A review of employment effects of European Union policies and measures for CO_2-emission reductions

Report of a study for WWF Germany

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1 Introduction

Various policies and measures are currently discussed on national and international levels to reduce CO_2-emissions and help protect the earth's atmosphere. The EU discussions focus on the so-called common and coordinated policies and measures, and many initiatives have been started within the Union to introduce such policies. (see EFOFYS 1998).

Policies and measures to reduce greenhouse gas emissions have to be justified for environmental reasons primarily. However, especially in times of high unemployment, the economic effects of such policies are important aspects in the political debate. Thus, the employment effects of CO_2-reduction policies have been discussed intensively in the past. Various arguments have been put forward and several analyses (with different results) have been carried out, e.g. in the context of the proposals for a European CO_2/energy tax in the early 1990s or in the Second Assessment Report of the IPCC (1995).

Policies to increase employment in the EU are still on top of the EU policy list and in June 1999, policy measures to address unemployment will be intensively discussed at the meeting of the Head of States in Cologne, Germany. Thus, the latest results on the interaction between CO_2-reduction policies and employment are an important aspect to be considered in this context.

This paper aims at providing a rough review of the likely employment effects of European Union policies and measures for CO_2-emission reductions. This review concentrates mainly on the so-called common and coordinated policies and measures. Furthermore, the analysis is restricted to presenting and systemising existing results on the effects of a CO_2 /energy tax and putting forward a rather qualitative evaluation of the various sectoral policies discussed.

The paper is organised as follows. In section 2, the economic impact mechanisms of climate protection policies are discussed. This allows the different arguments brought forward in the debate on the employment effects of CO_2-reduction policies to be systemised and evaluated. Section 3 presents some of the latest results on the macroeconomic effects of a CO_2/energy tax. The likely effects of the sectoral policies on the different economic impact categories are discussed in section 4. Conclusions are presented in section 5.

2 Overview on economic impact mechanisms

Key strategies for climate protection include measures to reduce energy demand (rational use of energy) and to substitute fuels with low carbon content for fuels with high carbon content. These measures include instruments ranging from command-and-control policies and information programmes to the use of financial instruments such as subsidies or the introduction of CO_2/energy taxes. The use of these instruments triggers various reactions by companies and consumers, which can be observed as structural effects on a sectoral or regional level. The sum of all these adaptations, together with the induced reactions, are reflected as changes in macroeconomic variables such as GNP or employment. However, a consistent modelling between the microeconomic reactions and the sectoral and macroeconomic effects is difficult to achieve.

On a macroeconomic level, various economic impact mechanisms affect the supply and demand sides. In general, **four different classes of effects** can be distinguished: price and costs effects, revenue recycling effects of an energy tax, demand effects, and innovation effects (see Table 1).

Price and cost effects:
- Additional costs due to realising expensive energy conservation potentials
- Reduction of costs by realising individually profitable measures (no regret potential)
- Substitution effects due to changes in the relative prices

Revenue recycling effects:
- Reduction in costs of labour, if energy tax revenues are used for lowering taxes on labour (employment double dividend)
- Macroeconomic cost reductions, in case price effects of energy tax are overcompensated by a lowering of other distortionary taxes (welfare double dividend)

Demand effects:
- Positive and negative, direct and - according to the interlinkages between sectors and branches - indirect demand effects
- Positive or negative effects on the flow of income

Technological innovation/competition effects:
- Impacts of the diffusion of climate protection policy on productivity
- Improvement of technological competitiveness on the international commodity market for technologies of rational energy use (first mover advantage)
- Stimulating the generation of new technological solutions (generation effect), including long-term effects on cost

2.1 Price and cost effects

Climate protection policies can lead to price and cost effects on the supply side. If before the policy measure is introduced, all factors of production are used optimally, the new measure will generally lead to an **increase in costs of production** in the affected industries and eventually to lower output and employment levels (output effect). In addition, increased production costs reduce international competitiveness thus aggravating the loss in employment. (e.g., Lintz 1992; Blazejczak et al. 1993). However, whether employment actually falls depends also on the ease of substitution between energy and capital or energy and labour (substitution effect). Since the use of energy has become more expensive, firms and households will try to substitute energy. If energy can easily be substituted for by labour, the demand for labour will increase, counterbalancing the negative output effect on employment. The effects on employment also depend on the characteristics of the labour market, for example, the bargaining power of unions and employers when negotiating over the wages, or the way in which labour supply reacts to changes in the real wage rate.

In reality, however, there are several reasons for why agents may not be optimising, such as bounded rationality, split incentives (user/investor dilemma), and market failures (Jaffe and Stavins 1994, Eyre 1997, Almeida 1998). There are numerous empirical studies for the energy sector indicating an extensive **economically feasible energy conservation potential** which pays off in the short term. Grubb et al. (1993) estimate this so-called no-regret potential for the western industrialised countries at approx. 20 %, and the IPCC estimates this potential at 10-30 % over the next 2-3 decades. Thus, climate protecting policies may lead to the adoption of more efficient technologies and production processes, which may decrease total production costs and **increases total output and employment**.

To sum up, the actual effects on costs and prices consist of different partial effects, which may compensate or enforce one another. The size of these effects depends on the actual situation analysed and cannot be generalised. Important parameters are the envisaged CO_2-reduction, the substitutability between energy, capital and labour, labour market characteristics, and the size of the no-regret reduction potential.

