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Climate policy and the international steam coal demand

by

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Ottar Mæstad[1]

Abstract

This paper analyses the impact of climate policies on the international steam coal demand, focussing particularly on Western Europe and Japan. Steam coal consumption is heavily concentrated on a few industry sectors (power production, steel and cement). We scrutinize the coal demand structure of these industries, assess the impact of climate policies on production costs and competitiveness, and discuss likely consequences for coal demand. Our scenarios for the future coal demand in Western Europe and Japan show that demand reductions in the range of –25 to –50% are not unlikely between 2000 and 2010.

1. Introduction

The international transport of coal is one of the biggest segments in international shipping, accounting for about 35% of the dry bulk market (Fearnleys, 2001). Since 1978, seaborne coal trade has increased by an average annual rate of 5.9% (IEA, 2001a). But there are clouds on the horizon. Concerns about global warming have led politicians to promote policies that attempt to reduce the consumption of fossil fuels, and in particular the more carbon intensive ones, such as coal. Such policies might be a threat to the future development of the international coal market.

This paper identifies crucial factors affecting the future development of seaborne coal trade. Our strategy is to scrutinize the present demand structure, first by identifying the main users of seaborne coal, and then by evaluating how the competitive position of coal in its main applications might be affected by climate policies.

[1] Comments from Patrik Söderholm are greatly appreciated.

This paper is concerned exclusively with the steam coal market. Steam coal accounts for more than 85% of global hard coal consumption and almost 65% of seaborne coal trade (IEA, 2001a). Coking coal accounts for the remaining shares. Coking coal is used mainly in order to produce coke for the steel industry, and the development of the coking coal market therefore largely depends on the development of the world steel market. The impact of climate policies on the steel industry and the coking coal trade has been studied by Mæstad *et al.* (2000), Mæstad and Mathiesen (2002) and Mæstad (2003).

Steam coal is used extensively only in a few sectors (power production, steel and cement). Our analysis shows that climate policies are not likely to reduce steam coal demand from the steel industry significantly. Neither will reduced coal demand from the cement industry have a dramatic impact on aggregate coal demand and transport. However, major changes are likely to take place in the power production sector. Scenarios of the future coal demand in Europe and Japan show that reductions from 2000 to 2010 in the range of –25 to –50% do not seem unlikely. In Japan, these reductions will be translated directly into reduced import demand and reduced transport. In Europe, part of the reduction in coal demand can be accommodated through reduced domestic coal production. The reduction in European coal imports is projected in the range of –15 to –75%.

The paper is organised as follows: We first identify the major steam coal importing countries in the world (Section 2). In Section 3, the main applications of steam coal are discussed. The potential impact of climate policies in the main applications of steam coal is analysed in Section 4. Section 5 develops scenarios for the impact of climate policies on international steam coal demand, and Section 6 concludes.

2. Major steam coal importers

Only a relatively small share of world steam coal production is exported. Out of the total world production of 3.2 billion tonnes in 1999, only 355 million tonnes were traded internationally (IEA, 2001a).

The industrialised countries are the main importers of steam coal. Most of these countries have also committed to reducing their emissions of greenhouse gases by ratifying the Kyoto Protocol. Figure 2.1 shows the global steam coal trade by destination. Countries with Kyoto restrictions on their emissions of greenhouse gases (i.e., the so-called Annex B countries) account for more than 60% of steam coal imports. Among the Annex B countries, Western Europe and Japan are the dominating import destinations with 86% of total Annex B imports. An analysis of the impact of climate policies on the international steam coal market must therefore pay particularly close attention to these two regions; they are in a special position by both having committed to reducing their greenhouse gas emissions and being important customers of the seaborne coal trade.

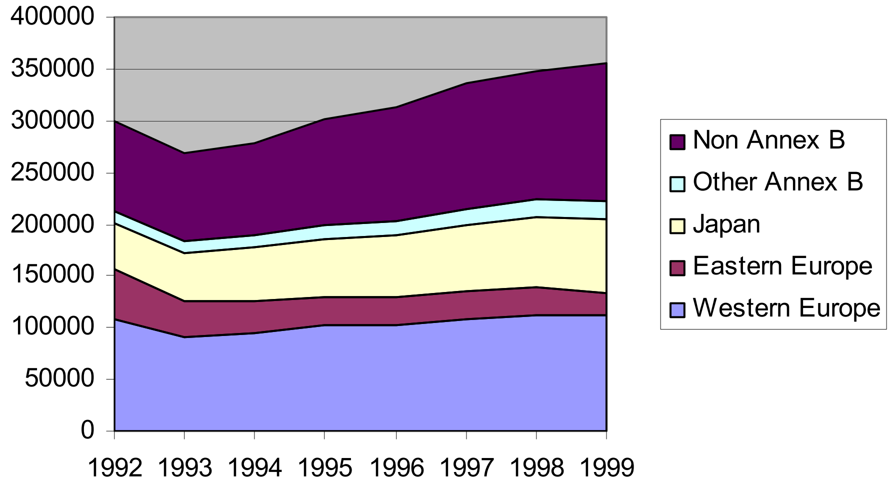

Fig. 2.1 Steam coal importing countries (1000 tonnes)

In Western Europe, the major steam coal importers are Germany (15%), Spain (14%), Netherlands (14%), United Kingdom (12%), France (10%) and Italy (10%) (see Table 2.1).

Table 2.1. Steam coal imports in Western Europe by country (2000 estimated)

	Million tonnes	Share
Germany	18 325	15 %
Spain	17 431	14 %
Netherlands	17 229	14 %
United Kingdom	14 984	12 %
France	12 554	10 %
Italy	11 817	10 %
Denmark	7 529	6 %
Belgium	6 415	5 %
Portugal	5 880	5 %
Ireland	3 806	3 %
Finland	2 581	2 %
Greece	1 661	1 %
Sweden	1 033	1 %
Austria	903	1 %
Norway	833	1 %
Switzerland	248	0 %
Total	**123 229**	

Source: IEA (2001a).

Total steam coal consumption in Japan is around 80 million tonnes and practically everything is imported. Western Europe, on the other hand, produces some steam coal domestically. The domestic production covers some 60 million tonnes out of the total consumption of almost 190 million tonnes (IEA, 2001).

Much of international steam coal trade goes on long distance hauls. Figures 3.2. and 3.3 show the steam coal imports into Japan and Europe by origin. The imports of steam coal in Japan were for a long time completely dominated by Australian coal. During the 1990s, coal producers in China and Indonesia entered the Japanese steam coal market and presently enjoy a market share of 39%, as compared to 48% for Australian coal. Relatively small amounts are imported from South Africa and North America, but these quantities are important for the price structure of the international coal market (see below).

Steam coal imports in Western Europe have been more volatile over time than the Japanese import level. Also, the imports are more diversified on different countries of origin. South America (i.e., Colombia and Venezuela) is an important supplier for Western Europe, and so are South Africa, Russia and Poland. The share of imports from Russia and Eastern Europe increased in the late 90s, to some 23% of total steam coal imports. The share of North American steam coal in the European market has been declining in the same period, despite growth in the overall import level.

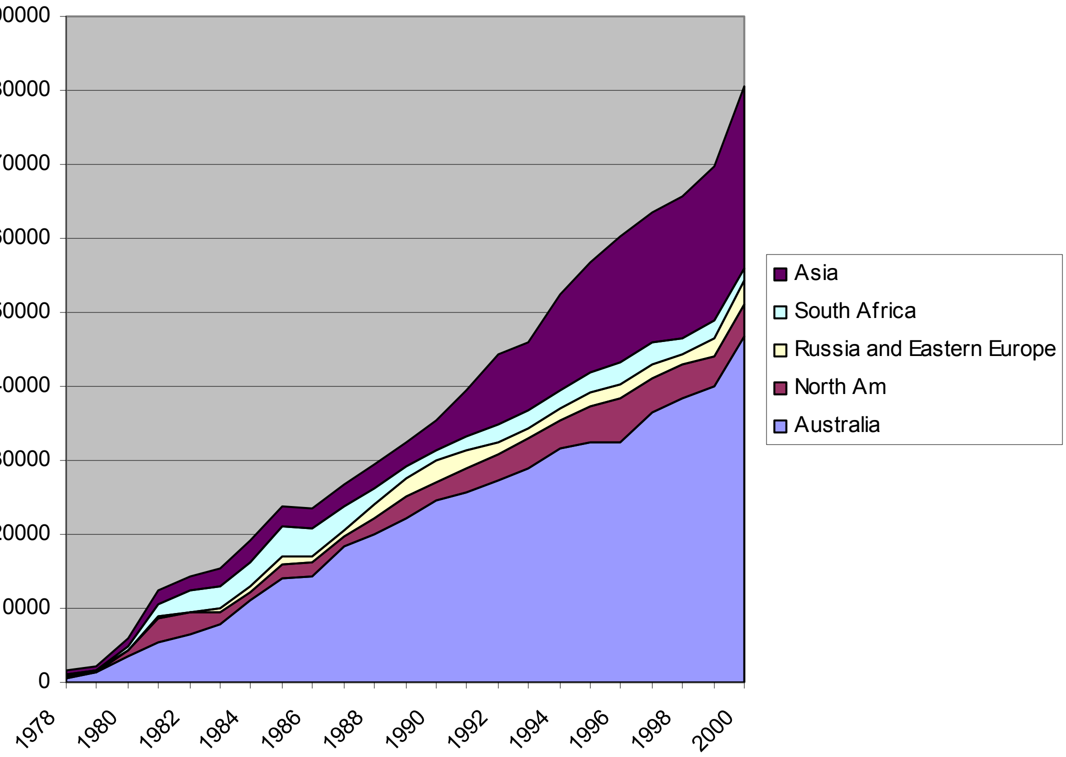

Fig 2.2 Japan's steam coal imports by source (1000 t)

