Carbon pricing and its future role for energy-intensive industries

Key features of steel, cement, aluminium, basic chemicals, pulp & paper

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Executive Summary

Energy-intensive industries (EIIs) will continue to play a very important role in low-carbon development across OECD and Non-OECD countries. However, EIIs are particularly exposed to impacts of emissions pricing policies, and the constraints arising from national climate policies thus are a double-edged sword. On the one hand, steel, cement, aluminium, basic chemicals and pulp and paper represent the classic sectors of industrialisation and rising living standards. Their rise in emerging economies is once more demonstrating this traditional role. Products from these sectors are also an integral part of a low-carbon restructuring of the economy, be it in new energy technologies, in new buildings and insulation projects, or as light materials. On the other hand, these industries often represent some of the largest sources of energy consumptions and greenhouse gas emissions and are similarly integral in meeting emissions reduction targets.

Industries often contest the introduction of national emissions pricing due to fierce competition in international markets. Moreover, uncertainties about future demand, costs, technological breakthroughs, and risks related to political frameworks determine firms' investment decisions and other strategic parameters. However, without a carbon price to internalise environmental impacts there will be little incentive to reduce carbon-intensity along the value chain. Giving direction to structural change while avoiding economic decline, and maintaining diversity within and across industries in an economy, is a major challenge for policymakers.

This report gives an overview of five sectors, which are energy-intensive and subject to carbon pricing in the EU and in other countries. The questions addressed are:

- What are the characteristics of cement, steel, aluminium, basic chemicals and pulp & paper industries? What are the cost impacts from carbon pricing, the cost structures and cost-pass-through ability?

- What drives investment in these sectors?

- Which factors needs to be considered if policymakers want to induce investment in more carbon-efficient production under carbon pricing?

Key messages

1. In the short term, a carbon price affects the strategic environment of the EIIs investigated, but this can be addressed through targeted cost compensation by governments. Moreover, EIIs could compensate for the remaining direct carbon cost through a mix of passing costs through, particularly for speciality products, importing cheaper inputs, using profits to stabilise final product prices, deploying available technologies to reduce emissions, or by cutting other costs.

2. The growth of Asian markets has induced a shift in demand and related location of supply which will continue over the next decades and will affect all five EII investigated. For some, e.g. basic chemicals, there is a cost advantage of locating in regions with cheap sources of hydrocarbons. New discoveries and exploitation of large deposits, including shale gas, will continue to exert cost pressures on the existing plants in Europe and in other countries without access to cheap gas.

3. The CO_2 cost does not represent the most important issue for the EII's investment decisions. Prices of energy and raw materials and their availability (e.g. cheap gas as an energy source and feedstock into the chemicals industry), favourable investment environment (e.g. tax breaks) are much stronger incentives. Nevertheless, the future markets for low-carbon products are also important factors. Being close to the demand for speciality products may counteract the trend of moving out of traditional markets. Subsidies relating to "green" investment could further incentivise maintaining production in markets with a CO_2 price.

4. Support for innovation and breakthrough technologies for reducing energy-intensity are key determinants for EIIs exploring future investment opportunities in Europe and other OECD countries. The 2020 time horizon for the EU's climate policies and targets does not provide sufficient reliability for these industries to invest in low carbon innovation at scale. The 2013 Green Paper on a climate and energy strategy by the European Commission[1] recognises this and proposes 2030 targets. If the targets are addressing the whole range of energy production, use and emissions, and are combined with R&D

[1] European Commission (2013)

incentives, this could provide some regulatory certainty for EII's long-term low-carbon investment decisions.

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How to read this report
The purpose of this report is to give an overview on what drives investment decisions of energy-intensive industries, and how this relates to carbon pricing now and in the future. The research for this report was finalized in 2011. The project "International industrial competitiveness, carbon leakage and approaches to carbon pricing" included research on the industries' future challenges under carbon pricing and shifts in global demand and production costs. It incorporates feedbacks from discussions amongst researchers and industry representatives. For this synthesis report we have added updates on the 2012 and 2013 policy trends in the EU and, where appropriate, for the sectors.