2.2 Revenue recycling effects

A major component of climate protection policies is the introduction of an energy/CO_2-tax. Such a tax increases the costs of energy relative to other inputs. Possible substitution and output effects have already been pointed out, but to fully evaluate the impact of a tax, the **use of the additional tax revenue** has to be taken into account as well (revenue recycling). If the tax revenues are used to lower the contributions to social security by employers, the **costs for labour decrease**. This creates an incentive to substitute labour for other factors of production leading to higher levels of employment. Thus, an energy tax may reduce CO_2–emissions (first dividend) and reduce unemployment (second dividend). If the taxes which are lowered to compensate for the tax increase have a higher distortionary effect than an energy tax, total welfare may increase (for overviews see Majocchi 1996, or Park and Pezzey 1998). While the theoretical circumstances under which double-dividends may arise are highly debated, there is strong empirical evidence that these dividends in terms of lower unemployment exist (e.g. Goulder 1995, see also section 3), but its magnitude also depends on the characteristics of the labour market.

2.3 Demand effects

When there is unemployment, and climate protection policies lead to an increase in effective aggregate demand, positive output and employment effects are to be expected. When analysing the effects on aggregate demand, different partial effects can be distinguished. The **direct demand effects** of the political measures can be either positive or negative: measures to increase the rational use of energy (substitution of energy use by capital) require additional investments (demand increase), however, the demand for traditional energy sources decreases at the same time. Substituting one energy source for others changes the demand for the respective forms of energy. As the production of energy requires numerous inputs from other production sectors, the direct demand effects trigger **indirect effects**. The size of these indirect effects depends on the interdependencies between the sectors of the economy. For energy net importing countries, the indirect demand effects of a reduction in the consumption of imported energy sources such as oil, natural gas and uranium, affect primarily energy exporting countries. In addition to the direct and indirect demand effects there are the typical **macroeconomic income effects** on aggregate demand which are caused by changes in investment and savings behaviour. The impact of the demand effects on employment also depend on the monetary policy by the central bank and on the collective wage bargaining process.

2.4 Innovation effects

In addition to costs and demand effects, climate protection policies can also change the long-term competitiveness of a country. First of all, the impacts of the diffusion of climate protection policies on **industrial productivity** have to be taken into account. Here, there are two opposite hypotheses: the first assumes that investments in climate protection policies have no direct effect on productivity, but lead to a crowding-out of other more productive investments. Thus, this hypothesis concludes that climate protection investments lower productivity. According to the second hypothesis, climate protection investments are a component of productive investments themselves, accelerate the modernisation of the capital stock, and lead to an increase in productivity. Which of theses two hypotheses seems to be more plausible depends to a great extent on the specification of the investments.

Second, in addition to low prices, success in the world market also depends on the **quality of products**. Particularly in the case of technology-intensive goods, high market shares depend on the innovation ability of an economy and on an early market presence (first mover advantage, Porter hypothesis). Thus, an ambitious national policy to reduce CO_2-emissions could lead to a specialisation of these countries in the production of climate protection goods. This, in turn, gives these countries an edge in the evolving market for such goods. During a subsequent expansion of the international demand for climate protection goods, these countries could then be more successful in the world market due to their early specialisation (see Blümle 1994; Porter/van der Linde 1995).

Third, the effects of a climate protection policy on the **generation of industrial innovations** itself have to be analysed. If technological progress considered to be autonomous, climate policies will not effect the rate of technological change. However, may be more likely that technological change is induced by market conditions. Thus, climate policies will trigger additional research and development activities (Grubb 1995, and Goulder and Schneider, 1996). If climate policies result in an incorporation of climate protection into the traditional target system of research and development activities, additional processes are likely to be developed which may increase productivity as well as contribute to climate protection.

2.5 Direction of effects

In this section, the most likely **effects of the various mechanisms on employment** are illustrated in Figure 1. Positive effects are indicated by the area above the x-axis, negative effects by the area below the x-axis.

- Cost effects: The curve CE reflects the cost effects; it accounts for both high and low cost CO_2-reduction measures. As long as the measures realised belong to the no-regret potential, a positive impact on employment is most likely. Thus, the curve runs above the x-axis. Only if high cost measures are implemented, the costs effects will create an impulse towards negative effects on employment, which is indicated by curve CE running below the x-axis.
- Demand effects: The curve DE (demand effects) reflects that CO_2-measures most likely increase the demand within Europe because within Europe the demand for fuel and power products triggers much more imports than the demand for machinery goods or building and civil engineering works. Thus, the conservation of energy by capital equipment and investments in insulation leads to an import substitution increasing the final demand for European production. In addition, the production within the machinery and building businesses is much more labour intensive. Calculations accounting for all direct and indirect demand effects performed with the European Economic Input-Output Tables reveal that the income for European workers is much higher if the demand for machinery and building goods are increased compared to an increase in demand for fuel and power products.
- Revenue recycling effects: as pointed out above, there is significant empirical evidence for a double dividend in terms of higher employment which is reflected through DD in Figure1.

- The innovation effect combines the different partial effects described earlier. An empirical analysis for Germany concludes that climate protection investments within industry tend to increase productivity (Walz 1999). Even though sound empirical analysis is still lacking, the hypotheses is plausible that CO_2-reduction policies will generate additional innovations. The arguments brought forward with regard to the first mover advantage also indicate another positive effects of CO_2-reduction policies on innovation. As a result, the combination of innovation effects tend to increase employment as indicated by IE. However, the magnitude of this effect is difficult to assess.

