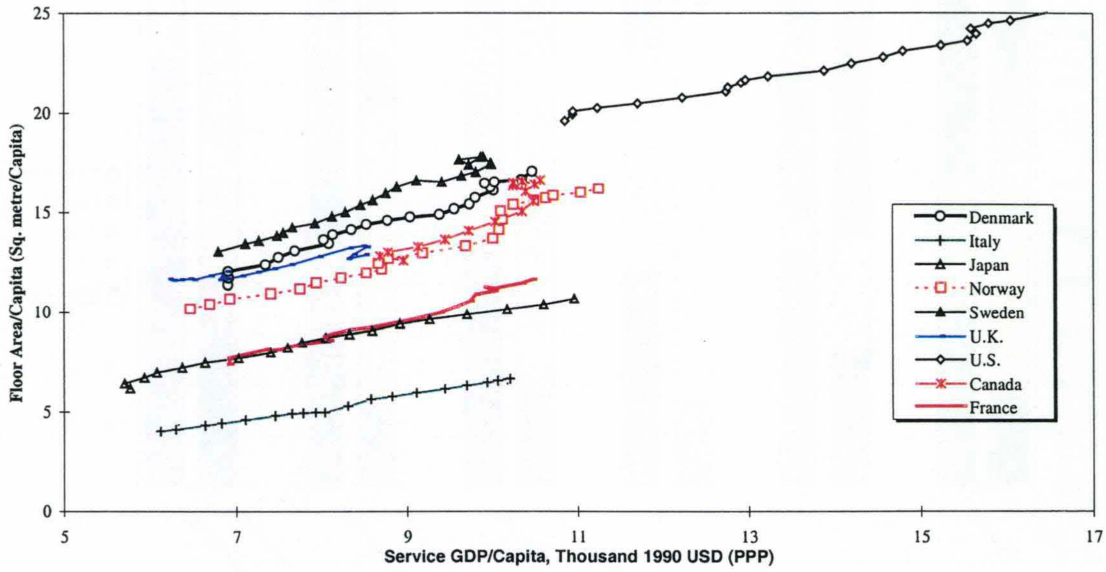
Figure 5.2
Shares of Fuels and Electricity in the Commercial/Service Sector



5.2 Activity Development

This study uses both floor area and value-added as measures of activity development in the service sector. In 1973 the share of value-added from the Norwegian service sector in total GDP was almost 60 percent, about average for the countries studied. Output grew 92 percent between 1973 and 1995, more than in most countries, yet the share of services in GDP declined in Norway, contrary to the development in all other countries. This is related to the rapid expansion of the Norwegian oil industry after 1973. Service floor area grew by 78 percent in the same period, leaving Norway, at almost the same level as Sweden and Denmark and higher than in many other European nations (Figure 5.3). As in almost every other country, value-added in services grew faster than floor area. In Norway, however, service value-added per square metre only increased by 9 percent over the period, among the lowest rates of increase of the examined countries.

Figure 5.3
Commercial/Service Floor Area and Service Value-added
1973-1995

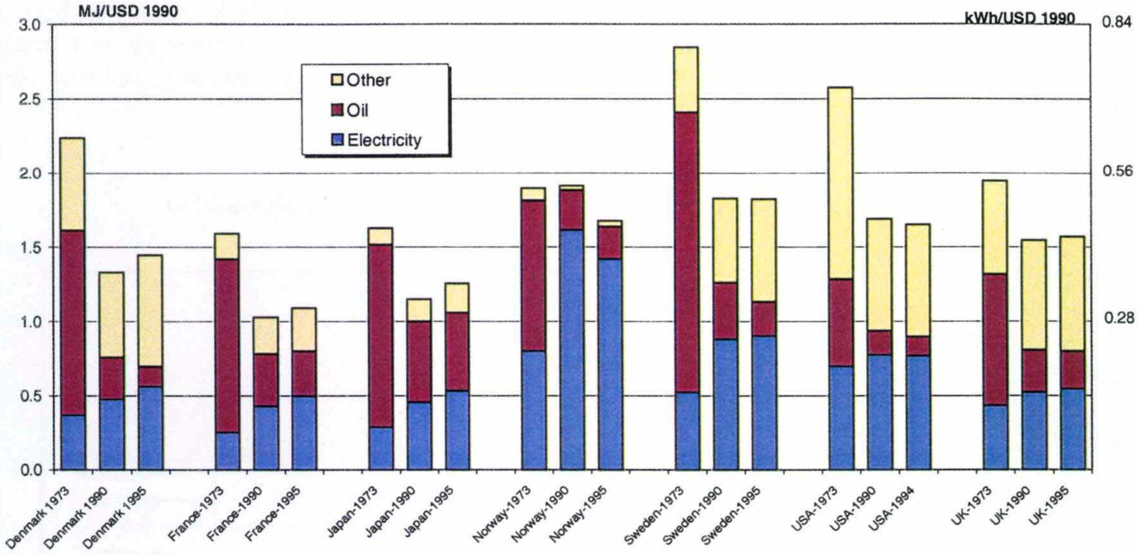


5.3 Energy Use and Intensities

Dividing total energy use by value-added yields a measure of aggregate energy intensity in the service sector (Figure 5.4). 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 5.4 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 seen in Figure 5.1, energy use increased significantly after 1995, a development that is further discussed in Chapter 7.

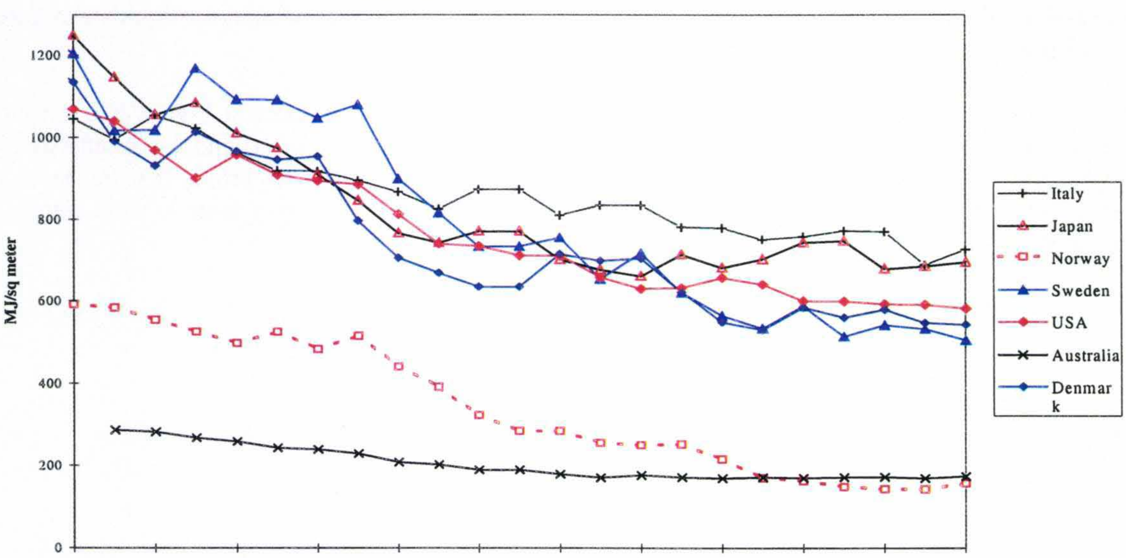
Despite the decline after 1990, energy per value-added in 1995 was among the highest in Norway, along with Sweden and the United States. The differences across all countries are not large, especially considering that the energy consumption data are not climate-corrected. In terms of electricity per unit value-added, however, Norway is undoubtedly highest of all. This is not surprising given the very low electricity prices in Norway.

Figure 5.4
Energy Per Unit of Commercial/Service Sector Value-added



Since accurate data on how much energy is used for space heating are not available for all countries, fuel use, including district heating, per unit of floor area is used to represent space heating intensity (Figure 5.5). In countries such as Norway and Sweden where electricity is used in significant quantities for space heating, this indicator understates space heating use, while significant uses of fuels for water heating, cooking, and even small process services (food, photo labs, etc) could distort the picture in the other direction. Between 1973 and 1990, this "heat indicator" fell significantly in Sweden (56 percent) and Norway (72 percent). These declines are greatly affected by growing shares for electricity for heating at the expense of oil in the first half of the 1980s. This makes the numbers hard to compare with countries with little electric heating. After 1990 most countries still reduced their fuel intensity, although at a more modest pace.

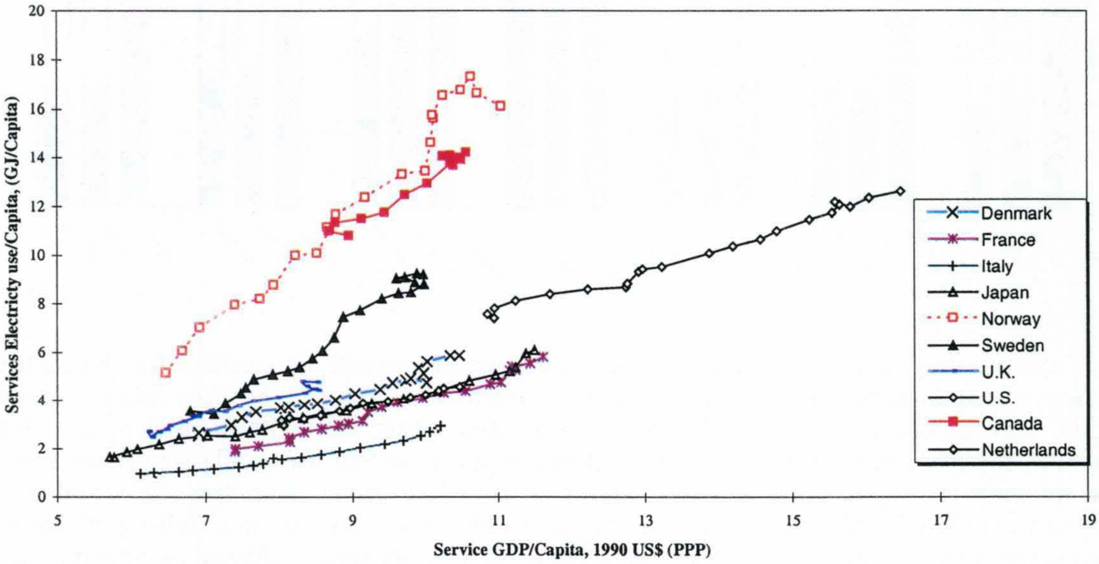
Figure 5.5
Service Sector Fuel/Heat Intensity



Compared to other countries electricity use per square metre increased significantly in Norway between 1973 and 1995, to a large extent due to higher shares of electric heating. It is interesting to note how electricity use has been coupled to sectoral value-added in most countries, as shown in Figure 5.6. Where electricity-based heating did not rise, the growth can mostly be explained by the increasing penetration of office equipment and space-cooling systems. Without knowing how much electricity was actually used for heating, it is difficult to interpret the trends for Norway, and thus also difficult to assess the development of heating efficiency.

Figure 5.6

Commercial/Service Sector Electricity Use and Service Value-added 1973-1995



Estimates for space heating in service sector do exist for some countries. Figure 5.7 shows these estimates per service floor area versus heating degree-days for 1994. Since data separating electric space heating from other uses of electricity are not available for Norway, space heating was estimated by taking 90 percent of the liquids, all of the solids, 90 percent of district heating, and 40 percent of all electricity to be direct space heating. The figure expresses space heating as useful energy, using conversion efficiencies of 100 percent for electricity and district heat, 66 percent for liquids and gases and 55 percent for solids.

While there is no exact relationship that can be derived from the estimates in Figure 5.7, a rough coupling between increased winter severity (measured in heating degree-days) and useful energy use per square metre for heating can be discerned. This suggests, but does not prove, that the level of service sector heating in Norway is consistent with that in other countries over a wide range of climates.

Figure 5.7
Estimated Useful Space Heating Energy Use in the Commercial/Service Sector and Winter Climate
1994

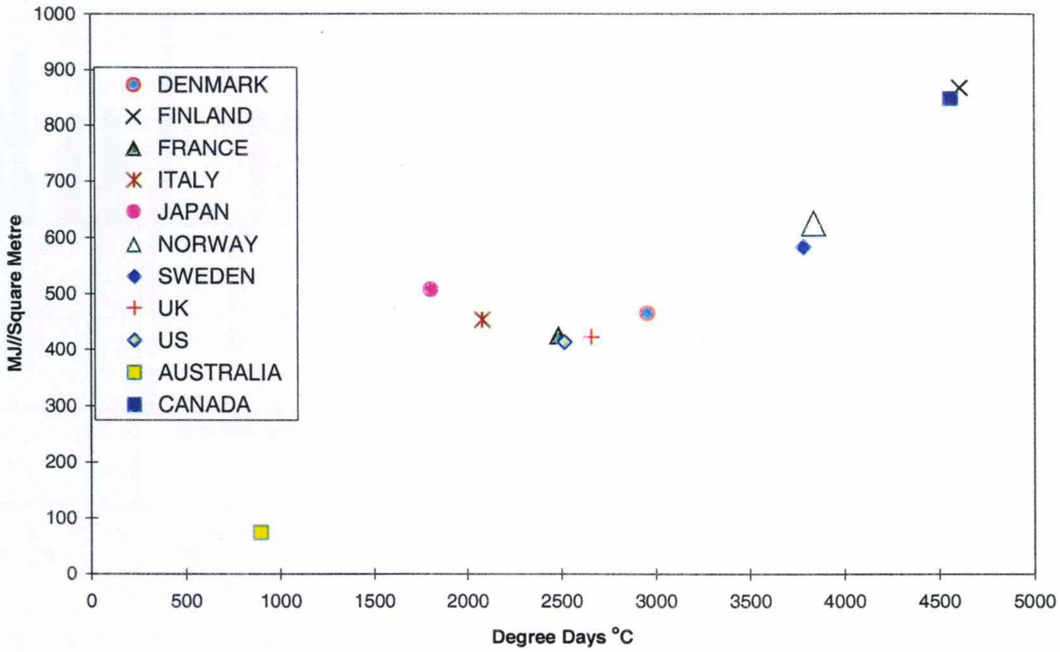
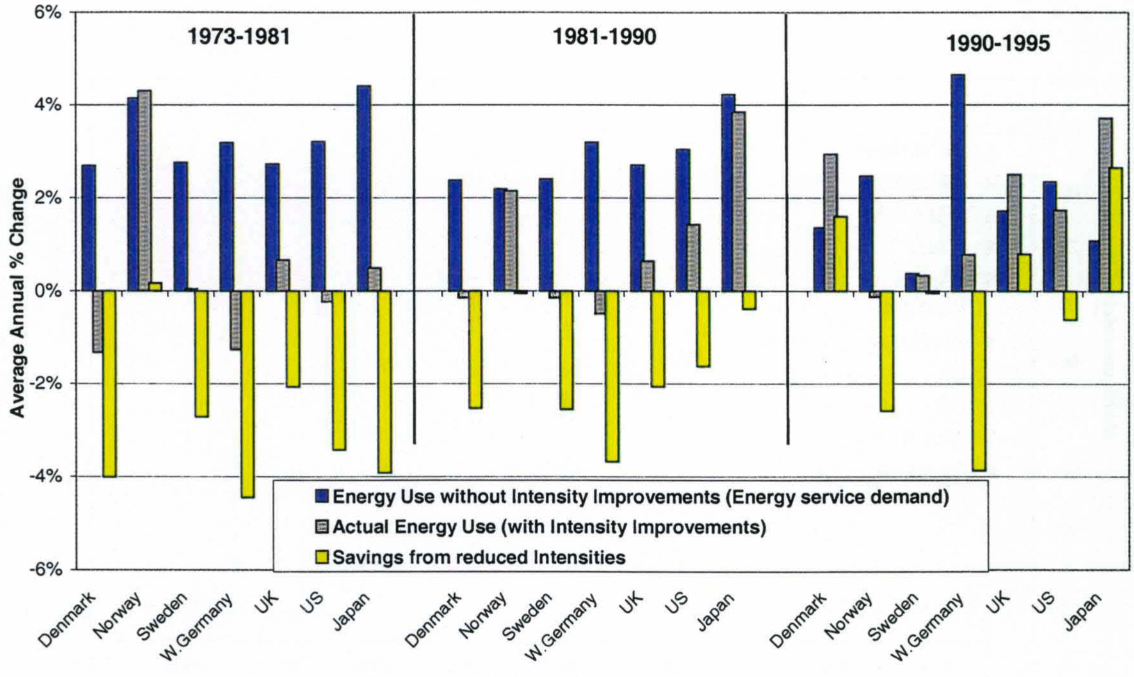


Figure 5.8 shows changes in energy service levels, actual energy use and intensities in the service sector for three periods, expressed as average annual percentage change in each factor. (Refer to similar figure for residential).

