UNIVERSITY OF CAMBRIDGE | Electricity Policy Research Group

Fraunhofer Institute Systems and Innovation Research

ESTIMATION OF CARBON COSTS IN THE CHEMICAL SECTOR

FRANK MARSCHEIDER-WEIDEMANN
KARSTEN NEUHOFF

DISCUSSION PAPER

Convened by: Climate Strategies

Climate Strategies aims to assist governments in solving the collective action problem of climate change. Sponsors include departments from European governments and other stakeholders.

Dec 3rd 2008

Project Authors:

Name of Author	Institution	
Frank Marscheider-Weidemann	Fraunhofer Institute Systems and Innovation Research	Fraunhofer Institute Systems and Innovation Research
Karsten Neuhoff	University of Cambridge	UNIVERSITY OF CAMBRIDGE | Electricity Policy Research Group

Contact:

Frank.Marscheider-Weidemann@isi.fraunhofer.de

karsten.neuhoff@econ.cam.ac.uk

About Climate Strategies

Climate Strategies aims to assist governments in solving the collective action problem of climate change. It connects leading applied research on international climate change issues to the policy process and to public debate, raising the quality and coherence of advice provided on policy formation. Its programmes convene international groups of experts to provide rigorous, fact-based and independent assessment on international climate change policy.

To effectively communicate insights into climate change policy, Climate Strategies works with decision-makers in governments and business, particularly, but not restricted to, the countries of the European Union and EU institutions.

Contact Details:
Managing Director: Jon Price
Climate Strategies
c/o University of Cambridge,
13-14 Trumpington Street
Cambridge, CB2 1QA, UK

Office: +44 (0) 1223 748812
www.climatestrategies.org
jon.price@climatestrategies.org

1. Introduction

With the current economic crisis governments are concerned that ambitious climate policy might result in a relocation of activities of their energy intensive industry to countries with less ambitious climate policy.

To better understand such concerns, this study analyses the cost increases if the Chemical industry has to buy CO_2 allowances and faces higher electricity costs due to the impact of emission trading on the power sector. For most chemicals, either cost increase is limited, or international trade is limited due to expensive or risky transport. For these activities higher European carbon prices will not result in relocation of production and thus leakage of emissions and jobs to other regions.

However, for some specific substances, including PVC, Soda, and Ammonia, cost increases for carbon allowances are high relative to net production value. Further analysis is required to identify the most suitable instruments to address concerns about leakage for these substances, and where necessary identify the most suitable instrument to tackle leakage: Conditional free allowance allocation, state aid or internationally coordinated border adjustment are possible options.

The study illustrates how detailed analysis of individual production processes allows identification of specific leakage concerns and that can be the basis for tailored solutions to address these concerns.

The analysis provides a general approach to calculate CO_2-costs in the chemical industry. The industry produces already in 1981 more than 100,000 different chemicals. The current number for substances marketed with volumes > 1 t was given as 30,000 (CEC, 2003). The portfolio is hugely varied; while some of the basic chemicals are low cost products, pharmaceutical products can be very expensive. The former face a highly competitive global industry and the production of these basic chemicals amounts to about 85 % of the energy used in the Chemical Industry. Therefore the study focuses on the production cost increase of basic chemicals.

With the economic downturn in 2008, the demand for and prices of many chemicals have been falling. To a large extent this aspect is already reflected in this analysis, as input and product prices are based international prices for chemicals from the year 2003, e.g. before the recent boom, and thus depicts a longer-term picture. The analysis for individual chemicals is based on examples using typical energy carriers so it should be noted that the results might not be valid for every specific production process that might be based on other energy carriers.

2. Methodology

The cost increase faced by industry due to CO_2 prices can be compared to the gross production value in a sector, a metric referred to as "Value at Stake".

Looking at the EU economy – at an aggregate level – costs for CO_2 allowances (at 20 Euros/t CO_2) correspond to 0.5% of GDP. At this level, however, these costs do not translate to a 0.5% increase in costs for European industry because, where allowances are sold, the government can use the revenue to reduce other taxes.

Therefore the impact of carbon costs – as one component of an analysis to assess potential risk for us leakage - cannot be identified at an aggregate level, but requires sector and activity specific analysis. Any relocation of carbon intensive production results in the leakage of the associated emissions. Therefore the analysis of carbon leakage, and instruments to address carbon leakage, do at the same time address concerns about company relocation and job or production leakage.

Changes in demand for final products, or shifts in production process will contribute to a changing production structure that is not associated with carbon pricing and is therefore not analysed here and should not be addressed with instruments of climate policy. Some industries are shifting their production towards countries with cheaper resources, e.g. because of gas in the middle-east or lower labour costs in other countries. This is a autonomous development that unrelated to carbon pricing. Our analysis aims to provide information on costs that allows decision makers to differentiate among drivers for decisions.

Carbon pricing by itself can, and should, result in a shift of demand towards less carbon intensive products. This process will happen with global harmonised carbon prices, and should not be undermined if there is a world with asymmetric carbon prices. After all, the change towards less carbon intensive products creates the opportunities for producers to innovate and supply those new products.

For this purpose, we assess the impact at the level of individual production processes in the chemical industry. We use a multi-stage approach of ‘cost screening’ for each of the process steps illustrated in Figure 1. This is described below:

In **Stage 1**, we look at the carbon costs of generating the feedstocks, e.g. naphtha. From the literature we take a figure of 0.405 t carbon dioxide emissions for the production of 1 t of naphtha (Reinaud 2005). This results in a cost increase of 8.1 Euros per ton naphtha. It is unclear whether this cost increase will result in a price increase for naphtha – as typically argued in the chemical industry – or will reduce the profits of the refining industry and not alter input costs for the chemical industry – as argued by the refining industry. Probably the reality is somewhere in the middle.

In **Stage 2** of the ‘cost screening,’ we calculate the costs for a specific production process of basic chemicals. Cost increases can be caused by fuel induced cost increases (including process emissions) and indirectly increased by higher electricity prices (assuming at this stage a 10 Euros/MWh cost increase). We relate this cost increase to the gross value added of the production process. This is not a metric with a clear threshold, as the risk of leakage or competitiveness distortions from carbon pricing will depend on many other factors like transport costs, regional demand and access to local input factors. However, we do think it provides a robust first screen in order to then focus more detailed analysis on sectors that exhibit a significant cost increase relative to gross value added.

For **Stage 3**, in which the basic chemicals are converted to the next product in the value chain, we only use examples that are likely to be the most carbon intensive: polyethylene, polypropylene and polyvinyl chloride.

