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Impacts of the EU Emissions Trading Scheme on the industrial competitiveness in Germany

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1 Introduction

An intended effect of the EU Emissions Trading Scheme (EU ETS) is the reflection of greenhouse gas emissions related costs in the production costs of installations covered by the Directive. To the extent that the additional costs of covering greenhouse gas emissions are passed-through and included in product prices, the EU ETS also increases costs on the demand side, including electricity-intensive industries (e.g. aluminium industry).

Since the EU ETS only covers installations located in the EU, this partial implementation of climate policy may lead to competitiveness distortions for carbon- and energy intensive companies in the EU. Production in sectors which export to, or import from, regions which have not implemented a comparable climate policy may be at disadvantage depending on i) the carbon intensity of the production process, ii) the price for EU allowances (EUAs), iii) the significance of the additional carbon costs in relation to other production costs, and iv) the extent to which these additional costs may be passed-through. Consequently, the EU ETS may lead to a shift in production or – in extreme cases – even to a relocation of industrial production facilities to regions without an ambitious climate policy, and would thus imply carbon leakage.

Recognizing that in a global context of competitive markets, carbon leakage may be an issue for energy-intensive industries facing international competition, the proposal for a new ETS Directive foresees that installations from certain sectors may receive up to 100% of the needed certificates for free. The European Commission has therefore envisaged to asses in the year 2010 which industrial sectors cannot pass through the cost of EUAs needed for production without loosing a significant market share outside of the EU.[1] In March 2008, the European Council considered carbon leakage to be a concern that needed to be analysed urgently and addressed within the new ETS Directive. At the same time, the Council stated that an international agreement remains the best way to address this issue.[2] Allocating allowances free of charge to companies rather than selling them on the market, would – at least under perfectly competitive markets - not alter the marginal costs and hence the competitiveness of production in the EU. However, free allocation would lower average costs and hence the financial burden to companies receiving allowances for free.

The aim of this paper is to assess the following issues

- Which sectors in Germany may face significant increases in direct or indirect costs because of the EU ETS?
- Which sectors are likely to face a high exposure to international competition which could then lead to carbon leakage?

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1 See European Commission (23.1.08): Questions and Answers on the Commission's proposal to revise the EU Emissions Trading System, http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/08/35&format=HTML&aged=0&language=EN&guiLanguage=en, as of 5 March 2008.

2 Council of the European Union, Presidency Conclusions, 14 March 2008. http://www.eu2008.si/en/News_and_Documents/Council_Conclusions/March/0314ECpresidency_conclusions.pdf.

- Which mechanisms exist to address competitiveness/leakage concerns arising in the context of the EU ETS?

The structure of this paper is as follows. Section 2 explores to which extent the EU ETS affects production costs in industry sectors in Germany and the UK. In particular, a distinction is made between direct and indirect cost effects of the EU ETS. Direct costs are related to emissions operators are obliged to surrender EU allowances for, i.e. energy and process emissions. The analysis of increases in indirect costs is limited to the most relevant case, i.e. effects of higher electricity prices.

Presumably, the extent to which additional costs may be passed on also depends on industry sectors' exposure to international trade. Section 3 therefore uses indicators based on export and import shares to analyse differences in trade exposure across industry sectors. Combining the results with the findings on cost exposure from section 2 then allows for a comprehensive evaluation of sectors that face both high exposure to international competition and to CO_2-related cost effects. Results for Germany are compared with those for the United Kingdom.

Alternative ways to asses the possible pass-through of direct and indirect costs from the EU ETS are explored in section 4. In the economics literature the price elasticity of demand and the Armington elasticity are used to measure changes in demand or market share in response to price changes. As a general rule, the pass-through of additional costs will be higher, the lower the loss in demand or in market share. Section 4 ends with a brief discussion of other options to evaluate the impact of the EU ETS on product prices, including econometric analyses.

Finally, section 5 discusses possible mechanisms to address competitiveness/leakage concerns within the context of the EU ETS. The mechanisms considered include free allocation for direct and possibly also indirect emissions, tax adjustments at the border for imports and exports, direct compensation and sectoral agreements.

2 Effects from carbon pricing on the cost structures of EU ETS industries

The EU Emissions Trading Scheme may have direct and indirect effects on the production costs of industries. Direct costs are caused by emissions originating from the production process itself (which include energy and process emissions); for these emissions operators are obliged to surrender EU allowances. Indirect costs are caused by, for example, higher electricity prices: electricity generators pass on the opportunity costs of the Emissions Trading Scheme to consumers. The same indirect cost effect may apply to other intermediate inputs to production which may become more expensive due to pass-through of CO_2 related costs. As these are more difficult to identify and are potentially smaller in nature, the current study focuses on electricity-related indirect costs only. Moreover, even those firms which do not fall under the EU Emissions Trading Directive may face indirect costs from emissions trading. In the following section, the analysis of EU ETS related cost effects is carried out in detail for Germany, followed by a comparative discussion of results obtained for the UK.

2.1 Value at stake in Germany

In this section, we analyse the direct and indirect cost effects for those sectors in Germany that may potentially be exposed to distortion in competitiveness (for the selection criteria see Annex A (chapter 7). The analysis is based on the concept of ‘value at stake’ which has previously been applied to UK industrial sectors (see Hourcade/Demailly/Neuhoff/Sato 2007). The maximum value at stake is defined as the sum of potential direct and indirect costs in relation to the gross value added (GVA) of a given industrial sector.

For reasons of data availability, the analysis is carried out at the 4-digit-level of the NACE code.[3] There is one exception in the case of Germany: data for refined petroleum products (NACE code 23.2) is not available at the 4-digit level for confidentiality reasons. In this case; therefore, the analysis includes the sector “coke, refined petroleum products and nuclear fuel” at the 2-digit level. The sector is dominated by the production of refined petroleum products; 99% of the turnover in 2005 was due to refined petroleum products whereas the production of coke and nuclear fuel jointly contributed only 1% (Statistisches Bundesamt 2006).

Throughout the analysis, we assume an average EU allowance price of 20 Euro per t CO_2. A higher or lower price level would not hamper the explanatory power of the analysis as the maximum value at stake would increase or decrease in proportion to changes in the price for EUAs.

Indirect costs are calculated by multiplying the electricity consumption of an industrial sector and the estimated pass-through of CO_2 costs to electricity prices. The data for electricity consumption originates from the German Statistical Office (Statistisches Bundesamt 2007).

[3] No analysis was possible for the sector “refined oils and fats” (NACE 15.42) as no data on gross value added was provided.

It is assumed that the CO_2 costs incorporated in electricity prices in Germany are defined by the emissions originating from the marginal power plant in Germany, which presently is a hard coal based power plant. This means that the CO_2 costs are higher than, for example, in the UK where the typical marginal power plant is a natural gas-fired power plant. We assume a full pass-through of the costs of CO_2 to electricity prices; thus for a hard coal power plant with emissions of 0.967 t CO_2/MWh the price increase because of the additional costs for CO_2 would then amount to 19.34 €/MWh. In the future, it is likely that the current marginal power plant will be replaced by a more efficient one with lower emissions and therefore a lower CO_2 price will be incorporated in electricity prices. In general, the amount of pass-through may not only vary with the marginal production technology, but also with the price of EUAs, with the load type and also with the power market structure. For example, the pass-through rates found or applied in Sijm et al. (2006a, 2006b), or in Umweltbundesamt (2007) and Sensfuß (2007) were lower than assumed in this report. In any case, the indirect price effects would vary in proportion to changes in the pass-through rates.

Direct costs of an industrial sector depend on the emission intensity of production. Energy emissions are calculated using fuel input (Statistisches Bundesamt 2007) and emission factors (see Table 1). Process emissions are based on data from the German GHG inventory for the following sectors: iron and steel, cement; lime, fertilizers and aluminium.[4]

[4] Process emissions of the production of glass are not considered in the following analysis. These emissions occur for four industrial branches at a 4-digit level only (NACE Code 26.1x) and are relatively low (635 kt CO_2 in the year 2005).

Table 1 Emissions factors for fuels

Fuel	**Emissions factors t CO_2/TJ**
Hard coal	94
Coke (hard coal)	105
Briquettes (hard coal)	93
Other hard coal products	93
Lignite (Rohbraunkohle)	111
Lignite (Hartbraunkohle)	97
Briquettes (lignite)	99
Coke (lignite)	108
Other lignite (for fluidiced bed boilers)	100
Dry lignite	97
Other lignite products	97
Diesel oil	74
Light fuel oil	74
Heavy fuel oil	78
Liquified gas	64
Refinery gas	60
Petroleum coke	101
Other mineral oil products	80
Natural gas	56
Pit gas	55
Coke oven gas	40
Blast furnace gas	268
Other gases	183
Solid biomass	0
Liquid biomass	0
Biogas	0
Sewage gas	0
Landfill gas	0
Other renewables	0
Sewage sludge	0
Waste (municipal and industrial)	18

Sources: Umweltbundesamt, Information of companies and industry associations, AG Energiebilanzen, ifeu-Institut für Energie und Umweltforschung, calculations by Öko-Institut

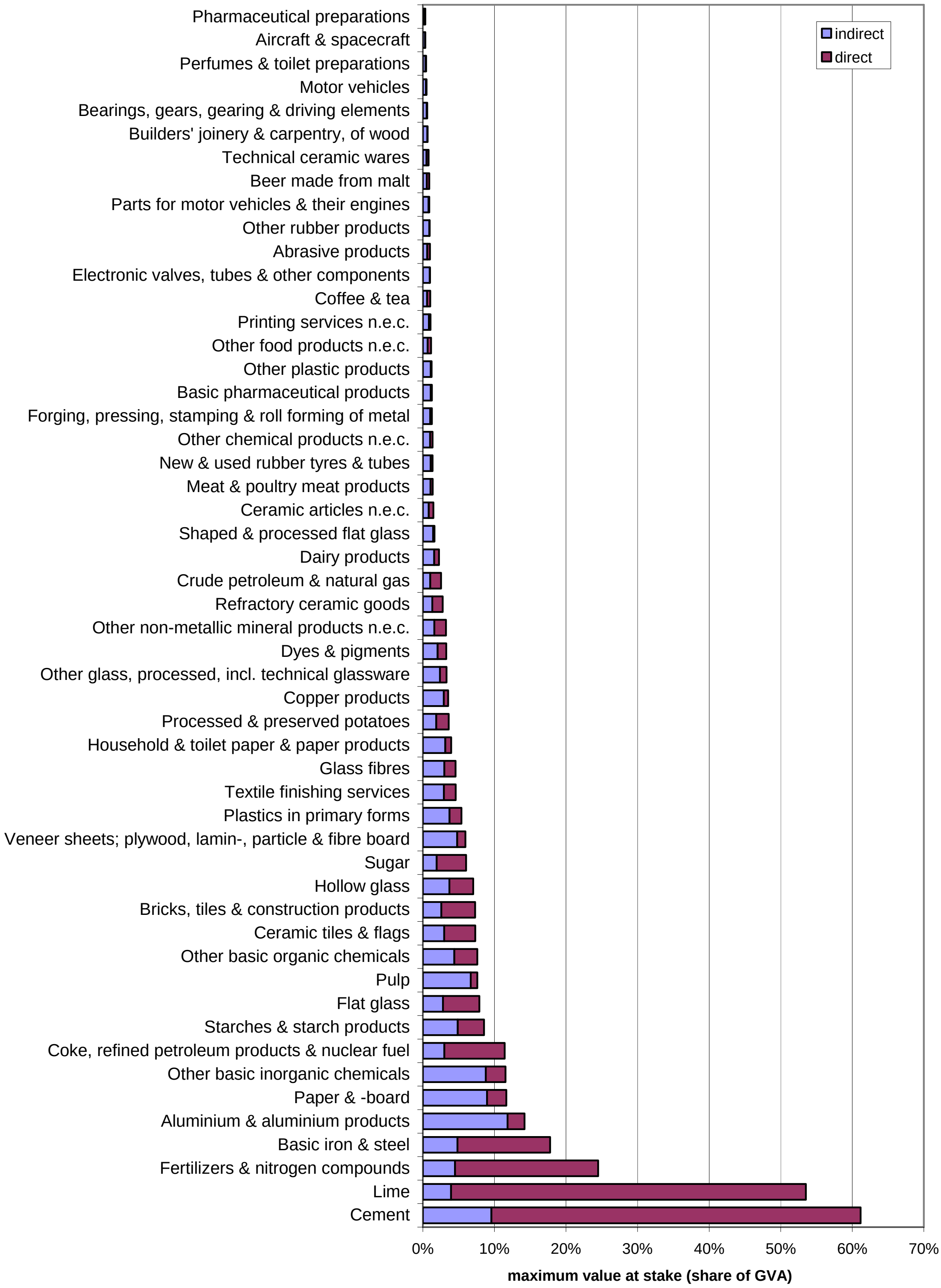
Direct and indirect costs are presented as shares of gross value added at market prices. The only exception is the refinery sector for which the gross value added at factor costs is used. Market prices differ from factor costs by the amount of indirect taxes net of subsidies. For most sectors there is little difference between the two values; gross value added at factor costs constitutes more than 90% of the gross value added at market prices.[5] The refined petroleum product sector presents a major exception. In this case, gross value added at factor costs only represents 13% of gross value added at market prices. This is due to the higher share of taxes in gross value added at market prices for petroleum products. To

[5] For the production of beer from malt (79%) and the production of coffee and tea (75%), for example, the share of gross value added at factor costs is slightly lower. Both sectors, however, have rather low emission intensities.

balance out this tax effect, we decided to use gross value added at factor costs for the production of petroleum products while staying with gross value added at market prices for all other sectors of production

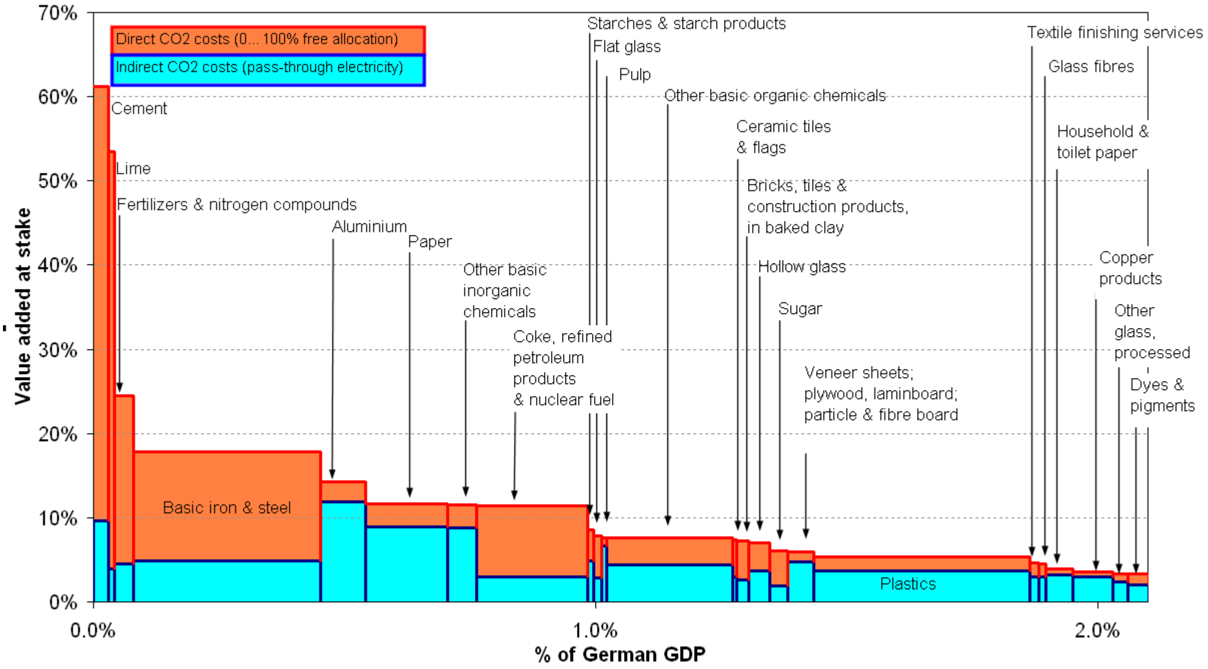
The analysis for 2005 shows that for most industrial sectors covered by the EU Emissions Trading Scheme the maximum gross value added at stake is below 2% (see Figure 1). For those sectors with a maximum value at stake of 2% or more, Figure 2 shows their value at stake in relation to their share in GDP.