Growing energy service levels (value added) drove up energy use in all three periods in all countries, although recessions in the early 1990s slowed the growth many places in the last period. Before 1990 falling energy intensities lead to savings in all countries, except for Norway. As for the residential sector there was no net change in the Norwegian intensity between 1973 and 1990. (See also Figure 5.4). Between 1990 and 1995, however, Norway had the most rapid decrease among all countries, except w. Germany. This development is also consistent with the trend seen in the residential sector.

Figure 5.8

Changes in Energy Service Demand, Actual Energy Use and Intensities in Commercial/Service Sector



CHAPTER 6: MANUFACTURING SECTOR

Highlights

- *The manufacturing sector's share of total GDP in Norway at about 12 percent in 1995 is lower than in any other country included in this study. This compares to more than 25 percent in west Germany and Japan. On the other hand, manufacturing energy use per value-added is higher compared with all the studied countries. 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.*

- *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 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.*

- *To account for these structural changes, this chapter investigates the development of energy intensity that would have occurred independent of variations in manufacturing output mix. The findings show that this structure-adjusted energy intensity in Norway did fall significantly between 1973 and 1995, though at a somewhat lower rate than in many other countries.*

- *The rates of decline in the structure-corrected intensity has not been constant in Norway: before 1981 the intensity fell very little compared to most other IEA countries, leading to less than 6 percent savings between 1973 and 1981. During the 1980s, however, the intensity in Norway fell at about the same rate as in many other countries, corresponding to another 16 percent savings. The intensity fell less after 1990 than during the 1980s. Still the reductions in Norway were more significant than in most, as many countries experienced a significant slow-down or even an increase in intensities after 1990. This development can be explained by the recessions that many countries went through during the early 1990s.*

Definitions

Sector*:* Manufacturing is disaggregated into seven sub-sectors:

- paper and pulp (ISIC 341);
- chemicals (ISIC 351 and 352);
- non-metallic minerals (ISIC 36);
- iron and steel (ISIC 371);
- non-ferrous metals (ISIC 372).
- food and kindred products (ISIC 31);
- "other industries" (containing all remaining subsectors of ISIC 3, except petroleum refining)

Activity*:* Value-added ("Bearbeidingsverdi" in Norwegian), measured in real terms (1990) and converted to US dollars using purchasing power parities (PPP).

Structure: Mix of manufacturing output, measured as relative shares of value-added among the sub-sectors.

Intensity*:* Delivered (final) energy use per activity.

Data

Norway: Annual energy data between 1970 and 1990 are from Statistics Norway's energy accounts (SSB "*Energiregnskap*"). As described in Unander et al. (1997), estimations based on the petroleum sales statistics had to be made in order to separate oil distillates used for transport [29]. Post-1990 data are from Statistics Norway's EDAT-files, which contain data for both energy balances and energy accounts. The EDAT-files list oil used for transport separately. When the industrial classification changed from ISIC to NACE in 1993 some companies' energy use in Statistics Norway's statistics was moved between the sector definitions used in this study, making comparison with earlier time series difficult. This effected energy data for ISIC 351-2, ISIC 36 and ISIC 371. With help from Statistics Norway, data from 1990 and subsequent years were recalculated to fit the new NACE classification. This report uses the ISIC version of the 1990 numbers for comparison with years before 1990, and the new consistent time series based on NACE to analyse trends from 1990. Value-added data are from OECD's STAN database to ensure consistency with other countries.

Other countries: Data are primarily taken from official energy statistics and balances.[30] In some cases, where these data are not disaggregated to the level required for international comparisons, they have been supplemented with data from other official sources such as industrial statistics and sales statistics for petroleum products, etc. Value-added data are from OECD's STAN database.

[29] Unander, Alm and Schipper, 1997, *Energy Use in Norway, An International Perspective*, Institute for Energy Technology, IFE/KR/E-97/006, Kjeller, Norway, 1997.
[30] Unander, Fridtjof, et. al, 1999, "*Manufacturing Energy Use in OECD Countries: Decomposition of Long-Term Trends*", Energy Policy 27 (1999), pp.769-778.

6.1 Trends In Manufacturing Energy Use

Figure 6.1 shows Norwegian manufacturing energy use for 1970 to 1997. From 1970 to 1993, energy use was fairly stable. In 1973 total delivered energy was 71 TWh, 20 years later it had fallen to 68 TWh. The trend changed with a 6 TWh increase in only four years after 1993. Over the entire 1973- 1997 period manufacturing energy use grew by a modest 0.15 percent on average per year.

Manufacturing energy use peaked in 1979 at 75 TWh, and then dropped to 64 TWh only three years later. The relatively high variations reflect short-term fluctuations in energy demand in the production of ferrous metals as well as a general reduction in oil use after the second oil price hike in 1979. Interestingly, after the first oil price hike in 1973 the use of oil in manufacturing was less affected than in the later price shock. The diminishing role of oil in Norwegian manufacturing is also shown in Table 6.1. Note the extreme decline after the second oil price hike and also the continued decline despite the drop in crude oil prices after 1986. Part of the reason for the continued decline is that taxes on oil products increased in the last part of the 1980s. Oil accounted for 32 percent (22.5 TWh) of manufacturing energy use in 1973. Its share was down to 9 percent (6 TWh) by 1993. Note, however, that the oil share has increased after 1993 and was up to 12 percent in 1997. Before the first oil price shock, data indicate that the oil share was relatively stable, about 37 percent in the 1950s and 35 percent in the 1960s.

Figure 6.1
Norway: Delivered Energy Use in the Manufacturing Sector 1970-1997

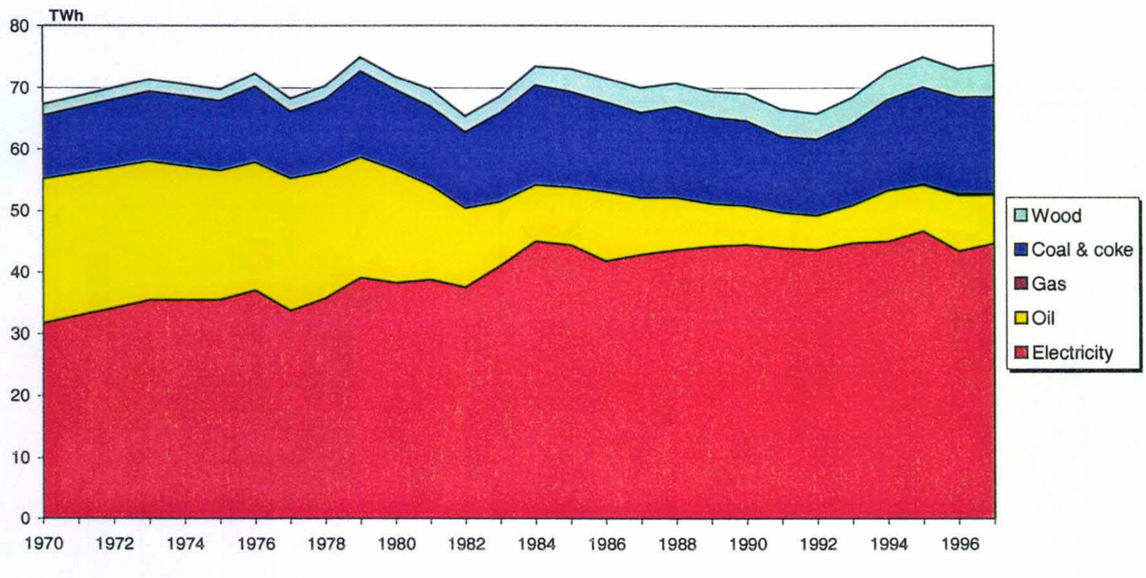


Table 6.1
Average Annual Change in Manufacturing Energy Use
(percent per year)

	1950-60	1960-73	1973-79	1979-85	1985-92	1992-97
Electricity	6.6	5.4	1.6	2.1	-0.2*	0.5
Oil	5.1	3.3	-2.3	-12.3	-7.5	6.9
Delivered Energy	4.5	4.8	0.9	-0.3	-1.4	2.3

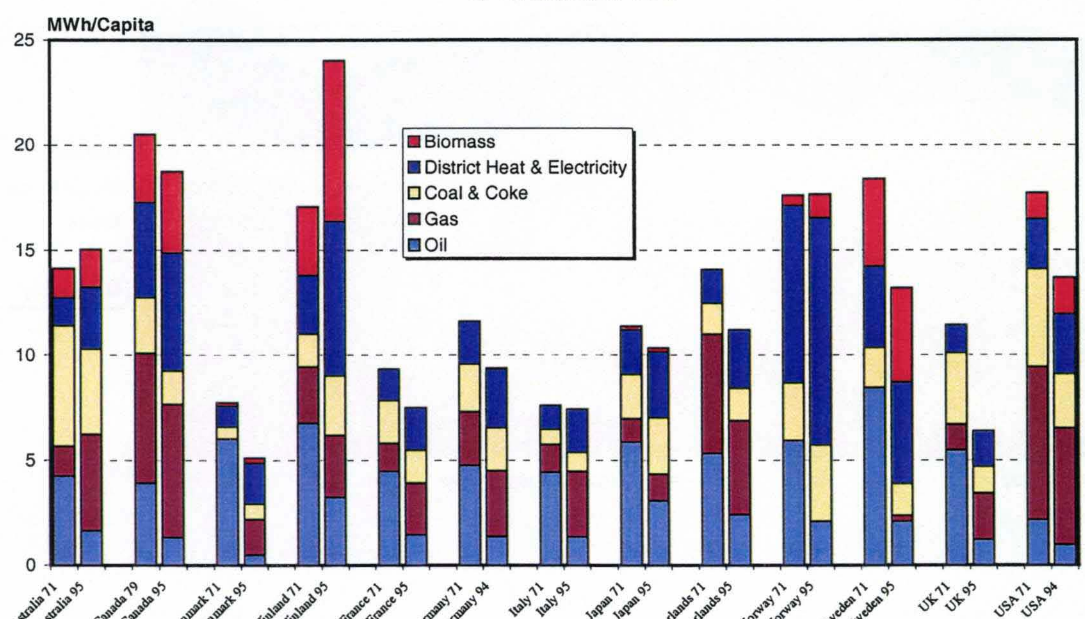
* Although electricity use was fairly constant between 1985-91, there was a sharp temporary drop of 7 percent in 1986 caused by the fall in oil prices combined with high electricity prices (cold winter and low hydro power production).

Electricity use in the manufacturing sector has grown faster than delivered energy (Table 6.1). Electricity provided a 37 percent share in 1950 which increased to 50 percent in 1965. After a small decline it returned to the 50 percent level in 1973, when electricity use was 35.5 TWh, and 25 years later it was up to 45 TWh, about 60 percent of manufacturing energy use.

Coal use in the manufacturing sector has been relatively constant: 16 percent in 1973, peaking at 22 percent in 1984 and fluctuating around 20 percent since then. Biomass use has been slowly increasing, from a low share of 2.5 percent in 1973 to 7 percent in 1997, mostly used in the production of paper and pulp where it constitutes about one-third of energy use. The Swedish and Finnish manufacturing industries rely much more on biomass than Norway. From 1973 to 1995 the share of biomass in Swedish manufacturing rose from 21 percent in 1973 to 34 percent in 1995, and in Finland from 15 percent to almost 32 percent.

The high shares of biomass for Sweden and Finland are also evident from Figure 6.2 which shows per capita energy use for manufacturing in thirteen IEA economies. From 1971 to 1995 manufacturing energy use declined steadily in a majority of the countries. Since energy use in most other sectors of the economy grew during the same period, manufacturing energy use today accounts for a significantly lower share of total energy than in 1971. Figure 6.2 shows that manufacturing energy consumption on a per capita basis fell everywhere except in Australia, Finland, the Netherlands, and Norway, despite the rapid growth in electricity use that took place in all countries.

