Long Term Manufacturing Energy Use in Norway: An International Perspective

Fridtjof F. Unander Institute for Energy Technology, Norway
Lee Schipper International Energy Agency, France*

Synopsis

Analysis of the development of structure and intensity of manufacturing energy use in Norway and in 9 other OECD countries using Laspeyres indexing method.

Abstract

In this paper we examine the evolution of the structure and intensity of energy use in Norwegian manufacturing using the Laspeyres indexing method. The development in Norway is contrasted and compared to that in 9 other OECD countries; Denmark, Sweden, Finland, (West)-Germany, U.K., France, Italy, USA, and Japan.

Our results show that Norwegian manufacturing energy use stands out compared to the other countries we have studied; aggregated energy use per manufacturing output (measured as value added) is higher than in any other country, and Norway is the only country where this aggregate intensity has not been reduced since the 1970s. The development of this intensity can to some extent be explained by increasing shares of energy intensive sectors. However, normalizing for the differences in manufacturing structure by adjusting to the average output mix of all 10 countries, still leaves Norway with the highest energy intensity for manufacturing. Holding the structure of manufacturing output constant, the Norwegian energy intensities showed by far the least reductions of all countries, corresponding to 18% savings of manufacturing energy use from 1973 to 1993, while most other countries achieved between 30 and 40% savings. Most of the savings in Norway came in three raw material sectors, chemicals, paper/pulp, and nonmetallic minerals, and were to some extent a result of substitution of oil with electricity in the early 1980s when oil prices were high. The higher efficiency of electric boilers indicates that without the substitution to electricity the Norwegian energy intensities would have been ever higher in comparison with the other countries in our study.

Low energy prices, for electricity very low, compared to other countries, and energy intensities in all sub-sectors among the highest of the countries we have studied, lead us to believe that there is a significant potential for energy savings in Norwegian manufacturing industries.

*On leave from Lawrence Berkeley National Laboratory, USA

1. Introduction

Compared to other OECD nations Norway is in an unique energy situation, being the third largest oil exporter worldwide in 1995, having vast resources of natural gas, and also being endowed with hydro power that supplies almost all domestic electricity use. As a consequence of the access to inexpensive hydro power, Norway has developed a very electricity intensive manufacturing production. Although Norway has reached one of the highest standards of living in the world through its oil income, the expansion of the capital intensive oil sector has resulted in the value added share of manufacturing industries being of the lowest of all OECD countries, leaving Norway with an economy very dependent on the production of raw materials. Consequently, Norwegian manufacturing has a high ratio of energy use to value added compared to other OECD countries.

In this paper we analyze the evolution of Norwegian manufacturing energy use that has taken place since the first oil price shock in 1973, around the same time as the Norwegian petroleum industry started expanding. To better understand the development of energy efficiency we separate changes in energy use resulting from changes in industrial structure or output mixture from those resulting from changing energy intensities in each sub-sector. The development in Norway is contrasted and compared to that in 9 other OECD countries; Denmark, Sweden, Finland, (West)-Germany, U.K., France, Italy, USA, and Japan.

The study builds on two earlier analyses of Norwegian energy use, one made by (Schipper, Howarth, and Wilson 1990), where energy use in Norway was studied through 1986, and the second by (Bartlett 1993) who extended the studies through 1990. The first study included some international comparison, while the second was a study of Norway alone. This time more data are available for other countries allowing for an increased focus on placing Norwegian manufacturing energy use in an international perspective. The international comparisons draw on two earlier papers on manufacturing energy use (Torvanger 1991) and (Howarth et al. 1991).

We start out by giving a short description of the methodology and data used in the study. In section 3 we present the results by first reviewing trends in Norwegian manufacturing energy use. We then compare the development of manufacturing output and aggregate energy intensity in our group of OECD countries, before investigating the impact changes in structure and energy intensity have had on manufacturing energy use in the same countries, and finally we summarize our findings in the conclusion.

2. Methodology and data

2.1 Methodology

Manufacturing energy use is disaggregated into six separate sub-sectors and a sub-sector that contains all remaining sub-sectors. These are: food and kindred products (ISIC 31); paper and pulp (ISIC 341); chemicals (ISIC 351 and 352); non-metallic minerals (ISIC 36); iron and steel (ISIC 371); and non-ferrous metals (ISIC 372). In our analyses we sometimes refer to production of raw materials, defined here as ISIC 341, ISIC 351&352, ISIC 36, ISIC 371, and ISIC 372. Petroleum refining (ISIC 353/4) is excluded from considerations for all countries in this analysis, because of the difficulties associated with the disaggregation of feedstocks from energy consumed.

For each of these sub-sectors, we examine the structure of output (measured as shares of value added in each sub-sector, including the residual sub-sector) and the energy intensity, measured as delivered or final energy[1] per unit of value added. We measure the impacts of changes in output, sub-sectoral energy-intensity, and the structure of output on total energy use, using a Laspeyres decomposition to evaluate changes in each country's manufacturing energy use, and to compare changes over time by country (Howarth 1991). We measure energy intensities in terms of economic output because of the near impossibility of measuring accurately the energy intensities of individual manufacturing products over long periods of time for all countries, and the even more daunting problem of representing manufactured products by a few well-defined raw materials for which physical energy intensities are known.

We start with the basic identity of energy use (E) in manufacturing in year (t) following the "3-term energy decomposition" equation:

$$E = Y \sum_i \left(\frac{E_i}{Y_i} \right) \left(\frac{Y_i}{Y} \right) R \qquad (1)$$

where E - energy, Y - output (activity), i - manufacturing sub-sector, R - residual. The first term Y outside the summation series is referred to as *activity* component. The second term Ei/Yi is referred to as the *energy intensity* component, and the third term Yi/Y is the *structure* component.

To isolate the effect of one component (independent of the other components) on aggregate energy use, we construct “Laspeyres” indices of equation 1, such that one component is allowed to vary with time (t) while the other components are held at a 1973 base year (0) value (Denmark at the 1972 value). The resulting indices thus describe the magnitude of change in energy use (in terms of % change from the base year) due solely to the component in question. These indices are referred to as the “effects” of a given component. The following are the derived effect of each component:

$$\text{activity effect} = \Delta\%_{\text{activity}} = \frac{Y_t}{Y_0} \tag{2}$$

$$\text{intensity effect} = \Delta\%_{\text{energy intensity}} = \frac{\sum_i \left(\frac{E_{it}}{Y_{it}}\right) Y_{i0}}{E_0} \tag{3}$$

$$\text{structure effect} = \Delta\%_{\text{structure}} = \sum_i \frac{E_{i0}}{E_0} \frac{\left(\frac{Y_{iT}}{Y_T}\right)}{\left(\frac{Y_{i0}}{Y_0}\right)} \tag{4}$$

2.2 Data

In order to assure international comparability, disaggregation is limited to 2 or 3 digit ISIC sectors. Moving to a consistent 3 or 4 digit disaggregation over the entire period, while desirable, runs into enormous data limitations and costs as well. We acknowledge that this may obscure some of the elements that differentiate Norway’s manufacturing from that of other countries. However, also for Norway, lack of data, particularly before 1976, makes it difficult to study structural effects on a more disaggregated level. For Italy activity could not be disaggregated for ferrous and nonferrous metals sub-sectors, nor was it possible to isolate paper and pulp from printing, and also the disaggregation of the chemicals industry for Italy is not sufficient to resolve the major restructuring that occurred in the 1970s. Thus calculations for Italy are not completely comparable with the other OECD countries.