Figure 1 Maximum value at stake as share of gross value added for German industrial sectors, 2005



Sources: Statistical office, Öko-Institut

Figure 2 Value at stake relative to GDP – area in light blue represent indirect costs, areas in red reflect direct costs



Sources: Statistical office, Öko-Institut

For those sectors for which the potential value at stake depends mostly on the increase of electricity prices (indirect CO_2 costs), a change in allocation rules would not solve the potential production cost increase these sectors are facing. This refers to aluminium production, paper, other basic inorganic chemicals or veneer sheets, plywood, laminboard, particle and fibre board production. For those sectors with high direct CO_2 costs it must be borne in mind that the maximum value at stake is based on the assumption of full auctioning of emissions allowances. Direct costs (red bars) could be lower if part or all of the allowances were allocated for free, depending on whether, and to what extent, the concept of opportunity costs is applied.

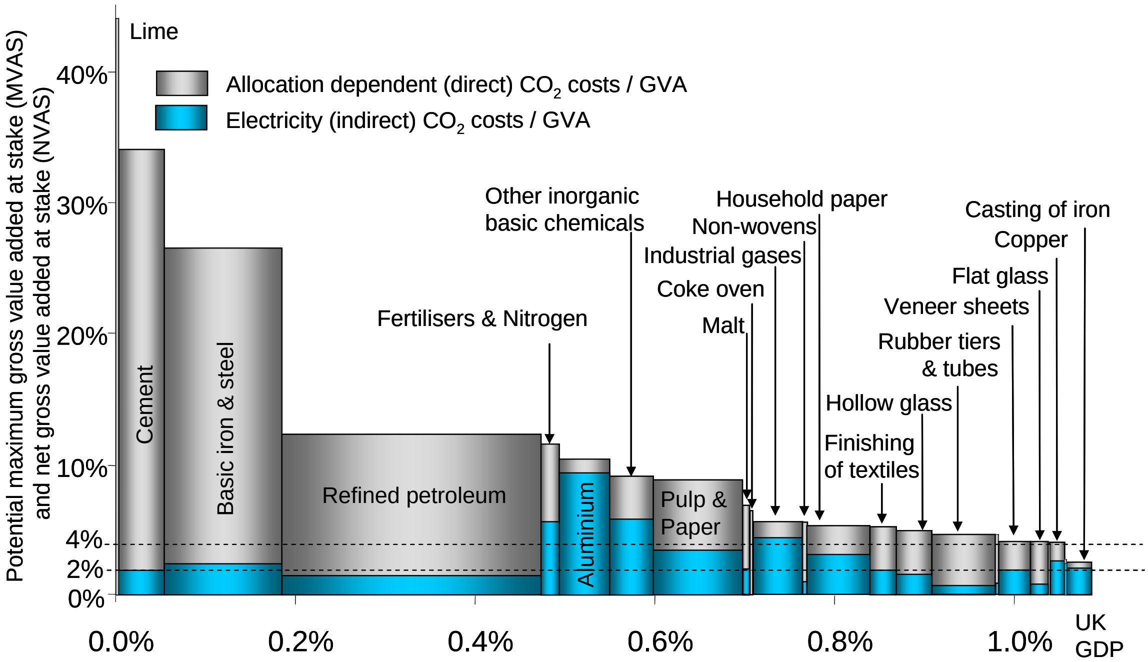
2.2 Comparison to value at stake in the UK

A similar analysis was conducted for UK industries using the same concept of value at stake (Hourcade et al. 2007). Unlike in Germany, marginal power generation in the UK is provided by a natural gas based power plant. For this reason, the indirect costs effect due to a CO_2 price of 20 € per EUA is lower in the UK. As before a full pass-through of the costs of CO_2 to electricity prices is assumed. For British industries, the add-on on electricity prices would then amount be 10 €/MWh, whereas in Germany an add-on of 19.34 €/MWh was assumed. It should be noted that theses differences in cost pass-through depend on the specific energy mix and the resulting merit order in each country and may be likely to level out with increased competition and electricity trade within the EU.

The value at stake in relation to GDP for UK industries is shown in Figure 3. The comparison of British and German data shows that only a limited number of areas of industrial activity (roughly 20) face a significant increase of indirect costs (relative to GVA), i.e. more than 2%.

Most sectors are included in both cases even though the extent of the direct or indirect cost effect and, thus, the ranking of value added at stake may differ slightly. These are: Lime; cement; basic iron & steel; fertilizers and nitrogen compounds; refined petroleum & coke[6]; aluminium; pulp, paper and paperboard; other inorganic basic chemicals; household and toilet paper; flat and hollow glass; veneer sheets, plywood, lamin-, particle and fibre board; copper products and finishing of textiles). Several sectors were included in the UK but not in Germany because no German installation participating in the emissions trading scheme declared to belong to these sectors (malt; throwing and preparation of silk; other textile weaving; non-wovens; manufacture of industrial gases and casting of iron). Some sectors which passed the threshold in Germany did not pass it in the UK due to the lower indirect cost effect from electricity (dyes and pigments; other basic organic chemicals; plastics and ceramic tiles and flags).

Figure 3 CO_2 cost screen: UK sectors potentially exposed under unilateral CO_2 pricing



Price increase assumption: CO_2 = €20/t CO_2; Electricity = €10/MWh

Source: Hourcade/Demailly/Neuhoff/Sato 2007

2.3 Overview: Empirical results for direct and indirect costs from the EU ETS

This section provides a literature overview of the results of various studies on the impacts of emissions trading on production costs. The additional monetary costs due to the EU ETS in

[6] Due to data availability the sector coke, refined petroleum products and nuclear fuel (NACE 23) is included at 2-digit level for Germany whereas the other sectors are shown at 4-digit level. GVA refers for this sector to GVA at factor costs.

the studies surveyed include the direct costs for internal abatement measures and for buying allowances (net revenues from selling allowances) plus the indirect costs from increases in electricity prices, assuming a 100 % cost pass-through in the electricity sector. Rather than using figures for actual abatement costs, the studies used the price for EUAs. Since cost-minimizing companies are expected to realize all abatement measures with costs below the price for EUAs, the studies tend to systematically overestimates compliance costs. These additional costs were related to (typically short-term) marginal and average production costs without considering any pass-through opportunities.[7]

The IEA (2005) distinguishes between a scenario with 2 % and one with 10 % purchasing of allowances at an allowance price of 10 €/EUA. The framework conditions of both scenarios are comparatively moderate. The three other studies assume 100% purchasing and allowance prices of 15 €/EUA (Umweltbundesamt 2007), 20 €/EUA (McKinsey/Ecofys 2006) as well as 15 and 30 €/EUA (Smale et al. 2006). As a consequence, the increase in production costs reported in IEA (2005) tends to be lower than in the other studies (see Table 2). Compared to other sectors, cement production in Germany appears to be particularly affected via higher production costs – the estimates range up to an increase in marginal costs of 144 %. At the same time, especially for steel and aluminium production, it becomes obvious that it is necessary to differentiate by process (primary versus secondary processes). If this is done, then the production of electric steel, bricks/roof tiles and various paper products are the least affected. There are striking differences in the estimates for refineries: Smale et al. (2006) only predict an increase of 0.3 – 0.6 % (relative to marginal costs), while McKinsey/Ecofys (2006) estimates a price increase of 20 % (even compared to average costs).

[7] Hence, as was also the case when calculating the maximum value at stake in the previous section, the maximum additional costs are considered. The bases, i.e. gross value added versus average/marginal production costs, however, differ.

Table 2 Impacts of emissions trading on production costs - overview

Product	Marginal Cost Increase (%)	Average Cost Increase (%)	Auctioning (%)	EUA Price (€/t)	Study
Steel	8.0		100	15	Smale et al. (2006)
	17.0		100	30	Smale et al. (2006)
- Electric Arc Furnace		0.8	2	10	IEA (2005)
		0.9	10	10	IEA (2005)
		2.9	100	20	Mc Kinsey (2006)
- Basic Oxygen Furnace		0.7	2	10	IEA (2005)
		1.3	10	10	IEA (2005)
		17.3	100	20	Mc Kinsey (2006)
Cement		1.9	2	10	IEA (2005)
		3.4	10	10	IEA (2005)
	84.4	28.0	100	15	Umweltbundesamt (2007)
	70.0		100	15	Smale et al. (2006)
	144.0		100	30	Smale et al. (2006)
- dry process		36.5	100	20	Mc Kinsey (2006)
Newsprint		1.1	2	10	IEA (2005)
		1.6	10	10	IEA (2005)
	2.6		100	15	Smale et al. (2006)
	6.0		100	30	Smale et al. (2006)
Aluminium		3.7	2	10	IEA (2005)
		3.7	10	10	IEA (2005)
	4.0		100	15	Smale et al. (2006)
	13.0		100	30	Smale et al. (2006)
- primary aluminium		11.4	100	20	Mc Kinsey (2006)
- secondary aluminium		0.5	100	20	Mc Kinsey (2006)
Paper	29.1	6.9	100	15	Umweltbundesamt (2007)
- Chemical pulp for market		1.0	100	20	Mc Kinsey (2006)
- Paper from chem. Pulp		2.1	100	20	Mc Kinsey (2006)
- Chemical pulp and paper		2.4	100	20	Mc Kinsey (2006)
- Mechanical pulp and paper		5.5	100	20	Mc Kinsey (2006)
- Thermo-mechanical pulp and paper		7.5	100	20	Mc Kinsey (2006)
- Recovered fibre pulp and paper		3.4	100	20	Mc Kinsey (2006)
Container glas		5.9	100	15	Umweltbundesamt (2007)
Flat glas		4.8	100	15	Umweltbundesamt (2007)
Bricks		3.9	100	15	Umweltbundesamt (2007)
Roof tiles		2.9	100	15	Umweltbundesamt (2007)
Refinery	0.3		100	15	Smale et al. (2006)
	0.6		100	30	Smale et al. (2006)
		20.5	100	20	Mc Kinsey (2006)

Emission-saving potentials were not considered when calculating the figures; these can play a role when determining the competitiveness/cost burden. For instance, a company with high, favourably-priced saving potentials is more adaptable than companies with low or expensive saving potentials.

3 Trade Intensity

3.1 Concept

The intensity of competition with producers from other countries differs significantly between industrial sectors. Some goods such as bread and fresh bakery products or newspapers are predominantly produced for, and consumed within, national markets. International trade is negligible in these cases and, thus, international competition, or distortion thereof, is no matter of concern even if production costs increased due to unilateral policy measures. The case is different for industrial sectors which export large shares of their domestic production or which face high competition from imports for their domestic sales.

There are several indicators to measure the intensity of foreign competition on domestic markets. One is the indicator ‘exposure to foreign competition’ (see Coppel/Durand (1999), OECD (2003a) and (2003b); Graichen/Matthes (1999)) which combines the assessment of export orientation of domestic production with the import penetration of the domestic market. A slightly different indicator called ‘trade intensity’ is used by Hourcade/Demailly/Neuhoff/Sato (2007); it relates the sum of traded goods to total market supply (the sum of domestic production and total imports of the country under consideration).[8] The values for the two indicators are of a comparable magnitude with major differences occurring only for sectors with high imports and low exports. The following analysis is based on the indicator of trade intensity.

$$\text{Trade Intensity} = \frac{\text{Exports}_{\text{regional}} + \text{Imports}_{\text{regional}}}{\text{Turnover} + \text{Imports}_{\text{total}}}$$

The trade intensity can meaningfully be estimated for trade of a specific country (or region) with a group of other countries (region) only. For the purpose of the EU ETS it is constructive to calculate the trade intensity only with countries outside of the EU (non-EU), as all EU countries take part in the Emissions Trading Scheme. For this reason, the trade intensity indicator here relates the sum of exports into and imports from this region of non-EU countries to total market supply in the country under consideration (sum of turnover and all imports of this product), indicated by the indices in the equation above.

We have added an analysis of trade with the group of countries which belong to neither the EU nor the OECD (non-EU and non-OECD) to assess the changes that would occur if other major industrialised countries committed to comparable CO_2 reduction efforts. The approach

[8] Whereas the exposure indicator relates exports to domestic production, the trade intensity indicator relates them to the total market supply which includes production and total imports. The exposure formula is as follows:
exposure = exports/turnover + (1-exports/turnover)*imports/(turnover+imports-exports).
If turnover was replaced by the value of total supply (turnover + imports), the exposure and the trade intensity indicator become equivalent.

cannot reflect whether additional countries outside of this group implement policies which would lead to a comparable increase in energy costs. If other countries implement similar policies like the EU Emissions Trading Scheme, competitors from these countries would have no advantage over domestic producers in terms of a CO_2 cost increase.

3.2 Results for Germany

The trade intensity for Germany is evaluated in retrospect using data from the German Statistical Office for 2005, which is the most recent year available. Import and export data is taken from the foreign trade statistics; turnover and gross value added (GVA) data originate from the statistics on structural costs of the manufacturing industry (Kostenstrukturerhebung im Verarbeitenden Gewerbe und Bergbau). The two sets of data use slightly different classifications. Although they are harmonised this may cause minor variances: The foreign trade statistics provide data on import and export goods according to the national classification system. The statistics of structural costs, however, aggregates data according to a company's main purpose of business. This implies that side- and by-products are included in the main product category.

For the analysis, the sectors subject to the EU Emissions Trading Directive were identified and supplemented by additional relevant sectors (see Annex A (chapter 7)). Again refined petroleum products are analysed at 2-digit level. For three sectors the analysis was not possible due to lack of data – for "refined oils and fats" (NACE 15.42) no turnover data was provided and for "textile finishing services" (NACE 17.3) as well as "forging, pressing, stamping & roll forming of metal" (NACE 28.4) no import/export data was available.

The following graph (see Figure 4) shows the exposure to foreign competition from countries not belonging to the EU (non-EU exposure) as well as from countries that belong to neither the EU nor the OECD (non-EU and non-OECD exposure) for 2005. The analysis shows that roughly one quarter of the sectors face a trade intensity with non-EU countries of less than 10%. Half of them face intensities between 10% and 25%; and the remaining quarter faces intensities of over 25%. Naturally exposure to non-EU competition will always be higher than exposure to non-EU and non-OECD competition; for some sectors the difference is higher than for others depending on the main trading partners.