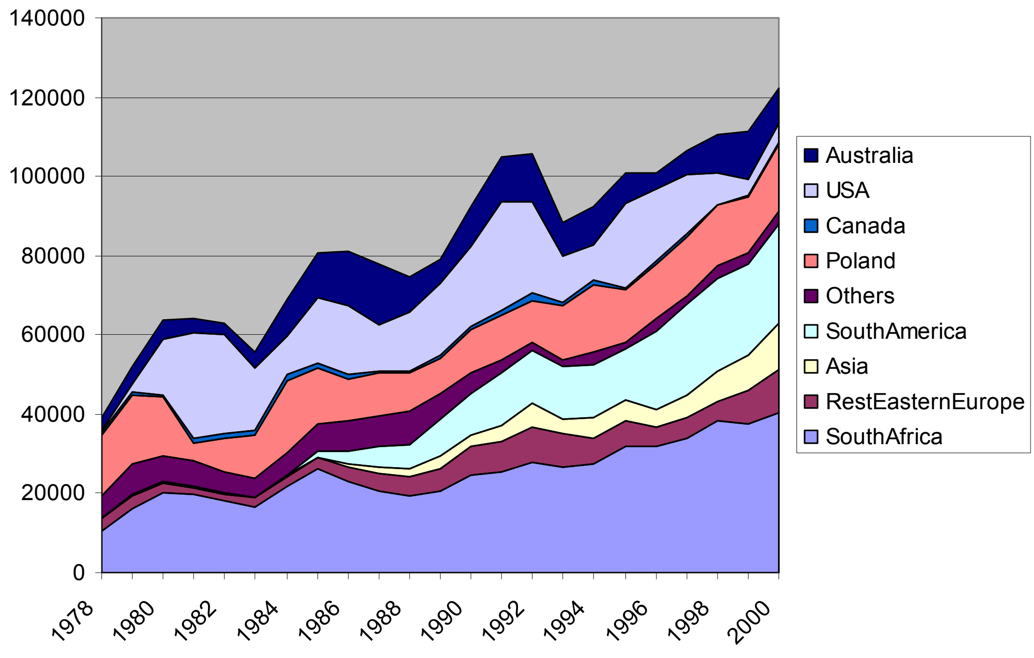

Fig 2.3 Western Europe's steam coal imports by source (1000 t)

3. Applications of steam coal in Western Europe and Japan

Not only are the imports of steam coal fairly concentrated to a few regions; the use of steam coal is also heavily concentrated to a few sectors. Both in Japan and Western Europe, more than 80% of steam coal consumption is used for generation of electricity or heat (see Table 3.1).

The steel industry is also a major consumer of steam coal, although most of the coal that enters the steel industry is in the form of coking coal. The development of the PCI (Pulverised Coal Injection) technique in blast furnace iron making explains the rise in steam coal demand from the steel industry over the last decades. In Western Europe, the steel industry now accounts for 7% of steam coal consumption.[2]

Most of the remaining industry consumption of steam coal goes to the sector "non-metallic mineral industry", where the cement industry is a major consumer. Coal is used in the cement production as a source of energy. Unfortunately, precise data on the consumption of coal in the cement industry are not available, but some estimates are presented below.

Households consume 3% of the steam coal in Western Europe, whereas the consumption of coal in the Japanese household sector is negligible.

Table 3.1. The main users of steam coal (1999). Shares.

	Western Europe	Japan
Power and heat	0.83	0.81
Steel industry	0.07	0.03
Non-metallic minerals industry	0.04	0.10
Other industries	0.03	0.05
Households	0.03	0.00

Source: IEA (2001).

We now turn to the analysis of how climate policies might affect steam coal demand. Our attention will be focussed on the major users of steam coal; mainly the electricity sector but also steel and cement production.

[2] The somewhat lower figure in Japan can be explained by the fact that Japan classifies PCI coal as coking coal in their statistics.

4. Impact of climate policies on steam coal demand in selected industries

A number of measures can be used in order to reduce emissions of greenhouse gases. In Europe, most countries seem to opt for a system based on tradable emission permits. Agents that emit greenhouse gases must then hold permits corresponding to their emissions. Since the permits have a market value, it will be costly for firms to use them. This will induce firms to reduce their emissions, either through a reduction in output levels or through a change in the mix of inputs (e.g., switching to cleaner fuels). The actual response pattern will vary across industries depending on the market conditions in the various output markets and on the technological possibilities to substitute towards a less polluting mix of inputs. In this section, some of these aspects are discussed in some detail for the major coal consuming industries.

4.1 Power production

Most steam coal is used to generate electricity, and the development of the power sector is therefore of utmost importance for the future trends in the international steam coal trade.

Electricity is a homogenous good in the sense that the quality of the good is not affected by the production method. With no possibilities for product differentiation, the pressure for cost efficiency tends to be strong. Changes in relative costs among primary fuels may thus have large impacts on the market shares of various fuels.

A comparison of the mix of primary energy sources in the electricity production in Western Europe and Japan reveals that the structure is remarkably similar (Figure 4.1). Coal presently accounts for about ¼ of electricity production both in Western Europe and in Japan. This is a relatively low share compared with the USA, where 50% of the electricity is generated from coal. Nuclear power is the most important primary energy source in electricity production, both in Western Europe and Japan, with a share of about 30%. The main difference between the energy mix in Japan and Western Europe is that Western Europe has a higher share of hydropower. Japan compensates by using more oil and natural gas.

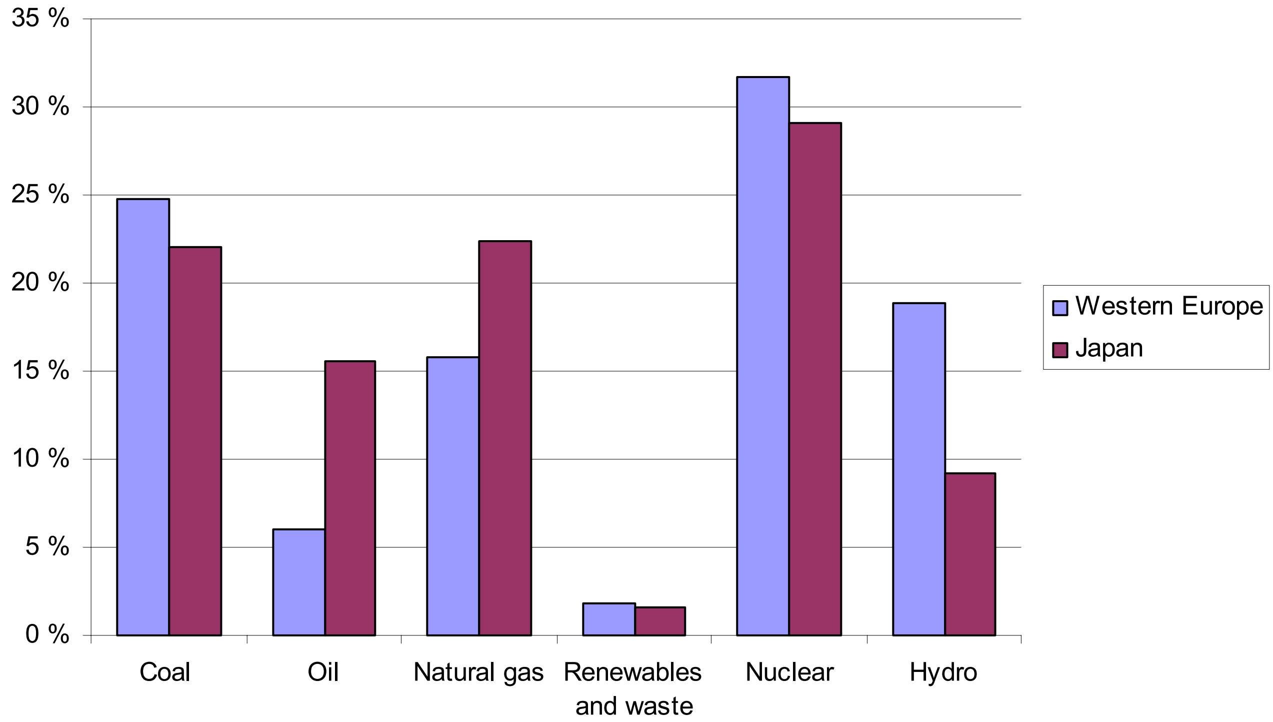

Fig. 4.1 Electricity production by fuel (2000)

