Final Report

Amendment to the European Directive on Emission Trading:

Impact on the German Cement Industry

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On behalf of:
Verein Deutscher Zementwerke e.V. and
Bundesverband der Deutschen Zementindustrie e.V.

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EXECUTIVE SUMMARY

This final report summarizes the results of analyses conducted by McKinsey & Company, Inc., on behalf of the German Cement Works Association (Verein Deutscher Zementwerke e.V. or VDZ) and the Federal Association of the German Cement Industry (Bundesverband der Deutschen Zementindustrie e.V. or BDZ) to determine the impact of changes to the EU Directive on Emission Trading on the costs of CO_2 emissions and consequently on the international competitiveness of the German cement industry.

Cement production generates high process-related CO_2 emissions. The largest share originates from the raw material limestone (process CO_2); the remainder comes from the fuels used in the process (fuel CO_2). Consequently, the cement industry expects to incur high additional costs when the CO_2 reduction targets are tightened in the future and, additionally, CO_2 allowances must be bought at auction.[1] The European Commission's draft of January 2008 provides for amendments to the Emission Trading Directive 2003/87/EC, including a general CO_2 reduction target for sectors subject to emission trading (ETS sectors) of 21% by 2020 relative to 2005. In addition, the auctioning of emission allowances is to become a basic principle of the EU Emission Trading System (EU-ETS). For the industrial sector auctioning is to be phased in gradually until it becomes mandatory for the purchase of all emission allowances in 2020. The Commission's proposal provides for exceptions only in the event of the risk of "carbon leakage" in a given industry sector. "Carbon leakage" is defined as the relocation of CO_2 emissions into regions beyond the scope of the EU-ETS as a result of production volumes being shifted to such regions. Unlike the industrial sector, the

[1] Furthermore, there are also indirect CO_2 emissions associated with the consumption of electric power, which imply additional costs via the effect of emission trading on electricity prices.

energy industry will have to adopt the auction process for the purchase of all of its required CO_2 emission allowances starting in 2013.

Against this background, the study examines how the foreseeable changes to CO_2 costs will affect the international competitiveness of the German cement industry. The study focuses primarily on the production of cement clinker (referred to simply as clinker), as the key intermediate product in the cement production process. Clinker is used to make various types of cement by grinding it in cement mills with other components. Clinker is the element of the cement production process most likely to be at risk of carbon leakage for the following reasons: clinker production in the EU is subject to the Emission Trading System and is responsible for nearly all of the CO_2 emissions generated by a cement plant. Furthermore, clinker has largely the same composition worldwide and can easily be transported and stored.

This study assumes that clinker produced in Germany will be at risk to be replaced with clinker imports when the full costs of production in Germany, including CO_2 costs, move permanently to a level significantly higher than the full cost of production in a country not governed by the EU-ETS ("non-EU-ETS country") plus the associated costs of transport to Germany. Accordingly, the analysis compares the full costs for domestic and imported clinker at cement grinding plants in Germany. Based on this the study assesses the risk of carbon leakage and additional CO_2 emissions from transport and more CO_2-intensive production abroad. In the context of the European Emission Trading Directive, this study reflects the Commission proposal of January 2008: The year 2020 was chosen as the reference year because from this point onwards, the cement industry is likely to have to purchase all CO_2 allowances by participating in auctions.

All of the scenarios analysed using the variables described assume that there are sufficient export capacities for clinker in non-EU-ETS countries. The industry expects significant over-capacities up to 2012, and capacity will be expanded if exports to Germany prove to be profitable. This long-term perspective (to 2020) must take full costs into account. This means that production costs are compared on a full-cost basis, including depreciation and taking into account transport costs and CO_2 costs. For the imports to Germany, plants in Egypt, Saudi Arabia, and China were selected because they are representative and are located in regions with available capacities that already export to Europe.

The results of the basic scenario developed in the study indicate that in 2020, around 50% of clinker production in Germany will be threatened by imports, assuming CO_2 costs of EUR 35/metric ton. This production volume corresponds to around 12 million metric tons of clinker. The use of imported clinker would displace approximately 9.8 million metric tons of CO_2 emissions (carbon leakage), which, in turn, would generate an additional 0.8 million metric tons of CO_2 emissions.

Since the parameters used in the basic scenario are subject to some uncertainty, appropriate sensitivity analyses were also carried out. These analyses looked at how the clinker production at risk would be affected by CO_2 costs of between EUR 25 and EUR 50 per metric ton and differences in logistics costs of approximately +20%/-40% from the basic scenario. Combining the extreme values of these parameters in each case gives the range of the sensitivity analyses: the results of the calculations show that 25% to 86% of German clinker production is at risk.

In summary, all scenarios indicate that significant carbon leakage can be expected as a result of the costs for CO_2 in the German cement industry. Moreover, around 19% of German clinker production would still be at risk if the cement industry simply had to purchase allowances amounting to a 21% share of its CO_2 emissions (i.e., in line with the European reduction obligations), and the remaining allowances were allocated free of cost.[2]

[2] Assuming that the reduction target of 21% applies only to "fuel CO_2" and not to "process CO_2", approximately 18% of clinker production would be threatened.

CONTEXT, GENERAL CONDITIONS AND PROJECT OBJECTIVES

Context and General Conditions

The European Directive on Emission Trading System (EU-ETS) defines the general conditions for this study. Based on the draft of the European Commission of January 23, 2008 on the amendment to Directive 2003/87/EC, the following *key* principles apply:

- ***Reduction target of 21% by 2020*** – Based on 2005 figures, all sectors involved in EU emission trading are required to reduce their CO_2 emissions by 21% by the year 2020.
- ***Auctioning as a basic principle*** – Auctioning will be introduced as the basic process for the allocation of CO_2 allowances.
- ***Reduction of free allocations to 0% in 2020*** – Full auctioning of allowances will be the norm in the electricity sector as of 2013. The free allocation of emission allowances for the industrial sector is planned to be reduced on a linear basis from 80% in 2012 to 0% in 2020.
- ***Exceptions for carbon leakage*** – In 2013 and in every following year to 2020, the EU plans to allocate free allowances covering up to 100% of the given industry's requirements to production sites in industries where there is a considerable risk of CO_2 emission relocation (carbon leakage). Carbon leakage refers to the relocation of production (and therefore the relocation of CO_2 emissions) to non-EU-ETS countries.

Project Objectives

In view of the key principles in the proposed amendment to the EU-ETS for the period following 2013, this study analyzes how the CO_2 costs will affect the international competitiveness of the German cement industry. In particular, the study examines whether and to what extent carbon leakage and additional CO_2 emissions may occur.

METHOD AND KEY ASSUMPTIONS

The study analyzes the expected market developments through to 2020 assuming different costs for CO_2 emissions and is based on publicly available information reflecting the current spectrum of expert opinion. The analysis looks at the possible economic implications of costs incurred for CO_2 emissions, and does not make any recommendations for political action.

