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THE EUROPEAN UNION BALANCING BETWEEN CO_2 REDUCTION COMMITMENTS AND GROWTH POLICIES

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ABSTRACT

This article is an empirical study of the energy system development in the European Union. The analysis covers the years 1960-1998. The decomposition analysis of energy and CO_2 intensities of the different EU countries and Norway reveal large differences between the individual countries. The reasons for the differences in energy intensity changes are explained by the structural changes of the economies. The changes in CO_2 intensities are explained by the energy intensity changes and fuel switching. The study verifies the conclusion that there are still big challenges in the harmonisation of energy and climate policy in the EU.

Key words: energy, CO_2 emissions, decomposition analysis, European Union

1. INTRODUCTION

According to the Kyoto Protocol, EU member states have to reduce GHG emissions together by eight per cent from the 1990 level during the first commitment period 2008-2012. The commitment was shared between 15 EU member states according to the Burden Sharing Agreement as contained in the Council Conclusions of 16 June 1998. The development of the EU's common energy policy (CEP) has taken place in the context of a growing global concern about the whole range of political and economic issues related to the sector. Two of the first three treaties were concerned with the integration of energy policy across Europe. Despite the existence of these treaties (European Coal and Steel Community (ECSC) Treaty 1951 and European Atomic Energy Community (Euratom) Treaty 1958) there have been continuous conflicts between the role of the member states and that of the EU. The reality has been that the member states have been dominant, largely because of their ownership of parts of energy sector and their control over fiscal policy. The security of energy supplies has been central to national industrial policy, and has been seen as a strategic issue. However, the EU's single market has become more important, so has the development of the internal energy market (IEM). (Barnes and Barnes, 1999).

There exist three basic possibilities to reduce the CO_2 emissions of a country: (i) reduction of economic output (GDP), (ii) reduction of the energy intensity of the economic production or (iii) reduction of the CO_2 intensity of the energy production. The first option is usually not interesting for the policymakers. So the key question in the analysis of EU's single market is, how energy and CO_2 intensities are developing among EU15- countries. This article describes some important trends among EU15-countries and in Norway, which is not EU member country.

In this study we shall make a comparative analysis of energy utilisation and CO_2 emissions in the European Union member countries. Our analysis is based on decomposition methods, which have been used in recent energy sector analyses. For example, Ang (Ang, 1995a, 1995b, 1, 2), Ang and Zhang (Ang and Zhang, 1999), Sun (Sun, 1998, 2000), and Sun and Malaska (Sun and Malaska, 1998) have used the decomposition method to compare energy-related CO_2 emission levels between countries and regions. Nordic, country level sectoral analyses have been carried out by e.g. Schipper et al (Schipper, Howarth and Geller 1992, Schipper, Howarth, Andersson and Price, 1993, Schipper, Johnson, Howarth, Andersson, Andersson, Price, 1993, Schipper, Perälä, Johnson, Khrushch, Ting, Unander, 1995). Similar methodology with this article was utilised in the studies of Luukkanen and Kaivo-oja (2001, 2002a, 2002b) for energy system analysis and Hoffrén et al (2001) for material flow analysis. In this study, we continue this research tradition of using the complete decomposition model, but we shall also provide dynamic analyses of the significant changes in the energy sectors and CO_2 emissions of EU-15 economies. A scenario approach linked with decomposition analysis is presented in Kaivo-oja et al (2001).

This article is organised in the following way: In section 2, we present general development trends in EU-15 countries and in Norway. In section 3, we present the methodology and models of the article. In sections 4-7, we report the results of the comparative analyses. In section 8, we summarise the results and draw conclusions.

2. DATA AND GENERAL DEVELOPMENT TRENDS IN EU-15 COUNTRIES

The data used for the analyses was taken from IEA statistics (IEA, 1999, IEA, 2000). Figures 1 and 3 plot the Total Primary Energy Supply (TPES) and the CO_2 emissions from fossil-fuel combustion in the EU from 1960 to 1998. The GDP data was compiled for the individual countries at market prices, in local currency and at annual rates. The data has been scaled up or down to 1990 price levels and then converted to US dollars using the yearly average based on 1990 exchange rates. All the presented data is macro economic, country level data. The analysis here is restricted to macroeconomic scales and sectoral or engineering bottom-up analyses are not presented in the article.

The decomposition results are given in relative terms: all the figures are compared to the levels of 1990, which is the base year for the Kyoto Protocol. This type of comparison provides information about the development of the energy systems in the different countries in relation to the Kyoto target. The aim is not to evaluate the differences between the countries, because the targets of the Kyoto Protocol are national.

Total primary energy supply has increased in EU-15 in 30 years two and a half fold as can be seen in Figure 1. The fast growth of the sixties has slowed down after the energy crises in 1973 and 1979 and in the nineties the average growth rate has been about one per cent per year. But if we look at the energy intensity of the European economies we can find out that it has been declining after the first oil crisis in 1973 (Fig. 2). Decreasing energy intensity means that less primary energy is used to produce one US dollar of economic output. Decreasing energy intensity means increasing energy efficiency. One way of lowering the CO_2 emissions is to increase energy efficiency – if less energy is needed to produce the required economic welfare fewer emissions will be released.

The decreasing energy intensity can be a result of two different types of development. If the energy technology improves, less primary energy is needed to fulfil the desired tasks. With the increasing efficiency of e.g. a power plant it is possible to produce the same amount of electricity with less coal or gas. Secondly, if the structure of the economy changes to a less “heavy” direction, less energy is needed to produce same amount of economic output. In many European economies the shift from heavy industry dominated economy to service and ICT dominated economy has already taken place or is gradually taking place. This type of de-coupling of energy from economic growth has taken place in the European economy after the oil crises in the seventies. In the European energy system the final energy demand grows faster than primary energy demand because of improved rates of conversion efficiency in power generation. Also the increase in the share of electricity and continuous decline in solid fuels are reasons for this.

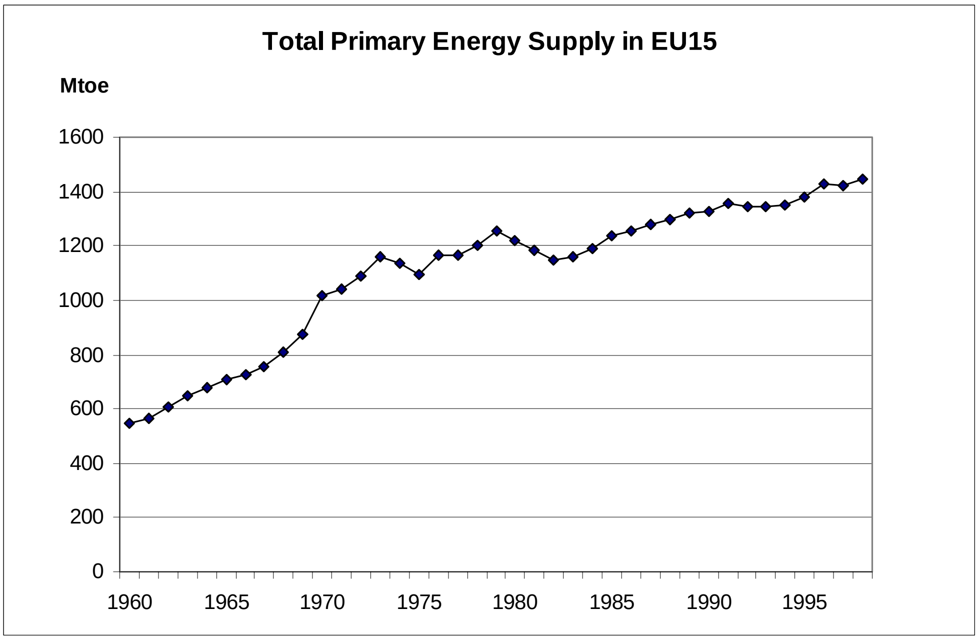


Figure 1. Total primary energy supply (TPES) in EU15 countries from 1960 to 1998 (IEA 1999, 2000)

Table 1. Average growth rape of percentage of TPES in EU-15

1960-97	*1960-70*	*1970-80*	*1980-90*	*1990-98*
2.6	6.4	1.8	0.9	1.0

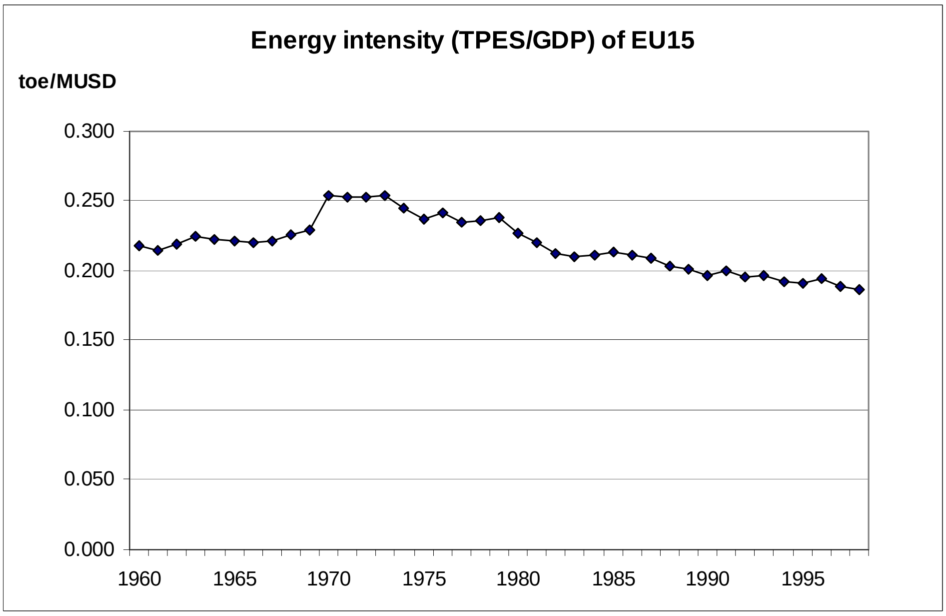


Figure 2. Energy intensity of EU15 measured as total primary energy supply divided by value added of economic output (tons of oil equivalent / million US dollars in 1990 value) (Data source IEA 1999, 2000).

Figure 3 illustrates the total CO_2 emissions in EU15. After the oil crises in the 70's the emission amount has stabilized. This is due to two reasons. First, the energy intensity of the economies has decreased, as was shown in Fig. 2, and second, the CO_2 intensity of energy use has decreased as can be seen in Figure 4. The reason for the decreasing CO_2 intensity of energy use is fuel shift towards less carbon intensive fuels. Such a change takes place e.g. when coal based electricity production is replaced by hydro, nuclear, wind, biomass or gas based production. The general national level fuel switching in relation to carbon intensity can be measured by the difference of the percentage changes of the intensity effect of CO_2 emissions and the intensity effect of energy use (more details of the concepts in the following chapters). In the following text fuel switching refers to this national level change in the intensity effects. Decreasing fuel switch curve indicates decreasing carbonisation of the energy production system. Figure 6 shows that the fuel switching in EU-15 has been a continuous process towards less carbon intensive production.

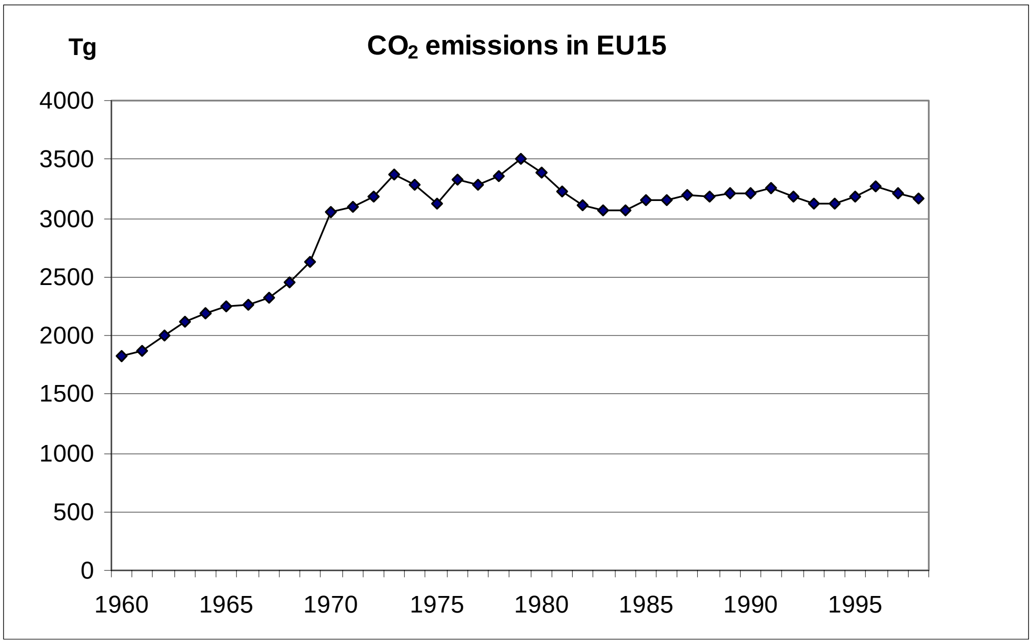


Figure 3. Total CO_2 emissions in EU15 countries in teragrams (Tg = Mton) (Data source IEA 1999, 2000).

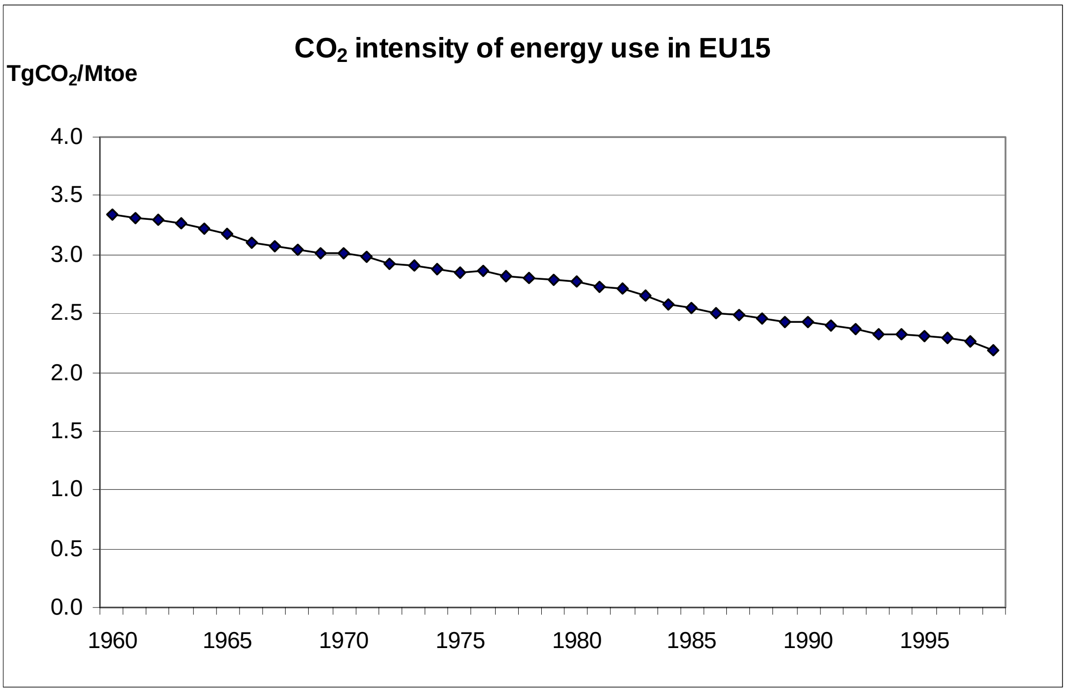


Figure 4. CO_2 intensity of total primary energy supply in EU15 (teragrams of CO_2 / Mtoe) (Data source IEA 1999, 2000).