The aggregate figures for Western Europe in Fig. 4.1 conceal substantial variations across countries. The share of coal in electricity production in Western Europe ranges from zero in Norway, Switzerland, Luxembourg and Iceland to more than 60% in Greece. Among the larger European countries, Germany stands out with a particularly high coal share (52%), while France is found at the other end of the scale with a coal share of only 6%. It is also worth noting that in some European countries, brown coal accounts for a major share of the coal input. Since brown coal typically is domestically produced, a reduction in brown coal consumption will not significantly affect international coal trade and transportation.

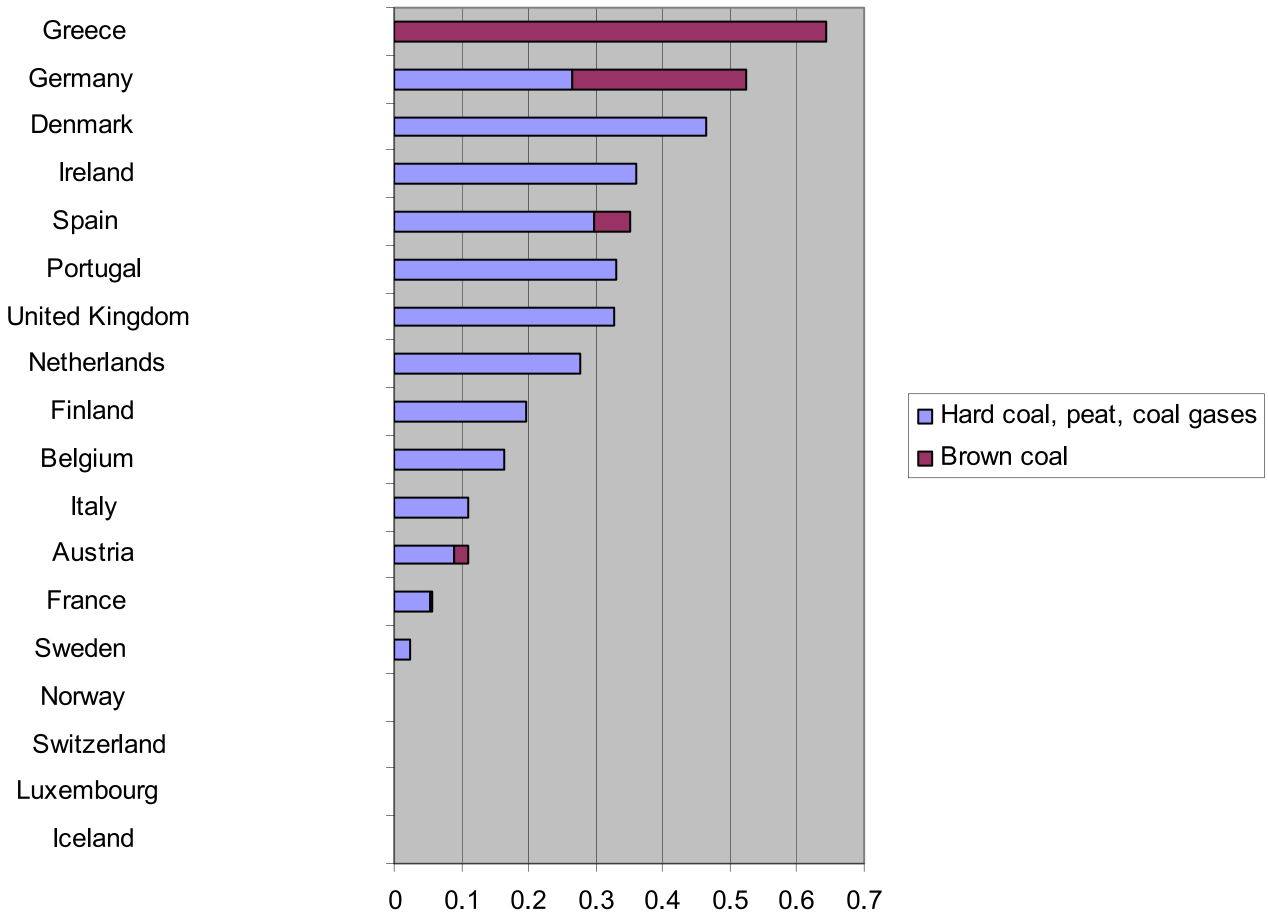

Fig 4.2. Coal share of electricity production in Western Europe (2000)

Effect of climate policies on costs

Climate policies will increase the costs of coal power relative to electricity produced by other primary fuels. Emissions per unit of electricity for each fuel source are determined by the carbon content per unit of energy in the primary fuel and by the energy efficiency of various power plants. These factors are accounted for in Table 4.1, which shows that coal power is on average about 50% more polluting than oil power and between 100 and 150% more polluting than gas power. We note that there are large differences between countries in the emission intensities for coal power (as well as for the other fossil fuels). Most of this variation is due to differences in energy efficiencies across power plants. This implies that the impact of CO_2 taxes or emission permits on the competitiveness of coal power is likely to differ among countries.

Table 4.1: CO_2 emissions in the production of electricity and heat (g per kWh)

	Coal and coal products	Oil	Natural gas
Western Europe Average* (Standard deviation)	870 (201)	562 (292)	348 (95)
Japan	847	598	428

**Average for the EU countries plus Norway, excluding United Kingdom and Luxembourg.*
Source: IEA (2001b).

The impact of climate policies on the costs of electricity production will of course depend on the price of CO_2 emission permits. A number of studies have been undertaken in order to estimate likely prices of CO_2 emission permits under the Kyoto Protocol (see Springer (2003) for an overview). Recent estimates range from a price of 5 USD per tonne CO_2 to prices above 20 USD. Studies which assume global trading with emission permits typically reach estimates in the lower end of this range, while studies assuming that emission trading takes place only among the Annex B countries or only within the EU typically estimate permit prices towards the high end of the scale. For the sake of illustration, we will use a permit price of 15 USD per tonne CO_2 in the following.

Based on data provided by Strömberg and Söderholm (2003), we calculate that a price of 15 USD per tonne CO_2 will have a dramatic impact on fuel costs in fossil fuel power plants.[3] The impact is greatest in coal-fired plants with low energy efficiency. We calculate that the fuel costs in an old coal fired unit with energy efficiency of 31% will more than double – from 16 USD to 33 USD per MWh. The impact is much smaller on gas-fired power stations, in our example represented by a modern Combined Cycle Gas Technology (CCGT) plant with energy efficiency of 57%. According to our calculations, the fuel costs in such plants will increase from 16 to 21 USD per MWh.

[3] Note that the cost data in Strömberg and Söderholm (2003) do not include existing taxes.