Method

The basic assumption of the study is that producers in Germany will use cost analyses to make a rational decision about whether to produce clinker domestically or to import it from a non-EU-ETS country. When one of the options represents a significant cost saving over the other option, the producer will choose the more cost-efficient option once the cost difference exceeds a certain threshold. For larger companies, in particular, the study assumes that clinker can be produced at the companies' own installations in non-EU-ETS countries. This scenario seems likely because in this case criteria such as market access, quality, security of delivery, and prices (costs) are largely internalized.

- ***Analysis timeframe*** – Based on the allocation scheme described previously, companies will face the highest CO_2 costs in 2020. By then, the proposal of the European Commission stipulates full compliance with the reduction target of 21% as well as the fullest possible implementation of auctions for CO_2 allowances. For these reasons, 2020 is the reference year for the analyses presented in this report. Accordingly, the report assumes that the cement industry must purchase 100% of its allowances in auctions. All calculations were based on real costs expected in 2020[3].
- **Model calculation** – The model assumes that German producers will decide whether or not to produce clinker in Germany based on the expected production costs in Germany versus in non-EU-ETS countries, on the expected CO_2 emission costs for German producers, and on the expected transport costs for clinker produced abroad. Therefore, for the purposes of this study, estimates were needed for the expected costs of production, CO_2 emissions, and transport in

[3] The expected effect of the EU-ETS was calculated on an annual basis. However, this report only includes the effect expected for the year 2020.

2020. The following approach was selected *(Exhibit 1):*

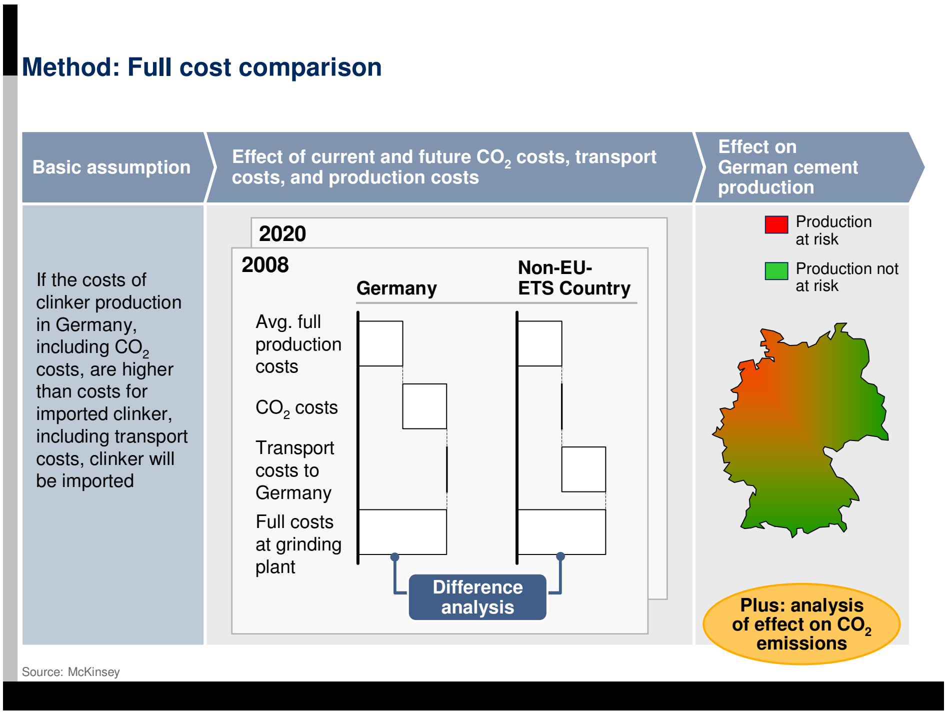


Exhibit 1: Method

– *Clinker production vs. cement production* – Clinker is responsible for nearly all of the CO_2 emissions generated by cement production (0.78 metric tons of CO_2 per metric ton of clinker)[4]. Furthermore, clinker has nearly exactly the same composition worldwide and, unlike cement, is easy to transport[5]. Cement is produced in cement mills by grinding clinker and using other ingredients such as granulated blast furnace slag, fly ash, limestone, and pozzolana. Independent of the origin of the clinker, the required type and quality of cement is generally manufactured and adjusted to meet end customers' requirements only at the grinding stage. If domestic production switches to imports, this shift will most likely affect clinker production. The analyses in this study therefore focus on a possible substitution of German clinker with imported clinker.

[4] Initial value: Actual CO_2 emissions 2006 / actual clinker production 2006 for Germany; Forecast to 2020 based on expected market development, development of the average share of secondary fuels, and the development in the share of biomass

[5] Cement is hygroscopic, and therefore requires particular care during transport as well as a specialized – and thus expensive – logistics chain

- *Average production costs based on full costs* – The study identified the average full costs of production and their development to 2020 for Germany and for possible non-EU-ETS export countries. The individual cost types were determined based on typical volumes and expected prices. Assumptions were made for the costs of personnel, electricity, fuel, raw materials, maintenance and repairs, depreciation, and miscellaneous. For Germany, the full costs assumed for clinker production represent the average for German plants.

  By contrast, the full production costs of imports from clinker production plants in non-EU-ETS countries were assumed to be in the lower third of the cost curve, as a sufficient number of such factories already exists. Furthermore, it can be assumed that new investments will be best-in-class installations with efficient cost structures.

  A full-cost analysis is also necessary because of the need to map long-term and enduring developments (not a spot market)[6]. This means that regardless of their age, existing installations can expect significant reinvestments in the long-term, while decisions on building new installations can only be made taking investment costs into account. The cost comparison therefore assumed constant depreciation based on investment costs for a new installation.

- *CO_2 emissions costs* – The study is based on the general assumption that cement producers in Germany will have to buy CO_2 emissions allowances for each metric ton of CO_2 emissions in 2020. The corresponding costs have been included in the calculation of the production costs at the above-mentioned rate of 0.78 metric tons of CO_2 per metric ton of clinker.

- *Transport costs to Germany* – Transport costs must be included as additional costs for exports to Germany. First, the most likely export routes were determined for overseas shipping to Germany (if overseas transport is included in the Emission Trading System, it accounts for additional CO_2 costs of 2% to 4% of the transport

[6] The full-cost analysis represents a conservative assumption. When based on marginal costs for imported clinker, the equilibrium shifts in favour of imports. Such a scenario is feasible if the development of the global demand for construction remains below the cement industry's expectations, and significant global overcapacities persist over a longer period. Given the long-term timeframe of the study, however, clinker produced in Germany has to be analysed on a full-cost basis.

costs; these were therefore disregarded as negligible). Within Germany, the main routes were defined based on the expected target region as well as topographical facts. Both inland barge shipping and road haulage were considered. Rail transport currently plays a minor role in the German cement industry, and was therefore not considered. For transport inside the exporting country, an average distance of 50 km to the nearest deep-sea port was assumed. This estimate roughly corresponds to the average distance of existing and planned installations.

