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ETCLIP – The Challenge of the European Carbon Market: Emission Trading, Carbon Leakage and Instruments to Stabilise the CO2 Price

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Simone Cooper, Susanne Dröge (Climate Strategies)

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Abstract

The European Commission has assessed in 2009 the sectors that will be covered under the Phase III of the EU emissions trading scheme (EU ETS) in order to estimate the impact from unilateral carbon pricing on the environmental effectiveness of the EU ETS. It has identified 164 sectors being at "risk of carbon leakage". There are, however, analytical difficulties with correctly identifying sectors at risk. Using only quantitative criteria like cost impact and trade intensity leads to too broad results. Qualitative assessments focusing on those sectors with the highest share in carbon emissions under the EU cap could instead offer a better understanding of the nature of the risk of leakage. This study offers an example of an in-depth analysis to identify the scale and nature of the risk of carbon leakage. It investigates the European steel, cement and pulp and paper industries.

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Contents

Executive Summary

The EU remains a world leader in the implementation of carbon pricing policies and Phase III of the EU Emissions Trading Scheme (EU ETS) is likely to result in a high carbon price relative to other schemes worldwide. Although a number of policy proposals have been put forward in different world regions, the development of a global CO_2-market is still many years away. As such, production cost differentials caused by carbon pricing are likely to remain a key area of focus for both industry stakeholders and policymakers alike. Carbon pricing has the potential to affect a sector's level of competitiveness and market competition in the EU relative to international competitors. The scale of the impact of the carbon price on a sector's relative competitiveness will differ across sectors and needs to be understood and distinguished from other production and market drivers affecting a sector's competitiveness so that remedial policies can be introduced to reduce any international market distortions that could arise.

When faced with a carbon price, installations have four principle options to respond:

1) Absorb the costs;

2) Pass on some or all costs to downstream consumers in the form of increased product prices;

3) Reduce the carbon costs they face by introducing technologies or processes which abate the amount of emissions they generate;

4) Relocate production to areas without carbon costs through increased imports or relocation of physical capital.

This fourth option results in carbon leakage and is of great concern from an economic, environmental and political perspective. This potential relocation to areas outside of the EU prompted the European Commission to undertake an assessment of which sectors could be at risk. The EU Commission used two criteria (cost impact in relation to gross value added and trade intensity) and three related thresholds, determined in the revised EU ETS Directive[1], and identified 164 (out of a total of 258) manufacturing subsectors as being at risk of leakage in Phase III of the EU ETS. A number of studies, additional to that of the Commission's, have also been undertaken to understand the risk of leakage manufacturing sectors may face in Europe and abroad, due to unilateral carbon pricing. They use different methodological approaches, assessment criteria, thresholds, level of sector disaggregation and modelling assumptions and cover different geographical regions under different carbon pricing scenarios. However, all studies repeatedly identify a limited number of sectors at risk including steel, cement, paper and pulp, aluminium and some chemical subsectors and refineries.

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[1] European Commission (2009) http://register.consilium.europa.eu/pdf/en/08/st03/st03737.en08.pdf

This large number of sectors identified by the European Commission's assessment is due to the inclusion of the single trade intensity threshold which led to the inclusion of 118 sectors. In addition, it indicates broader analytical difficulties with correctly identifying sectors at risk. Adding more quantitative criteria is complex with inherent subjectivity with regards to the relative weight and thresholds for criteria. Instead a more holistic approach is recommended and qualitative assessments which detail a sector characteristics could instead be undertaken to better understand the nature of the risk of leakage a sector may face. However, qualitative analysis is costly and given budget constraints, a deeper analysis of a small set of sectors with high cost impacts may have reduced the resources invested by the Commission. There may however be additional uses for this assessment in determining sectoral benchmarks. The approach for determining sectors at risk is likely to be determined ultimately by resource constraints; both time and money.

This study offers an example of the sort of in-depth analysis that could be undertaken to identify the scale and nature of the risk of leakage faced by the European steel, cement and pulp and paper industries. It finds that each sector faces a different type of leakage risk.

When faced with carbon costs, installations have the option of absorbing the carbon costs or passing them on by increasing the product prices. To understand the choice each sector faces requires an understanding of the market conditions they operate in i.e. their pricing and market structure and also their cost structure. A detailed understanding of a sector's cost structure allows for a contextualisation of carbon costs relative to other production costs. This helps to disaggregate production location decisions due to carbon pricing from other input costs.

Installations can also reduce their carbon costs by undertaking mitigation activities. These mitigation options will have different costs and operate over different timeframes. In some instances the carbon price might not be sufficient to incentivise the necessary production transformation and supplementary policies may be required in the short term at least.

This study finds that for the steel sector, prices and profits are very susceptible to changes in economic growth. This sensitivity is compounded by the fact that the EU and other historically large producers are facing increased competition from less carbon constrained countries. China in particular has expanded production capacity at an enormous rate in recent years to become the world's largest steel producer. This increased competition has led to cost saving measures being introduced in the industry across a number of regions. As more cost saving measures are introduced, carbon costs are likely to play an increasing role in determining long term investment strategies and the location of production and the potential scale of the risk of leakage in the steel sector has been recognised in a number of economic models and by industry representatives.

In the cement sector, there is a higher risk of import leakage rather than the complete relocation of production in the short term. Due to the relative homogeneity of the factor inputs, installations covered by the EU ETS may choose to import clinker from extra-EU sources. Increased cement imports from extra-EU regions began prior to the EU ETS in 2004. Carbon pricing therefore has the potential to compound existing market trends in the cement industry to the detriment of both the environment and European industry. The complete relocation of plants to extra-EU regions is unlikely given the high sunk costs. Moreover, large regional markets allow for some flexibility regarding pricing strategies compared with other commodities, yet this is bound by transport costs.

The pulp and paper sector has already made good progress in recent years to shift fuel use towards renewables. It has introduced energy efficiency measures which were likely to be driven by cost saving objectives rather than environmental ones. Additional mitigation options may be more costly. Even prior to the introduction of the EU ETS, the European sector was in decline in terms of employment and production levels which has been exacerbated by the recent economic downturn. The European sector faces rising input costs as more regions develop their pulp and paper sectors to reflect growing demand, particularly in emerging economies; often for higher value paper products as the economy industrialises. Even if a complete relocation of production for EU producers is unlikely and costly (large operations enjoying economies of scale) for European producers, carbon may become a bigger component of the sector's cost schedule and may influence mid-long term investment decisions.

The EU has chosen free allocation with a benchmark of the top ten EU producers in a sector as the principal policy option to address carbon leakage. This means that all installations that meet the benchmark will receive 100% free allowances while all others will receive less. To provide free allowances levels down the carbon costs for producers but it does not per se prevent them from importing more or relocating and cash in the allowances and benefit from additional revenues. In order to help prevent carbon leakage, free allocation thus should be contingent on continued operation, implemented using benchmarks and address the relevant stage in the production chain (this latter piece of information can be required through in-depth sectoral analysis).

The Directive also references other tools for addressing leakage: the inclusion of importers, sectoral approaches, agreements and mechanisms (SAAMs) and state aid for indirect cost impacts. This study finds that these policy options will have different strengths and weaknesses when assessed against different socio-economic criteria. E.g. sectoral approaches have gained increasing attention in the international and domestic policy arena both in the context of emissions trading and as a distinct policy option to encourage regional, and perhaps global, engagement.

1 Introduction

Carbon leakage is an issue high on the EU agenda, this was particularly true during the development of the European Commission's Energy and Climate package in 2008. It continues to be a key area of consideration for the EU following international policy developments at COP 15 and COP 16 and the absence of fully developed post-Kyoto framework for undertaking country-level emissions reductions targets. The issue of leakage will also be of increasing importance for policymakers should the European Commission decide to move beyond a 20% emissions reductions commitment by 2020. For the EU to make these more ambitious emissions commitments, concerns about the competitiveness impacts of carbon pricing need to be properly addressed. First by assessing the reality of the issue of carbon leakage in different sectors and secondly by introducing the most appropriate remedial policies to those sectors identified as being most at risk. Policy measures to address the risk of leakage should aim to limit any negative side effects associated with carbon pricing.

This report begins by offering some context to the issue of carbon leakage both within the EU and also in other regions considering carbon pricing. It provides detailed information on the characteristics of certain energy and trade-exposed sectors, namely cement, steel and paper and pulp to offer international perspectives of major emissions-intensive sectors. This is done by creating sector 'deep-dives' and look at the characteristics which determine the potential sources of competitiveness and leakage concerns caused by carbon pricing. In particular, the analysis looks at the underlying patterns of trade for these sectors so as to better understand the environment they operate in relative to international competitors who don't face equivalent carbon costs. Chapter 1 of the report looks at the methodological approaches to assess the risk of leakage more broadly and offers an overview of the studies which have been applied to different geographical regions and sectors to quantitatively determine the risk of leakage. The chapter concludes by consolidating these various sources of information on the cement, steel and paper and pulp sectors and offer its own analysis on the anticipated impact Phase III of the EU ETS could have on trade flows and international competitiveness of these sectors.

Chapter 2 of the report offers more in-depth insights into the cost structures and abatement technologies in the steel, cement and pulp and paper sectors in the EU and compare them to their extra-EU competitors. When faced with a carbon price, installations have 4 distinct options:

1) Absorb the costs

2) Reduce the carbon costs by introducing technologies or processes which abate the amount of emissions they generate

3) Pass on some or all costs to downstream consumers in the form of increased product prices

4) Relocate production to areas without carbon costs i.e. leading to carbon leakage

The final chapter looks at the potential for sectoral approaches, agreements and mechanisms (SAAMs) and other remedial policy options to address the risk of carbon leakage. It begins by outlining the three principle conceptual options available to policymakers to equalise carbon costs between EU and extra-EU trade partners that compete in the same markets: levelling up, levelling down and levelling at the border. The chapter looks at the relative strengths and weaknesses of these three policy options from an economic efficiency, administrative and geopolitical and legal viewpoint. The principle focus of the ensuing discussion is then on the policy option of SAAMs, exploring a selection of the different types of SAAMs that have been proposed and discussed in policy and academic literature. Finally we offer some broad conclusions on the feasibility and effectiveness of this policy instrument to address the issue of carbon leakage. The chapter concludes with a short case study that explores how a sectoral approach could be applied in the steel sector in different global regions.

1.1 International perspectives of major emission-intensive sectors

The risk of carbon leakage is an issue of concern for industry and policymakers around the world who are considering the introduction of carbon pricing. Carbon leakage occurs when emissions in a carbon pricing region (using an emissions trading scheme or a carbon tax) are reduced because they shift to other regions rather than because of mitigation actions. This could occur in the form of increased imports from or a relocation of trade-exposed energy intensive industries to countries that don’t face equivalent carbon costs.

Carbon leakage is of concern from an environmental perspective because global emissions will not decrease, but emission sources merely relocate. Depending on where the relocation occurs, emissions from the shifted production may increase (e.g. if the energy source used in production is more carbon intensive) or decrease (e.g. if the energy source used in production is less energy intensive). While a decrease of global emission due to relocation is a positive effect from an environmental point of view, this is still carbon leakage. From a political point of view this kind of leakage challenges the environmental integrity of national climate policy, and could lead to a loss in political credibility.

In addition to political and environmental concerns associated with the risk of carbon leakage, the issue is also of concern from an economic viewpoint. Installations that operate within the carbon pricing region will have additional input costs from carbon that may not necessarily be experienced by their competitors who operate outside the region. Thus, depending on the installation’s cost structure, this may lead to loss of market share, lower profits and to reduced staff, close-down or relocation abroad. Even though this risk is likely to be sector-specific within the carbon pricing region, there are potentially significant macroeconomic implications if the scale of the effect, i.e. the number of sectors ‘leaking’ abroad is high. This would impact GDP and employment across the entire carbon pricing region.

In order to better understand the ways in which carbon pricing affects global emissions, research by Climate Strategies[2] explores the mechanics of the risk of leakage further by offering a typology of channels for it to occur. The report finds that carbon pricing impacts on:

1. International Energy Markets

Carbon pricing especially affects the national price of fossil fuels. This will reduce overall demand for fossil fuels in a region with carbon pricing. If – like with the EU – there is a demand effect on world markets, world energy prices will fall. This will in turn lead to increased demand and consumption of fuels elsewhere in the world. Due to the international economic integration, macroeconomic effects from energy markets can drive carbon leakage.

2. Firm's production costs and their operation and investment decisions

Carbon pricing has also a microeconomic impact on industries' direct and indirect costs. This channel of leakage is of particular interest to policymakers as it reveals more accurately the sector-specific source of the risk of leakage, allowing for a targeted remedial policy response. It is this channel of leakage that will be of specific interest for this report as we explore sector specific characteristics of energy and emissions intensive industries to pinpoint the likely source of leakage.

3. The dynamics of technological innovation and policy diffusion

Carbon pricing can affect both technology development and deployment. In principle a long-term carbon price signal offers the incentive to introduce new lower carbon technologies or production practices. However, a carbon price signal is not always sufficient to incentivise a full low carbon transition so that new technologies can compete with incumbent ones. Additional and supplementary policies may be required. Furthermore, the incentive the carbon price creates to innovate and gain market share might be limited by the threat of competitors outside of the carbon pricing region 'leapfrogging' up the technology development process without the same level of expenditure on research.

The net impact from these three leakage effects on global emissions is unclear as the three channels affect emissions levels in different ways, sometimes with counteracting impacts. E.g. the global energy channel would result in an increase in emissions whilst the technology channel could result in a fall in emissions.

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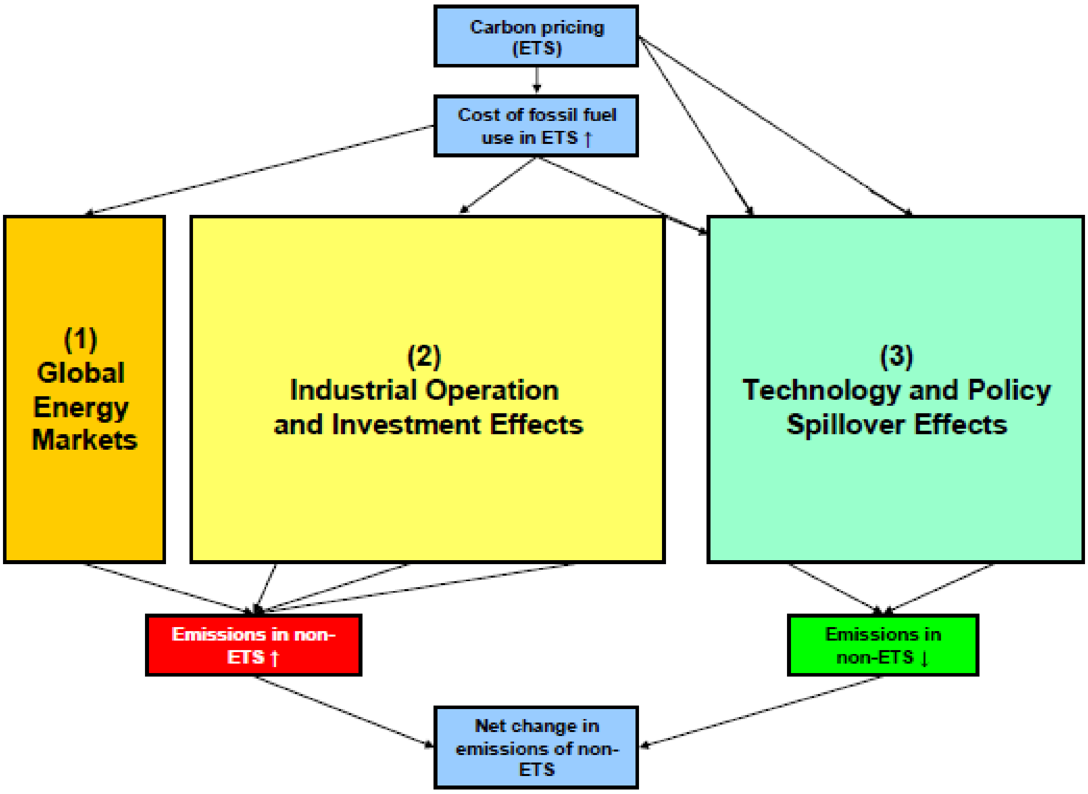
[2] Climate Strategies (2009) Dröge, S. et al. Tackling Leakage in a World of Unequal Carbon Prices

Figure 1: Carbon pricing and the channels for carbon leakage.



(Source: Climate Strategies, Droege et al. 2009)

Due to the environmental, economic and political concerns associated with carbon leakage, governments around the world that are introducing or considering carbon pricing have incorporated provisions in their policies to identify sectors at risk of carbon leakage and then mitigate this risk.

In December 2009, the European Commission completed its quantitative impact assessment and identified 164 manufacturing sectors as being at risk of carbon leakage during Phase III (2013-2020) of the EU emissions trading scheme. Following the EU ETS directive, the Commission applied two criteria:

1. Carbon costs as a percentage of GVA, assuming a CO2 price per tonne of € 30

2. Trade intensity given trade data average from 2006-2007

Individual and combination thresholds were applied to decide whether or not a particular sector (at NACE 4 level of sector disaggregation) could be at risk of carbon leakage. These thresholds were:

- The extent to which the **sum of direct and indirect additional costs** induced by the implementation of this directive would lead to a substantial increase of production cost, calculated **as a proportion of the Gross Value Added, of at least 5%;**

AND

- The **Non-EU Trade intensity** defined as the ratio between total of value of exports to non EU + value of imports from non-EU and the total market size for the Community (annual turnover plus total imports) **is above 10%.**

OR

- If the **sum of direct and indirect additional costs** induced by the implementation of this directive would lead to a particularly high increase of production cost, calculated **as a proportion of the Gross Value Added, of at least 30%;**

OR

- If the **Non-EU Trade intensity** defined as the between total of value of exports to non EU + value of imports from non-EU and the total market size for the Community (annual turnover plus total imports) **is above 30%**[3]**.**

In cases where data was incomplete or unreliable, supplementary qualitative assessments of sectors were used to identify if there was a risk of leakage.

The high number of sectors identified as being at risk was largely due to the single trade intensity criterion (above 30%), which was exceeded by many sectors (118 were added to the list of sectors at risk due to this single criterion). The full list of sectors at risk with their respective reasons for inclusion are outlined in Annex 3

For the initial allocation of emission rights in Phase III, the EU ETS Directive foresees three groups of sectors as outlined in Table 1.The first group is built by power sector installations, which have to auction 100% of allowances starting in 2013, with an exemption for Eastern European and Swedish installations (starting with 70%). The second group is comprised of the manufacturing industry, installations have to buy an increasing number of allowances from auctions, and receive a declining share for free (from 80 to 30% by 2020). The third group is built by those manufacturers which are identified as being at risk of carbon leakage. They receive free allowances if they meet an industry benchmark, which is being determined along the top ten European producers in a sector.

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[3] European Commission http://ec.europa.eu/environment/climat/emission/carbon_en.htm

Table 1 : Sector groupings and their respective permit allocation methods for Phase III of the EU ETS

Sector	Power Generation	Manufacturing industry	Sectors at risk of carbon leakage
Allocation methodology	Full auctioning of EUAs from 2013.	Free allocation defined as a share of a declining cap based on 2005-2007 emissions. From 80% of the emissions that would be emitting in 'best practice' 2013 to 30% in 2020.	May receive 100% free allocation of the emissions that a 'best practice' producer would emit, adjusted for the declining cap or alternative measures such as a global SAAM, state aid or the requirement for importers to buy allowances

Source: European Commission

The approach by the European Commission to identify sectors at risk has come under criticism[4] in a number of areas relating to: lack of analysis to support the chosen thresholds, inconsistencies with the assumptions on auctioning, the simplistic nature of the assessment, the limited use of the qualitative assessment and the lack of sensitivity regarding the impact of the economic downturn on industrial emissions. However, the quantitative analysis was the first of its kind for the EU-27 and at the four digit NACE code level and the Commission Services were faced with severe data problems.

A number of other studies have used modelling techniques to identify sectors more at risk of carbon leakage. They use different methodological approaches and cover different geographical areas. Accordingly, the results differ and are not easy to compare. This also highlights the difficulties of pinpointing the main drivers and assessment criteria for determining sectors at risk of leakage.

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[4] See Climate Strategies (2010), Droege, S & Cooper, S. Tackling Leakage in a World of Unequal Carbon Prices - A study for the Greens/EFA Group, for a description of the main criticisms made against the European Commission's methodological approach.

Table 2: Selected studies calculating the impact of carbon pricing on competitiveness and leakage.

Author	Title	Method	Geography	Sectors	Results
Baron et al. (2009)	Sector analysis of competitiveness impacts, including cement, aluminium and steel - working draft	Analysis of production methods, abatement potential, regulatory environment, trade flows and existing models on sector leakage.	Global	Cement, aluminium, steel and refineries	Using 2005-2006 data, there is no evidence of a change coinciding with the EU ETS but 2 years of data is not comprehensive enough to accurately determine the impact. Trade flows and carbon prices need to be monitored.
Climate Strategies, Mohr et al. (2009)	Trade flows and cost structure analysis for exposed industries in the EU-27	Analysis of production process, input structure (& energy use), trade flows and intensities	EU 27	Aluminium, basic iron & steel and Ferro-alloys, fertilizers and nitrogen compounds, other basic inorganic chemicals, paper and paperboard.	Growth in trade volume in these sectors is driven by higher world market prices, shares of intra-EU trade in total trade have been constant, major trade partners are similar across sectors analysed & big changes in trade partners' positions are rare during 2003-2007.
Climate Strategies, Monjon & Quirion (2009)	Addressing leakage in the EU ETS results from the CASE II model	Quantitative assessment of 9 scenarios outlining remedial policy options for addressing leakage	EU 27	cement , aluminium , steel and electricity	Simulations show that even in the case of full auctioning, without 'anti-leakage' policy the leakage ratio is 10%. This is due to zero leakage in the power sector so leakage rates are lower in steel (39%), aluminium (21%) and cement (20%). Results are dependent on Armington elasticities.
Climate Strategies, Smale et. al (2006)	The impact of CO2 emissions trading on firm profits and market prices	Cournot representation of an oligopoly market which analyses the extent of cost-pass through, changes in	UK	Cement, newsprint, steel, aluminium and petroleum	Sectors anticipated to profit in general, with a modest loss of market share in the case of steel and cement, and closure in the case of aluminium

Author	Title	Method	Geography	Sectors	Results
		output, changes in UK market share and changes in firm profits.			
European Commission Economic Paper 298 (2007)	Imposing a unilateral carbon constraint on energy-intensive industries and its impact on their international competitiveness – Data and analysis	The paper calculates the product price increases required to maintain unit profits at present levels, based on probable allocation in the EU ETS up to 2020. It also looks at pass through cost increases	EU 27	Iron & steel, aluminium, copper, other non-ferrous metals, cement and lime, glass, ceramics, paper & pulp, chemical	The impact of a €20/t co2 EUA should raise output prices for most sectors by between 0.1-5%, primary steel 6.5-12%, primary aluminium 7.5-10%, building materials 20-45% & ammonia 14-25%
McKinsey (2006)	EU ETS review of competitiveness		EU 27	Power generation, Steel, pulp and paper, cement, refining, aluminium	At 20€/t CO2, the power sector is likely to benefit in the short and medium term and regain the ability to invest in new power plant, steel BOF will have significant impacts on its competitiveness and EAF to a smaller extent, pulp and paper only partly compensated through free allowances, net impact on cement is uncertain with different intra-Europe impacts, neutral impact on refining, large indirect cost for primary aluminium and marginal increase for secondary.
The Carbon Trust (2004)	Economic model of oligopoly behaviour predicting the		UK	electricity, cement, newsprint, steel, aluminium	Models the results all these variables in all sectors in Phase I, II and III of the EU ETS

Author	Title	Method	Geography	Sectors	Results
	impact of CO2 pricing on EBITDA, sales, number of firms, investment in energy efficiency and emissions abatement and degree of cost pass through				

Source Climate Strategies, Droege et al. 2009

Climate Strategies has advocated the need for a more sector-specific approach to identify sectors at risk[5]. Quantitative criteria are a useful first indicator of the likelihood of a risk of leakage[6], however, the types of leakage that each sector faces can differ (e.g. it could be through importing an intermediate product or there could be complete relocation). The nature of the risk of leakage is therefore dependent on a number of assessment criteria that extend beyond the two applied by the European Commission, and which vary from sector to sector.