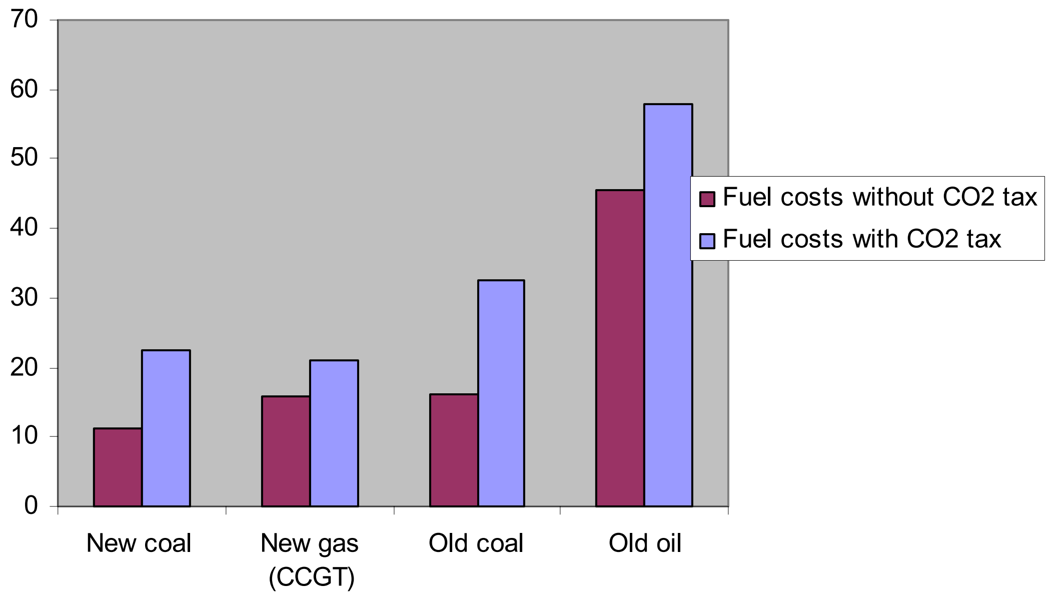

Fig. 4.3. Impact of a CO_2 tax of 15 USD on fuel costs in power plants (USD/MWh).

It is rather obvious that such a strong change in the relative fuel costs will have impacts on the fuel mix in the power sector. We may expect both a shift from fossil fuels towards other primary fuels, e.g., renewable energy sources, and a shift away from coal (and maybe oil) to gas. That the coal share is going to decline is thus rather obvious. The more difficult question is, however, by how much?

Reductions in the demand for coal can come through

1) reduced production volumes in existing coal power plants
2) change in fuel mix towards cleaner fossil fuels in existing coal plants
3) a forced rate of closures of coal power plants and reduced investments in new coal fired plants

In the following, each of these issues is discussed in turn with the aim of indicating some orders of magnitudes. More exact predictions, however, would require knowledge of the cost structures of both coal power plants and their competitors at a level of detail that is beyond the scope of the present study.

Production volumes in existing coal fired plants

Profit maximising coal power producers will produce at their capacity limit as long as the price of electricity exceeds their variable production costs. Otherwise, they will choose a smaller quantity, at which the price of electricity exactly equals the variable costs of production. If variable costs exceed the price of electricity at all production levels, the optimal production level is zero.

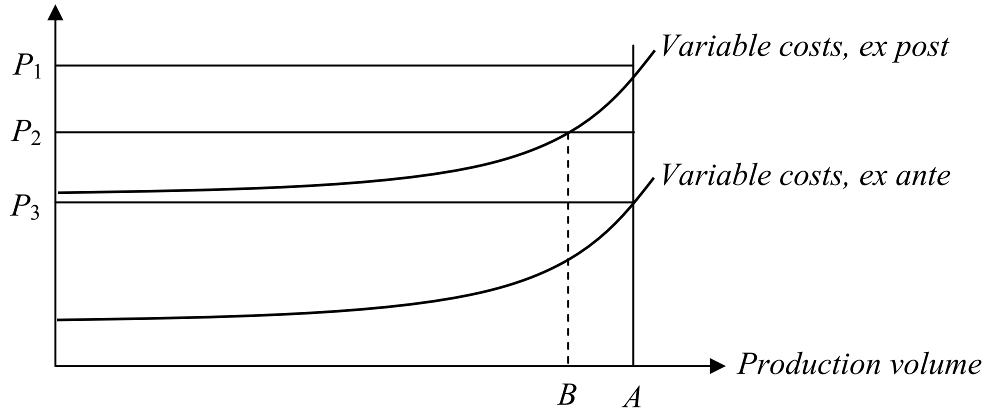

Fig. 4.4 Costs, prices and optimal production levels

The various cases are illustrated in figure 4.4. *A* denotes the capacity limit, and P_1, P_2 and P_3 are various price levels of electricity. At the *ex ante* variable costs, it is optimal to produce at the capacity limit at all three price levels. When variable costs increase, the optimal production level will be unaffected if the price of electricity is P_1, it will be reduced to *B* if the price is P_2, and will be reduced to zero if the price is P_3.

Average spot market prices on electricity at the European Energy Exchange in 2003 (January – mid June) have been 30 USD/MWh at base load and 37 USD/MWh at peak load (see www.eex.de).[4] As can be seen from figure 4.1, a CO_2 price of 15 USD/tonne will increase fuel costs of old coal fired plants to 33 USD/MWh, implying that such plants will have severe problems covering their variable costs of production. Reductions in production volumes of old coal fired plants are therefore not unlikely. In modern coal fired and gas power plants, however, the margins between prices and variable costs are larger, and CO_2 taxes or emission permits are not likely to lead to reduced production volumes in such plants.

An important caveat to the reasoning above is that electricity prices could rise when climate policies are introduced, at least in the short run. Electricity demand is known to be fairly inelastic. Hence, a shortage of supply will tend to drive prices upwards. Higher electricity prices are therefore likely to prevent a massive shut-down of old coal fired plants. In the long

[4] The Euro / Dollar exchange rate used is 1.1.

run, however, as more efficient technologies expand (see below), there will be a downward pressure on prices, causing old coal plants to leave the market.

Interfuel substitution

The possibilities for interfuel substitution in existing power plants have been analysed in a series of papers (see Söderholm (1998) for an overview). Electricity production is often assumed to be a putty-clay technology. This means that although substitution possibilities exist *ex ante*, i.e., prior to the construction of the plants, the possibilities to substitute between inputs are substantially reduced once the capital investments have been made. Nevertheless, as Söderholm (1998, 2001) points out, there are several reasons why interfuel substitution possibilities exist also *ex post*, i.e., in the short run.

First, some power plants are designed as dual- or multi-fired plants. Fuel switching can then in principle occur within a day. In some coal plants, it is also possible to add oil to the pulverised coal input. The share of multi-fired electricity generating capacity is quite high in several European countries (Table 4.2). In the eight countries considered, the (weighted) average share of multi-fired plants among the fossil fuelled plants is 37 percent. About half of the multi-fired plants are oil/gas plants and are thus irrelevant for the consumption of coal. Among the multi-fired coal plants, 56 percent are coal/oil plants, 14 percent are coal/gas plants, and the remaining 31 percent are coal/oil/gas plants.

Second, there may be fuel substitution possibilities within firms that operate several single-fuelled plants with different fuels. Such substitution may arise if there are cost linkages among the plants so that marginal costs are rising in the aggregate production level. In that case, changes in fuel cost may change the rank ordering of plants and thus lead to reduced outputs in plants which increase their relative costs.

Third, some conversions of power plants to burn alternative fuels are relatively inexpensive. For instance, converting an existing coal plant to gas firing is much cheaper than to build a new combined cycle gas plant (see Söderholm (2001)).

Table 4.2: Multi-fired electricity generating capacity in fossil-fuelled plants, 1996 (GW)

	Coal/Oil	Coal/Gas	Oil/Gas	Coal/Oil/Gas	% multi-fired	% coal multi-fired
Austria	0.30	1.27	2.73	0.24	74	30
Belgium	1.06	0.11	2.10	3.86	90	63
Germany	8.92	1.88	9.27	7.03	33	22
Netherlands	1.25	2.90	10.24	0	79	23
Ireland	0	0	1.31	0	34	0
Italy	6.47	0	15.66	2.64	55	20
Spain	0.66	0.01	2.29	0.12	14	4
United Kingdom	5.61	0	0.80	0	12	11

Source: Söderholm (2000).

While most of the analyses of interfuel substitution in the electricity sector are conducted on US data (e.g., Atkinson and Halvorsen (1976), Joskow and Mishkin (1977) and Bopp and Costello (1990)), Söderholm (1997) estimates interfuel price elasticities in eight Western European countries. His average estimates are reported below:[5]

Table 4.3. Own- and cross-price elasticities in electric power generation, Western Europe.

	Coal/PC*	Oil/PO	Gas/PG	Coal/PG	Coal/PO	Oil/PG	Oil/PC	Gas/PC	Gas/PO
Short run	-0.22	-0.95	-0.94	0.19	0.29	0.64	0.30	0.45	1.44
Long run	-0.97	-2.30	-1.91	0.31	1.24	0.49	1.40	0.73	1.00

*PC stands for Price of Coal, etc.
Source: Söderholm (1998).

These figures suggest that there are particularly large interfuel substitution possibilities between oil and gas, which may be explained by the extensive capacity of dual oil/gas fired power plants. Significant substitution possibilities also seem to exist between coal and gas/oil.