Key Assumptions

The following additional basic assumptions were used in the analysis:

- ***Sufficient export capacities in non-EU-ETS countries –*** Sufficient clinker capacity for exports already exists in non-EU-ETS countries. By 2012, additional clinker factories will start operating. Moreover, producers will invest in more installations in non-EU-ETS countries if demand increases and clinker can be exported to Europe at a profit. The full-cost analysis described earlier ensures that the relevant investment costs are taken into account in the analysis.

  Three representative countries were selected: Egypt (representing North Africa), Saudi Arabia (representing the Middle East), and China. In the long-term, it is likely that these countries will have enough capacities for export owing to the market structure (China) or location (Egypt) – although Egypt's government has currently implemented export restrictions in order to improve supply for the local market in the short-term. Capacity expansions are also expected in the Middle East, hence the inclusion of this region (here represented by Saudi Arabia) in the analysis.

  For the period 2005-2010, cement production capacities are projected to grow by 8.2% per year in these three regions[7]. Assuming an average clinker factor[8] in these regions of 0.9 to 0.95, this growth corresponds to a cumulative clinker volume of around 475 million to 500 million metric tons – nearly 20 times the annual clinker production volume in Germany.

- ***Production cost comparison at grinding plants in Germany –*** The likely recipients of the expected clinker imports are existing

[7] Sources: OneStone Consulting, International Cement Review: Global Cement Report 7th edition

[8] Clinker factor: proportion of clinker per metric ton of cement

cement grinding plants in Germany. They have the necessary market access and logistics chain, and can use imported clinker volumes for cement production without having to make additional investments. This study therefore analyzes transport costs to these locations, differentiating between integrated and non-integrated grinding plants (part or not part of a cement factory with clinker production); Non-integrated plants will incur additional transport costs for moving clinker from its production site to the grinding station. For simplicity, the study assumes that non-integrated grinding locations currently purchase their clinker from the nearest clinker site with sufficient capacity.

In 2007, around 7.7 million metric tons of clinker were exported from German production[9] directly or as a cement constituent. The main importers were Germany's direct European neighbours, primarily because their border areas form a direct market for German producers. For these export volumes, the study compares production costs of German clinker versus non-EU-ETS clinker at the grinding plant locations in the respective countries. Some of these export destinations cannot be economically served by imports from non-EU-ETS countries assuming otherwise equal conditions. Therefore, the study only analysed German exports to Benelux, the UK, and Scandinavia, which, in 2007, accounted for about 4.5 million metric tons of clinker. Since transport costs must also be considered for exports from Germany, Rotterdam was selected as the reference port as a simplifying assumption. The choice of Rotterdam is justified because a large share of German exports is in fact delivered via this port, and comparable transport costs can be assumed for the other export destinations. Accordingly, Rotterdam is used as the reference for comparing the full production costs for Germany's clinker exports and the clinker imports from non-EU-ETS countries.

- ***Analysis of CO_2 balance (Exhibit 2) –*** The kilns used in Germany for clinker production are of the highest international standard in terms of CO_2 efficiency.[10] Potential relocation of production therefore means that CO_2 emissions are not reduced, but simply displaced – and potentially even increased. Such an increase could be caused by three main factors:

[9] Both cement and clinker are exported from Germany with cement generally comprising CEM I cement. For the sake of consistency, cement exports were converted to the equivalent in clinker using the corresponding clinker factors.

[10] Dry process in part with precalcination and high share of secondary fuels containing biomass

– Cement factories in non-EU-ETS countries are also assumed to use the latest state-of-the-art technology, but a lower proportion of CO_2-neutral secondary fuels (biomass)

– Energy, i.e., electric power generation in some non-EU-ETS countries is more CO_2-intensive than in Germany (indirect emissions)

– Additional CO_2 emissions are generated during transport

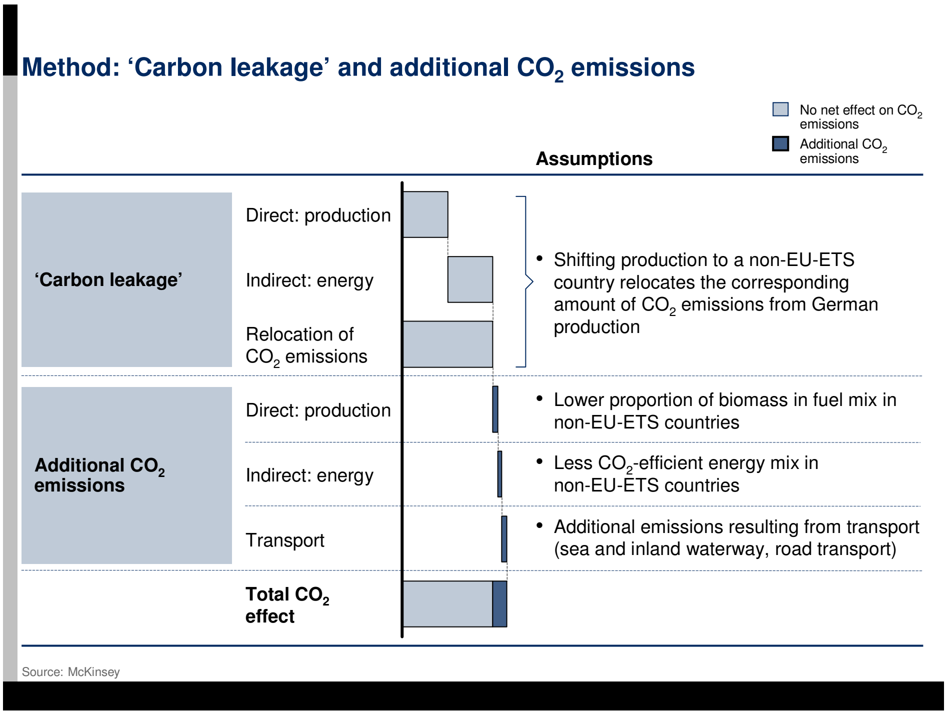
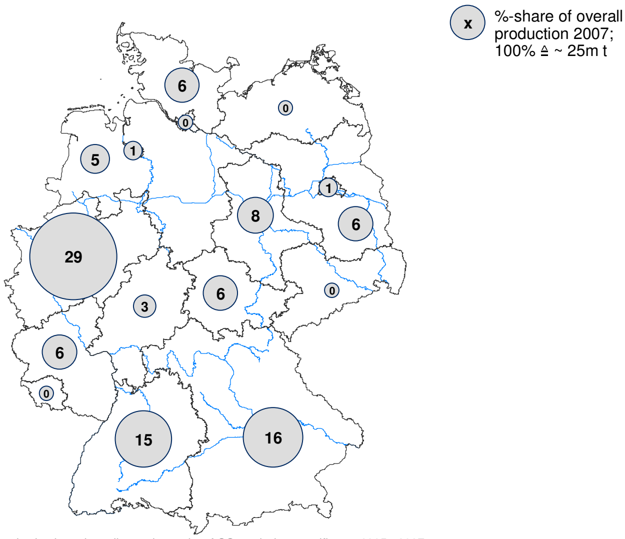


Exhibit 2: Relocation and production of additional CO_2 emissions

The comparative cost data for the respective grinding locations was used to draw a map of Germany showing which regions could expect substitution of locally produced clinker with imports. The production volumes in these regions were classified as potentially at risk, and the effect of relocation to non-EU-ETS countries on CO_2 emissions was calculated.