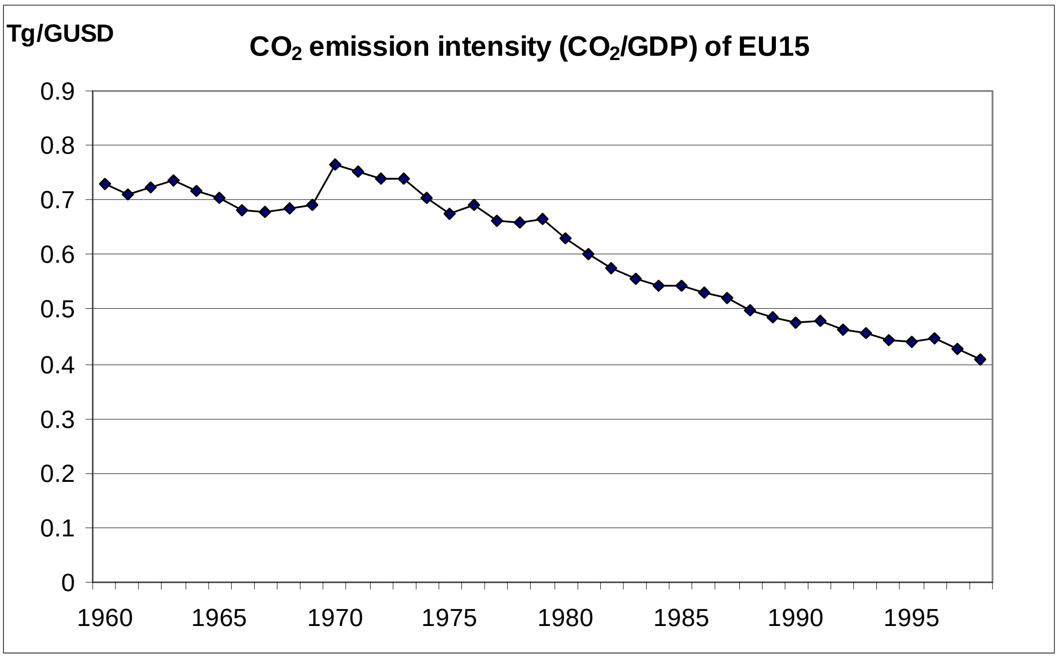


Figure 5. CO_2 emission intensity of the economy of EU15 countries (teragrams of CO_2 / Giga (10^9) US dollars in 1990 price) (Data source IEA 1999, 2000).

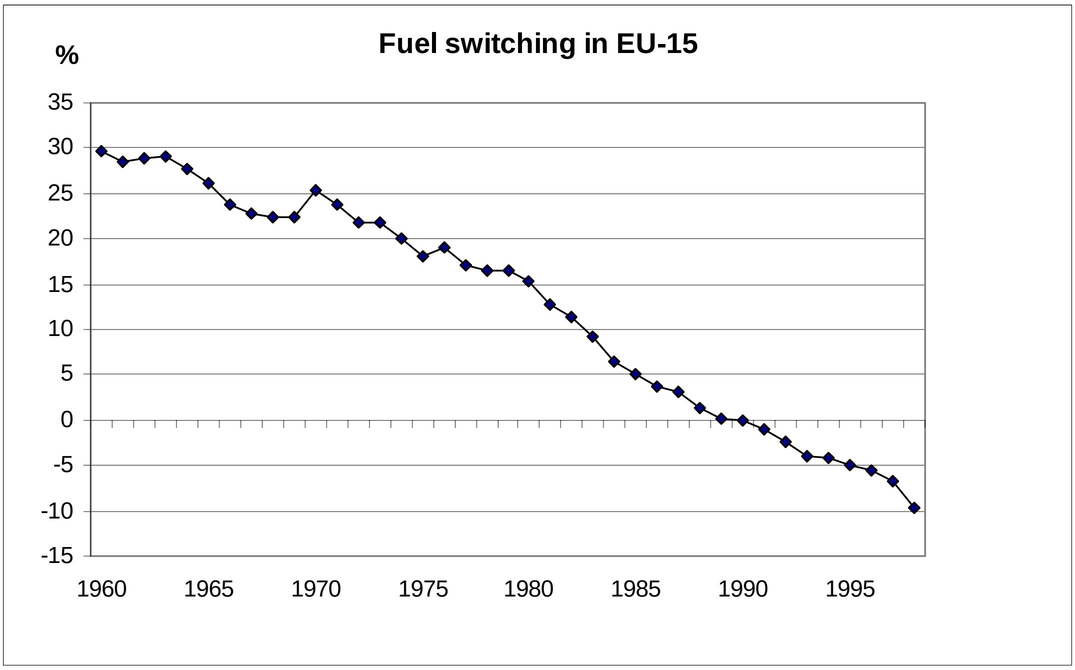


Figure 6. Fuel switching in relation to carbon intensity in EU-15 countries as a percentage change compared to 1990 level. Decreasing curve indicates decreasing carbonisation of the energy production system. The fuel switching is calculated as the difference between the percentage changes of the intensity effect of CO_2 emissions and the intensity effect of energy use.

3. DECOMPOSITION METHOD IN THE STUDY

The operationalisation of the productivity ratio of energy P(E,Q) can be defined as:

$$P(E,Q) = \frac{\text{economic outcome}}{\text{energy input}} = \frac{Q}{E} \qquad (1)$$

The intensity of energy consumption can be defined, in different sectors (i), as inverse to the previous formula:

$$eI_i = \frac{E_i}{Q_i} \qquad (2)$$

where eI_i is the energy intensity in sector i, E_i is energy use in sector i and Q_i is the value added of sector i.

To decompose the energy use of an economy we can use the following equations.

$$E = Q \times \frac{E}{Q} = Q \times \sum_i eI_i \frac{Q_i}{Q} = Q \times \sum_i eI_i s_i \qquad (3)$$

where the sum is taken from all sectors and

$$s_i = \frac{Q_i}{Q} \qquad (4)$$

is a structural factor of the economy, i.e., the share of sector i production of the total production.

In a similar manner we can decompose the CO_2 emissions P:

$$P = Q \times \frac{P}{Q} = Q \times \sum_i pI_i \frac{Q_i}{Q} = Q \times \sum_i pI_i s_i \qquad (5)$$

where

$$pI_i = \frac{P_i}{Q_i} \qquad (6)$$

is the sectoral CO_2 intensity.

In Eqs. (3) and (5) the energy use and the CO_2 emission are thus decomposed in relation to the structure of economy.

The aim of this decomposition analysis is to model the changes in energy consumption and emission production. The explanatory variables are: the activity level in the economy, sectoral intensity, and structural shift.

Several methods and indexes have been developed for the purposes of decomposition analysis and they have mainly been used to analyse the energy sector.

Sun (1996) has developed a difference method, which has no residual term unlike other methods. From this Complete Decomposition Model, we have developed the dynamic energy model in the following way:

$$\Delta E = E^t - E^0 \qquad (7)$$

$$\begin{aligned}
EQ_{effect}{}^t &= (Q^t - Q^0)\sum_i eI_i^0 s_i^0 + \tfrac{1}{2}(Q^t - Q^0)\sum_i (eI_i^0(s_i{}^t - s_i{}^0) + s_i^0(eI_i{}^t - eI_i{}^0)) \\
&+ \tfrac{1}{3}(Q^t - Q^0)\sum_i (eI_i{}^t - eI_i{}^0)(s_i{}^t - s_i{}^0) \\
EI_{effect}{}^t &= Q^0 \sum_i s_i^0 (eI_i{}^t - eI_i{}^0) + \tfrac{1}{2}\sum_i (eI_i{}^t - eI_i{}^0)\left[\, s_i^0(Q^t - Q^0) + Q^0(s_i{}^t - s_i{}^0)\,\right] \\
&+ \tfrac{1}{3}(Q^t - Q^0)\sum_i (eI_i{}^t - eI_i{}^0)(s_i{}^t - s_i{}^0) \\
ES_{effect}{}^t &= Q^0 \sum_i eI_i^0 (s_i{}^t - s_i{}^0) + \tfrac{1}{2}\sum_i (s_i{}^t - s_i{}^0)\left[\, eI_i^0(Q^t - Q^0) + Q^0(eI_i{}^t - eI_i{}^0)\,\right] \\
&+ \tfrac{1}{3}(Q^t - Q^0)\sum_i (eI_i{}^t - eI_i{}^0)(s_i{}^t - s_i{}^0)
\end{aligned} \qquad (8)$$

where superscript *0* refers to the base year value and *t* refers to the values of the comparison year varying from n_1 to n_n, in this case from 1960 to 1998.

This model produces an exact decomposition so that:

$$\Delta E = EQ_{effect} + EI_{effect} + ES_{effect}\,. \qquad (9)$$

The Q_{effect} is the activity effect that describes the effect of total economic growth on sectoral energy use. The I_{effect} is the intensity effect, which reveals the impact of the technological change and the change in production systems on sectoral energy consumption. The S_{effect} is the structural effect, which reveals the impact of change in the sectoral share of total production on energy consumption.

In a similar way we can develop equations for the decomposition of CO_2 emissions:

$$
\begin{aligned}
& PQ_{effect}{}^{t} = (Q^{t} - Q^{0})\sum_{i} pI_{i}^{0} s_{i}^{0} + \tfrac{1}{2}(Q^{t} - Q^{0})\sum_{i} pI_{i}^{0}(s_{i}{}^{t} - s_{i}{}^{0}) + s_{i}^{0}(pI_{i}{}^{t} - pI_{i}{}^{0})) \\
& + \tfrac{1}{3}(Q^{t} - Q^{0})\sum_{i}(pI_{i}{}^{t} - pI_{i}{}^{0})(s_{i}{}^{t} - s_{i}{}^{0}) \\
& PI_{effect}{}^{t} = Q^{0}\sum_{i} s_{i}^{0}(pI_{i}{}^{t} - pI_{i}{}^{0}) + \tfrac{1}{2}\sum_{i}(pI_{i}{}^{t} - pI_{i}{}^{0})[\ s_{i}^{0}(Q^{t} - Q^{0}) + Q^{0}(s_{i}{}^{t} - s_{i}{}^{0})\ ] \\
& + \tfrac{1}{3}(Q^{t} - Q^{0})\sum_{i}(pI_{i}{}^{t} - pI_{i}{}^{0})(s_{i}{}^{t} - s_{i}{}^{0}) \\
& PS_{effect}{}^{t} = Q^{0}\sum_{i} pI_{i}^{0}(s_{i}{}^{t} - s_{i}{}^{0}) + \tfrac{1}{2}\sum_{i}(s_{i}{}^{t} - s_{i}{}^{0})[\ pI_{i}^{0}(Q^{t} - Q^{0}) + Q^{0}(pI_{i}{}^{t} - pI_{i}{}^{0})\ ] \\
& + \tfrac{1}{3}(Q^{t} - Q^{0})\sum_{i}(pI_{i}{}^{t} - pI_{i}{}^{0})(s_{i}{}^{t} - s_{i}{}^{0})
\end{aligned} \tag{10}
$$

To analyse the dynamics of the change we have used Eqs. (8) and (10) to calculate the differences in the long-run time-series data from 1960 to 1998 compared to the reference year 1990, which has been chosen as it is the base year for the Kyoto Protocol (UNFCCC, 1998).

In this analysis of the EU and the Nordic countries, the sixteen individual countries refer to the different sectors (*i*) of the equations.

4. COUNTRY LEVEL ANALYSES OF ENERGY AND CO_2 INTENSITY: LARGE EU COUNTRIES

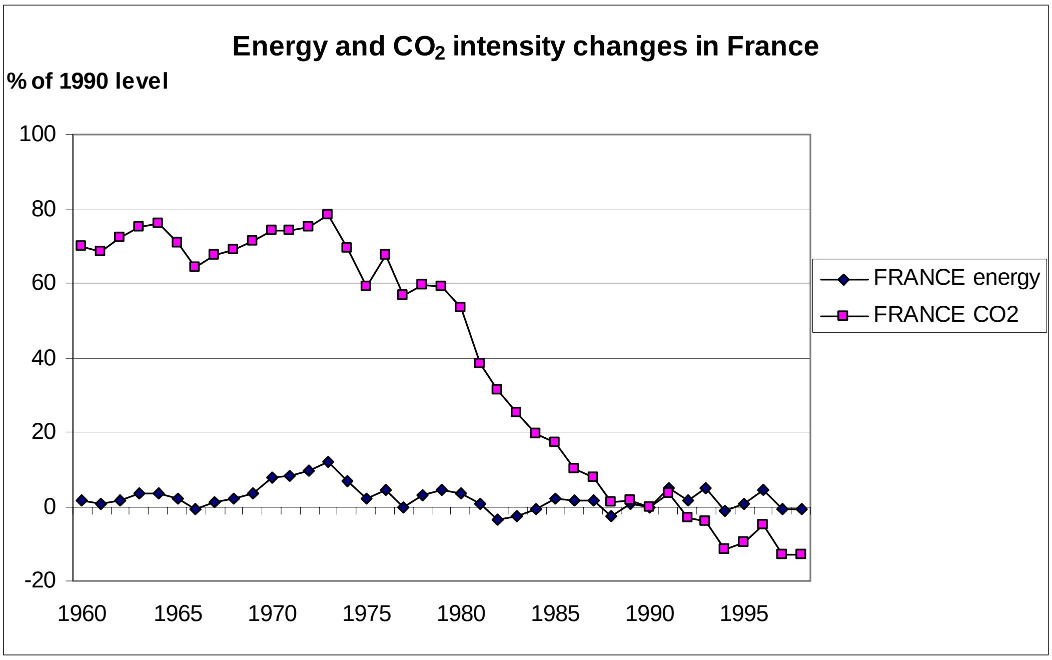
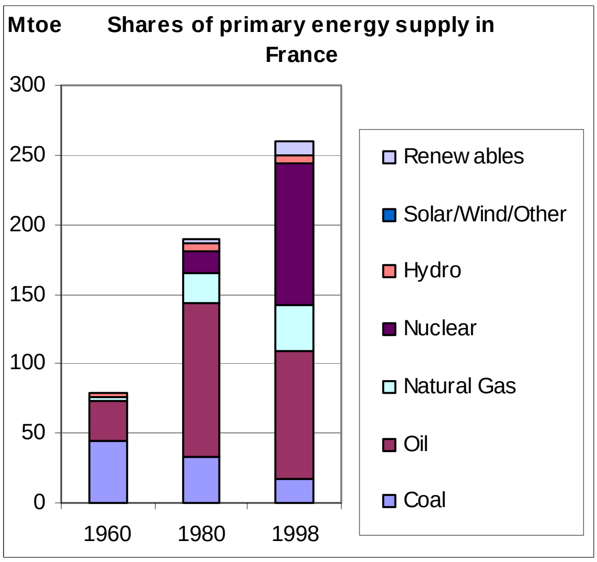


Figure 7. Energy and CO_2 intensity effect changes in France



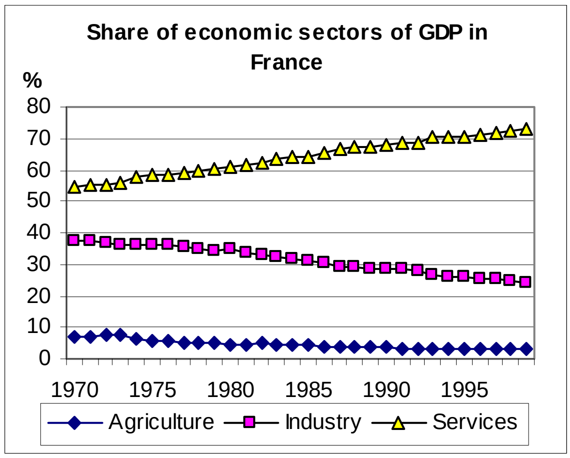


Figure 8. Shares of primary energy supply and economic sectors of GDP in France.

France is an interesting case, when we analyse energy production trends among EU countries. Figure 7 illustrates the dynamic changes in energy and CO_2 intensity effects in France. The intensity effect of energy use does not have any clear increasing or decreasing trend during the analysed time period. This means that the total energy efficiency in France has not improved. The French macroeconomic production structure has remained as inefficient in relation to energy use as it was in the sixties.