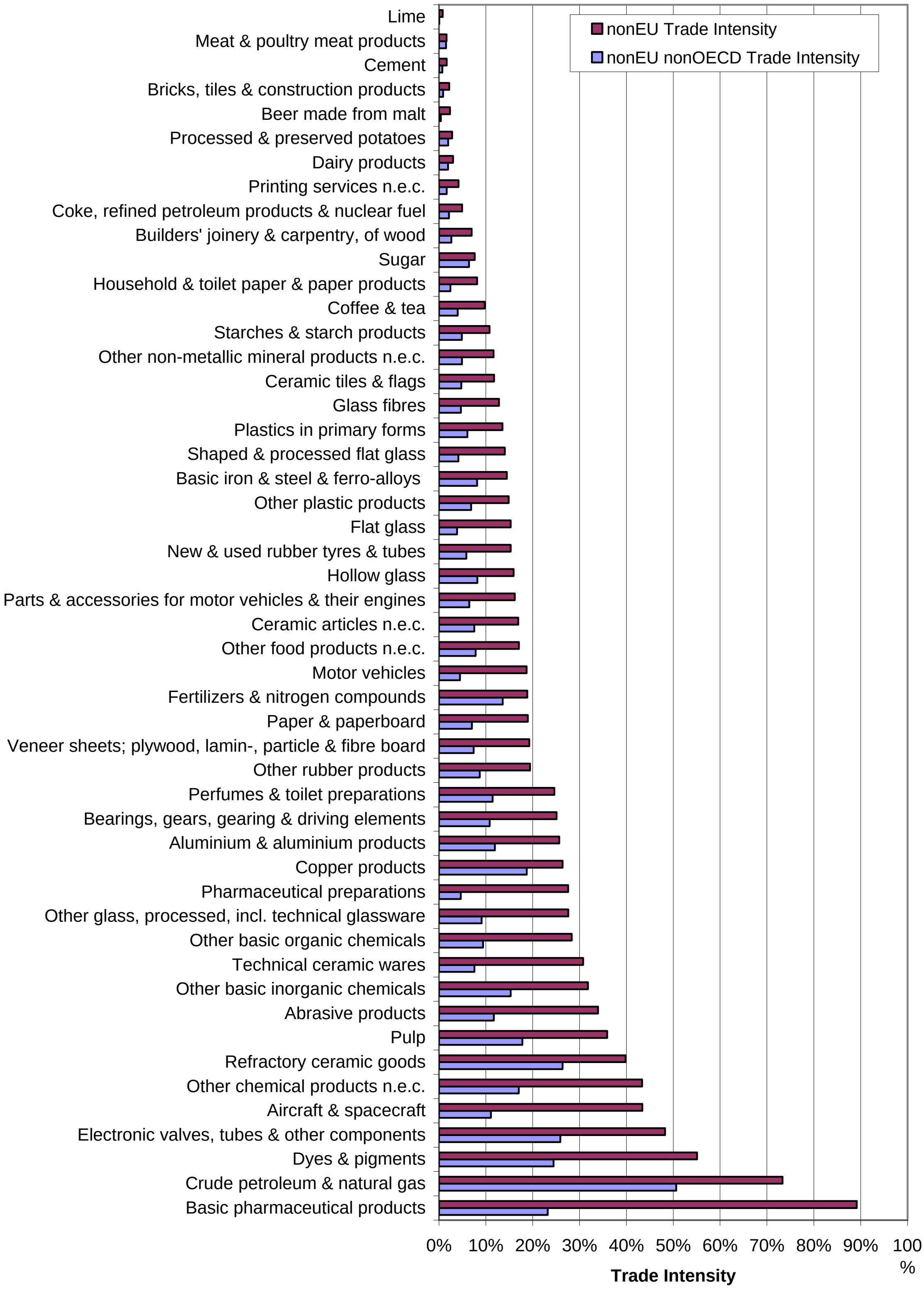
For these results, it has to be kept in mind that the indicator evaluates the intensity of trade, which is only a proxy for, but not equal to, the intensity of competition. In reality, the intensity of competition with producers from countries where no ambitious climate policy is in place depends on other factors besides output prices. However, as the data is not available at the necessary level of detail, they cannot be empirically assessed:

- How segmented is the market within a given sector, i.e. is the good in question a homogeneous commodity or a specialised product? International competition will have a greater effect on the producers of commodities for which clients have no major preferences.
- Does the production require a close cooperation between producers and clients? If for technological or organisational reasons close links between producers and clients exist cost increases would not necessarily result in lower sales. Similarly, sales to subsidiaries may not change even if prices were higher.

- Can the good easily be transported at costs that are reasonable in comparison to the value added of the product? Transport costs are highly relevant for international trade and serve to explain existing price differentials across countries.
- Is there a high uncertainty of exchange rates with regard to the country of production?

Producers of standardised goods with low transportation costs and competitors in countries with a low exchange rate risk will face tougher competition than producers of specialised goods, of goods that require a close cooperation with the client or of goods that cannot be transported. It is not possible to distinguish these factors in the present analysis; this could only be explored in separate sector specific focus studies. For a specific set of sectors, which are identified to be exposed to both international competition and high cost increases because of the EU ETS, we analyzed some of these factors in more detail (see Appendix C). This serves to get a better picture of the production processes, main inputs to production and trade structure.

Figure 4 Trade Intensity for Germany with countries not belonging to the EU and with countries neither belonging to the EU nor to the OECD, 2005



Sources: German Statistical Office, Öko-Institut

3.3 Sensitivity analysis – indirect effects

The analysis of trade intensity may underestimate possible indirect effects. For example, goods produced in Germany that are exported to other EU Member States might still be exposed to competition from non-EU countries. This is because the other EU country may choose to start importing this good from outside the EU rather than from Germany because of possible lower import prices from countries that are not subject to the EU ETS.

A detailed analysis would require examination of the exports from Germany to each individual EU Member State as well as of the trade intensity in that country. This would require national import and export data (for EU and non-EU trading partners) for all EU Member States.

An approximation is to calculate the exposure following the same indicator as above but replacing exports from Germany to a specific region (as for example non-EU countries) with total exports. Regional import remains unchanged since imports from other EU countries fall under the emissions trading scheme as well. This indicator tends to overestimate the exposure as it does not differentiate between exports to other EU Member States and exports to non-EU countries. It can thus be considered as a maximum trade intensity indicator to non-EU countries. The trade intensity which takes into account the indirect effects, i.e. export distortion to other EU countries due to the EU ETS, would therefore lie between the two values shown in Table 3.

$$\text{Trade Intensity} = \frac{\text{Exports}_{\text{total}} + \text{Imports}_{\text{regional}}}{\text{Turnover} + \text{Imports}_{\text{total}}}$$

Table 3 Sensitivity of non-EU Trade Intensity for Germany

NACE-Code	Industrial Sector	Trade Intensity nonEU	Maximal Trade Intensity nonEU
WZ-111	Crude petroleum & natural gas	73%	79%
WZ-1513	Meat & poultry meat products	2%	9%
WZ-1531	Processed & preserved potatoes	3%	17%
WZ-1542	Refined oils & fats	-	-
WZ-1551	Dairy products	3%	22%
WZ-1562	Starches & starch products	11%	27%
WZ-1583	Sugar	8%	19%
WZ-1586	Coffee & tea	10%	27%
WZ-1589	Other food products n.e.c.	17%	43%
WZ-1596	Beer made from malt	2%	9%
WZ-173	Textile finishing services	-	-
WZ-202	Veneer sheets; plywood, lamin-, particle & fibre board	19%	48%
WZ-203	Builders' joinery & carpentry, of wood	7%	16%
WZ-2111	Pulp	36%	47%
WZ-2112	Paper & paperboard	19%	53%
WZ-2122	Household & toilet paper & paper products	8%	39%
WZ-2222	Printing services n.e.c.	4%	13%
WZ-23	Coke, refined petroleum products & nuclear fuel	5%	12%
WZ-231	Coke oven products	-	-
WZ-232	Refined petroleum products	-	-
WZ-2412	Dyes & pigments	55%	97%
WZ-2413	Other basic inorganic chemicals	32%	65%
WZ-2414	Other basic organic chemicals	28%	56%
WZ-2415	Fertilizers & nitrogen compounds	19%	47%
WZ-2416	Plastics in primary forms	14%	38%
WZ-2441	Basic pharmaceutical products	89%	123%
WZ-2442	Pharmaceutical preparations	28%	62%
WZ-2452	Perfumes & toilet preparations	25%	52%
WZ-2466	Other chemical products n.e.c.	43%	85%
WZ-2511	New & used rubber tyres & tubes	15%	38%
WZ-2513	Other rubber products	19%	46%
WZ-2524	Other plastic products	15%	36%
WZ-2611	Flat glass	15%	43%
WZ-2612	Shaped & processed flat glass	14%	34%
WZ-2613	Hollow glass	16%	43%
WZ-2614	Glass fibres	13%	33%
WZ-2615	Other glass, processed, incl. technical glassware	28%	51%
WZ-2624	Technical ceramic wares	31%	52%
WZ-2625	Ceramic articles n.e.c.	17%	31%
WZ-2626	Refractory ceramic goods	40%	70%
WZ-263	Ceramic tiles & flags	12%	30%
WZ-264	Bricks, tiles & construction products	2%	15%
WZ-2651	Cement	2%	17%
WZ-2652	Lime	1%	12%
WZ-2681	Abrasive products	34%	69%
WZ-2682	Other non-metallic mineral products n.e.c.	12%	27%
WZ-271	Basic iron & steel & ferro-alloys	14%	40%
WZ-2742	Aluminium & aluminium products	26%	53%
WZ-2744	Copper products	26%	55%
WZ-284	Forging, pressing, stamping & roll forming of metal	-	-
WZ-2914	Bearings, gears, gearing & driving elements	25%	52%
WZ-321	Electronic valves, tubes & other components	48%	69%
WZ-341	Motor vehicles	19%	43%
WZ-343	Parts & accessories for motor vehicles & their engines	16%	46%
WZ-353	Aircraft & spacecraft	43%	76%

Sources: German Statistical Office, Öko-Institut

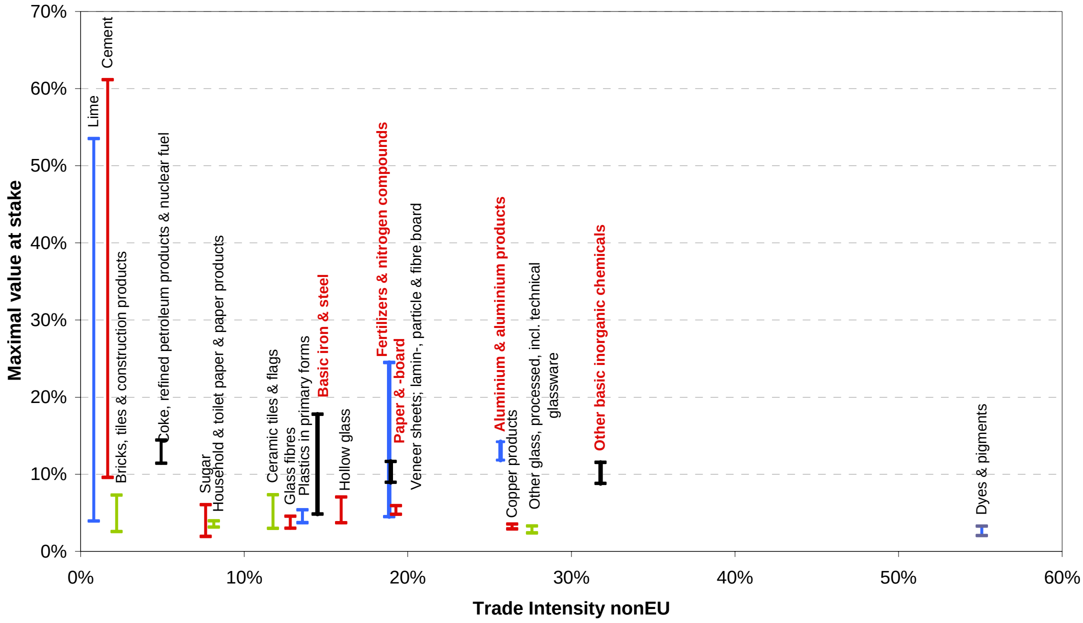
3.4 Combination of value at stake and trade intensity for Germany and the UK

To assess whether the potential price increase induced by the EU ETS will affect the profitability of domestic production it is important to evaluate whether producers can pass through the CO_2 related costs. One indicator to assess this possibility is the trade intensity; another indicator is the observed or estimated change in demand for domestically produced commodities in response to price changes (see chapter 4).

Combining the analyses of value at stake and exposure, we find that only a few industrial sectors simultaneously face high trade intensity and a high maximum value at stake.

Figure 5 and Figure 6 indicate the value at stake (the lower end of the bars indicates the indirect costs[9]; the upper end of the bar the sum of indirect and direct costs) and the trade intensity with countries outside of the EU for Germany and UK.

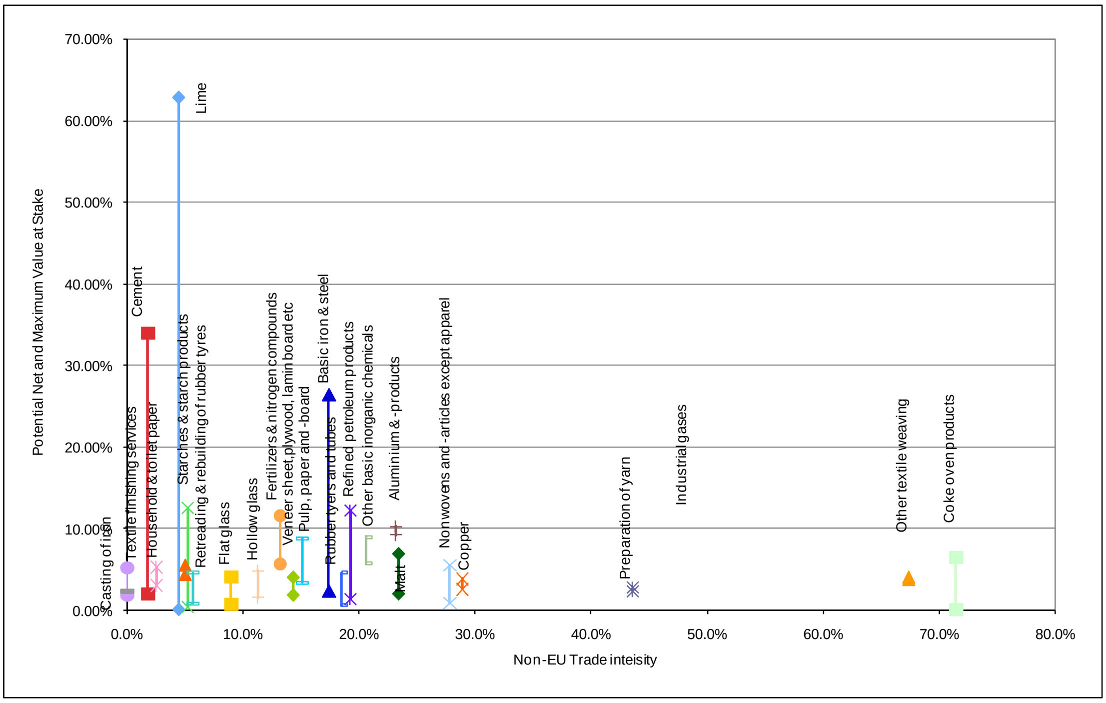
Figure 5 Trade intensity and maximum value at stake (relative to GVA) for German sectors



Source: Data from German Statistical Office, calculations Öko-Institut

[9] Note that this reflects a case of free allowance allocation (with no opportunity cost pass-through) to industry, so that EU ETS related costs would only occur as indirect cost through increased electricity prices.

Figure 6 Trade intensity and maximum value at stake (relative to GVA) for UK sectors



Source: Based on Hourcade/Demailly/Neuhoff/Sato 2007. Please note the different scale for trade intensity in the case of UK compared to Germany. For most sectors, the UK is more trade intensive than Germany.

To point out those sectors with high trade intensity as well as high value at stake, we chose to draw a line at the 10% level for each case. This is an ad-hoc assumption. Alternatively, a moving average approach could be applied to identify a broader range of exposed industries within specific criteria. Within the chosen 10% span, three sectors can be considered to be exposed both in Germany and UK:

- basic iron and steel;
- fertilizers and nitrogen compounds; and
- aluminium and aluminium products.

In Germany two sectors would additionally be exposed at this level:

- paper and paperboard; and
- other basic inorganic chemicals.[10]

These two sectors are not included for the UK because of lower pass-through rates in the electricity sector; they would, however, be included if the same pass-through rate as in Germany was applied.

[10] For these five sectors, which are identified to be exposed to both international competition and high cost increases because of the EU ETS, an in-depth sectoral analysis for Germany is provided in Appendix C. This includes a description of the main production processes, the main inputs and the main trading partners and shares.

In the UK trade intensity with non-EU countries for refined petroleum products is higher than in Germany; therefore this sector qualifies in the UK only:

A number of other sectors reveal a high intensity of trade but low value at stake which implies that the increase in production costs due to the EU ETS is relatively small and negative effects on competitiveness may not be likely. Similarly, sectors with high EU ETS related cost effects but low trade intensity are not expected to be significantly threatened by international competition.