List of Abbreviations

BAT	Best available technology
BF	Blast furnace
BOF	Blast oxygen furnace
CCS	Carbon capture and storage
CEFIC	European Chemicals Industry Council
CEPI	Confederation of European Paper Industries
CEMBUREAU	The European Cement Association
CIS	Commonwealth of Independent States
CO_2	Carbon dioxide
CHP	Combined Heat and Power
DRI	Direct reduced iron
EAF	Electric arc furnace
EII	Energy intensive industries
EPA	Environmental Protection Agency
ETS	Emissions trading scheme
EU	European Union
GHG	Greenhouse Gases
GVA	Gross value added
IEA	International Energy Agency
Mt	Megatonne
NACE	Statistical Classification of Economic Activities in the European Union (Nomenclature statistique des activites economiques dans la Communauté europėene).
TGR	Top gas recycling.
ULCOS	Ultra Low CO_2 steel
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development

1. Introduction

Energy-intensive industries (EIIs) will continue to play a very important role in low-carbon development across OECD and Non-OECD countries. However, EIIs are particularly exposed to impacts of emissions pricing policies, and the constraints arising from national climate policies thus are a double-edged sword. On the one hand, steel, cement, aluminium, basic chemicals and pulp and paper represent the classic sectors of industrialisation and rising living standards. Their rise in emerging economies is once more demonstrating this traditional role. Products from these sectors are also an integral part of a low-carbon restructuring of the economy, be it in new energy technologies, in new buildings and insulation projects, or as light materials. On the other hand, these industries often represent some of the largest sources of energy consumptions and greenhouse gas emissions and are similarly integral in meeting emissions reduction targets.

Industries often contest the introduction of emissions pricing due to fierce competition in international markets where there is no equivalent pricing policy. Moreover, uncertainties about future demand, costs, technological breakthroughs, and risks related to political frameworks determine firms' investment decisions and other strategic parameters. However, without a carbon price to internalise environmental impacts there will be little incentive to reduce carbon-intensity along the value chain. Giving direction to structural change while avoiding economic decline, and maintaining diversity within and across industries in an economy, is a major challenge for policymakers.

Since 2008, these conflicts of interests have become obvious in the carbon leakage debates in the EU. Unilateral carbon pricing, as undertaken by the EU since 2005, has brought strong resistance from EIIs to the fore.[23] This resistance has intensified with each phase of the EU ETS. Similar disputes were observed in the US, Australia and Japan, when the design of ETSs were on the political agenda and such conflicts could reasonably be expected in South Korea and even China if the plans for and implementation of their national carbon pricing policies will progress.

The international future of carbon pricing will be characterized by fragmentation and differences in design will reflect national priorities. For energy-intensive industries this poses a challenge for the mid- to long-term[4] given the increasing integration of markets and pending investment decisions in Europe. Due to their high share in carbon emissions worldwide, these sectors are most affected by any policy measure, which seeks to regulate or price the emissions from industrial sources. Given the slow progress of international climate policy negotiations, industries have to consider the different carbon costs across major trading regions as part of their overall cost portfolio and to which they can adjust by changing both operation and investment strategies.

Carbon prices are only one part of production costs, others including labour, raw material and energy and taxes. Therefore, the discussion of the impacts of carbon pricing on the competitiveness of sectors and on the potential for carbon leakage (a relocation of production or investment driven by carbon price differentials), stemming from industries' reactions to such a cost impact, needs to include other drivers of investment, such as global demand, production trends, location competition etc.

This report provides a more in-depth analysis to inform policymakers seeking the creation a favourable business environment that facilitates restructuring towards low-carbon production and technologies in their countries, while at the same time maintaining a price for carbon. The EIIs will continue to play a very important role for low-carbon development across OECD and Non-OECD countries. Anticipating specific challenges and global trends will help to further the necessary political stimulus for sustainable investment decisions.