Exit and entry

One way of reducing CO_2 emissions from the power sector is to close down old an inefficient coal plants and replace them with either renewable energy sources, gas fired plants, or more efficient coal fired plants. In this section we ask which prices of CO_2 emissions that will make such alternative technologies competitive with an old coal fired plant. While new plants are

[5] These estimates are based on a Generalised Leontief specification. Using a translog specification for the short run model yields substantially lower elasticities (Söderholm, 1997)

typically more efficient and therefore may have lower fuel costs, old plants have the advantage that capital costs are largely sunk. At the outset, all new technologies will have higher costs than the old coal plant, but as fuel prices increase due to a CO_2 tax or emission permits, the costs of the old plant will rise more rapidly than the costs of new plants. At some critical level, costs are equalised. Then it will be profitable to close the old plant and replace it with a new one.

Our exposition draws heavily on Söderholm and Strömberg (2003) who compare the costs of an old coal fired plant with six different new technologies. The alternatives are:

Table 4.4: Power generation technologies

Plant type	Fuel	Power capacity (MW)	Heat capacity (MW)	Investment cost (USD/kW)	Fuel-to-electricity efficiency (%)	Total efficiency (%)
Old power plant	Coal	150	0	0 (sunk costs)	31	31
Power plant	Coal	800	0	1000	45	45
Combined heat and power (CHP)	Coal	130	200	1400	35	89
Combined Cycle Gas Technology (CCGT)	Gas	400	0	560	57	57
Combined heat and power (CHP)	Gas	50	47	740	42	81
Power plant	Biofuel	150	0	1800	40	40
Combined heat and power (CHP)	Biofuel	50	130	2100	29	104

Some of the alternatives combine heat and power production. The incomes from heat sales are then deducted from the costs estimates.[6] The results are presented in figure 4.5.

[6] Other important assumptions are: The price of heat is 17.6 USD/MWh. The discount factor is 7 percent and the lifetime of new plants is 20 years. Power plants are operated for 7500 hours a year and CHP plants for 4000 hours.

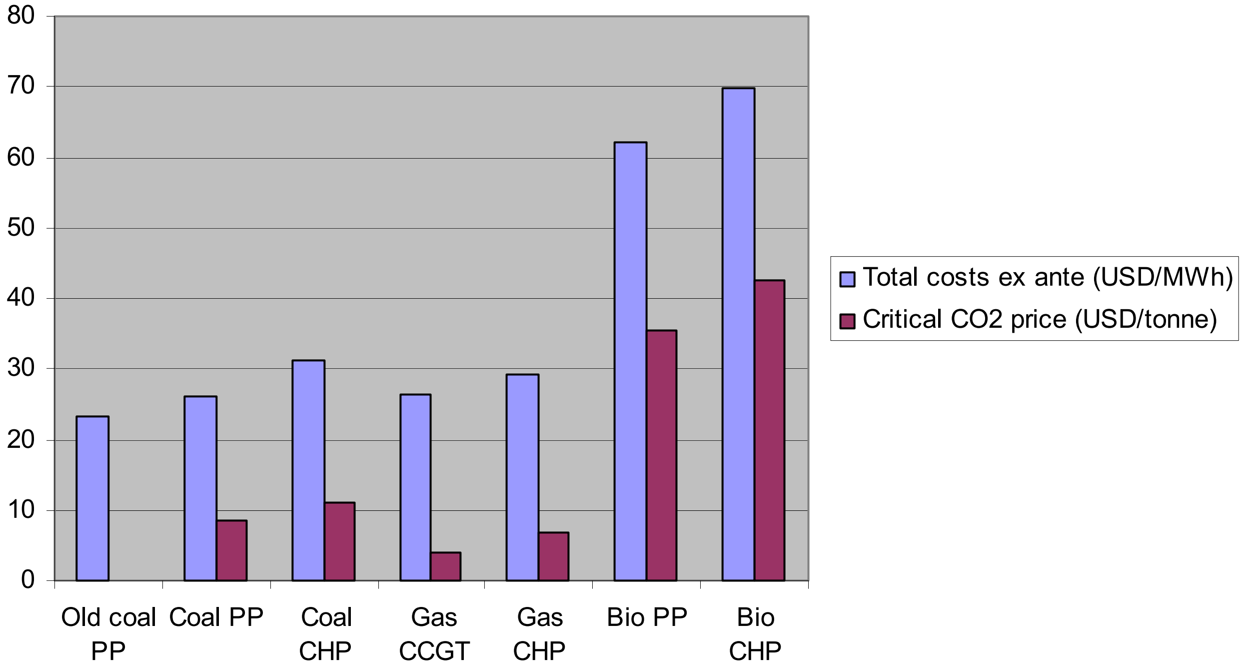

Figure 4.5: Critical CO_2 prices for profitable replacement of old coal fired power plant

At the outset, all new technologies are at a cost disadvantage vis-à-vis the established coal plant. As the price of CO_2 rises, savings due to lower CO_2 emissions will eventually outweigh these initial cost disadvantages. When the critical CO_2 price is reached, it is profitable to replace the old plant with the new alternative. The alternatives with the lowest critical CO_2 price are the most cost efficient ways of reducing CO_2 emissions in the power sector for a given electricity consumption.

Already at a CO_2 price of 4 USD, it will be profitable to replace the coal fired plant with a Combined Cycle gas plant. Hence, climate policies are likely to create a clear incentive to replace coal with gas. But it is also noteworthy that replacement with the new coal plant is a highly interesting alternative as well at relatively low prices of CO_2. Reduced demand for coal may thus come from both substitution from coal to gas and from investments in more efficient coal plants.[7]

The critical levels of CO_2 prices estimated by Söderholm and Strömberg (2003) are highly sensitive to assumptions about fuel prices. For instance, the coal price used in their simulations is 5 USD/MWh. Sensitivity analysis shows that a one-dollar change in the coal

[7] Note that due to siting problems, the potential for investments in new coal may in practice be limited to repowering of existing sites.

price will cause more than a four dollar change in the critical CO_2 price. According to IEA (2002), the price of coal tends to vary more than this. The average coal price for electricity producers in OECD Europe varied between 10 USD/MWh in 1995 and 5.5 USD/MWh in 2000. Hence, considerable uncertainty is attached to the estimates of the critical CO_2 price.

Climate policies could lead to general equilibrium effects on fuel prices. A shift from coal to gas will tend to lower the coal price and increase the price of gas. If we let both the gas and the coal prices change by 20% relative to the baseline used by Söderholm and Strömberg (2003), the critical CO_2 price for the CCGT plant increases from 4 to 13 USD/tonne CO_2. At the same time, the critical CO_2 price for the new coal plant increases from 9 to 12 USD/tonne CO_2. This shows that changes in fuel prices may seriously reduce the attractiveness of substituting into gas technologies. Furthermore, fuel price changes of this kind will tend to make the new coal-fired plant more attractive relative to the gas-fired alternatives.

A study by Eurelectric (2000) confirms that natural gas options together with nuclear capacity are the cheapest ways of reducing CO_2 emissions in the power sector. However, the estimated costs are considerably higher then in the study by Söderholm and Strömberg (2003), ranging from 10 USD/t CO_2 for a natural gas based CHP plant to 82 USD/t CO_2 for a new clean coal plant. A major reason for the higher cost estimates in the paper by Eurelectric is that their reference plant is a coal plant with higher efficiency than in the Strömberg/Söderholm study (38% vs. 31%). Moreover, the Strömberg/Söderholm cost estimate for new coal power is lower because they assume repowering at existing sites, which is considerably cheaper than a new plant including new site and new infrastructure.

4.2 Other sectors

4.2.1 Steel

Most coal that is used in the steel industry is in the form of coking coal. Coking coal is used to produce coke, which is used in the blast furnace process as a reducing agent, as a source of energy, and in order to provide a strong and preamble support for a free flow of gases through the furnace. During the last decades, steam coal has also become a more commonly used input in the blast furnace process. Steam coal that is injected directly into the blast furnace in pulverised form (PCI) reduces the need for coke, but the substitution possibilities are limited because PCI cannot serve the role as a support for the free flow of gases. Nevertheless, it is not unusual that steam coal accounts for some 20% of the total coal consumption in the blast furnace process.

Climate policies may influence the demand for steam coal in the steel industry through several mechanisms. First, total steel demand may be reduced as climate policies drive up the costs of steel production and the prices of steel products. However, since the demand for steel is relatively inelastic, the reduction in aggregate steel production is likely to be modest.[8]

Secondly, climate policies may lead to substitution towards steel technologies that do not use coal as input. Between 30 and 40 per cent of total steel production is based on the melting of scrap, with electricity as the main energy source. The CO_2 emissions from this production route are only some 25 per cent of the emissions from the blast furnace process. Hence, climate policies are likely to stimulate to a further reduction in the share of blast furnace iron-making. The possibilities of massive substitution towards the scrap-based route are however limited by the availability of high quality scrap.