For the sectors that reveal high values at stake and high trade intensities, market positions are likely to change under the EU ETS due to increased production costs and high exposure to international competition. Depending on the allocation mechanism, firms may face high CO_2-related costs and will need to adjust their activities. It must be noted, however, that even though the selected indicators (trade intensity and value at stake) provide a consistent illustration of the effects of different allocation schemes, they do not present information on companies' actual decision making schemes, i.e. they do not allow immediate conclusions on whether firms may consider full or partial relocation to countries outside the Emissions Trading Scheme.

As the analysis was carried out in retrospect and as values might change in the future, a sensitivity analysis for Germany was conducted for all years for which data were available (2000 to 2005). It revealed that the magnitude of values for trade intensity remains comparable over the years (see Annex B (chapter 8)). Furthermore, the Emissions Trading Scheme was already in place in 2005; furthermore, the average price for EU allowances in that year was 18 Euro per ton of CO_2 – a value close to the 20 Euro assumed in this analysis.

However, not all results from the past can be used for future projections which must reflect CO_2 as a new cost factor. Especially the assessment of future investment decisions is difficult or impossible from a macro-analysis based on statistical data. This is even more important if the assessment of relocation of production and potential leakage effects must be carried out in the framework of very complex decision making structures. Additional bottom-up case studies could complement the type of analysis presented in this paper.

Approaches to address competitiveness effects and leakage concerns would need to be considered on a sector by sector basis. As the number of exposed sectors is limited a focussed treatment of these sectors should be possible; several options for treatment are explored in section 5. A more in-depth analysis of the exposed sectors should be carried out to identify reasons for national differences and whether all products of the mentioned sectors are exposed or whether the exposure is limited to some products.

4 Pass-through of direct and indirect costs from the EU ETS

An analysis of the trade structures and the potential cost burden represents sub-aspects of the possible impact of the EU emissions trading on the international competitiveness of companies. In the end, what is decisive is the extent to which companies are able to pass on the additional costs caused directly or indirectly by the EU ETS. The effect of cost increases on production and competitiveness may be twofold: i) loss of domestic demand due to consumer's choice to buy alternative and less expensive domestic substitutes or imported products and ii) loss of export shares to countries that do not face comparable abatement policies.

4.1 Demand elasticities to assess the potential of cost pass-through

In the economics literature the *price elasticity of aggregate demand* and the *Armington elasticity* (Armington 1969) are used to measure changes in demand or market share in response to price increases. The price elasticity of aggregate demand measures the percentage change in domestic demand in response to a one percent increase in the aggregate price. Assuming that domestic consumers distinguish products by their source, the price elasticity of aggregate demand reflects the change in demand for domestic goods relative to their imported (imperfect) substitutes in response to a change in the relative price of domestic goods to imported goods. Hence, the effect on demand for domestically produced products following an increase in the price of the domestic product may be decomposed in two effects: (i) a loss in output to foreign producers, which depends on the magnitude of the Armington elasticity; and (ii) a loss in output because aggregate demand is lower, which depends on the elasticity of aggregate demand. The larger the expenditure share for domestically produced products, the larger is the impact of the aggregate demand effect and the lower the impact of the Armington-effect. As a general rule, the pass-through of additional costs will be higher, the lower the decrease in aggregate demand and the lower the Armington elasticity.

4.1.1 Price elasticity of demand

The price elasticity of aggregate demand measures by how much (in %) the demanded quantity of a good changes if the price of the good increases by one percent. If the price elasticity is above one (in absolute terms), the demand is termed "elastic" and "inelastic" otherwise.

If additional costs (e.g. in form of prices for CO_2 allowances) are imposed on a good with a low price elasticity of demand, passing on additional costs only results in a small drop in demand. In this case, only a minor steering effect is triggered by the price of goods with low price elasticity – at least in the short run. The reverse holds for goods with high price elasticities. In the long run, however, the large price increase sets stronger incentives to reduce demand (and thus emissions) than if only a small part of the additional costs were passed on. Consequently, a distinction must be made between whether short-term or long-term price elasticities are involved. Since buyers normally have greater possibilities to react in the long term, long-term price elasticities are usually larger than short-term ones. Hence, to assess the long term consequences of climate policy on international competitiveness, the long term price elasticities would be the more appropriate measure.

If the demand for a commodity decreases as the result of a price increase, this is not automatically accompanied by a drop in demand for the entire sector's output. If similar products exist, which serve as substitutes, the demand may shift to similar products produced domestically or to identical or similar products which were produced abroad if their prices have not increased in a similar way.

Figures for price elasticities are usually obtained from econometric time series regressions and capture the response of aggregate demand, i.e. demand for alike products produced domestically and abroad. Table 4 reviews such estimates for industrial countries. The figures in Table 4 stem primarily from IEA (2005), Hepburn et al. (2006) and Smale et al. (2006), who in turn draw on the available secondary literature. Hepburn et al. (2006) indicate a range of estimates from "low" through "best guess" to "high", where the high values apply more to the long-term and the low values to the short-term price elasticities. Comparing the few estimates available for the various sectors, a very rough sector ranking in terms of demand elasticity would be (starting with highest absolute value): aluminium, steel, paper, cement.

Table 4 Overview: price elasticities of aggregate demand in the literature

Sector	Elasticity	Study	Comments
Steel	-0.3	Winters (1995)	
	-0.62	Smale et al. (2006)	
	-0.3/-0.6/-1	Hepburn et al. (2006)	Data for coated sheet steel, low/best guess/high
- Electric Arc Furnace	-1.56	IEA (2005)	
- Basic Oxygen Furnace	-1.56	IEA (2005)	
Cement	-0.27	IEA (2005)	Data for Denmark
	-0.8	Smale et al. (2006)	
	-0.3/-0.8/-3.0	Hepburn et al. (2006)	low/best guess/high
Newsprint	-1.88	IEA (2005)	
	-0.5		
	-0.25/-0.3/-0.5	Hepburn et al. (2006)	low/best guess/high
Aluminium	-0.86	IEA (2005)	
	-0.8	Oxera et al. (2006)	
	-1.1	Smale et al. (2006)	

Sources: Winters (1995), Smale et al. (2006), Hepburn et al. (2006), IEA (2005), Oxera et al. (2006)

In any case, it should be kept in mind that the estimates for price elasticities vary widely and do so by country/region, period underlying the estimates, type and degree of disaggregation of the product (the greater the disaggregation, the higher the estimated elasticity in absolute terms), with regard to time (short vs. long-term elasticities), and method of estimation. In addition there are problems with transferring estimate results derived from historical data to the future if the technical and economic conditions change. Finally, the level of pass-through also depends on the supplier structure (perfect competition, oligopoly, monopoly) (see e.g. Sijm et al. 2005). All of this makes it harder to formulate a general statement about the level of price elasticity and to quantify the pass-through of additional costs of the EU ETS.

Even if the price elasticity for a commodity could be estimated with accuracy, this figure would not necessarily indicate the loss in market share of domestic producers. In particular, if alike products are imported, the demand elasticities described above would refer to both products produced domestically and products produced abroad but sold domestically. The next section tries to disentangle these effects in greater detail.

4.1.2 Armington elasticity

The elasticity of substitution between commodities produced in different countries is called Armington elasticity in the literature (Armington, 1969). This harbours the assumption that products of the same product groups which originate in different countries are substitutable to a limited extent. In the end, this limited substitutability reflects the heterogeneity of consumption goods from the viewpoint of the consumers and of inputs from the perspective of companies.[11] In the empirical literature, in particular in applied general equilibrium modelling of international trade, Armington elasticities allow for the modelling of intra-industry trade, i.e. trade within identical product groups (e.g. cars) across countries. Conceptually, the demand for a particular good is modelled via a two-stage process. In the first stage, the total demand for an aggregate product, say cars, is determined without specifying the demand for cars produced domestically and abroad, e.g. Japan or France. Usually, demand for this aggregate good is negatively related to the own (aggregate) price. The second stage determines the quantities to be consumed of the products from various countries (adding up to the total demand)[12]. Typically, preferences for goods (or inputs into the production process) are represented via a CES utility (or production) aggregator function which aggregates domestic and imported commodities[13]. In this case, the relative market share for the domestically produced good can be expressed as (e.g. Galloway et al. 2003, p. 52)

$$\frac{C_h}{C_f} = \left(\frac{p_f}{p_h} \cdot const \right)^{\sigma}$$

Thus, the demand for the domestic commodity (C_h) relative to the demand for the imported commodity (C_f) is inversely related to the ratio of the prices for the domestic commodity (p_h) and the imported commodity (p_f) to the power of the Armington elasticity σ.[14] By definition, σ is constant in CES aggregator functions. The Armington elasticity depicts the percentage

[11] In an alternative interpretation, product differentiation is the result of companies' attempts to position their products in niche markets.

[12] See, for example, Davis and Kruse (1993) for further details, in particular, on how to correctly aggregate quantities and prices.

[13] CES stands for constant elasticity of substitution. CES utility and production functions are the workhorses for much of the applied modelling because they are relatively easy to implement and parsimonious, i.e. economic relations may be expressed using only a few parameters. Arguably, the best-known and simplest CES function is the Cobb-Douglas Function, where σ = 1. In this case the expenditure (or cost) share of goods (or input factors) remains constant as income (or cost levels) change.

[14] Technical note: If the quantities refer to commodity demand by private households (rather than input demand by companies), the demand functions are the (conditional) compensated or Hicksian demand functions.

change of relative demand for the domestic commodity if the relative price of the domestic commodity changes. For example, if $\sigma = 2$, a one per cent increase in the relative domestic price results in a loss of two per cent in the relative demand for domestic products. If $\sigma = 0$, domestic and foreign commodities are perfect complements and an increase in the relative prices of the domestic commodity would not lead to any substitution away from domestic commodities. The larger the Armington elasticity, the more easily imported commodities may substitute domestic commodities. Therefore, the Armington elasticity may serve as an indicator for the extent to which companies facing international competition are able to pass-through cost increases without losing market shares to imported goods. Sectors exhibiting a low Armington elasticity may pass on the additional carbon costs resulting from the EU ETS more easily to their domestic customers. In contrast, companies from sectors with relatively high Armington elasticities would risk losing significant demand for their products.[15]

Most existing estimates for Armington elasticities rely on time series data. There are 5 large studies for the US: Stern, Francis and Schumacher (1976), Shiells, Stern and Deardorff (1986), Reinert and Roland-Holst (1992), Shiells and Reinert (1993) and Gallaway, McDaniel and Rivera (2003). The most recent study by Gallaway, McDaniel and Rivera (2003) should be highlighted, since they estimate long- and short-term Armington elasticities for 309 sectors at the 4-digit level of Standard Industrial Classification (SIC) for the period 1989 - 1995 in the US (see columns 2 and 3 in Table 5). The authors conclude that long-term elasticities are on average double the size of short-term elasticities. This means, for the same change in the relative price, the percentage change in the share of the demand for the domestic commodity is twice as high in the long run as in the short run. A comparison with the estimates by Reinert and Roland-Holst (1992) (column 2) also shows that a higher disaggregation of the sectors results in higher estimated substitution elasticities.[16]. Erkel-Rousse and Mirza (2002) rely on panel data for industrialized countries and find high price elasticities. The majority of their estimates range from 1 to 13. As expected, the highest estimates tend to correspond to industries producing homogeneous goods.

There are similar studies for other countries, although some of them are already relatively old: Lächler (1985) provides Armington elasticities for Germany, Corado and de Melo (1986) for Portugal, Kapuscinski and Warr (1999) for the Philippines and Panagarya, Shah and Mishra (2001) for Bangladesh. Hummels (1999) and Hertel, Hummels, Ivanic and Keeney (2004) estimate Armington elasticities using a cross-sectional analysis and arrive at much higher estimates (see column 5). The figures from Demailly and Quirion (2007) represent average values from their own literature research. While estimates for Europe are generally rare, most recently, Welsch (2007) has applied time series econometric analyses to estimate Armington elasticities for Italy, Germany, the UK and France. Specifically when accounting for possible nonstationary time series data, the majority of the estimated Armington elasticities are between 0 and 1, and hence substantially lower than most previous studies

[15] Welsch (2007) uses the value of 2 as a benchmark to distinguish between high and low substitution elasticities.

[16] A higher disaggregration allows to differentiate more products of similar nature and thus leads to higher substitution effects. For example on a more disaggregated level butter may be replaced with margarine which would not be possible to single out on the aggregate level ‘food products’.

have found. But large differences exist across sectors and countries.[17] The findings by Welsch (2006) for several industry sectors in France illustrate that Armington elasticities may change over time.

As indicated above, to estimate the total impact of a price increase on the demand for the domestically produced commodity, the effects related to the Armington elasticity and the effects related to the (aggregate) demand elasticity have to be combined. The higher the expenditure share of a consumer good (or cost share of a production input), the higher will be the effect related to the aggregate demand elasticity, and the lower will be the effect related to the Armington elasticity. Thus, even if the aggregate demand elasticity is small (in absolute terms), passing-through the additional costs from the EU ETS may lead to significant losses in demand for the domestic commodity, if the cost/expenditure share is low and the Armington elasticity is high.[18]

The results described above suggest that using estimates of Armington elasticities to assess the impact of the EU ETS for the relevant industry sectors in Germany, or using estimates from other regions instead may easily be challenged. Based on the multitude of different results, it seems little surprising that computable general equilibrium (CGE) modellers tend to rely on "guesstimates" when it comes to selecting the parameter values for Armington (and other) elasticities. Similar to McDaniel and Balistreri (2003), the findings presented in this section suggest that (1) stronger disaggregation of sectors results in higher Armington elasticities, (2) long-term elasticities are higher than short-term ones and (3) time series analyses result in lower elasticities than cross-cutting studies, and (4) Armington elasticities are higher for more homogenous products. In particular, the wide range of estimates cast

[17] Counter to intuition and economic theory, Welsch (2007) also finds negative values for some Armington elasticities. Another (potentially serious) drawback is the short time series of only 12 years. Further, since Welsch (2006, 2007) and others typically use observed market data on prices and quantities, estimates may suffer from simultaneous equation bias: it is not clear whether observed price changes are due to shifts in demand or supply or both. Other studies also find counter-intuitive outcomes. For example, Galloway et al. (2003) report negative values for the Armington elasticities in some sectors, but the negative estimates are usually not statistically significant. Since most studies (including Galloway et al., 2003 and Reinert and Roland-Holst, 1992), use single-equation estimation techniques, their results may also be subject to a simultaneous equation bias. A notable exception is Erkel-Rousse and Mirza (2003) who apply instrument variable techniques to address this potential misspecification problem.

[18] More formally, given the demand structure implied by the Armington assumption, the direct own price elasticity of demand in a region may be expressed as (e.g. Duffy et al. 1990): $\varepsilon_{ii} = -(1 - s_{ii})^* \sigma_i + s_{ii} * \eta_i$ where ε_{ii} reflects the own price elasticity of demand for a particular commodity from region i in region i with respect to to the price of that commodity; s_{ii} is the expenditure share of products from region i in region i, σ_i stands for the Armington elasticity (as discussed in section 4.1.2.) and η_i is the aggregate (or overall) elasticity of demand in region i (discussed in section 4.1.1). Thus, the higher the expenditure share of a consumer good (or cost share of a production input), the higher will be the effect related to the aggregate demand elasticity, and the lower will be the effect related to the Armington elasticity. Thus, even if the aggregate demand elasticity is small (in absolute terms), passing-through the additional costs from the EU ETS may lead to significant losses in demand for the domestic commodity, if the cost/expenditure share is low and the Armington elasticity is high.

doubts on the usefulness of most empirical estimates of Armington elasticities for policy recommendations.[19]

[19] In fact, in light of the wide range of estimates available for cost increases, pass-through rates, aggregate demand elasticities, and Armington elasticities, projections for the changes in demand for the domestically produced product (in response to the EU ETS) implied by the formula presented in footnote 18 may take on a very wide range of outcomes.