Production volumes of the German clinker production are based mainly on the CO_2 emissions values for 2005 to 2007, as reported by the industry to the German Emission Trading Authority (Deutsche Emissionshandelsstelle, DEHSt). These estimates were validated and updated in subsequent expert meetings.

Clinker production, Germany (according to federal state)*



* Assumption: Regional distribution of production based on allocated quantity of CO_2 emissions certificates 2005 - 2007
Source: German Emission Trading Authority (Deutsche Emissionshandelsstelle, DEHSt), International Cement Review, VDZ, expert interviews, McKinsey analysis

Exhibit 3: Clinker production in Germany, 2005 to 2007

The model calculation assumes that producers will switch to imported clinker, and domestic production is thus at risk, when the difference in production cost exceeds EUR 5/metric ton. Furthermore, it is assumed that a cost difference in a bandwidth of +/- 5 EUR/metric ton puts additional German production volumes at least partly at risk (50% of this category).

RESULTS AND IMPLICATIONS

The results of the basic scenario are presented below. In the following section, they are supplemented with the results of sensitivity analyses for input parameters.

Description of the Basic Scenario

In line with the method described previously, the basic scenario describes the cost comparison between an average cost-efficient clinker production plant in Germany and a plant with above-average efficiency in one of the non-EU-ETS countries.

This basic scenario was calculated using the following assumptions for the development of production costs, transport costs, and CO_2 emission costs up to 2020. All the assumptions used in this report are summarized in detail in the Appendix.

- ***Production costs –*** *Exhibit 4* shows a comparison of the production costs in 2020 between plants in Germany, Egypt, Saudi Arabia, and China. The approximate full production costs estimated for 2020 in EUR per metric ton are as follows: Germany 37 vs. Egypt 19, Saudi Arabia 20, and China 18. The key cost drivers up to 2020 are fuel and electricity prices. Fuel prices are expected to develop similarly in all regions analysed. The basic scenario for 2020 assumes a moderate decrease in the real price of coal, the primary fuel, as a result of a better equilibrium between supply and demand and lower transport costs (see below). For secondary fuels, increasing shortages are expected to increase global prices. For electricity, the basic scenario assumes that developments will differ between Germany and the non-EU-ETS countries. In Germany, the real price of electricity is expected to be around EUR 70/MWh in 2020. This development is based on two assumptions: moderate fuel costs in the long term, i.e., up to 2020, and utilities in Germany expanding their power generation capacity. In China, the price of energy is expected to remain at the current level because the price effects of deregulation, higher production efficiency, and moderately falling coal prices (see above) are expected to offset one another. In Saudi Arabia and Egypt, significant price increases are expected as a result of different developments in these markets. On the one hand, the supply of cheap gas for electricity generation will probably grow more slowly than demand; on the other hand, it is assumed that subsidies to the energy sector will decrease.

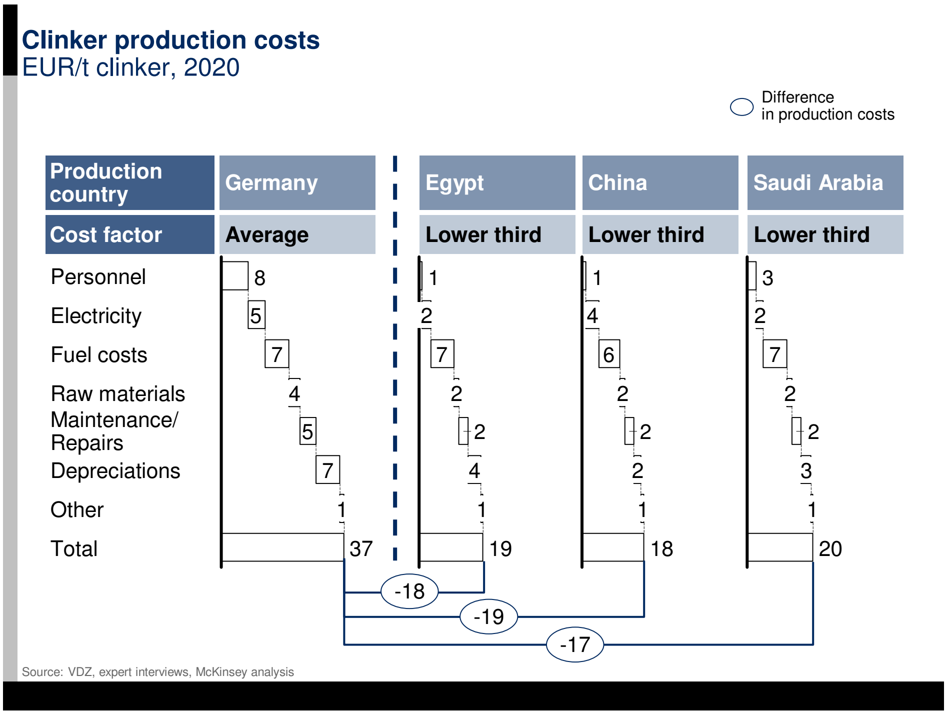


Exhibit 4: Clinker production costs in Germany and abroad, 2020

For the representative exporting non-EU-ETS countries, it is also assumed that there will be no external export restrictions in 2020, i.e., it is expected that the current restrictions for Egypt will be lifted once supply and demand for the local market have evened out.

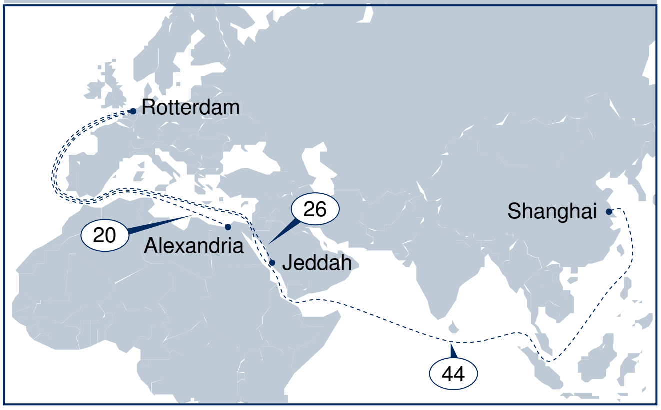
- ***Transport costs -*** Freight rates for overseas shipping have increased considerably in the last two to three years (approximately 18% p.a. from 2004 to 2008)[11], mainly because of undersupply of freight capacities. With the construction of new freight capacities by 2020, freight rates are expected to fall to about 60% of the price level of 2008. This estimate assumes that worldwide economic growth will slow down slightly (largely caused by slower growth in China) and that supply and demand for shipping capacities will be more balanced than today. *Exhibit 5* shows the assumed transport costs for some sample transport routes.