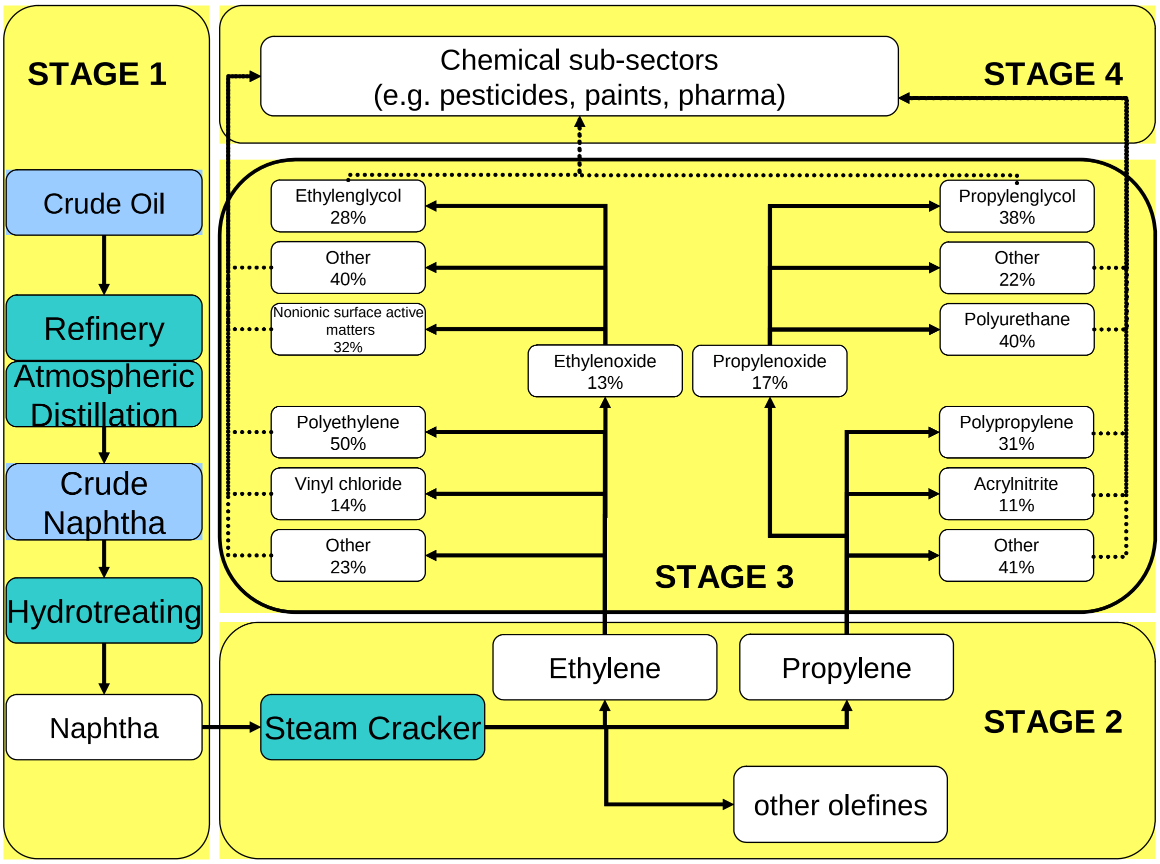

Figure 1. Concept for the analysis of the chemical industry

In the chemical sector (like in steel and cement), the manufacture of a product normally involves several process stages with intermediary products that can be traded and can thus in principle contribute to leakage. For such production processes, it is not sufficient to assess process steps independently. So we calculate the cost increases in **Stage 4** for whole sub-sector branches like e.g. "Manufacture of pesticides and other agro-chemical products". We also take into account the specific energy consumption.

Germany is chosen as an example because it is the largest producer of chemicals in Europe. We take the year 2003 as the base year, because production and sales figures as well as an energy balance are available for this year and can be matched to energy consumption figures from the German statistic office (Destatis, 2007a; AGEB, 2007).

Production values from the official industry statistic (Destatis, 2005a) and the German Association of the Chemical Industry (VCI, 2007) are used. To get prices for chemicals, we use the German foreign trade statistics for the year 2003 (Destatis, 2003a). Dividing the traded monetary quantity by the traded physical quantity for both imports and exports we get a weighted average price. This is of course a simplified approach because there are many different levels of purity and quality involved even with "simple" products such as soda ash and aluminium oxide. When prices in trade statistics were unavailable, we use other sources, e.g. for Acetylene information was used from gas trading companies. These calculations are also used for the price of inorganic raw materials (Table 1). The use factors are taken from literature (Bradke, 1998; Ecoinvent, 2004).

In order to calculate the net production value of a chemical, we only consider the costs of the energy consumption and the raw materials. These are the main cost factors for basic chemicals; personnel costs, for example, only constitute about 20% of total costs (Destatis, 2003b).

	Costs [Euro/t]	Carbon intensity of production
Sodium chloride	24.7	1.75 t/t for Chlorine, 1.5 t/t for soda ash
Lime (CaO)	73.3	0.9 t/t for calcium carbide
Calcium carbonate	14.6	1.2 t/t for soda ash
Bauxit	111.4	1.03 t/t for aluminium oxide

Table 1. Costs for raw materials and their input into processes

The production value given for the sub-sectors of the Chemical Industry is the net production value. In 2003, the gross production value for the sub-sector "basic chemicals" was 65,576 million Euros, the net production value 30,639 million Euros, the gross value added 18,125 million Euros and the net value added 14,384 million Euros (Destatis, 2005b).

		Conversion efficiency [%]	Price of energy service including efficiency [million Euro/PJ]
Electricity	277,800 MWh/PJ	0.7	3.89
Coal	0.098 t CO2/GJ	0.85	2.31
Gas	0.056 t CO2/GJ	0.9	1.25
Oil	0.077 t CO2/GJ	1.0	1,55
Average factor			1,70

Table 2. Factors for the combustion of energy carriers (IPCC, 2007)

Because many products like hydrogen, methanol or ammonia are made from natural gas (favourable in respect to CO_2-emissions) as well as from heavy oil/waste oil we use an average factor of 1.7 million Euros/PJ for the fuel used, see Table 2.

Chemical production processes, especially steam crackers and distillation generate multiple products. This raises the question of how costs due to CO_2 emissions and gross value added should be attributed. We use the following formula to determine the share X_i of both gross value added and of total direct and indirect emissions to different t output factors. In our calculation, Q_i is the production volume and p_i the product price (per ton) for the different outputs.

$$X_i = Q_i * p_i / SUM_i (Q_i * p_i)$$

3. Calculations

For the calculations of the value chain we made the following assumptions supported by statistics, industry data and research reports (German IKARUS-Project: Bradke, 1998; Patel et al., 2000; Patel et al., 2006). We used industry sources for prices and quantities of the different production factors to attribute the gross value added and emissions to the different products.