Figure 7 Overview: Empirical estimates of Armington elasticities

Reinert and Roland-Holst (1992)			Gallaway, McDaniel and Rivera (2003)				Hertel et al. (2004)		Demailly und Quirion (2007)		Welsch (2007)		
BEA	Sector	Elasticity	SIC	Sector	Elasticity short-term	Elasticity long-term	Sector	Elasticity short-term	Sector	Elasticity	Sector	Elasticity Germany	Elasticity Ø D, FR, IT, UK
1	Iron and ferroalloy ores mining	1.220											
5	Crude petroleum and natural gas	0.310					Oil	10.4					
							Gas	34.4					
							Petroleum, coal products	4.2					
							Gas manufacture, distribution	5.6					
6	Stone, sand, and gravel	0.970											
8	Chemical and fertilizer mineral mining	1.130											
56	Paper mills, except building papers	0.970	2621	Paper mills	1.055		Paper products, publishing	5.9			Paper and printing products		0.342
57	Paperboard mills	1.500	2631	Paperboard mills	0.887								
59	Sanitary paper products	1.420	2676	Sanitary paper products	0.393								
60	Building paper and board mills	0.970											
61	Paper coating and glazing	1.680											
62	Paperboard containers and boxes	1.480	2652	Setup paperboard boxes	0.757								
			2653	Corrugated, solid fiber boxes	1.501								
66	Industrial inorganic and organic chemicals	0.480	2812	Alkalis and chlorine	0.760		Chemical, rubber, plastic prod	6.6			Chemical products	1.878	0.972
			2813	Industrial gases	0.962	1.050							
			2816	Inorganic pigments	0.483	1.152							
67	Agricultural chemicals	0.310	2874	Phosphatic fertilizers	1.215								
			2879	Agricultural chemical products	1.028	1.620							
68	Chemical Preparations	0.960	2891	Adhesives and sealants	1.181	1.873							
			2892	Explosives	0.917								
			2893	Printing ink	0.709								
			2895	Carbon black	−0.242								
			2899	Chemical preparations	1.111	1.811							
69	Plastics materials and resins	1.710	2821	Plastics materials, resins	0.873	4.834							
84	Glass and glass products,except containe	0.360	3211	Flat glass	0.889								
			3229	Pressed and blown glass	4.847								
			3231	Glass produced from pur. glass	1.108								
86	Cement, hydraulic	1.090	3241	Cement, hydraulic	0.729				Cement	2			
87	Brick and structural clay tile	1.040											
88	Ceramic wall and floor tile	0.880	3253	Ceramic wall and floor tile	0.529								
			3255	Clay refractories	0.950	1.463							
90	Ceramic plumbing and electrical supplies	0.840	3261	Vitreous plumbing fixtures	0.784								
			3264	Porcelain electrical supplies	0.949	1.023							
91	China and earthenware products	1.450											
93	Stone and nonmetalic mineral products	0.820	3281	Cut stone and stone products	0.874		Mineral products n.e.c.	5.8			Non-metallic minerals and mineral products	0.915	-0.931
			3291	Abrasive products	1.164	2.382							
			3295	Minerals, ground/treated	1.073	1.128							
			3297	Nonclay refractories	0.797								
			3299	Nonmetallic mineral products	1.211								
94	Primary steel	0.760	3312	Steel works, blast furnaces	2.042		Ferrous metals	5.9	Steel	6	Ferrous and non-ferrous ores and metals	0.687	0.533
			3315	Steel wire products	0.540		metals n.e.c.	8.4					
							Metal products	7.5			Metal products, except machinery and transport eq.	0.229[1)]	1.267
95	Iron and steel foundries	3.080	3321	Gray iron foundries	0.359	0.757							
96	Metal heat treating and primary metal	0.690	3399	Other primary metal products	1.342	1.232			Aluminium	2			
97	Primary copper	0.910											

4.2 Correlation analysis to assess cost pass-through

An evaluation of the impact of the EU ETS on product prices can also be conducted using empirical and statistical analysis to estimate the direct correlation of CO_2 prices and product prices, in particular using regression analysis. This approach has been applied in several studies, in most cases to the electricity sector (Sijm et al. 2008, Bunn and Fezzi 2007) but also to the industrial sector (for example to the cement sector, Walker 2006). The results of these studies vary depending on the country, time horizon and price index under consideration.

A first insight on the correlation of CO_2 pricing and product prices may be gained from a simple graphical illustration of the development of CO_2 and of output prices, e.g. placing CO_2 price trends on the x-axes and product price trends on the y-axes of a chart. While this approach seems straightforward for the electricity sector (with information on daily or hourly spot market prices available), it provides a major challenge for sectors other than electricity. No single price index exists for products that are much less homogenous than electricity. Rather, for most industries, each product has its own market price that may or may not be affected by the EU ETS. Optimally, each of these prices would need to be correlated to CO_2 prices in order to assess the impact of the EU ETS. Such an analysis would, thus, require collecting a vast amount of product price data, which most often is not publicly available. Alternatively, aggregate price indices may serve as proxies. However, these data are often reported on an annual basis only and would not provide sufficient data points to perform a correlation analysis. For some products, quarterly and/or monthly data may be available.

Apart from the problems associated with the collection of prices on manufacturing products, a correlation analysis would face another important set of challenges. First and foremost, a simple correlation of product prices and CO_2 costs would most likely not provide statistically significant conclusions. A number of simultaneous reactions may lead to changes in product prices which would not allow to single out a CO_2 price based effect. A time series regression would perform well if the main explanatory variables were included. This implies that prices for all variable inputs to production (energy prices, intermediate input prices etc.) would need to be included. In addition, changes in product prices may be driven by developments outside of the EU ETS system boundary. High steel demand from China, for example, affects international steel prices and provides a parallel and exogenous driver of product prices in the European Union that would need to be separated from CO_2 based price effects.

All in all, and in line with the above mentioned literature, it can be concluded that a correlation analysis aiming at singling out the effect of CO_2 pricing on product prices would provide a major challenge and most likely give limited insights because of 1) insurmountable data constraints for output prices other than for electricity; 2) estimation bias because of missing data; 3) correlation in independent variables (for example, prices for gas and intermediate inputs); 4) exogenous shocks (such as unexpected price changes); 5) parallel changes in impact factors outside the EU ETS system boundary.

5 Options for treatment of carbon and trade exposed industries

There are several options to deal with distortions in competitiveness and carbon leakage resulting from both exposure to EU ETS induced CO_2 costs and exposure to international competition. The main options are briefly discussed below.

1. *Free allocation for direct emissions*

   Installations from sectors which are significantly exposed to both carbon prices and international competition could be exempted from the gradual phase-out of free allocation between 2013 and 2020. This would compensate operators for the costs related to direct emissions.

   However, compensation by free allocation addresses only the profitability of plant operation and not necessarily carbon leakage or competitiveness. Eventually, competitiveness is determined by the marginal costs of production, which include the opportunity costs of carbon and are – under ideal conditions – independent of the amount of allowances companies receive for free. Likewise, if free allocation of allowances is not terminated after the closure of a plant, a company may “cash-in” on free allowances and still shift production abroad. The empirical evidence from the first two trading periods of the EU ETS shows that no Member State was able to implement effective plant closure provisions which could avoid this effect (without regard to the fact that plant closure provisions can create significant distortions of the CO_2 price signal in general).

   Further, free allocation for direct emissions would not address the effects of indirect CO_2 costs (from electricity prices) which seem to be most significant for some of the exposed sectors.

   Moreover, free allocation for the exposed sectors can only be implemented on a broad level and cannot reflect whether a certain installation is effectively subject to exposure to international competition or not. Therefore, competition distortions within the EU could remain, even if EU-wide harmonized allocation provisions can be implemented (benchmarks, etc).

   Last but not least, the adjustment of the compensation may be rather sluggish if an international agreement would lead to a situation which would no longer require compensatory measures for the exposed sectors.

2. *Free allocation for indirect emissions*

   Installations with high exposure to international competition and high indirect CO_2 costs from power could be allocated for indirect CO_2 emissions alternatively or in addition to free allocation for direct emissions.

   This approach would require a fundamental change of the general design of the EU ETS and could create additional distortions and distributional effects under the EU ETS. It would require an EU-wide harmonized allocation approach for indirect emissions which would be even more complicated than for direct emissions. This is mainly because of the fact that the extent of CO_2 cost pass-through varies in regional electricity markets because of differences in marginal power generation, even if an effective competitive market structure can be assumed.

As in the case of free allocation for direct emissions, compensation for indirect emissions only addresses profitability and can only be implemented on a broad level. It may thus fail to address international competitiveness and leakage concerns.

3. *Border tax adjustments*

Border tax adjustments (BTAs) refer to import tariffs/taxes and export subsidies on certain products imported from, or exported to, regions where companies are not subject to ambitious climate policies.[20] If such adjustments are designed so that importers (exporters) face the same carbon costs as domestic producers (foreign producers) they would cost-efficiently address carbon leakage (and distortion of competition). Thus, in contrast to other options considered, BTAs address differences in marginal production costs across regions resulting from partial implementation of climate policies. BTAs may also serve as a means to induce participation of those countries in a global effort to reduce greenhouse gas emissions which so far have not taken appropriate measures. Adjustment measures at the border are also foreseen in current proposals for other regional emissions trading schemes, including those for the US or for Australia.

However, implementing appropriate BTAs may be difficult in practice. First, for the “ideal mechanism” watertight commodity-specific information on carbon emissions would have to be available not only for commodities produced in the EU but also for commodities imported. Alternatively, charges and exemptions may be based on benchmarks as proxies. Second, the set of commodities which would be subject to BTAs has to be defined. Since the EU ETS also results in an increase in the price of intermediate commodities such as electricity, the competitiveness of companies which do not participate in the EU ETS but intensively use these intermediates may also be affected negatively (e.g. large parts of the chemical industry). Third, it is doubtful whether BTAs would be compatible with current WTO/GATT rules.[21] The refund for exports may violate subsidy clauses, while import tariffs may be viewed as forbidden discrimination.[22] However, BTAs might be allowed if they are based on emissions of best-available technologies[23]. Fourth, the set of countries affected by BTAs have to be defined.[24] The fact that countries are subject to emission targets

[20] Refunding carbon costs for exports presupposes that companies have to purchase allowances. Hence in the context of the new ETS Directive, compensation would have to be limited to the share of allowances companies have to purchase. In addition, compensation would have to be adjusted over time to reflect the proposed decrease in free allocation between 2013 and 2020.

[21] See Umweltbundesamt (2008) for a recent legal assessment.

[22] The latter may be avoided if exports into the EU were taxed by the exporting rather than by the importing region. In this case, revenues from export taxes may smooth opposition by exporting countries.

[23] See, for example: Ismer and Neuhoff (2004).

[24] Depending on the selection of countries affected by BTAs, there will be significant differences in terms of countries/regions benefitting within the EU. For example, old Member States would benefit

within the UNFCCC is likely to be an imperfect indicator for the carbon costs companies face in these countries. Finally, since BTAs lead to higher production levels in the EU compared to a case without special treatment of carbon and trade exposed industries, demand for EUAs will increase and prices for EUAs will be higher. However, this effect is likely to be small and might be compensated by the benefits of the full carbon price signal feeding through the economy and thus facilitating the substitution towards more carbon efficient processes, products and services. If the border adjustment scheme requires importers to purchase EUA allowances (rather than paying a tax),[25] the additional demand for EUAs and the price increase is expected to be higher – assuming that production abroad is more carbon-intensive than in the EU.[26]

4. *Direct compensation (state aid)*

Another approach to address competitiveness and leakage concerns may involve compensation of affected companies that can prove the problem of leakage.[27] They could be compensated by direct transfers within a special framework which allows state aid for this purpose.[28]

Much more in-depth analysis is needed to design and assess this option for compensation. However, three potential advantages can be identified for such an approach. First, the compensation could be limited to those individual companies which can prove the problem of leakage (hardship rule). This would reduce the potential competition distortions within the EU which must be assumed at least for option 1 and 2. Second, it would not only have an effect on the profitability of production but would more likely be effective in avoiding leakage. Third, the compensation can be adjusted more easily if an international climate agreement is implemented which would no longer legitimate compensatory measures.

5. *Sectoral agreements*

Sectoral agreements refer to voluntary or government-lead global or regional agreements on limiting or reducing greenhouse gas emissions in a specific sector. They may be set between industries, industry associations, governments and/or non-governmental organizations and offer the opportunity to engage a wider set of

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more than new Members States from BTAs imposed on Non Annex B countries. Further, exporting sectors in the EU would benefit more than sectors facing import competition (for both points, see Peterson and Schleich 2007).

[25] According to Article 10b in the proposed Directive importers of products produced in sectors or sub-sectors determined in accordance with Article 10a may be included in the Community scheme.

[26] Also note that "general equilibrium effects", including adjustments in the terms of trade, exchange rates, or factor prices, will dampen the effects of BTAs. In the simplest case, the effect of a BTA may even be neutral, i.e. only have nominal effects on the price levels, but no real effects in terms of production or trade levels (see Lockwood and Whalley, 2008). In essence, the arguments mirror the discussion on whether the "origins principle" or the "destination principle" at the border should be applied for value added taxes (see also Grossman 1980).

[27] How this could be proofed and when (ex-ante or ex-post) may be a matter of discussion and would require further investigation.

[28] How such a framework may look like would need to be investigated from a legal perspective.

countries into climate policy. To ensure a more even level playing field and thus address competitiveness concerns and potential leakage effects they need to be designed in a way that they ensure that CO_2 costs are reflected in product prices.

Voluntary, private sector-lead agreements are considered unlikely to address competitiveness concerns and to create a level playing field. Sectors may agree to voluntary emissions reductions because they may create a competitive advantage for participating firms or they may defer a stringent government policy. Such agreements are hard to establish on a global level since on a global level no competitive advantage would result and no supranational government policy would be available to serve as a threat.[29]

Government-led global sectoral agreements are more likely to address competitiveness concerns. They ensure that all firms in participating countries are covered and that these firms face a level playing field. However, incentives may be needed to induce countries to participate. These could include transfers to attract countries to participate or measure to reduce disincentives to participate, such as border tax adjustments. Additionally, differentiated regional benchmarks may serve as an initial incentive to participate. However, such differentiated benchmarks will still provide incentives for relocation and leakage, and would need to converge to rule out leakage. Given that an incentive structure is needed to attract participation from all (or at least the most important international trade) countries, such sectoral agreements may be difficult to be put into practice and will face challenges similar to those pointed out for BTA and other global measures. Moreover, sectoral agreements for sectors which are significantly exposed to both carbon prices and international competition would only cover direct emissions. Indirect emissions are more difficult to tackle. They would need to be derived based on electricity intensity of production as well as the emissions intensity of electricity generation for this sector for each country. Alternatively, average country specific emission intensities of electricity generation could be used. However, this implies that sectoral agreements for indirect emissions would need to be tackled on a more detailed level.

[29] Compare Colombier and Neuhoff (2007).

6 Conclusions

This paper presents a discussion of methods, and provides empirical results, for the analysis of effects of the EU ETS on product costs and subsequent impacts on international competitiveness. The discussion shows that the combination of intensity of trade indicators and value at stake indicators reveals meaningful results that allow assessing the potential for distortion in competitiveness induced by the EU ETS.

Other indicators or methods to assess price induced changes in national demand, imports or exports, such as aggregate demand or Armington elasticities, are commonly used but are considered less suitable because of their ambiguity and dependence on estimation method and data sample. Reliable elasticity values for the case of German industries are rare. Correlation analysis which aims to evaluate the impact of the EU ETS on product prices using empirical and statistical analysis suffers from insurmountable data constraints, estimation biases, and can therefore not be unconditionally recommended.

The analysis of trade intensities and value at stake showed that a small number of sectors may in fact be exposed to distortions in competitiveness due to both high trade intensity and high value at stake. For Germany, these include “basic iron and steel”; “fertilizers and nitrogen compounds”; “paper and paperboard”; “aluminium and aluminium products” and “other basic inorganic chemicals”. A number of other sectors reveal a high intensity of trade but low value at stake which implies that the increase in product costs due to the EU ETS is relatively small and negative effects on competitiveness may not be likely. Similarly, sectors with high EU ETS related cost effects but low trade intensity are not expected to be significantly threatened by distortions in international competitiveness.