[11] Source: Baltic Dry Freight Index; calculation based on annual average values

Transport costs to Germany – Examples
EUR/t clinker, 2020

(x) Sea freight costs

Sea freight – Non-EU-ETS-country to Europe/Germany



Inland transport – Non-EU-ETS Country	
EUR/t	
Road transport to sea port*	6.3

Inland transport – Germany**	
EUR/t per 100 km	
Inland shipping	3.5
Road transport	8.6

* Assumption: ~ 50 km average distance from clinker production to port, incl. fixed costs
** Variable cost only - additional fixed costs (e.g., changeover costs) considered in calculation
Source: Expert interviews, McKinsey

Exhibit 5: Transport costs to Germany – Examples

- ***CO_2 emissions costs –*** The basic scenario assumes that the EU implements the proposed reduction target resulting in CO_2 costs of EUR 35/metric ton for 2020.

Result in Basic Scenario

Based on the estimates in the basic scenario it can be expected that, in 2020, about 50% or 12 million metric tons of clinker production in Germany will be at risk of substitution with imported clinker. As *Exhibit 6* shows, locations in northern Germany are most likely to be affected.

The threatened production volume of approximately 12 million metric tons corresponds to displaced CO_2 emissions of 10.6 million metric tons including additional CO_2 emissions of about 0.8 million metric tons. This means that not only can a significant amount of carbon leakage be expected, but also that the expected relocation will significantly increase the CO_2 emissions by around 7% of the displaced emissions.

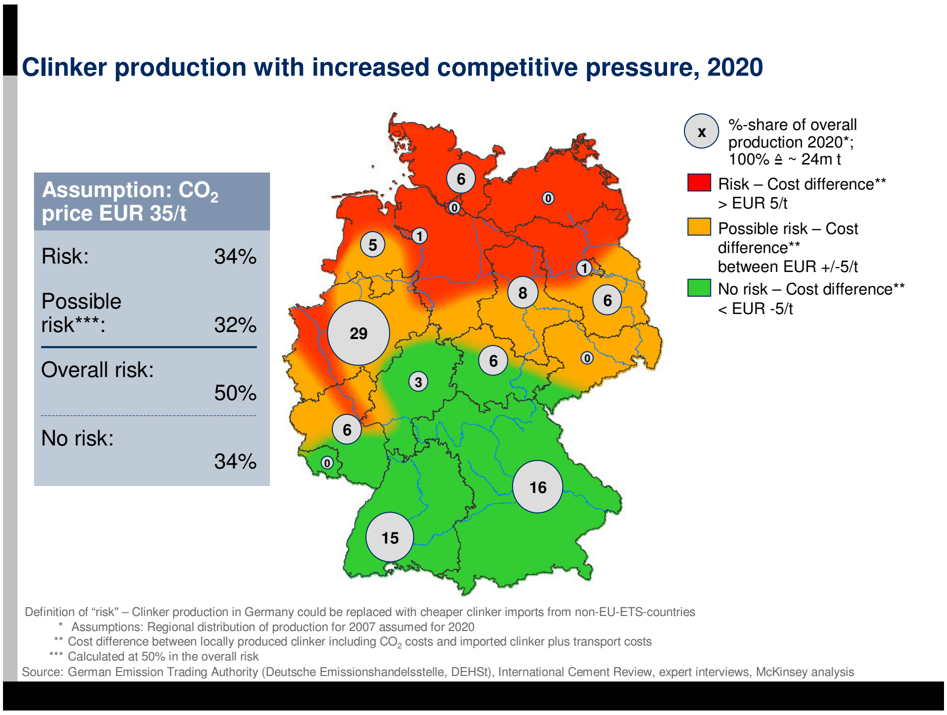


Exhibit 6: Clinker production with increased competitive pressure, 2020

This basic scenario predicts that most imports will come from Egypt (or North Africa as a region): key factors for this are both the lower logistics costs versus other non-EU-ETS countries and the cheaper production compared to Germany. Despite cost disadvantages in relation to Egypt, imports from Saudi Arabia (or the Middle East) to Germany cannot be ruled out. By contrast, under the given assumptions, imports from China to Germany are not competitive because the transport costs are higher compared to the other regions.

Finally, the study examined a scenario in which CO_2 allowances would be allocated free of cost to the cement industry. Above and beyond the freely allocated allowances, companies would have to purchase as many additional allowances as they need to achieve compliance with the CO_2 reduction target of 21% compared with 2005. Given that this commitment is supposed to apply to all CO_2 emissions (process CO_2 and fuel CO_2) and assuming that cement producers will have to buy the allowances required to meet the 21% target at a price of EUR 35 EUR/metric ton, this means that around 19% of German clinker production is still at risk of carbon leakage. If the commitment applied only to "fuel CO_2" this would reduce the share of German clinker production at risk to around 18%.

Sensitivity Analyses

The result of the analysis depends on the assumptions made regarding production costs, CO_2 costs, and transport costs. Given the uncertainties of assumptions in a projection to 2020, sensitivity analyses were carried out for the main parameters.

Building on the basic scenario, two additional scenarios were defined, each with high and low costs for the three main cost blocks: production, CO_2 and transport. They reflect different perspectives on how the global economy is likely to develop by the year 2020 *(Exhibit 7).*

Definition of the scenarios

	Low costs	Basic scenario	High costs
CO_2 prices	• EU-ETS will be implemented in reduced form (lower targets; more JI/CDM*) • EU with stronger focus on areas such as feedstock and food costs and on value creation in Europe	• EU maintains the stipulated reduction targets, and EU-ETS will be implemented as planned • Other key countries also agree on CO_2 reduction	• EU maintains own position on climate change – Implementation of additional measures (e.g. CCS**) on CO_2 reduction – Major restriction of JI/CDM*
Transport costs	• Slowing of global economy • Significant surplus capacities in shipping transport • Larger ships (Capesize) used for clinker transport	• Less growth in global economy resulting from less growth in China • Balanced supply and demand for shipping	• Further strong economic growth • Continued surplus demand for sea freight

* Joint Implementation (JI) and the Clean Development Mechanism (CDM) ** CCS: Carbon Capture and Storage
Source: McKinsey analysis

Exhibit 7: Definition of the scenarios

First, the study determined how changes to the input parameters would affect the overall result. As *Exhibit 8* shows, the biggest determinants of the risk of carbon leakage are the differences in production costs, in CO_2 prices and in transport costs for imports. The different sub-scenarios show that the range of production volumes at risk resulting from different production cost assumptions is about 41% to 52% (the difference between minimum and maximum is about 11 percentage points). For transport costs, the range is about 37% to 70% (a difference of approximately 33 percentage points) and for CO_2 prices about 29% to 74% (a difference of approximately 45 percentage points.) The largest spans between the low and high figures were found to be in CO_2 prices and in transport costs (45 and 33 percentage points respectively), so they were used as the key drivers for the sensitivity analysis.