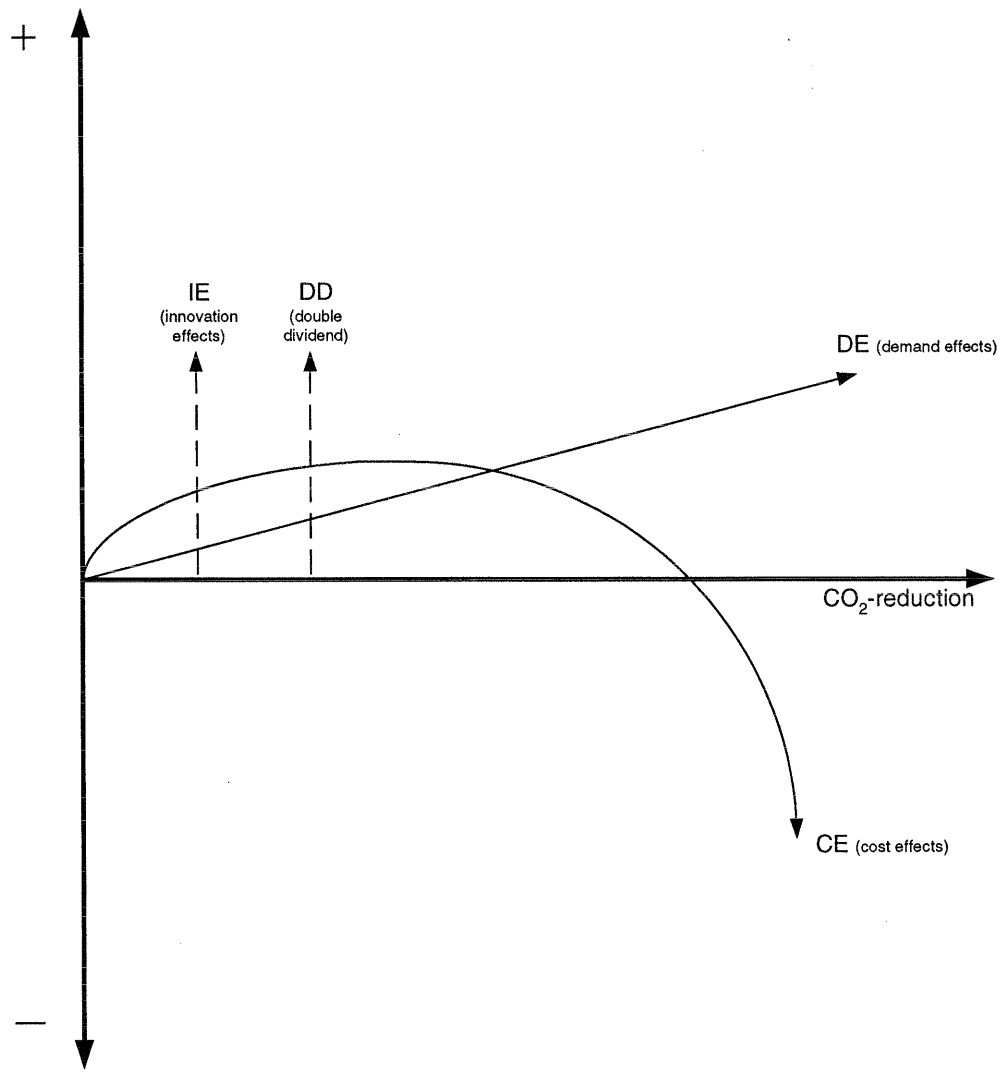


Figure 1: Direction of the different economic effects on employment

3 Empirical results of modelling the effects of an energy/CO_2-tax

Among the different CO_2-reduction policies, the impacts of an energy tax have been studied the most. In section 2 it has been pointed out that appropriate revenue recycling is likely to reduce unemployment. In addition, the introduction of a broad-based energy tax is much more likely to trigger the pure macroeconomic income as well as relative price effects than policies aiming at a specific sectors or technologies only. For both reasons, the use of **complex macroeconomic models** is required to analyse employment effects resulting from a broad-based energy tax.

In the past, various studies have been performed analysing the effects of such an energy/CO_2-tax. In the early 1990s, the results obtained with the Hermes, Quest, and DRI models have been widely discussed (see CEC 1992, DRI 1994, IPCC 1995). They concluded that a tax of \$10 per barrel (using oil as reference) would result in rather small effects on both CO_2-emissions and general macroeconomic variables. In the previous years, additional modelling efforts have been performed explicitly allowing for revenue recycling to reduce labour costs. The following **models** were used **in** these **new studies**:

- The LEAN (Low Emission Assessment eNgine) model is an applied general equilibrium model. It was used by Welsch (1996) to analyse the effects of a moderate European CO_2/energy tax.
- The GEM-E3 (General Equilibrium Model-Energy, Environment, Economy) was developed by a European consortium for the CEC, DG XII. It was used by Conrad/Schmidt (1998) to model the effects of a 10 % CO_2-reduction due to the introduction of a CO_2-tax.
- The E3ME model is a large-scale, integrated, regionalised Energy, Environment/Economy macroeconometric model estimated on time series and cross section data. It was also developed for the CEC, DG XII by another European consortium. Barker (1998) applied the model to analyse the effects of a 10 % CO_2-reduction due to the introduction of a CO_2-tax.

The most important results of these new studies are shown in Figures 2 and 3, together with the results obtained with the Hermes model in the early 1990s. These results clearly demonstrate the **empirical existence of a double dividend** in terms of GDP and employment.

Looking at the results in more detail, the following aspects are worth mentioning.

- The existence of a double dividend emerges from these latest studies even more clearly as from the Hermes model. Thus, the improvements obtained in modelling have been working in the direction of increasing the positive results.