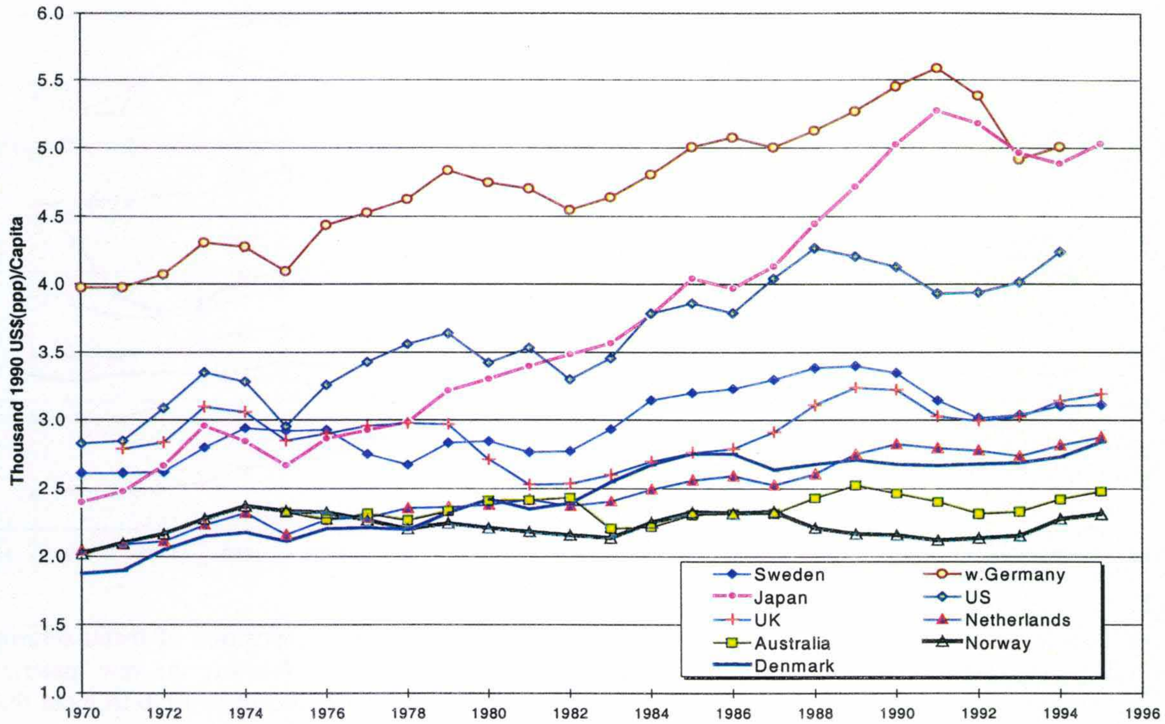
Figure 6.2
Manufacturing Delivered Energy Use per Capita
1971 and 1994-95



6.2 *Trends in Manufacturing Output*

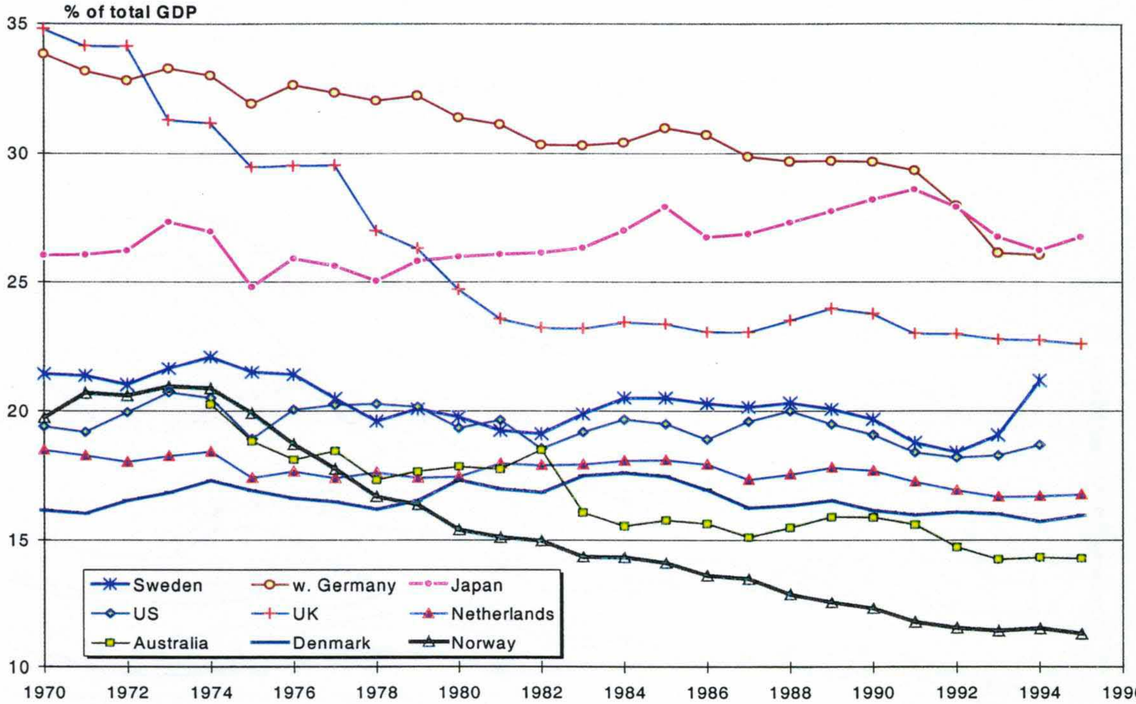
Since 1973 Norwegian manufacturing, measured in terms of real value-added per capita, has ranked among the lowest of the thirteen countries studied (Figure 6.3). By contrast in 1995 Japan produced more than twice as much while the value-added per capita in Sweden was 35 percent and in Denmark 23 percent higher than in Norway. The production growth in Norway has been very limited: manufacturing industries in 1970 contributed about US$2000 per capita while the production was only up to US$2300 per capita 25 years later. This is an average growth rate of about 0.5 percent per year, by far the lowest in this group of countries. Note how the recessions following the two oil price hikes in 1973 and 1979 reduced manufacturing output in a majority of the countries, as did the recession in the early 1990s.

Figure 6.3
Manufacturing Value-added per Capita



Norwegian manufacturing production is also low in terms of relative importance to the economy (Figure 6.4). In 1995 only 12 percent of the Norwegian GDP originated from manufacturing industries. This is far lower than in any other country. 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. A similar development took place in the United Kingdom, though the starting point in the early 1970s was much higher. For most other countries the decline is too small (about 2 percentage points in total for the group of countries) to give an indication that there is a significant long-term trend towards de-industrialisation in these IEA countries, but rather that production is broadly following the development of overall GDP.

Figure 6.4
Share of Manufacturing Value-added in Total GDP

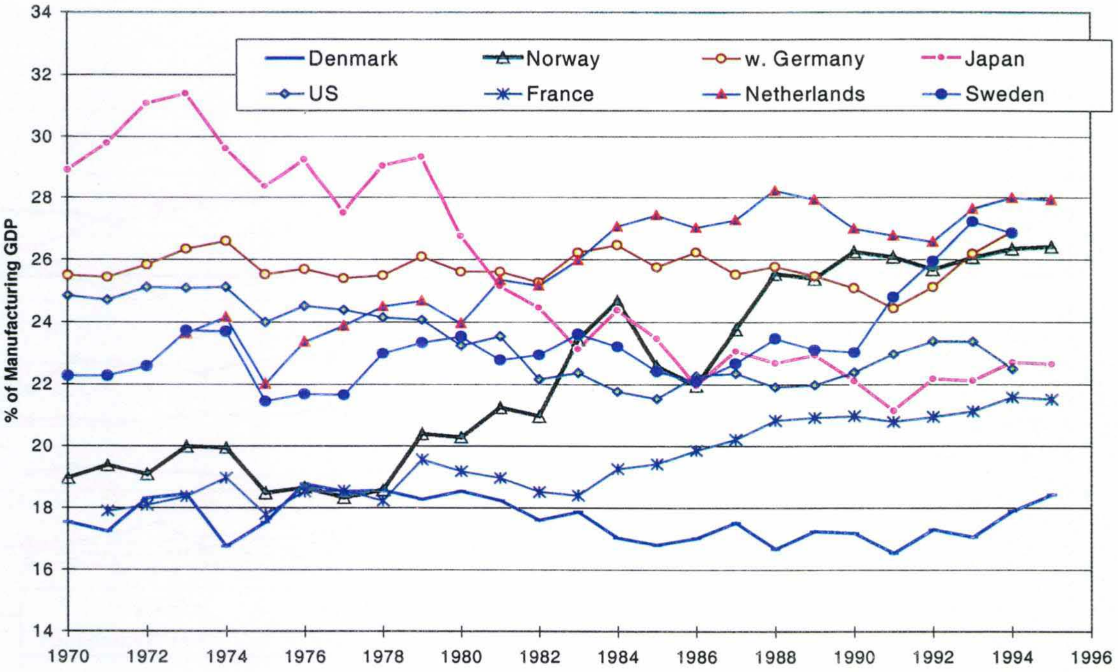


Separating the energy-intensive raw materials sectors shows that the composition of manufacturing value-added varies significantly among the countries (Figure 6.5).[31] In Norway the raw materials sector share of total manufacturing value-added has increased from 19 percent in 1970 to more than 26 percent in 1995.

In every country studied the share of raw materials production fell in the years immediately following the oil crisis in 1973. To some extent the same pattern is seen in a majority of the countries after the second oil price hike in 1979. Since 1980 the raw materials production shares in the larger IEA countries have been between 20 and 25 percent, with Denmark at the low end of the range, and Sweden, Finland, Australia, Netherlands and Norway at the higher end. Through the 1980s, the raw materials share grew or stayed constant in most countries such that the share in 1995 exceeded the 1973 level in all countries except Canada, Finland, Japan, and the United States. Hence, outside these countries, the data do not give any evidence that IEA economies have become significantly less dependent on the production of raw materials since the oil price shock in 1973.

[31] This study defines raw materials sectors as paper/pulp ISIC 341, chemicals ISIC 351/352, non-metallic minerals ISIC 36, ferrous metals ISIC 371 and non-ferrous metals ISIC 372.

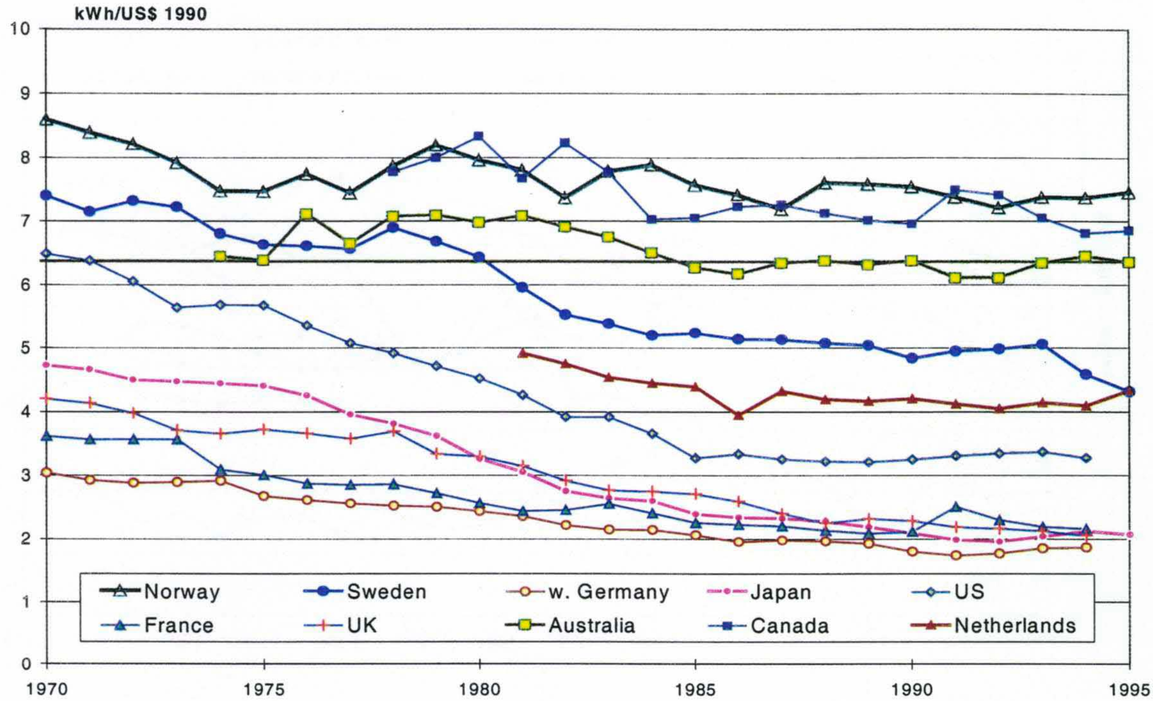
Figure 6.5
Share of Raw Material in Manufacturing Value-added



6.3 Aggregate Manufacturing Energy Intensity

Energy use per unit of value-added is comparatively high in Norway as illustrated in Figure 6.6. This is not surprising given the relatively energy-intensive composition of its manufacturing sector due to the high share of raw materials production (Figure 6.5). Together with other big raw material producers such as Australia and Canada, Norway is in the group of countries with high aggregate energy intensity, while large economies such as Japan, France, and the United Kingdom have less raw materials production and low intensities.

Figure 6.6
Aggregate Energy Intensity
(Total Manufacturing Energy per total Value-added)



What is the significance of the large spread in aggregate intensity among countries seen in Figure 6.6? As mentioned, the composition, or output mix, of the manufacturing sector plays a determining role for energy use. A way to normalise for the differences in the mix of output, is to calculate the energy intensity that would have occurred if each country had the same shares of sub-sectoral output that make up the average for the thirteen country group (IEA-13). This normalisation attempts to equalise the structure of manufacturing across countries by multiplying each country's sub-sectoral intensity by the respective sub-sectoral output shares given by the average IEA-13 structure.

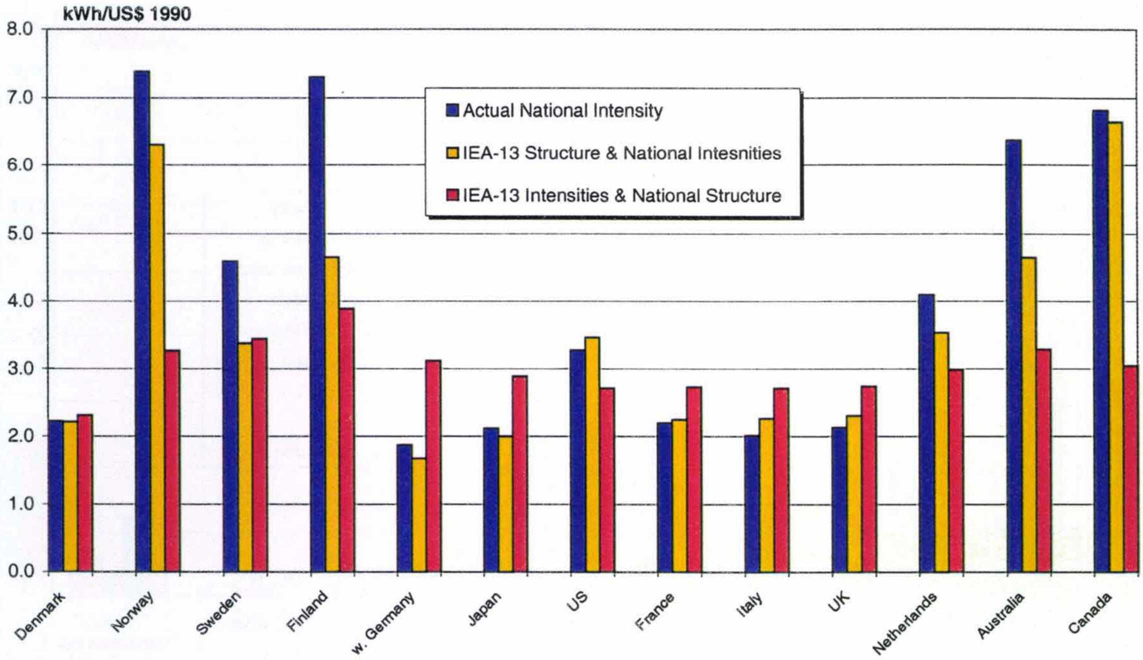
This normalised intensity is shown in Figure 6.7 as the second bar *(IEA-13 Structure & National Intensities)* next to the *actual* aggregate manufacturing intensity in 1994. Where the intensity *increases* in the alternative normalisation (the second bar), e.g. United States, United Kingdom, Italy, the country in question had an output structure *less* energy-intensive than the average of all countries; where a decline occurred the structure was *more* energy-intensive than the average. For Finland, Sweden, Norway, and Australia, the decline is large, indicating the importance of the high shares of energy-intensive products.