The changes in the intensity effect of CO_2 compared with energy intensity effect indicate that there has been a remarkable fuel switch in France. The carbon intensity remained quite stable to the year 1974, but after the turning point there has been a steady downward sloping trend till the year 1997. The decreasing trend is caused mainly by heavy nuclear power investments in seventies and eighties. In the case of France it is interesting to note the total energy efficiency has not improved, which may be due to heavy reliance on nuclear power and the related lack of incentives on the energy conservation. The French economy has gone through a structural change towards service economy, but this has not affected the energy intensity of the economy.

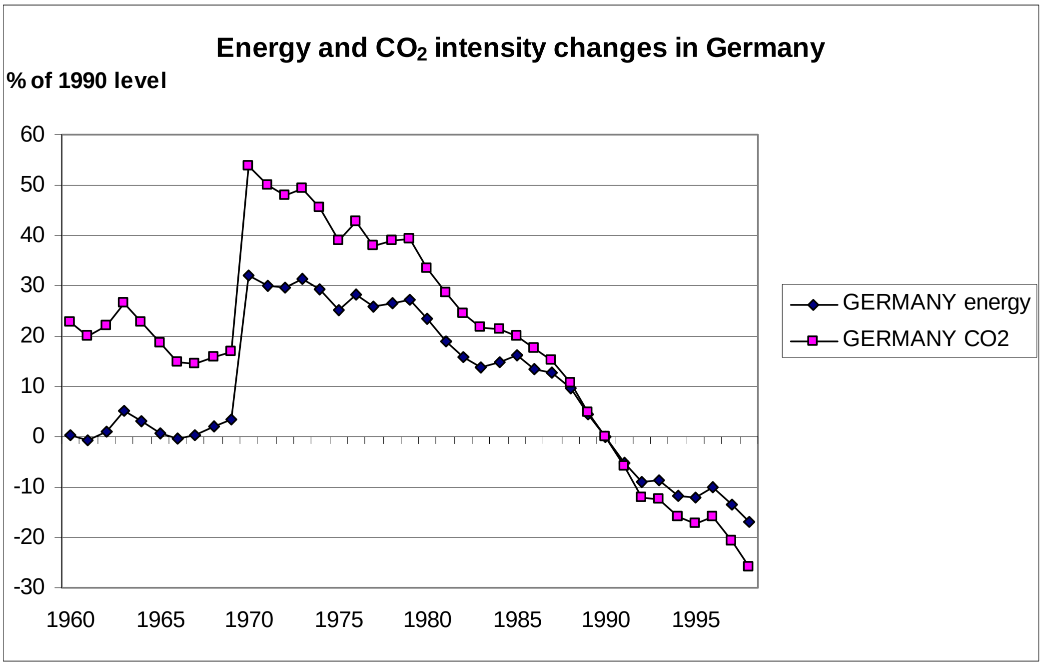


Figure 9. Energy and CO_2 intensity effect changes in Germany

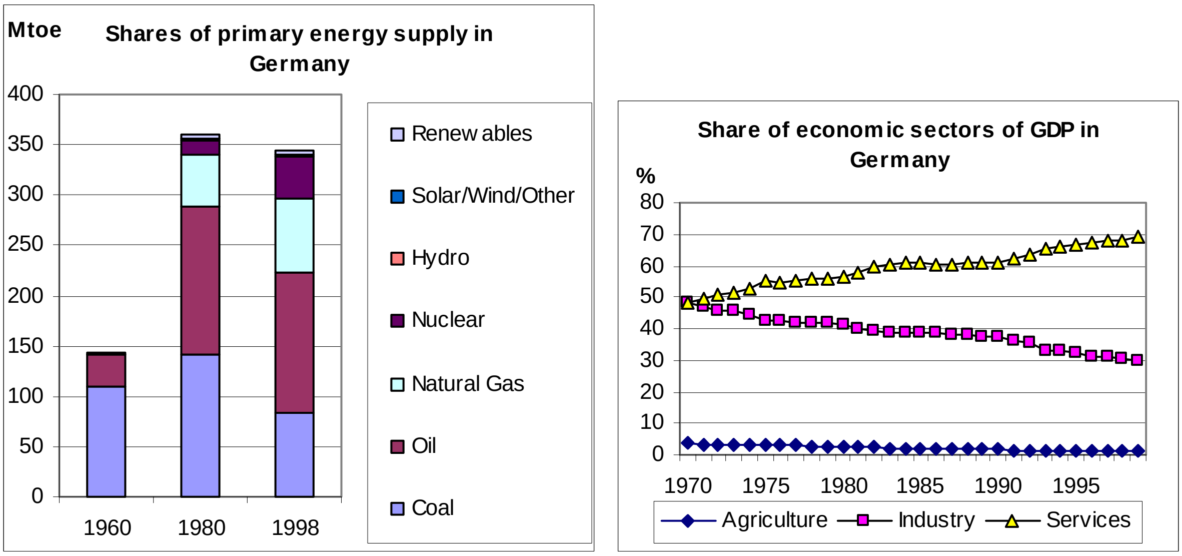


Figure 10. Shares of primary energy supply and economic sectors of GDP in Germany.

It looks that during the years 1969-1970 intensity of Germany's economy changed drastically towards more inefficient direction, but this is due to the changes in statistics. The statistics before 1970 include only Western Germany while the new federal states have been added in the IEA statistics for 1970-1998. The changes in the intensity effect of CO_2 compared with energy intensity effect indicate that there have been remarkable fuel switches in Germany as shown in Fig. 9. From 1960 to 1973 the energy intensity has remained at approximately the same level, while CO_2 intensity has decreased to some extent indicating slight fuel switch towards less carbon intensive energy production in Germany. After oil crisis 1973 the energy intensity has decreased considerably and the introduction of nuclear power plants has caused remarkable fuel switch decreasing the CO_2 intensity even faster up to the year 1988. During the years 1988-1991 there was not a remarkable fuel switch. In the 1990s the fuel switch has been mainly from coal to gas and the restructuring in the economy in the new federal states has improved the energy efficiency remarkably. It is interesting to notice the large structural change of the economy from industry-oriented production to service dominated system.

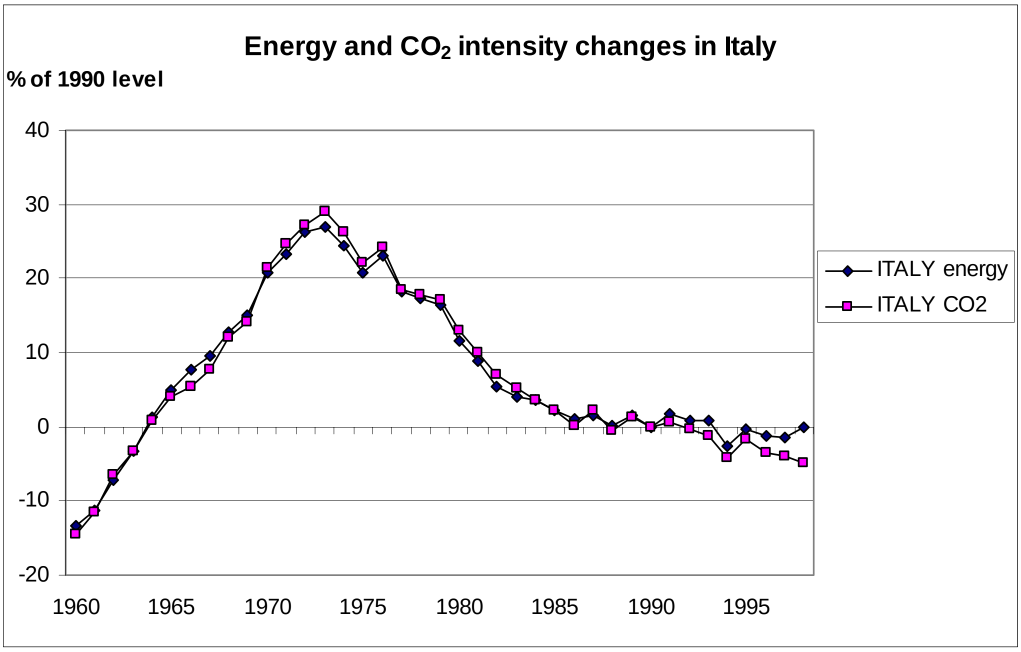


Figure 11. Energy and CO_2 intensity effect changes in Italy

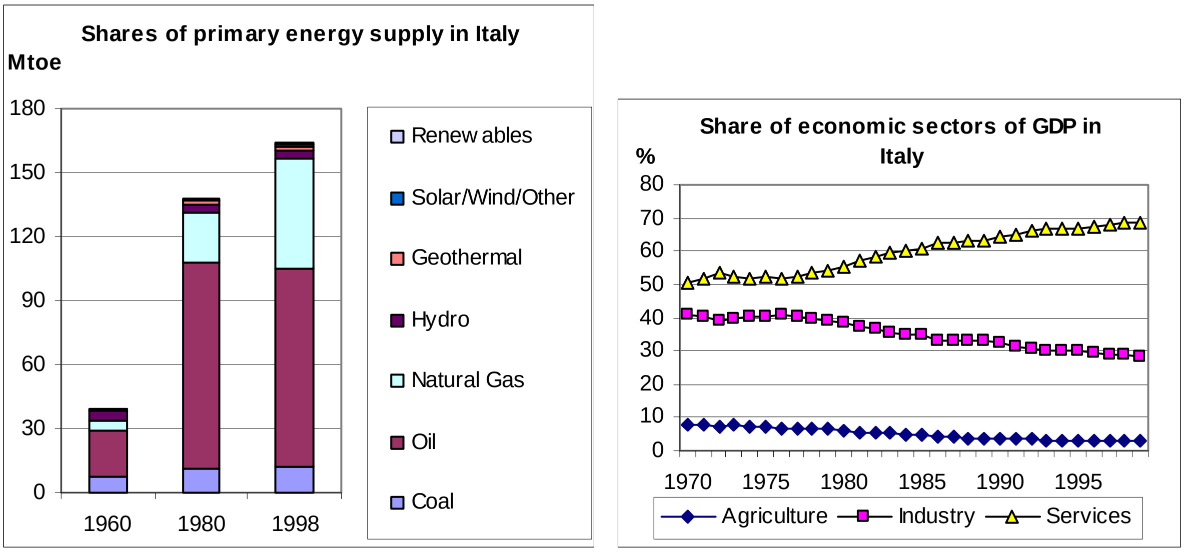


Figure 12. Shares of primary energy supply and economic sectors of GDP in Italy.

In Figure 11 the dynamic changes in the energy and CO_2 intensity effects in Italy are compared. In the 60's the intensity effects have been increasing considerably, but after the turning point in 1973 there has been a considerable change towards decreasing energy and CO_2 intensity effects. The results indicate that there have not been remarkable fuel switches in Italy, but increasing energy efficiency has caused the decreases in CO_2 intensity. Only a very small fuel switch towards less carbon intensive energy production can be observed after the year 1990. This is caused mainly by the increased share of natural gas.

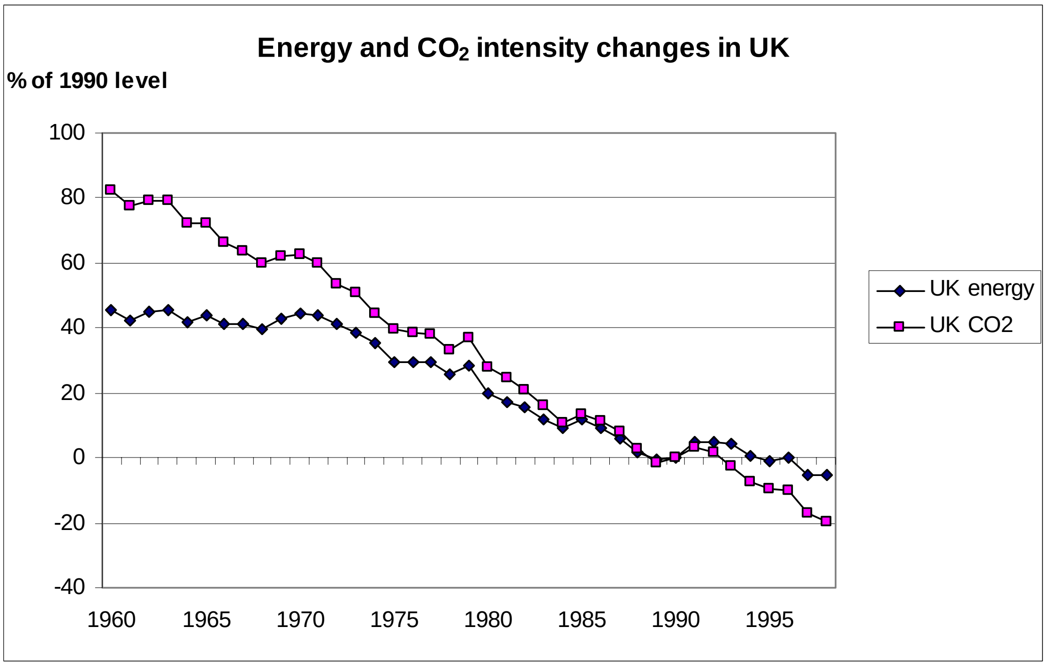
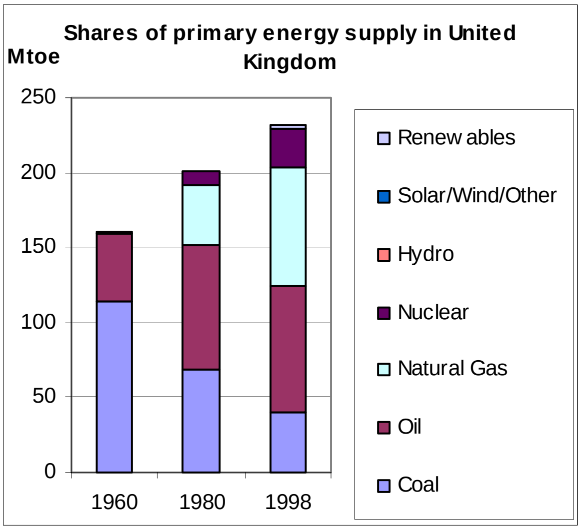


Figure 13. Energy and CO_2 intensity effect changes in the United Kingdom.



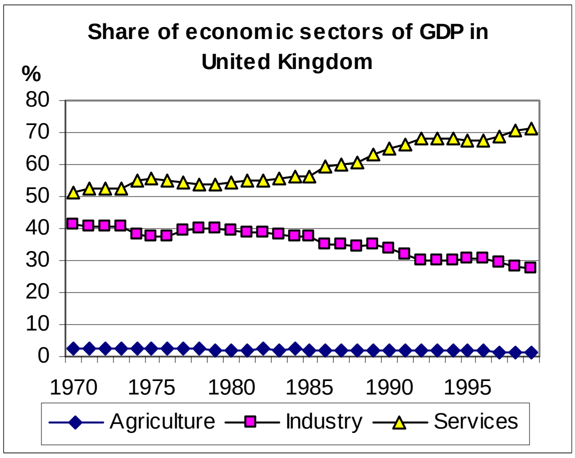


Figure 14. Shares of primary energy supply and economic sectors of GDP in the United Kingdom.

Figure 13 illustrates the dynamic changes in energy and CO_2 intensity effects in the UK. The intensity effect of energy use has slightly decreased till the year 1989 indicated by a slow downward sloping trend. The intensity effect on CO_2 has decreased still faster indicating that there has been a fuel switch towards less carbon intensive energy production in the UK, an increased use of nuclear energy and a switch from coal to gas. In the case of the UK the start of oil and gas production in the North Sea has not increased the energy intensity effect, which means that the introduction of a major domestic energy source does not automatically lead to wasteful use of energy or lead to heavier production structure.

Figure 15 summarises the fuel switching that has taken place in the large EU countries. The fuel switching at national level is indicated by the difference of the percentage changes of the intensity effect of CO_2 emissions and the intensity effect of energy use. Decreasing curves indicate decreasing carbonisation of the energy production system.