Real value added is used as activity indicator the figures are deflated from current prices to 1980-prices using subsectoral deflators. To allow for international comparison the figures in Norwegian kroner are converted to US$ using purchasing power parities (PPP). The same procedure is applied for all the other countries included in this study. PPP reflects the purchasing power in international markets for each country measured in US$, and may deviate from currency exchange rates, influenced by trade with currencies. In 1980 the PPP-rate from NOK to US$ was 8,31.

Data are taken from national energy balances and industrial statistics of the ten nations, as described in (Howarth et al. 1991), (Howarth, Schipper, and Andersson 1993), and a series of national energy-use studies; Denmark (Schipper et al. 1995), Sweden (Schipper et al. 1993), and Finland (Schipper et al. 1995). Analyses of U.S. manufacturing were described in (Schipper, Howarth, and Geller 1990), and (Golove and Schipper 1995). The Norwegian data used in this study are to some extent based on the data reported in (Bartlett 1993). The latter study included data through 1990, and some preliminary data for 1991. In addition to extending the analyses with three years and reorganizing the sectors somewhat, we have also corrected and updated the previous data using available new information.

3. Results

3.1 Trends in Energy Use

The Norwegian manufacturing energy use has been fairly constant over the period 1970-93 (Figure 3-1), in 1973 total delivered energy use was 257 PJ, 20 years later 249 PJ, corresponding to a 3% decrease over the entire time period. This development is in contrast to the rapid growth in manufacturing energy use prior to 1973, between 1950 and 1960 energy use grew at an annual average rate of 4,5% (from 89 PJ to 139 PJ), and even more between 1960 and 1970; 5,6% annually. The energy use reached its peak in 1979, 271 PJ, and its minimum only three years later with 237 PJ. The relatively high fluctuations around that time is caused partly by short-term fluctuations in energy needs in the production of ferrous metals, and partly by a general reduction in oil use as the oil prices jumped in the aftermath of the outbreak of the Iran-Iraq war in 1979 (OPEC II). Interestingly, after the first oil price shock in 1973 (OPEC I) the manufacturing oil use was less affected than in the later price shock. The trend of decreasing oil use continued until the oil price collapsed in 1986, but after a temporary increase in that year, the share of oil in manufacturing energy use has still been reduced. Part of the reason for this is that increased taxes have compensated for the decline in crude prices. The oil use accounted for 32% (81,1 PJ) of manufacturing energy use in 1973, and the share was down to 9% (22,6 PJ) in 1993. Investigating data for oil use prior to OPEC I, shows that the oil share did not change much, from approx. 37% in the 1950s to 35% in the 1960s. Table 3-1 also illustrates the diminishing role of oil in Norwegian manufacturing after 1973. Note again the extreme decline that occurred after the second oil price hike. Note also that the oil use continued to be reduced after crude prices dropped in 1986.

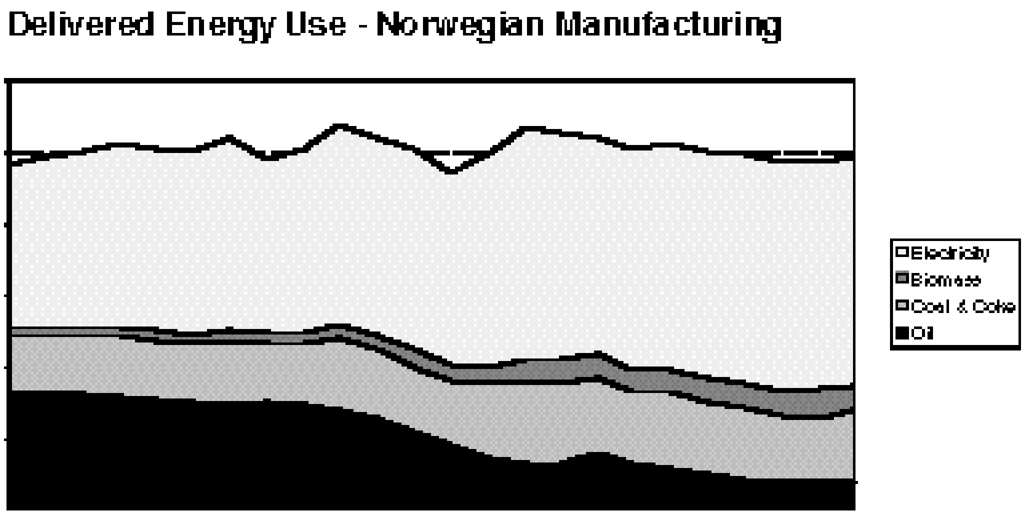

Figure 3-1. Delivered Energy Use - Norwegian Manufacturing

Table 3-1. Average Annual Change in Manufacturing Energy Use (%/year)

	1950-60	1960-73	1973-79	1979-85	1985-91	1991-93
Electricity	6,6	5,4	1,6	2,1	-0,1*	0,7
Oil	5,1	3,3	-2,3	-12,3	-6,7	0,1
Delivered Energy	4,5	4,8	0,9	-0,3	-1,4	1,0

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

As the table shows the electricity use was growing faster than delivered energy, resulting in that the electricity share increased from 37% in 1950 to 50% in 1965, and after a small decline returned to this level in 1973. In this year the electricity use was 127,9 PJ (35,5 TWh) and 20 years later it accounted 161,3 PJ (44,8 TWh). The increase was relatively steady. The share of electricity increased from 52% in 1979 to 60% in 1985, and has since 1990 been around 65%. The increasing share for electricity between 1950 and 1965 is a result of the low growth in coal use in this period. Most of the coal use in Norwegian industry is used as reducing agent in metal manufacturing. The coal share has been fairly constant since 1973, from 16% in that year, peaking at 21% in 1985, and down to 19% in 1993. The biomass use has been slowly increasing, from a low share of 2,5% in 1973[2] to 7% in 1993, of which the production of paper and pulp constitutes for a majority. (About a third of the energy use in this sector). The Swedish and Finnish manufacturing industries rely much more on biomass than Norway; in Sweden the share of biomass rose from 21% in 1973 to 35% in 1992, while the share increased from 15% to almost 25% over the same period in Finland.

3.2 Manufacturing Output

The Norwegian manufacturing industries were developing rapidly in the 1960s. Manufacturing output, measured in terms of real value added, grew at close to the same rate as the energy use, an average of 4,2% annually (compared to 5,6% for energy use). However, in 1973 Norway together with Denmark still ranked the lowest in manufacturing output (in real value added per capita) among the 10 OECD-countries we have studied (Figure 3-2). By contrast the Swedish production was approx. 50% higher than in the other two Scandinavian countries. The relative importance of manufacturing was about the same in the Norwegian and Swedish economies in the early seventies, constituting for 24% of total Gross Domestic Product (GDP) (Figure 3-3). The low Norwegian manufacturing output is thus reflecting the relatively low overall economic activity in Norway before the development of the oil sector started. The real value added per capita from Norwegian manufacturing industry has remained approximately on the same level the last twenty years. By contrast the Finnish manufacturing value added per capita almost doubled from 1970 until the recession hit the Finnish economy after the beginning of the dissolution of Soviet Union in 1990.