The third bar in Figure 6.7 (*IEA-13 Intensities & National Structure*) displays the aggregate energy intensity that would have occurred if each country had the average IEA-13 energy intensity in every manufacturing sub-sector, but its own sectoral output mix. In this case, increasing energy intensity (e.g. Denmark, w. Germany, Japan, France, Italy, and United Kingdom) compared to the actual value means that a country's energy intensities are *lower* than the IEA-13 average; and a *decline* indicates that the intensities are *higher* than average. The latter is especially the case for the big producers of raw materials; Norway, Finland, Australia, and Canada. Note that the United States is the only country where a higher than average energy intensity is combined with a less energy-intensive structure than the IEA-13 average.

Figure 6.7

Energy Intensity in Manufacturing

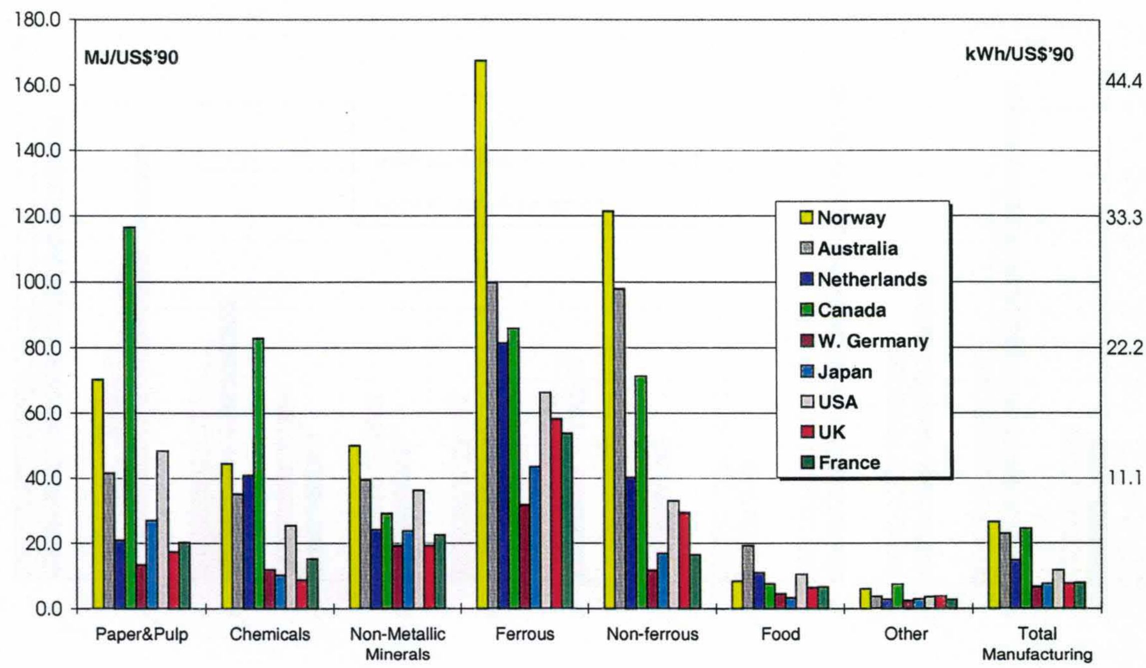
(1994 Actual, IEA-13 Structure and IEA-13 Intensities)



Looking at each sub-sector shows the same general spread in intensities as seen for total manufacturing: intensities in Japan and west Germany tend to be lower than average, while intensities in Australia, Norway and Canada tend to be higher (Figure 6.8).

For Norway, it is clearly the high intensities in the production of ferrous and non-ferrous metals that drive up the energy intensity of total manufacturing. No other country in the group rivals the level of the Norwegian intensities in these sub-sectors. These two sub-sectors account for about 45 percent of total manufacturing energy use in Norway, but only about 8 percent of value-added. The Norwegian intensities are also relatively high in the other raw materials sectors. This does not necessarily mean that the Norwegian manufacturing energy efficiency is lower than in most other countries, but rather that there are structural differences that cannot be isolated in a 3-digit ISIC data level comparison. For example, the structure of the Norwegian ferrous and non-ferrous metal sectors are themselves more energy intensive than in most other countries. Energy use in ferrous metals in Norway is dominated by the production of energy-intensive ferro-alloys like ferro-silisium, while aluminium, also a very energy-intensive product, constitutes a large share of non-ferrous metals. Furthermore, in the paper and pulp sector Norway has a larger share of the more energy-intensive pulp than most other countries. To normalise for structural impacts at this level requires a greater disaggregation of the energy-intensive sub-sectors than the available and comparable data allowed for in this study.

Figure 6.8
Sectoral Manufacturing Energy Intensities
1994



6.4 Impact of Changes in Manufacturing Structure

As discussed above, the high energy intensities in Norway are not necessarily due to low energy efficiency but rather to a very energy-intensive structure. To assess energy efficiency improvements it is interesting to look at how intensities have developed over time. Consider again Figure 6.6, which indicates that the aggregate intensity has not declined much in Norway since 1973, contrary to the development in most other countries. However, the changes in the Norwegian manufacturing structure towards a more raw materials based production can be expected to have affected this development significantly.

To estimate the impact changes in structure have had on energy use, intensities for each sub-sector are held constant, and only the shares of value-added are varied among the different sub-sectors. Figure 6.9 shows these trends for three years relative to the 1973 level. It illustrates the considerable variations among the countries. The two largest manufacturing producers, the United States and Japan, are the only countries where the manufacturing structure was significantly more energy intensive before the oil prices started rising after 1973 than in 1995. In Japan structural changes reduced energy use by 24 percent, in the United States by 17 percent, while other countries experienced reductions of less than 7 percent. Norway, Australia, and the Netherlands are the only countries where the structure became significantly more energy intensive. In these three countries, structure drove up manufacturing energy use between 1973 and 1995 by 22 percent, 14 percent, and 9 percent, respectively.

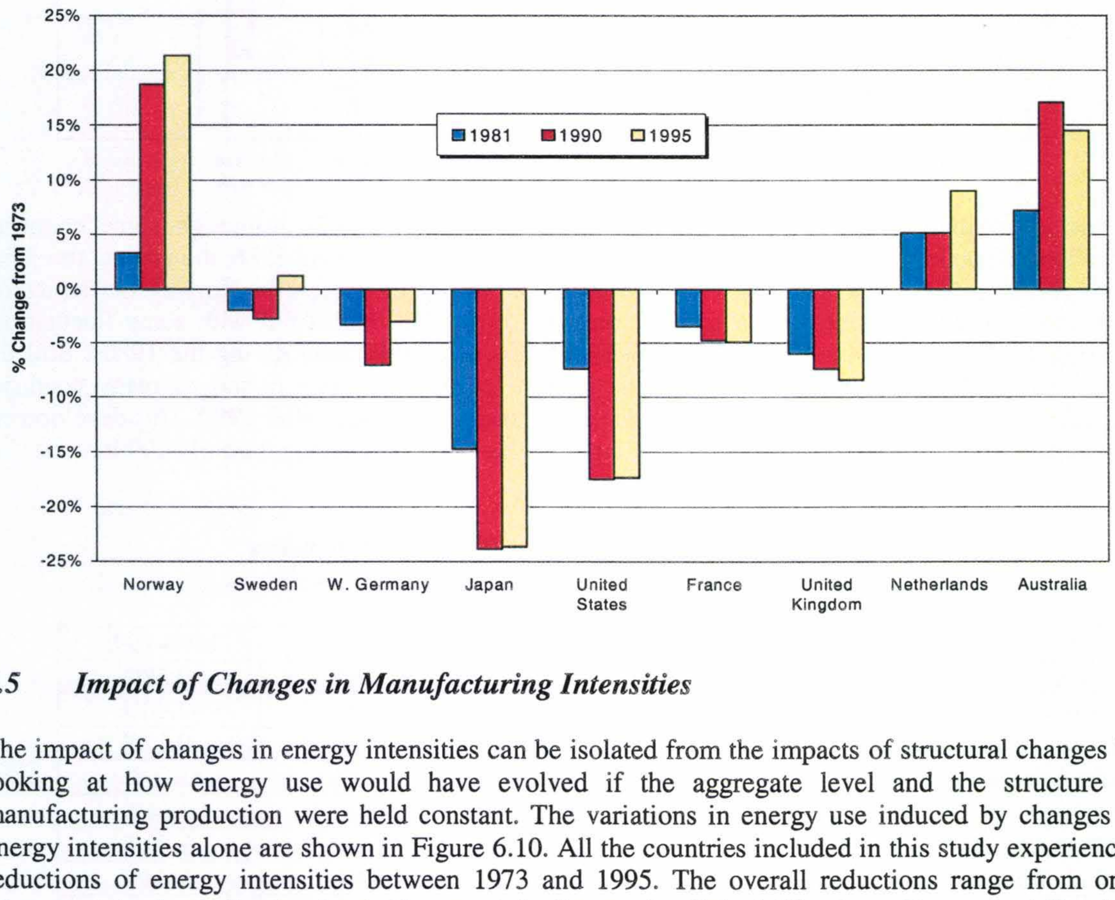
The decline in the United States was predominately caused by reductions in iron and steel production. In Japan reduced shares for all raw materials sectors throughout the early 1980s led to significantly less energy use. In west Germany the decline of iron and steel production has been a continuous trend since the early 1970s. Recent developments indicate that in all countries, except the United Kingdom, structure either remained constant or became more energy intensive between 1990 and 1994.

Between 1973 and 1981 the relatively small growth in the structure component in Norway is mainly due to expansion of the chemical industry. Chemicals also led the much more significant movement to a more energy-intensive industry structure through the 1980s, which was bolstered by the rapidly growing paper and pulp industry. Between 1990 and 1995 all energy-intensive raw material sectors increased their production, with especially strong growth in paper and pulp and non-ferrous metals. Over the 1973 to 1995 period as a whole, paper and pulp and chemicals production increased the most of all raw materials sub-sectors with about a doubling of value-added in both. However, it is the expansion of non-ferrous metals that had the strongest impact on energy use due to its very high energy intensity. The only raw material sub-sector that did not increase its production between 1973 and 1995 is non-metallic minerals. In the two non-raw materials sectors, food and kindred products and "other industries" production in 1995 was about the same as in 1973.

Figure 6.9

Impact on Energy Use from Changes in Manufacturing Structure

(Percentage Change from 1973 with Intensities at 1990-level)



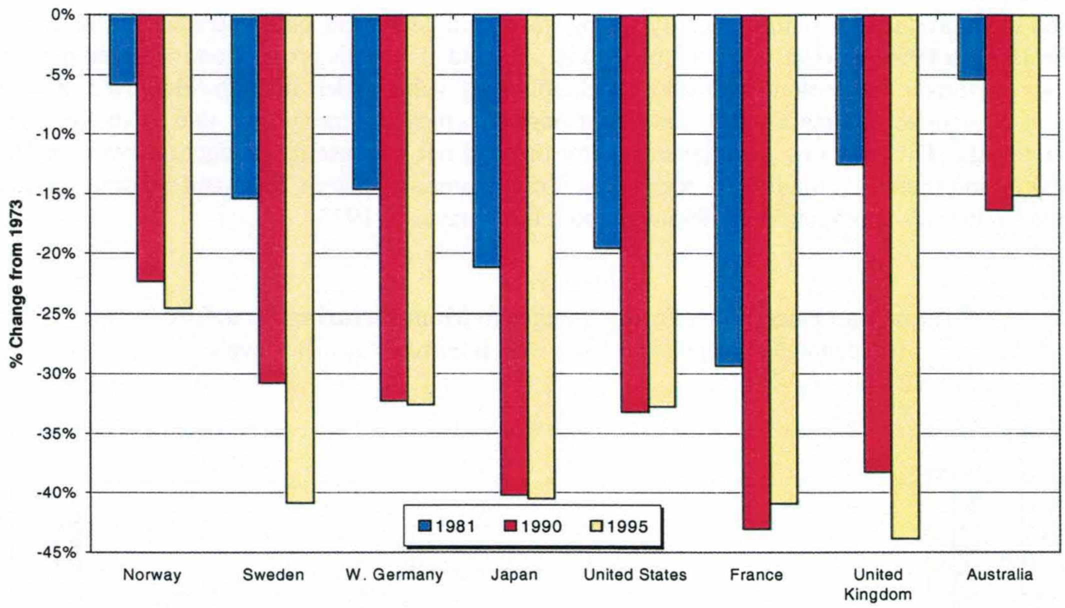
6.5 Impact of Changes in Manufacturing Intensities

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 Figure 6.10. All the countries included in this study experienced reductions of energy intensities between 1973 and 1995. The overall reductions range 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.

Figure 6.10

Impact on Energy Use from Changes in Manufacturing Intensities

(Percentage Change from 1973 with 1990 Manufacturing Structure)



Intensities declined in all countries until the mid-1980s (Table 6.2). Although some countries experienced continued reductions in intensities after the fall in oil prices in 1986, the general trend has been slower rates of decline than in periods with increasing oil prices. In Norway the structure-corrected intensity did not decline much during the 1970s, but then it fell with some fluctuations through 1990. The structure-corrected intensity fell less after 1990 than during the 1980s. Still the reductions in Norway were more significant than in most during this period as many countries experienced a considerable slow-down or even an increase in intensities after 1990. This development can be explained by the recessions that many countries went through during the early 1990s.