In this report we focus on three sectors in more depth to identify the exact nature of leakage that they may face in Phase III of the EU ETS: steel cement and pulp and paper. We use sector-specific information to analyse how carbon pricing would affect a firm's profit margins, pricing structure, ability to pass through carbon costs, incentives to mitigate and invest in technology and also their patterns of production and investment.

For the purpose of this study, in addition to detailing the European Commission's assessment criteria to determine the risk of leakage, the in-depth studies will also offer insights into the following range of additional qualitative and quantitative criteria[7]:

- Product characteristics
- Emissions and energy intensity of production
- Market structure
- Transport costs
- Export and import volumes

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[5] Climate Strategies, S. Droege & S. Cooper, 2010, Tackling Leakage in a World of Unequal Carbon Prices - A study for the Greens/EFA Group

[6] For a fuller explanation see Climate Strategies, S. Droege & S. Cooper, 2010, Tackling Leakage in a World of Unequal Carbon Prices - A study for the Greens/EFA Group

[7] See Annex for a description of each of these assessment criteria and rationale for their inclusion.

- Comparability of performance with installations abroad
- Total value at stake in UK and Germany following the introduction of a carbon price
- Location of demand growth
- Changing patterns of production and trade over time to identify underlying market trends.

The depth of analysis for each of these criteria, however, is constrained by information that is freely available in the public domain. Particularly at the European level, data at installation level is not available due to market sensitivities.

Steel cement and pulp and paper were chosen as they have previously been identified as being at risk of leakage in a number of modelling studies[8] as well as the European Commission's Impact Assessment in 2009. They comprise of 58% of total industrial emissions covered by the EU ETS.[9] Thus, any remedial policy the European Commission suggests to adopt against leakage has the potential to significantly impact on the operation of the European carbon market.

1.1.1 Steel

In this report, steel refers to the 'basic iron & steel and Ferro-alloys' sector which is coded as NACE 27.10 at the 4 digit level. It was one of the sectors identified as being at risk of carbon leakage by the European Commission because both trade intensity (32.3%)[10] and total carbon costs as a percentage of sector GVA (12.7%) exceed the thresholds (10% and 5% respectively)[11].

Product characteristics

Steel is produced in one of two routes[12], with a variety of inputs;

1) Through a **blast oxygen furnace** (BOF) using **iron ore** and **scrap steel.**

2) Through an **electric arc furnace** (EAF) to create **direct reduced iron** (DRI), **scrap and cast iron.**

Figure 2 offers a pictorial representation of the various combinations of inputs, processes and finishing techniques that are used in steel production.

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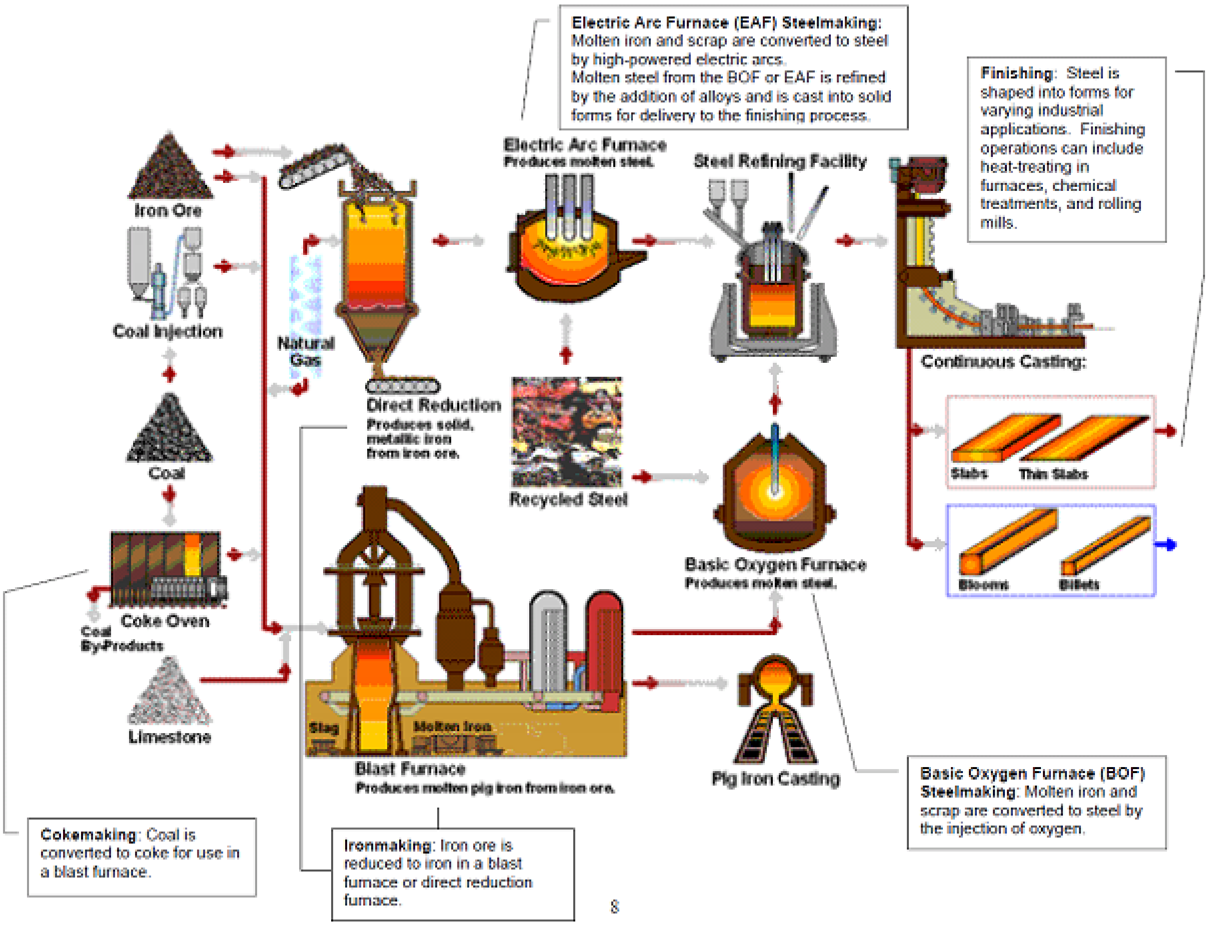
[8] See the literature tables in this chapter which reviews additional modelling studies that have identified which sectors of the economy are at risk of leakage for different regions. It is evident from these studies that steel, cement and pulp and paper are repeatedly identified as those at potential risk of carbon leakage.

[9] European Environment Agency pivot application data viewer available at: http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=473

[10] European Commission (2009), Quantitative outcome of the Impact Assessment to determine sectors at risk of carbon leakage. Available at: http://ec.europa.eu/environment/climat/emission/carbon_en.htm

[11] http://ec.europa.eu/environment/climat/emission/pdf/20090701_list_sectors.pdf

[12] A small percentage of steel is still produced using outdated technologies such as open-hearth furnaces.



Electric Arc Furnace (EAF) Steelmaking: Molten iron and scrap are converted to steel by high-powered electric arcs.
Molten steel from the BOF or EAF is refined by the addition of alloys and is cast into solid forms for delivery to the finishing process.

Finishing: Steel is shaped into forms for varying industrial applications. Finishing operations can include heat-treating in furnaces, chemical treatments, and rolling mills.

Cokemaking: Coal is converted to coke for use in a blast furnace.

Ironmaking: Iron ore is reduced to iron in a blast furnace or direct reduction furnace.

Basic Oxygen Furnace (BOF) Steelmaking: Molten iron and scrap are converted to steel by the injection of oxygen.

The **BOF** route produces molten steel which is refined, cast and then finished. It is often part of an integrated steel mill. This is a steel mill which includes a blast furnace to produce 'pig iron'. Pig iron is then used as an input (sometimes in combination with scrap steel) into the BOF. The BOF can operate in isolation (i.e. not part of an integrated mill) when only scrap is used as an input into the steel making process.

Scrap can also be used as an input for an EAF. This process cannot be part of an integrated steel mill as pig iron produced from a blast furnace is not used as an input in this type of furnace. Instead direct reduced iron (DRI), produced by passing gases over the iron ore to 'strip' away the oxygen to leave a sponge-like iron, can be used as an alternative input to scrap. Because it is not an integrated mill, the upfront investment costs for an EAF is smaller.

Crude steel, once produced, needs to undergo further finishing. It can be metallurgically treated, cast, rolled and shaped to be used by downstream sectors for various purposes. As such, these speciality steels e.g. stainless steel can command higher prices than their 'basic' counterparts. The price reflects the higher level of technical expertise required to produce them.

Although the quality of steel can differ, it is essentially a commodity and therefore producers in the market are price takers. Steel can be grouped into 'long' and 'flat' products. Long products are generally of lower quality and include items such as wire rods and reinforcing bars which are principally used for construction purposes. 'Flat' products such as slabs and Hot Rolled Coil (HRC) are of higher quality and often tailored to consumer specificities, as such, these products are more differentiated and traded internationally more often.

The price of steel fluctuates greatly depending on the level of demand from downstream sectors, most notably from construction which accounts for around half of total demand and the automobile sector. Worldwide steel consumption is around 1,300 million tonnes per year, i.e. approximately 0.25 tonnes per world citizen[13]. Since the economic downturn, the price of steel has fallen sharply as these pro-cyclical industries have contracted demand. This short term fall in the price was exacerbated by a realisation of overcapacity in the steel market. As a result of this, it has fallen by an average of 22% between January 2008 and April 2009[14]. HRC fell from $1100/t in July 2008 to under $500/t only 9 months later in April 2009, a fall of over 55%, exemplifying the volatility and susceptibility of steel prices to patterns in economic growth.

Emissions and energy intensity of production

The production of steel is one of the most energy- intensive manufacturing production processes and as such it has high associated production emissions. In 2007 it accounted for 5% of global emissions from fossil fuel combustion which extends to 10% if upstream mining and transport of iron ore, limestone, coal and other inputs and the downstream transport are included in the sector definition[15]. It is the largest contributor of emissions from the manufacturing sector. In Europe, in the same year, the sector represented approximately 23% of industrial emissions covered by the EU ETS and 5% of total emissions covered by the scheme[16]. If the entire production lifecycle of steel (i.e. Upstream mining and transport of iron ore, limestone, coal and other inputs and the downstream transport to market) is included in emissions accounting, the contribution of the steel sector to global CO_2 emissions rises to almost 10%[17].

Emissions from the steel sector are likely to be of growing concern in the future. Even if all known, workable abatement options are implemented, emissions in the steel sector are projected to grow by at least 50% globally in the period 2005-2030, making the steel sector's emissions growing as percentage of total global emissions[18]. This rise is due to projected large-

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[13] Climate Strategies, P. Wooders (2009), Sector Approaches in the Steel Sector.

[14] http://www.steelonthenet.com/prices.html

[15] Climate Strategies, P. Wooders (2009), Sector Approaches in the Steel Sector

[16] Wooders (2009) presentation to the OECD

[17] Climate Strategies, P. Wooders (2009), Sector Approaches in the Steel Sector.

[18] Climate Strategies, P. Wooders (2009), Sector Approaches in the Steel Sector.

scale increases in steel production capacity based on increasing demand in industrialising economies. Steel is a key input for developing the physical infrastructure in a region and increasing the mobility of its citizens but over time, there may be more material substitution for steel in response to rising carbon costs.

Table 3 shows the different production techniques available to produce steel and their corresponding average emissions levels per tonne of output[19]. The range of emissions is principally due to the fuel input in the production process[20]. The EAF route is less emission intensive because it relies more on scrap steel as an input. The widespread use of this technique is however constrained by the physical availability of scrap. Some countries like China who are relatively new players in the market for steel production will by default have less scrap readily available and so will rely more on iron ore as an input into steel making.

Table 3: Emissions ranges from different production practices

Production technique	Range of emissions
Integrated BF/BOF mill	1.5-2.5 tCO_2/t steel
EAF using **scrap**	0.4-0.6 tCO_2/t steel[21]
EAF using **DRI**	1.1- 2.5 tCO_2/t steel

Source: Climate Strategies, Wooders et al 2009.

Market structure

The largest producers of steel worldwide are:

1) China

2) Japan

3) USA

4) Russia

5) South Korea

These 5 countries account for 69% of total global steel production.

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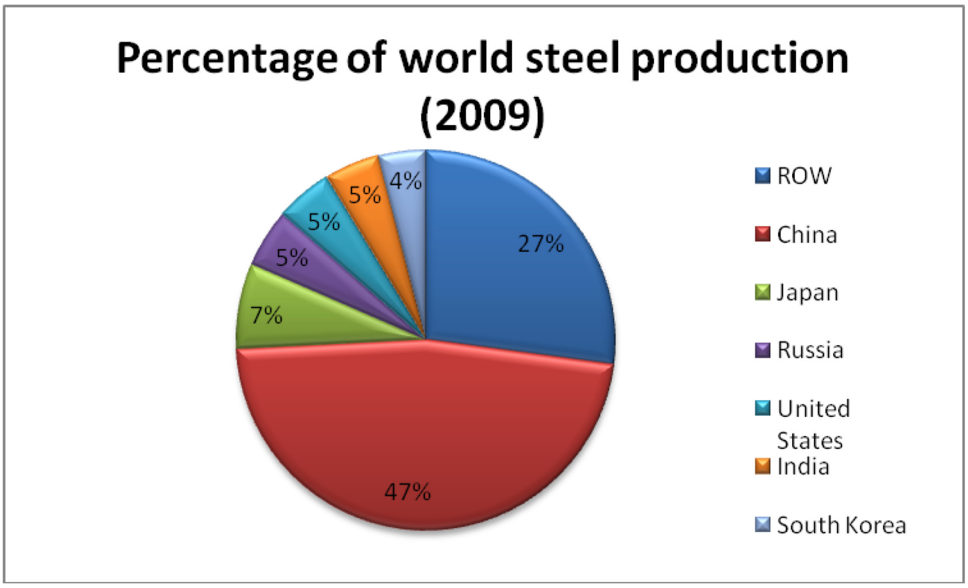
[19] Climate Strategies, P. Wooders (2009), Sector Approaches in the Steel Sector.

[20] According to the IPCC 4th Assessment Report, process emissions from the steel sector account for around 7% of total sector emissions for both the EAF and BOF routes

[21] Emissions are dependent on the electricity source.

Figure 3: World steel production by region



Source: World Steel Association 2009.

China is largely responsible for rising production capacity (and some of the rising demand) worldwide. Although the global economic downturn has reversed the upward trend in steel production, falling from a peak of 1400Mt per annum in 2008 to 1100 Mt per annum in late 2009, the longer term production, and capacity, is forecasted to continue to increase.

The scale of China's capacity expansion has led to increased demand for iron ore inputs from international sources (namely Brazil and Australia). This has driven up demand for and subsequently prices for international freight transport. These rising costs may serve to stabilise Chinese output soon. India is expected to be the newest source of capacity expansion[22] in the longer term.

As aforementioned, steel is essentially a commodity and so producers are price takers. Some regions, such as Japan, are able to focus their production on more speciality steels as they have higher levels of the necessary technical expertise. Steel does however have a fairly low price elasticity of demand because of a lack of substitutes which may give producers some power over prices.

The relative homogeneity of the product means that EU installations directly compete with non-EU installations. The introduction of carbon costs in Europe through the EU ETS may force installations to lower other production costs in order to remain competitive. The carbon cost differential may become increasingly important in the coming years if the decline in steel prices due to the economic downturn leads to a lower price trajectory than pre-crisis as this

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[22] Climate Strategies, P. Wooders (2009), Sector Approaches in the Steel Sector.

would force firms to reduce costs as much as possible, and could also lead to import or production leakage. However, it is not clear how much of a risk this is in the medium term as prices are rising again in 2010 to pre-recession levels[23].

The steel sector has a long, lumpy investment schedule. A typical plant lifetime is around 40 years but is a costly investment which benefits from economies of scale. Historically BOF plants have been built which typically produce 3 million tonnes of crude steel per annum (Mtpa) for an average cost of $2bn. There are however plants under discussion in the Gulf and parts of Asia that have a proposed production capacity of 6 Mtpa. Plants of this scale are less common. DRI and EAF plants are not integrated steel mills, they are smaller in size and so have smaller sunk costs. Steel output from these plants range from 0.15-0.5 Mtpa[24]. Given their long investment horizons, steel producers benefit from long term climate policy certainty.

Transport costs

Transport and mining represent major production costs for steel. Transport costs for steel have increased in recent years due to bottlenecks in sea transportation, most notably in terms of port availability. These bottlenecks are partly caused by increased international trade in steel and primary material.

EU export and import volumes

Around 40% of global steel production is traded internationally each year[25]. Globally, the main exporting regions are Russia and the CIS, Europe and Asia. The largest importers are Africa, the Middle East, Europe and North America.

Europe is both an importer and exporter of steel (usually specialising in the production of particular types of steel products). Between the years 2003-2007, the European iron and steel sector saw its international trade volumes[26] increase by 123% from €113,983m to €258,893m (in current prices) largely due to rising import intensities. The main non-EU trade partners are China, Turkey, Russia, USA, Ukraine and Switzerland. Intra- EU trade has remained stable at around 77% of production during this period. Table 4 gives an indication of the scale of trade flows in 2007.

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[23] http://www.steelonthenet.com/price_info.html

[24] Climate Strategies, P. Wooders (2009), Sector Approaches in the Steel Sector.

[25] Climate Strategies, P. Wooders (2009), Sector Approaches in the Steel Sector.

[26] Defined as the sum of import and export volumes

Table 4: European Iron & steel trade in million € current prices, 2007.

Trade partner	Exports	Imports
China	1902	6547
Turkey	4254	2306
Russia	720	5280
USA	3411	1355
Ukraine	262	3054
Switzerland	2126	729

Source: Climate Strategies, Mohr et al. (2009), Trade flows and cost structure analysis for exposed industries in the EU-27.

Looking forward, it is anticipated that the import intensity of steel will continue to rise in Europe as production capacity increases elsewhere. Currently more than 50% of global steel capacity is located in developing countries and production capacity is rising[27], particularly in China which is already the world's largest producer.

Comparability of performance with installations abroad

It is particularly difficult to compare the performance of steel installations abroad for two reasons. Firstly, because of the different sector classification systems used. Not all countries use the NACE 4 digit classification system adopted by the EU. Instead countries define their steel sectors at a higher level of sectoral disaggregation into particular stages of the production process. Japan for example gives a finer resolution of the sector definition. This enables policymakers to pinpoint the risk of leakage more accurately. E.g. in Asuka (2009)[28], it is possible to see that most of the risk of carbon leakage in the basic steel making sector stems from the pig iron production. However, divergences in the sector definitions make international comparisons harder.

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[27] Climate Strategies, P. Wooders (2009), Sector Approaches in the Steel Sector.

[28] Asuka, J et al. (2009) ETS and International Competitiveness Issues

Table 5: Regional profiles of steel production 2007

Region	Iron and steel (Mt)	Reported Energy Use (Mtoe)	Energy use (Toe) per tonne of product	CO_2 emissions ($MtCO_2$)	CO_2 (t) emissions per (t) of product	CO_2 emissions (t) per tonne of energy use (Toe)
Europe	228	71	0.3	258	1.1	3.6
USA	98	31	0.3	91	0.9	2.9
China	495	276	0.6	1095	2.2	4.0
India	53	33	0.6	151	2.8	4.6

Source: IEA Energy Technology Perspectives 2010.

A second reason as to why it is difficult to make meaningful international comparisons between the performance of international installations and sectors is the insufficient disaggregation of the information available on furnace types. Even when this information is available, it hides differences in the energy efficiency of plants across countries. For BOF processes, the IEA estimates[29] that the energy efficiency gap between the top and the bottom countries is about 50%. They attribute this large variance to differences in plant size, level of waste energy recovery and quality control. Even with these data limitations, it is useful to observe the composition of production techniques used in each country as outlined in figure 4.

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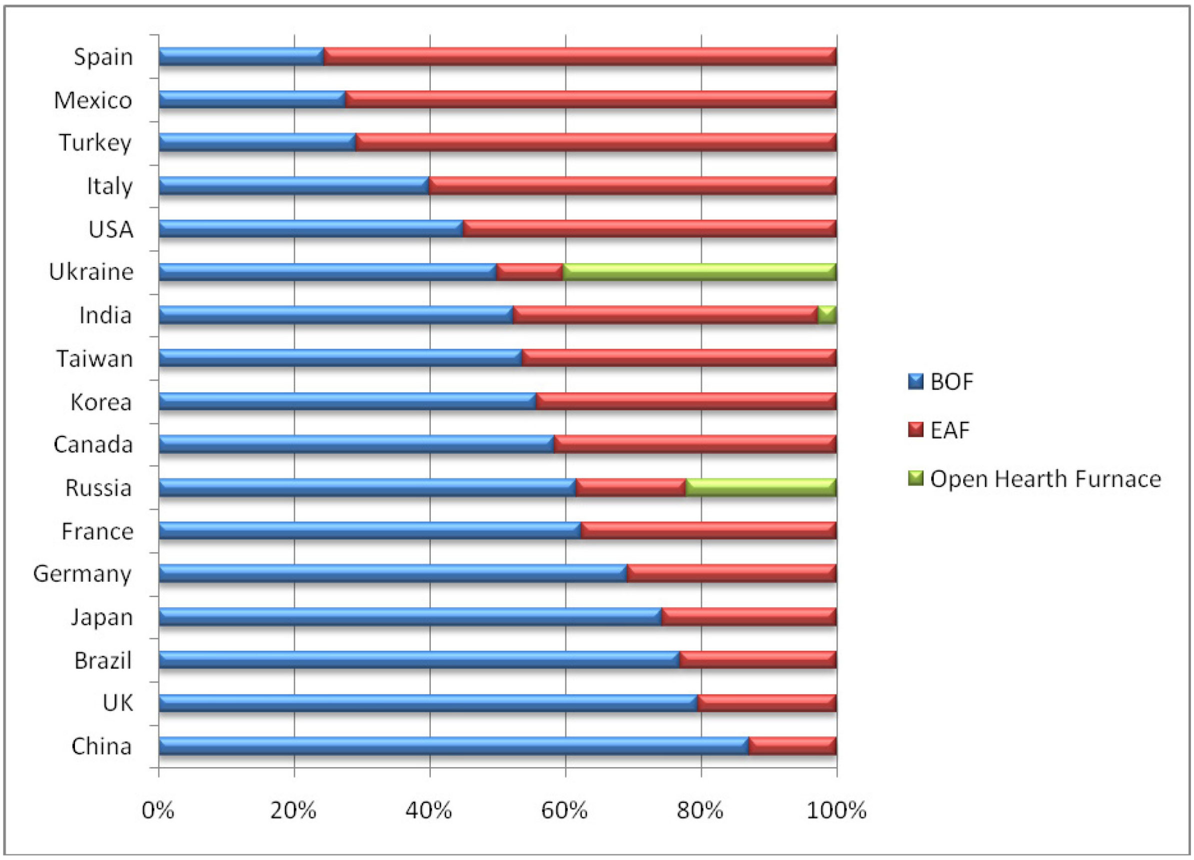
[29] IEA (2007), Tracking Industrial Energy Efficiency and CO_2 Emissions.