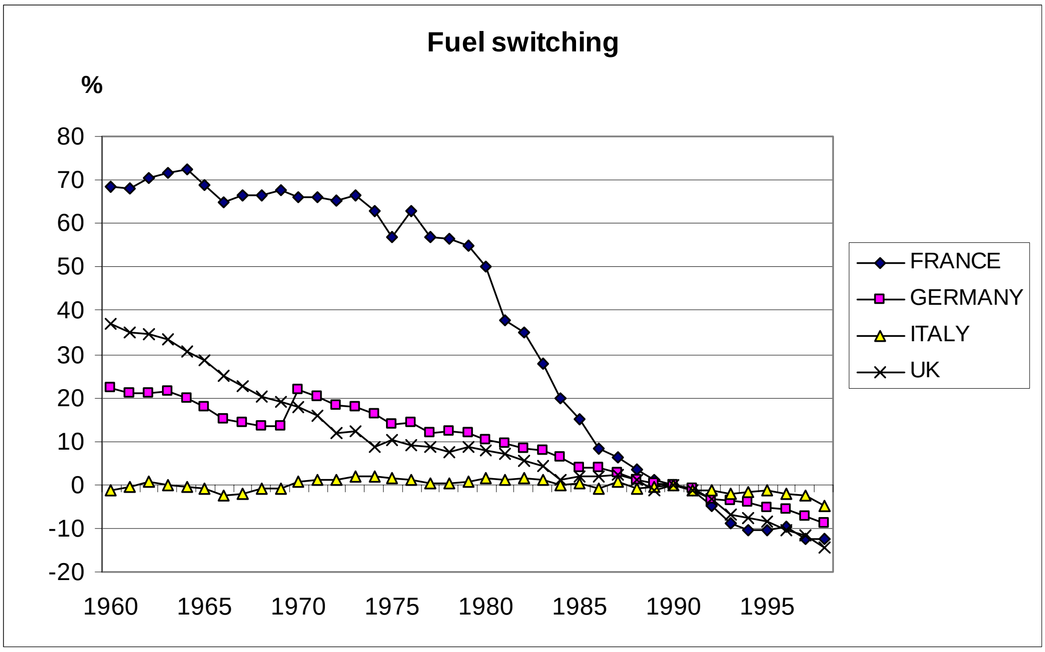


Figure 15. Fuel switching in France, Germany, Italy and the UK

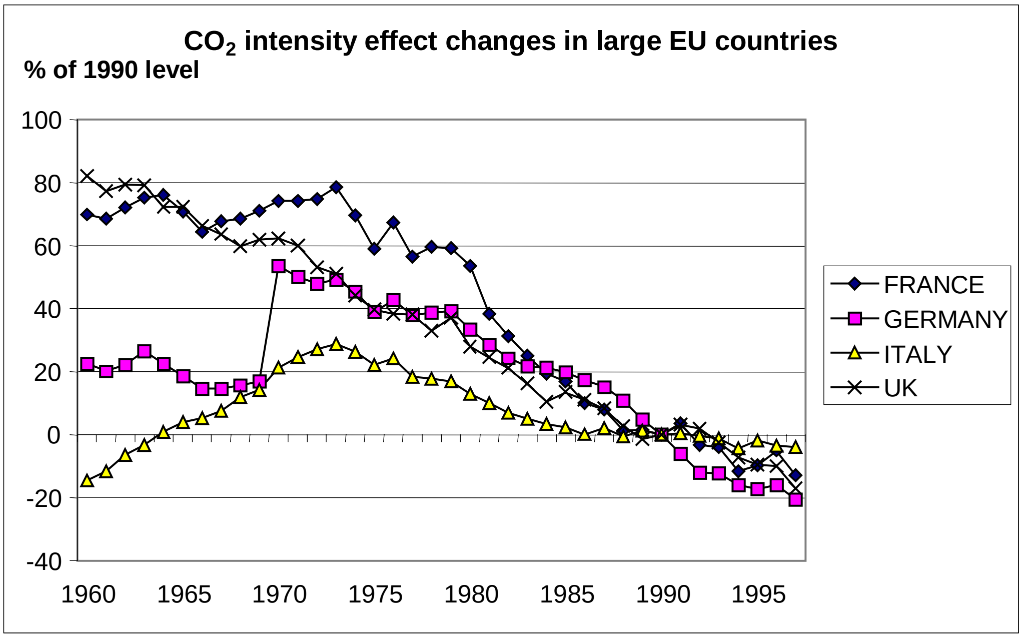


Figure 16. CO_2 intensity effect changes in the large EU member countries (% of 1990 level)

5. COUNTRY LEVEL ANALYSES OF ENERGY AND CO_2 INTENSITY: NORDIC COUNTRIES

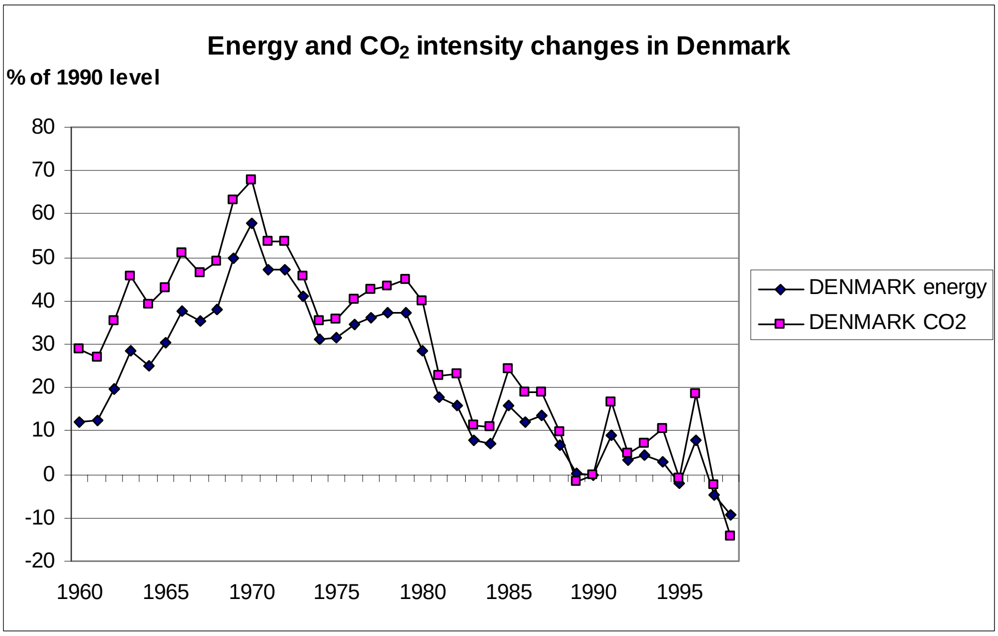


Figure 17. Energy and CO_2 intensity effect changes in Denmark

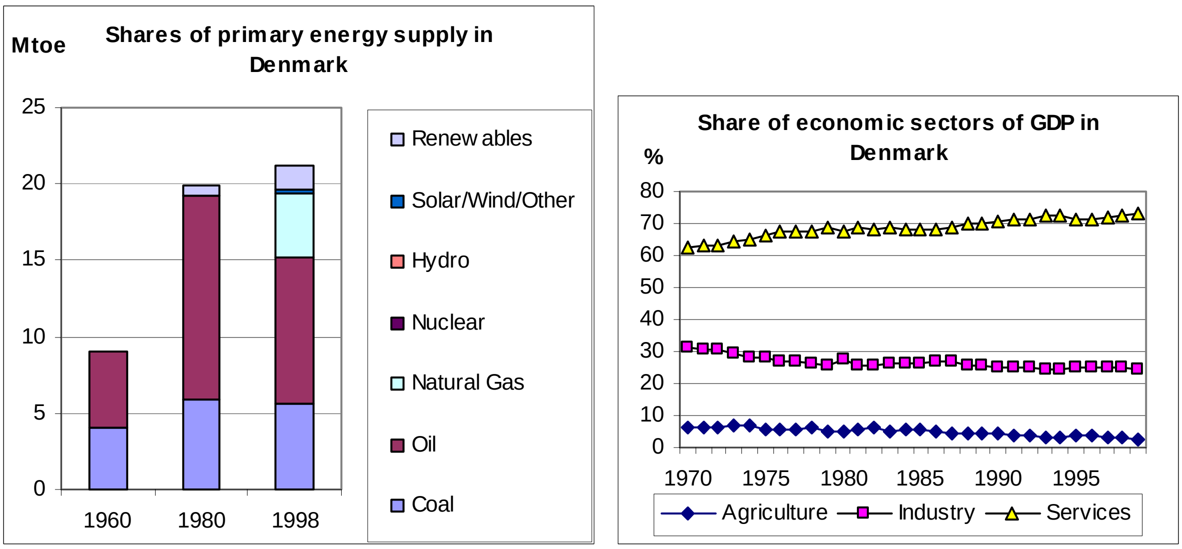


Figure 18. Shares of primary energy supply and economic sectors of GDP in Denmark.

In Figure 17 the dynamic changes in the energy and CO_2 intensity effects in Denmark are compared. In the 60's the intensity effects have been increasing considerably, but after the turning point in 1970 there has been a considerable change towards decreasing energy and CO_2 intensity effects. The results indicate that there has been some fuel switch towards increased use of natural gas, but increasing energy efficiency has mainly caused the decreases in CO_2 emissions. The Danish economy has been very service intensive already in the 70s.

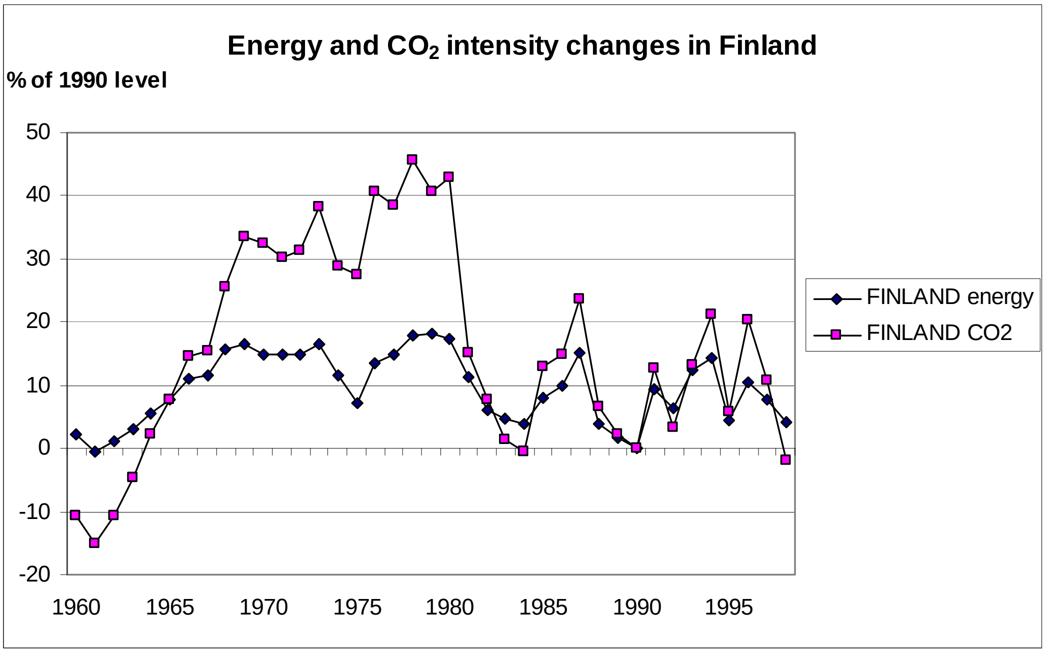


Figure 19. Energy and CO_2 intensity effect changes in Finland

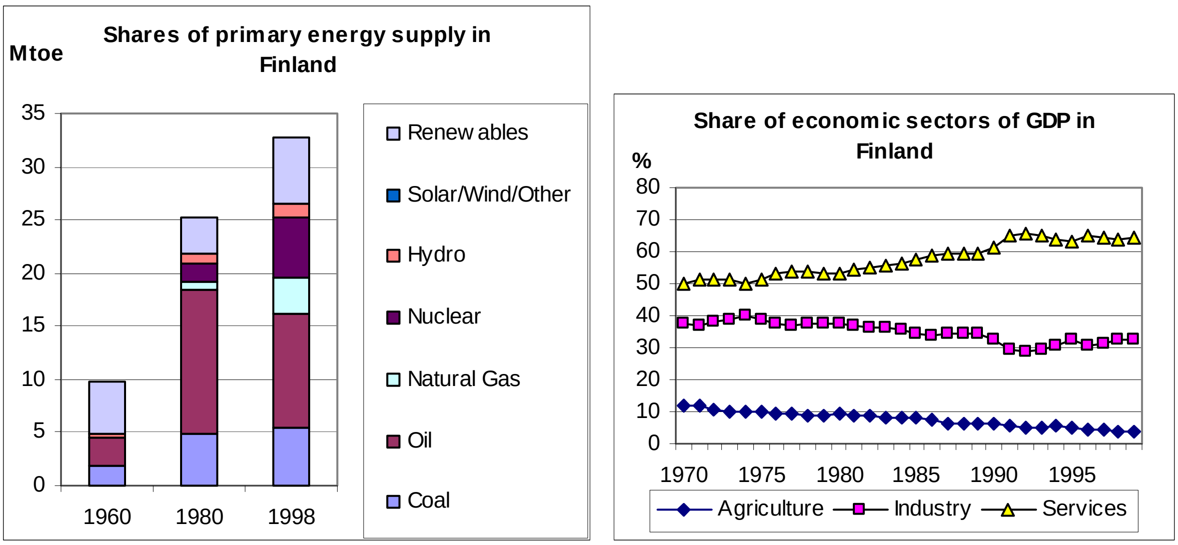


Figure 20. Shares of primary energy supply and economic sectors of GDP in Finland

In Figure 19 the dynamic changes in the energy and CO_2 intensity effects in Finland are compared. The intensity effect of energy use does not have any clear increasing or decreasing trend during the analysed time period. This indicates that there have not been any significant improvements in the total energy efficiency in Finland. In the year 1960 a little bit less amount of energy was used to produce one FIM of GDP than in the year 1998. This means that there has not been a change towards less energy intensive production mode. In the 90s the tendency in the economy has been re-industrialisation, which has been one reason for the non-improving energy efficiency.

The changes in the intensity effect of CO_2 compared with energy intensity effect indicate that there have been remarkable fuel switches in Finland. In the 1960s there has been fuel switch towards carbon intensive energy production. In practice woodfuel was replaced by oil and coal. In late 70's and early 80's the introduction of four nuclear power plants caused remarkable fuel switch towards less CO_2 intensive energy production. After 1982 there has not been any considerable fuel switch in Finland. The large fluctuations in energy and CO_2 intensity effects are mainly caused by changes in hydropower production in the connected Nordic electricity utilities sector. The fluctuations are similar to those in Denmark, which indicates that the domestic coal based condensing power production adapts to changes in hydropower supply. Fluctuations in energy intensities are due to hydropower fluctuations because of the difference in the efficiency of condensing coal fired power production and hydro production.