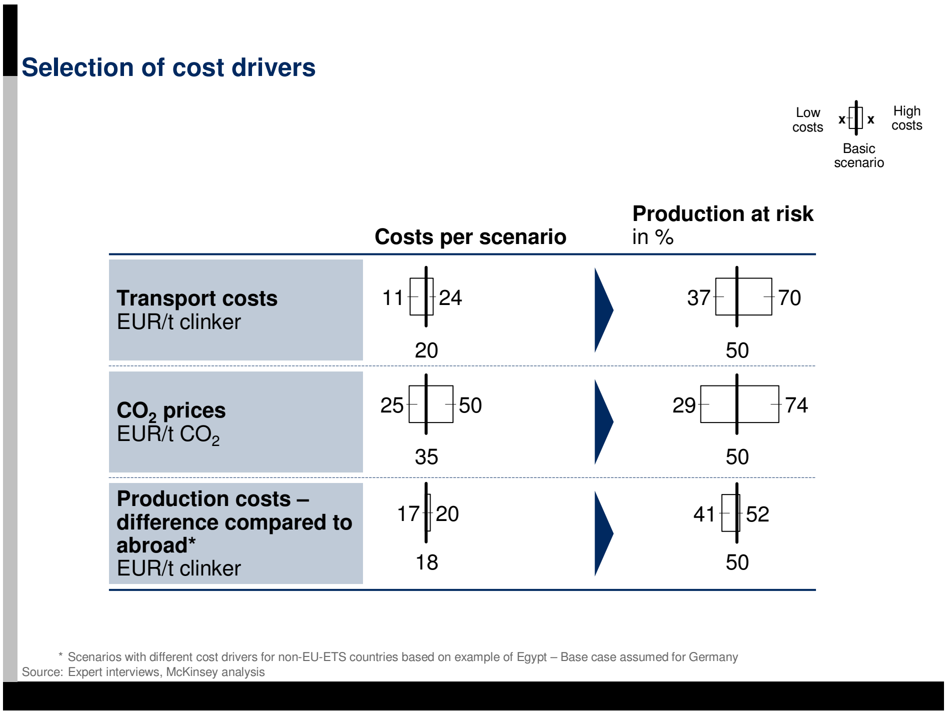


Exhibit 8: Selection of cost drivers

Depending on the combination of assumptions for CO_2 prices and transport costs, some 25% to 86% of German production is at risk. This corresponds to a total CO_2 emissions effect of approximately 5.3 million to 18.3 million metric tons of CO_2 (of which 0.4 million and 1.3 million metric tons, respectively, are additional CO_2 emissions; *Exhibit 9).*

Sensitivity analysis 2020 – Extreme values

Production at risk (in %)
Relocated and additional emissions (in million metric tons of CO_2)

	Transport costs Basis: Egypt - Rotterdam		
CO_2 costs	**High costs** 120% of basic scenario	**Basic scenario** 100%	**Low costs** 57% of basic scenario
Low costs EUR 25/t CO_2	25 5		
Basic scenario EUR 35/t CO_2		50 11	
High costs EUR 50/t CO_2			86 18

Source: Expert interviews, McKinsey analysis

Exhibit 9: Sensitivity analysis 2020 – Extreme values

In summary, in all of the scenarios analysed, the proposed amendment to the Emission Trading System will increase the costs of CO_2 for the German cement industry and can thus be expected to result in significant carbon leakage and additional CO_2 emissions for the German cement industry.

APPENDIX: DETAILS OF THE CALCULATIONS

Clinker Production Costs

As presented in the body of this report, the average full costs of production and their development to 2020 were identified for Germany as well as for Egypt, Saudi Arabia, and China. The individual cost types were determined based on typical volumes and expected prices.

Exhibit A and *Exhibit B* show the assumptions made for the costs of personnel, electricity, fuel, maintenance and repairs, depreciation, and miscellaneous factors.

Assumptions for production costs (constant values)
Real values

		Location of works (cost position)				Sources and assumptions	
Factor	**Unit**	**Germany** (average)	**Egypt** (better than average)	**Saudi Arabia** (better than average)	**China** (better than average)	**Germany**	**Egypt/ S-A/China**
Capacity	t/year	694.400	3,000,000	3,000,000	2,100,000	VDZ	OneStone Consulting
Utilization	Percent	90	90	90	90	VDZ (base 320 days/year)	McKinsey
Electricity consumption	kWh/t clinker	65	65	65	65	VDZ	VDZ
Energy consumption	kJ/kg clinker	3,688*	3,300	3,300	3,300	VDZ	Expert interview
Coal calorific value	kJ/kg	26,000	26,000	26,000	22,000	VDZ	VDZ
Raw material costs	EUR/t clinker	3.5	1.5	1.5	1.5	VDZ	Expert interview
Specific plant overheads (e.g. insurance, labs)	EUR/t clinker	1.3	0.8	0.8	0.8	McKinsey	McKinsey
Maintenance/ repairs	EUR/t	4.5	2.5	2.5	2.5	McKinsey assumption	Expert interview
Investment costs	EUR/me-tric tons of clinker p.a.	165	85	70	50	VDZ, BDI Stu-dy, 86% of a cement works	OneStone Consulting
Depreciation period	Year	25	25	25	25	Annual reports	Annual reports
Proportion of biomass in secondary fuels	Percent	30	80	80	70	VDZ	HOLCIM/ VDZ ECRA presentation

Source: Expert interviews, McKinsey analysis   * Falling to 3613 by 2020

Exhibit A: Assumptions for production costs (constant values)

The following key assumptions were made:

- ***Cost positions of clinker production plants*** – For Germany, the assumed full production costs represent the average for German clinker production plants. By contrast, for imports from non-EU-ETS countries, the full production costs were assumed to be in the lower third of the cost curve, as a sufficient number of such factories already exists. Furthermore, it can be assumed that new investments will be best-in-class installations with efficient cost structures. An average utilization of 90% was assumed for all plants.

- ***Primary fuels*** – A moderate decrease in the real price of coal, the primary fuel, is expected in 2020 compared to today. Currently, coal prices are influenced not only by the imbalance in supply and demand and high transport costs, but also by a number of external factors (e.g., flood in Australia, hard winter in China) that are unlikely to play a role in 2020. The moderate decrease in coal prices by 2020 will be driven by lower transport costs and a better balance between fuel supply and demand as a result of tapping into additional coal deposits.
- ***Secondary fuels –*** Global cost increases are expected for secondary fuels as a result of increased shortages. The price will be determined on the one hand by supply and demand and, on the other, by the energy content of the respective secondary fuel. An average price of approximately 40% of the primary fuel costs was assumed for long-term development, i.e., up to 2020.