We summarise the state of research undertaken in the Climate Strategies project on carbon leakage and international competitiveness, looking into the industries' ability to pass through their carbon costs and the extent to which carbon pricing might affect future investment decisions. The report mostly represents

[2] According to Fish (1995) for steel the economic cycle starts with cheap labour and continues with (1) manufacturing units built (industrialization), (2) steel imports increase, (3) infrastructure development commences, (4) steel imports further increase, (5) factories are built, (6) economic growth takes off
[3] For an overview of the positions taken in the debate see e.g. EurActiv <http://www.euractiv.com/climate-change/eu-emissions-trading-scheme/article-133629>
[4] The long-term for the EII is defined for a period of up to 40 years in the future.

insights for the EU, but also refers to international trends in five sectors sectors. For each sector in this paper (Steel, Cement, Aluminium, Chemicals, Pulp & Paper) the focus is on criteria which determine the future production and location decisions: carbon cost impacts, cost pass-through ability, abatement options, and the regulatory environment. The factors that determine an industry's reaction to carbon pricing will be weighted very differently according to a sector's characteristics and this report will also shed light on the relative importance of specific factors sector-by-sector.

In examining these issues, this report first explores the criteria which determine the market characteristics and operating conditions of EIIs under different carbon pricing policies. Following this, a detailed review of five case study EIIs (steel, cement, aluminium, chemicals and pulp & paper) is presented. The role of the regulatory and policy environment is then considered for all the sectors, and the insights arising from this project are summarised.

2. Driving factors behind the adjustment to CO-pricing

The analysis of the impacts from CO_2 pricing on a sector's national and international competitiveness and its subsequent adjustment to the challenges includes several categories. Various factors drive the relocation of emissions through the substitution of domestic production by imported inputs or final products, or through the full relocation of a production site, known as carbon leakage. We have identified four categories of factors:

(1) the impact of carbon pricing on cost structures;
(2) the ability of a sector to pass through carbon costs to its customers;
(3) the sector's potential to apply abatement technologies;
(4) the regulatory and policy environment

Categories 1-3 will be investigated sector-by-sector, while we look at the fourth category as a cross-cutting issue for all EIIs in section 4.

2.1 The impact of CO_2 pricing on a sector's cost structure

The impact of carbon costs on an EII producer will depend on the amount of CO_2 emitted during the production process; in absolute and relative terms. This will lead to both **direct carbon costs** associated with of complying with the rules of the carbon pricing policy (e.g. purchasing of emission certificates or paying the taxes charged). Depending on the electricity input, **indirect carbon costs** may also be incurred from carbon emitted upstream. Downstream firms need to pay the carbon cost from upstream processes, in particular from electricity generation, as far as the costs are passed on to them. A relative cost indicator is the **value at stake,** which determines the cost increase from CO_2 pricing, both direct and indirect, for each sector relative to the sector's contribution to the region's Gross Value Added (GVA). In addition, there are **unrecoverable, or sunk, costs,** e.g. incurred investment costs. A sector with high sunk costs, e.g. due to a minimum capacity or infrastructure requirements based on production technology, is likely to make very cautious investment choices with a long time horizon as it has relatively limited mobility in the short run.

2.2 Cost pass-through ability of a sector

Cost pass-through options depend on a range of factors concerning both the supply and the demand side. We have listed the following as some of the most important factors:

- **Level of competition and product price adjustment:** The competitive position of an industry confronted with carbon costs determines its flexibility to change the product price accordingly, and thus to pass on the carbon costs to consumers. If full cost pass-through is not an option, profit margins will change. If there is a positive margin, it can be used to limit the price increase to safeguard a producer's competitive position.
- **Price elasticity of demand:** The actual change in sales after a price increase depends on the overall demand elasticity. Elasticity describes consumers' responsiveness to a change in the product price and depends on various market characteristics. The size of the market (international and/or domestic) and the producer's market share indicates the potential scale of a loss in demand, in combination with the market share.
- **Differentiation of products and related services**: The competitive position of a producer also depends on the way in which the products and related services are differentiated to serve customers. This differentiation may be based on quality, but also on marketing and branding when it comes to final consumption. High levels of product differentiation makes them less substitutable and is likely to increase a consumer's willingness to pay, and thus lowers the demand elasticity.
- **The demand trends**: The absolute growth in demand and changes in demand characteristics make price increases under fixed capacities more likely and cost pass-through easier, as long as no new capacity is installed. Accordingly, an increasing price and anticipated demand growth determines investment decisions both in national and foreign locations, and thus drives the location of emission activities, too.