3.1 Stage 1: Feedstock and fuels

Important feedstocks for the Chemical Industry are naphtha, fuel oils and natural gas. In some of the processes, for example in steam cracker, these feedstocks are partly burned as fuel to provide the necessary energy, but the main part of the feedstock is converted into organic chemicals (so called non-energy use).

Table 3 illustrates the varying emissions of producing fuels. For Natural Gas, e.g. the TGT amount differs from 2,460 kg/TJ (German gas) to 21,958 kg/TJ (PROBAS, 2008). As fuels are traded on international markets, their price is determined by the international prices. These are currently not cost reflective but determined by oligopoly or scarcity pricing. We assume that primary fuel prices will stay globally harmonised and do therefore not pursue an analysis of leakage associated with primary fuel prices.

In this article, only the emissions from the naphtha production are taken into account for the chemical industry, because gas, fuel oil and coal are traded globally and do not reflect price differentials from the carbon costs during fuel extraction.

	Euro/t CO2	t CO2/t of fuel	Certificate costs Euro/t of fuel
Coal	20	0.422	8.4
Gas	20	0.108-.964	2.2-19.6
Oil	20	0.405	8.1
Naphtha	20	0.405	8.1
Fuel mix			6.1

Table 3. Emission factors and costs for the producing of energy carriers (without combustion; PROBAS, 2008; Reinaud, 2005).

3.2 Stage 2: Selected basic chemicals

3.2.1 Steam cracker

The net production value for ethylene from steam crackers in 2003 was estimated at 1,015 million Euros (see Table 4). Under our CO_2 price assumptions, production costs under full auctioning would thus increase by approx. 91 million Euros, or 9 % relative to net production value. The figures for propylene and butylene are also given in Table 4.

When cracking naphtha or gas oil, many other petrochemical products are also formed in the chemical equilibrium. That is why the specific energy consumption in Table 4 is referred to all mentioned olefins. Because Naphtha is mainly used for the cracking process in Europe we also calculated a naphtha-induced cost increase for producing the naphtha (stage 1), using the figures from Table 3.

3.2.2 Chlor-alkali process

The net production value for the joint production of chlorine and NaOH was estimated at 110 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 161 million Euros, or 146 % relative to net production value.

Chlorine is a primary chemical on which two-thirds of the chemistry industry's turnover depends. Chlorine and caustic soda (sodium hydroxide, as it is technically called) are co-products that are produced in equal proportions from the electrolysis of brine. 1.75 t NaCl is needed per ton of chlorine (BREF, 2001).

Three different electrolysis processes exist for manufacturing chlorine: the membrane process, the diaphragm process and the mercury-cell process. For environmental reasons, mercury-cell plants are currently phased out because of their mercury emissions. New plants are built employing the membrane process because this has the most economic capital and energy costs. To calculate the average energy demand, a mix of different production processes is assumed for 2003: 34 % use of membrane process, 27 % mercury and 32 % diaphragm process with the remaining 7 % of chlorine produced from HCl electrolysis. Heat is necessary to concentrate the Sodium hydroxide to a 50 % solution, which is usual in trade. For 1 ton of chlorine 1.13 tons of NaOH is produced. Hydrogen as by-product of the electrolysis is not shown in Table 3 because it is often flared (R2H, 2008). The specific energy consumption is transferred to the chlorine production.

	Average foreign trade price	Quantity	Gross production value	Net production value	Specific energy consumption		Cost increase [%]			
	[Euro/t]	[1,000 tons]	[Million Euro]		Fuel [GJ/t]	Electricity [kWh/t]	Fuel induced (Stage 1)	Fuel induced	Electricity induced	Sum
Steam cracking		11,175	5,114	2,125	4.91	51.9				
Ethylene	466	5,240	2,442	1,015			4.2	4.4	0.4	9.0
Propylene	449	3,651	1,641	682			4.3	4.4	0.4	9.1
Butadiene	485	1,160	545	226			3.9	4.4	0.4	8.7
Butene	417	1,124	484	201			4.8	4.4	0.4	9.6
Chlor-alkali electrolysis			933	110	1.20	2,911	-	7.0	139.2	146.1
Chlorine	162	3,769	610	72						
Sodium hydroxide	84	3,821	323	38						
Air separation			1,371	933	0	470	-	0	11.4	11.4
Oxygen	96	9,869	952	648						
Nitrogen	67	6,269	419	285						
Hydrogen	170	336	1,238	1,011	61.6	2,770	-	3.5	1.3	4.8

	Average foreign trade price	Quantity	Gross production value	Net production value	Specific energy consumption		Cost increase [%]			
	[Euro/t]	[1,000 tons]	[Million Euro]		Fuel [GJ/t]	Electricity [kWh/t]	Fuel induced (Stage 1)	Fuel induced	Electricity induced	Sum
Al_2O_3	374	710	266	145	8	270	-	6.7	1.9	8.5
Soda ash	137	1,493	205	176	9.2	40	-	13.3	0.5	13.7
Methanol	228	2008	458	199	2.5	120	-	4.3	1.7	6.0
Ammonia	183	3,404	623	348	4.6	47	-	7.7	0.6	8.3
CaC_2	356	176	63	18	3	3,100	-	4.9	41.4	46.3
Acetylene	5,000	120	600	487	43.5	6,300	-	1.8	2.2	4.0
Aromatics production		3,360	1,256	565	3	15	-	3.0	0.1	3.2
Benzene	382	2,165	827	372						
Toluene	348	612	213	96						
Xylenes	371	583	216	97						

Table 4. Figures and percentage cost increases for stage 2 chemicals

3.2.3 Separation of air into O_2 and N_2

The net production value for the joint production of oxygen and nitrogen together was estimated at 933 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 106 million Euros, or 11.4 % relative to net production value..

Although adsorptive and membrane applications for air separation have been developed, most oxygen still comes from big cryogenic air separation plants. The purification and refrigeration of the air is followed by a distillation step. By-products are noble gases like Argon, Neon or Helium. Oxygen and Nitrogen are also used in other sectors outside the Chemical Industry, e.g. steel or glass production.

3.2.4 Hydrogen

The net production value for the joint production of hydrogen was estimated at 1,011 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 48 million Euros, or 4.8 % relative to net production value.