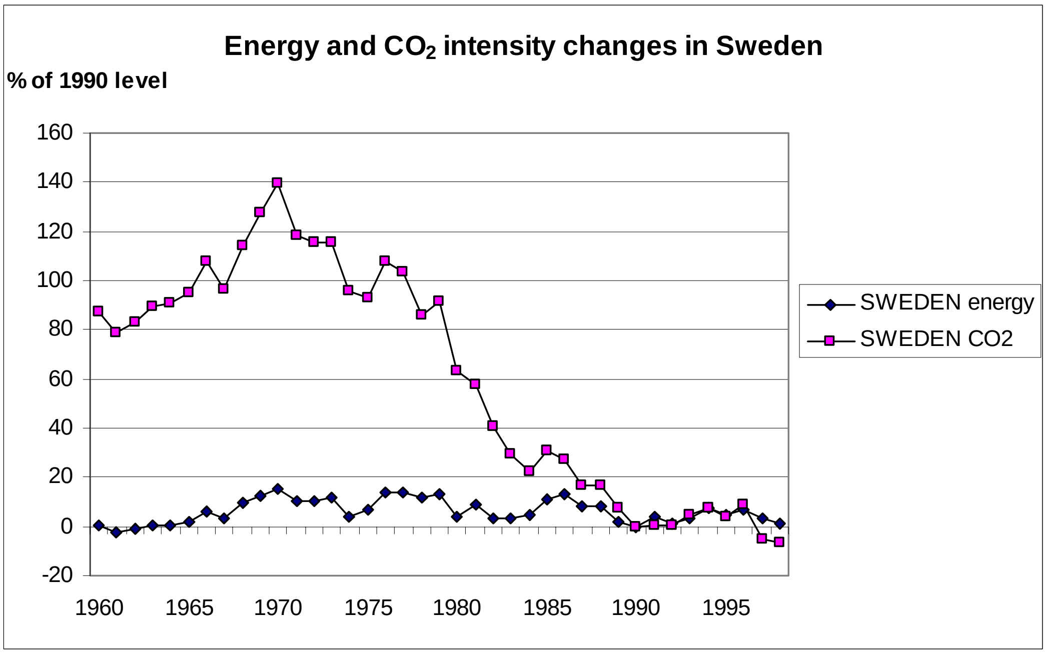
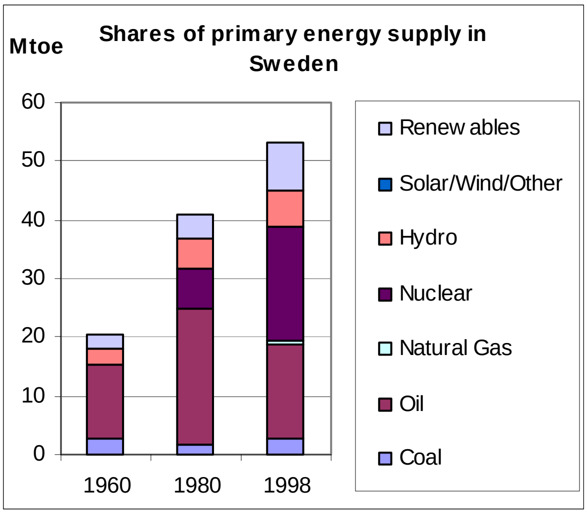


Figure 21. Energy and CO_2 intensity effect changes in Sweden



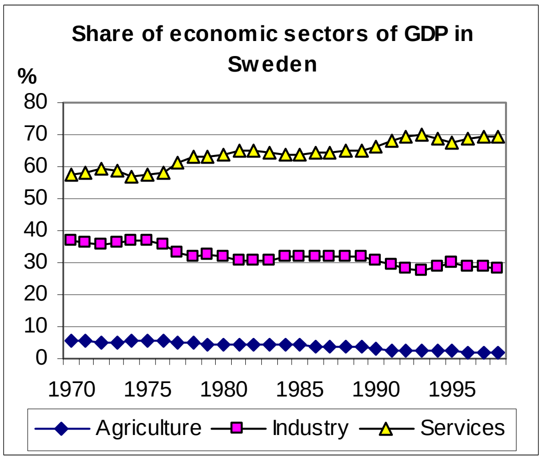


Figure 22. Shares of primary energy supply and economic sectors of GDP in Sweden

Figure 21 illustrates the dynamic changes in energy and CO_2 intensity effects in Sweden. The intensity effect of energy use is quite similar to the Finnish case and it does not have any clear increasing or decreasing trend during the analysed period. The total energy efficiency in Sweden has not improved. The Swedish production structure has remained as inefficient in relation to energy use as it was in the sixties.

The changes in the intensity effect of CO_2 compared with energy intensity effect indicate that there have been remarkable fuel switches in Sweden. The carbon intensity increased in the sixties, but after the turning point in 1970 there has been steady downward sloping trend till the year 1990. The decreasing trend is caused by hydro and nuclear power investments in seventies and eighties. After 1990 the downward sloping trend has broken and there has not been considerable increase in CO_2 efficiency. The effects of hydro production fluctuations on the intensity effect are much smaller than in Finland and Denmark indicating that they have caused mainly changes in electricity export and import and not in fossil based production. Swedish electricity production is, to a very large extent, based on hydro and nuclear production and only few percentages is based on thermal production (Schipper, Johnson, Howarth, Anderson, Anderson and Price 1993).

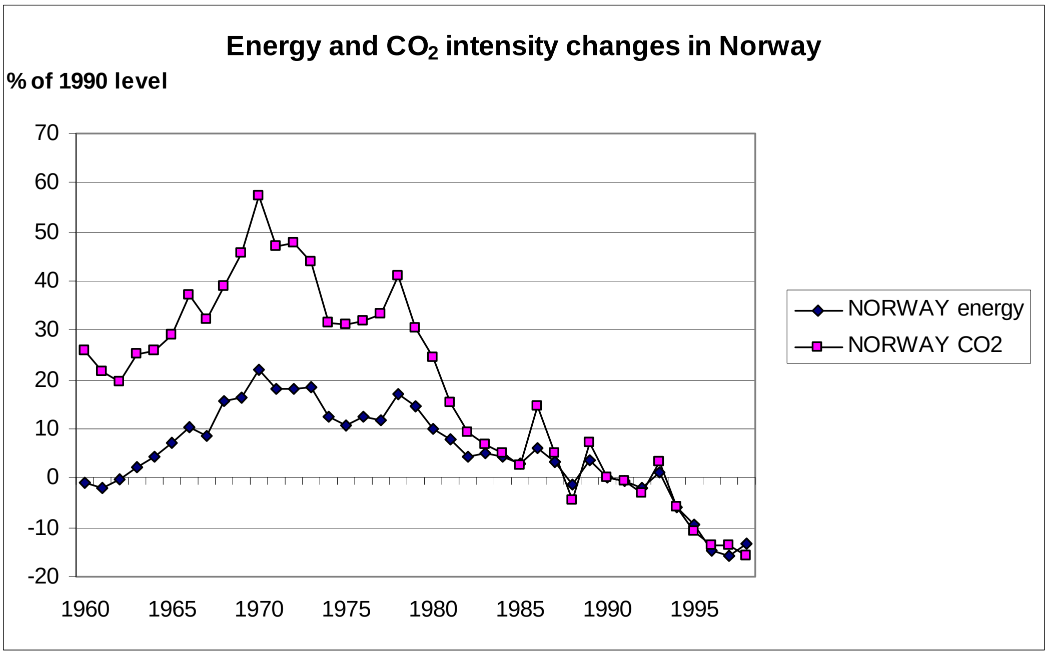
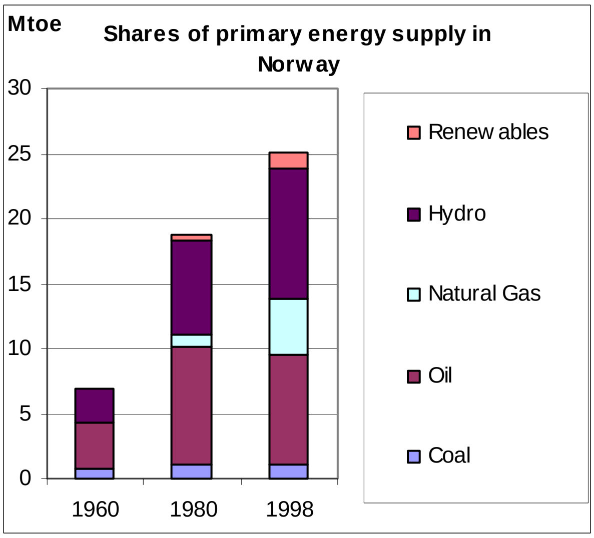


Figure 23. Energy and CO_2 intensity effect changes in Norway



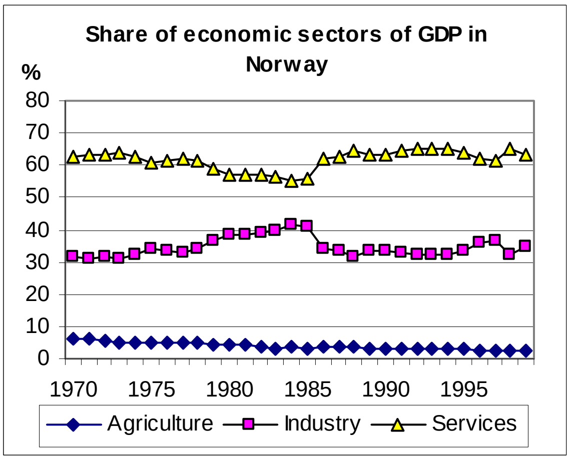


Figure 24. Shares of primary energy supply and economic sectors of GDP in Norway

Figure 23 illustrates the dynamic changes in energy and CO_2 intensity effects in Norway. The intensity effect of energy use has slightly increased during the sixties after which there has been a slow downward sloping trend.

The sharper downward sloping trend in the intensity effect of CO_2 compared with energy intensity effect indicates that the hydro based electricity has increased its share in the total energy production. The hundred-percentage reliance on hydropower in electricity production is a remarkable feature in the Norwegian case. The effects of hydro production fluctuations in Norway on the intensity effect are much smaller than in Finland and Denmark indicating that they have caused mainly changes in electricity export and import. The structural changes in the Norwegian economy are quite different from many EU countries. The importance of oil and gas production is indicated by the large share of the industrial sector. The sharp oil price decrease in 1985 can be seen in the sectoral shares of the economy.

Figure 25 summarises the fuel switching that has taken place in the Nordic countries. The fuel switching is indicated by the difference of the percentage changes of the intensity effect of CO_2 emissions and the intensity effect of energy use. Decreasing curves indicate decreasing carbonisation of the energy production system.

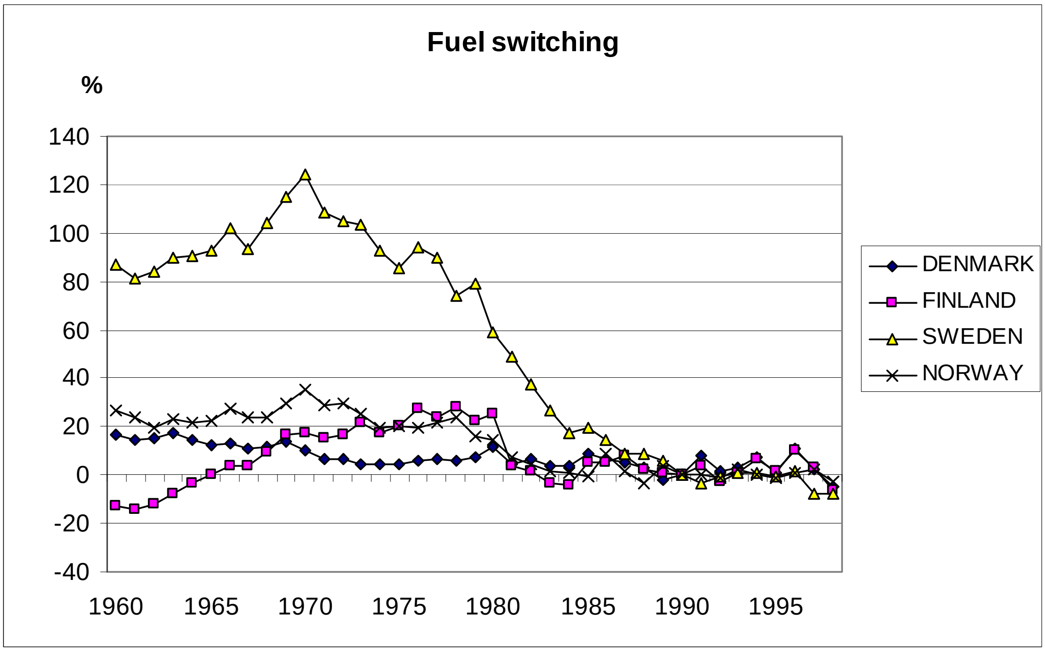


Figure 25. Fuel switching in Denmark, Finland, Sweden and Norway

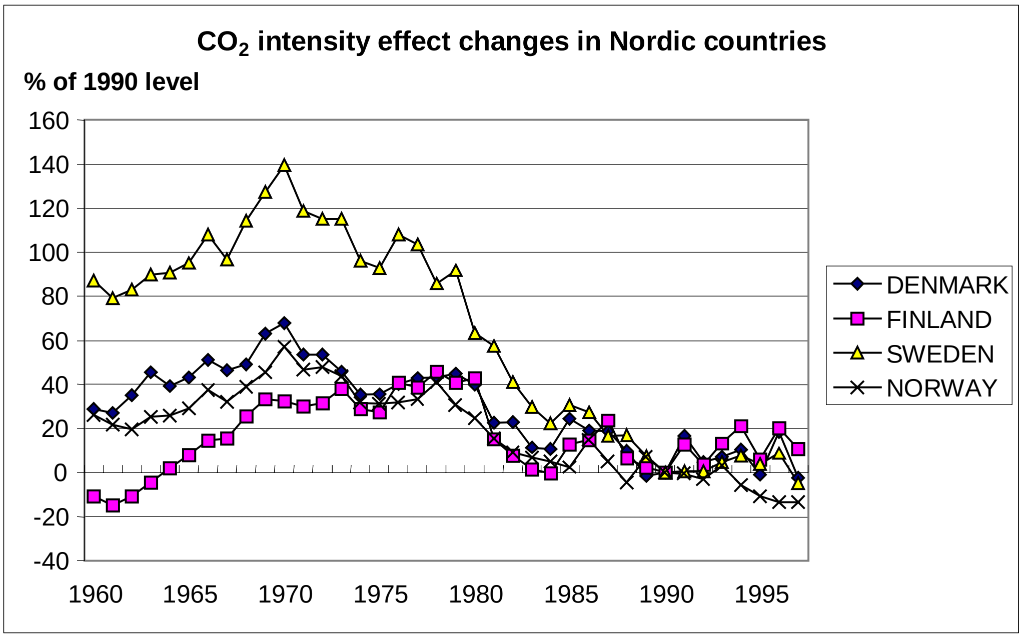


Figure 26. CO_2 intensity effect changes in the Nordic countries (% of the 1990 level)

It is obvious that the Nordic energy system reveals a large degree of flexibility for meeting international CO_2 commitments. Hydro and wind power, increased use of bio fuels, end use conservation and efficiency measures, increased power production from combined heat and power units but also increased reliance on natural gas, are all factors that may play an important part in reducing CO_2 emissions in the future.

6. COUNTRY LEVEL ANALYSES OF ENERGY AND CO_2 INTENSITY: COHESION COUNTRIES IN EUROPEAN UNION

Both energy and CO_2 intensity effects have been growing considerably in Greece (see Fig. 27). This indicates that more energy is used and more emissions are released to produce same amount of GDP. From the sixties to the nineties there is no indication of fuel switch. The energy production in Greece has been almost totally based on coal and oil leading to carbon intensive structure of the economy. In the late nineties one can observe a slight change towards less carbon intensive energy use. The share of agricultural production is still quite large in Greece.