For the sectors that reveal high values at stake and high trade intensities, market positions are likely to change under the EU ETS due to increased production costs and high exposure to international competition. Firms may need to adjust their activities which may involve shifting production - or even relocating their business activity - to countries without comparable mitigation policies, which would imply carbon leakage.

Approaches to address competitiveness effects and leakage concerns would ideally be considered on a sector by sector basis. They include continued free allocation of emissions rights (grandfathered or output-based), direct payments to affected sectors, sectoral agreements and border adjustment measures. Such policies would allow pursuing unilateral stringent emissions reductions while not putting the economic performance of those sectors at stake. While a detailed assessment of such policies is beyond the scope of this analysis, it can be concluded that in some cases economic distortion through indirect cost effects can occur even with free allocation of emissions allowances to industrial sectors. In order to keep international trade distortions within the European Union at a minimum, harmonized allocation rules, such as sector specific minimum auction requirements, will be essential.

Finally, when deciding on which sectors are highly exposed to possible distortions in competitiveness and which measures should be implemented to address competitiveness and leakage it should be kept in mind that CO_2 costs are only one of multiple factors affecting companies’ production and investment decisions. Other factors that may deserve detailed investigation include product differentiation and market segmentation within a sector (including specialty products), close cooperation with domestic/European partners and intrafirm trade, differences across countries in the costs for labour and other input factors, in infrastructure quality, transportation costs, political and legal environment, or exchange rate risks.

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8 Annex A: Industrial sectors chosen for comparison

The industrial sectors chosen in the analysis correspond to the sectors where operators of ETS installations submitted emission inventory reports to the German Emissions Trading Authority (DEHSt). Only sectors with 3 or more installations were considered. Two sectors were added: other non-metallic mineral products (as this contains rockwool that entered the Emissions Trading Scheme in 2008) and copper products (due to its high electricity consumption). There were no disaggregated data for coke and refined petroleum products; as a result, this category remains aggregated at the 2-digit level in the NACE code.

Of the 1 849 German installations participating in the Emissions Trading Scheme in 2006, every second one reported that it belonged to sectors of the manufacturing industry and mining (NACE codes 10 to 36, see Table 6). Of the remaining installations, 96% produce and distribute electricity, gas and heat (NACE 40); installations of the public administration, military and hospitals complete the picture.

The industrial sectors with the highest number of installations are the production of bricks, tiles and construction products in baked clay (NACE 26.4) and the production of paper and paperboard (NACE 21.12). In total operators reported to belong to 105 different sectors, but 37 out of these reported one installation each.

An analysis of the data reported by operators showed inconsistencies between the sectors according to NACE codes and the activity according to Annex 1 of the German Law on Emissions Trading (TEHG) (see Graichen, J. et al (2006)). For example industrial combustion installations were incorrectly assigned to industrial sectors; this is especially true with regard to the production of paper and paperboard (NACE 21.12) and the production of sugar (NACE 15.83).

Table 5 Industrial branches and number of installations participating in the emissions trading scheme in Germany according to operator information

NACE Code	English	German	No. of installa-tions
WZ-111	Crude petroleum & natural gas	Erdöl & Erdgas	8
WZ-1513	Meat & poultry meat products	Verarbeitetes Fleisch	3
WZ-1531	Processed & preserved potatoes	Kartoffeln	4
WZ-1542	Refined oils & fats	Öle & Fette, raffiniert, Nebenprodukte	4
WZ-1551	Dairy products	Milch & Milcherzeugnisse (ohne Speiseeis)	13
WZ-1562	Starches & starch products	Stärke & Stärkeerzeugnisse	5
WZ-1583	Sugar	Zucker	34
WZ-1586	Coffee & tea	Kaffee & Tee, Kaffee-Ersatz	8
WZ-1589	Other food products n.e.c.	Sonstige Nahrungsmittel (ohne Getränke)	10
WZ-1596	Beer made from malt	Bier	17
WZ-173	Textile finishing services	Textilveredlung	9
WZ-202	Veneer sheets; plywood, lamin-, particle & fibre board	Sperrholz & Spanplatten	11
WZ-203	Builders' joinery & carpentry, of wood	Bautischler- & Zimmermannsarbeiten	3
WZ-2111	Pulp	Holz- & Zellstoff	5
WZ-2112	Paper & paperboard	Papier, Karton & Pappe	140
WZ-2122	Household & toilet paper & paper products	Haushalts-, Hygiene- & Toilettenartikel	12
WZ-2222	Printing services n.e.c.	Drucke, a.n.g.	6
WZ-23	Coke, refined petroleum products & nuclear fuel	Kokerei-, Mineralölerzeugn., Brutstoffe	-
WZ-231	Coke oven products	Kokereierzeugnisse	5
WZ-232	Refined petroleum products	Mineralölerzeugnisse	39
WZ-2412	Dyes & pigments	Farbstoffe & Pigmente	4
WZ-2413	Other basic inorganic chemicals	Sonst. anorganische Grundstoffe & Chemikalien	10
WZ-2414	Other basic organic chemicals	Sonst. organische Grundstoffe & Chemikalien	29
WZ-2415	Fertilizers & nitrogen compounds	Düngemittel & Stickstoffverbindungen	17
WZ-2416	Plastics in primary forms	Kunststoffe, in Primärformen	5
WZ-2441	Basic pharmaceutical products	Pharmazeutische Grundstoffe	3
WZ-2442	Pharmaceutical preparations	Pharmaz. Spezialitäten & sonst. Erzeugn.	8
WZ-2452	Perfumes & toilet preparations	Duftstoffe & Körperpflegemittel	3
WZ-2466	Other chemical products n.e.c.	Chemische Erzeugnisse, a.n.g.	9
WZ-2511	New & used rubber tyres & tubes	Bereifungen, neu, aus Kautschuk	5
WZ-2513	Other rubber products	Andere Gummiwaren (ohne Bereifungen)	4
WZ-2524	Other plastic products	Andere Kunststoffwaren	3
WZ-2611	Flat glass	Flachglas	16
WZ-2612	Shaped & processed flat glass	Bearbeitetes Flachglas	4
WZ-2613	Hollow glass	Hohlglas	49
WZ-2614	Glass fibres	Glasfasern	12
WZ-2615	Other glass, processed, incl. technical glassware	Sonstiges Glas	17
WZ-2624	Technical ceramic wares	Andere technische Keramikwaren	6
WZ-2625	Ceramic articles n.e.c.	Andere keramische Waren, a.n.g.	8
WZ-2626	Refractory ceramic goods	Feuerfeste keramische Werkstoffe	26
WZ-263	Ceramic tiles & flags	Keramische Fliesen & Platten	3
WZ-264	Bricks, tiles & construction products	Ziegel, sonstige Baukeramik	165
WZ-2651	Cement	Zement	46
WZ-2652	Lime	Kalk	52
WZ-2681	Abrasive products	Mühl-, Mahl-, & Poliersteine	5
WZ-2682	Other non-metallic mineral products n.e.c.	Mineralerzeugnisse, a.n.g.	-
WZ-271	Basic iron & steel & ferro-alloys	Roheisen & Stahl	39
WZ-2742	Aluminium & aluminium products	Aluminium & Halbzeug daraus	4
WZ-2744	Copper products	Kupfer & Halbzeug daraus	2
WZ-284	Forging, pressing, stamping & roll forming of metal	Schmiede-, Press-, Zieh-, Stanzteilen u.ä.	3
WZ-2914	Bearings, gears, gearing & driving elements	Lager, Getriebe, Zahnräder & Antriebselemente	4
WZ-321	Electronic valves, tubes & other components	Elektronische Bauelemente	4
WZ-341	Motor vehicles	Kraftwagen & -motoren	18
WZ-343	Parts & accessories for motor vehicles & their engines	Kraftwagenzubehör , -teile & -motoren	15
WZ-353	Aircraft & spacecraft	Luft- & Raumfahrzeuge	5

Sources: DEHSt Data (as of 29/11/2006), Öko-Institut

9 Annex B: Trade Intensity 2000-2005

Table 6 Trade intensity for German sectors with countries outside the EU, 2000-2005

		Trade Intensity nonEU					
NACE	**Industrial Sector**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
WZ-111	Crude petroleum & natural gas	73.7%	69.8%	69.9%	67.6%	68.2%	73.3%
WZ-1513	Meat & poultry meat products	2.2%	3.4%	2.4%	2.5%	1.4%	1.6%
WZ-1531	Processed & preserved potatoes	1.3%	1.7%	2.6%	2.5%	2.6%	2.8%
WZ-1542	Refined oils & fats	-	-	-	-	-	-
WZ-1551	Dairy products	3.7%	3.8%	3.5%	3.2%	3.2%	3.0%
WZ-1562	Starches & starch products	17.8%	14.8%	14.5%	12.2%	12.8%	10.8%
WZ-1583	Sugar	5.9%	8.1%	4.6%	4.9%	4.5%	7.6%
WZ-1586	Coffee & tea	8.2%	7.4%	7.4%	7.8%	8.5%	9.8%
WZ-1589	Other food products n.e.c.	14.2%	14.1%	15.2%	14.9%	16.4%	17.1%
WZ-1596	Beer made from malt	2.3%	2.6%	2.8%	2.7%	2.5%	2.4%
WZ-173	Textile finishing services	-	-	-	-	-	-
WZ-202	Veneer sheets; plywood, lamin-, particle & fibre board	18.2%	17.9%	17.6%	18.3%	19.9%	19.3%
WZ-203	Builders' joinery & carpentry, of wood	4.8%	5.0%	5.0%	5.4%	6.0%	7.0%
WZ-2111	Pulp	46.3%	44.2%	41.1%	39.5%	37.9%	35.9%
WZ-2112	Paper & -board	16.2%	16.1%	16.6%	17.1%	18.5%	19.0%
WZ-2122	Household & toilet paper & paper products	6.9%	8.0%	7.1%	7.8%	8.3%	8.1%
WZ-2222	Printing services n.e.c.	3.9%	3.8%	4.6%	4.8%	4.4%	4.2%
WZ-23	Coke, refined petroleum products & nuclear fuel	4.3%	3.5%	3.1%	3.0%	4.0%	4.9%
WZ-231	Coke oven products	-	-	-	-	-	-
WZ-232	Refined petroleum products	-	-	-	-	-	-
WZ-2412	Dyes & pigments	55.8%	49.9%	51.8%	35.3%	31.2%	55.1%
WZ-2413	Other basic inorganic chemicals	28.7%	26.3%	22.6%	33.5%	31.9%	31.8%
WZ-2414	Other basic organic chemicals	21.3%	19.4%	26.0%	24.2%	32.4%	28.4%
WZ-2415	Fertilizers & nitrogen compounds	18.4%	18.8%	17.0%	15.7%	14.8%	18.9%
WZ-2416	Plastics in primary forms	11.9%	12.2%	12.7%	13.6%	13.0%	13.6%
WZ-2441	Basic pharmaceutical products	73.0%	83.6%	87.2%	86.4%	83.7%	89.1%
WZ-2442	Pharmaceutical preparations	30.9%	36.0%	27.0%	25.5%	28.5%	27.6%
WZ-2452	Perfumes & toilet preparations	16.9%	18.8%	20.0%	20.9%	21.1%	24.6%
WZ-2466	Other chemical products n.e.c.	40.4%	41.7%	41.5%	41.5%	46.0%	43.4%
WZ-2511	New & used rubber tyres & tubes	14.4%	14.0%	13.9%	14.2%	14.7%	15.3%
WZ-2513	Other rubber products	16.6%	17.5%	17.6%	18.3%	19.5%	19.4%
WZ-2524	Other plastic products	13.0%	13.0%	13.0%	13.0%	14.2%	14.9%
WZ-2611	Flat glass	13.8%	15.3%	12.2%	13.2%	15.7%	15.3%
WZ-2612	Shaped & processed flat glass	10.9%	13.3%	12.7%	12.8%	13.0%	14.0%
WZ-2613	Hollow glass	12.9%	13.6%	14.4%	14.0%	15.8%	15.9%
WZ-2614	Glass fibres	11.1%	14.0%	13.0%	11.8%	11.4%	12.8%
WZ-2615	Other glass, processed, incl. technical glassware	29.7%	31.1%	25.9%	23.3%	26.4%	27.6%
WZ-2624	Technical ceramic wares	27.6%	28.4%	29.1%	30.4%	32.7%	30.8%
WZ-2625	Ceramic articles n.e.c.	11.4%	12.2%	13.9%	13.6%	15.5%	16.9%
WZ-2626	Refractory ceramic goods	35.8%	34.2%	35.3%	37.2%	40.6%	39.8%
WZ-263	Ceramic tiles & flags	8.6%	9.8%	9.7%	9.6%	11.3%	11.8%
WZ-264	Bricks, tiles & construction products	0.8%	1.1%	1.3%	1.3%	1.7%	2.2%
WZ-2651	Cement	1.0%	0.9%	1.4%	1.6%	1.5%	1.7%
WZ-2652	Lime	1.1%	1.1%	1.3%	1.2%	0.8%	0.8%
WZ-2681	Abrasive products	29.1%	28.9%	29.6%	29.1%	32.0%	34.0%
WZ-2682	Other non-metallic mineral products n.e.c.	10.0%	11.0%	11.8%	11.3%	11.7%	11.6%
WZ-271	Basic iron & steel	11.2%	12.6%	12.3%	12.6%	12.7%	14.5%
WZ-2742	Aluminium & aluminium products	24.5%	24.1%	24.0%	25.0%	25.5%	25.7%
WZ-2744	Copper products	26.0%	21.4%	21.3%	22.4%	26.4%	26.4%
WZ-284	Forging, pressing, stamping & roll forming of metal	-	-	-	-	-	-
WZ-2914	Bearings, gears, gearing & driving elements	21.4%	22.7%	22.5%	23.0%	24.7%	25.1%
WZ-321	Electronic valves, tubes & other components	54.8%	51.4%	48.2%	49.8%	49.2%	48.3%
WZ-341	Motor vehicles	18.1%	18.4%	19.5%	19.1%	18.1%	18.7%
WZ-343	Parts for motor vehicles & their engines	13.0%	13.1%	13.7%	14.4%	14.6%	16.2%
WZ-353	Aircraft & spacecraft	51.0%	51.1%	48.2%	47.2%	46.2%	43.4%

Sources: German Statistical Office, calculations by Öko-Institut

Table 7 Trade intensity for German sectors with countries neither belonging to the EU nor to the OECD, 2000-2005