Hydrogen is used in various reactions in the whole organic and inorganic Chemical Industry. Most industrial hydrogen is produced by steam reforming of natural gas (Boustead, 2005).

3.2.5 Aluminium oxide

The net production value for the production of aluminium oxide was estimated at 145 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 12.3 million Euros, or 8.5 % relative to net production value.

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

3.2.6 Soda ash

The net production value for the production of Soda ash (sodium carbonate) was estimated at 176 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 24 million Euros, or 13.7 % relative to net production value.

In the Solvay process, Soda ash is produced by first adding ammonia and then carbon dioxide into a saturated NaCl-solution.

$$NH_3 + CO_2 + NaCl + H_2O \rightarrow NaHCO_3 + NH_4Cl$$

Through Calcination of the sodium hydrogencarbonate the Soda ash (Na_2CO_3) is produced:

$$2\ NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2.$$

Carbon dioxide and the ammonia are then recycled:

$$2NH_4Cl + CaO \rightarrow 2NH_3 + H_2O + CaCl_2$$

The inputs into the Solvay process are brine and limestone, while calcium chloride is discarded as waste. The specific energy consumption depends on the purity and physical structure of the Soda ash.

3.2.7 Methanol

The net production value for methanol was estimated at 199 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 11.9 million Euros, or 6.0 % relative to net production value.

After ammonia, methanol is the next largest product made from synthesis gas. As is the case with ammonia, synthesis gas is mainly produced from natural gas because of the reasonable capital costs and energy consumption involved (Ullmann, 2008). In the frame of waste utilization such as, e.g. high vacuum distillation residues, the wastes are gasified to synthesis gas and converted into methanol.

The most favourable method is a combination of steam reforming and partial oxidisation. In the latter, energy is released which would otherwise have to be supplied from outside the reaction zone in conventional reforming. Both processes can be controlled so that the best ratio for methanol production of hydrogen to carbon monoxide (about 2) can be selected. The formation of methanol from synthesis gas is exothermic:

$$2\ H_2 + CO \rightarrow \quad H_3COH \qquad \Delta H = -90.7\ kJ/mol$$

Globally, natural gas is the most commonly used raw material for producing methanol. In Germany, however, more than 50% of the feedstock for methanol is from distillation residues and heavy oils. Off-gas from acetylene production is also used. This is taken into account when calculating the net production value for methanol: Based on our assumptions, if natural gas were used to produce methanol in Germany, the high average gas price for industry here would result in methanol costing more to produce than its sales would generate.

3.2.8 Ammonia

The net production value added for the production of ammonia was estimated at 348 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 28.9 million Euros, or 8.3 % relative to net production value added.

About 1.4 % of the world consumption of fossil energy (not including combustion of wood) goes into the production of ammonia. In developing countries, ammonia is generally one of the first products of industrialization. 83 % of world nitrogen consumption is for fertilizers, so it can be taken as a measure of fertilizer production. 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 also formed as a by-product in coking plants, but the amount produced is less than 1 per cent. Ammonia is produced by the Haber-Bosch method in 3 steps (Ullmann, 2008):

1. Production of a mixture of H_2, CO, N_2
2. Conversion of CO to CO_2 and isolation of the CO_2 from the process gas
3. Conversion of H_2 and N_2 to NH_3

The first stage is the most energy-intensive. The hydrogen required for making ammonia results principally from the partial oxidation or steam reforming of hydrocarbons using steam and catalytic converters. This is followed by the isolation of carbon monoxide by converting and rinsing or absorbing the carbon dioxide formed. Finally, the exothermic conversion of nitrogen and hydrogen to ammonia takes place:

$$3\ H_2 + N_2 \rightarrow 2\ NH_3 \qquad \Delta H = -\ 45{,}9\ kJ/Mol$$

Some ammonia production is combined with urea production, in which case the carbon dioxide can be reused:

$$2\ NH_3 + CO_2 \rightarrow CO(NH_2)_2 + H_2O$$

In other processes, the production of ammonia and methanol is combined. An air separation unit supplies the required nitrogen and the oxygen obtained is used to produce methanol synthesis gas (Arpe, 2007).
The specific energy consumption of the process depends on the feedstock used. The lowest consumption is achieved with the use of natural gas, the highest consumption results from gasification of coal (Ullmann, 2008).

3.2.9 Calcium Carbide

The net production value for the production of calcium carbide was estimated at 18 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 8.6 million Euros, or 46.3 % relative to the net production value.

Calcium carbide is produced with an electric arc furnace loaded with a mixture of lime and coke at 2000 °C:

$CaO + 3C \rightarrow CaC_2 + CO$.

Calcium carbide can be converted at high temperature to calcium cyanamide, which is used as fertilizer: $CaC_2 + N_2 \rightarrow CaCN_2 + C$

3.2.10 Acetylene

The net production value for the production of acetylene was estimated at 487 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 19.5 million Euros, or 4.0 % relative to net production value..

The relatively low effect of CO_2 pricing on the production of acetylene is an effect of the high price of this gaseous chemical. Because acetylene tends towards spontaneous decomposition, it is sold in special gas cylinders. Huge amounts of acetylene is sold in bundles of gas cylinders, which results in the price of 5,000 Euro per ton, see Table 4.

Acetylene can be produced from calcium carbide:

$CaC_2 + H_2O \rightarrow C_2H_2 + CaO$.

It is also produced directly from hydrocarbons, in a process that requires high temperatures and very short reaction times. In Germany this is technically realised in combustion (BASF process) or in electro-thermic processes (Hüls Arc Process).

3.2.11 Aromatics

The net production value for the production of benzene, toluene and xylene was estimated at 565 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 17.9 million Euros, or 3.2 % relative to net production value.

The specific energy demand for the aromatic compounds is relatively low, because they are mainly separated by extraction or extractive distillation from aromatic rich compounds, like e.g. pyrolysis gasoline or reformate. Some special processes are used to transform an aromatic compound into another, e.g. hydrodealkylation to produce benzene from toluene.

3.3 Example for Stage 3 Substances: Polyolefines

The net production value for the production of polyethylene was estimated at 204 million Euros for 2003. For our CO_2 price assumptions, production costs under full auctioning would thus increase by 32 million Euros, or 2.6 % relative to net production value.. Based on Arpe (2007) we assume that the following shares of primary products are used as input factors for polyethylene, polypropylene and PVCs.

	Ethylene	Propylene	Cl_2
Polyethylene	50 %	-	-
Polypropylene	-	42 %	-
PVC	14 %	-	36%

Table 5. Share of ethylene, propylene and chlorine for polyolefines in Germany (Arpe, 2007)

In addition to the direct emissions from the production of polyethylene, it is assumed, that the additional costs from stage 2 are passed over to the Polyolefine producers.