Figure 4: Country share of furnace use by type for steel production 2005



Source: WSA/IISI 2006.

As figure 4 demonstrates, the global majority of steel is produced using BOF (approximately 2/3) and the remainder (1/3) is produced using EAF technology. In Europe, EAF accounts for 40% of steel production but is substantially higher in some MS such as Greece (100%) Spain (78%) and Italy (63%) and lower in others like Germany (31%). Only Russia and the Ukraine have a high prevalence of open hearth furnaces.

Another reason for differences between countries in the energy use per tonne of steel produced is the quality of the iron ore used. The iron content of the extracted iron ore and the chemical composition of the gangue (the non-iron, waste component of the ore deposit) can affect the amount of energy used in a furnace. For a blast furnace (the production process needed to create pig iron) the characteristics of the iron ore can make a 1-2GJ/t[30] difference in energy needs.

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[30] IEA (2007), Tracking Industrial Energy Efficiency and CO_2 Emissions.

Total value at stake

Value at stake was chosen by the European Commission as a criterion to determine the magnitude of leakage. It is calculated as the cost increase from CO_2 emissions for each sector relative to the sector's contribution to the region's Gross Value Added (GVA). This gives context to the scale of carbon costs relative to the product's value. Table 6 outlines the value at stake for the USA, Germany and UK and gives some indication of the steel sector's relative importance in the economy.

Table 6: Regional value at stake

Country	Indirect value at stake (%)	Direct value at stake (%)	Total value at stake (%)	% of GDP	Rank of sectors at risk
USA	3	7	10	0.25	7th
Germany	4	23	27	0.35	3rd
UK	2	24	26	0.15	3rd

Source: Climate Strategies, Hourcade et al. (2007), Graichen et al. (2008), Houser et al. (2008)[31]

Location of demand growth

Although there has been a short term fall in demand for steel from downstream sectors due to the economic downturn from 2008, this is expected to rebound in the longer term as economic growth regains momentum. The steel sector represents an important part of the economy, particularly in the early stages of industrialisation when a country is growing rapidly as higher levels of construction is seen to develop infrastructure. Demand is likely to increase globally, exponentially even, in rapidly developing countries such as China and India over the next 20 years. The impact a growing economy will have on the price of steel may however be dampened by a rapidly increasingly global production capacity.

Conclusions

The steel sector contributes up to 23 per cent to the CO2 emissions capped under the EU ETS. The potential of carbon leakage from this sector under rising carbon prices hinges on a number of factors. The prices and profits in the steel sector are very susceptible to changes in patterns of economic growth. The competitive pressure for EU producers increases in particular from countries which are likely not to impose a carbon constrained soon. China in particular has expanded production capacity at an enormous rate. Increased competition and high price elasticity of demand has led to cost saving measures being introduced in the industry. Thus, carbon costs are likely to play an increasing role in determining long term

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[31] Full references can be found in the bibliography. Note that these are estimations taken from charts in the referenced publications.

investment strategies and the location of production. The scale of the risk of leakage in the steel sector has been recognised in a number of economic models and by industry representatives who cite,"the steel industry is one of the sectors most exposed to carbon leakage"[32]. This statement is confirmed in academic studies[33]. For the EU, the specific features such as the role of quality steel for domestic producers as well as the international growth dynamics in steel demand will determine the extent to which carbon pricing will translate into a shift in steel production.

1.1.2 Cement

The European Commission's Impact Assessment[34] identified that the total value at stake for the cement sector (NACE code 26.51), i.e. the cost increase from CO_2 relative to GVA, as 59.2%. The cement sector ranked third highest for this criterion after the manufacture of fertilizers and nitrogen compounds (92.4%) and the manufacture of lime (85.9%). The bulk of this increase in costs originates from process emissions[35]. The trade criterion for cement was calculated to be relatively low at 6.8%. As a result, the cement sector exceeded the single threshold for the cost impact criterion (more than 30%) and was identified as being at risk of leakage in Phase III of the EU ETS.

Cement prices differ across regions. In 2006, the average price of cement in Germany was US$71/tonne, in Canada it was €66/tonne whilst Chinese cement was sold in the order of $32/tonne[36].

Product characteristics

Similar to steel, cement is a commodity and is made in two stages; firstly clinker is produced from limestone in a kiln. This clinker is then milled with other materials to produce cement.

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[32] Eurofer statement on ETS implementation – 5 November 2009.

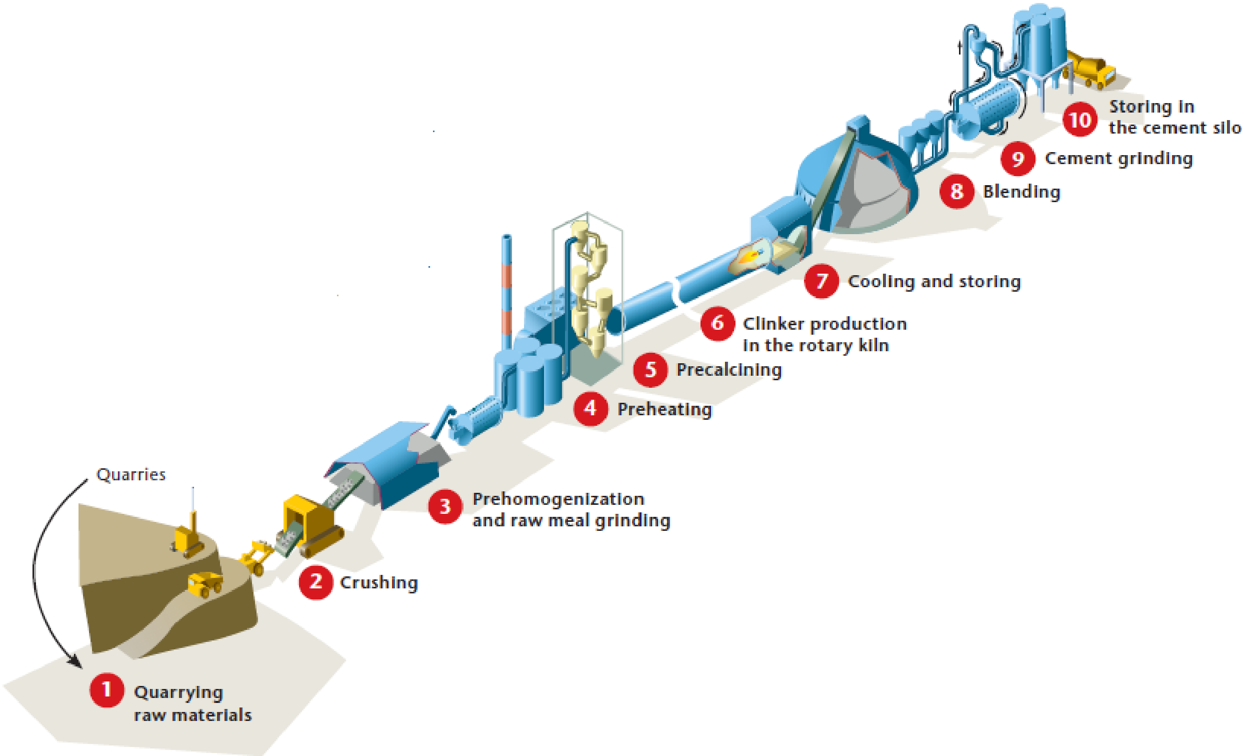
[33] Examples of studies include: Carbon Trust (2004) Hourcade et al (2007) Graichen et al. (2008) de Bruyn et al. (2008) Asuka, J et al (2009). Full references can be found in the bibliography

[34] European Commission (2008b), Commissions Services paper on Energy Intensity Industries exposed to significant risk of carbon leakage: first results of the quantitative analysis.

[35] For an in-depth analysis on the cost structure of the cement industry see Boston Consulting Group (2010) Assessment of the impact of the 2013-2020 ETS proposal on the European Cement Industry

[36] MPRA (2010) Global Cement Industry: Competitive and Institutional Dimensions

Figure 5: Cement production process



Source: World Business Council for Sustainable Development, Cement Sustainability Initiative (website).

Activities 1-5 are the steps required to produce lime. Raw deposits are mined and mixed with 'corrective' materials to ensure the correct chemical composition. The mixture is then crushed, milled and heated and then is passed through a pre-calciner to decompose limestone to lime. Lime can then be used to create cement.

The lime production process is classified as being 'wet' or 'dry' depending on the water content of the raw feedstock. A wet process is more energy intensive as additional energy is required to evaporate water before passing the mixture through the pre-calciner (step '5' in Figure 5). It is easier to control the chemical content of the mixture in the wet process but the dry process uses less energy and is therefore less emissions intensive as well. Perhaps as a result of this, dry kilns are predominantly used around the world.

The partially molten lime mixture is then fired in a rotary kiln, or a less efficient vertical shaft kiln, to produce pellets of clinker which are then cooled and mixed with other mineral components, most notably gypsum. This newly blended mixture is then ground into a grey powder known as cement.[37]

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[37] World Business Council on Sustainable Development, Cement Sustainability Initiative website http://www.wbcsdcement.org/

Cement is classified based on the quantity of clinker substitutes it contains. The grade of the cement is identified based on the main clinker substitute only if the substitute exceeds 40% of the weight of the mixture. If clinker comprises of 40% or more of the total weight, the mixture is classified as Portland cement. During its production, emissions will be between 0.73-1.08 t/CO_2 per tonne of cement[38]. This figure can be reduced by blending cement with clinker alternatives

Emissions and energy intensity of production

Direct emissions from the cement sector currently account for approximately 25% of industrial CO_2 emissions and 4% of total emissions globally. Indirect emissions add a further 5-10% to this figure. The creation of clinker is the most emissions-intensive part to the cement production process (accounting for around 60% of sector emissions)[39]. Accordingly, direct emissions cause a high cost impact from carbon pricing in this sector. In addition to high process emissions, indirect emissions arise from electricity use throughout the production process[40].

In 2008, total direct emissions from the European cement industry were 155MtCO_2, accounting for approximately 4% of economy-wide EU CO2 emissions[41] and 8% of EU ETS emissions in 2008. Non-OECD countries contribute the largest share of global cement sector emissions (80%) with China alone accounting for approximately half of their total contribution to world cement sector emissions[42]. According to the IEA[43], India, although the world's second largest producer, only accounts for 6% of global cement production, demonstrating major disparities in the relative sizes of cement sectors worldwide. Figure 6 shows the relative sizes of emissions contributions in cement producing regions worldwide.

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[38] MRPA (2007) Imposing a unilateral carbon constraint on European energy-intensive industries and its impact on their international competitiveness – data and analysis.

[39] Boston Consulting Group (2010) Assessment of the impact of the 2013-2020 ETS proposal on the European Cement Industry

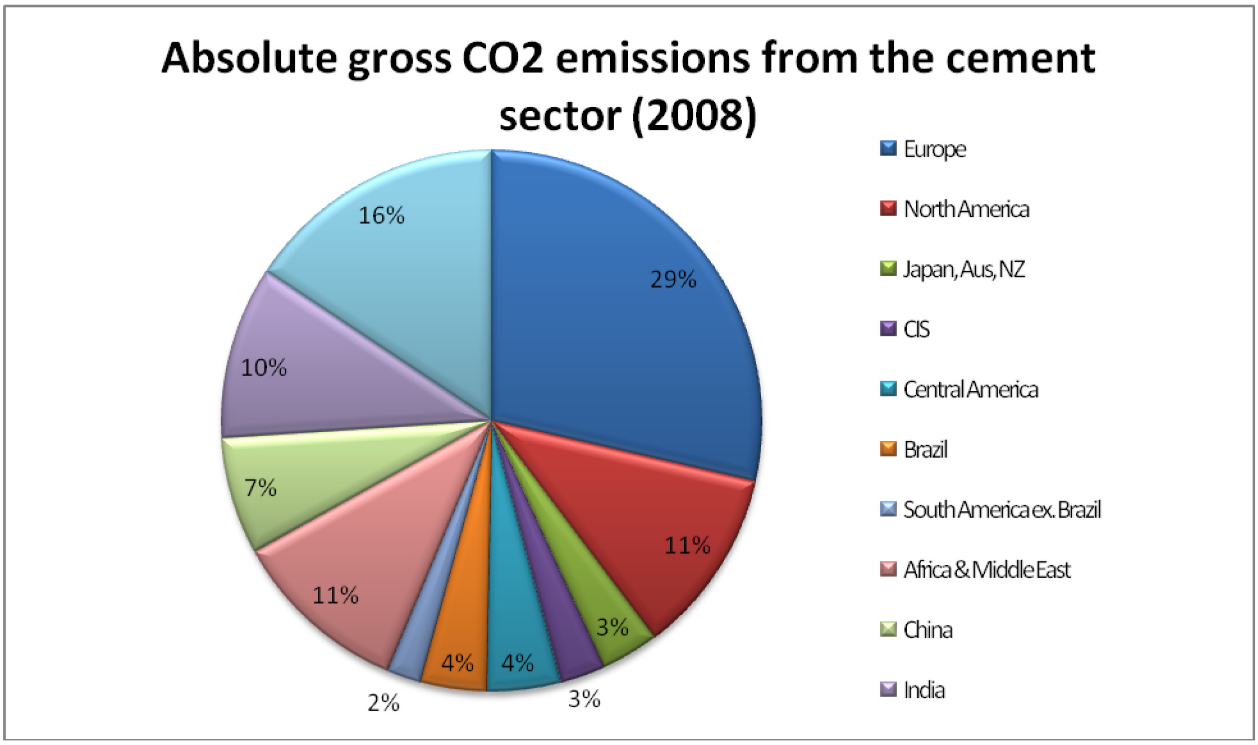
[40] Climate Strategies, Cook, G (2009). Climate Change and the Cement Industry, assessing emissions and policy responses to carbon prices,

[41] Climate Strategies, Cook, G (2009). Climate Change and the Cement Industry, assessing emissions and policy responses to carbon prices,

[42] The CSI is an industry-led global sustainability program undertaken by the cement sector.

[43] IEA (2007) Tracking Industrial Energy Efficiency and CO_2 emissions

Figure 6: Regional emissions from the cement sector



Source: CSI.

According to the Cement Sustainability Initiative (CSI)[44] the global average CO_2 emissions intensity of cement was 661kg per tonne of cement product in 2006. The sector has introduced a number of initiatives to reduce the emissions intensity of production since 1990. The CSI notes that the global emissions intensity of cement production decreased by around 14% between the years 1990-2009. The IEA[45] confirms this with their own assessment that the average CO_2 intensity of cement production. It has declined at a rate of 1% per annum between the years 1994-2003. However, approximately half of the emissions from the cement sector arise during the chemical reaction when making clinker. These emissions are inherent to the production process and using current mitigation options such as increasing the energy efficiency of the kilns or switching to low carbon fuels will not significantly affect the cement sector's emissions.

The cement production process is energy intensive, particularly fuelling the kilns, and as such, the share of energy costs is high for cement, comprising of between a quarter to a third of the product price. CEMBUREAU[46] estimates that for every tonne of cement produced, 60 to

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[44] CSI (2010), News release "New Cement Industry Figures on CO_2 and energy performance show reductions in emissions intensity".

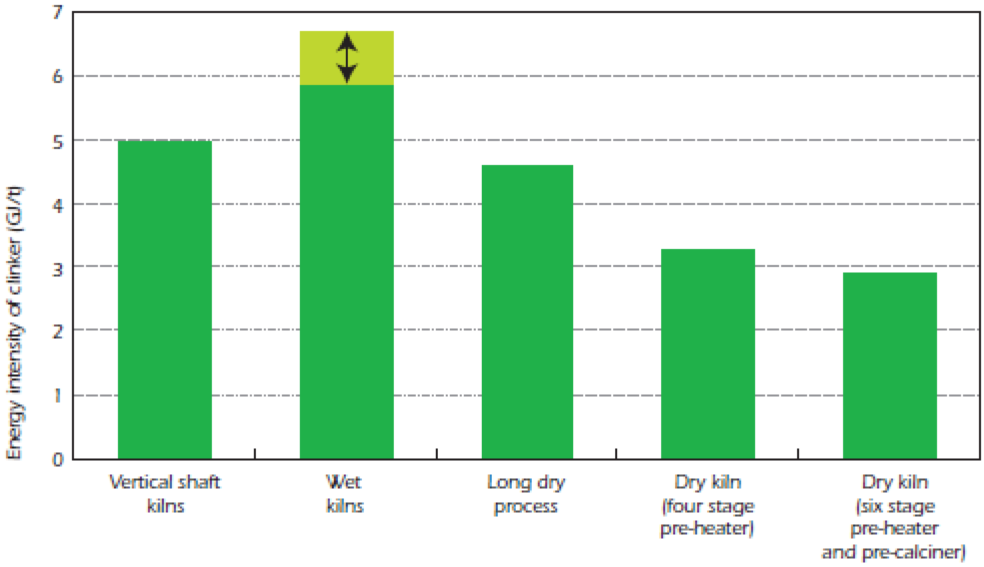
[45] IEA (2007) Tracking Industrial Energy Efficiency and CO_2 emissions

[46] CEMBUREAU is the representative organisation of the cement industry in Europe

130 kg of fuel oil or its equivalent is required, depending on the cement variety and the process used, and this equates to approximately 105 KWh of electricity.

Figure 7 offers an overview of the energy intensity of production of clinker for different types of kilns[47]. The figure reflects the fact that 'wet kilns' have approximately half the thermal efficiency of dry process production.

Figure 7: Energy intensity of clinker production per kiln



Source: IEA 2007.

Market structure

As aforementioned, Kyoto Non-Annex I countries are the largest producers of cement and they contribute relatively more to global cement sector emissions. These countries have experienced major expansion in cement production capacity in the past 20 years. In 1990, they accounted for a third of total cement production. By 2008 this grew to 57% following an absolute increase in production over this time of 321 million tonnes (production output Annex I countries by contrast grew only by 21million tonnes)[48].

Figure 8 demonstrates the scale and the location of production increase.

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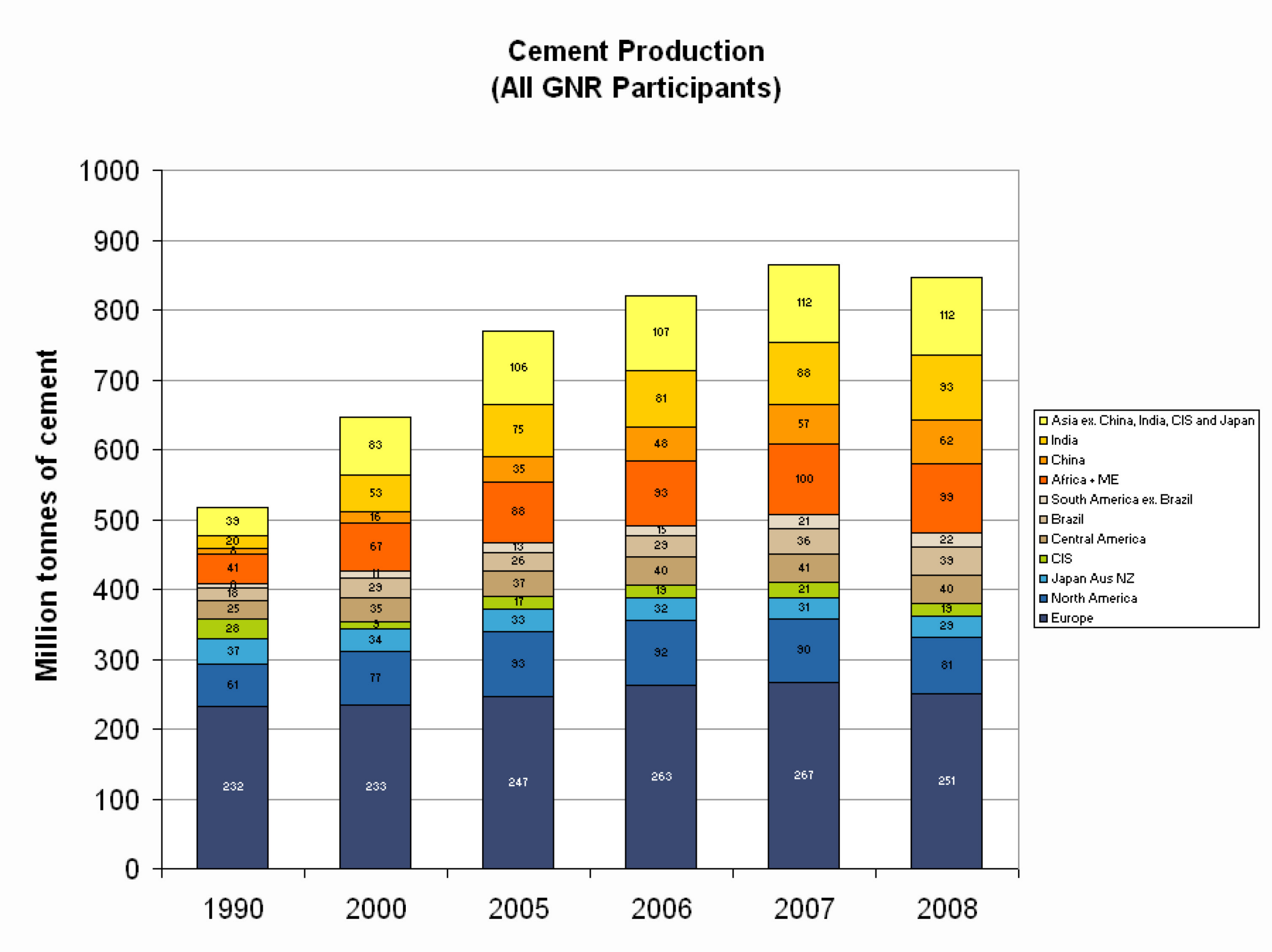
[47] The lighter green part in the 'wet kiln' bar reflects the range of energy intensity of production which is dependent largely on the design of the kiln.