		Trade Intensity nonEU nonOECD					
NACE	**Industrial Sector**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
WZ-111	Crude petroleum & natural gas	53.0%	46.5%	44.5%	41.2%	45.2%	50.6%
WZ-1513	Meat & poultry meat products	2.0%	3.2%	2.2%	2.3%	1.3%	1.5%
WZ-1531	Processed & preserved potatoes	0.9%	1.2%	1.8%	1.7%	1.8%	2.0%
WZ-1542	Refined oils & fats	-	-	-	-	-	-
WZ-1551	Dairy products	2.4%	2.5%	2.1%	2.1%	2.1%	1.9%
WZ-1562	Starches & starch products	7.6%	6.1%	5.9%	5.0%	5.3%	4.9%
WZ-1583	Sugar	4.7%	6.9%	3.3%	3.7%	3.2%	6.4%
WZ-1586	Coffee & tea	2.9%	3.3%	3.3%	3.3%	3.4%	4.0%
WZ-1589	Other food products n.e.c.	6.1%	6.2%	6.8%	6.4%	7.2%	7.8%
WZ-1596	Beer made from malt	0.3%	0.4%	0.5%	0.5%	0.4%	0.4%
WZ-173	Textile finishing services	-	-	-	-	-	-
WZ-202	Veneer sheets; plywood, lamin-, particle & fibre board	8.2%	7.7%	6.8%	7.0%	7.4%	7.4%
WZ-203	Builders' joinery & carpentry, of wood	2.1%	2.0%	1.7%	1.7%	2.2%	2.6%
WZ-2111	Pulp	14.3%	13.6%	14.1%	15.0%	16.1%	17.8%
WZ-2112	Paper & -board	5.0%	5.1%	5.7%	5.9%	6.4%	7.1%
WZ-2122	Household & toilet paper & paper products	1.4%	1.5%	1.7%	2.0%	2.2%	2.4%
WZ-2222	Printing services n.e.c.	1.6%	1.3%	1.5%	1.5%	1.8%	1.7%
WZ-23	Coke, refined petroleum products & nuclear fuel	2.3%	2.0%	1.6%	1.5%	2.0%	2.1%
WZ-231	Coke oven products	-	-	-	-	-	-
WZ-232	Refined petroleum products	-	-	-	-	-	-
WZ-2412	Dyes & pigments	22.7%	21.2%	23.1%	15.1%	13.5%	24.5%
WZ-2413	Other basic inorganic chemicals	9.4%	8.3%	9.2%	14.3%	15.0%	15.3%
WZ-2414	Other basic organic chemicals	6.8%	5.9%	7.3%	7.4%	9.6%	9.4%
WZ-2415	Fertilizers & nitrogen compounds	13.6%	13.4%	11.9%	11.1%	10.9%	13.6%
WZ-2416	Plastics in primary forms	4.7%	5.1%	5.2%	5.6%	5.6%	6.1%
WZ-2441	Basic pharmaceutical products	19.0%	20.9%	21.5%	21.1%	22.3%	23.2%
WZ-2442	Pharmaceutical preparations	6.1%	7.0%	5.2%	4.5%	4.5%	4.7%
WZ-2452	Perfumes & toilet preparations	8.0%	9.3%	10.1%	10.2%	9.9%	11.5%
WZ-2466	Other chemical products n.e.c.	12.8%	13.4%	14.7%	15.2%	17.0%	17.0%
WZ-2511	New & used rubber tyres & tubes	4.5%	4.7%	4.5%	4.8%	5.1%	5.9%
WZ-2513	Other rubber products	6.6%	7.4%	7.7%	8.2%	8.7%	8.7%
WZ-2524	Other plastic products	5.5%	5.7%	5.7%	5.7%	6.3%	6.9%
WZ-2611	Flat glass	2.3%	2.3%	1.8%	2.4%	3.7%	3.9%
WZ-2612	Shaped & processed flat glass	2.7%	4.1%	4.0%	3.6%	3.7%	4.1%
WZ-2613	Hollow glass	4.7%	5.6%	6.2%	6.4%	7.6%	8.2%
WZ-2614	Glass fibres	2.4%	3.5%	3.8%	5.4%	4.6%	4.7%
WZ-2615	Other glass, processed, incl. technical glassware	8.7%	8.3%	7.6%	7.0%	7.9%	9.1%
WZ-2624	Technical ceramic wares	6.1%	5.4%	6.3%	6.9%	8.1%	7.6%
WZ-2625	Ceramic articles n.e.c.	5.4%	5.5%	6.7%	6.8%	7.5%	7.5%
WZ-2626	Refractory ceramic goods	22.6%	21.6%	22.0%	22.2%	26.4%	26.4%
WZ-263	Ceramic tiles & flags	2.5%	3.4%	3.7%	3.8%	4.8%	4.8%
WZ-264	Bricks, tiles & construction products	0.3%	0.3%	0.4%	0.4%	0.7%	0.9%
WZ-2651	Cement	0.7%	0.5%	0.9%	0.8%	0.7%	0.7%
WZ-2652	Lime	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%
WZ-2681	Abrasive products	8.8%	9.5%	9.8%	9.5%	10.7%	11.7%
WZ-2682	Other non-metallic mineral products n.e.c.	3.1%	3.7%	4.6%	4.7%	5.0%	4.9%
WZ-271	Basic iron & steel	4.5%	6.1%	6.1%	7.0%	6.6%	8.1%
WZ-2742	Aluminium & aluminium products	9.6%	9.7%	9.6%	10.5%	12.1%	11.9%
WZ-2744	Copper products	17.0%	13.0%	13.0%	13.7%	17.2%	18.7%
WZ-284	Forging, pressing, stamping & roll forming of metal	-	-	-	-	-	-
WZ-2914	Bearings, gears, gearing & driving elements	7.0%	8.3%	8.4%	9.1%	10.4%	10.8%
WZ-321	Electronic valves, tubes & other components	24.0%	23.4%	22.9%	25.6%	26.2%	25.9%
WZ-341	Motor vehicles	3.3%	4.2%	4.3%	4.2%	3.9%	4.5%
WZ-343	Parts for motor vehicles & their engines	4.3%	5.0%	5.6%	6.1%	6.0%	6.5%
WZ-353	Aircraft & spacecraft	7.6%	7.5%	9.1%	12.7%	13.0%	11.1%

Sources: German Statistical Office, calculations by Öko-Institut

10 Annex C: Analysis of exposed sectors[30]

This chapter takes a closer look at the exposed sectors in Germany, which are above the 10% level each for value at stake and trade intensity. In the following, it identifies processes and products, energy use and trade flows. Trade flows are analysed for the year 2005 and for Germany's main non-EU trading partners in the respective sectors.

The exposed sectors refer to the different NACE categories. In general, energy-intensive processes in the basic inorganic chemical industry include chlorine-alkali-electrolysis, the separation of air (oxygen and nitrogen), the production of hydrogen, aluminium oxide, soda, ammonia and of calcium carbide. Using a higher level of aggregation, the processes belong to the following NACE categories: fertilizer & nitrogen compounds (24.15), production of aluminium (27.42) and other inorganic chemicals (24.13). Gases (24.11) also belong to this group, but they are not an exposed sector and, therefore, not studied in detail. Moreover, the basic iron and steel (27.1) as well as the paper and paperboard (21.12) sectors are exposed in Germany.

10.1 Fertilizer and nitrogen compounds

About 1.4 % of total world consumption of fossil energy (not including combustion of wood) goes into the production of ammonia, roughly 83 % of which is used for fertilizers (e.g. Bhattacharjee 2006, Ullmann 2006, Gielen 2007). The remainder mostly serves as a building block for the synthesis of many pharmaceuticals. As such, ammonia may be applied as a gas or converted to other chemical forms such as urea and applied either in granular form or in solution.

Ammonia is typically produced by the Haber-Bosch method consisting of the subsequent three steps (Ullmann 2008):

1. Production of a mixture of hydrogen, carbon monoxide and nitrogen by first converting natural gas or liquefied petroleum gas (i.e. propane and butane) or petroleum naphtha into gaseous hydrogen and then removing the sulphur compounds. Catalytic steam reforming then leads to hydrogen plus carbon monoxide.
2. The water gas shift reaction is used to convert the carbon monoxide into carbon dioxide and more hydrogen from the process gas.
3. The hydrogen is then catalytically reacted with nitrogen to form anhydrous liquid ammonia in the so called ammonia synthesis loop.

Since the 1930s, when steam reforming of hydrocarbons for ammonia production started specific energy consumption per t of ammonia has come down from more than 80 GJ to best available technology levels of about 28 GJ (Rafiqul 2005). The average specific energy use in Western European countries is around 35 GJ (Gielen 2007, Rafiqul 2005). The first stage is the most energy-intensive stage accounting for more than half of total specific energy use and almost three quarters in modern plants (Rafiqul 2005). In general, though, specific

[30] Contributions by Clemens Cremer, Daniel Fehrenbach and Frank Marscheider-Weidemann (all Fraunhofer ISI) to this Annex are gratefully acknowledged.

consumption levels depend on the type of feedstock used. Using natural gas requires the lowest and the gasification of coal the highest specific energy use (Ullmann 2008, Rafiqul et al. 2005). If natural gas is used, about 80% are typically consumed as reformer feed and 20% as reformer fuel.

Alternatively, ammonia may also be formed as a by-product in coking plants. But less than one percent of total ammonia is produced via this route, and none in the US or in Europe.

Trade structure

Non-EU trade in fertilizers and nitrogen compounds is the lowest in comparison with the other four sectors. Figure 8 shows that the 10 main import partners account for 96%, whilst the Russian Federation alone makes up 72%. Non-EU imports (total: 96 million EUR) equal about 13% of intra-EU imports to Germany (total: 751 million EUR). Non-EU exports (total: 570 million EUR) are nearly six times higher than imports and correspond to 58% of intra-EU exports from Germany (total: 989 million EUR). Main non-EU destinations are Brazil, the USA and India (s. Figure 9).

Figure 8 Main import partners of Germany for fertilizers and nitrogen compounds in 2005

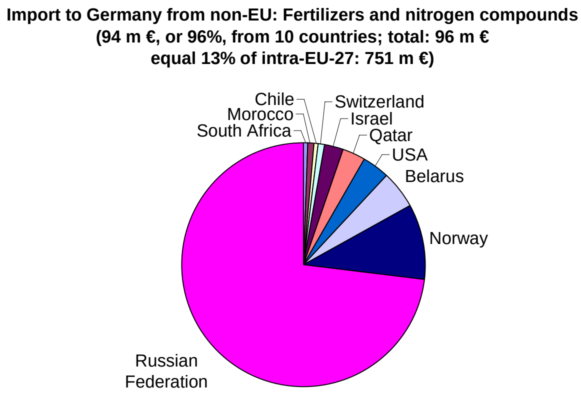
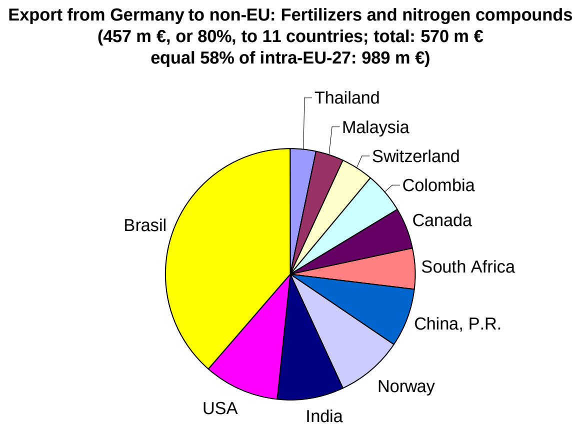


Figure 9 Main export partners of Germany for fertilizers and nitrogen compounds in 2005



Source: Calculations by Öko-Institut based on DESTATIS[31]

10.2 Steel production

The two main processes to produce crude steel are the basic oxygen furnace (BOF) route and the electric arc furnace (EAF) route[32]. For the production of BOF steel in integrated steelworks two steps may be distinguished. First, starting from iron ore, pig iron is produced

[31] DESTATIS: GENESIS-Online database (accessed 21 July 2008)

[32] Other conversion processes for steel production like the open hearth furnaces process (or the direct reduction route for iron production) are no longer (or not) used in Germany.

in blast furnaces which are fed with sinter, coke and additives. In the second step, pig iron is converted to steel in a basic oxygen furnace. In the alternative EAF route, steel is made in electric arc furnaces where scrap is melted into crude steel.

For the EAF route, electricity is the principal energy input. In comparison, for the BOF route coke is the main fuel and used, in particular, to generate thermal heat for the conversion process. In addition, coke also serves as reducing agent for the reduction of the iron oxide into metallic iron. Many integrated steelworks include a coking plant on site, where coke is produced from coal via heating in the absence air (pyrolysis), yielding coke as primary product, as well as coke oven gas and liquid products like tars.

Before sold on the final market, crude steel needs to be treated metallurgically, cast and rolled. Hence, the most relevant final products are made from rolled steel.

BOF steel typically allows for a wider variety of products as it is newly produced from iron ore and does not contain alloy elements. In contrast, EAF steel made from scrap contains alloy elements that are brought into the product with the scrap, which cannot easily be separated from the steel. Hence, EAF steel is usually considered to be of lower quality than BOF steel. Consequently, BOF steel tends to be transformed into rather flat products, such as sheets for car manufacturing, while EAF steel is used for long products such as concrete reinforcing bars in the construction sector. There are, however, options to improve the quality of EAF steel e.g. by adding highly pure iron produced via the DRI route to the input. This allows diluting the concentration of undesired alloy elements.

According to the International Iron and Steel Institute (2007) the share of EAF in Germany is about 31% and hence below the EU 27 average of 38% and much lower in some other EU member states like Spain (76%) or Italy (60%). Production of crude steel in Germany is now around 47 million tons, an increase of almost 10 % since 1995. Germany is a net exporter of long products as well as flat products.

Energy use

Between 1991 and 2002 total aggregate energy use per ton of steel in Germany decreased from 4.56 MWh/t to 3.85 MWh/t, i.e. by about 30 %. More specifically, specific fuel use dropped by 16 % from 3.88 MWh/t to 3.28 MWh/t, while specific electricity use declined by 15 % from 0.68 MWh/t to 0.58 MWh/t.[33] Since the share of EAF has increased over that time period, the specific electricity use in EAF was more profound while the decline in specific fuel use was smaller than suggested by these aggregate figures.

Table 8 provides an overview of the average energy use for the various production steps of the two routes of steel production in Germany[34]:

[33] Information based on Odyssee-Mure Database.

[34] To calculate specific figures per ton of BOF steel the following factors were applied: *0.81 t sinter/t oxygen steel*, *0.35 t coke/t oxygen steel* and *0.93 t crude steel/t oxygen steel* (Statistisches Jahrbuch der Stahlindustrie 2005, BREF 2001).

Table 8 Specific energy use in the production of steel in Germany

	fossil fuels [GJ/t steel]	electricity [kWh/t steel]
Sinter	1.8	33.3
Coking plant	3.3	40.0
Blast furnace	15.2	106.4
BOF steel	**16.7**	**140.0***
EAF steel	**0.4**	**535.9**
* need to add 55 kWh/t steel for the production of oxygen		

Source: Calculations by Fraunhofer ISI based on DESTATIS (2004)

Trade structure

Non-EU trade in basic iron and steel and ferro-alloys is manifold (s. Figure 10). However, the Russian Federation, South Africa and Switzerland account for half the imports of the main dozen of countries. Non-EU imports equal 21% of intra-EU imports to Germany (total: 12633 million EUR). Intra-EU exports from Germany value a comparable amount (total: 11788 million EUR), whereas non-EU exports resemble 35% (total: 4166 million EUR) of these. The 13 main non-EU destinations make up 80%, of which the principal ones are the USA, Switzerland, China P.R. and Turkey (s. Figure 11).

Figure 10 Main import partners of Germany for basic iron and steel and ferro-alloys in 2005

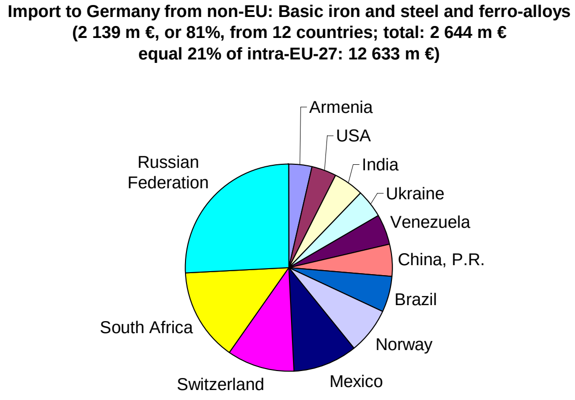
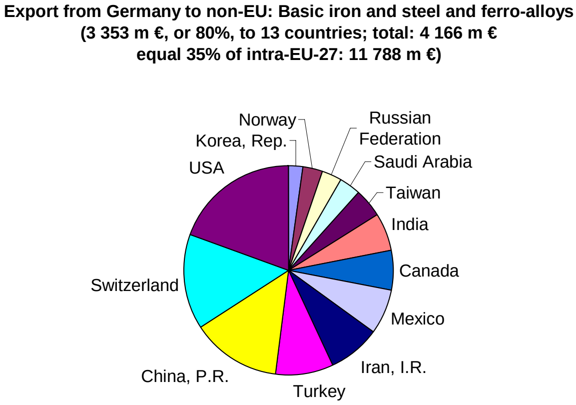


Figure 11 Main export partners of Germany for basic iron and steel and ferro-alloys in 2005



Source: Calculations by Öko-Institut based on DESTATIS[35]

[35] DESTATIS: GENESIS-Online database https://www-genesis.destatis.de/genesis (accessed 21 July 2008)

10.3 Aluminium production

Along the production chain, primary aluminium requires four to six tonnes of bauxite, transformed into two tonnes of aluminium oxide (Al_2O_3), also called alumina, transformed into one tonne of final aluminium metal.