- The differences between the studies are largely due to the fact that the studies are based on modelling approaches which differ in the ways they take into account the various impact mechanisms described in section 2. An economic model may have been selected which can only consider measures which increase cost (e.g. applied general equilibrium models). In doing so, the effects of the implementation of energy saving potentials that are profitable on an individual economic level are disregarded.
- Especially for the general equilibrium models, the effects on employment are more positive than for GDP. This is, in particular, the result of factor substitution: the tax revenue is used to lower labour costs, thus labour is substituted for other factors of production.
- The large range of results with the LEAN model is striking. This range is due to variations in the use of the revenues of the energy/CO_2-tax. The different macroeconomic effects depend on whether tax revenues are used to reduce levies on labour, to reduce the public budget deficit or to increase public spending. The extent of variation within this study indicates that for the macroeconomic impact the general economic policy framework might actually be more decisive than the energy policy.
- The studies shown in Figures 2 and 3 concentrate on cost and double dividend effects of an energy/CO_2-tax; however, they neglect almost entirely the possible innovation effects presented in section 2. Thus, the impacts of increased innovation, productivity growth and first mover advantages are not considered sufficiently. Therefore, the model analyses discussed above are likely to result in more positive outcomes for the entire economy once these effects are taken into account.

Given this background for interpreting the different results, it seems plausible to conclude that introducing an energy tax would have **moderate, but positive macroeconomic effects**, especially when embedded in an appropriate general economic policy framework. The rather small differences in the percentage of employment induced by the ecological taxes translate into a substantial number of additional jobs, e.g. 1.9 million in the case of the results calculated with the E3ME model (Barker 1998). Thus, it can be concluded that the introduction of an energy/CO_2-tax would make an important contribution to the **reduction in unemployment**.

Figure 2: Range of results of selected studies on the impact of an energy/CO_2-tax on GDP

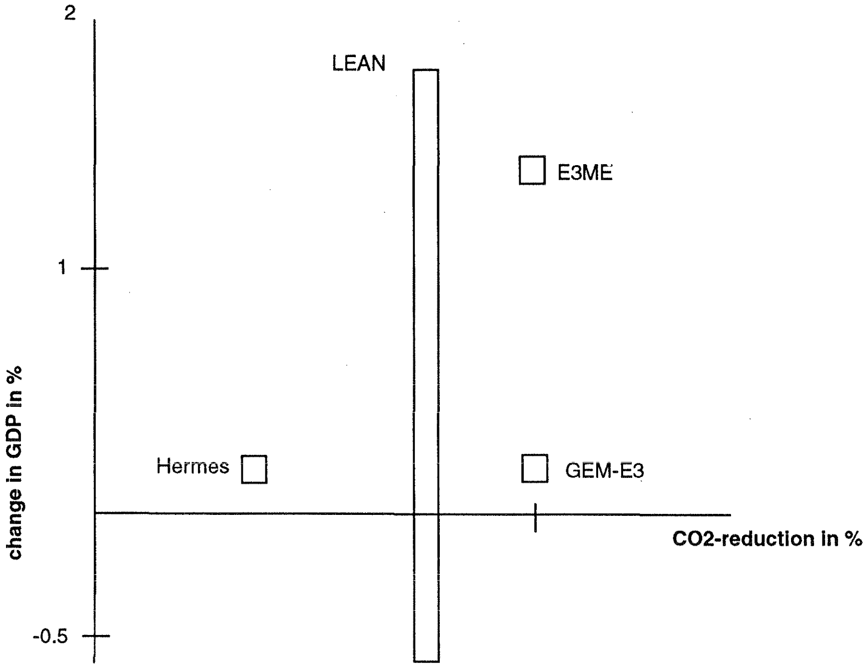
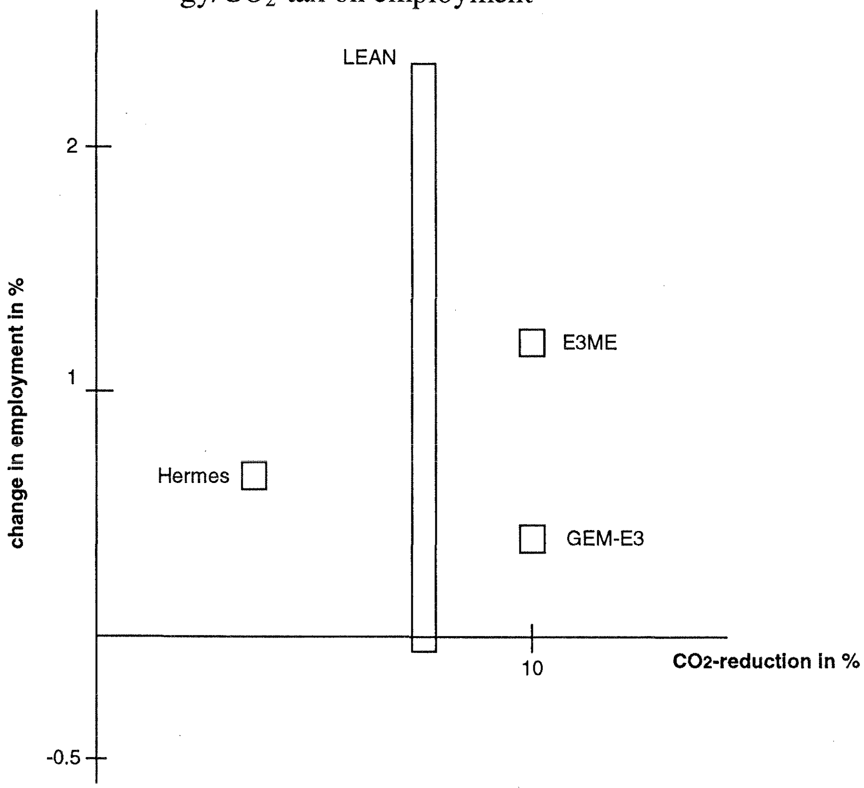


Figure 3: Range of results of selected studies on the impact of an energy/CO_2-tax on employment



4 Evaluation of sectoral and technology-oriented policies

In this section the most important sectoral policies are evaluated with regard to their likely impact on the economy. Policies for the promotion of the following **sectors and technologies** are considered (see EFOFYS 1998):

- industrial process efficiency
- cogeneration
- domestic appliances efficiency
- insulation measures for buildings
- fuel economy of cars
- renewable energy sources

In section 2 it has been argued that it is necessary to consider different impact mechanisms in order to derive a full picture of the economic effects. However, a consistent quantitative analysis taking into account all relevant impact mechanisms is still lacking for these sectoral policies. Therefore, a rather **qualitative analysis** is performed to analyse how the various different policies trigger the impact mechanisms costs, demand, and innovation. In contrast to a broad based energy/CO_2-tax the sectoral and technology oriented policies are analysed at a meso level. This implies that economic effects such as macroeconomic income effects, or the effects of the use of revenues (which are relevant for tax policies only) have to be neglected.