  The share of secondary fuel used in clinker production is expected to increase, with different levels depending on the country and respective infrastructure. While secondary fuel as a share of all fuel used is expected to average 56% in Germany in 2020, the corresponding figure for Egypt is 20% and for Saudi Arabia and China, 10%.
- ***Electricity –*** The development of electricity costs largely depends on the development of fuel costs, supply and demand, and the cost of CO_2 emissions for countries that participate in the Emission Trading System. In Germany the electricity price is expected to be around EUR 70/MWh in real terms in 2020. This figure is based on the assumption of moderate fuel costs in the long term and an expansion of power generation capacities in Germany. In Saudi Arabia and Egypt, the real price of electricity in 2020 is expected to increase approximately 50% over 2008. The key drivers are specific to Egypt and Saudi Arabia and include (1) the growth rate for the supply of cheap gas for electricity generation is expected to be lower than the growth of demand and (2) subsidies for energy in the industrial sector are expected to fall. In China, a stable energy price is expected with possible price effects from deregulation, an increase in production efficiency, and moderately falling coal prices (see above) all balancing one another out.
- ***Export taxes*** – The study also assumed that there will be no external export restrictions for the non-EU-ETS countries Egypt, Saudi Arabia,

and China in 2020. The current restrictions for Egypt are expected to be lifted once supply and demand for the local market have returned to equilibrium. A linear reduction to 0% export taxes in 2020 has been assumed.

Assumptions for production costs (2008 - 2020)
Real values

Factor	Country	2008	2010	2012	2014	2016	2018	2020	Source
			Forecast						
Share of secondary fuels in fuel mix Percent	Germany	50	51	52	53	54	55	56	VDZ, McKinsey
	Egypt	5	8	10	13	15	18	20	VDZ, McKinsey
	Saudi Arabia	5	6	7	8	8	9	10	VDZ, McKinsey
	China	5	6	7	8	8	9	10	VDZ, McKinsey
Secondary fuel price in percentage of primary fuel costs	All	0	7	13	20	27	33	40	Expert interview
Electricity price EUR/MWh	Germany	66	79	77	71	64	66	67	EEX, McKinsey Integrated Perspective, Middle Case (v5831)
	Egypt	25	27	29	31	33	35	38	HSBC, EIU 2007 for 2008; McKinsey: 50% increase by 2020
	Saudi Arabia	21	23	26	29	31	34	31	SEC for 2008; McKinsey: 50% increase by 2020
	China	60	60	60	60	60	60	60	CEIC for 2008, McKinsey: constant
Electricity net cost and taxes in EUR/MWh	Germany	16	16	16	16	16	16	16	VDZ, expert interview
Personnel full costs EUR thousand/FTE	Germany	44	45	46	47	47	48	49	VDZ 2007 for 2008, Global Insight for forecast to 2020
	Egypt	5	6	6	7	7	8	8	W. Wyatt database, EIU, McKinsey
	Saudi Arabia	12	14	16	16	17	17	17	James F. King (2005), McKinsey
	China	5	7	8	10	11	12	14	Expert interview, China Labor Statistical Yearbook 2005, McKinsey
Employees per plant FTE	Germany	100	100	100	100	100	100	100	VDZ, McKinsey
	Egypt	300	300	300	300	300	300	300	VDZ, McKinsey
	Saudi Arabia	300	300	300	300	300	300	300	VDZ, McKinsey
	China	150	150	150	150	150	150	150	VDZ, McKinsey
Coal price EUR/t	Germany	94	77	75	74	74	74	74	McKinsey Integrated Perspective, Middle Case (v5831)
	Egypt	78	64	62	62	62	62	62	IntCemRev (Yemen), Development similar to Germany
	Saudi Arabia	78	64	62	62	62	62	62	IntCemRev (Yemen), Development similar to Germany
	China	55	43	39	37	37	38	43	JFK
Clinker factor in %	Germany	71	70	70	69	68	68	67	McKinsey
Export taxes EUR/t	Egypt	10	9	7	5	3	2	0	IntCemRev, McKinsey: lin. reduction by 2020
	Saudi Arabia	0	0	0	0	0	0	0	McKinsey
	China	0	0	0	0	0	0	0	McKinsey

Source: VDZ, expert interviews, McKinsey analysis

Exhibit B: Assumptions for production costs (2008 to 2020)

Transport Costs

The analysis of transport costs from non-EU-ETS countries to the grinding locations in Germany is based mainly on four elements: transport costs within the exporting country, overseas shipping, inland shipping to and within Germany, and road transport within Germany. The details of the individual calculations are given below. *Exhibits C, D, and E* show the key assumptions on which the calculations are based.

- ***Abroad: Transport within the exporting country*** – Since the existing and planned clinker production plants in the non-EU-ETS countries Egypt, Saudi Arabia, and China are not directly situated near deep-sea ports, additional transport costs must be factored into the calculations. After analyzing distances from production sites to ports, an average distance of 50 km was assumed for existing and planned installations suitable for exports. The cost of road transport for this distance was assumed to be similar to that in Germany.

- ***Non-EU-ETS country to Germany: Overseas shipping*** – To estimate the transport costs for overseas shipping, the first step was to determine the most likely shipping routes. For Europe and Germany as destinations, three deep-sea ports were selected that are already used for importing and exporting clinker or cement: Rotterdam, Hamburg, and Bremerhaven. The representative ports selected for the non-EU-ETS countries were Alexandria for Egypt, Jeddah for Saudi Arabia, and Shanghai for China.

  Step 2 was to create a detailed model to calculate the transport costs for all possible routes up to 2020. The model is based on all main cost drivers for overseas shipping: ship size, freight rates, handling costs, waiting times, port, towage and anchorage charges, transport time, fuel costs, and the return load factor. The return load factor is the share of the ship's capacity used to transport cargo on the return journey. The freight rates and the return load factor are the key cost drivers.

  With the construction of new transport capacities, freight rates are expected to fall by 2020 to about 60% of the price level of 2008. This estimate assumes that growth of the world economy will slow slightly (largely caused by slower growth in China), and that supply and demand for shipping capacities will be more balanced than today.
  To determine the return load factor, the study analysed import/export statistics for bulk material at the three ports in Europe/Germany for the last three years. As a consequence, a return load factor of 10% was used for analysis. This means that 10% of ship capacities is used on the return journey. Constant values were used for the other cost drivers.