The main quantity of Al_2O_3 is used for electrolysis in the aluminium production. For this use the ore bauxite is purified in the Bayer process. In a first step, bauxite is converted to aluminium hydroxide $Al(OH)_3$ by treating with NaOH at 175 °C. The $Al(OH)_3$ is dissolved as complex $[Al(OH)_4]^-$ and filtered from the impurities (red mud). After cooling the $Al(OH)_3$ precipitates it is calcinated at 1050°C to form water free Al_2O_3.

In a second step, the aluminium electrolysis takes place. In the Hall-Héroult process, the aluminium oxide (Al_2O_3) is dissolved and electrolysed in a bath of molten cryolite (Na_3AlF_6) within a large carbon or graphite lined steel container known as a "pot". Since strong bond energies persist between aluminium and oxygen, a high energy input has to be used. On average, the specific energy consumption is about 15.7 kWh/kg end product. Therefore, smelting plants are usually located near (or on-site) abundant electricity generating plants, such as hydro-electric based plants.

Over the years, recycling has become more and more important, as it needs only 5% of the energy input required for the production from bauxite ore. Furthermore, no difference exists between primary and recycled aluminium in terms of quality or properties.

According to the International Aluminium Institute[36] global production in 2006 was 60.4 million tons, of which more than half was primary.

Trade structure

Non-EU trade in aluminium and aluminium products is diverse. Figure 12 shows that the 10 main import partners account for 90% of non-EU imports, whilst the Russian Federation, Norway, Switzerland and Iceland already claim almost 75%. Non-EU imports (total: 2609 million EUR) equal 56% of intra-EU imports to Germany (total: 4650 million EUR), while corresponding non-EU exports (total: 2096 million EUR) represent 42% of intra-EU exports (total: 5048 million EUR). The 13 main non-EU export partners claim 80%, of which the USA, Switzerland and China P.R. are the biggest ones (s. Figure 13).

[36] See http://www.world-aluminium.org/About+Aluminium/Production (accessed 21 July 2008)

Figure 12 Main import partners of Germany for aluminium and aluminium products in 2005

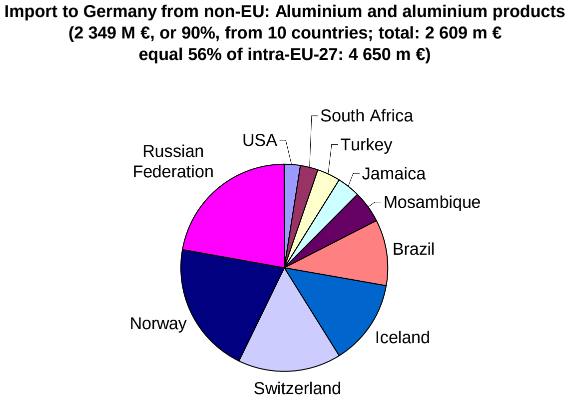
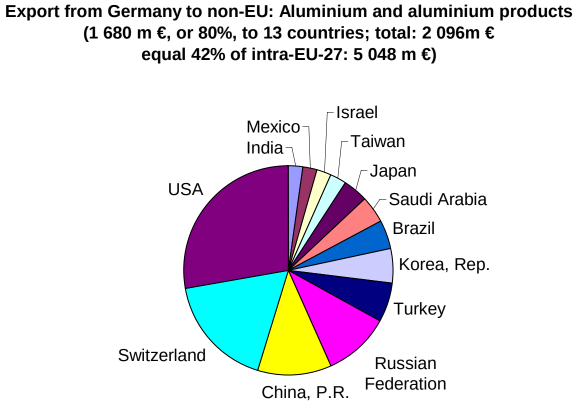


Figure 13 Main export partners of Germany for aluminium and aluminium products in 2005



Source: Calculations by Öko-Institut based on DESTATIS[37]

10.4 Pulp and paper production

Paper production takes place in two main steps: transformation of raw materials into fibrous materials called pulp, and transformation of pulp together with filler materials and additives into paper.

The two main raw materials for pulp production are wood and recovered paper. Two thirds of the wood comes from forestry, one third consists of saw mill by-products. After debarking and chipping the wood, there are two main, distinctly different, ways of transforming it into pulp: chemical pulping and mechanical pulping. Mechanical pulp production is virtually always located on the site of the actual paper plant. Chemical pulp is produced in either integrated or non-integrated market pulp plants.

Recovered paper is typically used by paper mills located in the region where the paper is collected. The process consists of repulping, screening, washing and disperging the fibres. Depending on their destination, a more extensive recycling includes several de-inking measures.

Besides these fibrous materials, non fibrous filler materials which are low in energy use such as kaolin are used to a considerable and growing extent.

The actual paper production starts with mixing and conditioning a blend of these materials suitable for the intended specific product (stock preparation). In the paper machine, the fibre suspension is pumped on a wire where the sheet formation takes place as the water drains from the wire. Then it is mechanically further dewatered by pressing in press rolls and finally

[37] DESTATIS: GENESIS-Online database (accessed 21 July 2008)

dried by steam heated cylinders. Depending on the paper grade the paper can then be calendared and coated before it is shipped to customers.

The German paper industry exhibits a rather high recovered paper utilization rate (66%) compared to the EU-25 average (48%). Indeed, the actual recovery rate of 77% is even more elevated (EU-25: 61%) (VDP 2007). Thus, recovered paper is the most important raw material to papermaking. While Germany is by far Europe's largest paper and board producer (23%), the German pulp and paper industry imports around three quarters of its demand in chemical pulp. Table 9 provides an overview of the raw material used in German pulp production.

Table 9 Types of raw material used in the German pulp production (in 2005)

Raw material	**kt/yr**
Pulp from recovered paper	12747
Chemical pulp	4998
Mechanical pulp	1625
Filler materials	4319

Source: VDP (2007)

The German pulp and paper industry produces around 3000 varieties of products. Production volumes for the different paper grades are presented in Table 10 on an aggregate level. Slightly less than half the products are exported.

Table 10 Paper grades produced in Germany (in 2005)

Paper grade	**kt/yr**
Newsprint	2451
Other graphic paper	8088
Packaging grades (board, ...)	8479
Other grades (Sanitary, household, specialty grades, ...)	2643

Source: VDP 2007

Energy use

Since 1950, average specific energy use in the German pulp and paper production has decreased by about three quarters (VDP 2007) to now about 2050 kWh/t. The typical energy use for the various processes and process steps in the pulp and paper production is displayed in Table 11.

Table 11 Typical energy use for pulp and paper production

Process	Product	Steam demand (GJ/t of product)	Net electricity import (GJ/t of product)
Mechanical pulp	Pulp		7.3
Thermo-mechanical pulp	Pulp	-3.4*	8.3
Market chemical pulp mill – softwood	Pulp	14.3	0,7
Market chemical pulp mill – hardwood	Pulp	13.0	0.9
Waste-paper preparation	Pulp	0.3	0.7
Extensive waste-paper preparation	Pulp	0.5	1.2
Papermaking via paper machine (average)	Paper	5.1	2.2
Integrated chemical pulp and fine paper mill – softwood	Paper Pulp	19.3 12.1+	2.8 1.8+
Integrated chemical pulp and fine paper mill – hardwood	Paper Pulp	16.1 12.9+	2.5 2.0+

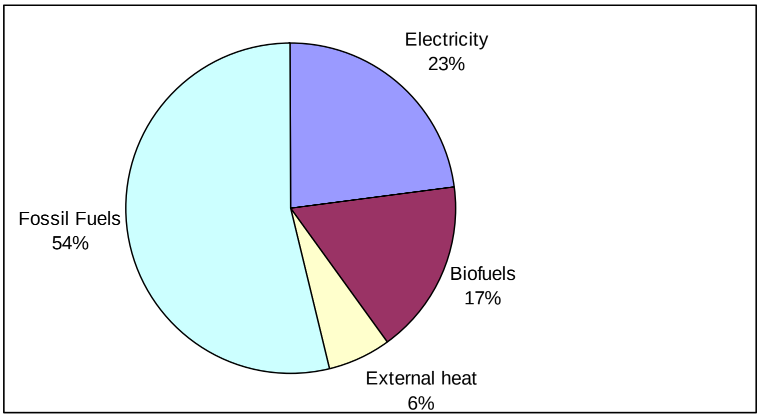
*negative sign reflects bonus for recovered heat

+Share of energy use attributable to pulp

Source: International Energy Agency (2006, p. 423)[38]

Figure 14 shows that, to a large extent, the fuel mix consists of fossil fuels, mostly natural gas, and electricity. Still, bio-fuels make up 17% of the energy demand in Germany.

Figure 14 Fuel share in the production of pulp and paper in Germany (in 2006)



Source: VDP (2007)

[38] Figures are corrected for obvious typos in the original IEA document.

Trade structure

The structure of non-EU trade in paper and paperboard strongly differs between imports and exports (s. Figure 15 and Figure 16). Switzerland mainly dominates imports with 55%, while nine other countries make up 43% of non-EU imports. Non-EU imports (total 1258 million EUR) correspond to 19% of intra-EU imports to Germany (total: 6606 million EUR). Non-EU exports from Germany (total: 2970 million EUR) resemble 39% of exports to EU countries (total: 7592 million EUR). Non-EU export countries are various as the 20 main non-EU export partners account for 81%, of which the USA, Switzerland, the Russian Federation and Turkey claim more than half.

Figure 15 Main import partners of Germany for paper and paperboard in 2005

Import to Germany from non-EU: Paper and paperboard (1 234 m €, or 98%, from 10 countries; total: 1 258 m € equal 19% of intra-EU-27: 6 606 m €)

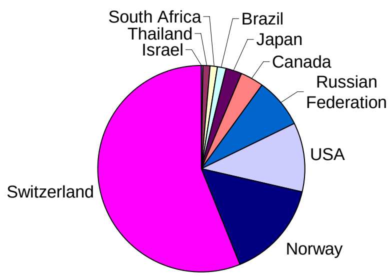
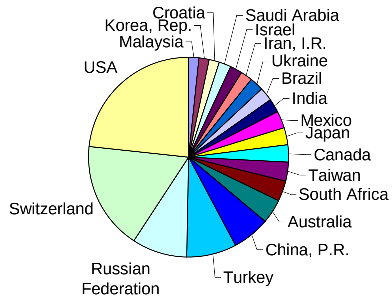


Figure 16 Main export partners of Germany for paper and paperboard in 2005

Export from Germany to non-EU: Paper and paperboard (2 396 m €, or 81%, to 20 countries; total: 2 970 m € equal 39% of intra-EU-27: 7 592 m €)



Source: Calculations by Öko-Institut based on DESTATIS[39]

10.5 Other basic inorganic chemical industry

Alkali chlorine electrolysis

Chlorine is a primary chemical which accounts for about two-thirds of the chemical industry's turnover. It is produced through electrolysis, i.e. via passing an electric current through a solution of brine (= common salt dissolved in water). The main co-products of this process are chlorine gas (Cl_2) and caustic soda (= sodium hydroxide NaOH). Chlorine gas is widely used for pharmaceuticals, medical devices, windows, flooring and pipes. Caustic soda is an alkali and used in the food industry, textile production, soap and other cleaning agents, water treatment and effluent control. Table 12 provides an overview of electricity and fuel consumption together with data on activity levels. Hydrogen as also by-product of the electrolysis but is not shown in Table 12 because it is often flared (R2H 2008).

[39] DESTATIS: GENESIS-Online database (accessed 21 July 2008)

Chlorine is produced via one of three alternative electrolysis processes: the membrane process, the diaphragm process and the mercury-cell process. Of these processes, the mercury process uses the most electricity, but no steam. However, it is being phased out for environmental reasons and typically replaced by the membrane process. Thermal energy is required to concentrate the sodium hydroxide (to a 50 % solution), whereby – as indicated above – hydrogen is produced as a by-product. The specific energy consumption figures in Table 12 refer to the production of chlorine, which is the main product.

Production of sodium carbonate

The main production process for the production of sodium carbonate (soda) is the Solvay process. The main stages are brine purification, limestone burning and lime slaking, ammonia absorption, precipitation of bicarbonate, filtration of bicarbonate, calcination of bicarbonate and recovery of ammonia. Soda is the most important sodium salt and used for the manufacturing of glass (50 %), in the chemical production (23 %), for paper (5 %) and for the production of soap (5 %) (Roempp 2008).

Production of calcium carbide

Calcium carbide is produced via an electric arc furnace loaded with a mixture of lime and coke at very high temperatures (2000°C). Calcium carbide can be processed at high temperature to calcium cyanamide, which is used as fertilizer. Other applications include manufacture of acetylene – a feedstock for the chemical industry mainly in the production of polyvinyl chloride, steelmaking and for carbide lamps.

Table 12 Overview of the manufacture of basic inorganic chemistry

		Production 1000 t		Specific electricity kWh/t	Specific fuel GJ/t
Chemical industry					
24.1 Manufacture of basic chemicals	NACE				
Electrolysis of alkali-chlorides		7,589		3153	1.2
Cl_2	2413 11 110		3,769		
NaOH	2413 15 270		3,821		
Hydrogen	2411 11 500	336		2772	61.6
Al_2O_3	2742 12 000	710		270	8.0
Soda	2413 33 103	1,493		40	9.2
Ammonia	2415 10 750	3,404		47	4.6
Calcium carbide	2413 54 500	176		3100	3.0

Source: Calculations by Fraunhofer ISI based on AGEB 2007, Destatis 2003, 2005a, 2005b, 2007a, VCI 2006

Trade structure

Non-EU partners claim relative high shares of Germany's trade in other basic inorganic chemicals in comparison to intra-EU trade (s. Figure 17 and Figure 18). Non-EU imports (total: 871 million EUR) correspond to 75% of intra-EU imports (total: 1164 million EUR). The 13 main non-EU countries of origin account for 92%, of which the USA, Norway, the Russian Federation and Brazil are the principal ones. Non-EU exports from Germany (total: 1196 million EUR) correspond to 55% of intra-EU exports (total: 2182 million EUR). The 16 main non-EU destinations for export claim 82%, of which the USA, Japan and Switzerland claim more than half.

Figure 17 Main import partners of Germany for other basic inorganic chemicals in 2005

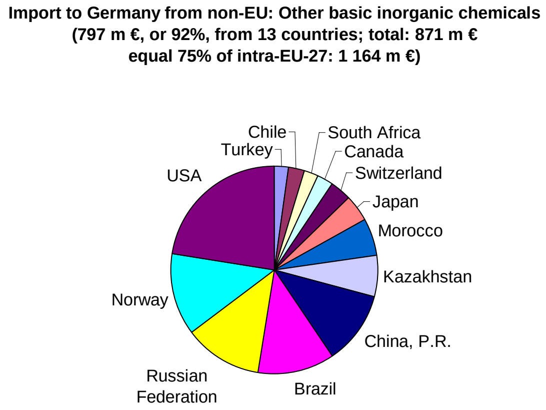
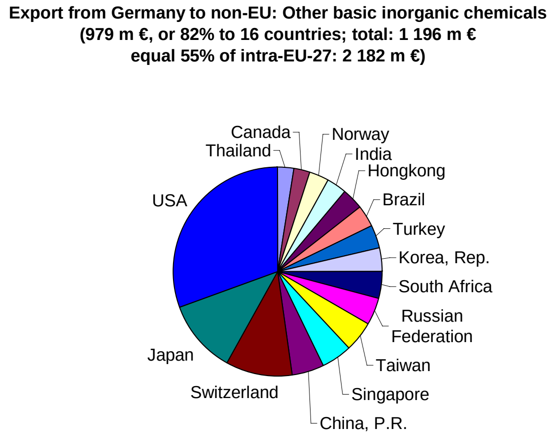


Figure 18 Main import partners of Germany for other basic inorganic chemicals in 2005 of Germany for other basic inorganic chemicals in 2005



Source: Calculations by Öko-Institut based on DESTATIS[40]

[40] DESTATIS: GENESIS-Online database (accessed 21 July 2008)

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