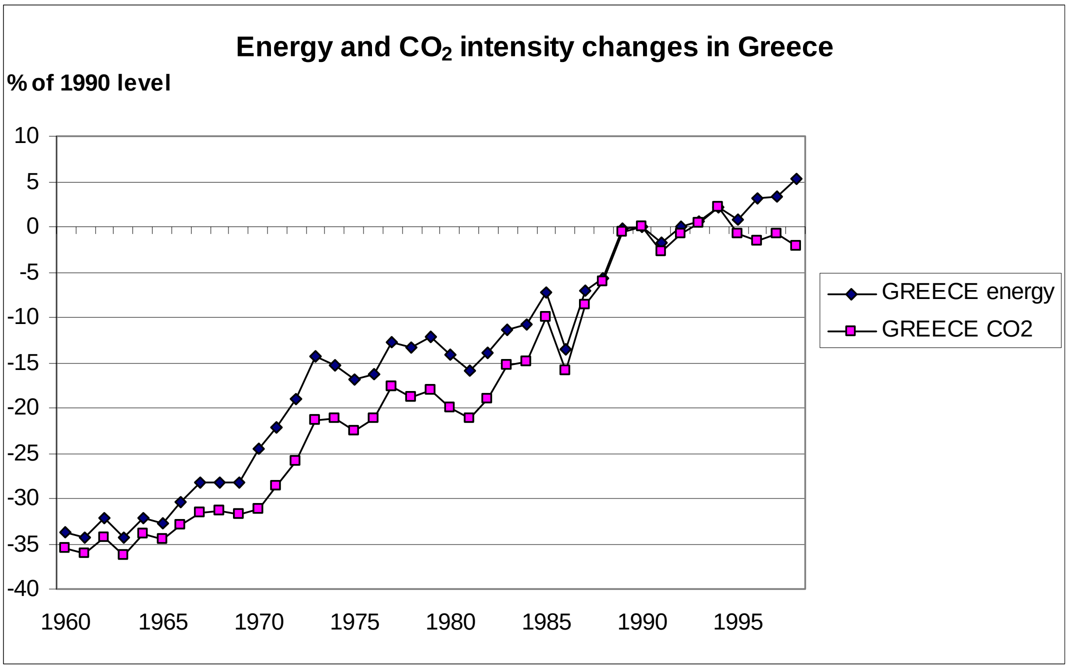
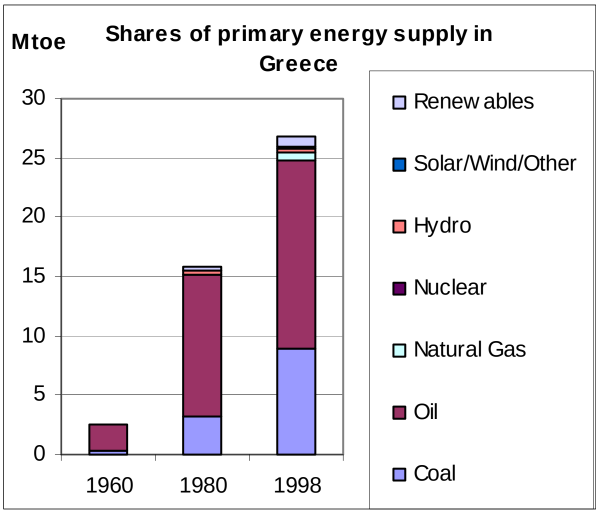


Figure 27. Energy and CO_2 intensity effect changes in Greece



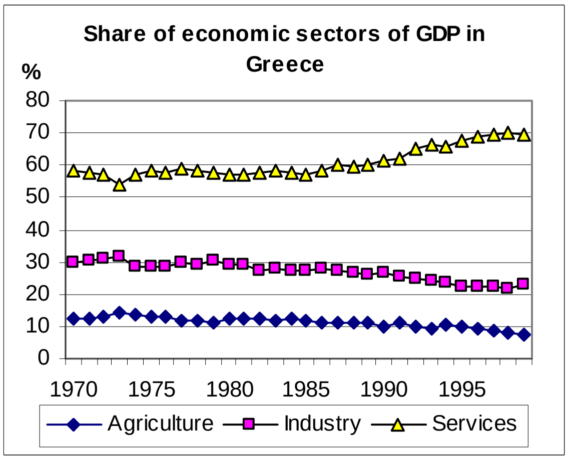


Figure 28. Shares of primary energy supply and economic sectors of GDP in Greece

One can see in Fig. 29 that energy and CO_2 intensity effects in Ireland have been decreasing considerably, especially in the nineties. This is related to the structural change in Irish economy. Especially chemical industry and computers and instrument engineering have increased their share in the GDP producing larger economic output with less energy input. The increasing CO_2 efficiency in Ireland is mainly due to the increasing energy efficiency – there seems to be no larger fuel shift although in the late nineties natural gas has increased its share.

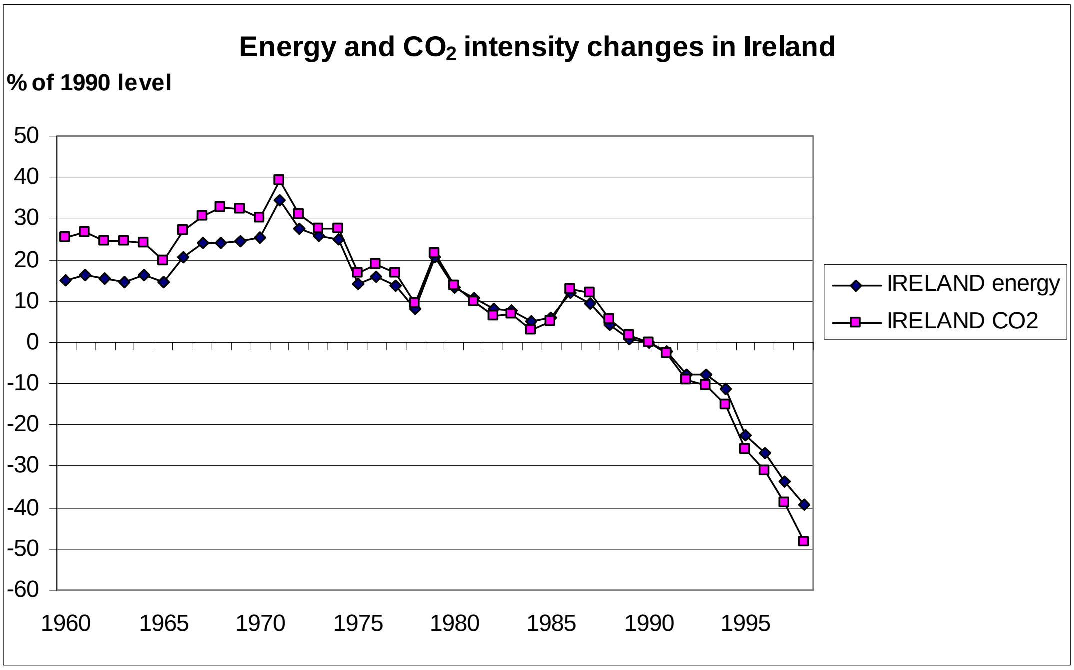


Figure 29. Energy and CO_2 intensity effect changes in Ireland

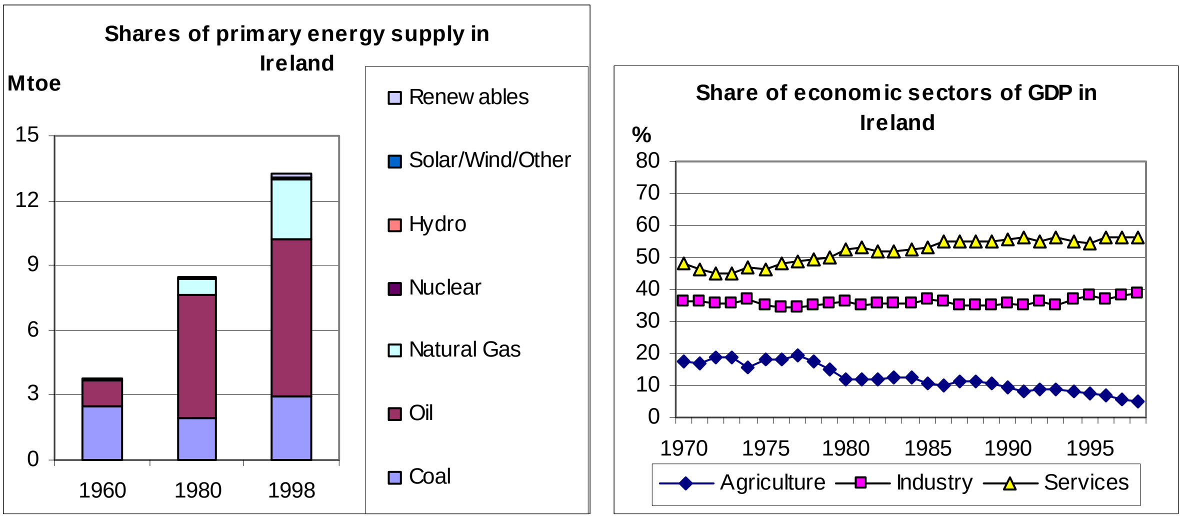


Figure 30. Shares of primary energy supply and economic sectors of GDP in Ireland

In Portugal the energy and CO_2 intensity effects have been increasing hand in hand. This indicates that there have not been any major fuel switches in Portugal and the economy is developing in a more energy intensive direction. Start of oil refinery industry in the 1980s and especially the fast growth of road transport fuel consumption in the 1990s are the main reasons for the increasing energy intensity of the Portuguese economy. Decreasing share of agriculture in GDP is also one reason affecting the development.

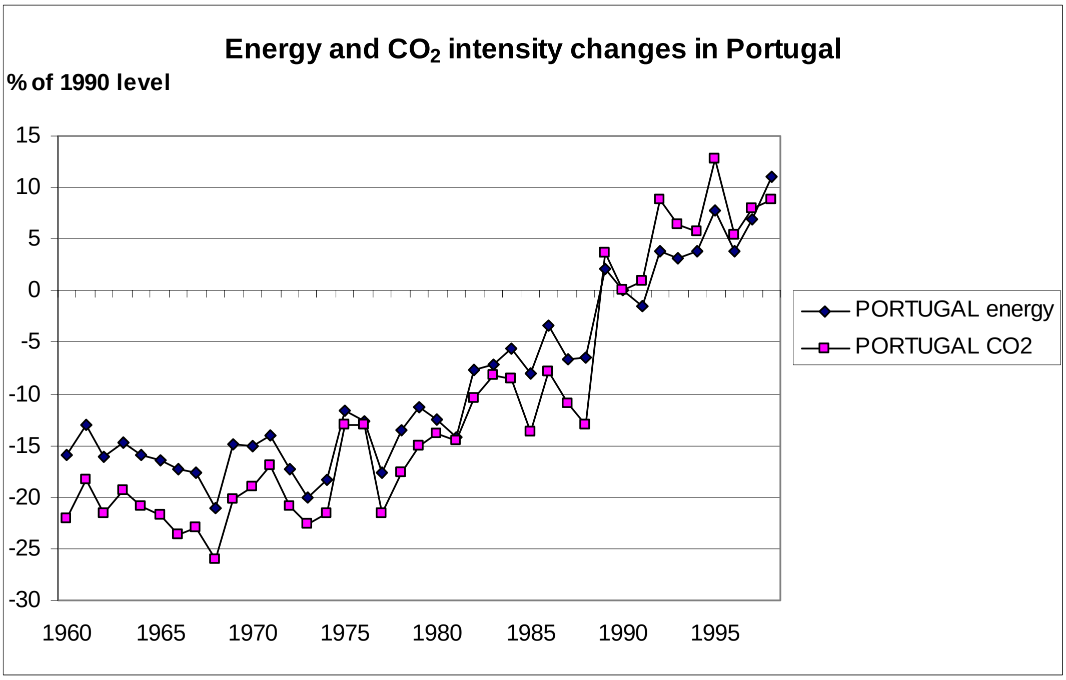
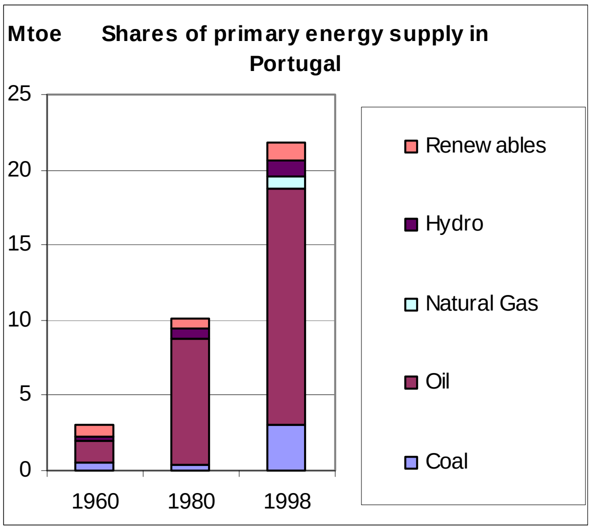


Figure 31. Energy and CO_2 intensity effect changes in Portugal



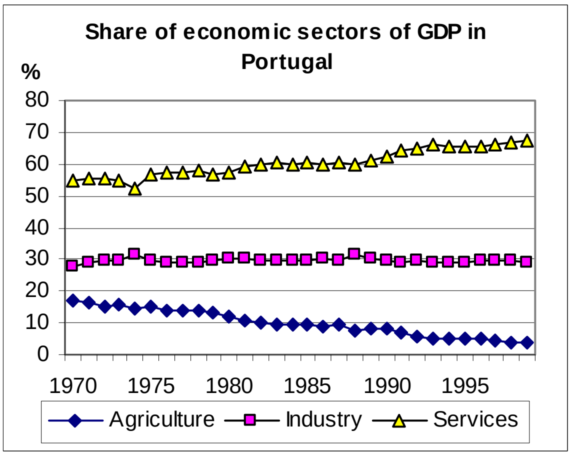


Figure 32. Shares of primary energy supply and economic sectors of GDP in Portugal

In Spain the shapes of the development of energy and CO_2 intensity effects have been similar up to 1980 indicating no fuel switches. From 1980 to 1988 the CO_2 efficiency has improved considerably due to the introduction of nuclear power. After 1988 the CO_2 efficiency has again started slightly to decrease along with the energy efficiency (see Fig. 33).

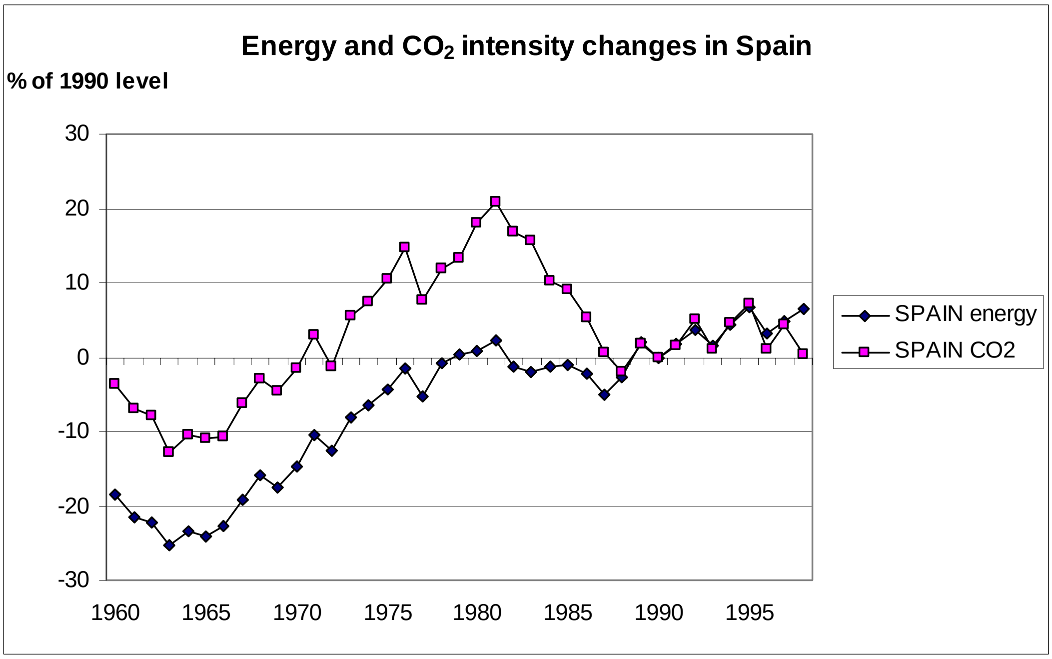
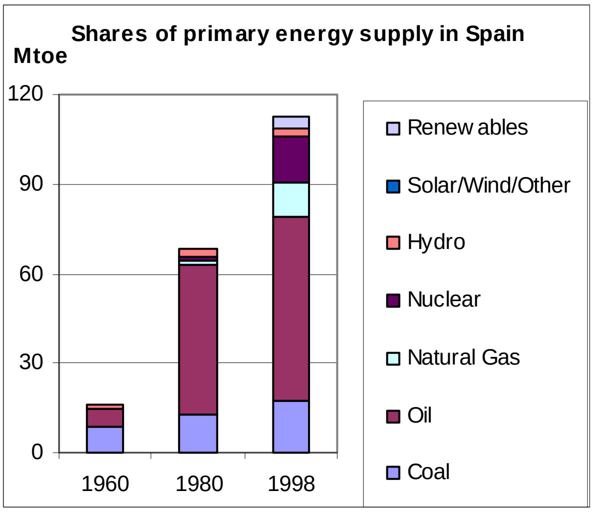


Figure 33. Energy and CO_2 intensity effect changes in Spain



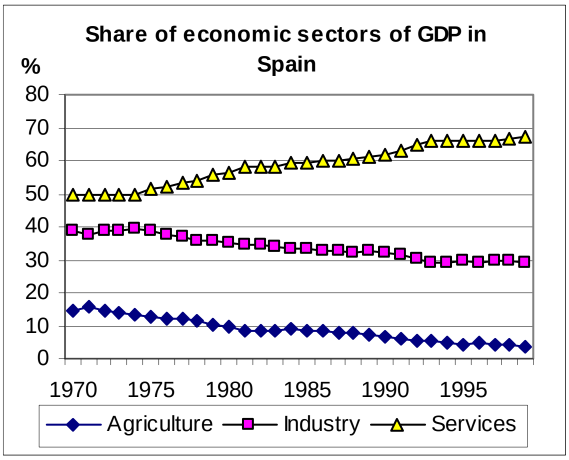


Figure 34. Shares of primary energy supply and economic sectors of GDP in Spain

Figure 35 summarises the fuel switching that has taken place in the EU cohesion countries. The fuel switching is indicated by the difference of the percentage changes of the intensity effect of CO_2 emissions and the intensity effect of energy use. Decreasing curves indicate decreasing carbonisation of the energy production system.