Assumptions for transport costs (1/3)
Real values

Factor	Unit	Capesize	Panamax	Source
Load volume	t	150,000	70,000	Clarkson
Speed	kt	14	14	McKinsey
MDO* consumption	t/day	15	14	McKinsey
HFO** consumption	t/day	56	27	McKinsey
Docking fee/day	EUR	777	616	Port of Rotterdam
Port charges/visit	EUR	70,000	43,750	Port of Rotterdam
Towage charges/visit	EUR	4,800	3,600	Port of Rotterdam
Anchorage charges/visit	EUR	3,200	1,560	Port of Rotterdam
Pilot charges/visit	EUR	13,000	9,436	Port of Rotterdam
Time in port	Days	7	6	Port of Rotterdam

* Marine Diesel Oil
** Heavy Fuel Oil
Source: VDZ, expert interviews, McKinsey

Exhibit C: Assumptions for transport costs (1/3)

Assumptions for transport costs (2/3)
Real values

Factor	Unit	Value	Source
Loading costs (port)	EUR/t	2.5	Expert interview
Probability of empty return journey	Percent	90	Port statistics – Bremen, Rotterdam
Road transport (fixed costs)	EUR/t	2	Expert interview
Road transport (variable costs ex. fuel)	EUR/ (t • km)	0.049	McKinsey
Road transport (variable fuel costs)	l/(t • km)	0.026	McKinsey
Changeover from sea port to river	EUR	1.5	Expert interview
River transport	ct/km	3.5	Expert interview
Road to air distance factor	km/km	1.28	Springer
Distance to sea port – Egypt, Saudi Arabia, China	km	50	McKinsey

Source: VDZ, expert interviews, McKinsey

Exhibit D: Assumptions for transport costs (2/3)

Assumptions for transport costs (3/3)
Real values

Factor	Unit	Forecast							Source
		2008	2010	2012	2014	2016	2018	2020	
Freight rates (Capesize)	EUR/d	65,000	40,625	23,663	24,228	30,111	35,825	41,111	JFK
Freight rates (Panamax)	EUR/d	45,500	24,375	15,237	15,408	19,130	22,734	26,048	JFK
MDO* fuel price	EUR/t	550	550	550	550	550	550	550	Analyst reports, McKinsey: constant
HFO** fuel price	EUR/t	306	306	306	306	306	306	306	Analyst reports, McKinsey: constant
Diesel price (Germany)	EUR/l	1.4	1.4	1.4	1.4	1.4	1.4	1.4	POS price, McKinsey: constant
Suez canal charges (Capesize)	EUR/t	1.3	1.3	1.3	1.3	1.4	1.4	1.4	R K Johns/Leth
Suez canal charges (Panamax)	EUR/t	1.9	1.9	1.9	1.9	2.0	2.0	2.0	R K Johns/Leth

* Marine Diesel Oil
** Heavy Fuel Oil
Source: VDZ, expert interviews, McKinsey

Exhibit E: Assumptions for transport costs (3/3)

- ***Europe/Germany: Inland shipping*** – The next main element in the logistics chain is transport by inland waterway. First, the actual position of the integrated clinker production locations and the non-integrated grinding locations were determined, and then the distance to the river was estimated. Since transport on the waterway is generally cheaper than road transport, the maximum possible distance on waterways was assumed. To calculate the overall costs, the corresponding transport costs per metric ton per kilometre as well as fixed costs were used, e.g., handling costs. Constant values based on 2008 were assumed for the year 2020.
- ***Germany: Road transport*** **–** Consequently, the shortest possible distance was determined for road transport. Constant transport costs per metric ton per kilometre and fixed costs were also used here for the year 2020 based on 2008 values.

CO_2 Emission Costs

The CO_2 costs for clinker production were calculated based on various scenarios for CO_2 prices, as explained in the body of the report. In addition, the expected CO_2 emissions were determined based on the expected development of clinker production taking into account the share of secondary fuels used. For the year 2020, emissions are expected to be 0.78 metric tons CO_2 per metric ton of clinker in Germany.[12]

CO_2 Balance

Potential relocation of production means that CO_2 emissions are not reduced, but simply displaced to other regions – or even increased in those other regions. To quantify this effect, the CO_2 balance was analysed: the volume of displaced CO_2 emissions and the additional CO_2 emissions resulting from the relocation were determined. To calculate the displaced emissions, the production volume at risk was used along with the corresponding CO_2 emissions. Three further factors were considered when analyzing the additional emissions. *Exhibits F and G* show the main assumptions.

Assumptions for CO_2 balance – indirect emissions from electricity production (1/2)
Real values

			Forecast							
Factor	**Unit**	**Country**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018**	**2020**	**Source**
Indirect emis-sions	t CO_2/MWh	Germany	0.53	0.53	0.53	0.52	0.52	0.52	0.51	McKinsey BDI Study
		Egypt	0.53	0.53	0.52	0.51	0.51	0.50	0.50	McKinsey GHG Abate-ment Cost Curve Model (Africa without RSA)
		Saudi Arabia	0.54	0.54	0.54	0.53	0.53	0.53	0.52	McKinsey GHG Abate-ment Cost Curve Model (Middle East)
		China	0.68	0.67	0.66	0.66	0.65	0.64	0.63	McKinsey GHG Abate-ment Cost Curve Model

Source: VDZ, expert interviews, McKinsey analysis

Exhibit F: Assumptions for CO_2 balance (1/2)

- ***Fuel*** – Factories in non-EU-ETS countries use the latest state-of-the-art technology, but a lower share of CO_2-neutral secondary fuels (biomass). Given that secondary fuels on average have a lower CO_2

[12] Initial value: Actual CO_2 emissions 2006 / actual clinker production 2006 for Germany; forecast to 2020 based on anticipated market development, development of the average share of secondary fuels, and share of biomass

emissions balance, clinker production in Egypt, Saudi Arabia, and China will generate higher CO_2 emissions. These "extra" emissions are calculated based on the different expectations about the share of secondary fuels (biomass) used in the respective non-EU-ETS countries.

Assumptions for CO_2 balance – direct emissions from transport (2/2)
Real values

Factor	Unit	Value	Source
CO_2 Balance: Ocean	g/(t • km)	2.2	ELCD, similar scenario
CO_2 Balance: River	g/(t • km)	23.0	ELCD, similar scenario
CO_2 Balance: Road	g/(t • km)	44.0	ELCD, similar scenario
Methane bal.: Ocean	g/(t • km)	5.6 E-05	ELCD, similar scenario
Methane bal.: River	g/(t • km)	3.6 E-03	ELCD, similar scenario
Methane bal.: Road	g/(t • km)	3.6 E-04	ELCD, similar scenario
CO_2/Methane	t CO_2equ./ t Methane	23	EIA

Source: VDZ, expert interviews, McKinsey analysis

Exhibit G: Assumptions for CO_2 balance (2/2)

- ***Energy generation*** – Energy generation in some non-EU-ETS countries is more CO_2-intensive than in Germany. Clinker production in Egypt, Saudi Arabia, or China can therefore generate additional indirect CO_2 emissions in the energy sector. This additional effect was determined based on the CO_2 emissions expected for electricity generation in 2020 for the four countries Germany, Egypt, Saudi Arabia, and China. Of these, China is the only country with significantly higher indirect CO_2 emissions due to energy generation. In Egypt and Saudi Arabia, these indirect emission volumes from electricity generation are projected to be nearly equal or lower than in Germany in 2020.
- ***Transport*** – Additional CO_2 emissions are also produced during transport. The calculation here was based on the current technology for sea, inland waterway, and road transport, including the current CO_2 emissions that occur for these modes of transport.

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