The third mechanism for reduced coal demand from the steel industry is also related to substitution towards scrap. Even when steel is made from iron ore and coal, a certain amount of scrap is needed. The share of scrap in the total metal input may vary from 10 to 35 percent. By increasing the share of scrap towards its theoretical maximum, the emissions of CO_2 can be substantially reduced due to reduced coal consumption.

The combined effect of all these mechanisms is estimated by Mæstad (2003) and Mathiesen and Mæstad (2002) by a numerical steel industry model (SIM). Both these publications assume a CO_2 price of 25 USD /tonne CO_2, and the impacts on coal demand are not reported separately. Moreover, they assume that climate policies are implemented in all the Annex B countries of the Kyoto Protocol. By rerunning the SIM model with a CO_2 price of 15 USD per tonne CO_2, and by assuming that the USA and Australia do not implement CO_2 controls, we obtain the following results:

[8] Karlson (1983) has estimated the price elasticity of steel demand to –0.3.

Table 4.5: Changes in production levels and coal demand in coal-based steel making (Basic Oxygen Furnace). CO_2 price of 15 USD/tonne.

	Production (%)	Coal demand (%)
EU (excl Sweden and Finland)	-4	-11
Rest of Western Europe	-8	-13
Japan	-7	-13

A CO_2 tax or emission permits priced at 15 USD/tonne will, according to the SIM model, reduce coal demand by 11-13 percent in Western Europe and Japan. About half of the reduction is explained by reduced production of basic oxygen steel. The rest is due to substitution towards a higher share of scrap in the basic oxygen steel making process.

The SIM model does not distinguish between steam coal and coking coal. It is likely that a higher price of CO_2 price will make PCI (steam coal) relatively more attractive, since the use of PCI reduces total energy consumption and CO_2 emissions. But for the reasons mentioned above, the substitution possibilities are small. Hence, we should not expect big changes in the ratio of steam coal to coking coal in plants that already use the PCI technology. Plants that are still not using the PCI technology will however get stronger incentives to do so. We may therefore expect that the fall in steam coal demand from the steel industry will be somewhat lower than the reduction in coking coal demand. The figures in table 4.5 can thus be interpreted as upper bounds on the reduction in steam coal demand from the steel industry.
But due to the low share of the steel industry in the total steam coal demand, the impact on steam coal imports will be small; the decline will be less than one per cent.

4.2.2 Cement

Coal is used as a source of energy in cement production. According to Cembureau (1999), the consumption of coal and other fossil fuels produces emissions of 0.28 tonne CO_2 per tonne cement. Total CO_2 emissions per tonne cement are 0.83 tonnes, with the major part coming from the decarbonisation of limestone.

We do not have exact data on the consumption of coal in the cement industry. According to IEA (2001) the steam coal consumption in the non-metallic mineral industries was 6.6 mill tonnes in Western Europe and 7.3 mill tonnes in Japan in 1999. Since this category also includes other industries than cement, these amounts can only be regarded as upper bounds on the coal consumption in the cement industry. Note that these figures imply that a significant portion of energy consumption in the cement industry is covered by other sources than steam coal.[9] In particular, a large share of the energy consumption in the European cement industry is covered by petroleum coke, which is a by-product from oil refineries and thus does not count in the international steam coal trade. In addition, according to unofficial estimates from Cembureau, the share of alternatives to coal and coke is now approaching 20% in Western Europe. However, the picture seems to be somewhat different in Japan. In particular, the share of petroleum coke in the energy consumption of the cement industry seems to be much lower in Japan than in Europe.[10] This probably explains the relatively high share of coal consumption in the non-metallic minerals industry in Japan relative to Europe (see table 3.1)

Climate policies may influence the demand for coal from cement producers either through changes in output levels or changes in the fuel mix. Consider first the impact through changes in output levels. With an emission factor of 0.83 tonne CO_2 per tonne cement and a CO_2 price of 15 USD per tonne, climate policies will increase the price of cement by 12.5 USD per tonne. We do not have good price data on the price of cement. In the Norwegian market, the bulk price of cement is currently around 80 USD per tonne.[11] Hence, if the full costs of climate policies are levied on the consumers, there will be a pretty steep increase in cement prices (+15%). The increase in the price of concrete will be much lower, though, since, concrete consists of only 12% cement. Climate policies will thus increase the price of concrete by less than 2%.

We do not have estimates of the price elasticity of demand for concrete. However, with a price increase of only 2%, the impact on demand is likely to be quite small. In fact, since climate policies will also increase the price of steel, which is a major competing material to concrete, the demand for concrete and cement may actually increase. The SIM model predicts that a 15 USD CO_2 tax will increase the price of basic oxygen steel by up to 7%. Climate

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[9] In 1995, 172 million tonnes of cement were produced in the EU (Cembureau, 1997). By using an emission coefficient of 3.94 tonne CO2 per toe coal, by assuming that the energy content is 0.64 toe per tonne coal, and by letting the emission factor from energy use be 0.28 tonne CO2 per tonne cement, we obtain a coal consumption rate of 110 kg coal per tonne cement. Hence, the total coal consumption in EU, if only coal were used as energy input, would be 19 million tonnes.

[10] While coal consumption in the non-metallic minerals industry is larger in Japan than in Western Europe, the use of petroleum coke in this sector is only 1.1 mill tonnes in Japan as compared to 6.9 mill tonnes in Western Europe.

[11] Information is from personal communication with Norbetong (Inge Eek), suggesting a bulk price of 550-600 NOK. The price of small quantities varies considerably, from NOK 1500 to NOK 3000 per tonne.

policies will therefore probably induce some substitution from steel to concrete.[12] Our tentative conclusion based on these scattered data observations is therefore that climate policies are not likely to cause a substantial reduction in cement production levels.

Larger consequences can be expected from changes in the fuel mix in cement production. The temperatures in the cement kiln are very high (1450 degrees Celsius), facilitating the combustion of a number of alternative fuels. Some of the alternatives are tyres, rubber, paper waste, waste oils, waste wood, paper sludge, sewage sludge, plastics and spent solvents (Cembureau, 1997). Between 10 and 20 per cent of the energy consumption in cement production currently comes from alternative fuels, but technologically it is possible to substitute more than 50% of the coal with alternatives. This has already been achieved in some plants. It is expected that regardless of climate policies, we will see a trend towards increased use of alternative fuels in cement production, but climate policies will probably speed up the transition process. A reduction in the share of coal from 90% to less than 50% will reduce the demand for coal in the cement industry by some 50%. This may imply a reduction of up to 3-4 million tonnes in both Western Europe and Japan, which represents a reduction of the Japanese steam coal import demand of 4-5 per cent. With unchanged steam coal production levels in Europe, structural changes in the cement industry may cause a reduction in steam coal imports of 2-3 per cent. Hence, the impact via the cement industry appears to be potentially larger than via the steel industry.

[12] In an environmental assessment study from the University of Amsterdam, a concrete bridge was found to cause 8% lower CO2 emissions than a steel/concrete bridge (personal communication with Erik Stoltenberg Hansson, Norcem). This supports our suggestion that climate policies may induce some, albeit not very large, substitution from steel to concrete.

5. Scenarios for international steam coal trade

We have identified the major consumers of steam coal and pointed out how climate policies are likely to impact their steam coal demand. For the steel industry and the cement industry we were able to suggest some figures that indicate the potential reduction in coal demand, but no such estimates were provided for the most important sector; the power sector.

There are two ways ahead. One is to model the power sector in greater detail and analyse the impact of climate policies on the structure of this industry. There is work in progress on that issue, but until the results from that analysis are available, we have to follow another, much simpler route. Our approach here will be to take as our starting point the commitments that Western Europe and Japan have under the Kyoto Protocol and ask what it takes in term of reductions in coal consumption to reach these targets.

In addition to the development in steam coal demand, the future international trade with steam coal depends on the development in domestic production in importing regions. In Western Europe, domestic production accounts for some 35% of steam coal consumption. Most of the domestically produced coal is produced in heavily subsidised mines. Subsidies are on their way down, and one possible scenario is that reductions in coal demand will more or less be offset by a reduction in domestic production. In that case, international coal trade will be less affected by climate policies in Europe. In Japan, on the other hand, where domestic coal production is negligible, the development in the import demand can be inferred more or less directly from the consumption forecasts. The importance of domestic production for the import demand from Western Europe is discussed in greater detail below.