In Table 6 the cost increase as sum of stage 2 and 3 is described.

	Average foreign trade price [Euro/t]	Quantity [1,000 tons]	Gross production value	Net production value	Specific energy consumption		Cost increase [%]				
			[million Euro]		Fuel [GJ/t]	electricity [kWh/t]	Stage 2 fuel	Stage 2 elec.	Fuel induced	electricity induced	Sum
Polyethylene	753	2,051	1,253	204	-1.6	930	0.7	0.2	0.0	4.6	5.5
Polypropylene	777	1,664	1,293	467	9.7	600	1.6	0.1	1.2	2.5	5.3
PVC	616	1,524	939	375	2.5	403	2.2	6.2	5.0	1.7	20.4

Table 6. Figures for the polyolefines

3.4 Stage 4: the sub-branches of the Chemical Industry

Using the same methodology, it is also possible to calculate the cost increase for entire sub-sectors rather than individual products of the chemical industry, see Table 7.

	Net production value [million Euro]	Specific energy consumption		Cost increase [%]		
		Fuel [PJ /million Euro]	Electricity [PJ /million Euro]	Fuel induced	Electricity induced	Sum
24.1 Basic chemicals	30,640	6,795.9	5,000.0	1.2	1.9	3.1
24.2 Manufacture of pesticides and other agro-chemicals	1,493	340.7	361.7	0.1	0.1	0.2
24.3 Manufacture of paints, varnishes, coatings, inks etc.	4,926	432.4	618.6	0.1	0.2	0.3
24.4 Manufacture of pharmaceuticals	19,669	464.5	381.4	0.1	0.1	0.2
24.5 Manufacture of soap, detergents, cleaning, polishing	7,282	787.8	622.8	0.2	0.1	0.4
24.6 Manufacture of other chemical products	5,378	1,247.0	1,122.1	0.3	0.4	0.6
24.70 Manufacture of man-made fibres	1,629	5,390.9	3,858.3	1.1	1.5	2.4
24 Chemical Industry	**71.016**	**3,396.8**	**2,550.7**	**0.6**	**0.5**	**1.2**

Table 7. Figures for the Chemical Industry and the sub-branches

Although the cost increase is moderate for most sub-branches, it must be considered that in special cases the increase for a producer might be higher. The intra-sectoral trade is very high in the Chemical Industry, the corresponding figure from the German Input-Output table is 1.54, e.g. for 1 Euro produced in the sector an economic activity of 1.54 Euros took place in the Chemical sector (Destatis, 2007b). This activity is included implicitly in the NPV values in Table 7 , but it shows that a company with an inefficient production chain can be more deeply affected than the average firm.

4. Summary of results and interpretation

The results for the different stages are shown in the following figures 2 to 6. The analysis complements other work, e.g. (Graichen et al, 2008) by providing a higher resolution of the impact on individual products. Figure 2 shows that for the most basic chemicals (stage 2 of the production chain) production cost increases relative to net production value are low.

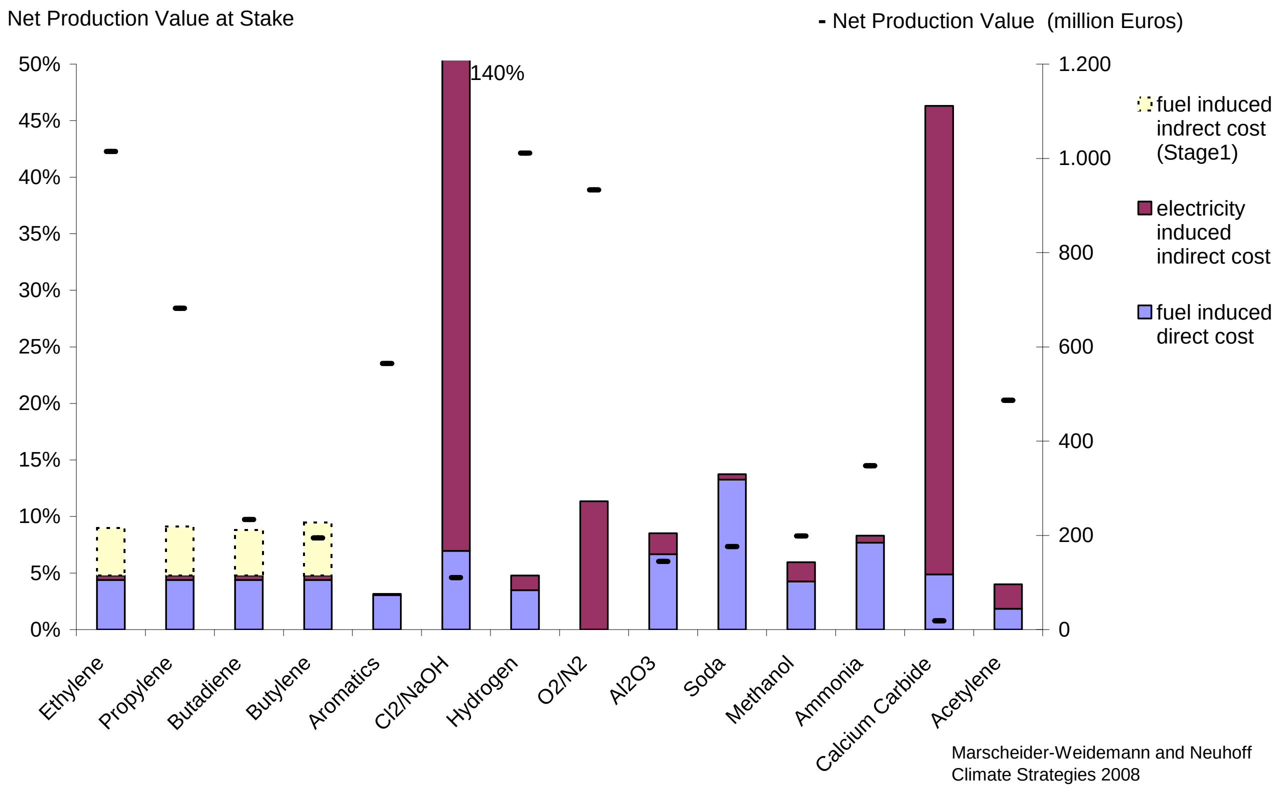

Figure 2. Results for the Stage 2 of basic chemical

Only for very low cost basic chemicals like chlorine (Cl_2/NaOH), soda or carbide is the cost increase high relative to the value added. Figure 3 illustrates the reason for this, using the example of Chlorine, by showing the shares of production costs for chlorine and sodium hydroxide.