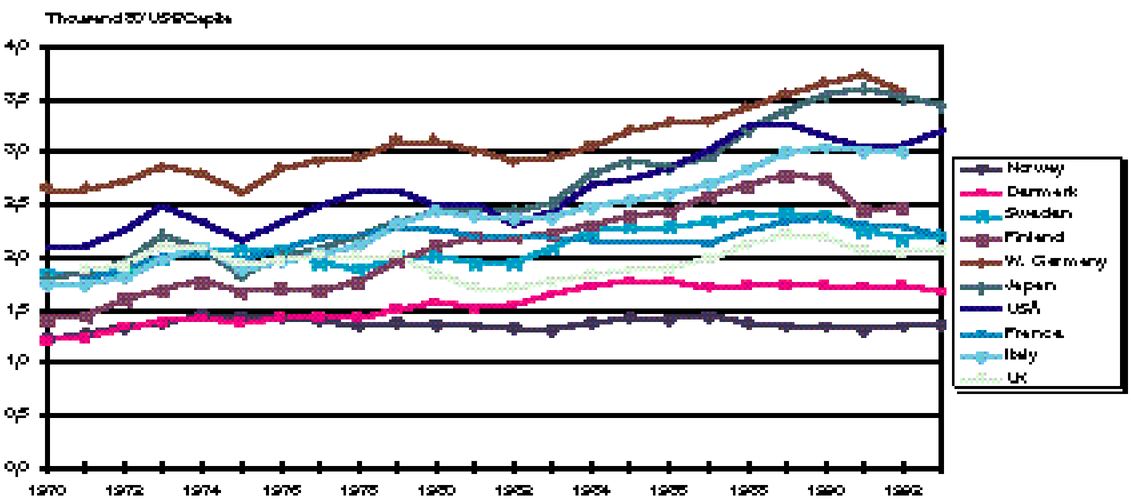

Figure 3-2. OECD Manufacturing Sector - Manufacturing GDP per Capita

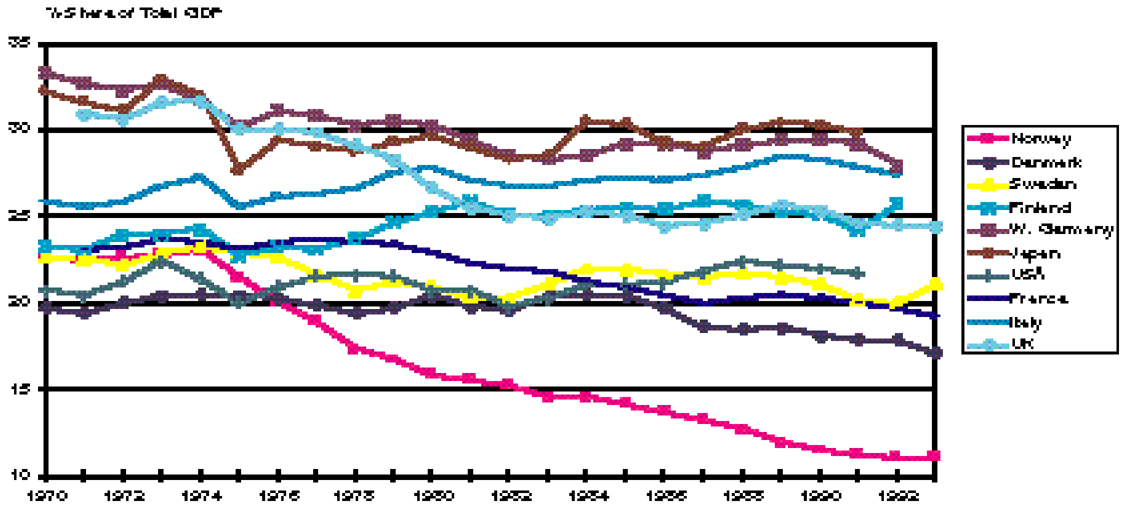

Figure 3-3. OECD Manufacturing Sector - Manufacturing GDP as Share of Total GDP

As the expansion of the capital intensive offshore oil industry took place, the manufacturing share of total GDP in Norway gradually decreased to 11% in 1992, less than half on its 1973-share. A similar trend is observed in the UK where the offshore sector was developed around the same time. For all other countries the data give no indication that there is a significant long term trend towards de-industrialization, but rather that the production is following the development of overall GDP.

Separating the energy intensive raw materials sectors (paper/pulp ISIC 341, chemicals ISIC 351/352, non-metallic minerals ISIC 36, ferrous metals ISIC 371 and non-ferrous metals ISIC 372), shows that the composition of manufacturing GDP varies significantly among the countries (Figure 3-4). Since 1980 the shares of raw materials in the larger OECD countries have been between 20 and 25% of total manufacturing value added, while Denmark has by far the lowest share, approx. 16% in 1991, and the other Nordic countries, Norway, Sweden and Finland clearly higher (in 1991 36%, 33%, and 31% respectively). In every nation the share of raw materials production fell in the years immediately following the economic disruptions after the oil embargo in 1973 (OPEC I). The same happened after the second oil price hike in 1979 (OPEC II), with the exceptions of Italy and Norway where the production of raw materials kept or increased their shares. The figure shows the relatively abrupt changes in the Norwegian raw materials share in the 1980s. In 1983-84 production of all raw materials, expect non-metallic minerals, rose, while the rest of manufacturing was stagnant, resulting in a higher share for raw materials. In the two following years the trend was reversed; production of raw materials decreased (mainly due to drop in chemicals), while the other manufacturing sectors were picking up. Since 1987 increased production of chemicals and paper/pulp has been driving the raw material share of Norwegian manufacturing up.