Various data sources form the basis for this evaluation. In addition to literature studies (e.g. EFOFYS 1998), the MURE database was used to evaluate the cost effects. To assess the specific demand effects, the European Input-Output-Tables (see Annex) were used. In a few instances, quantitative results were available, especially with regard to the demand effects (see for instance European Commission 1998). They were included into the arguments brought forward. An overview of the qualitative evaluations of the different sectoral policies is given in Table 2 in section 4.7.

4.1 Industrial process efficiency

Increasing industrial process efficiency can yield substantial reductions in CO_2-emissions, especially in the heavy industries (EFOFYS et al. 1998, Block et al., 1995). In order to realise this reduction potential, both sector specific process technologies (especially in heavy industry) and generic technologies (e.g. efficient electrical motor systems) have to be implemented (European Commission 1999, Jochem/Bradke 1999; Almeida 1997). The **cost effectiveness** of these technologies varies considerably, and also depends on the profitability requirements, which are required for a technology to be judged as cost-effective. According to EFOFYS (1998), a substantial part of the technical feasible reduction potential can be realised with payback periods below 4-6 years or at internal interest rates of 12 to 20 %. In sum, the improvements in industrial process efficiency were evaluated as being moderately cost-ineffective up to highly cost-effective (- to ++).

Positive **demand effects** from an increase in industrial process efficiency accrue primarily in the industrial machinery and electric goods sectors, which are the main producers for industrial capital goods. Calculations with the European Input-Output Tables confirm that demand for the products of these two individual sectors induces significantly lower imports than the demand for fuel and power products. Thus, the impact of increasing industrial process efficiency on the net demand within the EU can be judged as being positive (+).

Increasing industrial process efficiency has important effects on the various aspects of **innovation**. An analysis of the 58 most important energy efficient technologies within industry revealed that most of them will trigger positive effects on industrial productivity (Walz 1999). Up to now, the improvement in energy efficiency has been mostly only a by-product of the development of new production technologies. Thus, the future innovation potential might be much higher if energy efficiency is included as an explicit goal in the traditional R&D process. Furthermore, technological quality of products is the key parameter in the intense international competition for capital goods. Thus, first mover advantages play a key role in determining success on the world market. To sum up, these arguments clearly support the conclusion that the impact of industrial process efficiency on innovation will be very high (++).

4.2 Cogeneration in industry and the commercial/public sector

Cogeneration is a technique which reduces the primary energy consumption compared to a separate generation of heat and electricity. The aim of the Commission is a doubling of the current share of cogeneration in electricity generation by 2010. Various studies indicate that there is a large cost-effective potential for cogeneration (as reflected in the scenarios to 2020 of the Shared Analysis project, see Vouyoukas et al. 1999). The **cost effectiveness** of cogeneration depends not only on technical circumstances, but also on the effects of liberalisation of the electricity and gas industries. The EU Directive concerning the internal market for electricity and the future Directive on the internal gas market are important for the realisation of the potentials of cogeneration. While liberalisation will lower electricity prices, it will also lead to lower gas prices according to observations in the UK. Thus, there is a good growth potential in particular for decentralized cogeneration based on natural gas (COGEN 1997). If there is sufficient demand for heat generated during the summer (e.g. absorption technology for cooling), cogeneration might also be cost-effective for other applications such as hospitals and swimming pools. Within industry, the highest potentials are in the chemical, the paper, the mechanical engineering and the electrical engineering sectors (Gailfuß, 1998). Especially in industry, the application of cogeneration is very cost effective (EFOFYS 1998). This high no-regret potential is reflected by the evaluation of the cost impact (++) in Table 2.

Positive **demand effects** from an increase in cogeneration accrue primarily in the electric goods and industrial machinery sectors. Calculations with the European Input-Output Tables confirm that demand for the products of these two sectors induces a significantly higher demand for labour and lower demand for imports than the demand for fuel and power products. Thus, the impact of cogeneration on the demand within the EU can be judged as being positive.

The technologies for cogeneration are rather well developed. The potential for the generation of future innovation exists; it will be smaller for conventional engine and turbine-driven systems than for renewable energy, but it is expected to be very high for fuel cells within the next 10 - 15 years. As cogeneration is usually not integrated into the core production process in industry (except for gas turbines), effects on industrial productivity are rather small. At the same time, there exists an intense international competition to satisfy the growing world demand for cogeneration. Thus, the export potential of cogeneration is promising. Taken together, these different aspects lead to the conclusion that the impact of cogeneration on **innovation** will be positive, however not as strong as for industrial process efficiency.

4.3 Domestic appliances

The efficiency of newly marketed domestic appliances has been steadily improving in the past. Nevertheless, there still exists an additional improvement potential in the future (EFOFYS 1998). For some domestic appliances such as freezers and also fridges, buying energy efficient products also reduces total lifecycle costs (MURE, Database 1999, Gruber et al. 1996), even though there are sometimes problems to perceive the cost effectiveness as such (EC 1997). For appliances which are used less frequently such as ovens, dish washers, washing machines, and dryers, it is more difficult to recover higher investment costs through electricity savings. However, the investments for these appliances are not always higher than for less energy efficient appliances (IWU). In sum, the domestic appliances are evaluated as moderately negative to moderately positive (- to +).