- **Flexibility in substituting material, products, and services**: The degree of agglomeration, vertical or horizontal integration of an industry determines how flexible producers and customers are when looking for substitution to inputs that face carbon costs. This flexibility is determined by the position of a sector in the value chain, the market power of large-scale raw material buyers and sellers, and long term contracting, and the abatement options (see section 2.3).
- **Trade flows and transport cost**: international trade dynamics also determine the carbon leakage and competitiveness effects from carbon pricing. Observations on changing patterns of world trade helps to distinguish between the impacts of carbon pricing from existing international market trends. Many factors can be considered to understand the trade impact including import and export volumes, the level and location of international imports and exports for a product in a particular sector. In this context, the relationship between the carbon cost and the transport cost for a sector's products can drive the development of trade flows. As long as transport costs are relatively high, e.g. in relation to weight or to value, carbon costs can be passed through without leading to intensified international competition.

2.3 Abatement potential of a sector

Abating GHG emissions is the alternative option for EIIs to paying a price for carbon. Firms in EIIs engage in abatement efforts as long as this is less expensive than paying for emissions and that appropriate **technologies and substitutes** are readily available. Increasing the efficiency of the production process or substituting all inputs may not be possible for EIIs in the short-term, but in the mid-to-long-term new production technologies, fuels, or techniques might be introduced. The range of such investments for energy intensive sectors includes investment in lowering direct emissions from production processes and indirect emissions stemming from energy use. The major driver of lowering indirect emissions for EIIs is the energy price and availability.

Whether or not investment in new technologies takes place will not only be driven by carbon pricing, but depends inter alia on the market penetration rate for new technologies, on the established capital infrastructure of the sector, historical evidence of technological improvement, the maturity of the new technology (and costs) and the nature of a new technology (incremental or step-change). Also, the relative profitability of technical change needs to be looked at, i.e. the increased revenue from the technology, net of the increased costs of introducing it.

2.4 Regulatory and policy environment

Investment decisions both in new capacities and abatement technology take place against a backdrop of uncertainties, including a sector's future business model, its market position and cost expectations, impacts from regulation, and risks inherent to new technologies themselves. Producers are therefore experienced in making production and investment decisions under conditions of uncertainty. When evaluating the abatement potential and the risk of carbon leakage from relocation of investment (known as "investment leakage") producers must rely on today's knowledge about availabilities and risks, and the anticipated interactions between political support and future business opportunities.

The regulatory framework concerning climate and energy policy in carbon-constrained and non-carbon-constrained regions is an important determinant for investment, as are long-term expectations, contracts and the particular cost and pricing environment. EU climate policy remains the most serious international attempt to mitigate climate change across multiple countries simultaneously. For the EU ETS, the legislation is due to continue until 2020, and the ETS Directive includes a declining emissions cap beyond that year. Moreover, a 2013 consultation by the European Commission on the post-2020 framework[5] discusses aspects of the EU ETS in the context of its design post 2030 (e.g. in terms of the treatment of EITIs and the use of auction revenues to facilitate the transition to a low carbon future). However, the currently legislated 2020 time horizon does not compensate for the weak investment signals the ETS has been delivering since the CO_2-price declined sharply since 2011. Moreover, the 2020 time horizon does not suffice for EIIs with a 20 and 40 year cycles for large-scale capital investment. For the power sector and EIIs in Europe, the situation

[5] European Commission (2013)

is characterised by a carbon price, moderated by benchmarked free allowances[6] for EIIs. Carbon pricing will be part of their operating costs for the next eight years at least. However, uncertainty about short term interventions to the design of the EU ETS (e.g. structural reform or the review of the list of sectors at risk of leakage) by the European Commission combined with uncertain policy plans beyond 2020 could represent a significant risk for those EIIs who are at the brink of renewing their capital stock within the EU. Against the backdrop of an ongoing financial crisis, investments in industry fell by 2.5% of GDP between 2008-2011[7]. Production is 10% lower in manufacturing, business confidence is low and there are on-going difficulties with accessing finance.