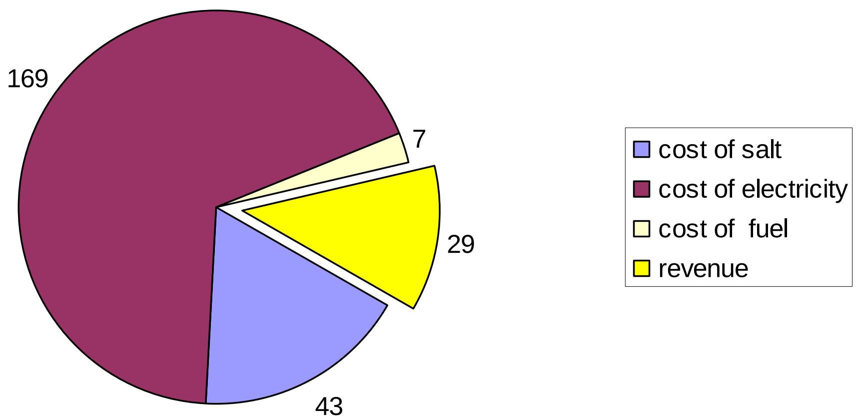

Figure 3. Share of costs for the production of chlorine and NaOH

The price for 1 t of chlorine and the corresponding NaOH by-product is approximately 250 Euro. Taking into account the average electricity price for energy intensive industry in Germany for 2003, 0.0579 Euro/kWh (BMWi, 2007), this cost segment amounts to 60 % of the price. The cost of brine contributes another 17 % (Lindley, 1997). The carbon dioxide certificates for the electricity will cost 80 Euro, which would exceed the net-revenue of 29 Euro if chlorine prices were to stay constant. This is a rough estimation, of course chlor-alkali electrolysis might have lower electricity costs than the average industry customer and some of the chlorine companies will produce higher value products like KOH or alcoholates instead of NaOH (Rothert, 2005).

Transport of Chlorine is costly and dangerous; hence it is very likely that increased Chlorine production cost will be passed on to European Chlorine prices, resulting in price increases of about 16%. As Chlorine is mainly used as an input factor for subsequent stages of chemical production, the impact of this price increase for the subsequent production stages was analysed.

While elemental chlorine is indeed dangerous and difficult to transport, some of its downstream products are not. Chlorine is in practice largely traded within the downstream products, for example PVC. Therefore we analysed stage 3 of the value chain. Thus we analyse for carbon intensive products, carbon cost increases from stage 2 and three are high relative to net production value during these two production stages.

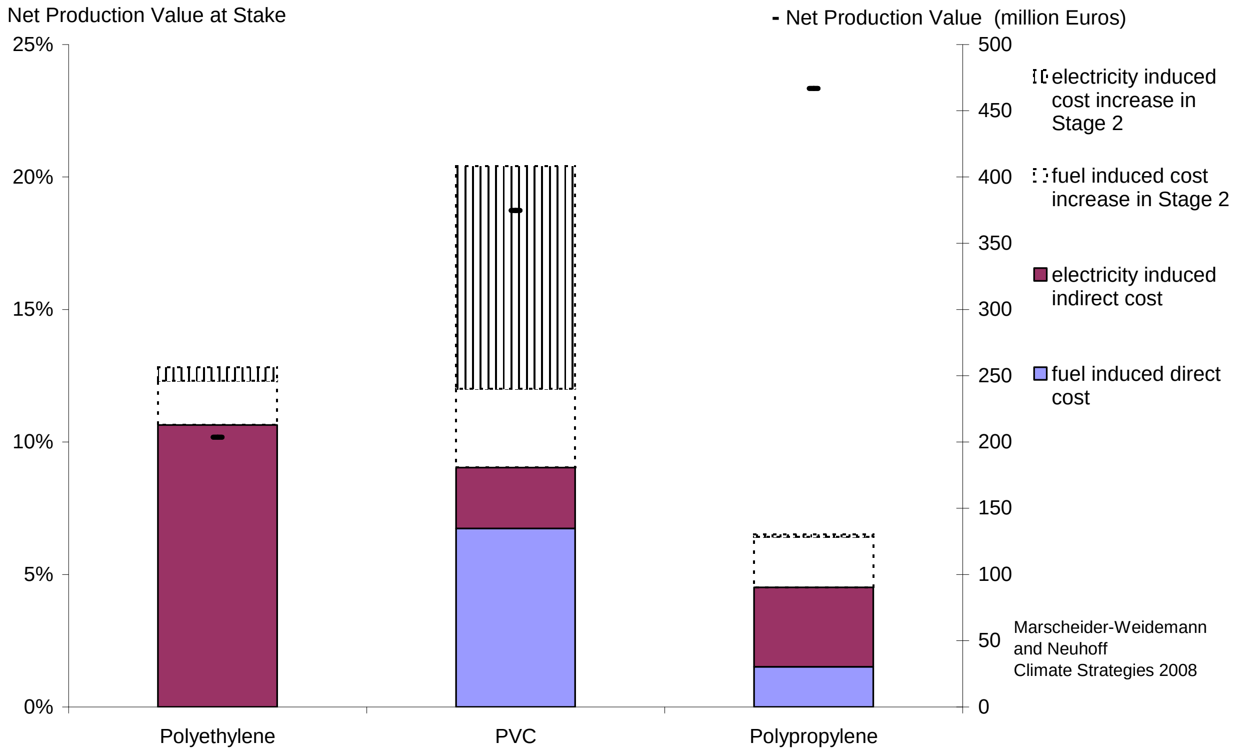

Figure 4. Results for the Stage 3 for selected carbon intensive products

To allow for a better evaluation of how significant the cost increase for these substances is, Figure 5 depicts the same total cost increase for these substances relative to the international sales price in the years 2003 and 2006. This puts the change of costs in perspective relative to the variations of sales price observed in recent years and suggests that the overall level of cost increase is even for the most carbon intensive chemicals relatively low.