[48] World Business Council for Sustainable Development, Cement Sustainability Initiative website http://www.wbcsdcement.org/gnr-2008/kyoto/GNR-Indicator_311c-kyoto.html

Figure 8: Regional cement production 1990-2008



Source: CSI Global Cement Database on CO_2 and Energy Information)[49].

To date the vast majority of cement plants have been built to supply local rather than regional or international markets. This is largely due to high transportation costs relative to the value per tonne of cement product.

Over the last two decades, the cement industry has seen increased market concentration. The top 10 largest cement producing firms accounted for around 39% of global cement production capacity in 2005, up from 20% in 1990. In Europe, 10 companies represent 66% of total European cement production and the largest five companies represent 50% of total production capacity in 2005. The share of output of the largest three manufacturers is about 50% in most European countries (e.g. Germany, Italy, Spain and Portugal) and more than 80% in the UK and France.

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[49] GNR – Getting the Numbers Right is GNR is a CO2 and energy performance information system, based on emissions data from individual cement plants belonging to the World Business Council's 'Cement Sustainability Initiative'.

A reason for the high industry concentration is the high sunk costs of investing in cement plants and the associated benefits of economies of scale. CEMBUREAU estimates this initial outlay to be above €150m per million tonnes of annual capacity[50]. Refinements or modifications to cement plants are also extremely costly. CEMBUREAU also notes that because of the large financial commitment (equivalent to three years of turnover), investment schedules are not only lumpy but long. Long term policy certainty, for example regarding carbon pricing, is extremely important in the cement sector for assured investment.

Transport costs

Cement has a low value relative to its weight. Transport costs (road, rail and sea) are high in the cement sector and are a key determinant of cement prices. They are also likely to remain high relative to CO_2 costs in the near term. Generally speaking cement travels between 200km to 300km by land (road and rail) between the plant and the consumer which dictates that most markets are regional. Anything longer and road transportation costs could exceed the costs of production. Shipping cement can be more economically efficient over longer distances. Distances of over 400km are often cheaper by sea than by land transportation[51] and, as such, is the transportation choice for approximately 75-80% of all internationally traded cement. CEMBUREAU estimates that in some instances it is now cheaper to ship cement across the Atlantic Ocean with 35,000 tonnes of cargo than to transport it 300km by road, suggesting the market is slowly becoming more international. There has been a growing trend in shipping of cement which reflects this relative cost advantage and growing capacity outside of Europe. For example between the years 2004-2006, there was a 6-fold increase in the [52]volume of cement exports from China.

Export and import volumes

High transport costs relative to value added are one reason why the import intensity of cement is low and the sector is quite concentrated in the EU. Installations on coastal areas are most exposed to international competitors through marine transportation. This can be cheaper if transported in bulk due to economies of scale. A number of Eastern European countries are within the 200-300km boundary which makes transporting cement financially viable and face external competition from neighbouring countries such as Russia and Croatia. As Table 7 shows, China and the USA aside, most extra-EU trade is with neighbouring countries.

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[50] http://www.cembureau.eu/about-cement/cement-industry-main-characteristics

[51] MRPA (2007) Imposing a unilateral carbon constraint on European energy-intensive industries and its impact on their international competitiveness – data and analysis

[52] Climate Strategies, Cook, G (2009). Climate Change and the Cement Industry, assessing emissions and policy responses to carbon prices,

Table 7: Import and export volumes of main non-EU trading partners in cement (2007).

Trade partner	Exports (€mill, current prices)	Imports (€mill, current prices)
Turkey	22	143
China	1	459
Egypt	8	76
USA	63	1
Croatia	16	42
Russia	30	13

Source: Climate Strategies, Mohr et al. (2009) Trade flows and cost structure analysis for exposed industries in the EU-27.

Comparability of production performance with installations abroad

Although the cement production process is relatively similar across the world, installations differ in terms of the production technology used, the fuel use and the blending rates of cement. There has, however, been a gradual shift towards increasing the energy efficiency (and often, by default, the emissions intensity) of cement production across the world. For example, installations in China are increasingly moving away from using less efficient, small-scaled vertical kilns in favour of large scale rotary kilns which are a more energy efficient method of clinker production thanks to recent government policies[53].

Europe has the lowest average emission intensity of production worldwide due to the choice of fuels and increased blending rates. However the range of emission intensities of cement production is only about 20% globally because the calcination process emits a fixed amount of emissions and the variability in emission is principally dependent on the fuel usage. [54]

Figure 9 outlines the types of kilns and fuels used in the principal cement producing regions worldwide.

Figure 9: Regional kiln and fuel use

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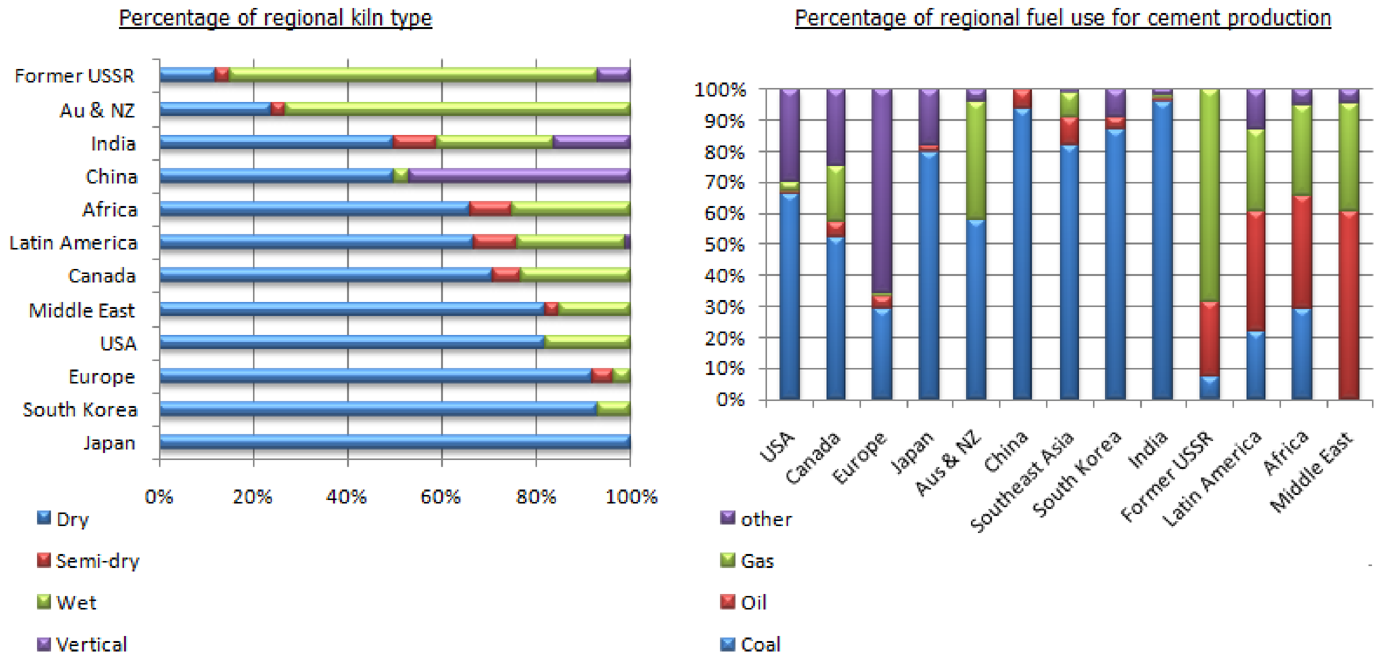
[53] Climate Strategies, Cook, G (2009). Climate Change and the Cement Industry, assessing emissions and policy responses to carbon prices,

[54] World Business Council for Sustainable Development, Cement Sustainability Initiative, Getting the Numbers Right (2009)



Source: IEA 2007.

The IEA[55] notes that Japan is most efficient at clinker production and is at the theoretical lower limit of heat consumption for advanced dry kilns with pre-heaters and pre-calciners. China is investing in more efficient modern large-scale dry kilns which will reduce the energy use per tonne of clinker produced. As Figure 9 shows, China has the highest percentage of vertical shaft kilns which are the least energy efficient. Similarly, former USSR countries have a relatively more energy intensive production process as they rely more on wet kilns although their emissions might be lower than expected as they use a large amount of gas for kilns.

Due to these differences in kilns and fuel types, the energy consumption per tonne of cement differs globally. The IEA estimates that on average, the energy consumption per tonne of Portland cement is between 3-4GJ/t. In the EU, this measure is approximately 3.7GJ/t whilst China, Canada and the USA have a higher energy requirement of between 4.2-4.6 GJ/t.

Total value at stake

Due to its high emission and energy intensity, the cement sector faces a relatively high impact from carbon pricing on its GVA and is accordingly identified as being at risk of leakage. Table 8 presents the relative importance of cement in the US, German and UK economy both in terms of its contribution to GDP and also the risk of leakage it faces relative to other manufacturing sectors in these countries.

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[55] IEA (2007) Tracking Industrial Energy Efficiency and CO_2 emissions

Table 8: Regional value at stake in the cement sector

Country	Indirect value at stake	Direct value at stake	Total value at stake	% of GDP	Rank of sectors at risk
USA	1	22	23	0.05	4th
Germany	8	47	55	0.05	2nd
UK	2	32	34	0.04	2nd

Source: Climate Strategies, Hourcade et al. (2007), Graichen et al. (2008), Houser et al. (2008).[56]

Location of demand growth

Demand almost entirely originates from the construction sector. Demand is forecasted to rise to around 3,100 Mt per annum in 2015 and 4,100 Mt in 2050 (IEA 2008c). This will be driven by growth in non-OECD regions who are expected to experience rapid development and to require buildings and infrastructure. Thus, construction booms and downturns can influence cement trade and prices dramatically.

Changing patterns of trade over time to identify underlying market trends

Because of the high emission content of clinker production, the highest risk of leakage is caused by increased clinker imports. They will rise if imports plus transportation cost are lower than reducing the clinker content of cement or increasing the domestic energy efficiency. This logic may explain why in recent years, extra-EU trade in cement has increased very rapidly with some regions. For example, in 2007, imports from China were valued at €459m while in 2004, the value was close to zero.

Conclusions

The cement sector in the EU is the sector with a high risk of carbon leakage due to the relative homogeneity of the factor inputs. Clinker, the source of the direct CO2 emissions in cement production, can be substituted for by imported clinker from extra-EU sources. Increased cement imports prior to the introduction of the EU ETS from extra-EU regions already indicate towards this trend, which is driven by lowering production cost. Carbon pricing may therefore compound existing market trends in the cement industry to the detriment of both the environment and European industry.

However, the complete relocation of plants to extra-EU regions is unlikely given the high sunk costs and largely regional markets which allow for some flexibility regarding pricing strategies. The crucial trade off for cement producers are the transport costs in relation to additional CO_2-costs. If transport becomes relatively cheap, carbon leakage becomes more likely. For this sector, the way to reduce leakage thus needs to relate to the trade flows of clinker.

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[56] Note that these are estimations taken from charts in the referenced publications.

1.1.3 Pulp and paper

For the purpose of this analysis, pulp and paper refers to 'pulp, paper and paperboard' which is coded as NACE 21.1. This three-digit level of sector aggregation was chosen because many analyses on this sector do not explicitly distinguish between pulp and paper given their linkages in the production chain. Both the manufacture of pulp (NACE 21.11) and the manufacture of paper and paperboard (NACE 21.12) were identified as being at risk of carbon leakage by the European Commission[57]. The former exceeded the European Commission's threshold for trade intensity (it was calculated to be 46.1%) and the latter exceeded the threshold for both the costs/GVA and trade intensity criteria (for pulp and paperboard these were calculated as 11.9% and 25.7% respectively).

Product characteristics

Paper production occurs in two stages:

1) Pulp production

2) Pulp is then transformed together with filler materials and additives into paper

Wood and recovered paper are used as inputs to pulp production. The wood is debarked and then chipped. Around two thirds of the wood comes from forestry whilst the remaining third is the by-product from saw mills. These inputs are transformed into pulp either through chemical pulping or mechanical pulping. The pulping process involves breaking down the raw material into individual fibres. Most pulp is used in the production manufacture paper and paperboard but some is used for thick fibreboard or products manufactured from dissolved cellulose. Inputs are blended, mixed and then conditioned. The type of inputs into the pulp production process differs depending on the intended final product. To make paper, the pulp mixture is then pumped onto wire to drain away the surface water before being pressed and dried by steam heated cylinders. Finishing techniques could include calendaring and coating. Figure 10 offers a pictorial representation of the production process, including the potential for recycling used paper and paperboard.

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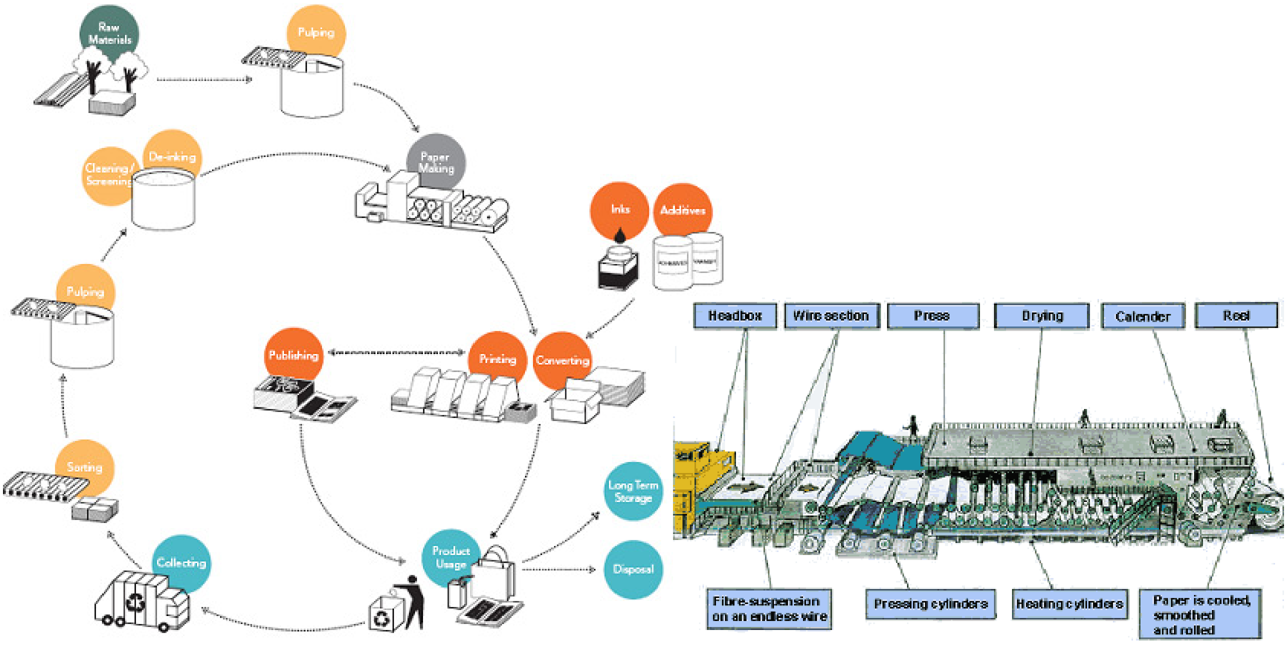
[57] European Commission (2009) website for carbon leakage http://ec.europa.eu/environment/climat/emission/pdf/draft_dec_carbon_leakage_list16sep.pdf

Figure 10: Stages in the paper production process



Source: Atrak pulp and paper industries, website.

Recovered paper can also be reused in the production process once it has been de-inked, re-pulped, washed and broken down into individual fibres akin to virgin pulp.

Prices for paper and pulp are dependent on the quality and degree of processing required during production. According to the IEA, in 2004 around 50% of total production is for packaging, wrapping and paperboard. Approximately a third of the product mix is printing and writing paper and the rest of production is newsprint, household and sanitary paper. Prior to the economic downturn pulp was priced between €370-€570 per tonne, recycled paper at €300/t, newsprint rolls at €450/t and higher quality writing or copy paper is usually priced between €700 and €850 a tonne[58]. Pulp prices peaked in July of 2008 but fell dramatically in the latter part of the year.

Emissions and energy intensity of production

Producing pulp and paper is a fundamentally energy-intensive process. However, significant efforts have been made across the sector to reduce energy use and the amount of emissions generated per tonne of product. A study by UBS investment research[59] noted that globally many companies have reported 20% or greater reduction in the purchased energy per unit of output between the years 1997-2007. Globally the energy intensity ranges between 11.1-

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[58] MRPA (2007) Imposing a unilateral carbon constraint on European energy-intensive industries and its impact on their international competitiveness – data and analysis

[59] UBS Investment Research (2008), Global pulp & paper economic outlook and financial performance.

21.9Gj/t paper depending on the production technique and final product[60]. The exact energy consumption per tonne of output depends on the quality and the finish of the product, but the IEA estimates that in aggregate the entire pulp, paper and printing sector used 40Mtoe in 2009. Unfortunately for producers, the financial gain of this reduced energy requirement has been partly offset by rising fuel and energy costs over the same time period.

Reduced energy use per tonne of product is only one of the reasons for the reduction in emissions per unit of output in the pulp and paper sector around the world. A number of sector-led initiatives have also resulted in additional reductions in emissions. For example, in Europe approximately 50% of the energy used in the production of pulp and paper is biomass. A similarly high percentage of the sector's energy needs is met by hydroelectric power, and natural gas which is relatively 'cleaner' than other fossil fuels likely due to the location of pulp and paper industries and the fuel mix in those regions. As a result some countries such as Sweden, Norway and Finland have some of the lowest emissions per tonne of product worldwide along with Canada. Other European countries which rely more on carbon-intensive fossil fuels perform less well with regards to emissions per tonne of output, e.g. Spain.

Emissions per tonne of output have also fallen in recent years due to increased recycling rates. Using recycled inputs is less emission intensive than using virgin inputs. The IEA identifies[61] increased recycling rates as a significant contributor to the decline in emissions per tonne of output in the pulp and paper industry in the UK, South Korea and Germany and the combined efforts to reduce both emissions and energy consumption has resulted in a significant fall in emissions per unit of output in recent years across the entire sector. It estimates that Europe contributed a total of 34MtCO_2 emissions in 2007. CEPI[62] confirms that in its member countries, direct emissions have fallen by 29% from 0.57kt CO_2 /kt of product to 0.35, and indirect emissions have fallen by 45% from 0.2Kt CO_2 /kt of product to 0.11 between the years 1990 to 2008[63].

Market structure

In 2008, Europe was the second largest regional producer of **pulp** with 35% of the worldwide total[64]. North America produces 37% of the total. Sweden and Finland are Europe's largest paper producers followed by Germany and Portugal.

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[60] IEA (2007) Tracking Industrial Energy Efficiency and CO2 emissions

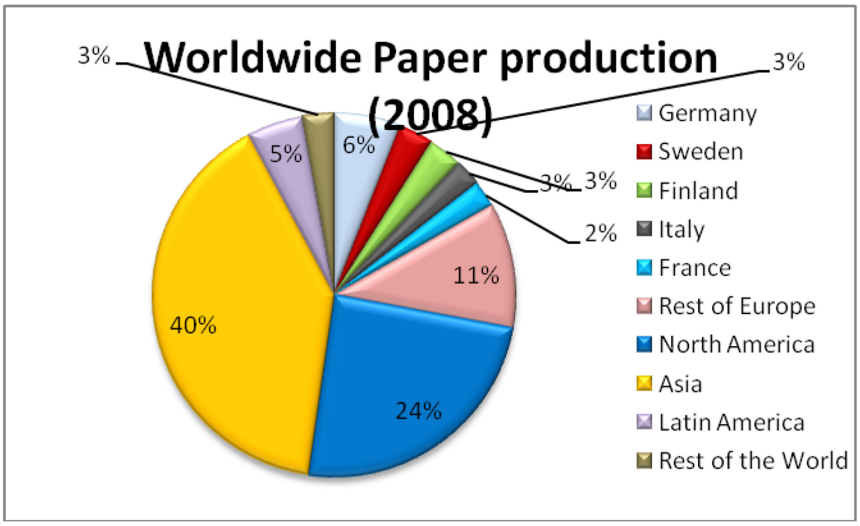
[61] IEA (2010) Energy Technology Perspectives

[62] CEPI is the Confederation of European Paper Industries regrouping the European pulp and paper industries.

[63] http://www.cepi.org/Objects/1/Files/CEPI-Report09.pdf.

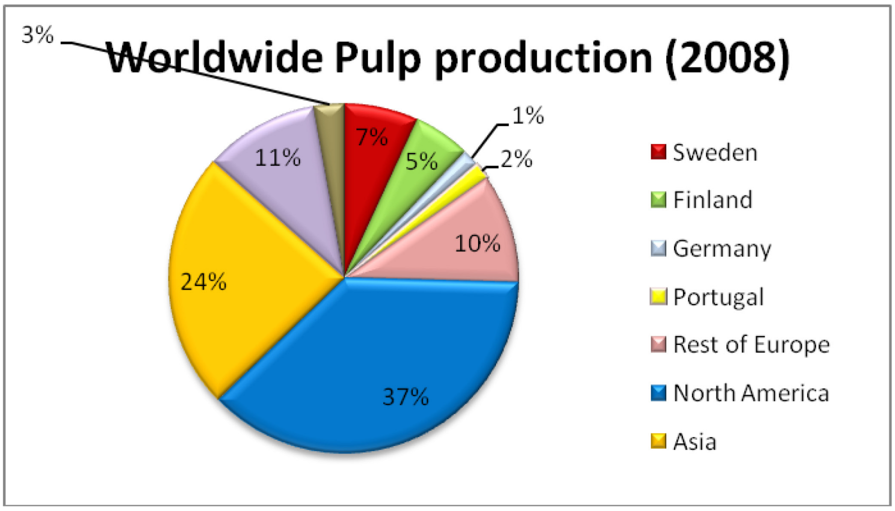
[64] CEPI (2009) Key Statistics 2009 European Pulp and Paper Industry.

Figure 11: Worldwide paper production by region 2008



Source: CEPI.

Figure 12: Worldwide pulp production by region 2008



Source: CEPI.