In economic terms, the use of efficient domestic appliances is equivalent with a substitution of energy by higher investments in efficient domestic appliances. In order to evaluate the demand effect of this substitution, the specific effects of a demand for electric goods were compared with the specific demand for fuel and power products using the European Input-Output Tables. The results confirm that demand for electric goods induces significantly lower demand for imports than the demand for fuel and power products. A closer look reveals that there are high export and import streams of domestic appliances on the national level, but mostly within the EU. Thus, the overall impact of domestic appliances on **demand** within the EU can be judged as being positive (+).

With regard to innovation effects, most of the arguments brought forward for traditional cogeneration systems also hold for domestic appliances. The technologies are rather well developed, although on a longer term significant breakthroughs for individual appliances similar to progress in the past might occur in the future (e. g. new refrigeration concepts making use of out-side cold; combined cold and power generation in analogy to CHP which would become interesting when the heat demand in residential houses has fallen to such low levels that the energy consumption for heating is comparable to the consumption for cooling; significant improvements in the design and the start-up properties of energy efficient light bulbs etc.). Thus, the future impact on the generation of innovation will not be as pronounced as for completely new energy-using technologies. At the same time, there exists an intense international competition to satisfy the growing world demand for some high tech appliances. Taken together, these different aspects lead to the conclusion that the impact of domestic appliances on **innovation** will be rather low (0 to +).

4.4 Insulation measures for buildings

Measures to improve insulation measures for buildings are a prerequisite for reducing the CO_2 emissions from the residential, commercial and public sector. A study for the DG XVII indicates that double glazing and high-performance double glazing for existing dwellings in colder EU countries has a pay-back period of 7 to 8 years (European Commission 1995). Other measures like insulation of cellar floors by 8 cm or the upper floors by 20 cm are most likely to become beneficial in the near future. However, if insulation measures are realised together with other renovation activities or already carried out by buildings under construction (low energy buildings, passive solar houses), they are most likely profitable (IWU 1997). In summary, it can be concluded that there are various measures with costs ranging from negative costs to positive costs (MURE Database 1999). Therefore, the **cost effectiveness** of insulation measures were evaluated as moderately negative to moderately positive (- to +).

Improving insulation is equivalent with a substitution of energy by higher investments in the building's envelope. In order to evaluate the demand effect of this substitution, the specific effects of a demand for construction and civil engineering products were compared with the specific demand for fuel and power products using the European Input-Output Tables. The results confirm that demand for construction and civil engineering goods induces significantly lower demand for imports than the demand for fuel and power products, and even lower imports than sectors such as machinery or electrical goods. Thus, the overall impact of domestic appliances on **demand** within the EU can be judged as being very positive (++).

This evaluation is also supported by quantitative results on the net employment effects. According to a recent study conducted by the Deutsches Institut für Wirtschaftsforschung (DIW) insulation measures are estimated to create around 77,400 additional jobs by 2005 in Germany. However, the effects are expected to be much lower in the long run, because the positive demand effects for construction goods are levelling out (DIW 1997). Another study carried out for the DG XVII indicates that replacing current single- and double glazing windows by high performance double-glazing windows may create 111,100 additional jobs for installation over a ten-year period for the seven EU countries and 127,000 jobs in all member states (European Commission 1995 and Groupment Européen des Producteurs de Verre Plat 1995).

With regard to **innovation** effects, increasing insulation for residential housing cannot increase industrial productivity. The insulation technologies are also rather well developed, although technical improvements and cost reductions are still on the agenda, and technical progress of window systems with variable transparencies will be of major importance in the next two decades. Thus, the future impact on the generation of innovation will be modest to even and covering mainly fields such as new wall insulation and window concepts as well as ventilation. The international competition within the construction and refurbishing business is relatively small indicating that first mover advantages will not play a key role except in window systems. In summary, the future innovation effects are estimated to be modest (+).

4.5 Fuel economy of cars

In the past, CO_2-emissions from the transport sector have been rising in all EU Member States. Thus, improving the fuel economy of cars will be one of the most important elements of emission reduction policies. In the last few months, the introduction of the fuel efficient VW Lupo has stirred up some discussions. Comparing the prices of the two different models (5,8 l per 100 km / 3 l per 100 km) of the VW Lupo would suggest a payback period (without compound interest) of 10 years. However, it can be argued that this price difference rather reflects a reaping of a first mover advantage than actual cost differences. Furthermore, future production costs are likely to decrease substantially due to the realisation of economies of scale and further learning. In addition, the purchase of the Smart (3,4 l / 100 km), which has lower initial costs could be cost effective nowadays. In summary, measures in the transport sector most likely will have (slightly) negative to positive **costs** (- to +). This conclusion can also be derived from an analysis of the MURE Database (1999).

Positive **demand effects** from an increase in industrial process efficiency accrue primarily in the transport equipment sector, which would have to supply more efficient motors to the vehicles sector. Calculations with the European Input Output Tables confirm that demand for the products of these two sectors induces a significantly higher demand for labour and lower demand for imports than the demand for fuel and power products. Thus, the impact of increasing industrial process efficiency on the net demand within the EU can be judged as being positive.

Increasing the fuel economy of cars does not effect industrial productivity directly. However, there is still very much potential for generating future innovations (Breitschwerdt 1998). Furthermore, technological quality is an important parameter in the intense international competition for cars. Thus, first mover advantages play a key role in determining success on the world market, especially when the other countries have to increase fuel economy in order to fulfil their international greenhouse gas reduction targets. To sum up, these arguments clearly support the conclusion that the impact of fuel efficient cars on **innovation** will be very high (++).