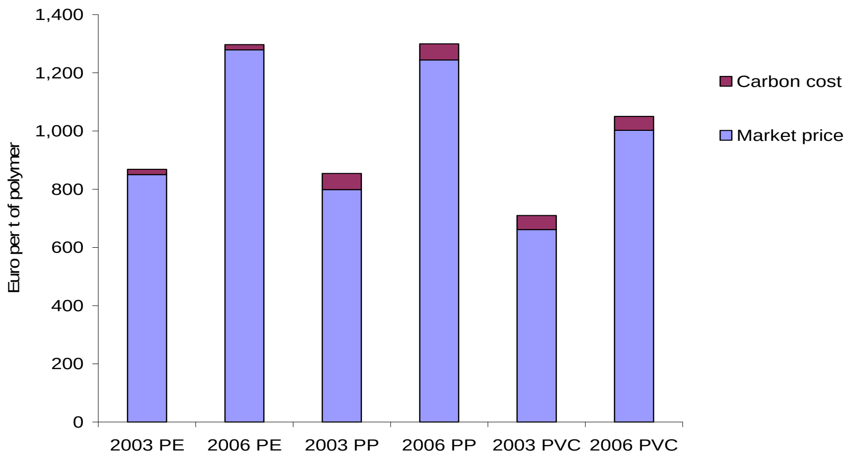

Figure 5. Incremental costs for polyethylene relative to market prices in 2003 and 2006.

Finally, we are interested in exploring the cost impact at the level of the aggregate chemical industry. Figure 6 illustrates the overall cost increase for basic chemicals, which is the highest of all sub-sectors and therefore motivated the investigation of the specific product categories. For other sub-sectors of the chemical industry potential cost increase is smaller relative to overall production value.

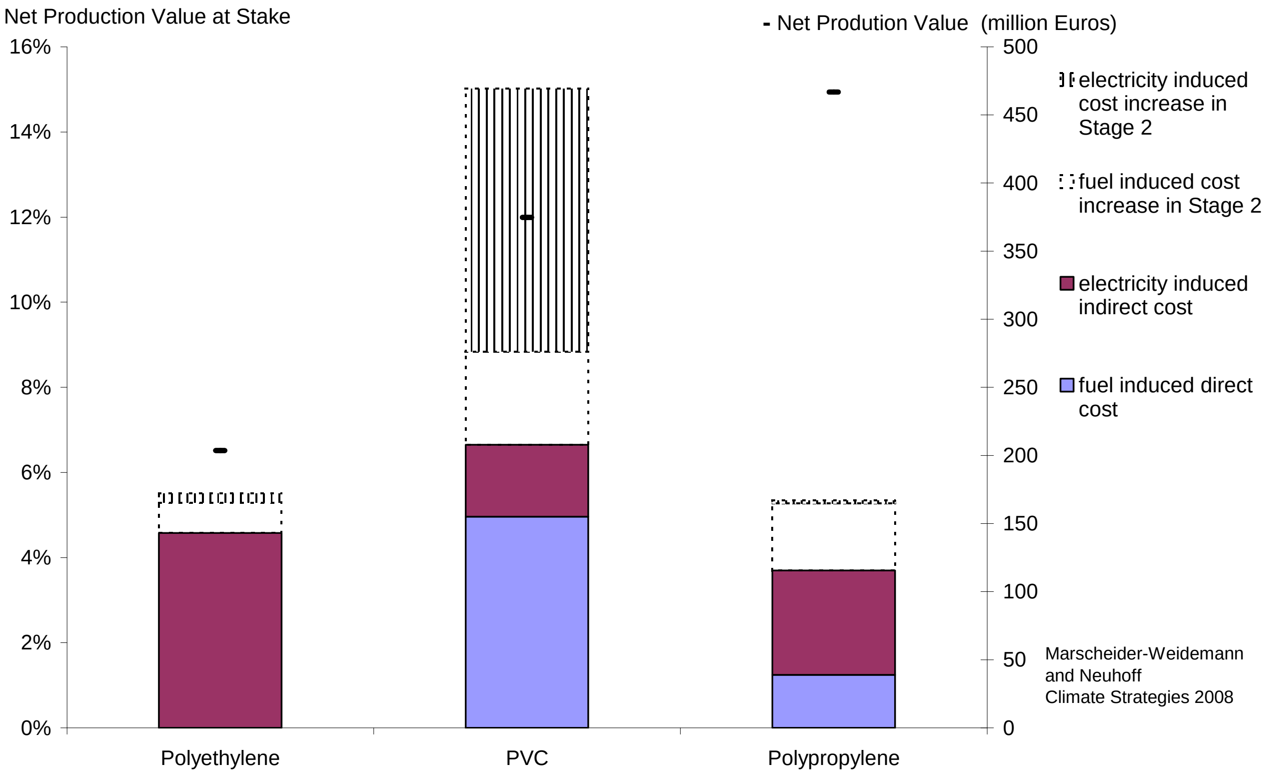

Figure 6. Results for Stage 4 – the level of industry sub-sectors

5. Conclusion

Most of the analysis of leakage concerns for chemical sectors takes an aggregate perspective on the chemical industry, or only separates between organic and inorganic activities (Hourcade e.a. 2008, Graichen e.a. 2008, WRI 2008, CE Delft 2008). At this level of aggregation the cost impact from carbon pricing is typically limited. This contrasts with some specific examples that are quoted, for example looking at Chlorine.

By expanding the analysis of the carbon intensity of production of individual chemicals to cover a wider set of substances, this paper shows that the concern about cost increases is focused on a few chemical. Among basic chemicals, cost increases relative to net production value are high for calcium carbide and would if the analysis is confirmed, warrant significant concerns for leakage. Costs increases are also significant for Cl_2 and O_2. However, for both gases the transport costs and in the case of Cl_2 transport risks will result in continued local production. Al_2O_3, Soda and Ammonia (basic fertilizer) also show significant cost increases relative to value added. Further analysis, including the ratio of capital to fixed costs, planned capacity expansion and required reinvestment, transport costs, and specific qualities provided for further production process steps are required to judge whether this warrants leakage concerns.

In the analysis of the third stage of chemical production processes, we therefore judged as to whether potential cost increases in preceding production stages could result in relocation of the joint second and third stage of production. For this analysis we focused on processes that are energy and carbon intensive and/or have high shares of cost resulting from carbon intensive input factors. Significant cost increases relative to net production value exist in this case for polyethylene (5.5 %), polypropylene (5.3 %) and PVC (15%) at 20 Euro/t CO_2. It is unclear how big this effect plays out – if the value added is for example measured relative to the product price, then cost increases are only Polyethylene (2.3 %), polypropylene (6.9 %) and PVCs (7.3 %) for 2003. Further analysis is required to assess whether this warrant concerns for leakage of production of the respective chemicals.