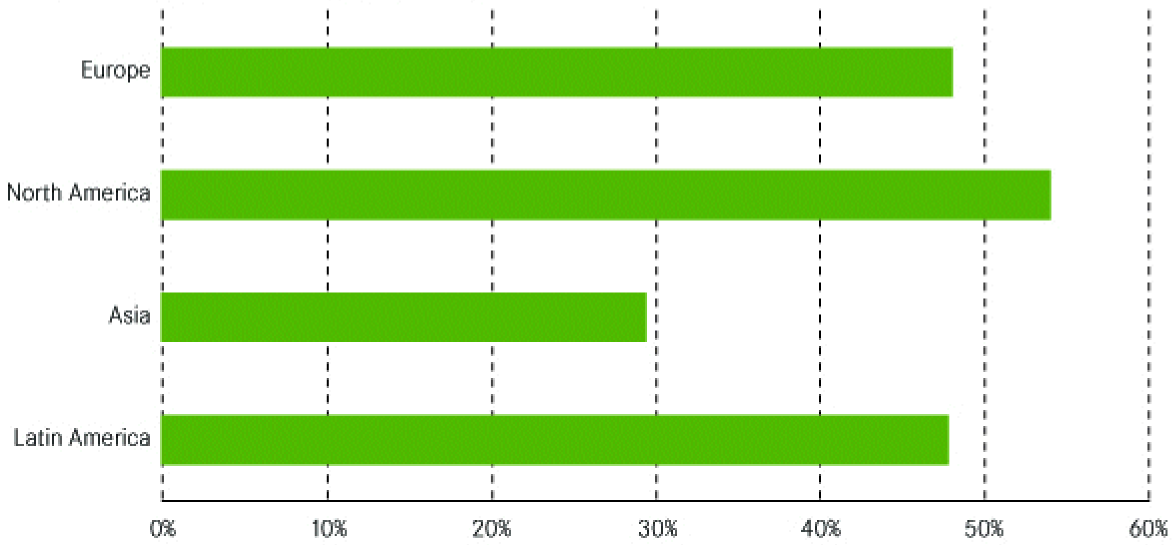
Europe accounts for a a similar percentage of global production for **paper**, accounting for 28% of the total. It is again the second largest regional producer, behind Asia who has seen large increases in production capacity and output in recent years.

Pulp and paper producers are concentrated in a small number of countries within the regions in Figures 11 and 12. The USA is the world's largest paper producer followed by China, Japan and Canada. In 2005, these four countries accounted for more than half of all global production of paper and paperboard. The relative contribution of these countries to global paper and paperboard production looks to change as China continues the trend of previous years and increases its production capacity.

Rapid expansion in Chinese production capacity has led to increased demand for inputs such as wood, recovered paper and pulp. This in turn has led to higher prices worldwide. Increased demand and competition for physical inputs is symptomatic for the entire cost structure in the sector. In recent years, the pulp and paper sector has experienced cost inflation for a number of its inputs. Higher upstream energy costs have led to higher prices for fuel, freight transportation, pulpwood, recovered paper, chemicals and other inputs. It is likely that energy and production efficiency improvements and rising input costs coupled with a susceptibility to changing patterns of downstream demand help explain the contraction of production and employment in the sector in recent years. During the economic crisis, global production of paper dropped by about 4% in 2008, and fell by a similar percentage in Europe. Direct employment suffered a loss of 10,000 jobs up to the end of 2008 in Europe. 55 plants were shut down. A further 20 closures occurred during the first months of 2009. This however may be the continuation of an existing sector trend as European industry employment fell by 33% between 1991 and 2006, the number of production mills fell by 22% but industry production rose by 51% during these years.

Figure 13 outlines the market share of the largest 10 companies operating in each region. Only in Asia is this figure below 30%. North America has the highest market concentration. In all regions, the market is dominated by a few international firms and a number of small and medium size enterprises.

Figure 13: Paper and paperboard market shares for the top 10 companies by region 2005



Related Data

Europe (CEPI area):	**1995**	**2005**
Number of companies:	**1,004**	**829**
Number of mills:	**1,404**	**1,219**

Source: CEPI.

Transport costs

Road continues to be the predominant transport choice for installations in the European pulp and paper industry. Although a shift away from road to rail would be aligned with the sector's cost cutting and emissions policies of recent years, CEPI argues that in its current form the rail network is too fragmented and unreliable to be effectively deployed on a large scale by pulp and paper producers. CEPI notes that these disadvantageous characteristics for rail have led to a decline in the percentage of rail freight between the years 1990 to 2005. This trend is forecasted to continue with the share of rail freight falling to 8% in 2020 from 12% in 1990.

However, more reliable and timely road transport is becoming increasingly costly. The IEA attributes this to rising energy prices and a tighter supply-demand balance. These are anticipated to increase transport costs further. External logistics are already estimated to average 10% of turnover.

Export and import volumes

Pulp

Europe is currently a net importer of pulp and a net exporter of paper. Finland and Sweden account for the majority of pulp produced in Europe (estimated to be 56% of total European production).

Paper

In 2008, 17% of total paper produced in Europe was exported. As Table 9 shows, both the import and export intensity of paper and paperboard production has remained relatively constant in recent years.

Table 9: Export and import intensity of paper and paperboard production in the EU.

Sector	Export intensity			Import intensity		
	2004	2005	2006	2004	2005	2006
Paper & paperboard	18%	18%	19%	6%	6%	6%

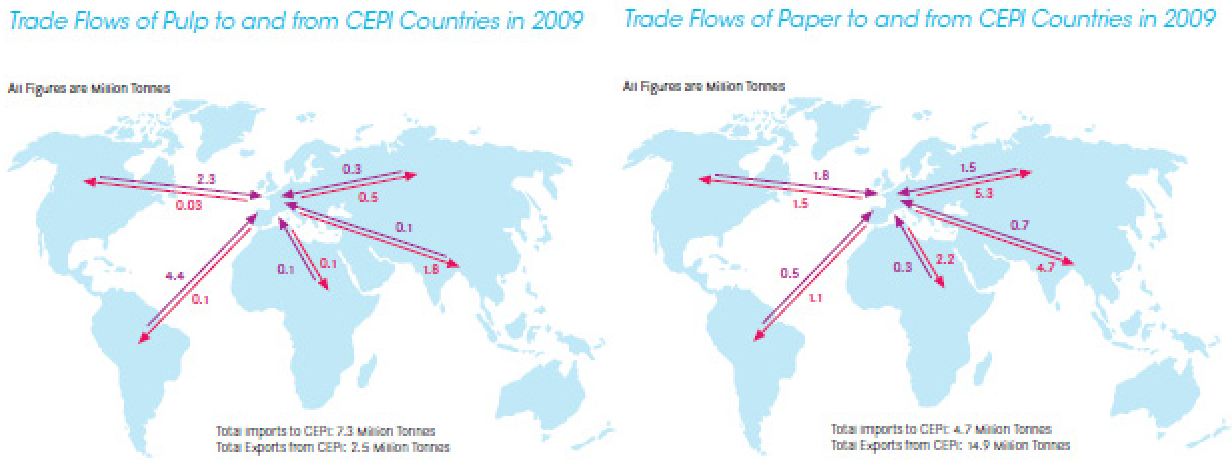
Source: Climate Strategies, Mohr et al. (2009) Trade flows and cost structure analysis for exposed industries in the EU-27.

In 2006, exports of paper amounted to almost €19bn (EU and Extra-EU) whilst imports from extra-EU destinations in the same year were valued at less than half of this at around €6.4bn.

The value of traded paper and paperboard has risen by 16% from €83,499m in 2003 which rose to €96,970m in 2007 (current prices). The share of intra-EU trade has been stable during this time. The EU's main trading partners were the USA, Switzerland, Russia, China, Norway and Turkey.

Figure 14 shows the flows of pulp and paper in and out of CEPI countries (accounting for 27% of global paper and board production). The scale of trade in pulp is much smaller than that of paper.

Figure 14: European pulp and paper trade flows



Source: CEPI.

As the figures above show, European producers[65] export more paper and import more pulp. The main locations for exporters are CIS and Asia.

Comparability of performance with installations abroad

According to RISI[66], the European pulp and paper industry has higher (and rising) labour productivity relative to all its in international competors with the exception of Japan as Figure 15 demonstrates.

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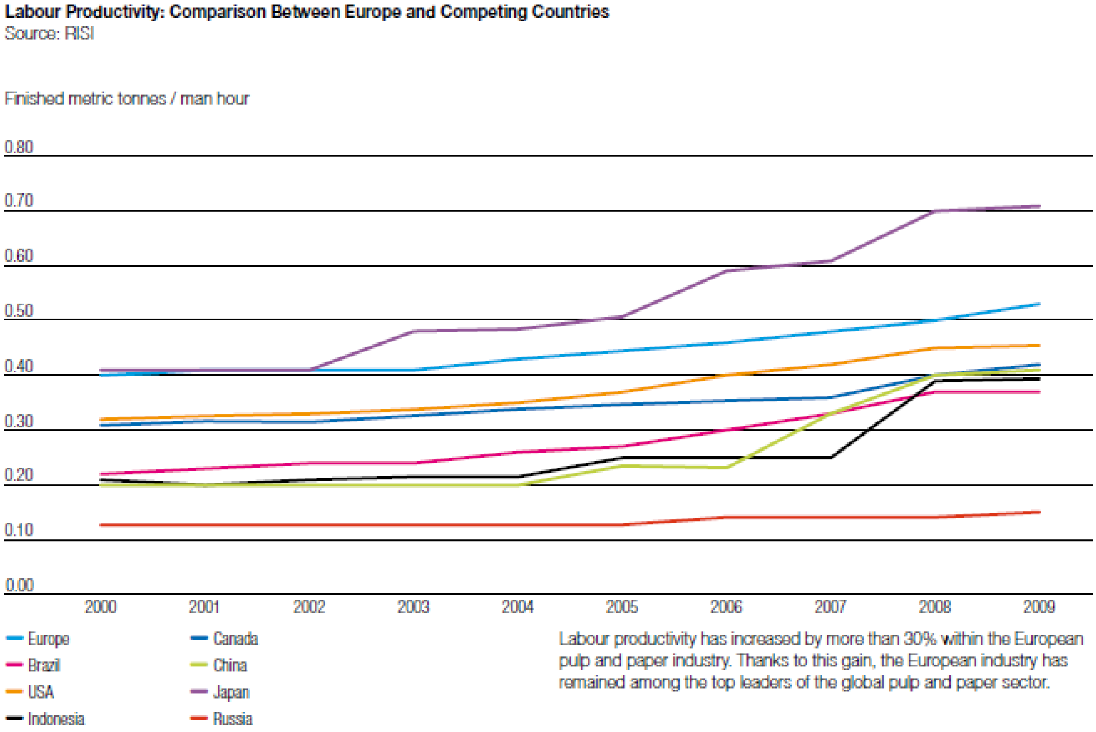
[65] Not all European countries are part of CEPI. Non-CEPI countries in Europe are Bulgaria, Cyprus, Denmark, Estonia, Greece, Ireland, Latvia, Lithuania, Luxembourg and Malta.

[66] RISI is an information provider for the global forest products industry.

Figure 15: Labour productivity, comparison between Europe and other countries



Labour Productivity: Comparison Between Europe and Competing Countries
Source: RISI

Labour productivity has increased by more than 30% within the European pulp and paper industry. Thanks to this gain, the European industry has remained among the top leaders of the global pulp and paper sector.

Source:RISI.

Total value at stake in UK and Germany

Further to the discussion on value at stake in the steel and cement sectors, the pulp and paper sector was also frequently identified by modelling studies as a sector with a relatively high value at stake across a number of regions. However, aside from Germany, country-specific analysis has not been undertaken on other large paper producing countries such as Sweden, Finland, Italy and Austria. Similar to Germany, pulp and paper sectors in these countries are likely to have a higher value at stake at a higher percentage of country GDP.

Table 10: Regional value at stake in the pulp and paper sector.

Country	Indirect value at stake	Direct value at stake	Total value at stake	% of GDP	Rank of sectors at risk
USA	1.5	3.5	5	0.1	13th
Germany	2	9	11	0.2	7th
UK	4.5	4	8.5	0.1	9th

Source: Climate Strategies, Hourcade et al. (2007), Graichen et al. (2008), Houser et al. (2008).[67]

Location of demand growth

In OECD countries, demand in the pulp and paper sub-sector is fuelled by demand for paper for printing and writing. In contrast, in non-OECD countries, pulp and paper consumption is concentrated in the category “other” paper and paperboard as paper consumption is closely linked to manufacturing output. As per capita income rises, it is expected that demand increases for printing and writing paper [68]

The increased use of computers and printers is causing a change in demand across the world with higher demand for printing and writing paper. The rapid uptake of the internet has reduced the demand for newsprint as electronic media replace traditional newspapers and periodicals[69].

Higher demand for pulp for printing and writing paper and lower growth rates for newsprint has increased demand for chemical pulp and lowered demand for mechanical pulp. In non-OECD countries, such as China and India, where wood pulp is relatively scarce, other fibres make up an important share of the pulp mix. Pulp demand has grown at a lower rate than paper demand during past decades as recycling rates have increased.

Conclusions

The pulp and paper sectors have a potential to contribute to carbon leakage as, like with most energy-intensive industries, they face major international competition and change in demand structures. With respect to emissions, pulp and paper have already made good progress in recent years to shift fuel use towards renewable and have introduced energy efficiency measures. These were driven by cost saving objectives rather than environmental ones. Thus, additional mitigation options may be more costly. Even prior to the introduction of the EU ETS, the European sector was in decline in terms of employment and production levels which has been exacerbated by the recent economic downturn. The European sector faces

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[67] Full references for these sources can be found in the bibliography. Note that these are estimations taken from charts in the referenced publications.

[68] IEA (2006) Energy Use, Technologies and CO2 Emissions in the Pulp and Paper Industry

[69] IEA (2006) Energy Use, Technologies and CO2 Emissions in the Pulp and Paper Industry

rising input costs as more regions, notably China, develop their pulp and paper sectors to reflect growing demand, particularly in emerging economies; often for higher value paper products as the economy industrialises. Even if a complete relocation of production for EU producers is unlikely and costly (large operations enjoying economies of scale), carbon may become a bigger component of the sector's cost schedule and may influence mid-long term investment decisions and thus the risk of carbon leakage.

2 Cost structures and abatement technologies

When confronted with carbon costs, firms can either increase their product prices, reduce profit margins, invest in cleaner technologies to reduce their emissions from production or relocate parts or all of their production to areas where there is no carbon pricing. To understand the choice each sector faces requires an understanding of the market conditions, i.e. the pricing and market structure, and also the cost structure. A detailed understanding of a sector's cost structure reveals the importance of carbon costs relative to other production costs, and also helps to identify the factors influencing location decisions.

Moreover, a better understanding of the abatement options and costs adds to the insight on location decision. A deeper understanding of the types of mitigation options available for each sector can allow policymakers to develop additional targeted remedial policies to assist the low carbon transformation of production practices to supplement the carbon price signal and to keep production within the national territory.

Again, each sector needs to be looked at in isolation. Cost structures and abatement potential differs because the production process, types of products and the market conditions in which they operate will differ.

2.1 Steel

2.1.1 Cost structures

Steel is one of the few industries where carbon costs could significantly increase production costs. Analysis in demonstrates that even for a carbon price of €20/tonne (the lower end of carbon price estimates for Phase III of the EU ETS) applied to a BOF/BF route (which is more emission intensive than EAF)[70] with emissions of 2tCO_2/t steel, an additional €40/tonne would be added to the production cost of steel. This is a significant sum in an industry where margins are tight for many producers and competition is increasingly global; global trade intensity of steel is around 40%.

The cost impact from a carbon price in the steel sector differs depending on the product. Using the EU as a case study, Climate Strategies[71]Wooders (2009) undertook preliminary

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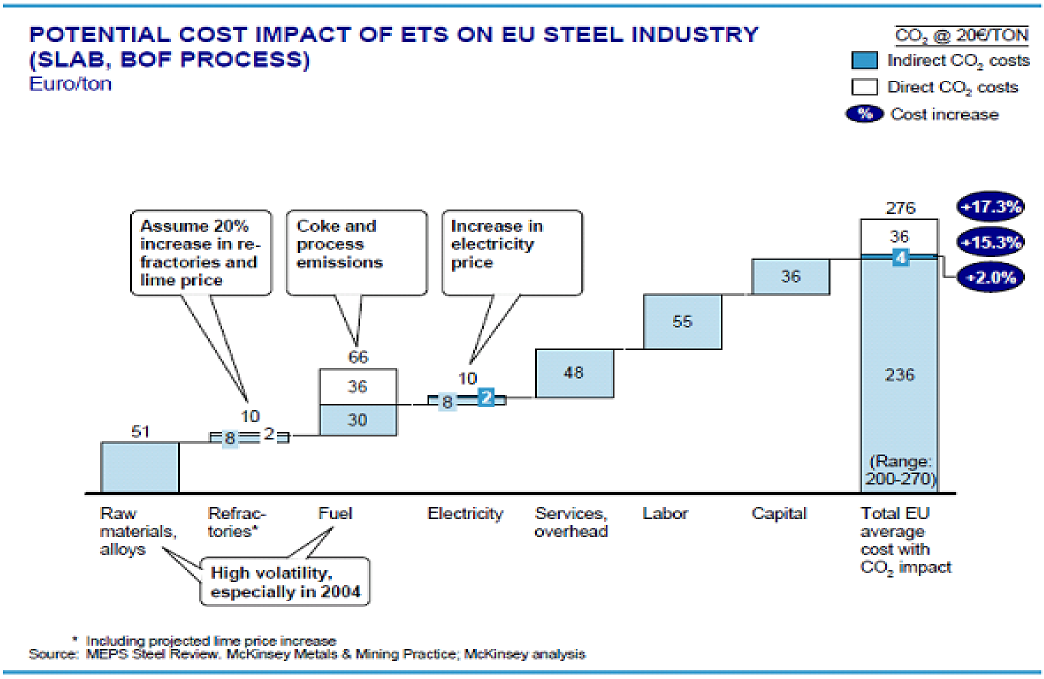
[70] For a fuller explanation, please see page 12 of this report

[71] Climate Strategies, Wooders (2009) Sector Approaches in the Steel Sector.

analysis for a carbon cost of €30/t CO_2 on prices for two steel products. Long products showed a 30% price increase from direct and indirect costs (with a 50% trade intensity), whilst flat products showed a cost increase of 15% (with a 30% trade intensity).

Figure 16 shows which components in the steel sector's production costs schedules are impacted by a carbon price (both indirectly and directly) for flat steel produced using a BOF route. Other types of steel and production routes will have differing cost schedules but this serves as an example to demonstrate the multiplicity of the impacts.

Figure 16: Potential cost impact of emissions trading on the EU steel industry



Source: McKinsey.

Figure 16 shows that for flat steel using BOF, there is one principle source of direct emissions from fuel combustion and two indirect sources. Although the calculations hide significant volatility in costs, especially with respect to commodity and fuel prices, these combined indirect and direct carbon costs are calculated to represent an additional 17.3% on top of existing costs.

Whilst, Figure 16 shows the aggregated cost structure for the steel sector in Europe, Climate Strategies research[72] demonstrates that there are regional variations on the cost structure in Figure 17. They attribute these differences to varying recycling ratios and production processes, plant efficiencies, prices, product mix, specialisation and the use of outsourcing or employment agencies. Indeed, even within a country, there are installation level variations in

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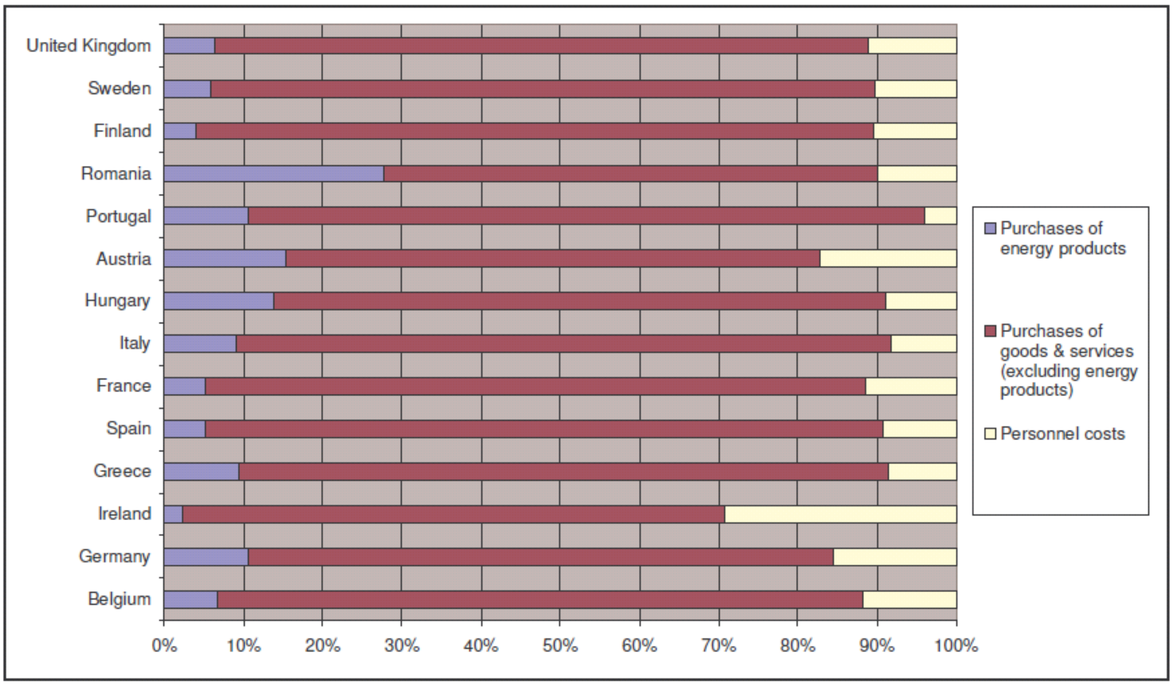
[72] Climate Strategies, Mohr et al. (2009) Trade flows and cost structure analysis for exposed industries in the EU-27

the cost structure and any carbon pricing policy will therefore create winners and losers within the European steel industry.

Figure 17: Potential cost impact of emissions trading on the EU steel industry



Source: Climate Strategies, Mohr et al. (2009) Trade flows and cost structure analysis for exposed industries in the EU-27.

2.1.2 Abatement technologies

As noted in section 1.1, there are large regional variations in the energy and carbon efficiency of steel production, depending inter alia on the type of furnace, the size and age of the plant.

Abatement opportunities in the steel sector seem to be limited in the short- to-medium term. There are few technical options to reduce emissions as technology is generally ‘locked in’ to the plant. Climate Strategies, Wooders, et al. (2009) identifies six categories of abatement options for the steel sector listed below. The latter two options are assumed to be rather long-term but it is worth noting that the cost of implementing abatement options 1-4 would be close to zero

1. The closure of inefficient, highly polluting plants

One option to mitigate emissions from the steel sector is to speed up the retirement of less efficient capital so that newer, less carbon-intensive technologies and production techniques can be introduced sooner as a replacement. Depending on a plant’s investment schedule, additional government support might be required to assist with the low carbon transition of the steel sector in a region

2. Improving energy efficiency and carbon efficiency at existing, non-obsolete plants

Due to increasing cost pressures and international competition, iron and steel manufactures have made large efficiency improvements, in terms of energy and material inputs. In recent years this took place in a number of locations worldwide with the notable exception of China. The IEA[73] identifies that there are still opportunities to improve production efficiency in China (thus reducing the emissions per tonne of output), as the gap between the average and the best plant in China is about 20% due to differences in the size of blast furnaces.