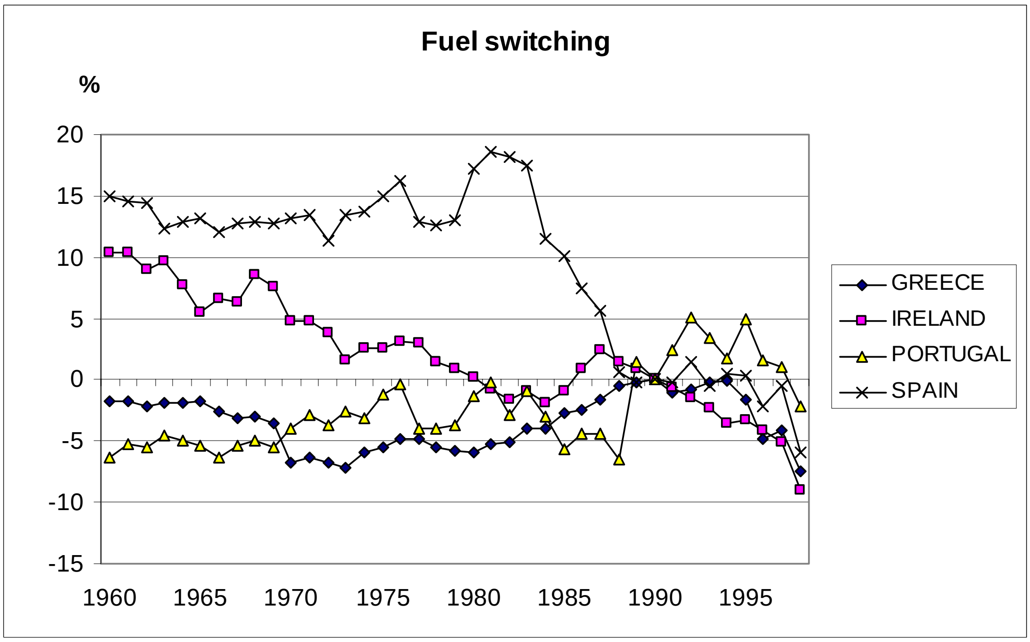


Figure 35. Fuel switching in Greece, Ireland, Portugal and Spain

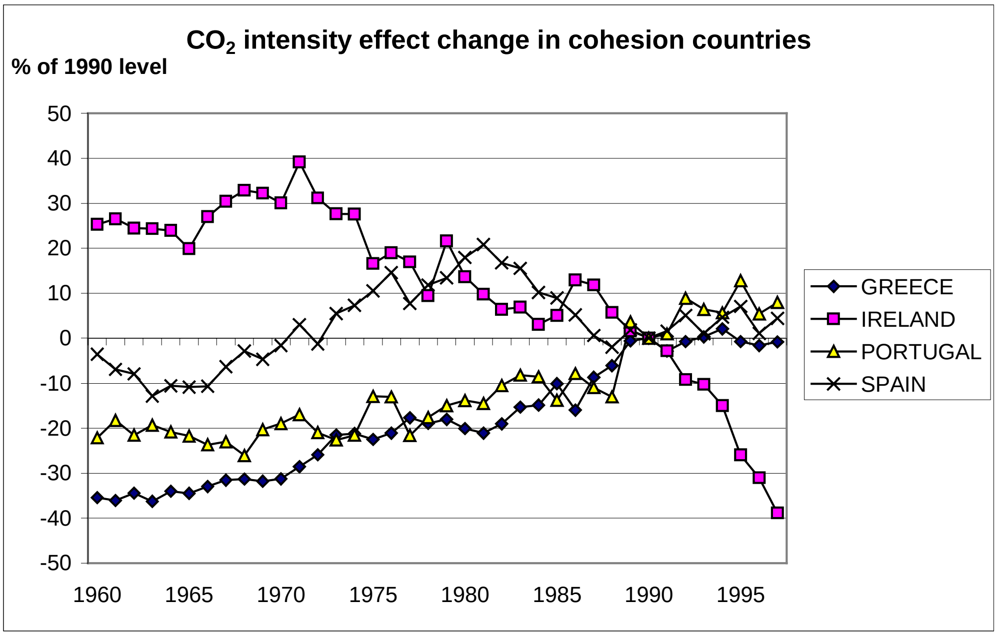


Figure 36. CO_2 intensity effect changes in the cohesion countries (% of the 1990 level)

7. COUNTRY LEVEL ANALYSES OF ENERGY AND CO_2 INTENSITY: OTHER EU COUNTRIES

In Austria the energy and CO2 efficiencies have increased considerably after the first energy crisis in 1973. The increasing natural gas consumption and hydro production have contributed to the fuel switch to less carbon intensive energy mix. (Fig. 37).

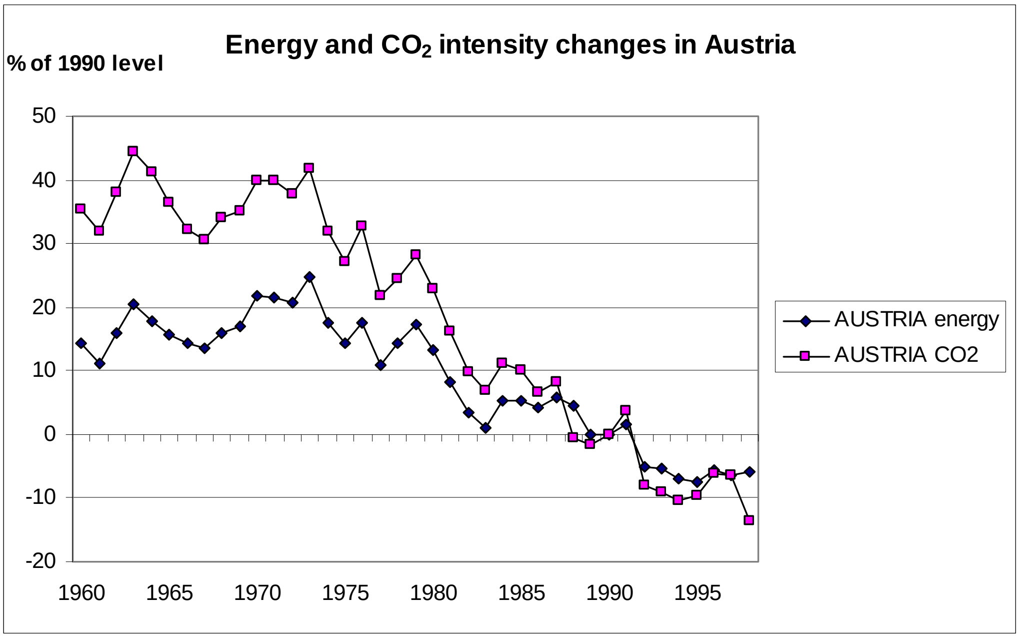


Figure 37. Energy and CO_2 intensity effect changes in Austria

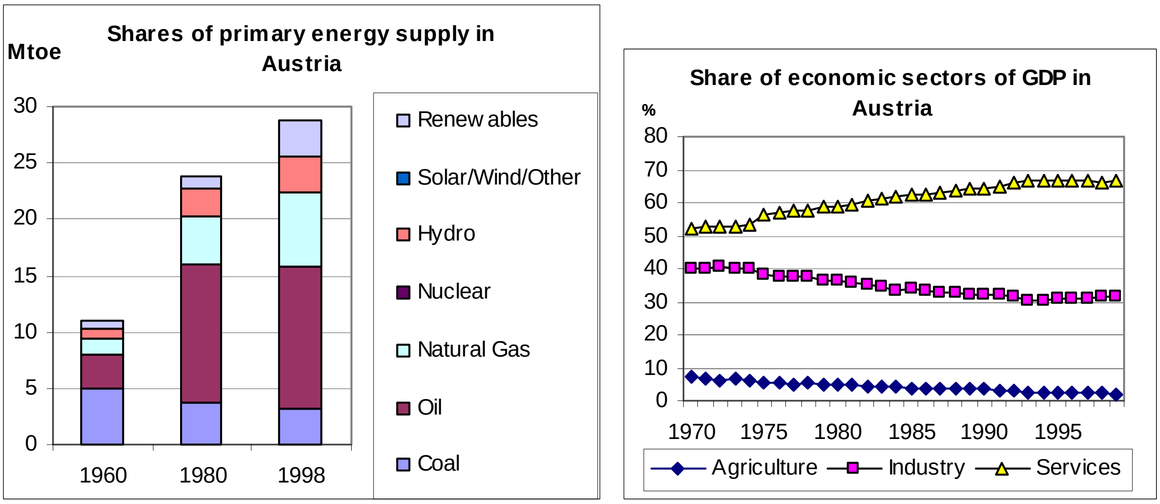


Figure 38. Shares of primary energy supply and economic sectors of GDP in Austria

In Belgium there has been a slight increase in the energy efficiency after the first energy crisis 1973 but the positive development has ended in the beginning of the 80s after the introduction of nuclear power. The improvement in the CO_2 efficiency has been remarkable after 1970. The introduction of nuclear power is the main reason, but also the energy efficiency has improved. The structural change in the economy has been considerable in Belgium. (Fig. 39).

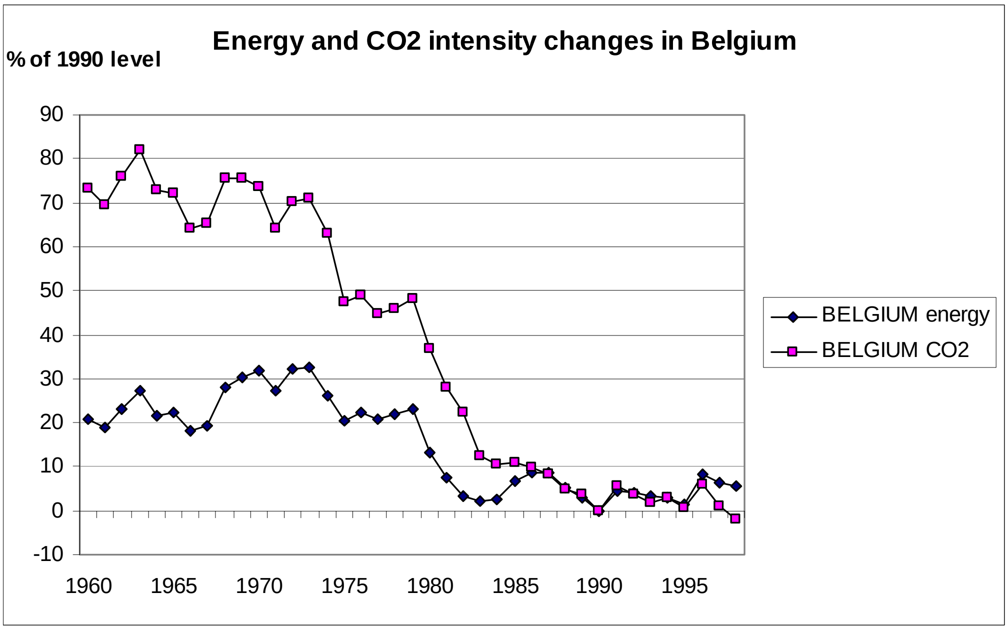
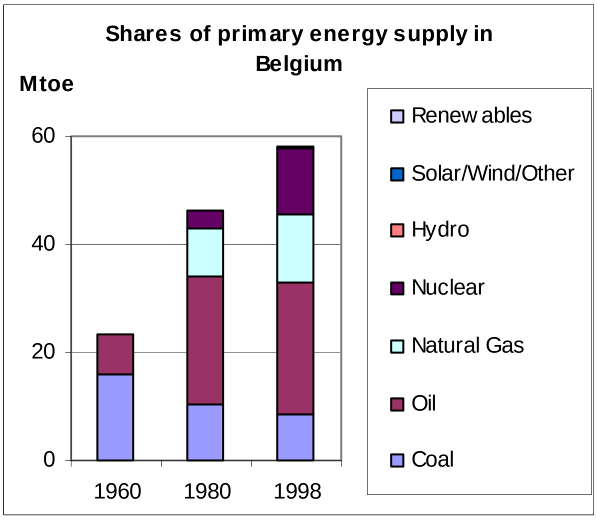


Figure 39. Energy and CO_2 intensity effect changes in Belgium



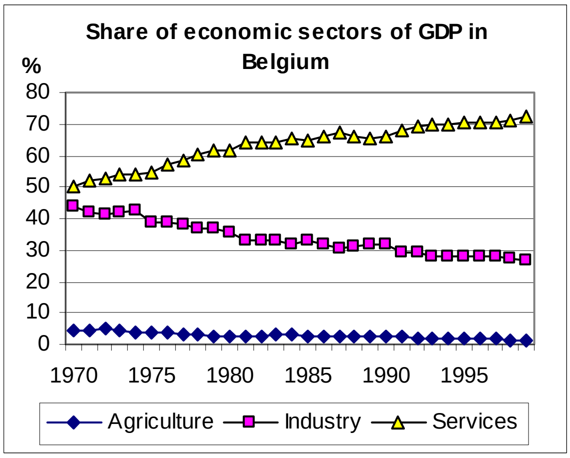


Figure 40. Shares of primary energy supply and economic sectors of GDP in Belgium

Luxembourg shows a remarkable increase in both energy and CO2 efficiency. There has been a large shift from coal to petroleum products and to some extent to natural gas. The total energy consumption has decreased while the economy has been growing. The change is caused by the large structural shift in the economy from industry dominated production to service economy. (Fig. 41).