5.1. Kyoto targets and steam coal demand scenarios

According to the Kyoto Protocol, Japan is going to reduce its emission of six greenhouse gases, including CO_2, to 94% of the 1990 emission level. Western European countries have varying emission targets, but in this section we will stick to the EU emission target of 92% of 1990 emissions.

Emissions in the EU remained fairly stable from 1990 to 2000, while there was a significant increase in emission levels in Japan. Based on data from WEO (2002) and IEA (2001b) and

IPCC (2000) we estimate that emissions in Japan have increased by about 15% in the period. Hence, current emission levels must be reduced by some 18% percent in 2010.

One way of achieving these emission reductions would be to reduce emissions from all sources, including coal, by 8% in the EU and 18% in Japan. However, there are reasons to believe that the reduction in coal demand will be even larger. First, the power sector, where most of the coal is used, must most likely reduce its emissions more than other sectors. The main reason is that the possibilities to substitute to cleaner fuels are greater in this sector than elsewhere in the economy. Moreover, the transport sector, which accounts for the bulk of oil consumption, turns out to be steadily growing, and the costs of significant emission reductions in this sector are probably high. In many industry sectors, energy conservation measures have already been implemented. The scope for further emission reductions is therefore typically smaller than in the power sector here as well.

Second, emission reductions in the power sector are going to affect coal disproportionally. This follows from the fact that emission reductions in the power sector are going to take place through substitution from coal to cleaner fuels. Alternatively, some emission reductions could come from decrease in electricity output, but that is not a likely outcome since electricity demand is known to be fairly irresponsive to price changes.

Söderholm and Strömberg (2003) have estimated the reduction in coal consumption needed in order to achieve certain emission reduction targets in the EU power sector under the assumptions that electricity output is kept constant and coal-fired capacity is replaced by a gas-fired combined cycle plant with efficiency of 55%. Their results are reported in table 5.1. By taking into account that the emission reductions in the power sector in Europe are going to be larger than 8% and by realising that the power sector accounts for 83% of total steam coal consumption, it does not seem unlikely that coal consumption in this region must fall by 25-50%.

Table 5.1. Emissions reductions and coal demand in EU power sector (%)

Change in CO_2 emissions	Change in coal demand
-10	-27
-15	-40
-20	-54

Source: Söderholm and Strömberg (2003)

We do not have a comparable study on Japanese data. But since the share of coal in electricity supply is roughly the same as in Europe (Figure 4.1), the restructuring of the power sector for a given reduction in CO_2 emissions may be of the same magnitude as in Europe. A higher share of oil in electricity production at the outset does however increase the possibilities to substitute gas for oil rather than for coal. On the other hand, emission reductions in Japan are going to be higher than in EU due to higher growth in emissions since 1990. A reduction in coal demand of 25-50% does therefore not seem unrealistic in the Japanese case either.

An important caveat is that these calculations assume that compliance with the Kyoto Protocol is achieved solely through domestic actions. If emission permits are bought from other countries, domestic emissions might increase, thus offsetting the negative impact on coal demand in Western Europe and Japan. Simulations of the international permit markets show that Russia is going to be the main permit-exporting region.[13] Since Russia is not important for seaborne coal trade, changes in Russian abatement levels will only have minor impacts on the international coal trade. International permit trade is thus going to have a positive impact on seaborne coal trade.

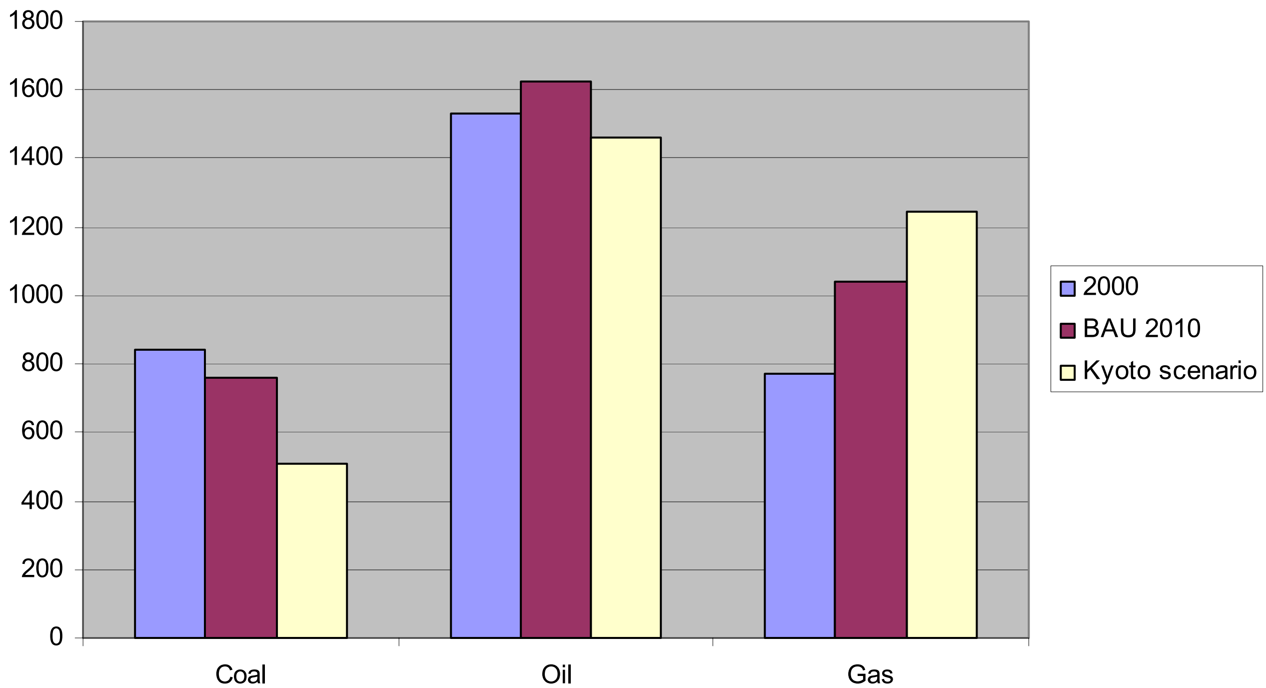

Figure 5.1. A scenario for European fossil fuel demand under the Kyoto agreement.

[13] See e.g. Weyant (1999).

Figure 5.1 presents one possible scenario of the development in demand for fossil fuels in EU towards 2010. The assumptions made are as follows:

- Oil consumption is reduced to 10% below the business as usual (BAU) emission level, as calculated by WEO (2002).
- Emissions of the two other important greenhouse gases (CH4 and N2O) are reduced to 10% below BAU level
- Emission permit import corresponds to 10% of the Kyoto emission target
- Gas consumption exceeds the BAU level by 20% in order to maintain supply of electricity

Under these assumptions, coal demand in the EU will be reduced by 39% in 2010 relative to the 2000 level.

5.2. Domestic production in Europe

We close this section by a discussion of the importance of domestic production in Europe for the impact on the international coal trade. The production of coal in Western Europe has declined by more than 50% in the 1990s, from a level of 730 Mt in the record years in the mid 1980s to 330 Mt in 2000. Despite a sharp reduction in brown coal production levels, the share of brown coal in total production in Western Europe has increased slightly to 75% of total production, meaning that hard coal production has been reduced even more than has brown coal production (Figures 5.2 and 5.3).

There are four significant hard coal producing countries in Western Europe; Germany (43%), UK (37%), Spain (13%) and France (5%). All these regions have experienced a fall in hard coal production, except Spain where the level of production has been remarkably stable since the early 1970s.

There are three significant brown coal producing countries in Western Europe; Germany (69%), Greece (26%) and Spain (5%). Reduced production of brown coal in Western Europe is solely due to a fall in German production. Production levels in Spain and Greece have been stable throughout the 1990s.