4.6 Renewable energy sources

The use of renewable energy sources is a key element of a sustainable energy strategy in the long term. However, the present **costs** of renewables depend very much on the specific circumstances and vary considerably across and within the various types of technologies and applications. Large wind power generators (1500 kW) with rather high wind velocities of > 6.5 m/s, large hydro-electric plants, biomass (including biogas for co-generation) or hydrothermal energy plants can be cost effective. For thermal energy generation, specific costs tend to be higher than fossil-fuel based technologies (MURE database 1999). Similarly, specific costs for electricity generation using small wind power generators (600kW) can be up to 50% higher than conventional generation costs. For photovoltaic (PV) plants electricity generation costs are substantially higher than the costs of the average fossil fuel based technology (MURE database 1999; EFOFYS 1998). Thus, in general, cost estimates for renewable energy sources in the short run vary from just being economical (0) to high cost (--).

The impact of renewables **on demand** depends to a large extent on the differences in import shares between conventional fuel and energy products and renewable energy. Thus, the demand inside the EU will increase if the technologies used are produced in the EU. Thus, if the EU is rather reluctant in pushing for renewables and is not taking the lead, it might happen that a large share of renewable technology has to be imported from abroad. In this case, the effect on demand would not be positive. However, if the EU takes the lead in developing technologies for renewables, their application would substitute imports leading to an increase of domestic European demand. Assuming such a proactive strategy, the demand effects were evaluated as being positive (+).

This positive demand effect is also reflected by various studies trying to quantify the employment potential of an increased use of renewable energy sources (e.g. European Commission 1997, EWEA, European Solar Industry Federation, Österreichischer Biomasse-Verband 1997). The technologies and economies covered, the methodologies used, and therefore the numbers given differ quite substantially; however, to give an impression, an analysis with the SAFIRE input-output model calculated that even 500,000 new jobs might be possible due to a doubling of the renewables share in electricity generation (European Commission 1997).

An evaluation of the **innovation effects** has to consider various aspects. On the one hand, renewable energy sources generally have a significant potential to generate new innovations, in particular, if market penetration programs such as the recent German government-sponsored PV program, which aims at inducing 100,000 additional PV systems, are introduced. It can be expected that these innovations will also lead to substantial reductions in the costs of PV systems installed. (Estimates show that the costs for one kWh of electricity from PV can be lowered by a factor of 3 when the production volumes reach > 30 MW_{el} annually). On the other hand, the market for PV is a global market with expected annual growth rates between 20 and 25% and great application potentials in remote areas and developing countries with no energy infrastructure in place (European Commission 1997). Besides PV, wind energy with its present high growth rates in Denmark, Germany, and Spain (but also in India and China), large heat pumps for close surface geothermal energy, and equipment for the generation of hydro-thermal energy enjoy good export opportunities (Jochem et al. 1996). At the same time technologies using renewables belong to the markets for which technological quality aspects are extremely important. Thus, it can be expected that first mover advantages will be very important for this kind of technology. Both aspects taken together justify to evaluate renewables as very positive (++) with regard to **innovation effects**.

4.7 Overview and interpretation

An overview of the effects of the different sectoral policies on the three impact mechanisms costs, demand, and innovation is presented in Table 2. A positive sign (+) indicates positive contributions to the economic effects, a negative sign (-) negative contribution to economic performance. Interpreting these results, the following **conclusions** evolve:

- The impact mechanism costs is triggered differently by the various sectoral policies. The cost effectiveness of the policies ranges from very positive for cogeneration up to even very negative for part of the renewable energy technologies.
- The specific demand effects are positive for all sectoral policies; this result is primarily due to the rather high imports which are induced by the demand for fuel and power products (see Table 3 in the Annex).
- The innovation effects differ between the sectoral policies. Rather modest effects can be expected from rather mature technologies in the residential sector (domestic appliances and insulation of residential housing); the highest innovation effects can be expected from technologies, where first mover advantages are important and where future innovation generation effects (e.g. renewable energy technologies, fuel cells, window systems, fuel economy of cars) or an increase in industrial productivity (industrial process efficiency) can be expected.

Table 2: Impact of costs, demand and innovation of different sectoral policies

Sectoral Policies	**Cost effects**	**Specific demand effects**	**Innovation effects**
(1) Industrial process efficiency	- to ++	+	++
(2) Cogeneration	++	+	+[1]
(3) Efficiency of domestic appliances	- to +	+	0 to +
(4) Insulation measures for buildings	- to +	++	+[1]
(5) Fuel economy of cars	- to +	+	++
(6) Renewable energy sources	-- to 0	+	++

[1)] higher innovation effects for fuel cells and window systems

In order to interpret these results, it is helpful to distinguish **two different clusters of technologies**:

- On the one hand, especially cogeneration, but also efficient domestic appliances and insulation measures for buildings will trigger the impact mechanisms in the short run such that the overall impact on the economy and the number of jobs will be positive. However, this positive impact tends to be rather modest.

- On the other hand, industrial process efficiency, the fuel economy of cars, renewable energy technologies, and also fuel cells and window systems will trigger important long term effects, primarily due to their high innovation potential. Thus, even if part of these technologies have a cost-increasing effect in the short run (especially some renewables), their application today is nevertheless a prerequisite to induce innovation effects which are important for the creation of additional jobs in the medium and long term.

The **qualitative evaluation** of the sectoral policies implies that **employment will increase**, especially as long as there is no substantial cost increasing effect. However, in order to quantify this job increase, it would be necessary to use economic models.