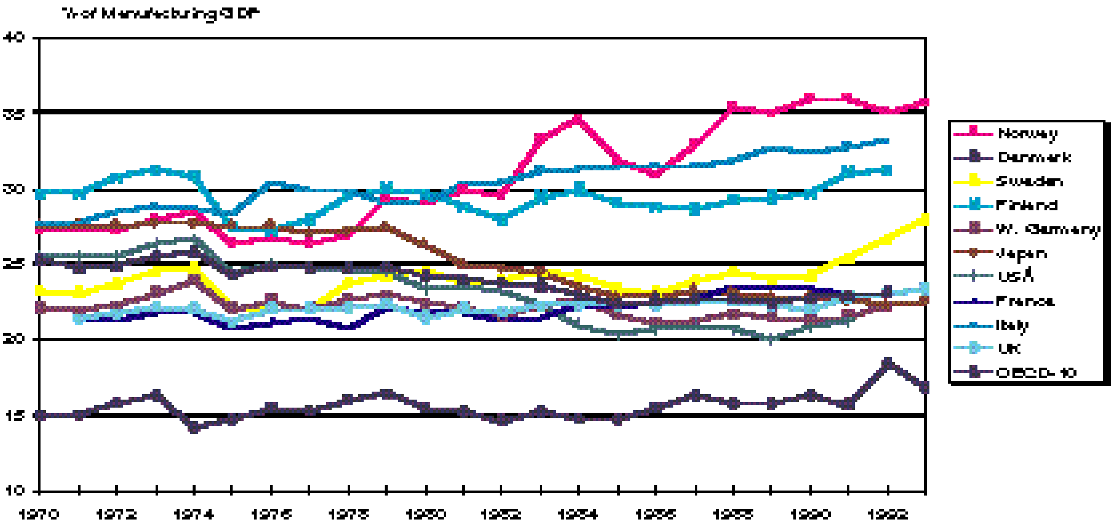

Figure 3-4. OECD Manufacturing Sector - Raw Materials GDP as Share of Manufacturing GDP

3.3 Aggregate Energy Intensity

Figure 3-5 shows per capita energy use per sub-sector for each country in 1973 and 1991. Despite having the lowest manufacturing output, the level of manufacturing energy use in Norway is very high; of the countries included in this study only Finland used more energy per capita in its manufacturing production in 1991. In Norway, as well in all the other countries, except Finland, the delivered energy use per capita in 1991 is lower than in 1973. This is partly a result of increased use of electricity instead of direct combustion of fuels. Hence, if we include losses in the power sector, and express the development in primary energy terms (not shown) the decline is small, or there is an increase, for each country. However, for Norway the difference between delivered and primary energy is minor since the losses in hydro power generation are small compared to those in thermal power stations.

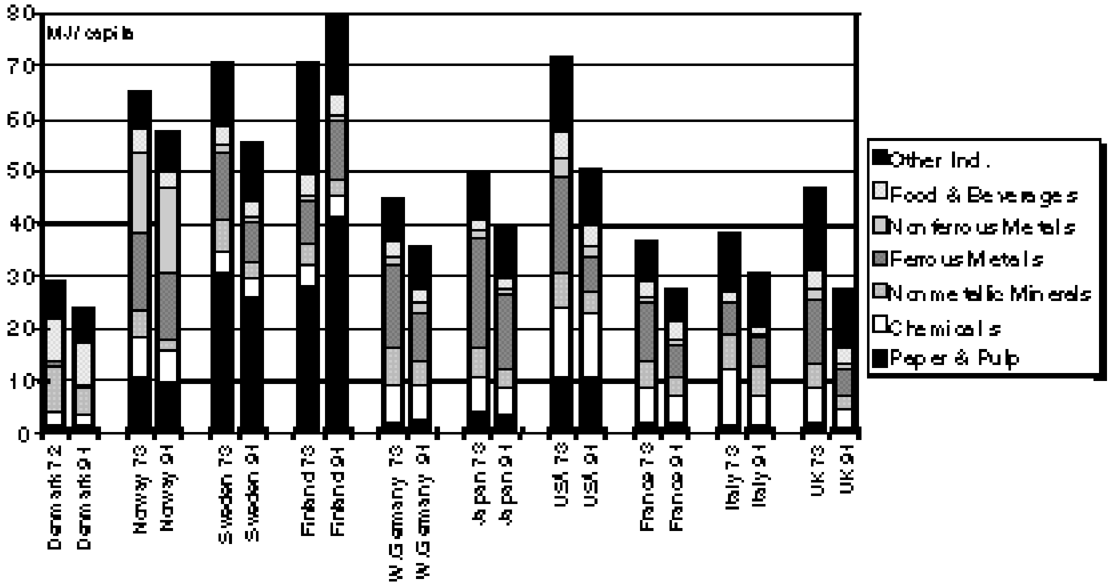

Figure 3-5. OECD Manufacturing Sector - Delivered Energy Use per Capita

Dividing the total manufacturing energy use by total manufacturing value added in real terms, yields a measure of specific energy use, or aggregate (delivered) energy intensity. The development of this intensity for each country is shown in Figure 3-6. The Norwegian intensity is of magnitude several times higher than for most of the other countries. Finland and Sweden are also clearly above the average.

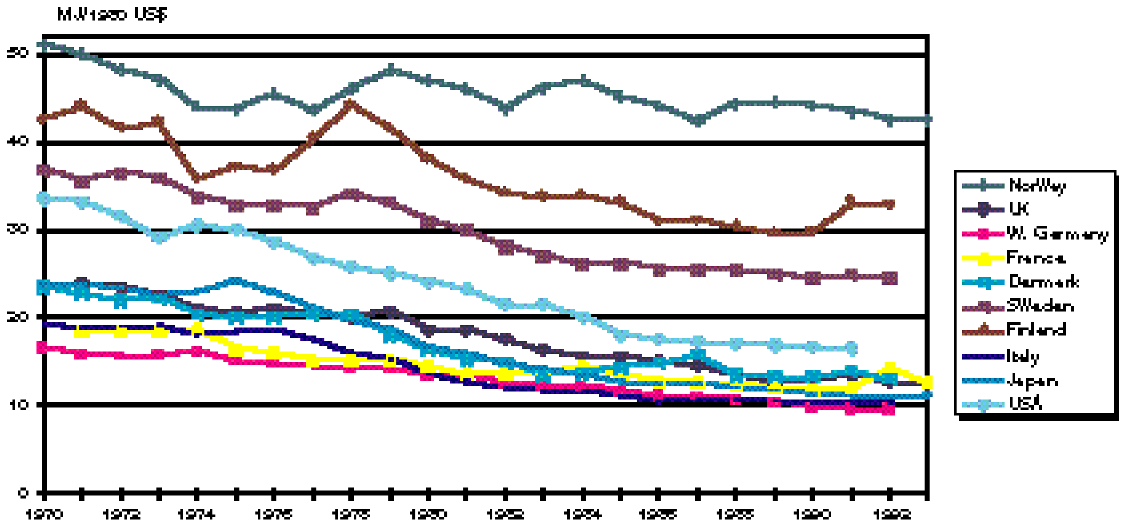

Figure 3-6. OECD Manufacturing Sector - Delivered Energy Intensity

What is the meaning of the large spread in aggregate intensity among countries, and why does Norway stand out as extreme as it does? Obviously the composition of the manufacturing production plays a significant role for the energy use in this sector. As we have discussed above the Norwegian value added share from production of energy intensive raw materials is higher than for any other country that we have studied, followed by Sweden and Finland (Figure 3-4). To normalize for the differences in the mix of output, we calculated the energy intensity that would have occurred in each country if they all had the same shares of sub-sectoral output that make up the average for all 10 countries. In other words, the normalization attempts to equalize the structure output everywhere by multiplying each country's sub-sectoral intensity by the respective sub-sectoral shares given by the average OECD-10 structure. This intensity is shown in Figure 3-7 *(OECD-10-structure)* next to the actual aggregate manufacturing intensity in 1991. Where the intensity increases in the alternative normalization (U.S., U.K.), 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. For Norway, but also for Finland and Sweden, the difference is large, indicating the importance of the high shares of energy intensive products. Investigating each sub-sector we see in general the same spread in intensities: in West Germany, Japan, or Italy (in comparable sub-sectors) the intensities tend to be lower than those in the U.S. or U.K., while intensities in Finland, Sweden, and Norway tend to be higher than the average.