3. Ensuring the new plant is built using best available technology

Conceptually, introducing more efficient and effective technologies into the production process is undoubtedly a key tool to mitigate emissions in the steel sector. However, research by Climate Strategies [74]has shown that a number of newly built plants are already constructed at levels that are close to best available technologies (BAT). This is particularly true in China and to a lesser extent in India. Both locations have experienced large capacity building in recent years and so additional policies to encourage BAT as normal investment practices may have a small marginal impact on emissions levels in the steel sector.

4. Increasing the use of scrap

The use of scrap in steel production as an input into the EAF furnace is limited by physical availability. Although efforts have been made to increase the use of scrap as input into the production process, regions with nascent steel sectors will hav e limited scrap availability. This is the case for China which has experienced the largest growth in the steel sector worldwide. As the steel sector and infrastructure matures, more scrap is likely to become available in these regions.

5. Adopting Carbon Capture and Storage (CCS)

Although CCS has been identified as an important mid- to long term mitigation option for the steel sector, significant effort is required to demonstrate, deploy and widely diffuse this new technology for both retrofitting and building new capacity. The IEA[75] estimates that for a goal of 1.1Gt of avoided CO_2 emissions in the steel sector by 2050, innovation and demonstration would be needed between now and 2020 to introduce CCS technologies in blast furnaces, smelting reduction plants and direct reduced iron DRI and large scale deployment would be needed by 2030[76]. Given the high investment costs and long time horizons, government support is required to fund demonstrations and signal certainty to industry that CCS will be a credible and required technology in the future.

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[73] IEA (2007) Tracking Industrial Energy Efficiency and CO_2 emissions

[74] Climate Strategies, Wooders (2009) Sector Approaches in the Steel Sector.

[75] IEA (2010) Energy Technology Perspectives

76 This is based on IEA scenario modelling to reach low carbon pathways by 2050

6. Developing and implementing breakthrough technologies

Even if options 1-5 were implemented, emissions in the steel sector in 2030 would still be 59% higher than 2005 levels because of rising global production capacity[77]. A net reduction in emissions and energy consumption is therefore heavily dependent on development and maturity of breakthrough technologies before 2050. This would ensure they are locked into new production capacity and used to improve existing plants. Given the risks, uncertainties and the need for rapid diffusion of new breakthrough technologies, new mitigation options would require supplementary policy support to coordinate and incentivise innovation.

2.2 Cement

2.2.1 Cost Structures

The European Commission[78] has estimated that the incremental costs of CO_2 allowances for the cement sector in Phase III of the EU ETS would be in the order of €15-€20/t of Portland cement. This is broadly in accordance with an estimate by the IEA[79] in 2005 that for a carbon price of €20/t CO_2 the incremental allowance cost would be €17.4 per tonne of cement. Taking average cement prices from section 1 for 2005, the price of Portland cement in Europe was US$88/tonne, approximately[80] €70.4/tonne. Energy requirements and shipping costs represent the majority of short run production costs and historically, shipping costs have been significantly higher than carbon costs, often equivalent to approximately half of the product price.

2.2.2 Abatement potential

There are a number of low cost abatement opportunities in the cement sector based on current technologies and production capabilities. Also, future technologies, such as carbon capture and storage, may become sufficiently mature to merit widespread application in the cement sector which would reduce emissions much further and as such, the burden of carbon costs[81].

A number of studies[82] have identified abatement opportunities in the cement sector.

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[77] Climate Strategies, P. Wooders (2009) Sector Approaches in the Steel Sector.

[78] European Commission website on carbon leakage. http://ec.europa.eu/clima/policies/ets/leakage_en.htm

[79] IEA (2005), "Industrial Competitiveness under the European Union Emission Trading Scheme", Information Paper, OECD/IEA, Paris.

[80] Using an average exchange rate of US$1 = €0.8

[81] Carbon Trust (2010), Tackling carbon leakage. Sector-specific solutions for a world of unequal carbon prices

[82] IEA (2007), Tracking Industrial Energy Efficiency and CO_2 emissions. Climate Strategies, Cook (2009) Climate Change and the Cement Industry, assessing emissions and policy responses to carbon prices,

1. Increased energy efficiency

Energy efficiency could be improved via kiln technologies (wet kilns are almost twice as energy-intensive as the current BAT) and waste heat recovering. As a result, this has reduced electricity consumption per tonne of cement produced. Wet kilns are still widely used in the CIS and in New Zealand and Australia and this change in kiln type could be a significant abatement opportunity these regions.

2. Product Innovation to reduce the use of clinker

It is possible that new cement types will be developed in the longer term called 'geopolymers' which have much lower process emissions. These new products are still in the early stages of innovation and the feasibility of their application is something that needs to be explored further.

According the IEA, significant additional R&D would be required to assess the regional availability and applicability of various substitution materials as there is not a simple worldwide panacea for shifting away from using clinker. The development and implementation of international standards for blended cements would also support greater use of clinker substitutes. It is possible that currently immature but radical innovations could be introduced to the sector to replace clinker entirely.

3. Higher shares of alternative fuel use

The use of less carbon-intensive fossil fuels and of waste and biomass fuels in the kiln offer the possibility of reducing CO_2 intensity

4. Greater volumes of clinker substitutes

Since clinker production is the most energy and emission intensive part of the cement production process, reducing the cement to clinker ratio by using substitutes such as industrial waste products (e.g. fly ash as a substitute for clay or bauxite and blast furnace slag as a substitute for limestone) could reduce emissions.

5. CCS deployment

Widespread CCS deployment, particularly for clinker production could reduce emissions but currently could only be introduced at very high costs. The IEA[83] estimates that the use of CCS in cement plants in Europe would double the investment costs of a cement plant and would increase its energy use and operating costs. However it sees the application of CCS as essential for reducing cement sector emissions below current levels by 2050. They calculate that in order to reduce emissions by 0.5Gt to 1.0Gt relative to BAU, CCS needs to be developed in a very quick timeframe. The IEA suggests that demonstration would need to begin by 2015 for both new builds and for retrofits. They anticipate commercial deployment

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[83] IEA (2010) Energy Technology Perspectives

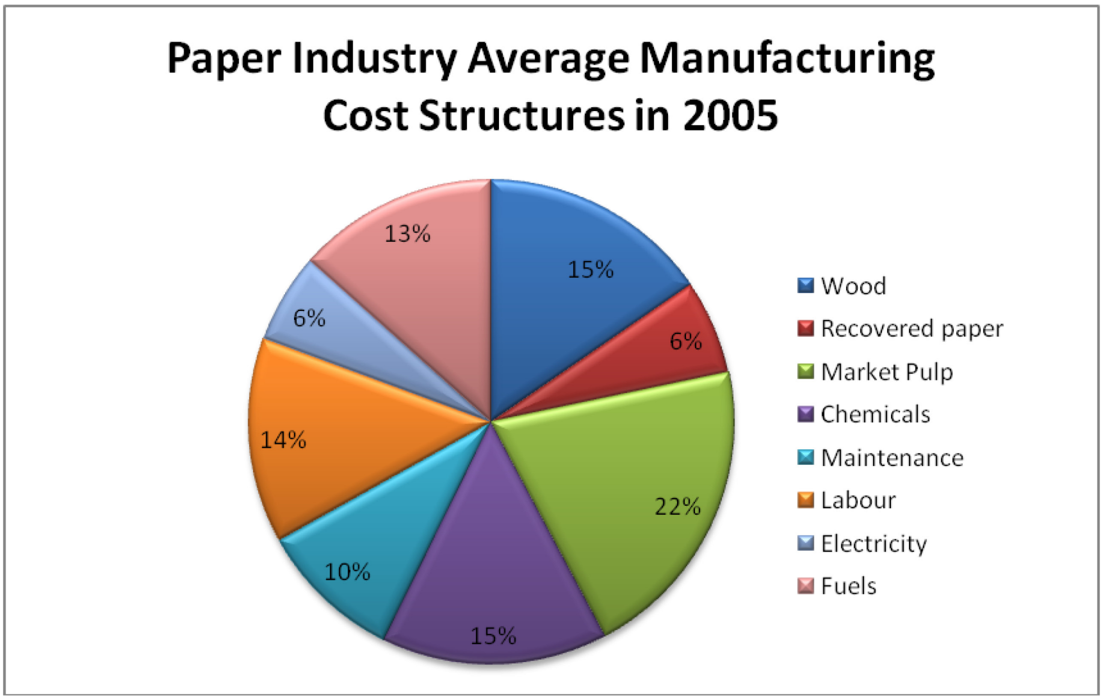
would need to begin by 2020 and be commercially available by 2030 so that by 2050 up to 40% of cement kilns operate with CCS technology.

2.3 Paper

2.3.1 Cost Structures

Figure 18 gives an overview of the current average global short run cost composition for the pulp and paper industry in 2005. It excludes transport and capital costs as the former is more varied depending on the location and level of infrastructure, and the latter needs to be viewed over a longer time horizon to deliver context. Physical raw inputs make up the largest component of the paper industry's cost structure and electricity and fuels comprise of around a quarter of total energy costs. Labour costs in 2005 were 14% but the industry has since experienced declining employment in Europe, and so this graph will vary regionally.

Figure 18: Average share of production costs in the pulp and paper industry



Source: RISI 2005.

Similar to the analysis for the steel sector, Climate Strategies research[84] identified regional variations in the cost structures of the pulp and paper industry in Europe. Most countries seem to have similar cost structures with the exception of Lithuania and Ireland whose energy purchases are relatively high and relatively low respectively compared to other input costs. A

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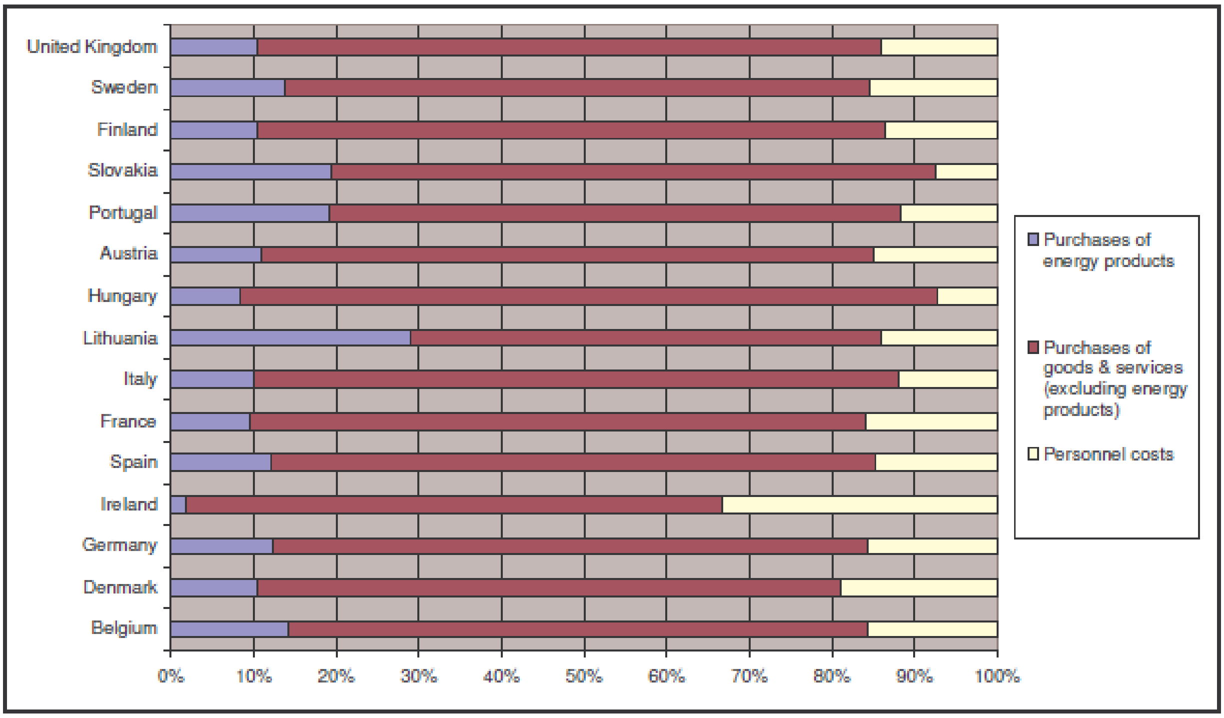
[84] Climate Strategies, Mohr et al. (2009) Trade flows and cost structure analysis for exposed industries in the EU-27

number of pulp and paper producing countries are able to use hedging strategies to limit the fluctuations in energy costs through the use of biomass when other sources of power are high.

Figure 19: Cost structure of European paper and paperboard producers.

Breakdown of operational costs in the EU production of paper and paperboard (2006)



Note: Only EU Member States with complete data are included.

Source: Eurostat, SBS (date of extraction 14 January 2009)

Source: Climate Strategies, Mohr et al. (2009) Trade flows and cost structure analysis for exposed industries in the EU-27.

2.3.2 *Abatement potential*

1. **Use of Best Available Technologies (BAT)**

There are currently significant differences in energy use and production efficiency for pulp and paper between countries worldwide due to differences in the product mix, processes used, plant size, technology, technical age of the capital, feedstock quality, regional fuel prices and the effectiveness of energy efficiency measures. The IEA analysed these factors for a number of regions for both heat and electricity use and found the regional differences to be significant. For example the remaining improvement potential for energy use was only 2% relative to BAT in Germany but 28% in the UK.

Over the next 10-15 years there is a real opportunity to improve the technology used in OECD countries as many pulp and paper facilities are nearing the end of their operating life.

Retrofitting mills with energy saving technologies is also an option where investment schedules are longer.

2. Fuel switching

The pulp and paper sector already uses a high percentage of biomass as their fuel source. According to the IPCC (2007), in developed countries biomass provides 49% of the fuel used by pulp, paper and paperboard mills. Although there has already been a significant move towards the use of biomass as energy source across the sector, increasing its share in the power mix for the pulp and paper sector would reduce emissions further.

3. Increased recycling rates

Similarly, paper recycling rates have increased in recent years. Each tonne of recycled pulp used offers a net energy saving potential of 10.9GJ/t.[85] However, the effect on an installation's emissions is dependent on the prevailing emission intensity and fuel use of the pulp and recycling mills.

Similar to scrap, there is a finite amount of paper that can be recycled, given the difficulties with recycling some types of paper, the recycling rate is calculated to be approximately 81%. Recycling rates vary across regions. The average recycling rate worldwide is around 45%. The EU has a higher recycling rate of around 52%. In 2007, the IEA [86]identified a global recycling potential of 35% and pinpointed North America and parts of Asia as key regions to realise this through more effective policies on waste disposal.

4. Technology

The most energy intensive, and thus emission intensive, part of the paper production process is the drying component. It accounts for up to 70% of fossil fuel consumption. According to a study by CE Delft in 2010, if the drying process reutilises the heat of vaporisation of the removed water, there could be a significant saving in fuel consumption. A number of processes including airless drying and super-heated steam drying are in pilot stages of development and may have the potential to reduce fuel consumption from paper drying by 70-90%. However, without additional policy support to encourage R&D, it is unlikely that these technologies would be sufficiently mature and commercially viable to be deployed on a large scale within the next two decades.

A second major breakthrough area for technology is the development of black liquor gasification with CCS. Black liquor is produced as a biomass-rich bi-product when wood pulp is processed for papermaking. It is then used as fuel in the paper production process. There are efforts, through gasification, to increase the efficiency of energy generated from black liquor and also to apply CCS technologies. If deployed on a large enough scale, there is the

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[85] CEPI (2006) Europe Global Champion in Paper Recycling: Paper Industries Meet Ambitious Target, Press Release

[86] IEA (2007) Energy Technology Perspectives

potential for the industry to become a net exporter of biomass energy[87]. However, a significant barrier to large-scale roll out of this technology is the high investment costs in the nascent phases of innovation. Chemrec, a company in Sweden has begun to actively develop the gasification process and has had some success with a commercial scale installation in the New Bern pulp mill. This company has been operational for a decade and has invested in a number of regional plants using similar gasification technologies in the demonstration phase.[88] Such examples suggest that this technology has been recognised by the industry as a possible way of mitigating emissions but is in very early phases of development and may require supporting government policies to speed up the innovation process.

3. Potential for sectoral agreements and other remedial policy options to address leakage

Three options exist for policymakers to address the negative impacts from carbon pricing which could lead to carbon leakage from the EU:

1) Levelling down carbon costs for EU producers
2) Levelling up carbon costs in other world regions
3) Levelling carbon costs at the border

Figure 20 depicts the three options:

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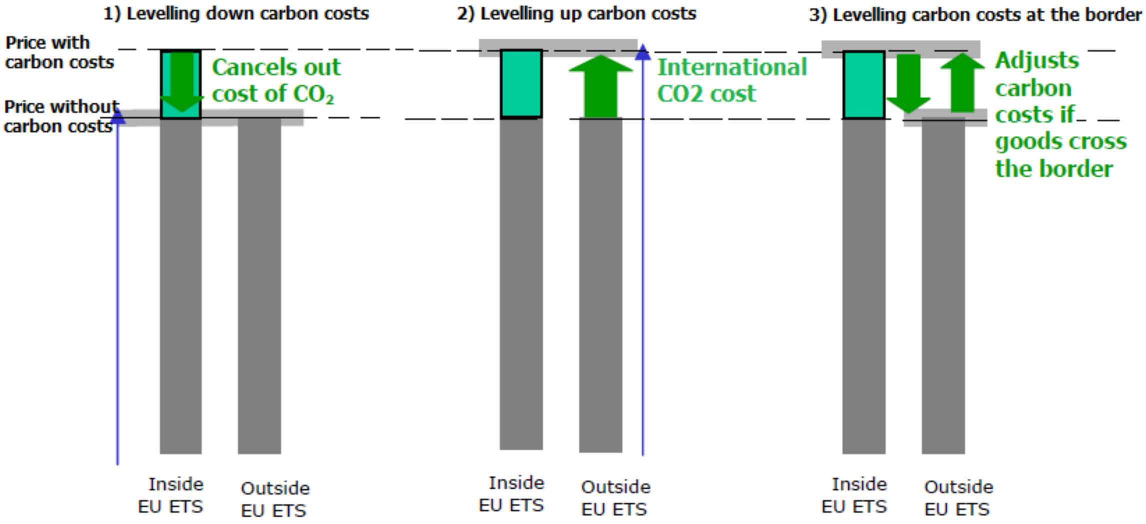
[87] Intergovernmental Panel on Climate Change (2007) Climate Change 2007: Working Group III: Mitigation of Climate Change

[88] CE Delft (2010) Technological Developments in Europe, A long-term view of CO_2 efficient manufacturing in the European region

Figure 20: Three options for policymakers



Source: Neuhoff 2008.

3.1. Levelling down carbon costs for EU producers

3.1.1 Free allocation

Free allocation is preferred by both industry and policymakers in the EU and was also discussed in the US as a tool for addressing carbon leakage. The rationale behind allocating allowances for free is to reduce the carbon costs faced by sectors that compete internationally and to minimise the competitive distortions from unilateral carbon pricing (levelling down the carbon costs for EU producers).

Economic efficiency and effectiveness

Free allocation has been the principle allocation methodology in Phase I and II of the EU ETS and can take a number of forms including: grandfathering (applied under the EU ETS so far, partly with benchmarking), output-based allocation (not allowed for under the EU ETS) with or without benchmarking. A number of distortionary incentives, relating to plant life and operation, energy efficiency investments and demand substitution, arise from these different free allocation methodologies[89]. Even though in the short term the incentives to relocate production could be reduced with free allocation, the incentives to improve production efficiencies are dampened in the longer term.

Free allocation needs to be linked to an installation's production location if leakage should be avoided. As such, Neuhoff (2008) recommends three design components to include in developing free allocation.

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[89] These are explored in more depth in Neuhoff (2008) Tackling Carbon. How to Price Carbon for Climate Policy, University of Cambridge

1. Free allocation must be made **conditional on continued operation**; otherwise an installation may cash in the emission certificates and relocate once they have received free allowances. Even if free allocation was conditional on continued operation, it can create the perverse incentive to maintain production and consumption levels just to receive more credit in future periods. The new entrants reserves, which are part of the EU ETS, can also contribute to false incentives, if companies choose to restructure in favour of new installations for which they would receive certificates from this reserve. Thus, as free allowances relate to partly large asset transfers, industry always has an incentive to adjust its behaviour in a manner that is not in line with the climate policy goal of the EU ETS: bringing forward efficient carbon reductions through pricing carbon.

2. **Benchmarks** can be introduced to give the industry an incentive to improve its emission performance under free allocation. All sectors deemed at risk of leakage will only receive full free allocation if they are amongst the top ten EU producers. If not, free allocation will be rationed. Benchmarks can also be applied on a quantitative basis, e.g. installed production capacity and production volumes before a past base year. Benchmarks can be adjusted over time to reflect anticipated efficiency and technological improvements in production.

The EU has developed 52 product benchmarks in Phase III of the EU ETS which reflect the average greenhouse gas performance of the 10% best performing installations in the EU producing that product, expressed in terms of allowances per tonne of output of product. This means that an installation whose output produces lower emissions than the benchmark will have surplus emissions to sell whilst more emissions intensive installations that have an emissions/output ration which is higher than the benchmark will be required to purchase the shortfall of emissions allowances at auction or in the market.

3. **Free allocation to the relevant step of the value chain**. Upstream (i.e. early stages of the production process) free allocation might be preferable to downstream (i.e. later stages of the production process closer to the final product) in some sectors as producers may choose to import an intermediate product if it is emission-intensive to avoid high carbon costs.

Administrative viewpoint

The revised EU ETS Directive proposes the use of benchmarked free allocation as a key policy tool for addressing leakage. Depending on how they are defined and measured against different production performance metrics, benchmarks can incentivise the shift to more efficient fuels, production processes and/or lower carbon products and services. Calculating benchmarks requires a large amount of administrative effort. Policymakers will require information on the production characteristics, including data, of all installations in a sector. The degree of public sector burden is dependent on the type of benchmark applied, e.g. if benchmarks are based on best available technologies, a very high level of detail is required about the production process, and they need to be applied in a way that doesn't distort the incentive to innovate and lower the carbon intensity of production further over time. There is a natural asymmetry of information when calculating benchmarks as policymakers are far less informed than the firms running the installations. As installations will perform differently when assessed against different production performance criteria, the number of free permits they receive relative to their competitors within the carbon pricing zone will also differ. The choice of the most 'appropriate' assessment metric requires a degree of subjectivity on the part of the public sector. This creates immense interest in sector lobbying, which could create a bias towards over-allocation.

Geopolitical and legal viewpoint

A high reliance on free allocation as the principle remedial policy option for all 164 sectors identified at risk by the European Commission may also prove difficult because of Article 21 in the Directive: a decrease in the percentage of free allowances as a proportion of overall Community-wide emissions from 80% in 2013 to 30% at the end of Phase III in 2020. This is another driver for considering additional policy measures to free allocation as the absolute number of free allowances will decline as there will be fewer free allowances per installations which would be exacerbated if the EU moves to a 30% emissions reduction commitment.