Table 6. 2

Impact on Energy Use due to Changes in Intensities

(Manufacturing Structure Constant at 1990 level)

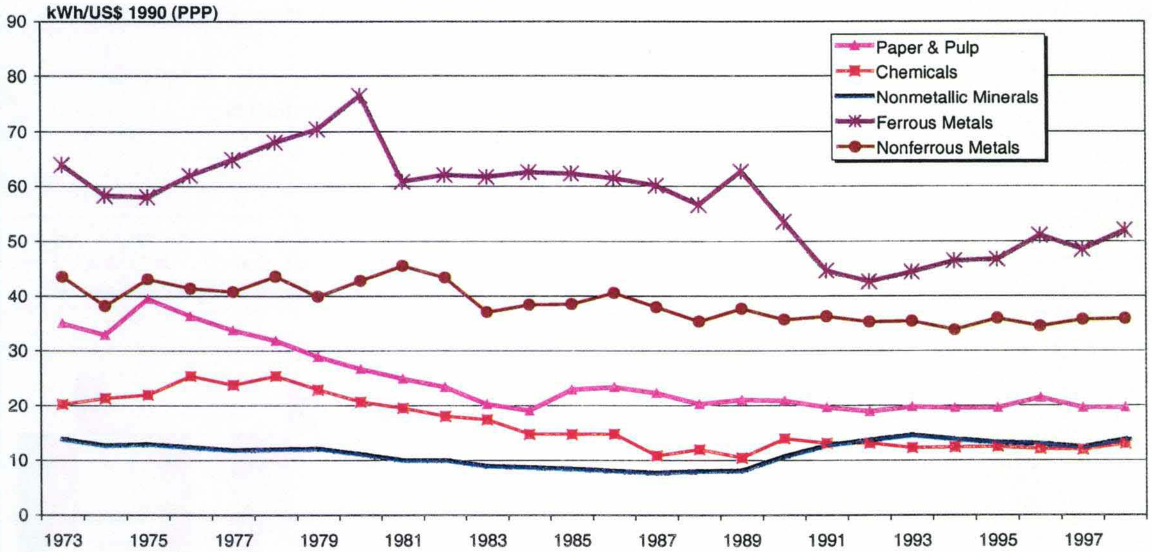
	1973-1981	1981-1986	1986-1990	1990-1995
Norway	-0.75%	-2.19%	-2.08%	-0.58%
Sweden	-2.09%	-2.51%	-1.88%	-2.90%
Japan	-2.97%	-3.40%	-2.65%	-0.12%
United States	-2.72%	-3.64%	-0.10%	0.16%
France	-4.34%	-2.65%	-2.10%	0.74%
United Kingdom	-1.67%	-4.02%	-3.68%	-1.92%
Netherlands	N/A	-5.21%	2.00%	-0.04%
Australia	-0.79%	-1.47%	-1.25%	0.30%
Canada	N/A	-0.81%	-0.83%	-0.31%

Which sectors contributed to the changes in the Norwegian intensity? Consider Figure 6.11 where the development of energy intensities in Norway's raw materials manufacturing sub-sectors is shown. The primary reason for the lack of significant reduction in structure-corrected intensity until 1981 is the increasing intensity in the two metals manufacturing sectors, outweighing progress made in paper and pulp and non-metallic minerals. The two latter sub-sectors continued to reduce intensities after 1981. But it was in the production of chemicals that the intensity declined the most between 1981 and 1990, when it fell by 51 percent, compared to 45 percent in non-metallic minerals, and 40 percent in paper and pulp. Between 1990 and 1995 intensities continued to fall in paper and pulp and chemicals, while there was a significant increase in non-metallic minerals.[32]

Intensity has varied more in the two metals manufacturing sectors. This is mostly due to rapid fluctuations in value-added levels, which may not only reflect changes in production (output).[33] These strong short-term changes in intensities should therefore be interpreted with care. However, the trend of falling intensity for non-ferrous metals in Figure 6.11 clearly indicates that savings were achieved over time. The intensity fell by 18% between 1973 and 1990, but has remained relatively constant since then. Energy use in this sub-sector is dominated by the production of aluminium, and the long-term trend suggests that there have been savings of energy use per unit aluminium produced. The intensity development in the production of ferrous metals is harder to interpret. It is difficult to conclude that significant energy savings have taken place in this sector without studying energy intensities for physical production of key products like GJ/ton of ferro-silisium. Outside of the raw materials sub-sectors (not shown in Figure 6.11), the intensity in food and kindred products fell slowly, but relatively steadily, resulting in a 12 percent decrease between 1973 and 1995. In "other industries" the intensity increased by more than 25 percent during the same period.

Figure 6.11

Norway: Energy Intensities for Raw Materials Industries



A part of the decline in energy intensities in the early 1980s was due to reduced oil use after the jump in crude oil prices in 1979. This was most important in the paper and pulp industry, which had access to cheap interruptible electricity and biomass for its boilers. Oil use in paper and pulp manufacturing declined from 4.5 TWh in 1980 to 1.3 TWh in 1983, with most of the shares picked up by electricity and biomass. Still a 20 percent reduction in energy intensity was achieved in paper and pulp over the three years. It can be argued, however, that some of the savings do not reflect increased energy efficiency on a useful energy level, since the thermal efficiency of an electric boiler is higher than for an oil boiler. On the other hand, biomass boilers have lower thermal efficiencies than an oil boiler and

[32] The changes in intensity between 1989 and 1990 in chemicals, ferrous metals and non-metallic minerals in Figure 6.11 are partly a result of the reclassification of some industries that occurred in 1990 for the data series used in this study. (See description of data sources at the beginning of the chapter). However, the changes in intensities discussed in the text above between 1973 and 1990 are based on data for 1990 consistent with earlier years, while the new estimated data for 1990 consistent with later years are used to evaluate the development between 1990 and 1995.

[33] Value-added is defined as the value of gross output less the value of intermediate consumption. Both of these have a volume and a price component. If the prices of commodities for intermediate consumption are increasing less than the prices of the output products, value-added could increase even if the production in volume, (or physical terms) is constant.

increasing share of biomass would pull the effect in the other direction. Taking the differences in boiler efficiencies into consideration indicates that fuel switching from oil to electricity in the first part of the 1980s did account for some of the decline in final energy intensity in this sector. The increase in biomass use in the last part of that decade, however, partly explains why the decline in intensity in paper and pulp stagnated during this period.[34] The total effect of fuel switching in this sector can thus be expected to have played a minor role in explaining the total decline in intensity between 1980 and 1990.

Consumption of oil in the production of non-metallic minerals was also greatly affected by higher oil prices; oil use fell from 3.5 TWh in 1979 to 0.5 TWh in 1983. Some of the oil was substituted by coal, with lower boiler efficiency. Yet, energy use per output in this sector dropped in the first part of the 1980s, indicating that real savings of useful energy took place during that period.

How does the development of energy intensities in the various energy-intensive manufacturing branches in Norway compare to other countries? Average percentage changes in energy intensities between 1981 and 1990 for Norway and three other big producers of raw materials (Canada, Australia and the Netherlands), as well as for the two largest IEA economies, Japan and the United States, are shown in Figure 6.12. In this group of countries, Norway, by far, had the strongest decline in intensity in chemical production. Norway also achieved higher than average reductions in paper and pulp and non-ferrous metals. On the other hand, the ferrous metals and non-metallic industries in Norway experienced an increase in intensities, contrary to trends in the other countries.

Figure 6.12
Average Annual Percentage Change in Energy Intensities for Raw Materials Industries 1981-1990

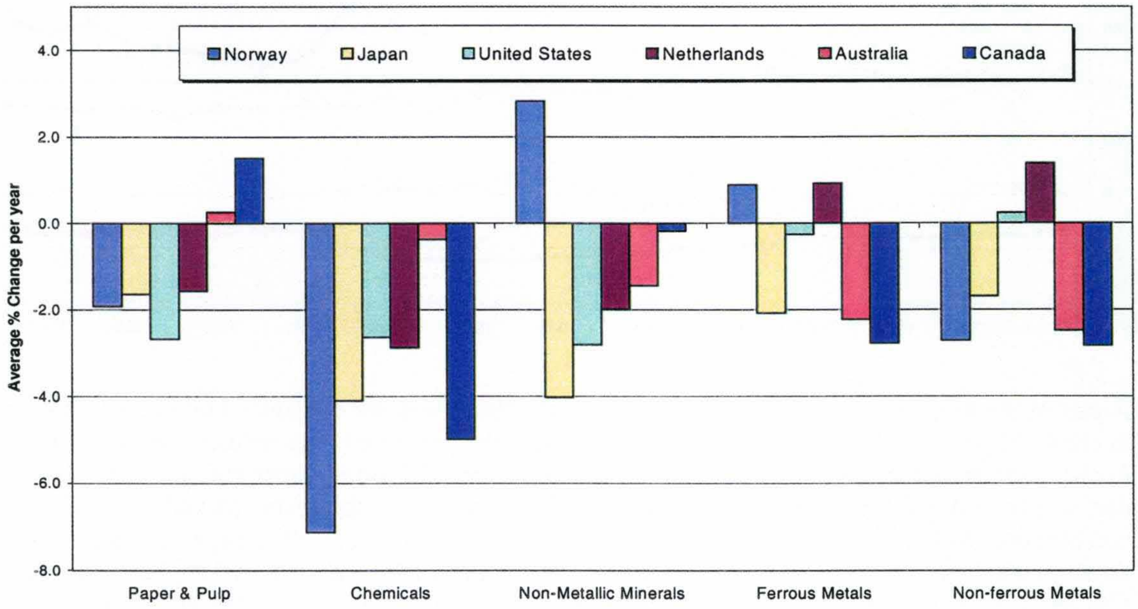
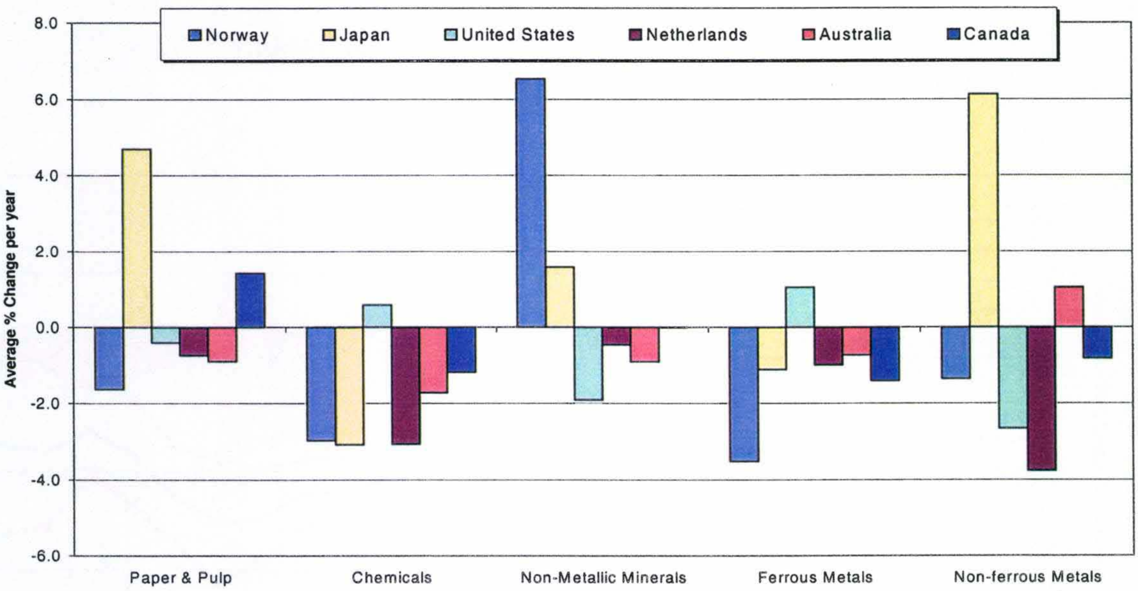


Figure 6.13 shows the same intensities for 1990-1995. This was a period of economic recession followed by slow recovery in most countries. The differences in intensity development among countries are affected by how deep the recession was and to what degree countries had recovered by 1995. The increase in intensities for some sectors in Japan clearly reflects a slow recovery from a

[34] The increase in energy intensity in paper and pulp for 1985/86 is partly a result of a hike in energy use caused by increased use of biomass and oil with lower thermal efficiency than the electricity it substituted. In 1987 electricity prices dropped, and this sector switched back to the more energy efficient electric boilers.

recession that hit the economy hard. In Norway the results were mixed: in the paper and pulp and ferrous metal sectors intensities fell more than in other countries and in chemicals the strong reductions continued though at a slightly slower rate than in Japan and the Netherlands. On the other hand, the sharp intensity increase in the non-metallic minerals sector, as also seen in Figure 6.11, stands out compared to other countries' developments. It is difficult to judge whether this indicates a negative energy efficiency trend in this sector, or if it is a result of additional shifts in the allocation of energy use between sectors not accounted for in the data used in this study.[35]

Figure 6.13
Average Annual Percentage Change in Energy Intensities for Raw Materials Industries 1990-1995



6.6 *Summary of Trends and Savings*

Changes in actual energy use that reflect variations in manufacturing activity, structure, and energy intensities in Norway are summarised in Figure 6.14. The data series for actual energy use show the change in actual manufacturing energy use over time compared to the 1973 level. Conversely, the activity, structure and intensity effects illustrate the change in energy use that would have occurred if only one of those components had changed at a time. (See methodology section in Chapter 2). For comparison, the change in energy use due to changes in aggregate intensity (see Figure 6.6), measured as total manufacturing energy per total value-added, is also included in Figure 6.14.

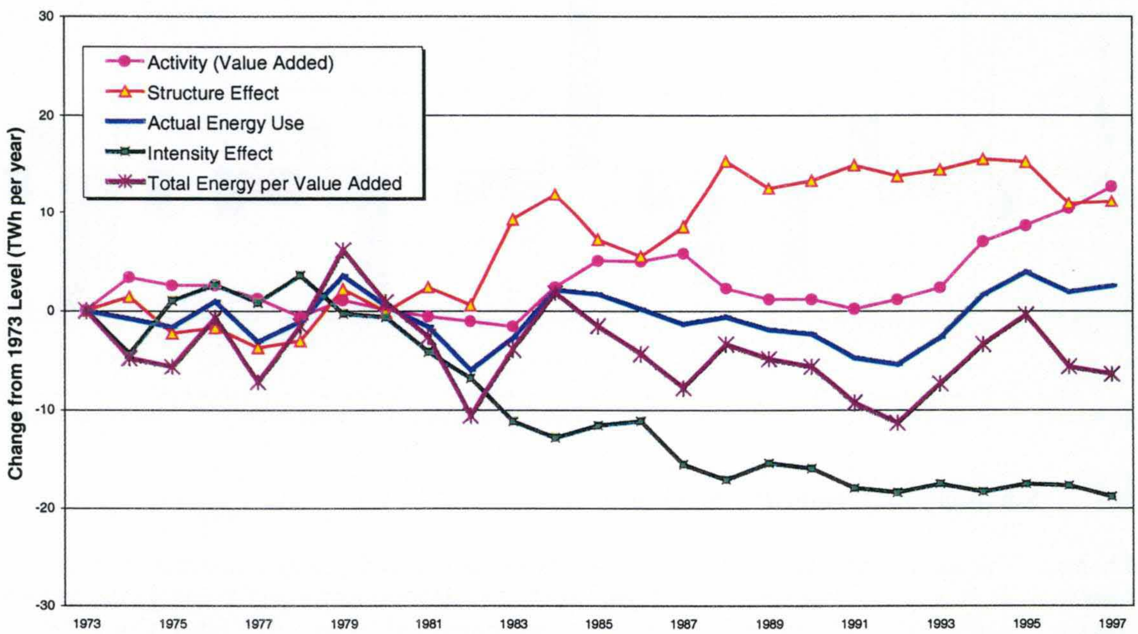
The figure shows that each index in 1980 had returned to its 1973 values: manufacturing output was at the same level, the structure was as energy intensive as in 1973, energy use was the same, and consequently, both the structure-adjusted intensity and the aggregate intensity were equal to 1973 levels. Since 1980 the structure component has fluctuated, but generally it has driven up energy use. Changes in the structure component alone would have increased energy use by more than 10 TWh between 1973 (or 1980) and 1997. As discussed, the growth in value-added over the whole period was moderate. It only increased significantly in the most recent years. The energy intensity effect reduced

[35] In Figure 6.12 the sectoral intensities are calculated using data for 1990 that are consistent with the old classification, hence the changes in intensities between 1981 and 1990 shown in the figure should reflect real changes in energy per value-added in these sectors. Similarly, the data used for calculating changes in Figure 6.13 are based on the corrected values for 1990, hence they should be consistent with the classification used in the following years.

energy use considerably during the 1980s, but the rate of decline slowed over the last ten years of the period analysed. Nonetheless reduced intensities led to a total reduction of energy use of about 19 TWh between 1973 and 1997.