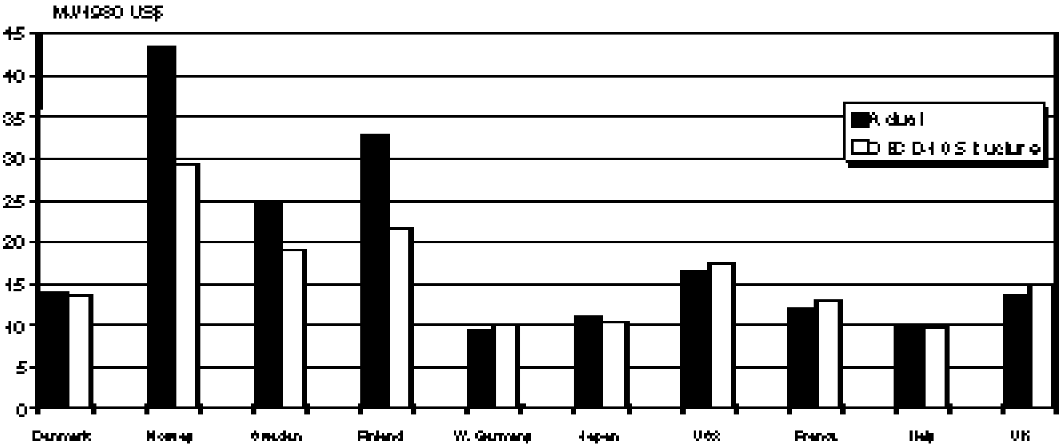

Figure 3-7. Delivered Energy Intensity in Manufacturing - 1991 Actual Structure and OECD-10 Average Structure

In 1991 Norway had the highest or second highest energy intensity in all the sub-sectors that we are including in this study, except for in production of paper and pulp where Norway is following Sweden and Finland. This results in that Norway, even after the normalization, still by far has the highest intensity. This does not necessarily mean that the Norwegian manufacturing energy efficiency is lower than in the other countries, but rather that there are structural differences that can not be isolated at a 3-digit ISIC level comparison. The structure of the paper and pulp and metals sectors in Norway (and in Finland and Sweden) is itself more energy-intensive than in the other countries because of extraordinarily high production of raw pulp and raw steel or alloys, driving up the intensity for each sub-sector. Normalizing for these structural impacts requires an even further disaggregation of the energy intensive sub-sector than we were able to collect comparable data for.

The Norwegian intensity as shown in Figure 3-6 stands out not only because of the level, Norway is also the only country that has not reduced aggregate intensity since the seventies. After a temporary decrease in the years following OPEC I, the aggregate intensity in the Norwegian industries has been fairly constant. The increasing share of raw materials (Figure 3-4) in Norwegian manufacturing may serve as an explanation for this development. On the other hand, also in the Swedish industry the share of raw materials has been increasing in the 1980s, while at the same time the aggregate intensity was steadily decreasing.

3.4 Impact of Changing Structure

To get an indication of the impact changing industry structure has on energy use, we hold the intensities and activity level for each sub-sector constant at 1973 level, and vary only the shares of value added among the different sub-sectors. Figure 3-8 presents the trends for each country. The figure shows that there are considerable variations among the countries. Again the development in Norway stands out; the effect of changing manufacturing structure increased the energy use by 19% between 1973 and 1991. The three largest manufacturing producers, USA, Japan and West-Germany are the only nations where the manufacturing structure is significantly less energy intensive in 1991 than it was before the oil prices started accelerating after 1973. In Japan the structural change reduced energy use by 18%, in USA by 15%, and in West Germany by 13%. In the other nations the manufacturing structure in 1991 was about as energy intensive as in 1973. However, the changes indicated for Italy are misleading, obscured by the aggregated nature of their data compared with other countries, as well as by a profound decrease in the production of raw chemicals (in ISIC 351).

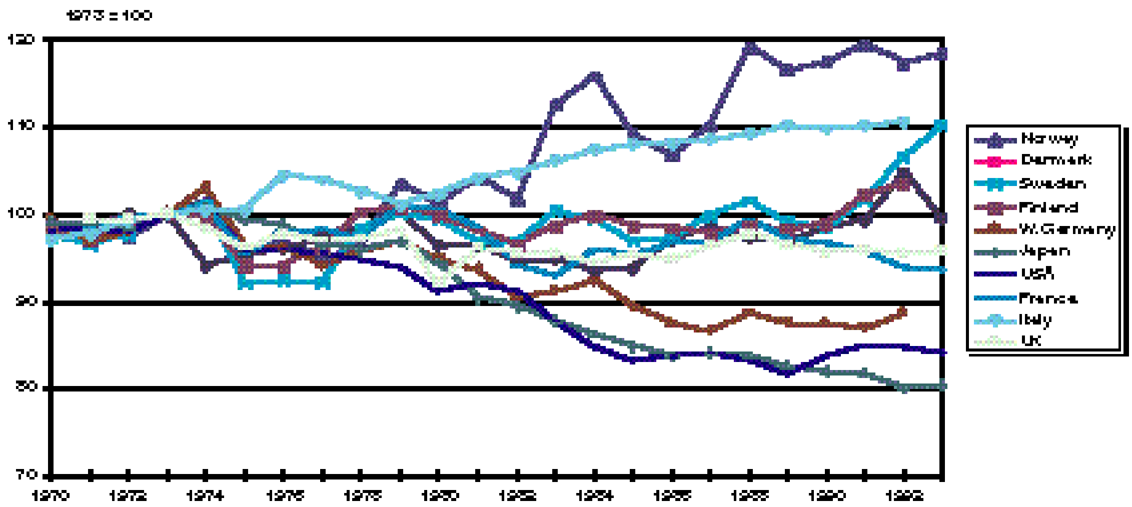

Figure 3-8. OECD Manufacturing Energy Use - Impact of Structural Change, Constant 1973 Activity and Intensity

The decline in USA was first and foremost caused by reductions in the iron and steel production, over two years (1981-83) the value added in these industries fell by almost 50%. In Japan the structural changes in the 1970s were smaller than of those in USA, however reduced shares for all raw materials sectors in the first part of the 1980s led to significant reduced energy use. This would have been sufficient to reduce manufacturing energy use by 13% between 1979 and 1986. In West Germany the movement away from iron and steel production has been a continuous trend from the start of our analysis period. Since 1979 the reduced shares of iron and steel and mineral products more than outlined the energy impact of increased production of chemicals, leading to a 10% decrease in manufacturing energy use between 1979 and 1991.