Free allocation could also fall under the auspices of international trade law. Due to the differences in carbon pricing policies across the world, the rules for free allocation will differ and so distort installations' performances in the international market. When the debate about a potential US cap and trade bill was peaking in 2009, it became clear that the US system would be less strict (lower carbon price) and that the free allocation would be based on past output with regular updates, creating a subsidy for all producers under the US ETS. Given the weak commitment in 2010 by other regions to embark on cap and trade, the anticipated threat of a "subsidy race" to improve domestic sectors' market position using free allocation is low though.

Trade-offs associated with free allocation

Sectors will react differently to receiving free allowances. Climate Strategies Hourcade et al. (2008) show that installations receiving free allowances will trade-off short term profits with longer term market share. If installations in a sector choose to pass on the opportunity costs of permits to consumers, this would lead to a price increase and higher profits but may compromise the installation's competitive position in the market. An installation's reaction to this trade off will be dependent on a number of sector and characteristics and market conditions. Differences in the impacts of free allocation on a sector's production location decision are another reason for exploring sector-specific characteristics; using a combination of qualitative and quantitative indicators, so that an industry's reaction can be anticipated. For example, if the cement sector was to receive free allowances, there is a risk of significant windfall profits for those who are landlocked and thus not under competitive pressure. For coastal production sites, free allocation would create a strong incentive to import clinker, the most carbon intensive part of the cement production process, and sell the allowances, as this would be the most profitable option to take.

At a sector level, free allocation dilutes the incentives, created by a carbon price, to introduce mitigation actions and decarbonise over time.

Widespread free allocation for manufacturers will significantly reduce the number of participants in auctions for EUAs (20% of allowances are auctioned in 2013 which rises to 70% in 2020). This reduces the potential auction revenue for the public sector that could be generated to finance mitigation, adaptation and low-carbon technologies both within Europe and as part of any international financing initiatives such as those proposed in the Copenhagen Accord.

3.1.2 Provision of State Aid

An alternative method of levelling down the carbon costs for EU producers is through direct cost compensation, i.e. the provision of State Aid. This policy could be used to offset both the direct and indirect costs (i.e. increased prices from upstream processes and electricity generation that also face higher carbon costs, currently included in the revised Directive Art. 10b to be considered by member states).

Economic efficiency and effectiveness

Direct cost compensation could be linked to incentives for sectors to continue operating in the EU, thereby reducing the risk of leakage. For example, the introduction of carbon costs may the deciding factor, which means an installation's looking to invest in new capital would enjoy higher returns outside of the EU, then a subsidy linked to low-carbon technology and capacity investment could be offered to offset the carbon costs in the EU ETS. This would be particularly effective from an EU standpoint in sectors with high capital-costs and long investment schedules.

In addition to being an effective policy for installations considering large capital investment, it is also a useful tool to address the risk of leakage in sectors facing high indirect costs, e.g. the aluminium sector. The EU has regional electricity markets and there are limited options for substituting EU-generated power for regions outside the carbon pricing zone (only a few Eastern European border countries not covered by the EU ETS would have the option of importing electricity; dependent on the transmission grid). Direct cost compensation would be appropriate in those sectors where there are a limited number of mitigation options for reducing indirect emissions. For example, support could be provided that are tied to investments in low carbon electricity.

Administrative viewpoint

Direct cost compensation would need to be limited to a few sectors to minimise the financial burden on the public sector. Rigorous analysis would also be needed to identify the sectors which would receive direct cost compensation so that it can stand up to international legal scrutiny. Sector production characteristics would also be needed for such an analysis in order to set the level of direct cost compensation. This would help to identify criteria that are most closely linked to the level of innovation and carbon intensity of a new production site. By this creation of any distortionary incentives could be reduced. Another justification for introducing tailored sector-specific compensation measures is to avoid the situation whereby widespread, generous subsidies could lead to lower product prices in a sector and distortions in the international market if the sector has high international trade intensity and international competitors don't receive similar subsidies.

Direct cost compensation would be determined and administered at the national level, just like indirect carbon costs (electricity) under the ETS revised Directive. The EU COM who would intervene and adjust subsidies if they are perceived to be too stringent or lenient could regulate this decentralised approach. As such, it requires administrative capacity at both the national and EU level but the degree of effort is dependent on the number of sectors identified as being eligible for direct cost compensation.

Geopolitical and legal viewpoint

A legal study of European Commission law by Johnston (2008)[90] supported the need for a rigorous analysis of the sector's production characteristics as a way of transparently identifying European policymakers' motivation for using direct cost compensation. The purpose behind any given aid measure will be crucial in assessing its acceptability under European Competition law, whether by fitting it within categories recognised by a block exemption regulation or the individual notification process.

Given the apparent difficulties with agreeing on a top-down SAAM, existing national policies should be the essential building blocks of an multi-national approach.

3.2. Levelling carbon costs at the border

Border adjustments in order to level carbon costs between producers with and without a carbon constraint are discussed based on two major political and economic motivations. First, the application of trade measures could serve as a sanction for countries that do not want to contribute to protect the global climate, but rather "free ride" on the efforts made by others. So any border measure (tariff, tax, quota) that is supposed to serve this purpose would be designed to discriminate imports from specific countries. While non-discrimination is one of the core principles of WTO law, the justification under WTO law for such behaviour could fall under Article XX which includes as an exemption clause the protection of a global resource. Yet a number of preconditions need to be fulfilled, before a discrimination of trade partners could be undertaken. First and foremost, any kind of least trade restrictive measure should have been considered and negotiated to solve the problem, only if this fails, trade measures should be considered. Moreover, a measure under Art XX GATT must not be arbitrary or a disguised protection.

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[90] Johnston, A. (2008); State Aid to Tackle Leakage: EC Law Considerations in Neuhoff and Matthes (2008)

A second approach to apply a border measure relates to actual unilateral carbon pricing (tax or emissions trading) and the need to prevent carbon leakage caused by cost differentials caused by pricing externalities. This approach considers the actual carbon emitted by a sector. Thus it is not the country of origin that matters, but rather the production method applied abroad, regardless of the actual territory. In theory such an adjustment must work both ways, allowing privileged market access to goods with lower carbon content than those produced in the importing region, here the EU. From a world trade law point of view, such a scheme needs to be non-discriminating (e.g. by assuming a carbon-content baseline for all imported like products and own producers) if applied unilaterally. Or as in the first approach, if it is applied in a discriminatory manner, it needs to be justified through Art. XX GATT.

3.2.1. Inclusion of importers in to the scheme

The amended EU ETS Directive (2003/87/E) stipulates in its Article 10b that an alternative remedial policy measure for sectors identified as being at risk of leakage is the inclusion in the Community scheme of importers of products which are produced by the sectors or sub-sectors.

Economic efficiency and effectiveness

Including importers in to the EU ETS would demand from importers to buy emission allowances or to pay a carbon price at the border equivalent to the price for allowances. This would incur a carbon cost on imported goods and would neutralise the cost differentials from different climate policy or no climate policy abroad. If such a levy is based on an equal treatment of all imported goods from a specific sector, the efficiency and effectiveness will be lowered, but non-discrimination according to international trade rules would be guaranteed. As the application of such a scheme must not discriminate amongst exporting nations and thus would need a single formula applied to all imports. In order to meet the environmental purpose of such a border measure, the implementation would be based on an assumed carbon emission per unit of a traded good as benchmark, e.g. for clinker assuming an average or a BAT emission standard.

Administrative viewpoint

The standardised calculation of the carbon price for imported goods is not an easy undertaking. Carbon emissions accumulate along the value chain. Thus, a manageable adjustment is reduced to primary goods at early stages of the value chain, not final products. This principle holds for basic industrial inputs or products, which are homogenous (e.g. clinker) and not subject to a long production chain (e.g. cars). Similar to the VAT adjustments across international borders, a transparent carbon-related basis (well-known production technologies and energy sources) could work for selected industries under the EU ETS.

Geopolitical and legal viewpoint

Border levelling can in principle be entirely compatible with World Trade law provided it is not implemented in a way that discriminates between products and sectors based on the climate policies of their country of origin. The distinction between different types of border measures needs to be clarified in a legal and political setting, finding common ground on what is a transparent and agreed way of handling carbon cost differentials multilaterally. Due to the misconceptions of the purpose and application of border adjustments, the political risks for the EU are amongst the greatest challenges when inclusion of importers to the EU ETS is concerned.

Policy options to address leakage must comply with both Article III of the GATT, which stipulates national treatment of like products from international production, and Article I GATT, which guarantees that all favourable conditions negotiated with one WTO member is automatically applied to all other members. These rules are only superseded by the exemption Article XX of the GATT, which allows for the suspension of non-discrimination for the necessary protection of a global resource. The atmosphere may constitute as such but there are no historical precedents on an approach to implement carbon cost border adjustments based on WTO rules. From a legal standpoint, the important components to consider are:

1) The tool chosen for a cost adjustment (e.g. tariff, tax, subsidy etc)

2) The treatment of products based on their emissions performance

3) The direction of adjustment (i.e. on imports or exports, levelling up or down).

The design of trade policy is a key determinant of the legality of any measure implemented[91].

3.3. Levelling up carbon costs for non-EU producers

3.3.1. Sectoral Approaches Agreements and Mechanisms (SAAMs)

SAAMs have a long-standing role in the debates on international climate protection. The term is not clearly defined as such agreement could be voluntary or binding, made by industries with or without government involvement[92]. The European Commission is favouring a binding approach in the post-Copenhagen policy environment. Negotiations have increasingly focused on this approach and the EU Commission actively looks for the most relevant sectors for such an approach

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[91] For more information please see WTO (2009): Trade and Climate Change. A report by the United Nations Environment Programme and the World Trade Organisation, Geneva, Switzerland.

[92] See e.g. Baron, R., Barnsley, I. (2008): Sectoral Approaches to International Climate Change Policy Workshop Background Paper, IEA Paris, <http://www.iea.org/work/workshopdetail.asp?WS_ID=380>

To date, a range of SAAMs have been discussed. Promising options include technology agreements for the explicit inclusion or exclusion of particular technologies and also the adoption of intensity targets for particular sectors.

Economic efficiency and effectiveness

The aim of an international SAAM is to ensure a more level playing field for installations in a sector with international competitors who don't face a carbon price. These SAAMs could take a number of forms e.g. technological standards or benchmarks and will all involve the levelling of carbon costs upwards for all international exporters and the EU installations alike.

However, there are difficulties with incentivising a binding agreement amongst international stakeholders. As outlined in Neuhoff (2009), this policy tool would work best in areas of strong governance and where industry is driving forward voluntary initiatives, as in the cement sector, in order to pre-empt governments from introducing less desirable climate policies. In order to increase their effectiveness and credibility, governments should at least signal that without a SAMM, other climate policy measures would be introduced for the sector in question.

Administrative viewpoint

A global SAAM would require global engagement and cooperation from both industry and policymakers. It would be administratively burdensome to monitor, report and verify the policy. The administrative effort expended will depend on the sector characteristics. The policy option may function best in a concentrated sector, dominated by multi-nationals as this would be easier to coordinate.

Prior to the introduction of a SAAM, a comprehensive understanding of how the sector operates is required. This is likely to require some sector engagement or indeed coordination, similar to that of the World Business Council on Sustainable Development's efforts with creating the Cement Sustainability Initiative (CSI). The CSI brings together 12 large cement companies worldwide to, inter alia, look into the possibility of a sectoral approach.

Geopolitical and legal viewpoint

Prior to UNFCCC COP15 meeting in Copenhagen, this idea received a lot of analytical attention[93], in particular for a potential application in the steel and cement sector. However, Copenhagen demonstrated the difficulties with getting engagement at an international level, including political support for an initiative that would raise production costs for domestic producers. The geographical scope of a SAAM could be scaled down to reflect regional markets. This may be more politically feasible than a global SAAM straight away.

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[93] For example, see Climate Strategies, Wooders, P (2009), The Role of Sectoral Approaches and Agreements and Climate Strategies, Demailly, D (2007), Preliminary analysis/proposal for a Sectoral Agreement: The case of the Chinese cement sector

Case study of a SAAMs in the steel sector – China, India and Japan

China, India and Japan represent over 50% of worldwide steel production. National policies are already being developed to mitigate emissions in the steel sector in these countries. E.g. voluntary agreements in Japan, the "Perform Achieve and Trade" scheme in India and energy efficiency standards in China. Research by Climate Strategies[94] suggests that it would be more effective to use these domestic sector initiatives as the essential building blocks of an international approach.

It is highly unlikely that these national mitigation efforts are sufficient alone to transform the sector and deliver significant greenhouse gas reductions. As the steel sector is both an emission and energy intensive industry, the level of unilateral ambition in mitigating emissions in this sector may be lowered to assail fears regarding competitive distortions arising from carbon pricing and other mitigation policies.

One of the challenges to establish SAAMs is therefore to think about how differing national sectoral initiatives in the steel and other sectors of the economy could be scaled up and harmonised to eventually create a widely inclusive sectoral approach, covering the majority of emissions of a sector. In developing countries, a key access could be via the proposed "Nationally Appropriate Mitigation Actions" (NAMAs), first suggested in the Bali Action Plan under the UNFCCC. National initiatives reflect common but differentiated responsibilities towards mitigating actions but coordinated under the UN provide a common framework for accounting mitigation actions, thus facilitating the possibility of stronger and more harmonised action in the mid- to longer term. This is particularly important for the steel sector as developing countries already account for over half of the world's steel production and they are the largest source of anticipated capacity expansion.

It is particularly important to understand the mitigation potential of a sector before developing policy and this may require extensive industry analysis along with public and private sector dialogue. For the steel sector in Japan, China, India and in regions beyond this, the following categories of abatement options and complementary policies to encourage adoption were developed by Climate Strategies.

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[94] Climate Strategies, P.Wooders (2010), Sectoral Approaches and Agreements - policy recommendations

Table 11: Categories of abatement options in the steel sector.

Abatement category	Potential complementary policies
1. The closure of inefficient, highly polluting plants	Make payments based on faster reduction than current policy.
2. Improving energy efficiency and carbon efficiency at existing, non-obsolete plants	Project-based scheme (e.g. continuation of CDM) supplemented by financial support schemes, ideally low cost capital.
3. Ensuring that new plants are built using BAT	Consider partial investment credit (e.g. low cost capital) if the new plant is built at BAT
4. Increasing the use of recycled scrap	Making payments against increased rates of collections made within the country only (to avoid leakage)
5. Adopting Carbon Capture and Storage (CCS)	Fund demonstration schemes covering different technologies and transportation subsidies
6. Developing and implementing breakthrough technologies.	Fund R&D, ideally at a wide international level

Source: Climate Strategies, P.Wooders (2009).[95]

Policy-makers have a range of options for SAAMS going forward. The two most promising options currently under general discussion are for technology agreements – the explicit inclusion or exclusion of various technologies – and intensity targets covering energy used or carbon emitted per tonne of steel produced. However, international agreements covering each of the six abatement categories individually could be easier to operationalise, for example groups of countries agreeing to support scrap collection and allow its international trade, to guarantee new plant is built to minimum standards or to contribute to a fund for CCS demonstration plants.

Also, progress on SAAMs in the steel sector needs an appropriate forum. Industry and government representatives already attend fora including the Asian Pacific Partnership[96], OECD Steel Committee, World Steel Association and WTO, but in addition to these fora, **the UNFCCC will be essential for progressing ambitious agreements.** However, this will need changes both in what is negotiated and the support provided to these negotiations.

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[95] For a fuller description of these policy options, please see the Climate Strategies study “International Sectoral Approaches and Agreements” by Peter Wooders, IISD.

[96] Climate Strategies, P.Wooders (2009) Sector Approaches in the Steel Sector.

It is recommended that the UNFCCC either builds or contracts the capacity to support steel-specific negotiations. The following steps would bring the process forward:

- **Setting up a steel-specific negotiation forum within the UNFCCC should be considered. This** forum would be informed by and draw on existing discussions within other fora, and include both government and industry representation;
- **This forum needs to be endowed with sufficient technical expertise to assess the level of commitment that individual countries are making** within their steel sectors. It is recommended that countries submit 'model agreements' defining their approaches – adding 'process' and 'governance' to the eleven criteria identified by the UNFCCC for the 2009 negotiations[2] provides a ready format for these, and the World Steel Association's CO_2 Emissions Data Protocol[3] gives an internationally-recognised boundary of the sector;
- It is not possible to conclude an ambitious set of national commitments unless **issues around competitiveness and leakage are included.** This will require resolution of the CBDR (common but differentiated responsibility) debate, at least on how it applies to the steel sector. It would also be assisted by agreeing guidelines around when BCAs could be applied and discussing the appropriate levels of free allowances which could be granted under Emission Trading Schemes;
- **The forum should investigate potential international agreements covering the six categories of abatement options** shown in Table 11. Initial suggestions are to investigate:
    - Whether companies paying into a fund for CCS demonstration and/or breakthrough technologies would be viable, in conjunction with rules precluding plant without CCS to be built or operated after certain dates;
    - minimum standards for new build plant
    - international actions to increase scrap recycling and liberalise its trade;
    - Financial support and technology transfer for the retrofit of non-obsolete existing steel plant.

None of these options preclude progressing current options on technology (as led by the Asian Pacific Partnership) and on sectoral crediting mechanisms and other intensity targets now being proposed as NAMAs

Conclusions

The EU due to its unilateral emission reduction targets is concerned about carbon leakage, the shift of co2- emissions to other world regions. This effect undermines the environmental consistency of the EU's climate policy. This effect depends on the reaction of industries to carbon pricing: those industries which have a high energy input and high direct emissions from production are prone to consider new options to reduce carbon costs. They can invest in abatement, shift the costs to consumers or could import their inputs or consider to relocate production fully.

In order to address the risk of carbon leakage from industrial relocation in Phase III of the EU ETS, the European Commission has first undertaken a quantitative assessment to determine which sectors might be most impacted by carbon prices. For some sectors an additional qualitative assessment was provided. This study recognises the value of in-depth qualitative analysis. It helps to identify the exact nature of the risk of leakage, which differs depending on sector-specific characteristics. Emissions from manufacturing are concentrated in a small number of sectors and so these sectors might require in-depth assessment given their contribution to the bulk of emissions. Based on EU ETS emissions data, cement, ceramics, coke, glass, refineries, basic iron and steel and aluminium represent around a third of EU ETS emissions and two-thirds of non-electricity emissions. Across the EU there are of course differences in the sectoral contribution to national emissions. For example, in Austria, pulp and paper emissions contribute more to total manufacturing emissions than those from aluminium.

This study offers an in-depth analysis to identify the scale and nature of the risk of leakage faced by the European steel, cement and pulp and paper industries. The study takes into account the overall trends in the industries, including international competition, technological innovation, demand and economic growth trends, and recent or overdue cost saving investments.

The **steel sector** is very susceptible to changes in economic growth. This sensitivity is compounded by the fact that the EU and other historically large producers are facing increased competition from less carbon constrained countries, which are fast growing. China in particular has expanded production capacity at an enormous rate in recent years to become the world's largest steel producer. This competition has led to cost saving measures in the industry across a number of regions. As more cost saving measures are introduced, carbon costs are likely to play an increasing role in determining long-term investment strategies and the location of production. Accordingly, the potential scale of the risk of leakage in the steel sector has been recognised in a number of economic models and by industry representatives.

In the **cement sector**, there is a higher risk of import leakage rather than the complete relocation of production in the short term. Due to the relative homogeneity of the factor inputs, installations covered by the EU ETS may choose to import clinker from extra-EU sources. Increased cement imports from extra-EU regions began prior to the EU ETS in 2004. Carbon pricing therefore has the potential to compound existing market trends in the cement industry to the detriment of both the environment and European industry. While high sunk costs prevent immediate relocation, largely regional markets allow for some flexibility to pass through the carbon cost to final consumers, yet this is bound by transport costs by road and rail.

The **pulp and paper sector** has already made good progress in recent years to shift fuel use towards renewables. It has introduced energy efficiency measures which were likely to be driven by cost saving objectives rather than environmental ones. Additional mitigation options may be more costly. Even prior to the introduction of the EU ETS, the European sector was in decline in terms of employment and production levels, exacerbated by the recent economic downturn. The European sector faces rising input costs as more regions develop their pulp and paper production, particularly in emerging economies - often for higher value paper products as the economy industrialises. Even if a complete relocation of production for EU producers is unlikely and costly (large operations with economies of scale), carbon may become a bigger component of the sector's cost schedule and may influence mid-long term investment decisions.

The EU has chosen free allocation as the principal policy option to address carbon leakage. Allowances are handed out after application of a benchmarking process for 53 products The benchmark is calculated using data for the top ten EU producers in a sector, thus taking into account the most efficient techniques, substitutes and alternative production processes. All installations that meet the benchmark will receive 100% free allowances while all others will receive less. The free allowances level down the carbon costs for producers. However, this does not per se prevent them from importing more or relocating and cashing in the allowances. In order to help prevent carbon leakage, free allocation thus should be contingent on continued operation, implemented using benchmarks and address the relevant stage in the production chain (this latter piece of information can be required through in-depth sectoral analysis).

The EU ETS Directive also references other tools for addressing leakage: the inclusion of importers, sectoral approaches, agreements and mechanisms (SAAMs) and state aid for indirect cost impacts. This study finds that these policy options will have different strengths and weaknesses when assessed against different socio-economic criteria. E.g. sectoral approaches have gained increasing attention in the international and domestic policy arena both in the context of emissions trading and as a distinct policy option to encourage regional, and perhaps global, engagement.

SAAMs have been proposed in a number of forms including technology agreements and explicit inclusion or exclusion of particular technologies and also the adoption of intensity targets for certain sectors. In order to get widespread engagement with SAAMs, both industry and governments would need to cooperate and coordinate with each other so that information about best practices are known and can be easily monitored, reported and verified.

Steel is a possible candidate for an SAAM as 50% of global production is concentrated in a few countries (requiring less coordination than if a global SAAM were to be introduced), namely China, India and Japan. A number of domestic initiatives are occurring in these countries which could provide the essential building blocks of an SAAM. These initiatives are divergent in their type and stringency but over time could be scaled up and harmonised to develop a framework for the industry as a whole. This longer term strategy is particularly important as steel capacity expansion is anticipated to be strongest in developing countries where domestic emissions policies are usually weaker. The case study identified a number of crucial issues including governance, engagement, comparability of effort, transparency, trade etc that would need to be addressed should an SAAM be introduced for a particular sector. There needs to be both top down and bottom up support for such an initiative with a distinct role for the UNFCCC or another similar international governing body.

Annex I – Literature Review Tables

A number of economic studies exist which assess the risk of leakage from carbon pricing for different regions and also for different sectors. They attempt to model the production decisions of a firm to ascertain the risk of relocation attributable to the impact of increased carbon costs. Each model uses a combination of assessment criteria and different economic modelling techniques to ascertain the sectoral impact of a carbon pricing scheme. Calculations for these studies are usually done at the NACE[97] 2 or NACE 4 level. Table 2.2 based on research by Climate Strategies[98] provides a short overview of some of the most recent modelling studies[99], which identify sectors at risk. The steel, cement and pulp and paper sectors have been highlighted when they frequently feature in the modelling results of sectors most at risk. The sectors identified as being at risk of leakage should not be viewed as exhaustive, rather they are those that modelling studies suggest are most at risk and so merit further examination of the sector-specific characteristics they possess, akin to the preceding analysis.