Note the big difference between the development of the aggregate energy intensity (total energy per total value-added) and the structure-adjusted intensity. This illustrates the important effect structural changes have had on manufacturing energy use. Since the structure became more energy intensive, using the aggregate energy intensity as a measure would significantly underestimate energy savings. Aggregate intensity in 1997 was only a little below the 1973 level, indicating about 4 TWh of savings if this measure had been used. Note also how much more the aggregate intensity has fluctuated compared to the intensity effect. The more violent fluctuations in the aggregate intensity are due to structural changes that cannot be separated using the aggregate measure.

Figure 6.14
Impact of Changing Structure, Activity, and Intensity in Norwegian Manufacturing



Since the manufacturing structure has developed differently among countries, country comparisons based on the aggregate intensity can be very misleading. Consider Figure 6.15 where a summary of changes in the same factors as in Figure 6.14 is shown for selected countries between 1981 and 1994.[36] Again, the figure illustrates how aggregate energy intensity ("actual/activity") underestimates savings in countries where the manufacturing structure has become more energy intensive (the Netherlands, Australia and Norway). In Japan and the United States, on the other hand, the structure became less energy intensive, and thus the aggregate intensity overestimates the savings. For example, based on the development of aggregate energy intensity, the reduction shown in Figure 6.15 for the United States manufacturing indicates 24 percent savings over the period, while in Norway only modest savings of 5 percent would be indicated by the same measure. Taking the structural

[36] The 1981 to 1994 period is used for this figure since data for the Netherlands and Canada are not available from 1973 and data for the United States and w. Germany are not available after 1994. As discussed above, only a very small reduction in intensity took place in Norway between 1973 and 1981, while many other countries experienced strong reductions. Hence, the results in Figure 6.15 would generally have indicated less savings in Norway and more savings in other countries if the period 1973 to 1994 had been displayed instead.

changes into account, however, the United States achieved only about 16 percent savings (intensity), and Norway about 21 percent.

Figure 6.15
Changes in Manufacturing Energy Use
1981-1994

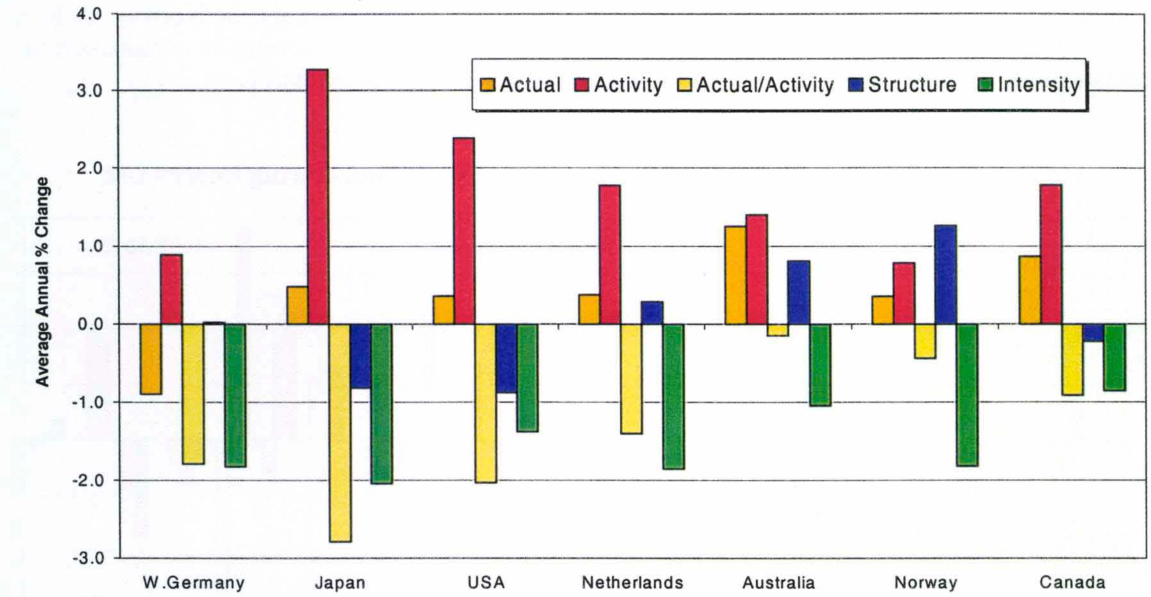


Figure 6.16 illustrates how savings from reduced energy intensities compare to other countries for three periods. The first column shows the change in energy use that would have occurred if intensities were frozen and only changes in manufacturing output and structure affected energy use. This can also be viewed as a measure of changes in the demand for energy service. The second column shows the changes in actual energy use, including the effect from changes in energy intensities. The third bar illustrates savings from reduced energy intensities, equal to the difference between the two first bars, (plus a small potential interaction term, refer discussion of similar figure in Chapter 3).

The figure shows that the energy service demand grew little, or even declined in most countries between 1973 and 1981. Important explanations are reduced output following recessions and a shift towards a less energy-intensive structure in some countries. Between 1981 and 1990 growth in energy service demand was generally strong. Norway was about average with 1.9 percent increase per year in this period. The growth in other countries ranged from 1.3 percent per year in the United States to 4.7 percent per year in Japan.

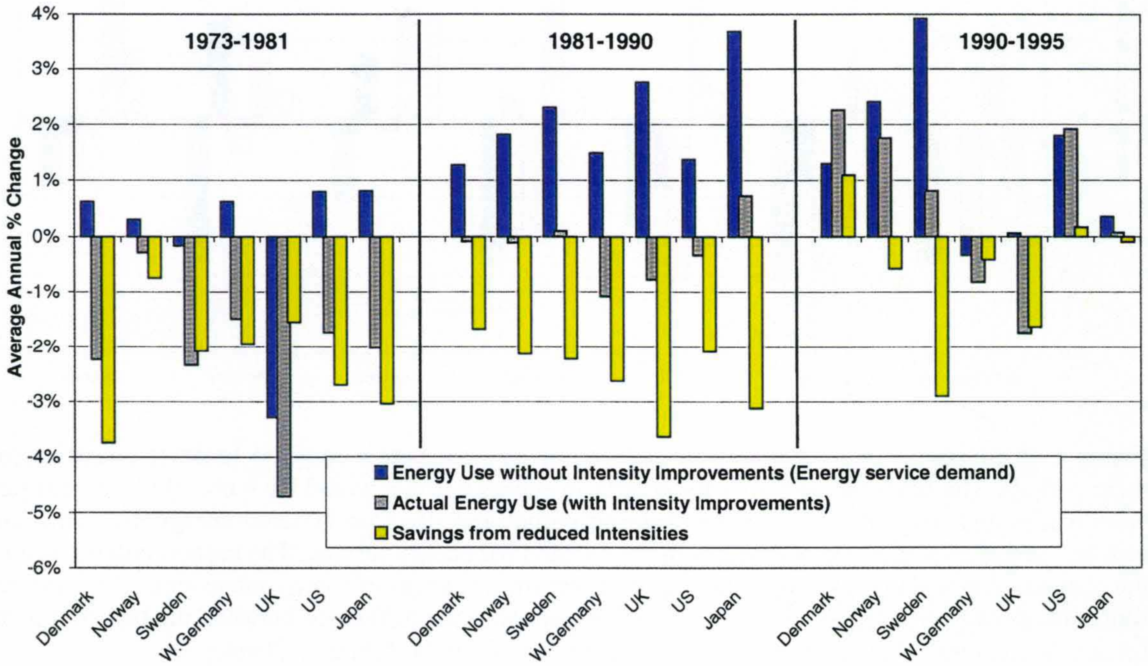
Between 1990-1995 Norwegian demand for energy service in manufacturing grew on average by 2.4 percent per year, more than in any of the other countries included in the figure, except Sweden. The high growth in energy service demand in Norway is a result of increased manufacturing production (value-added) augmented by a slightly more energy-intensive structure. In Sweden the development was driven by a strong recovery in some of the raw material sectors which pushed up both the structure and activity component.

Energy savings in Norway between 1973 and 1981 more outweighed the very modest increase in energy service demand so that actual energy use decreased as little. Still, as discussed before, the rate of decline in energy intensities in this period was lower than in any other country. During the next period the savings achieved in Norway were again enough to keep actual energy use in 1990 below the 1981 level. The savings in Norway amounted to more than 2 percent per year in this period, around average for this group of countries. Despite a net growth in actual energy use between 1981 and 1990 due a rapid increase in energy service demand, Japan achieved the highest saving rate in this period. Interestingly, except for Japan in this period, reduced energy intensities more than compensated for increases in energy service demand for all countries, so that actual energy use decreased.

After 1990 the situation changed. Most countries achieved smaller savings than before, in the United States and Denmark increasing intensities actually led to "negative" savings. In Norway as in a majority of the other countries the reductions in energy intensities were not enough to compensate for increasing energy service levels so that actual manufacturing energy use increased.

Figure 6.16

Changes in Energy Service and Energy Intensities for Manufacturing Energy Use



Presumably, the differences in energy savings among various countries 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.

Figure 6.17 shows the big differences in industrial electricity prices (including taxes) across countries, ranging from US$0.02/kWh in Norway (in 1990) to more than four times as much in Japan. Norwegian industry has had stable and low prices over the entire period, a unique competitive advantage for its electricity-intensive industries compared to the other IEA countries. Also the industrial fuel oil prices in Norway historically have been low, but the introduction of high taxes in the latter years raised the prices for industrial light oil to a level greater than in any other country except Italy (Figure 6.18). However, as the share of oil in the Norwegian manufacturing energy use today is low, the impact on energy efficiency from this price hike can be expected to be limited. On the other hand, if and when Norwegian electricity-intensive industries face increased electricity prices, as long-term contracts with guaranteed prices terminate and/or spot market prices in the Nordic market increase above the current low levels, there should be great potential for further improvements in energy efficiency.

Figure 6.17
Industrial Electricity Prices[37]
(including taxes)

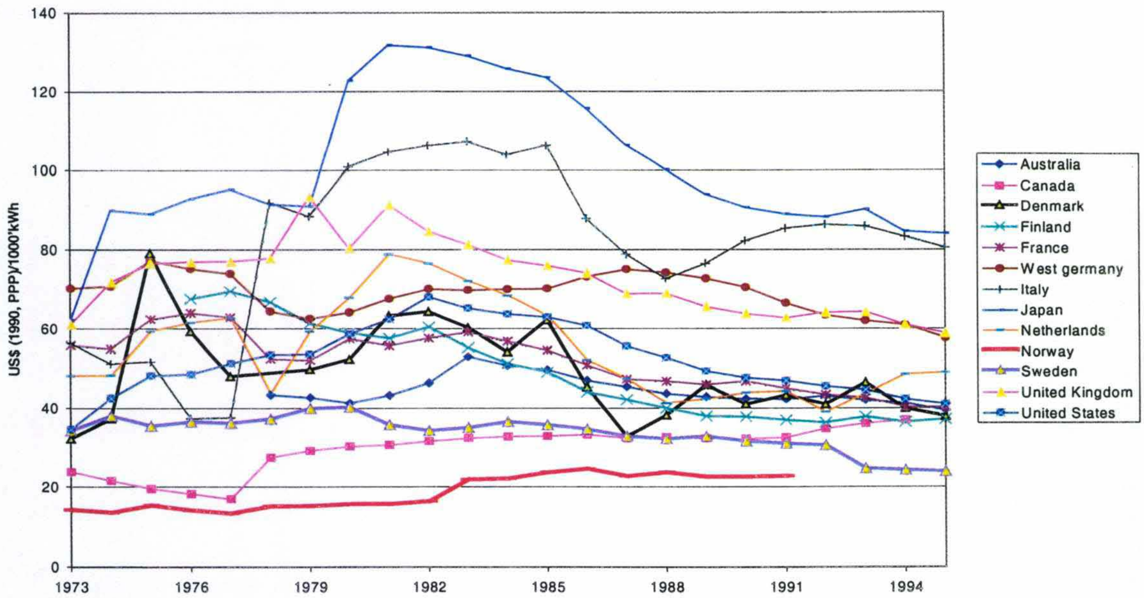
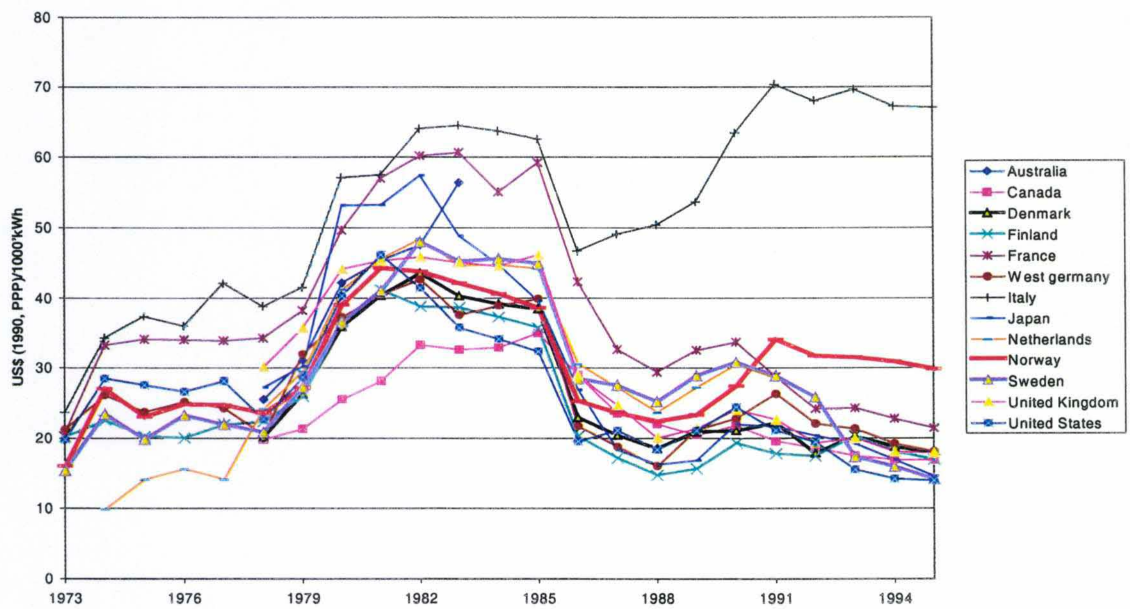


Figure 6.18
Industrial Light Fuel Oil Prices
(including taxes)



[37] Norway has not submitted electricity prices for industry to the IEA since 1991. However, data from Statistics Norway show relatively small changes in prices between 1991 and 1995. The prices shown in Figure 6.17 are weighted averages for all manufacturing sub-sectors. Electricity prices vary significantly among different sub-sectors, e.g. in 1995 electricity-intensive industries (raw material sectors except paper and pulp) paid about a third of the average for the rest of manufacturing.