In Norway inexpensive hydro power has given ground for expansion of electricity intensive production as primary aluminum and chemicals (fertilizer). These power intensive industries use a relatively low input of labor and were therefore less affected by the “crowding-out” effect the rapid development of offshore oil production had on other manufacturing industries (Howarth et al. 1991). The power intensive export industries in Norway are also guaranteed low electricity prices through long-term contracts, giving these industries a competitive advantage in international markets. As a result of these beneficial economic conditions the share of energy intensive industries has increased, and thus favoring a substantial growth in manufacturing electricity use over the time horizon studied. However, as Figure 3-6 shows the energy intensity of the Norwegian manufacturing structure went through stronger fluctuations in the 1980s than the other countries. Over the two years 1983-84 energy use from structural changes rose by 15%, caused by increased production of all raw materials, except for stone, clay and glass (ISIC 36) that has followed a steadily decreasing trend from 1973 and throughout the eighties. The dip in energy use from structural effects in 1985-86 is mainly due to a downturn of production of chemicals, but also to some extent in production of metals (ISIC 371&372). At the same time production of less energy intensive products expanded, resulting in a further decrease in energy use from structural changes over these two years. The trend was reversed during the recession in 1988-91 that hit the low-energy intensive industries, while production of paper and pulp, chemicals and non-ferrous metals grew. (The peak in 1988 is caused by a one-year sharp increase in both ferrous and non-ferrous metals). After the recession production in all sectors picked up, in 1993 especially paper and pulp and chemicals went through high growth, again raising the energy intensity of Norwegian manufacturing industries.

In Sweden the fluctuations in industry structure were less than in Norway, but also here increasing production in paper and pulp and chemicals has been driving up manufacturing energy use since the fall of oil prices in 1986. Structural changes caused by growth in these two sectors, and in production of iron and steel, while the rest of the economy was hit by recession have increased Swedish manufacturing energy use by 12% between 1990 and 1993.

3.5 Impact of Changing Energy Intensities

An important goal in all countries has been to save energy in manufacturing. As Figure 3-6 shows every country but Norway have achieved significant reductions in aggregate manufacturing energy intensity. But as discussed above Norway also went through a significant increase in the share of production of energy intensive raw materials during the same time period. To isolate the impacts of structural changes we study the development of energy use that would have evolved in each country if the aggregate level and the structure of manufacturing production remained at their 1973 values (Figure 3-9). The curves thus reflect the variations in energy use induced by changes in energy intensities measured as the energy required to generate one unit of value added given 1973 industrial structure and activity level.

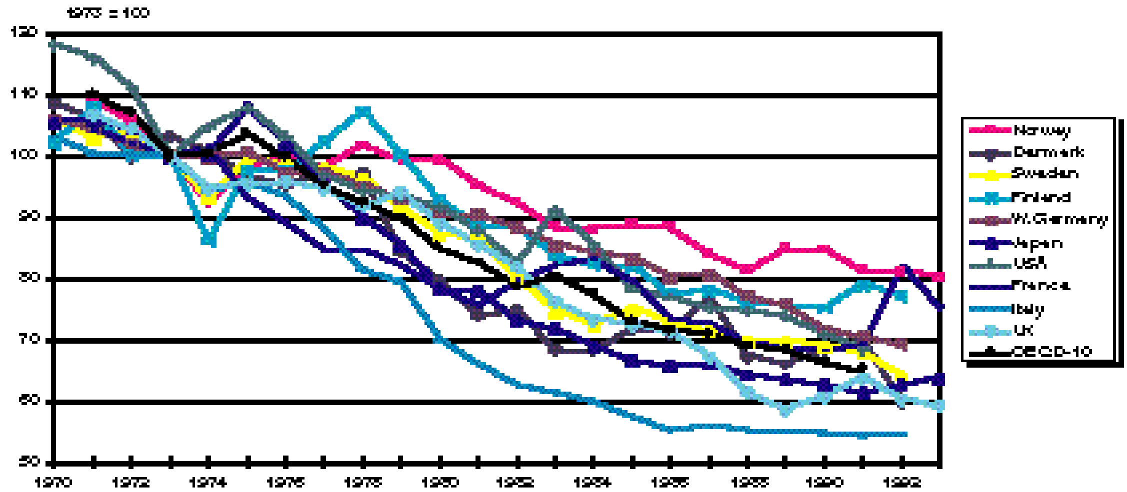

Figure 3-9. OECD Manufacturing Energy Use - Impact of Changing Intensities, Constant 1973 Activity and Structure

All of the countries included in our study achieved considerable improvements of energy intensities between 1973 and 1991, ranging from a 18% reduction in Norway to almost 40% in Japan and UK (and 46% in Italy, a result affected by the lack of disaggregated data for three sectors). After a temporary increase in energy intensities following the economic disruptions after OPEC I, the intensities steadily declined in most countries until 1985. Although some countries experienced continued improvement of intensities after the fall in oil prices in 1986, the general trend has been slower rates of decline than in the periods with increasing prices.

In Norway the energy intensity did not change significantly between the two oil price shocks; the intensity in 1980 was at the same level as in 1973. However, in the aftermath of OPEC II the intensity decreased by more than 11% from 1980 to 1983. After being constant for four years the intensity was reduced by 7% over 1986-88. In 1989-90 the intensity increased somewhat, before it fell by 3% in 1991 and improved by another percentage point over the two last years of our analysis, resulting in almost 20% energy savings over the 20-year period from 1973-93.

The intensities for each of the energy intensive sub-sectors in Norway are shown in Figure 3-10. As the figure shows production of chemicals, nonmetallic minerals, and paper & pulp all went through significant decreases of energy intensity over the time period. From 1973 to 1990 these three sectors improved intensity by approx. 54%, 44%, and 34%, respectively[3]. In the metal manufacturing sectors the intensity has been varying more, which can be a result of fluctuating output prices affecting the level of value added. Without studying energy intensities for physical production (e.g. GJ/tonne aluminum) it is difficult to conclude that significant energy savings have taken place. In the non-energy intensive industries (not shown), energy intensity rose by approx. 10% from 1973 to 1993, although production of provisions (ISIC 31) fell by 8% over the same period.

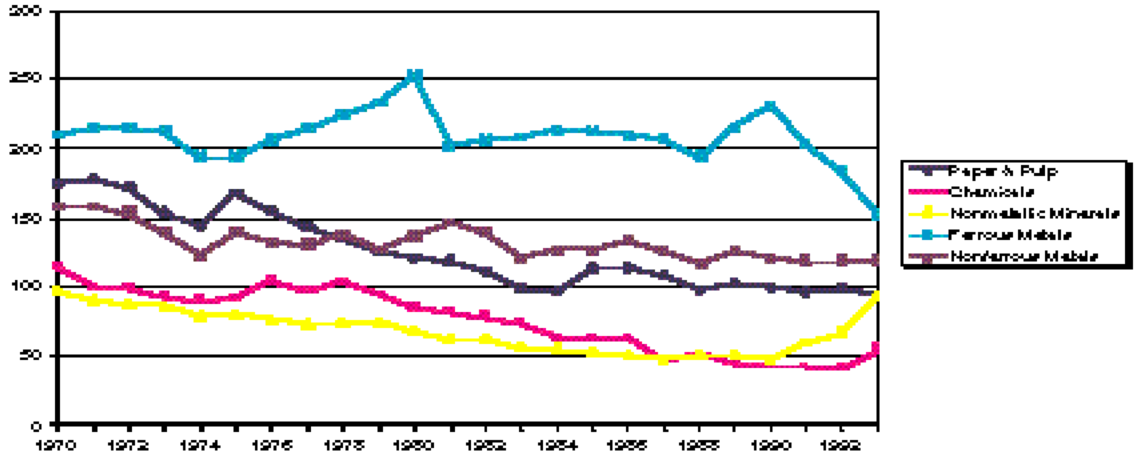

Figure 3-10. Norwegian Manufacturing - Energy Intensities in Production of Raw Materials