Such a subsequent analysis would have to assess the relative importance of fixed costs to variable costs of operation. With high fixed costs, as for example associated with steam crackers, leakage concerns emerge at times when steam-cracker capacity would have to be expanded, and could in this case be addressed with targeted subsidies. Who will bear the additional costs is also a somewhat open question. Will marginal carbon costs from NAFTA production be passed on to the chemical industry, or will NAFTA prices remain at international level and refineries bear the additional costs? Similar questions have emerged in the REACH process, that requires testing of all substances for human health impact and thus creates extra costs that can potentially be of significance for substances produced in small quantities (e.g. not the energy intensive basic chemicals).

Further factors also need to be considered. For example for PVC much of the cost increase can be attributed to Chlorine production. As the marine environmental protection commissions, PARCOM and HELCOM requires a replacement of the mercury process, ongoing investment in new capacity is required for Chlorine production. This not only improves the energy efficiency and thus reduces the exposure to carbon costs, but also provides an opportunity for state aid support to cover some of the costs of upgrading Chlorine production.

We hope that this analysis of the impact of carbon pricing on the chemical industry can support the analysis and discussion of leakage concerns to identify production processes at risk of leakage. The process specific analysis can then be used to determine whether leakage is associated with decisions on investment / reinvestment, operation or closure of a facility. This is the basis for the subsequent selection of a suitable instrument to address leakage, including state aid, free allowance allocation or internationally cooperation on border adjustment. The detailed understanding of the process will then help to understand the trade-offs associated with the different instruments so as to find the least distorting way to tackle leakage together with the chemical industry.

Literature

AGEB (2007): Working Association for Energy Balances. Arbeitsgemeinschaft für Energiebilanzen, http://www.ag-energiebilanzen.de/.

Arpe, H.-J. (2007): Industrial Organic Chemistry (in German). Wiley-VCH Verlag, Weinheim.

BMWi (2007): Entwicklung von Energiepreisen und Preisindizes.

Boustead, I. (2005): Reformer Hydrogen. Eco-profiles of the European Plastics Industry. PlasticsEurope. Data last calculated March 2005

Bradke, H. (1998): Instruments for Greenhouse Gas Reduction Strategies in Industry: The German IKARUS Project Energy Savings and CO_2 Mitigation Policy Analysis. Conference on Energy Use in Manufacturing, 37-44.

BREF (2001): Reference Document on Best Available Techniques in the Chlor-Alkali Manufacturing industry. December 2001. http://eippcb.jrc.ec.europa.eu/pages/FActivities.htm.

CE Delft (2008) Impacts on Competitiveness from EU ETS. An analysis for the Dutch Industry. CE Delft: The Netherlands.

CEC, Commission of the European Communities(2003): Proposal for a Regulation of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation an Regitration of Chemicals (REACH). SEC(2003 1171).

Destatis (2003a): Foreign trade. Aussenhandel nach Waren und Ländern. Dezember und Jahr 2003. Statistisches Bundesamt, CD-ROM.

Destatis (2003b): Cost structure of industry. Produzierendes Gewerbe: Kostenstruktur der Unternehmen des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden. Statistisches Bundesamt, Wiesbaden.

Destatis (2005a): Production in Industry. Produzierendes Gewerbe. Produktion im Produzierenden Gewerbe, Jahr 2004. Erschienen am 2.06.2005.

Destatis (2005b): Produzierendes Gewerbe. Kostenstruktur der Unternehmen des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden. 2003. Erschienen am 9.Juni 2005.

Destatis (2007a): personal communication. Special reporting of the energy consumption of the Industry. Statistisches Bundesamt.

Destatis (2007b): Volkswirtschaftliche Gesamtrechnungen. Input-Output-Rechnung. 2004. Statistisches Bundesamt, Wiesbaden

Ecoinvent (2004): The Life Cycle Inventory Data Version 1.1, June 2004 Dübendorf

Graichen, V.; Schumacher, K.; Matthes, F. C.; Mohr, L.; Duscha, V.; Schleich, J.; Diekmann, J. (2008): Impacts of the EU Emissions Trading Scheme on the Industrial competitiveness in Germany. Environmental Federal agency, Berlin.

Hourcade J-C., Neuhoff, K., Damailly, D. and Sato, M. (2008) Differentiation and dynamics of the EU ETS industrial competitiveness impacts. Climate Strategies: Cambridge. Available at ww.climate-strategies.org

Lindley, A. A. (1997): An Economic and Environmental Analysisi of the chlor-alkali production process. Final Report 30 June 1997. Prepared for the European CommissionPatel, M.; Jochem, E.; Marscheider-Weidemann, F.; Radgen, P.; von Thienen, N. (1999): C-Streams: C-STREAMS: Material and energy flows of non-energy use throughout the life cycle. Fraunhofer ISI, Karlsruhe.

Patel, M.; Crank, M.; Dornburg, V.; Hermann, B.; Roes, L.; Hüsing, B.; Overbeek, L.; Terragni, F.; Recchia, E. (2006): Medium and Long-term Opportunities and Risks of the Biotechnological Production of Bulk Chemicals from Renewable Resources. The Potential of White Biotechnology. The BREW Project. Final Report Prepared under the European Commission's GROWTH Programme (DG Research).

PROBAS (2008): PROBAS database, downloaded June 2008 at http://www.probas. umweltbundesamt.de/.

Reinaud, J (2005) (2005): The European Refinery Industry under the EU Emissions Trading Scheme: Competitiveness, trade flows and investment implications, IEA information paper.

R2H, Roads2HyCom (2008): database at http://www.roads2hy.com/

Rothert, A. (2005): Positionen zur Chemie mit Chlor. http://www.vci.de

Ullmann's Encyclopedia of Industrial Chemistry. Online Version.

VCI (2006): Chemiewirtschaft in Zahlen, 2006. Frankfurt. www.vci.de.

WRI Wold Resource Institute (2008) Levelling the carbon playing field: International Competition and U.S. Climate Policy Design. World Resource Institute: Washington DC.

Title: Estimation of Carbon Costs in the Chemical Sector
Publisher: Climate Strategies 2008
Contact: Contact: Jon.price@climatestrategies.org
Climate Strategies
C/O University of Cambridge
13-14 Trumpington Street,
Cambridge, CB2 1QA

For citation and reprints, please contact the publisher Climate Strategies

Acknowledgement:

Financial support from the UK research councils under the project TSEC and from Climate Strategies is gratefully acknowledged.

The author wishes to thank, without implicating Kate Grant, Sarah Lester, Felix Matthes, Philippe Quirion and Juila Rainaud and for many useful comments and assistance.

Climate Strategies is grateful for funding from their core supporters including The Carbon Trust (our founding supporter) governments of UK (DEFRA, OCC, DFID), France (ADEME with inputs from French Ministry of Finance), Grant Thornton, European Climate Foundation, and the Swedish Energy Agency.