In the late 80s and early 90s, detailed technological analysis has been linked to static Input/Output models. As a rule of thumb, these studies calculated 100 additional jobs per PJ of energy saved (Hohmeyer et al. 1985; Jochem/Schön 1994). Due to increasing labour productivity, this number is lower today, perhaps at 70 jobs per PJ saved. However, Input-Output-Models are a very powerfull tool for calculating the direct and indirect demand effects only, but they are not able to account for the other economic mechanisms sufficiently. Thus, a thorough quantification of the employment effects of the sectoral policies would require the use of macroeconomic models such as the ones presented in section 3. However, in contrast to the analysis presented in section 3, the use of these models would have to be linked to technology specific information derived from a detailed bottom-up analysis in order to analyse sectoral policies.

There have been only very few studies which use a combined top-down/bottom up approach (see Krause 1996). The Enquete Commssion of the German Bundestag used such an approach for having calculated the job effects of its proposed measures for CO_2-reduction (Enquete-Commission 1995; Walz et al. 1995). This analysis concluded that the proposed measures of the Enquete Commission leading to a 40 % CO_2-reduction in 2020 compared to 1990 would increase West German employment by about 100,000 jobs on average. However, this study was also not able to account for the effects on generation of innovations and first mover advantages sufficiently. To sum up, the quantification of the employment effects of European Union sectoral policies requires a thorough analysis using a combined bottom-up/top-down approach and drawing on the latest results of innovation research.

5 Conclusions

The protection of the earth's atmosphere requires substantial efforts to reduce CO_2-emissions while at the same time there is tremendous unemployment within Europe. This paper aims at providing a rough review of the likely employment effects of European Union policies and measures for CO_2-emission reductions. The analysis is restricted to a discussion of the various economic impact mechanisms, a presentation and systematisation of the latest results on the effects of an energy/CO_2-tax and a rather qualitative evaluation of the likely effects of different sectoral policies.

The analysis of the economic impact mechanisms of climate protection policies reveals that four different classes of effects and their likely implications for employment can be distinguished:

- Price and cost effects: realising the no-regret potential, which has been estimated to be around 20% implies non-increasing costs and is likely to have a positive impact on employment. Efforts that go beyond the no-regret potential are likely to have a negative effect on employment.
- Demand effects: positive growth and employment effects are to be expected within the EU, since the conservation of energy through capital equipment and investments in insulation leads to an import substitution increasing the final demand for European production.
- Revenue recycling effect: using the revenues generated by the energy tax to reduce labour costs is likely to produce a second dividend in terms of higher employment.
- Innovation effects: since energy efficient technologies are likely to benefit from first-mover advantages in the international markets, tend to increase overall productivity in industry, and might increase the generation of innovations, the innovation effects associated with climate policies tend to have a positive long run effect on employment.

The overall effects of measures and policies depends on the combination of the partial effects. In order to quantify the employment effects, it is necessary to use economic models which account for the different economic impact mechanisms.

Recent studies based on the LEAN, GEM-E3 and E3-ME models calculate the employment effects of an energy/CO_2-tax allowing for revenue recycling schemes. The results of these models imply that introducing energy/CO_2-taxes can have moderate positive macroeconomic effects. In particular, they can contribute to a moderate reduction in unemployment, especially when embedded in an appropriate general economic policy strategy.

A rather qualitative analysis was performed for industrial process efficiency, cogeneration, domestic appliances efficiency, insulation of housing, fuel economy of cars and various renewable energy sources. The cost, demand and innovation effects associated with these sectoral policies were analysed.

The analysis revealed, that positive effects on demand are likely for all policies. The effect on costs and innovations differ significantly between the sectoral policies discussed. In order to interpret these results, two technology clusters are distinguished. On one hand, cogeneration technologies, efficient domestic appliances and insulation will trigger the impact mechanisms in the short run such that a positive impact on the economy and on the number of jobs will result. However, these positive impacts tend to be rather modest in size.

On the other hand, industrial process efficiency, the fuel economy of cars, renewable energy technologies, fuel cells and new window systems will trigger important long-run effects, due to their high innovation potential. Thus, even if part of these technologies might have a cost increasing effect in the short run, their application today is nevertheless a prerequisite to induce innovation effects which are important for a successful economic performance and the creation of new jobs in the medium and long term.

The **qualitative evaluation** of the sectoral policies implies that **employment will increase**, especially as long as there is no substantial cost increasing effect. However, the quantification of the employment effects of European Union sectoral policies requires a thorough analysis using a combined bottom up/top down approach and drawing on the latest results of innovation research.

Appendix

A commonly used methodological instrument for the quantitative analysis of structural effects of policy measures is input-output analysis (Miller/Blair 1985). An input-output table subdivides an economy into a number of producing and final demand sectors. It contains the purchases and deliveries of goods and services between the sectors. The rows of the table contain the deliveries of goods and services from each of the sectors to all other producing sectors and to the sectors of final demand in monetary units. These deliveries add up to the total sectoral outputs. The columns contain the purchases of each sector from all other sectors needed for its own production activities plus „primary inputs“ such as imports and value-added components (salaries, depreciation, net operating surplus etc.).

Based on the information provided in input-output tables it is possible to calculate direct and indirect production across all domestic sectors that is needed to deliver a certain amount of specified goods to final demand. Furthermore, the amount of imported goods can be derived.

For the following analysis of the **specific demand effects** the Eurostat IO-table for 1991 covering EU-12 was used. In order to indicate the sectoral effects of a promotion of the analysed technologies, a specific demand of 1 billion ECU was assumed for each of the supplying sectors. The following table gives an overview of the direct and indirect effects of this demand on imports.

Table 3: Sum of direct and indirect effects of a demand of 1 billion ECU in various sectors on imports

	Imports (Mio. ECU)
Fuel and power products	522
Machinery	191
Electrical goods	274
Transport equipment	239
Building and civil engineering works	78

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