As mentioned, most of the decline in energy intensity occurred in two periods; 1980-83 and 1986-88. The reduced energy intensity in the first period was to a large extent caused by reductions in oil use after the jump in crude prices in 1979. This was especially apparent in paper and pulp that have access to cheap occasional (interruptible) power and biomass. Most of the reduced oil use in this sector (from 16,5 PJ in 1980 to 4,5 PJ in 1983) was compensated by increased use of electricity and biomass, but still a 20% reduction of energy intensity was achieved in this sector over the three years. However, it can be argued that some of these savings are not due to increased energy efficiency on a useful energy level, since the thermal efficiency of an electric boiler is higher than for an oil boiler. Also in production of nonmetallic minerals the oil use was greatly affected by the higher prices; from 10,4 PJ in 1980 to 1,7 PJ in 1983. Some of this was substituted by coal, but also in this sector the energy use per output dropped resulting in approx. 15% savings. About the same level of savings were achieved in the production of chemicals, consistent with the trend from 1978 throughout the 1980s that resulted in 60% less energy use per output in that sector.

The savings in 1986 to 1988 occurred despite the low oil prices in that period. The high economic growth in the western world resulted in an upturn for production of raw materials in Norway, and some of the savings might be a result of better capacity utilization in these sectors. However, the 20% increase in value added in chemicals from 1986 to 1987, at the same time as energy use in this sector actually decreased, may to some extent be an effect of reduced price of input commodities in the production[4]. The decline in energy intensity in paper and pulp is partly resulting from the hike in energy use in 1985/86 caused by increased use of biomass and oil with lower thermal efficiency than the electricity it substituted (see footnote in Table 3-1). In 1987 electricity prices dropped, and this sector switched back to the more energy efficient electricity boilers. The reduced intensity in 1991 is caused by reductions in energy use per output in metal manufacturing and in production of paper and pulp. In 1991-93 small changes occurred in nonferrous metals and paper/pulp, while unreliable disaggregated energy data make it difficult to judge the development in the other raw materials sectors (see endnote 3).

To investigate the changes in oil use we compare the 1991 use of oil with that in 1973, correcting for changes in the structure of manufacturing. Not surprising, Norway has had a major decline in oil use per unit of output, 75%. Only Sweden among the countries we have studied reduced the oil use more, about 85%. Roughly a quarter of this decline in Norway followed the overall reductions in energy intensity, the rest is caused by reduced share of oil in manufacturing energy use. Applying the same measure to electricity use shows that the Norwegian electricity intensity (1973 structure) was approx. the same in 1991 as in 1973. In Denmark the electricity intensity increased by more than 50%, but also in Sweden, Finland and U.K. the electricity intensity in 1991 was higher than in 1973.

The differences in energy savings among different countries as seen in Figure 3-9 are presumably due to differences in energy prices and in the relative importance of oil in the manufacturing industries. One explanation for the low energy savings in Norway is that rising oil prices have had a lesser impact on manufacturing energy use through its access to inexpensive hydro power, while higher reliance on oil is likely to have given countries like Italy and Japan more incentives for improving energy efficiency. Figure 3-11 shows the big differences in industrial electricity prices[5], ranging from 0,16 NOK/kWh (1,7 US cents) in Norway to four times as much in Italy and Japan. The Norwegian industry has been facing stable and low prices over the whole time period, an unique competitive advantage for electricity intensive industries compared to the other OECD-countries included in our study. Historically also the industrial fuel oil prices in Norway have been low, however, introduction of high taxes in the latter years raised the prices on heavy oil to a level greater than in any other country except Sweden (Figure 3-12). In Norway heavy oil prices are almost on the same level as medium distillate caused by introduction of high sulfur taxes. Consequently there has been a significant shift towards using lighter fuel oils even in Norwegian heavy industries.