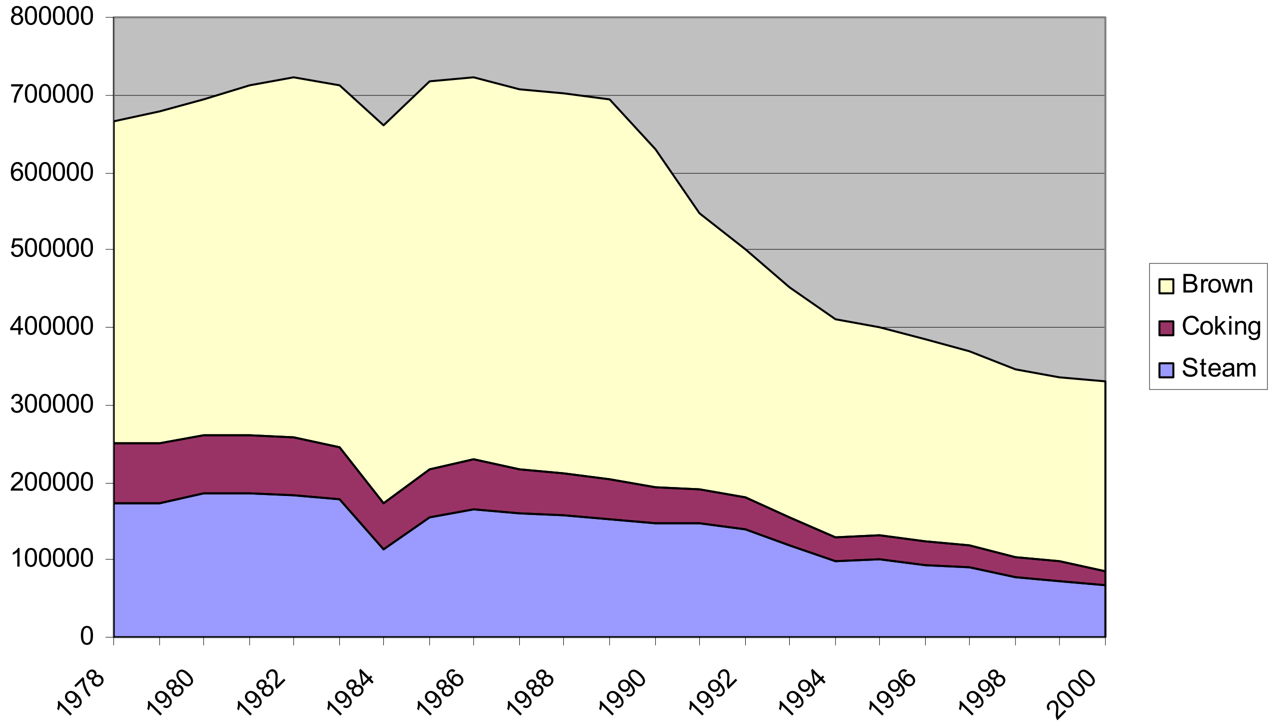

Figure 5.2. Coal production in Western Europe, by type (1000 tonnes)

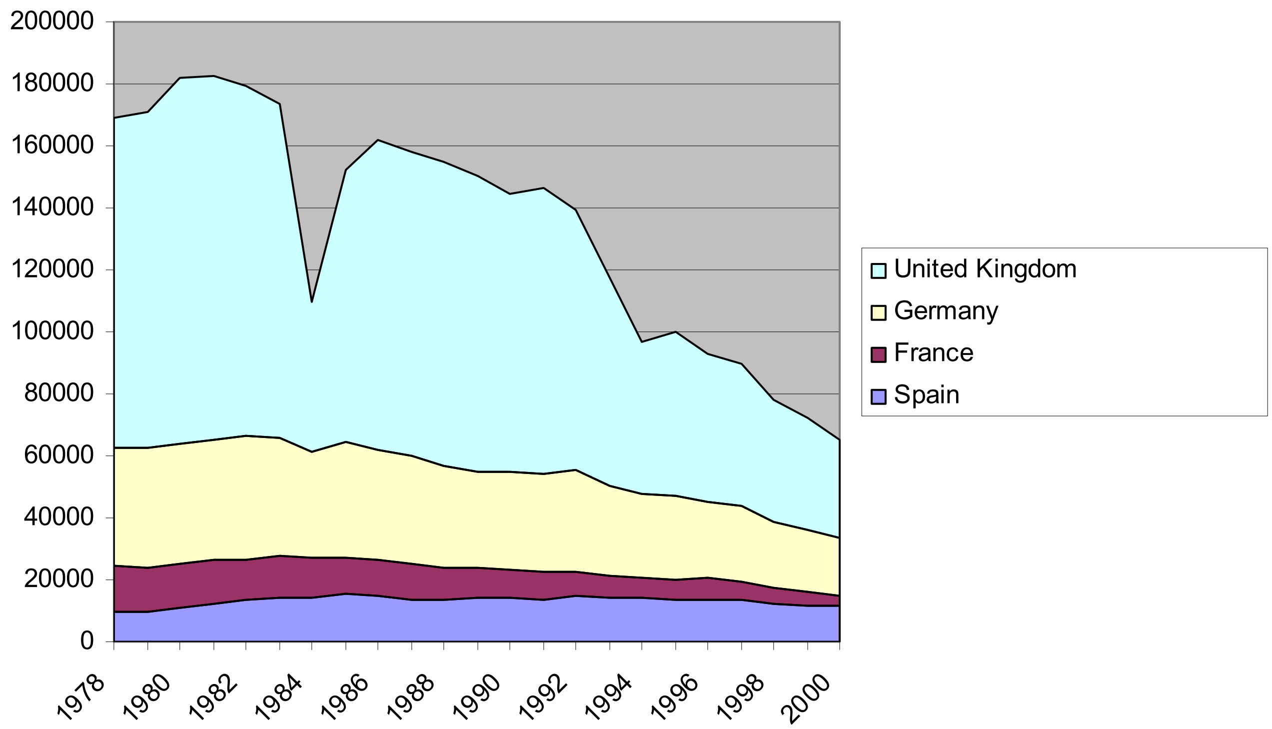

Figure 5.3 Steam coal production in Europe, by country (1000 tonnes)

Figure 5.4 shows how a reduction in European coal demand will affect European coal imports under various assumptions about the development in domestic coal production. Assuming that European production is cut before import is reduced, a reduction in coal demand of 40% will reduce coal imports by no more than 8%. If, on the other hand, coal production in Europe is maintained at its present level, the reduction in coal imports will be as large as 62%. It may seem unlikely that reductions in coal demand in countries that do not produce coal will be accommodated by reduced production in other European countries. Therefore, we calculate a third scenario where production reductions in a given country only will accommodate reductions in domestic coal demand. The reduction in coal imports will then be 22% if coal demand falls by 40%. We conclude that with a reduction in coal demand of 25-50%, the likely span of reductions in coal imports is from –15 to –75%.

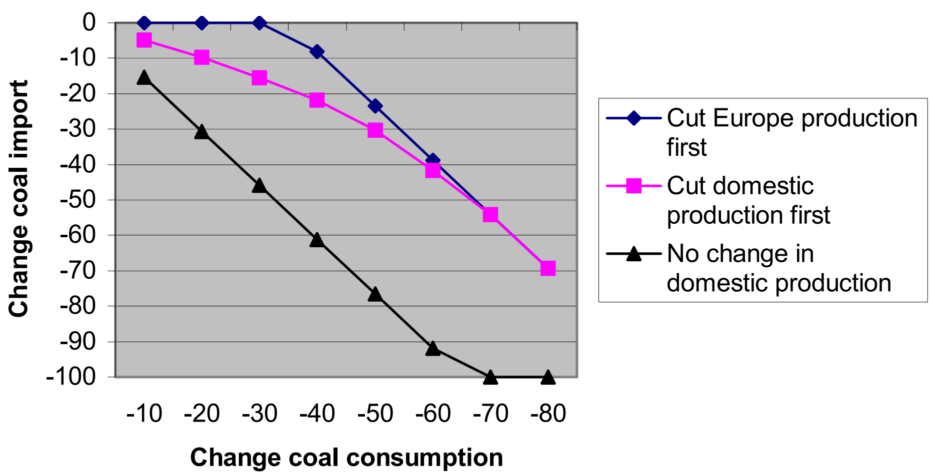

Figure 5.4. Coal demand and coal imports in Europe.

6. Concluding remarks

This paper has discussed the potential impact of climate policies on the international steam coal demand. International coal demand is fairly concentrated on a few importing regions. Coal is used extensively only in a few sectors (power production, steel and cement). Restructuring of the steel industry will only have a small impact on steam coal consumption (<1%), while the impact from the cement industry may be larger (-2-4%). The major changes will however take place in the power production sector. Due to good fuel substitution possibilities in power production, this sector will probably reduce its emission more than other sectors. This will hurt coal demand in particular since more than 80% of steam coal consumption takes place in this sector. Scenarios of the future coal demand in Europe and Japan show that reductions from 2000 to 2010 in the range of –25 to –50% do not seem unlikely. In Japan, these reductions will be translated directly into reduced import demand. In Europe, part of the reduction in coal demand can be accommodated through reduced domestic coal production. The reduction in European coal imports is projected in the range of –15 to –75%.

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