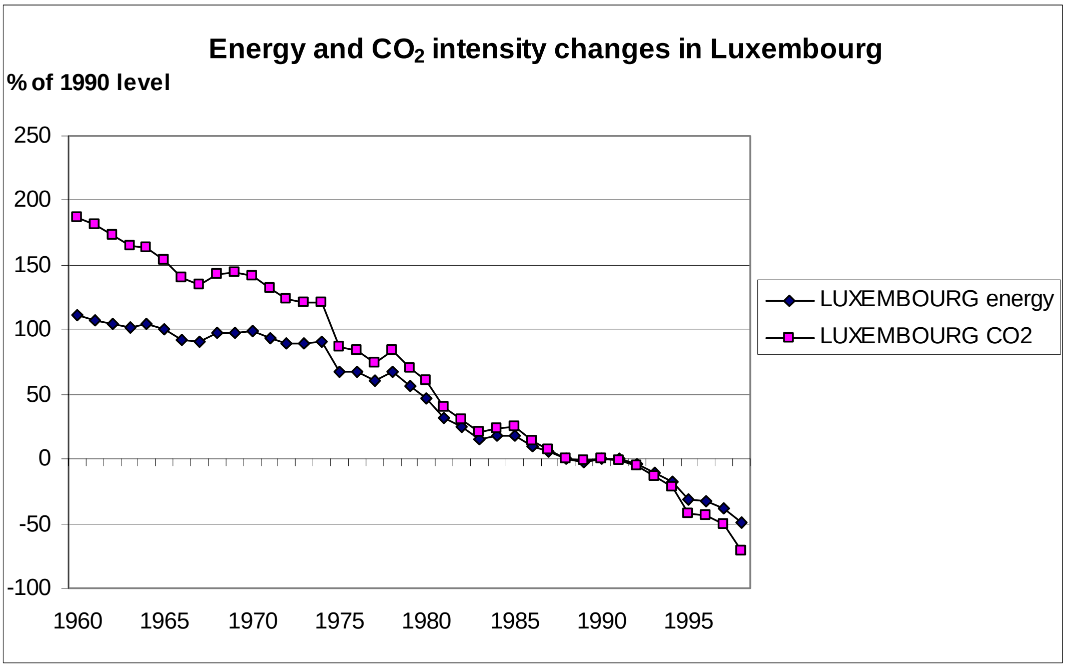


Figure 41. Energy and CO_2 intensity effect changes in Luxembourg

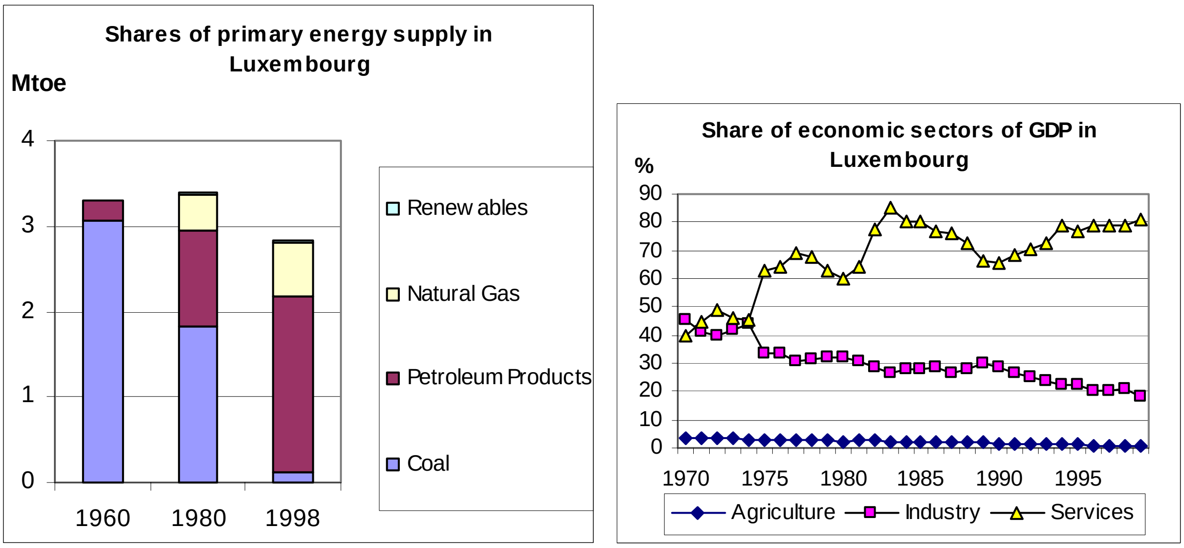


Figure 42. Shares of primary energy supply and economic sectors of GDP in Luxembourg

The first oil crisis in 1973 has been a turning point in the energy economy in the Netherlands. The development towards more carbon intensive economy ended and after the second oil crisis in 1979 there was a considerable increase in energy efficiency. After the first oil crisis there have not been any major fuel switches and the increased CO_2 efficiency has been due to the improving energy efficiency (Fig. 43).

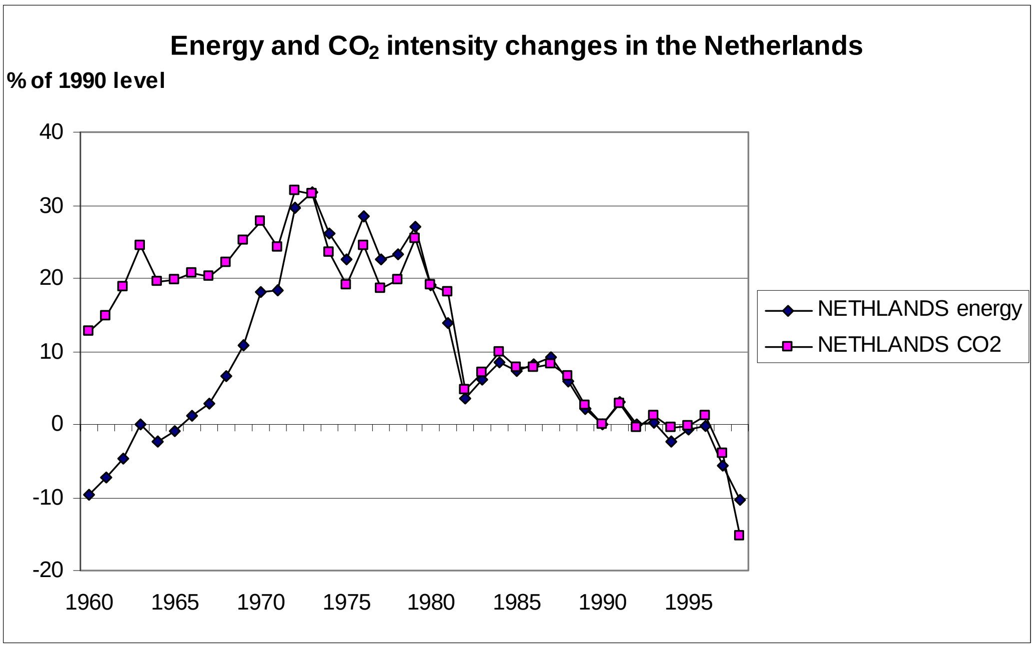


Figure 43. Energy and CO_2 intensity effect changes in the Netherlands

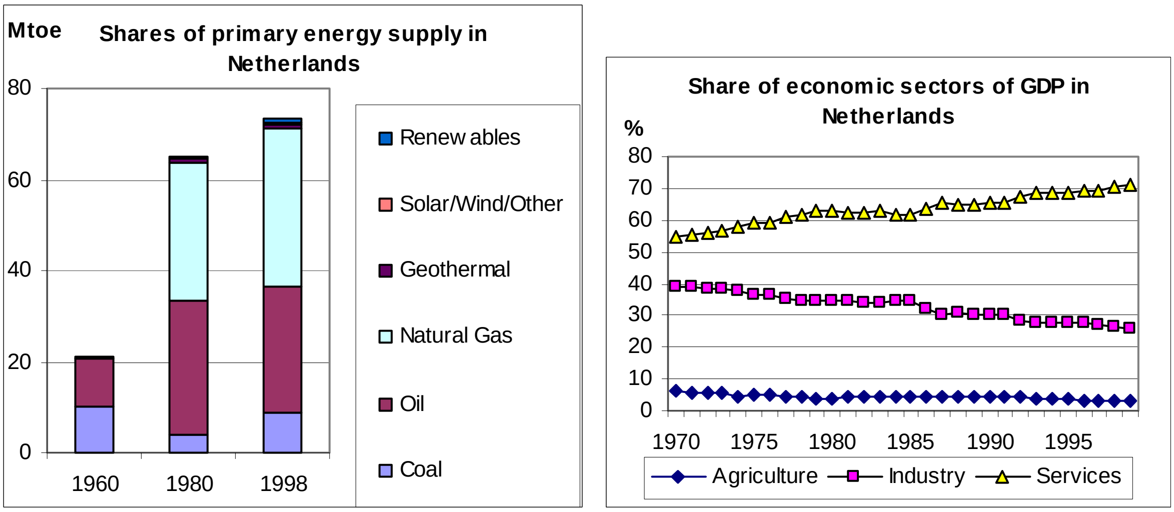


Figure 44. Shares of primary energy supply and economic sectors of GDP in the Netherlands

Figure 45 summarizes the fuel switching that has taken place in Austria, Belgium, Luxembourg and the Netherlands. In the figure 45 the fuel switching is indicated by the difference of the percentage changes of the intensity effect of CO_2 emissions and the intensity effect of energy use. Decreasing curves indicate decreasing carbonisation of the energy production system.

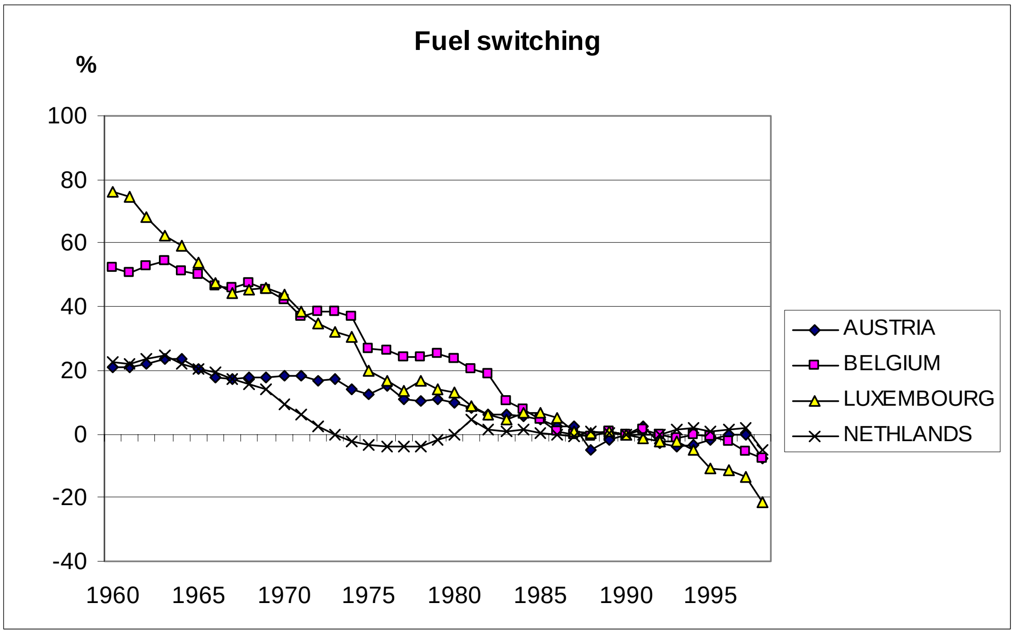


Figure 45. Fuel switching in Austria, Belgium, Luxembourg and the Netherlands

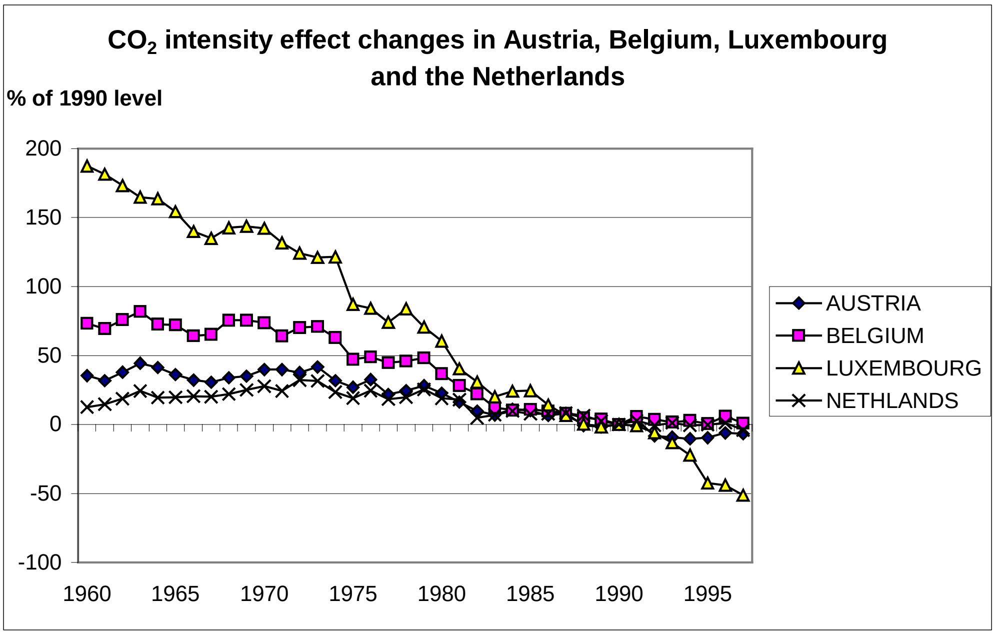


Figure 46. CO_2 intensity effect changes in other EU countries (% of the 1990 level)

8. CONCLUSIONS

There are basically three different possibilities for the reduction of CO_2 emissions of a country; (i) reduction of energy use, (ii) fuel switch to less carbon intensive fuels or (iii) efficiency improvement of the energy system. The efficiency improvement depends on (i) the socio-cultural development of the society, (ii) economic and structural development and (iii) technological development. Within the economic development especially the role of industrial development and its structure in the globalised economy (e.g. shift of heavy and polluting industry to developing countries and increase of ICT sector) in relation to the development of other sectors (e.g. service sector and tourism) is essential.

In this study we have carried out a comparative study of all the three factors for EU-15 countries and Norway. The research period 1960-1998 has been divided into two periods, from 1960 to 1973 and from 1973 to 1998 because the first oil crisis changed the energy sector development considerably. The results are summarized in Table 2.

Table 2. Annual primary energy consumption increase, fuel switching and energy efficiency improvement in the EU-15 countries and Norway.

Countries	Annual primary energy consumption increase		Fuel switching		Energy efficiency improvement	
	1960-1973	1974-1998	1960-1973	1974-1998	1960-1973	1974-1998
Austria	5,4	1,1	0	+ +	-	+ + +
Belgium	5,4	0,9	+	+ + +	-	+ +
Denmark	6,2	0,2	+	+	- -	+ + +
Finland	6,2	1,8	- - -	+ +	-	0
France	6,3	1,5	0	+ + +	0	0
Germany	6,9	0,1	+	+ +	0	+ + +
Greece	13,0	3,2	0	0	- -	- -
Ireland	5,1	2,5	+	+	-	+ + +
Italy	9,5	1,1	0	0	- - -	+ +
Luxembourg	2,4	-1,2	+ + +	+ + +	+ + +	+ + +
Netherlands	8,7	0,7	+ +	0	- - -	+ + +
Norway	6,1	2,1	0	+ + +	-	+ +
Portugal	7,0	4,5	0	0	0	- - -
Spain	9,5	3,1	0	+ +	-	-
Sweden	5,1	1,2	- -	+ + +	0	0
United Kingdom	2,5	0,2	+ + +	+ +	0	+ + +

+ = fuel switching to less carbon intensive fuels or improved energy efficiency

- = fuel switching to more carbon intensive fuels or decreased energy efficiency

0 means no remarkable change (less than 5%)

+ or **-** means small percentage change (from 5% to 15%)

+ + or **- -** means medium percentage change (from15% to 25%)

+ + + or **- - -** means large percentage change (over 25%)

The results show that there exist quite different trends in the European Union energy sector development and there is room for energy policy harmonisation in the EU. On the other hand we must remember that the EU countries are in different phases of their economic and industrial development, which is one reason for the observed trends. With the introduction of new member countries the variations and differences still increase. The accession process will raise new challenges for the harmonisation of the energy and climate policy. The acceptability of different policy instruments varies among EU countries and different stakeholder groups and the decision making of the economically important issues is problematic (see discussions in Hacker and Pelchen 1999 and Vehmas et al 1999). The climate policy of EU has been based on the burden sharing within the EU bubble, but in the future the accession process will have an effect on the policy formulations.

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