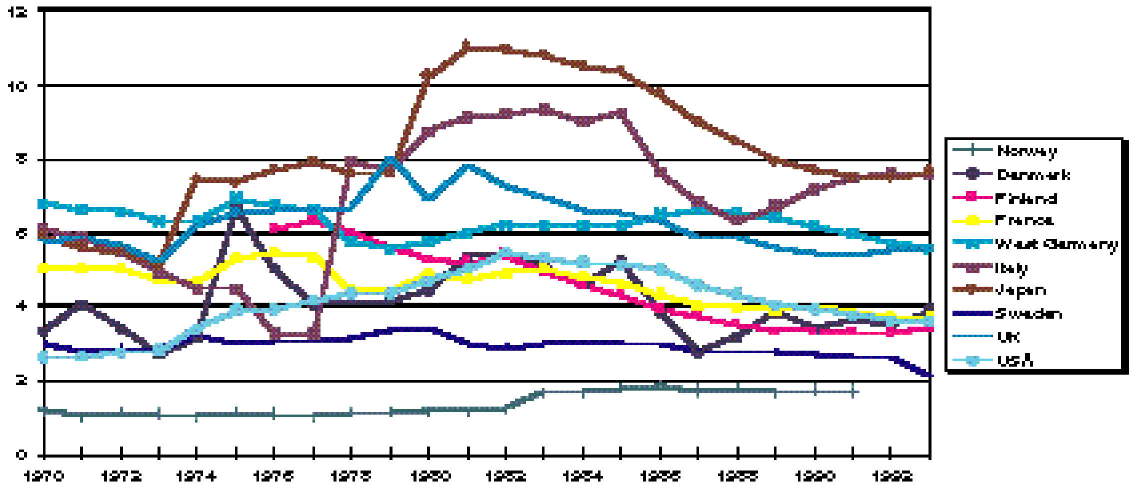

Figure 3-11. OECD Industrial Electricity Prices

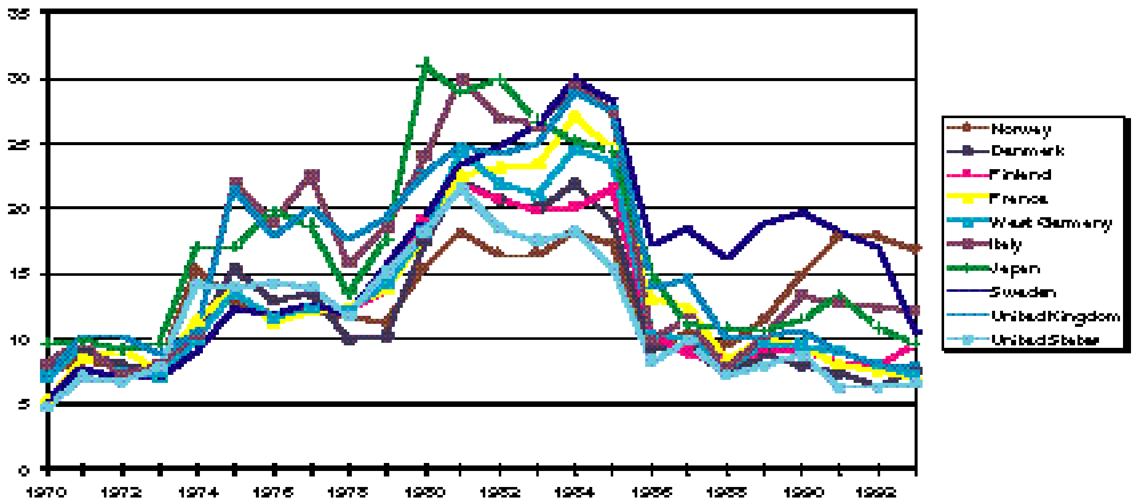

Figure 3-12. OECD Industrial Heavy Oil Prices

4. Conclusions

Norwegian manufacturing energy use stands out compared to other OECD-countries we have studied for several reasons:

- Manufacturing output, both measured per capita and as percentage of total GDP, is the lowest of all countries studied;

- High share of energy intensive raw materials in total manufacturing GDP is "compensating" for the low output; the aggregated energy use per manufacturing output is higher than in any other country, and Norway is the only country where this aggregate intensity has not been reduced since the 1970s. However, the development of this intensity can to some extent be explained by increasing shares of energy intensive sectors;

- Normalizing for the differences in manufacturing structure by adjusting to the average output mix of all 10 countries, Norway still has the highest energy intensity for manufacturing. This does not necessarily mean that Norwegian manufacturing has the lowest energy efficiency, but rather that there are structural differences that could not be isolated at our disaggregation level;

- Holding the structure of manufacturing output constant, the Norwegian intensities showed by far the least reductions of all countries, corresponding to 18% savings of manufacturing energy use from 1973 to 1991, while most other countries achieved between 30 and 40% savings. Most of the savings in Norway came in three raw material sectors, chemicals, paper/pulp, and nonmetallic minerals, and were to some extent a result of substitution of oil with electricity in the early 1980s when oil prices were high. The higher efficiency of electric boiler indicates that without the substitution to electricity the Norwegian energy intensities would have been ever higher in comparison with the other countries in our study;

- Low energy prices, for electricity very low, compared to other countries, and energy intensities in all sub-sectors among the highest of the countries we have studied, lead us to believe that there is a significant potential for energy savings in Norwegian manufacturing industries.

Deregulation and opening up of the electricity markets within Scandinavia will most likely lead to that Norwegian industries without long-term contracts will experience higher electricity prices in the near future. In a longer time perspective also the electricity intensive industries with long term contracts may have to face market prices. Avoiding a switch back to more fossil fuel use, and thus higher CO_2 emissions, may require higher environmental taxes on polluting fuels. With increasing prices on fossil fuel and electricity, biomass may stand out as an attractive alternative. The significantly higher utilization of this fuel in Swedish and Finnish industry indicates a large potential for biomass to expand its role in Norwegian manufacturing energy use.

Acknowledgments

The work that led to this paper has been sponsored by the Norwegian Water and Energy Administration, the Danish Energy Agency, and US Environmental Protection Agency.

Endnotes

[1]Delivered or final energy is defined as the amount of energy the consumers purchase, and does not account for losses in the energy sector (as the term primary energy does). Subtracting end-use losses from final energy yields the term useful energy.

[2]The share in 1973 may be somewhat underestimated because of incomplete energy statistics prior to 1976

[3]The changes in energy intensity in 1991-93 in the production of iron and steel, nonmetallic minerals, and chemicals are to a large extent due to that energy use has been moved from ISIC 371 to ISIC 36 and ISIC 351-2 in the Norwegian statistics. Unfortunately, for this study it has not been possible to resolve the problem, and consequently it is difficult to compare the development of energy use the recent years in these three sectors with data prior to 1991.

[4]Value added is defined as the value of gross product less the value of intermediate consumption. Both these have a volume and a price component. If the prices on commodities for intermediate consumption are falling more than the prices of the output products, value added would increase even if the production in volume, or physical terms) is constant. When the oil product prices fell in 1986 this can have been the case in the production of chemicals that uses a significant amount of LPG as feedstock.

[5]The currency exchange use in the figure is based on purchasing power parities (PPP). In 1985 the PPP-rate used to convert NOK to US$ was 9,51.

References

Bartlett, Sarita. 'The Evolution of Norwegian Energy Use from 1950 to 1991.' *Report 93/21*, Statistics Norway, 1993.

Golove, William, and Lee Schipper. 'Climate Restraint: Energy Use, Energy Efficiency, and CO_2 Emissions Measuring Progress in the United States.' Working paper, Berkeley, CA: Lawrence Berkeley Laboratory, 1995.

Howarth, Richard B., Lee Schipper, and Bo Andersson, 'Structure and Intensity of Energy Use: Trends in Five OECD Nations.', *Energy Journal*, Vol. 14, No. 2, April, 1993, 27-45.

Howarth, Richard B. , Lee Schipper, Peter A. Duerr and Steinar Stroem, 'Manufacturing Energy Use in Eight OECD Countries.', *Energy Economics*, Vol. 13, No. 2, April, 1991, 135-142.

Schipper, Lee, Richard B. Howarth, and Howard Geller, 'United States Energy Use from 1973 to 1987: The impacts of Improved Efficiency.', *Ann.Rev.Energy*, Vol. 15, 1990, 445-504.

Schipper, Lee, Richard B. Howarth, and Deborah Wilson, 'A Long-Term Perspective on Norwegian Energy Use.', *LBL-27295*, Berkeley, CA: Lawrence Berkeley Laboratory, 1990.

Schipper, Lee, Johnson, Frank, Richard B. Howarth, B.G. Andersson, B.A. Andersson, and Lynn Price, 'Energy Use in Sweden: An International Perspective.', Berkeley, CA: Lawrence Berkeley Laboratory, *LBL-33819*, 1993.

Schipper, Lee, Leena Peraelae, Frank Johnson, Marta Khrushch, Mike Ting, Fridtjof Unander, 'Energy Use in Finland: An International Perspective.', Berkeley, CA: Lawrence Berkeley Laboratory, *LBL-37510*, 1995.

Schipper, Lee, Martha Khrushch, Fridtjof Unander, Mike Ting, Osman Szegen, Lynn Scholl, and Todd Goldman, 'Energy Use in Denmark and other OECD Countries: Comparison of Trends through the early 1990s.', Danish Energy Agency, Copenhagen, 1995.

Torvanger, Asbjorn, 'Manufacturing sector carbon dioxide emissions in nine OECD countries, 1973-87.', *Energy Economics*, Vol. 13, No. 2, July, 1991, 168-186.