In order to assist policymakers with identifying the likely source of carbon leakage, modelling studies were extended to look at sector-specific impacts of carbon pricing to detect the sectors likely to be at risk. Similarly to the macroeconomic CGE models, the sectors identified as being at risk of leakage were largely dependent on the modelling assumptions and approach used. In addition the modelling results were dependent on the geographical coverage of the study and the degree of sector disaggregation. In particular, the assessment criteria and the thresholds used were found to be a crucial determinant of sectors at risk. The range of modelling approaches and the range of findings from these studies highlighted the complexities with accurately identifying a risk of leakage.

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[97] NACE is the acronym for "Nomenclature generale des Activites economiques dans les Communautes Europeennes" and is the classification system used for industry in Europe. It is linked to the UN International Standard Industrial Classification (ISIC) and so is comparable at NACE 2 level to industry classifications outside of the EU. NACE 4 is coded at the 4 digit level and is a higher level of sector disaggregation than NACE 2.

[98] Climate Strategies, Mohr et al. (2009), Trade flows and cost structure analysis for exposed industries in the EU 27. Climate Strategies Working Paper

[99] In addition to these studies, the European Commission has also undertaken a study on the impact of carbon leakage and has identified 164 sectors as being at risk of carbon leakage

Table 12: Modelling studies identifying sectors at risk.

Study	Country	Level of aggregation	CO2 price	Indicator of carbon cost impact			Ranking of sectors along carbon cost impact
				Denominator	Process emissions	Electricity	
Carbon Trust (2004)	UK	2-3 Digit SIC	€20/t CO_2	GVA	Yes	Yes	1. **Iron & Steel** 2. Aluminium 3. Chemicals 4. Food and tobacco 5. **Cement & construction** 6. **Pulp and Paper**
Morgenstern et al. (2004)	USA	4 Digit SIC	US$1/t	Total cost	No	Yes	1. Petroleum refining 2. Products of petroleum & coal 3. Lubricating oil & greases 4. Carbon black 5. Asphalt paving mixtures & blocks 6. Lime
Hourcade et al (2007)	UK	4 Digit SIC	€20/t CO_2	GVA	Yes	Yes	1. Lime **2. Cement** 3. **Basic Iron**

Study	Country	Level of aggregation	CO2 price	Indicator of carbon cost impact			Ranking of sectors along carbon cost impact
				Denominator	Process emissions	Electricity	
							& Steel 4. Refined petroleum 5. Fertilizers & Nitrogen 6. Aluminium
Houser et al. (2008)	USA	2 digit SIC	-	Final sales value	Yes	No	1. Alkalis & chlorine 2. Lime 3. **Pulp mills** 4. Primary aluminium 5. Smelters 6. Nitrogenous fertilizers 7. **Newsprint Mills**
Graichen et al. (2008)	Germany	4 digit NACE	€20/t CO_2	GVA	Yes	Yes	1. **Cement** 2. Lime 3. Fertilizers & nitrogen compounds 4. **Basic iron & steel** 5. Aluminium 6. **Paper**
de Bruyn et al. (2008)	Netherlands	2-4 digit SIC	€20/t CO_2	Total cost	Yes	Yes	1. **Cement, calcium, gypsum**

Study	Country	Level of aggregation	CO2 price	Indicator of carbon cost impact			Ranking of sectors along carbon cost impact
				Denominator	Process emissions	Electricity	
							2. Fertilizer 3. **Iron & steel** 4. Aluminium 5. Inorganic chemicals 6.Other base chemicals
Citi Group Investment Research (2008)	Australia	Company (ASX 100)	AU$20 /t CO_2	Market capitalisation	Yes	Yes	1. Energy developments (power) 2. **Cement, lime, construction materials** 3. **Steel** 4. **Paper** 5. SP AusNet (power) 6. AGL (power)
Commissions Services (2008)	EU-27	8 digit (partly aggregated) PRODCOM	€30/t CO_2	Product price	Yes	Yes	1. **Cement clinker** 2. Quick lime 3. Chlorine 4. **Grey Portland cement** 5. Ammonium

Study	Country	Level of aggregation	CO2 price	Indicator of carbon cost impact			Ranking of sectors along carbon cost impact
				Denominator	Process emissions	Electricity	
							nitrate 6. **White Portland cement**
Asuka, J et al (2009)	Japan		3000¥/t	GVA	Yes	Yes	1. **Pig iron** **2. Cement** **3. Ferro alloys** 4. Petrochemical basic products 5. Coal products 6. Industrial soda products
Sugino et al (forthcoming) (a) based on Morgenstern (2004)	Japan		¥4000/t CO_2 ≈ US$40/t CO_2	Total cost	No	Yes	1. **Pig Iron** 2. **Crude steel (converters)** 3. **Cement** 4. **Hot rolled steel** **5. Gas supply** **6. Cold-finished steel**
Sugino et al (forthcomin	Japan		¥4000/t CO_2 ≈	Value of shipments		Yes	1. Gas Supply

Study	Country	Level of aggregation	CO2 price	Indicator of carbon cost impact			Ranking of sectors along carbon cost impact
				Denominator	Process emissions	Electricity	
g) (b) based on criteria in the Waxman-Markey bill			US$40/t CO_2				2. Ocean Transport 3. **Pig Iron** 4. **Crude steel (converters)**
Sugino et al (forthcoming) (c) based on European Commission criteria	Japan		¥4000/t CO_2 ≈ US$40/t CO_2	GVA	Yes	Yes	1. Gas Supply 2. Compressed gas and liquefied gas 3. Ocean transport 4. **Pig iron** **5. Cement**

Source: Climate Strategies, Droege et al. 2009.

A number of computable general equilibrium (CGE) studies have also modelled the macroeconomic levels of carbon leakage from Annex I to non-Annex I countries. This aggregate measure suggest a range of impacts between 2% and 130%. This wide range in estimates demonstrates the sensitivities of modelling analysis to different assumptions, the assessment technique employed and even the definition of carbon leakage itself. It is however very useful when observed in conjunction with the sector-level modelling studies as it offers a quasi 'cap' on the scale of the potential impact of carbon pricing on economies. They should however be viewed with caution given the fact that they are slightly outdated and do not incorporate recent climate pledges and mitigation actions from both Annex I and non-Annex I countries into their analysis.

Annex II – Assessment criteria for determining the risk of leakage

Whilst the European Commission's 2 assessment criteria (trade intensity and additional CO_2cost in relation to GVA) capture some of the key elements that would affect production or investment leakage in a particular sector, additional insights can be offered by incorporating different assessment criteria. The list of criteria including in chapter 1 of this project aims to expand on the work done by the Commission by more realistically reflecting the microeconomic decision factors for a firm considering moving production or investment to regions without carbon pricing.

Product characteristics- When products in a sector are highly differentiated, they are less substitutable. Products may be differentiated based on quality, marketing and branding or content. This is likely to increase a consumer's willingness to pay for a good as they make their consumption decision on factors not exclusively restricted to price because the price of one product in the sector is not directly comparable to that of another. This may increase the ability of firms to pass through the cost of carbon to consumers. Individual consumer preferences may differ as they give different weights to decision criteria (i.e. costs, branding, quality) but can only be modelled in aggregate.

Emissions and energy intensity of production – both the emissions and energy intensity of production can act as a first indicator of sectors which may be of concern from an environmental and economic standpoint as energy intensive sectors are likely to have high emissions from production.

Market segmentation and industry structure – the industrial structure of a sector affects its ability pass through costs to consumers. Understanding the market segmentation and industry structure can give an indication of a sector's likely responsiveness to carbon costs. It relates to a number of market characteristics including the market size (international and/or domestic), market share between installations, the degree of agglomeration and vertical or horizontal integration. To give a simple example, a monopoly firm in a sector with few substitutes would be able to pass through carbon costs to consumers more easily than in a market which is closure to perfect competition

Transport costs – International transport costs is an important criterion for determining import leakage because it partially reflects the substitutability of production with regions outside of the carbon pricing zone. If international transport costs are low relative to carbon costs, ceteris parabis, it may be cheaper for domestic firms to increase imports from areas without carbon pricing than to produce and pay the allowance price.

Import volumes – Import volumes indicates the level and the location of international imports for a product in a particular sector. This criterion builds upon the European Commission's 'extra-EU trade intensity' criterion by allowing for a more in-depth insight in to international competitors in a particular sector. When coupled with additional metrics and information, one can model a sector's production and location decision much more realistically, particularly when the existence of multi-national firms are considered and their operating capacity in non-carbon pricing regions

Export volumes – This criterion is similar to that of 'import volumes' as it again adds another dimension of understanding to the European Commission's 'extra-EU trade intensity' criterion. The sector's main international markets can be identified, as well as their relative size. When this criterion is coupled with other metrics, additional insights can be gained about the sector characteristics which may affect their investment and production decisions. For example, export volumes coupled with domestic consumption levels, coupled with the sector's GVA would broadly indicate the size and importance for the sector in the carbon pricing region

Comparability of performance with installations abroad – this criterion has a multitude of descriptive indicators, including those which reveal differences in the regulatory and legal framework of the sectors between the EU and abroad, emissions and energy intensity, production costs and techniques and the substitutability of imports for European products (Armington elasticity). This overview will assist with understanding the competitiveness of EU and international installations.

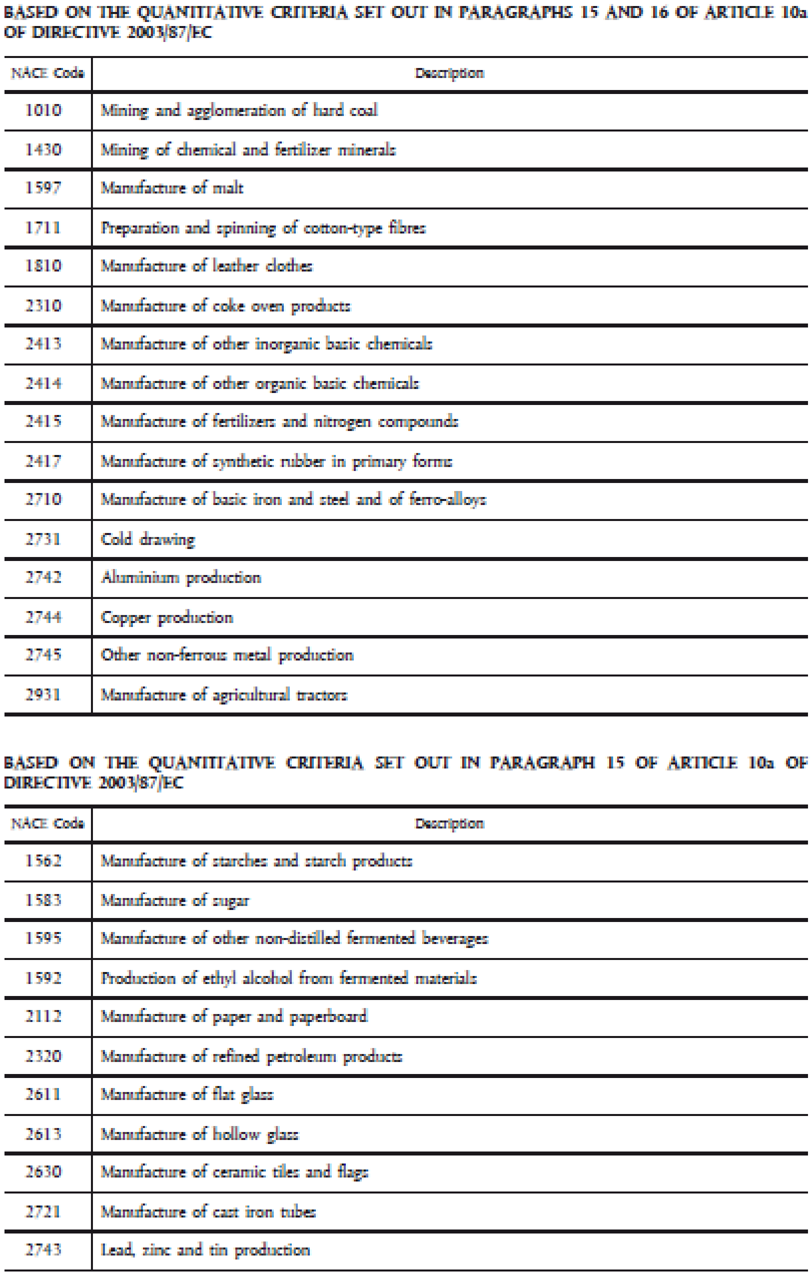
Total value at stake in UK and Germany following the introduction of a carbon price – Although these two countries alone are not representative of the impact of carbon pricing on these sectors from a EU27 viewpoint. The value at stake criterion is an important consideration. It calculates the cost increase from CO_2 emissions for each sector if relative to the sector's contribution to the region's Gross Value Added (GVA). Maximum value at stake refers to the to the % cost increase from carbon pricing relative to GVA if there are no free allowances. Net value at stake refers to the % cost increase in each sector from higher electricity pricing due to carbon pricing, relative to the sector's contribution to GVA. Differences in the GVA between these two countries would highlight the variation in impact that could be experienced across the EU27 countries.

Location of demand Growth – The location and the rate of demand growth is an important factor in production and investment decisions for installations in a sector. If demand growth is increasing outside of regions with carbon pricing, a firm looking to expand capacity may decide to increase production in a non-carbon pricing region. This decision may be compounded by the increased carbon costs that would be faced if they chose to stay in the carbon pricing region. Although this is a very stylised and simplified example, understanding demand growth for a particular sector can give context to the risk of leakage.

Changing patterns of production and trade - It is important to consider any underlying patterns of production and world trade and in a particular sector when trying to analyse the impact of carbon pricing on a particular region as this helps disaggregate existing market trends from any additional impact carbon pricing may have on a firm's investment and production decisions.

Value at stake - This is criterion calculates the cost increase from CO_2 emissions for each sector if relative to the sector's contribution to the region's Gross Value Added (GVA). Maximum value at stake refers to the to the % cost increase from carbon pricing relative to GVA if there are no free allowances. Net value at stake refers to the % cost increase in each sector from higher electricity pricing due to carbon pricing, relative to the sector's contribution to GVA.

Annex III – Sectors identified as being at risk of leakage by the European Commission



BASED ON THE QUANTITATIVE CRITERIA SET OUT IN PARAGRAPHS 15 AND 16 OF ARTICLE 10a OF DIRECTIVE 2003/87/EC

NACE Code	Description
1010	Mining and agglomeration of hard coal
1430	Mining of chemical and fertilizer minerals
1597	Manufacture of malt
1711	Preparation and spinning of cotton-type fibres
1810	Manufacture of leather clothes
2310	Manufacture of coke oven products
2413	Manufacture of other inorganic basic chemicals
2414	Manufacture of other organic basic chemicals
2415	Manufacture of fertilizers and nitrogen compounds
2417	Manufacture of synthetic rubber in primary forms
2710	Manufacture of basic iron and steel and of ferro-alloys
2731	Cold drawing
2742	Aluminium production
2744	Copper production
2745	Other non-ferrous metal production
2931	Manufacture of agricultural tractors

BASED ON THE QUANTITATIVE CRITERIA SET OUT IN PARAGRAPH 15 OF ARTICLE 10a OF DIRECTIVE 2003/87/EC

NACE Code	Description
1562	Manufacture of starches and starch products
1583	Manufacture of sugar
1595	Manufacture of other non-distilled fermented beverages
1592	Production of ethyl alcohol from fermented materials
2112	Manufacture of paper and paperboard
2320	Manufacture of refined petroleum products
2611	Manufacture of flat glass
2613	Manufacture of hollow glass
2630	Manufacture of ceramic tiles and flags
2721	Manufacture of cast iron tubes
2743	Lead, zinc and tin production

BASED ON THE QUANTITATIVE CRITERIA SET OUT IN POINT (a) OF ARTICLE 10a(16) OF DIRECTIVE 2003/87/EC

NACE Code	Description
2651	Manufacture of cement
2652	Manufacture of lime

BASED ON THE QUANTITATIVE CRITERIA SET OUT IN POINT (b) OF ARTICLE 10a(16) OF DIRECTIVE 2003/87/EC

NACE Code	Description
1110	Extraction of crude petroleum and natural gas
1310	Mining of iron ores
1320	Mining of non-ferrous metal ores, except uranium and thorium ores
1411	Quarrying of ornamental and building stone
1422	Mining of clays and kaolin
1450	Other mining and quarrying n.e.c.
1520	Processing and preserving of fish and fish products
1541	Manufacture of crude oils and fats
1591	Manufacture of distilled potable alcoholic beverages
1593	Manufacture of wines
1712	Preparation and spinning of woollen-type fibres
1713	Preparation and spinning of worsted-type fibres
1714	Preparation and spinning of flax-type fibres
1715	Throwing and preparation of silk, including from noils, and throwing and texturing of synthetic or artificial filament yarns
1716	Manufacture of sewing threads
1717	Preparation and spinning of other textile fibres
1721	Cotton-type weaving
1722	Woollen-type weaving
1723	Worsted-type weaving
1724	Silk-type weaving
1725	Other textile weaving
1740	Manufacture of made-up textile articles, except apparel
1751	Manufacture of carpets and rugs
1752	Manufacture of cordage, rope, twine and netting
1753	Manufacture of non-wovens and articles made from non-wovens, except apparel
1754	Manufacture of other textiles n.e.c.
1760	Manufacture of knitted and crocheted fabrics
1771	Manufacture of knitted and crocheted hosiery
1772	Manufacture of knitted and crocheted pullovers, cardigans and similar articles
1821	Manufacture of workwear
1822	Manufacture of other outerwear
1823	Manufacture of underwear
1824	Manufacture of other wearing apparel and accessories n.e.c.

NACE Code	Description
1830	Dressing and dyeing of fur; manufacture of articles of fur
1910	Tanning and dressing of leather
1920	Manufacture of luggage, handbags and the like, saddlery and harness
1930	Manufacture of footwear
2010	Sawmilling and planing of wood; impregnation of wood
2052	Manufacture of articles of cork, straw and plaiting materials
2111	Manufacture of pulp
2124	Manufacture of wallpaper
2215	Other publishing
2330	Processing of nuclear fuel
2412	Manufacture of dyes and pigments
2420	Manufacture of pesticides and other agro-chemical products
2441	Manufacture of basic pharmaceutical products
2442	Manufacture of pharmaceutical preparations
2452	Manufacture of perfumes and toilet preparations
2463	Manufacture of essential oils
2464	Manufacture of photographic chemical material
2465	Manufacture of prepared unrecorded media
2466	Manufacture of other chemical products n.e.c.
2470	Manufacture of man-made fibres
2511	Manufacture of rubber tyres and tubes
2615	Manufacture and processing of other glass, including technical glassware
2621	Manufacture of ceramic household and ornamental articles
2622	Manufacture of ceramic sanitary fixtures
2623	Manufacture of ceramic insulators and insulating fittings
2624	Manufacture of other technical ceramic products
2625	Manufacture of other ceramic products
2626	Manufacture of refractory ceramic products
2681	Production of abrasive products
2722	Manufacture of steel tubes
2741	Precious metals production
2861	Manufacture of cutlery
2862	Manufacture of tools
2874	Manufacture of fasteners, screw machine products, chain and springs
2875	Manufacture of other fabricated metal products n.e.c.
2911	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
2912	Manufacture of pumps and compressors
2913	Manufacture of taps and valves
2914	Manufacture of bearings, gears, gearing and driving elements
2921	Manufacture of furnaces and furnace burners
2923	Manufacture of non-domestic cooling and ventilation equipment
2924	Manufacture of other general purpose machinery n.e.c.

NACE Code	Description
2932	Manufacture of other agricultural and forestry machinery
2941	Manufacture of portable hand held power tools
2942	Manufacture of other metalworking machine tools
2943	Manufacture of other machine tools n.e.c.
2951	Manufacture of machinery for metallurgy
2952	Manufacture of machinery for mining, quarrying and construction
2953	Manufacture of machinery for food, beverage and tobacco processing
2954	Manufacture of machinery for textile, apparel and leather production
2955	Manufacture of machinery for paper and paperboard production
2956	Manufacture of other special purpose machinery n.e.c.
2960	Manufacture of weapons and ammunition
2971	Manufacture of electric domestic appliances
3001	Manufacture of office machinery
3002	Manufacture of computers and other information processing equipment
3110	Manufacture of electric motors, generators and transformers
3120	Manufacture of electricity distribution and control apparatus
3130	Manufacture of insulated wire and cable
3140	Manufacture of accumulators, primary cells and primary batteries
3150	Manufacture of lighting equipment and electric lamps
3162	Manufacture of other electrical equipment n.e.c.
3210	Manufacture of electronic valves and tubes and other electronic components
3220	Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy
3230	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus and associated goods
3310	Manufacture of medical and surgical equipment and orthopaedic appliances
3320	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
3340	Manufacture of optical instruments and photographic equipment
3350	Manufacture of watches and clocks
3511	Building and repairing of ships
3512	Building and repairing of pleasure and sporting boats
3530	Manufacture of aircraft and spacecraft
3541	Manufacture of motorcycles
3542	Manufacture of bicycles
3543	Manufacture of invalid carriages
3550	Manufacture of other transport equipment n.e.c.
3621	Striking of coins
3622	Manufacture of jewellery and related articles n.e.c.
3630	Manufacture of musical instruments
3640	Manufacture of sports goods
3650	Manufacture of games and toys

NACE Code	Description
3661	Manufacture of imitation jewellery
3662	Manufacture of brooms and brushes
3663	Other manufacturing n.e.c.

BEYOND NACE-4 LEVEL BASED ON THE QUANTITATIVE CRITERIA SET OUT IN PARAGRAPHS 15 AND 16 OF ARTICLE 10a OF DIRECTIVE 2003/87/EC

Prodcom Code	Description
15331427	Concentrated tomato puree and paste
155120	Milk and cream in solid forms
155153	Casein
155154	Lactose and lactose syrup
15891333	Dry bakers' yeast
24111150	Hydrogen (including the production of hydrogen in combination with syngas).
24111160	Nitrogen
24111170	Oxygen
243021	Prepared pigments, opacifiers and colours, vitrifiable enamels and glazes, engobes, liquid lustres and the like; glass frit
24621030	Gelatin and its derivatives; isinglass (excluding casein glues and bone glues)
261411	Slivers, rovings, yarn and chopped strands, of glass fibre
26821400	Artificial graphite, colloidal, semi-colloidal graphite and preparations
26821620	Exfoliated vermiculite, expanded clays, foamed slag and similar expanded mineral materials and mixtures thereof

AT NACE-4 LEVEL BASED ON THE QUALITATIVE CRITERIA SET OUT IN PARAGRAPH 17 OF ARTICLE 10a OF DIRECTIVE 2003/87/EC

NACE Code	Description
1730	Finishing of textiles
2020	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards
2416	Manufacture of plastics in primary forms
2751	Casting of iron
2753	Casting of light metals

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