CHAPTER 7: NORWEGIAN STATIONARY ENERGY USE SINCE 1990

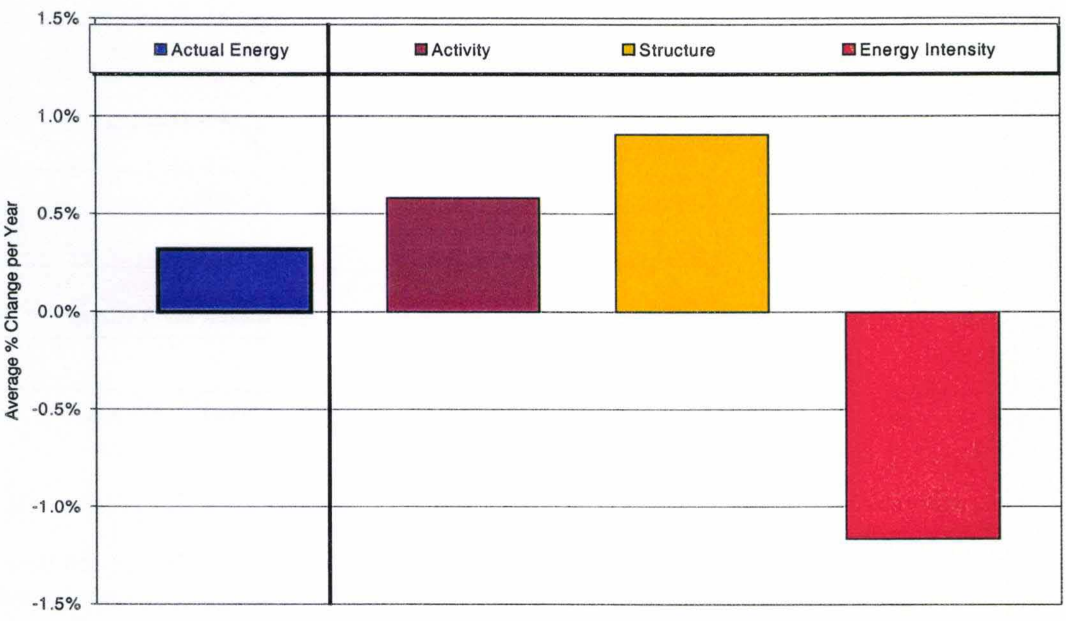
The previous chapters focus on comparing trends in Norwegian energy use with other IEA countries through 1995. This chapter provides a summary of the developments in Norway since 1990, focusing on the effect that changes in energy intensities have had on overall energy use in each of the three energy sectors and for stationary energy overall. Data for 1998 were still preliminary when this draft was prepared; hence 1998 is not included in most of the discussion.

7.1 *Residential Sector*

As discussed in Chapter 4 residential energy use in Norway has grown significantly since 1973. The growth seems to have at least temporarily levelled off as Norwegian homes are now heated to comfortable levels and growth in ownership of major energy consuming appliances has flattened out somewhat. As the bar for "Actual Energy" shows in Figure 7.1, the average annual growth in residential energy use has been about 0.3 percent since 1990, compared to 2.5 percent per year between 1973 and 1990. Electricity continues to increase its share of residential energy use in the most recent years, and grew on average 0.6 percent between 1990 and 1997 (not shown in the figure).

Recall that changes in energy use can be decomposed into changes in activity, structure and intensity. The activity component for residential is population. Figure 7.1 shows that this component grew at a little more than 0.5 percent per year between 1990 and 1997, while the structure component grew by almost 1 percent per year, driven by larger home area per capita and by some increase in appliance ownership. Taken together, activity and structure drove up energy service levels by about 1.5 percent per year in this period. The difference between the growth in energy services and actual energy use, almost 1.2 percent per year, is equal to the decline in energy intensities. For comparison (see Chapter 4), the intensity effect did not result in any net reduction of residential energy use between 1973 and 1990. This means that energy service levels and actual energy use grew at the same rate during this period, at about 2.5 percent per year on average.

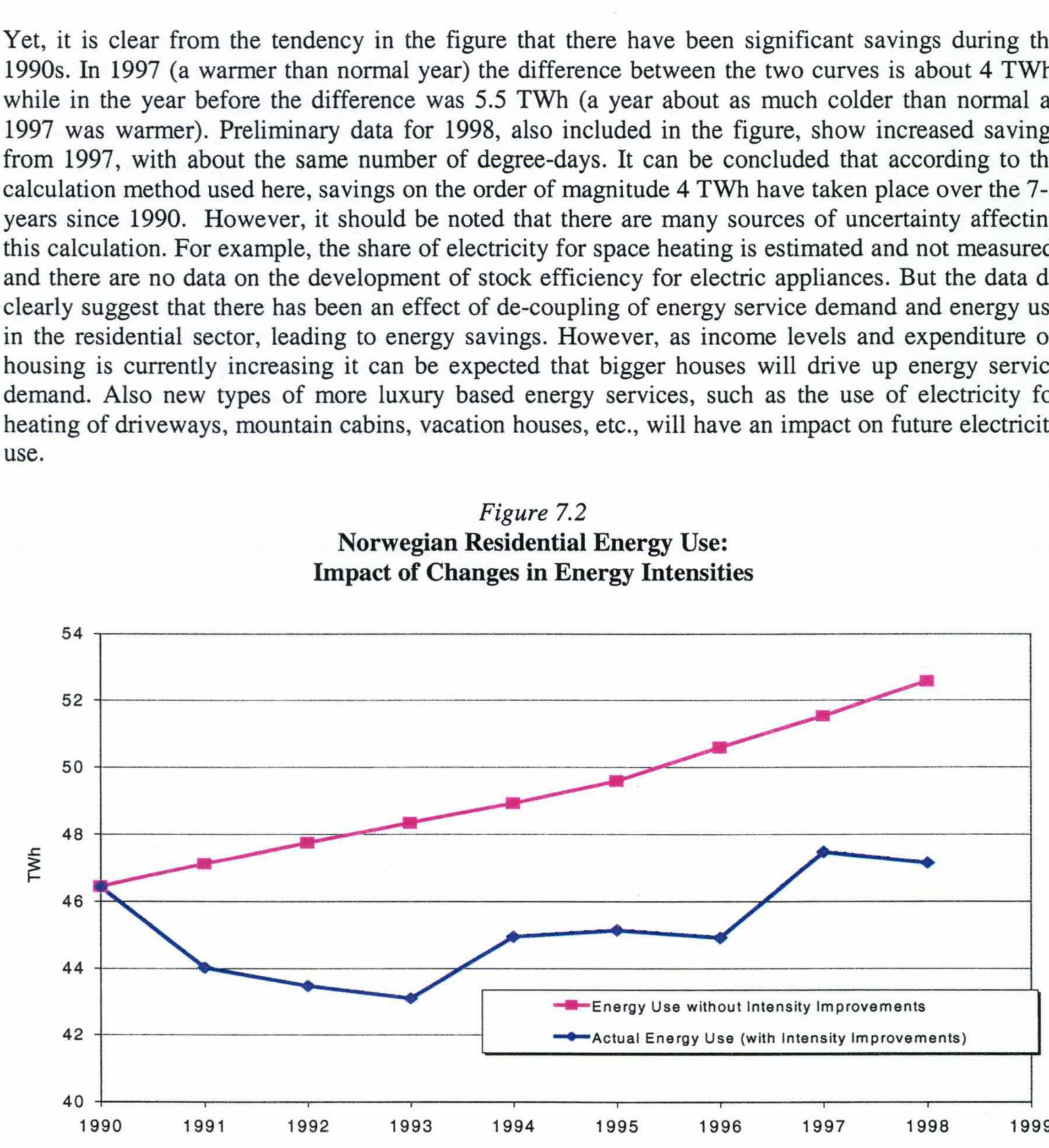
Figure 7.1
Changes in Residential Energy Use in Norway: Impact of Activity, Structure and Intensity 1990-1997



The yearly effect on energy savings from reduced energy intensities is illustrated in Figure 7.2. 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 two lines illustrates the savings from the reduction in energy intensities. The year-to-year fluctuations depicted in the lower line can to some extent be attributed to the climate correction used here. This correction does not entirely reflect the dynamics that climate variations induce, and may tend to overestimate space heating in warm years and vice versa in cold years. As discussed in Chapter 4, the climate-corrected energy use level in 1990 was high and hence does give a favourable starting point for calculating energy savings.

Yet, it is clear from the tendency in the figure that there have been significant savings during the 1990s. In 1997 (a warmer than normal year) the difference between the two curves is about 4 TWh, while in the year before the difference was 5.5 TWh (a year about as much colder than normal as 1997 was warmer). Preliminary data for 1998, also included in the figure, show increased savings from 1997, with about the same number of degree-days. It can be concluded that according to the calculation method used here, savings on the order of magnitude 4 TWh have taken place over the 7-8 years since 1990. 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 do clearly suggest that there has been an effect of de-coupling of energy service demand and energy use in the residential sector, leading to energy savings. However, as income levels and expenditure on housing is 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 of driveways, mountain cabins, vacation houses, etc., will have an impact on future electricity use.

Figure 7.2
Norwegian Residential Energy Use:
Impact of Changes in Energy Intensities



7.2 *Commercial/Service Sector*

Energy demand in the commercial/service sector grew significantly before 1990. It then fell between 1990 and 1995, before it started to grow rapidly over the next two years. Energy use is dominated by electricity and the increase over the last few years put additional strains on the overall growing electricity demand in Norway. Figure 7.3 shows that climate-corrected energy use grew an average of 2 percent per year between 1990 and 1997. However, it grew by 9 percent alone from 1996 to 1997! The activity component used for the service sector, value-added, increased an average of almost 3 percent in the 1990-1997 period, at a relatively stable rate. As mentioned, structure is not included as a separate component for the service sector as data for sub-sectors relevant for examining energy use are not available in an internationally consistent format. Hence the difference between actual energy use and the activity component is caused by the 1.2 percent reduction of energy intensity measured as energy per value-added.

Floor area could have been used as an alternative activity component. Since floor area did not increase as much as value-added, the intensity reduction between 1990 and 1997 in Norway would have been less based on energy per area. However, energy per square metre is a difficult indicator to interpret for the service sector. Little information exists on how much service sector floor area is actually heated and how much is used for storage space, etc. Furthermore, many end-uses such as water heating and electric equipment do not depend on area. Energy per value-added has the advantage that it relates energy to the economic output of the sector and hence is an indicator of "energy productivity".

Based on energy per value-added, the commercial/service sector did achieve savings after 1990. The reductions in intensity up to 1995 led to a difference between the energy service level (in this case the activity component only) of more than 4 TWh (see Figure 7.4). The rapid increase in energy use over the next two years, however, reduced these savings to about 2.5 TWh by 1997. Preliminary data for 1998 show only a very small growth in climate-corrected energy use between 1997 and 1998, despite continued growth in value-added. But 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.

Figure 7.3

Changes in Commercial/Service Sector Energy Use in Norway: Impact of Activity and Intensity 1990-1997

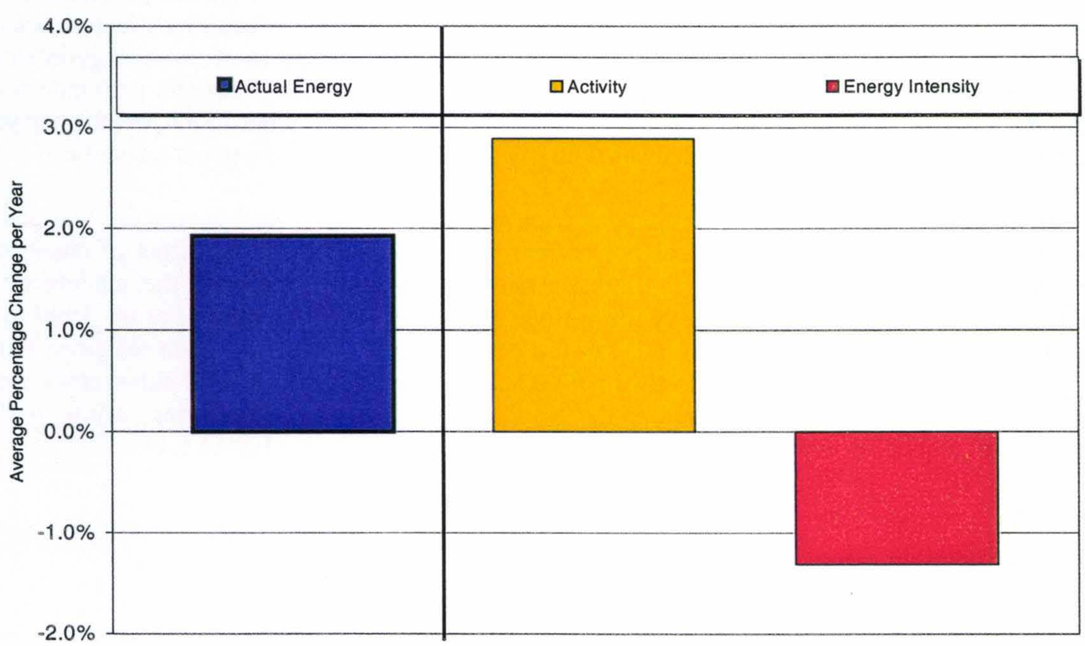
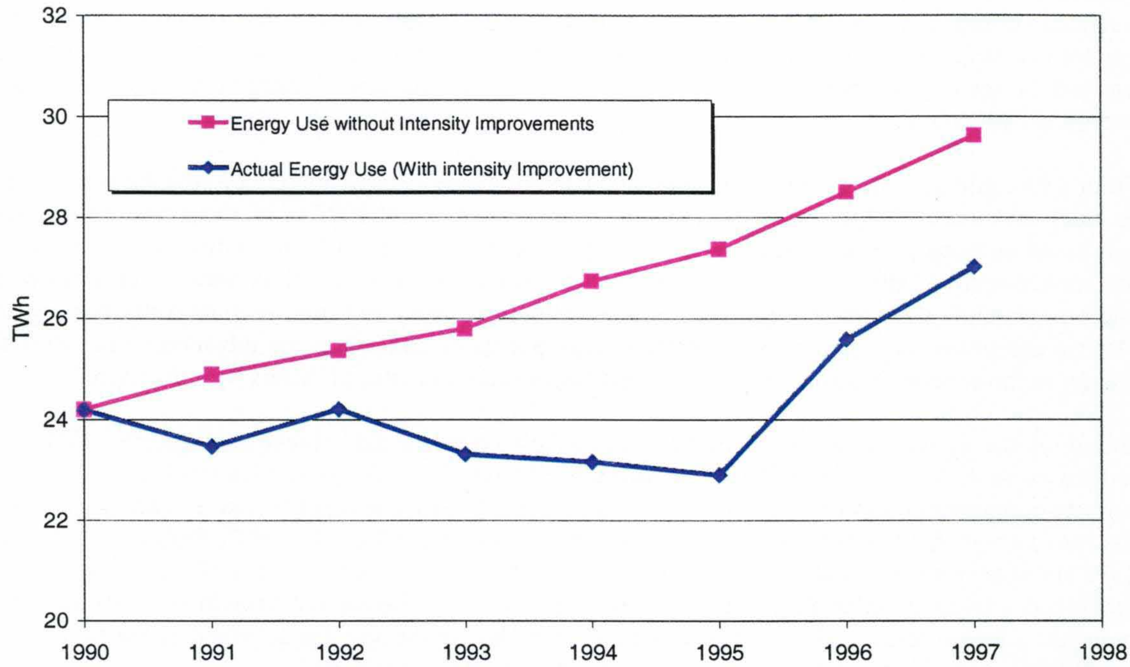


Figure 7.4
Norwegian Service Sector Energy Use:
Impact of Changes in Energy Intensities



7.3 *Manufacturing Sector*

In 1990 manufacturing energy use in Norway was a little lower than in 1973. Energy use continued to decline until 1993 after which it increased an average of 2.3 percent per year through 1997. Total energy between 1990 and 1997 grew an average 1 percent per year, driven by growth in activity levels of about 2.1 percent per year (Figure 7.5). Over the 1990-1997 period manufacturing structure became a little less energy intensive, primarily due to declining output shares from the energy-intensive production of ferrous and non ferrous metals and to some extent from the paper and pulp industry in 1996 and 1997. The decline had an average impact on energy use of about -0.35 percent per year, leading to a growth in energy service demand (activity plus structure) of 1.8 percent annually.

The difference between the growth in energy service and the growth in actual energy use was caused by declining energy intensities of about 0.8 percent per year. Recall that the effect of changes in intensities is calculated by letting only sub-sectoral intensities change, while the manufacturing structure, measured as the output mix of the various sub-sectors, is held constant at the 1990 level. The structure-corrected manufacturing intensity fell between 1990 and 1992. It then remained stable, until it again fell somewhat in 1997. Between 1990 and 1992 intensities fell in all sub-sectors except non-metallic minerals, food and kindred products and the group of "other industries", while in 1997 intensities for all sub-sectors except non-ferrous metals declined. (See also Figure 6.11).

Figure 7.5
Changes in Manufacturing Energy Use in Norway:
Impact of Activity, Structure and Intensity
1990-1997

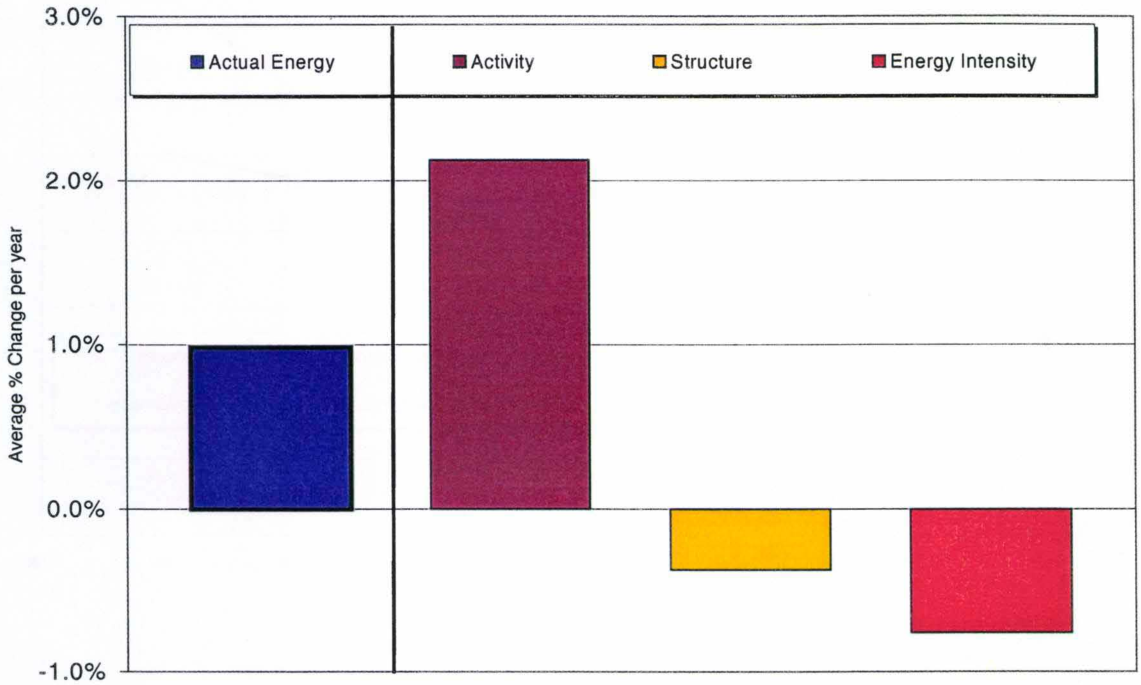
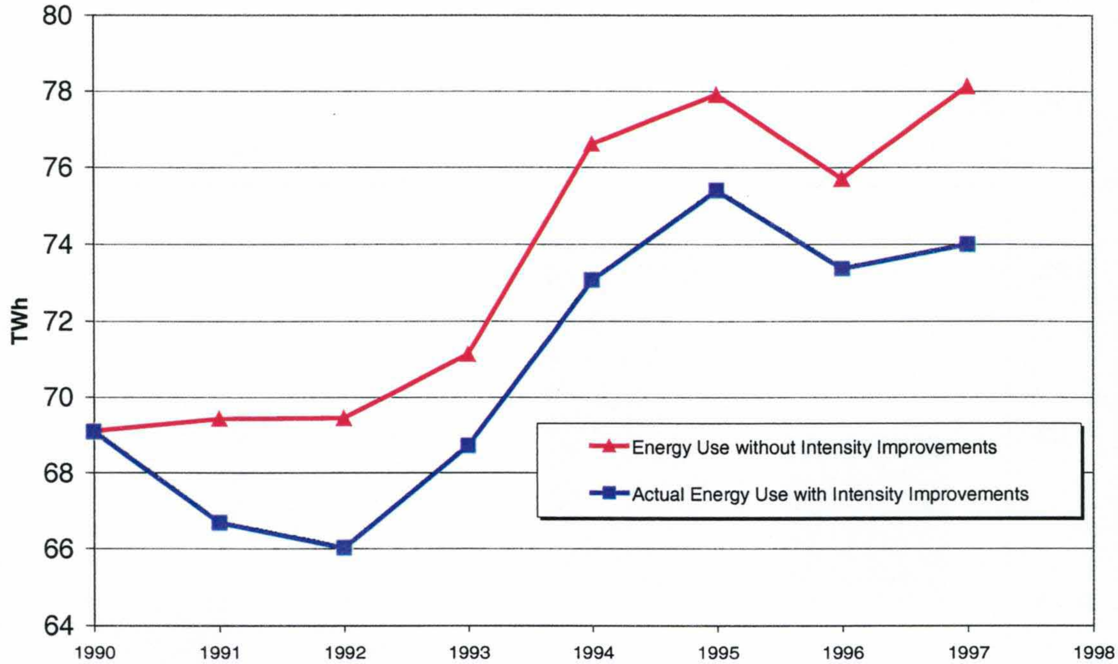


Figure 7.6 illustrates the effect the intensity development had on energy savings between 1990 and 1997. As calculated here, the fall in intensities between 1990 and 1992 corresponds to about 3 TWh savings. Over the next four years the difference between the two curves in Figure 7.6 varied very little, between 2.5 and 3.5 TWh, despite significant year-to-year changes in energy service demand (the upper curve). This indicates a stable level of intensities during this period. In 1997, however, falling energy intensities again led to savings. This results in a difference between the two curves of 4 TWh.

As mentioned for the two other sectors, care should be taken when interpreting these numbers. Using value-added as an activity component and the relative shares of value-added to describe structure developments has an advantage in that it links energy use to the economic output of the sector, i.e. provides a measure of "energy productivity". However, as discussed in Chapter 6, there are general uncertainties in the way this component is calculated and deflated to base year monetary values. Additional uncertainties exist because the Norwegian statistics have been restructured from ISIC to NACE standard (refer to Chapter 6). Even if this study is based on corrected data for Norway which should be consistent from 1990, some inconsistencies may remain in the time series data for both value-added and energy. However, after 1993 there should be no such effects. As well, since there were also reductions in energy intensity during the immediate years before 1990, the conclusion that there have been savings of energy per economic output of the order of magnitude discussed here appears relatively robust.

Figure 7.6
Norwegian Manufacturing Energy Use:
Impact of Changes in Energy Intensities



7.4 Summary of Changes in All Stationary Sectors

Figure 7.7 sums up the effect of changes in activity, structure and intensities on Norwegian stationary energy use between 1990 and 1997. The indices for the three sectors are added by using 1990 energy use as a weighting factor. As the figure indicates, growing activity levels drove up energy use by 1.8 percent on average per year, mainly due to increased value-added from the manufacturing and commercial/service sectors. There was little net change in the structure component between 1990 and 1997; only 0.1 percent annual increase on average. This means that the effect of increasing house area and appliance ownership which increased the structural component for residential was almost outweighed by the effect of manufacturing structure becoming less energy intensive. The latter sector carries a higher weight as energy use in 1990 was about 50 percent higher than in residential. All in all, this means that increasing energy service levels in the 1990s led to an annual average increase in energy use of almost 2 percent if the intensities had remained at the 1990 level. (See also Figure 3.5). But intensities did not remain constant, they declined at an average rate of 1 percent, such that actual energy use increased by about 0.9 percent annually. Interestingly, the rate of intensity reduction was about the same in all three sectors, with manufacturing averaging a little lower than 1 percent and service and residential sectors a little higher.

Figure 7.8 illustrates how the declines in energy intensities led to savings between 1990 and 1997. The difference between the curves increased relatively rapidly in the first two years. It then continued to increase slowly but steadily year by year. This means that the yearly fluctuations seen sector by sector outweighed each other and the steady trend towards increased savings appeared. 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 as discussed for each sector, this estimate is subject to many uncertainties. 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.

Figure 7.7
Changes in Stationary Energy Use in Norway:
Impact of Activity, Structure and Intensity 1990-1997

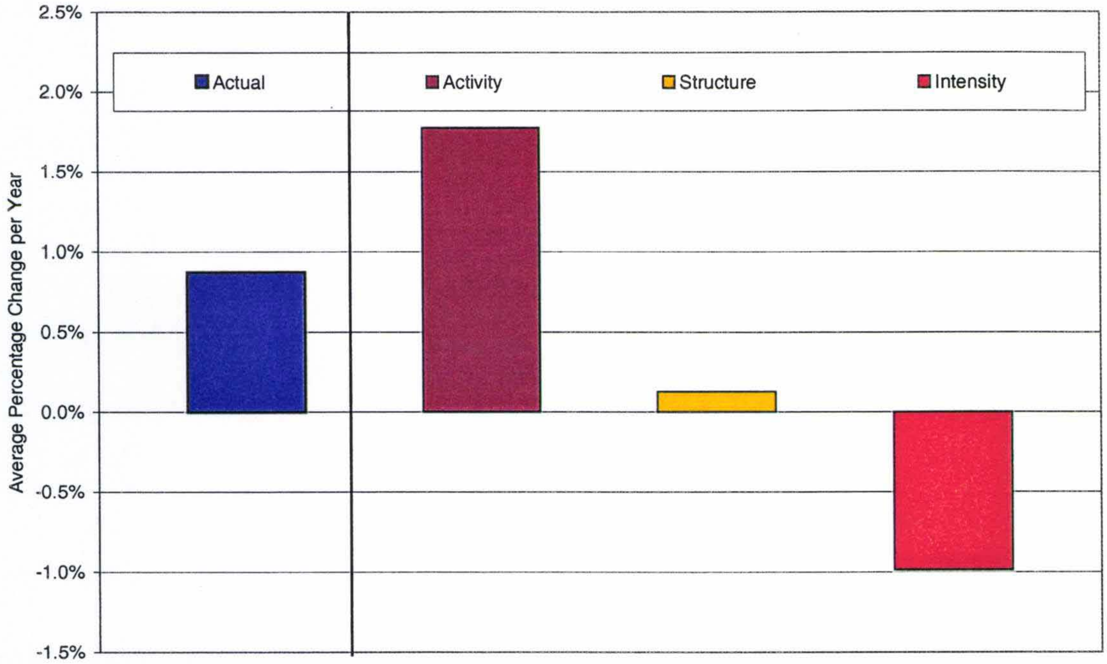
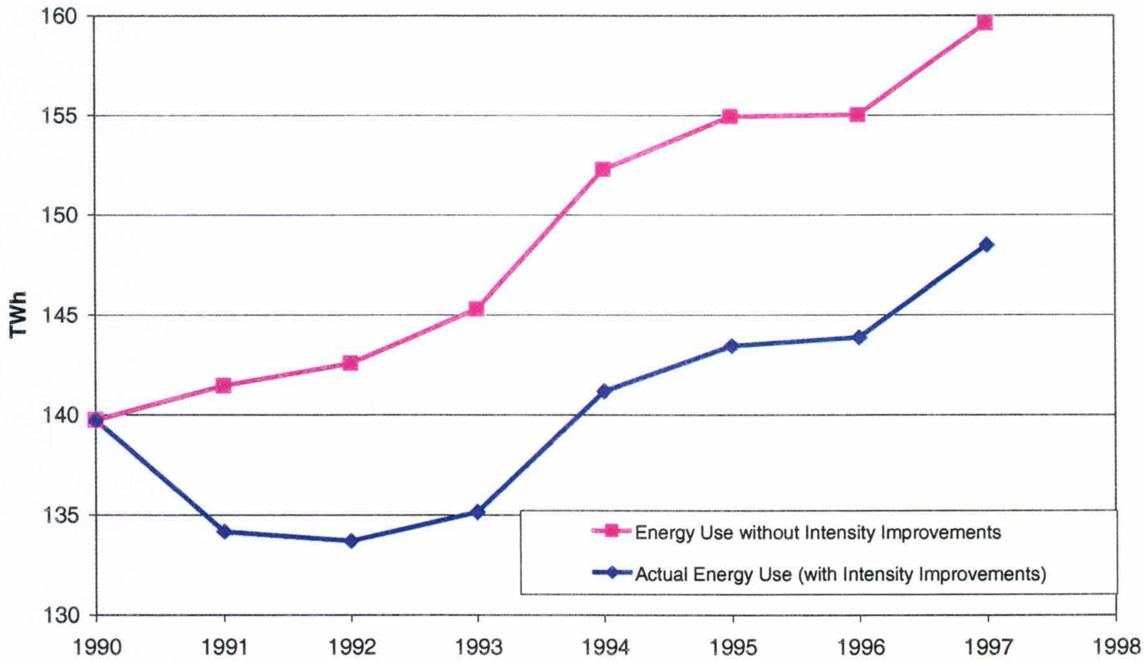


Figure 7.8
Norwegian Stationary Energy Use:
Impact of Changes in Energy Intensities



Norwegian
Water Resources and
Energy Directorate

NVE

Norwegian Water Resources and Energy Directorate
Middelthunsgate 29
P.O.Box 5091 Majorstua
N-0301 Oslo Norway

Telephone: +47 22 95 95 95
Telefax: +47 22 95 90 00
Internet: www.nve.no