[6] The free allocation of allowances to sectors at risk of carbon leakage depends on the performance in the sector or subsector. Only the top 10% (building the benchmark) of a sector will receive 100% of the allowances for free.
[7] European Commission (2012)

3. Analyses for key sectors

3.1 Steel

The steel sector is consistently identified as one of the most likely sectors to be at risk of carbon leakage[8] due to cost impacts from unilateral carbon pricing, limited large-scale abatement options and international markets.

Steel is the largest contributor of emissions under the EU ETS from the manufacturing sector. It accounted for around 5% of global emissions in 2007. This rises to 10% if upstream extraction, transport of raw materials and downstream transportation of the final product are included when defining the sector's boundary[9]. Production capacity is growing worldwide, particularly in emerging economies which use steel as a key input for infrastructure in rapid phases of industrialisation, and in industrialised countries investing in new energy sources. Thus, this sector is of high importance in addressing the climate change challenge from two perspectives: as a source of emissions and as an input to low-carbon installations (e.g. wind turbines)[10].

Sector characteristics

There are three principle routes of steel production: the combination of Blast Furnace (BF) and Blast Oxygen Furnace (BOF), the Electric Arc Furnace (EAF) with scrap and the EAF with Direct Reduced Iron (DRI). They differ inter alia in the inputs used emit different levels of CO_2 per tonne of output. The least emissions intensive production process is the use of EAF with scrap, but this is constrained by the physical availability of scrap. Table 1 offers an overview of emissions ranges (including indirect emissions from electric arc furnaces) from different production practices. According to Wooders et al. (2009) steel from an integrated mill (BOF) will typically result in emissions of 1.5-2.5 tCO_2/t steel. Using scrap steel and the EAF-only route, emissions are around 0.4 tCO_2/t steel. DRI emissions are lower if natural gas is used in power generation (a approximately 1.1 tCO_2/t steel) and higher if they use coal (approximately 2.5 tCO_2/t steel).

Table 1: Emissions from different production techniques in the steel industry
Source: Wooders et al. (2009)

Production technique	(Range of) Emissions
Integrated BF/BOF mill	1.5-2.5 tCO_2/t steel
EAF using scrap[11]	0.4 tCO_2/t steel
EAF using DRI[12]	1.1- 2.5 tCO_2/t steel

Products within the steel sector are relatively homogenous and either flat, e.g. slabs and hot rolled coil, or long, e.g. wire rod and reinforcing bar[13]. Long products are generally of lower quality and are mainly used for construction purposes; flat products are of higher quality and can be tailored to reflect consumer specificities. They tend to have a higher value per tonne of output and are therefore more profitable to transport and are more widely traded.

Demand for steel originates from a number of downstream sectors including construction and car manufacturing. These sectors play an important role in developing infrastructure during the industrialization of a country and in recent years the steel sector has correspondingly seen the highest demand growth from

[8] Carbon Trust (2004), Hourcade et al (2007), Houser (2008), Graichen et al. (2008) and de Bruyn et al. (2008). The CASE II model (Monjon and Quirion 2009) finds under the condition of full auctioning in Phase III of the EU ETS a leakage rate for the European steel sector of 39% of the total emissions reduced in 2016.
[9] Wooders et al. (2009)
[10] Wooders (2011) presentation to the OECD
[11] Emissions are dependent on the electricity source.
[12] Emissions are dependent on the electricity source.
[13] Wooders et al. (2009)

emerging economies. Production capacity has already increased in these countries, most notably in China. There are very few substitutes for steel on a large scale but small-scale alternatives include e.g. cement or wood. These materials could be used instead of steel as building reinforcement, but are also likely to face carbon costs if they are produced in the same region.

Steel production is concentrated in a few countries. China, Russia, South Korea, Japan and the USA account for around 70% of global steel production[14]. China is the largest source of expansion in production capacity and the Indian steel industry is expected to expand in forthcoming years. This rising capacity will likely have a significant impact on future emissions levels from the sector and on the intensity of competition. Wooders et al. (2009) suggest that even if new facilities were built to best available technology (BAT) levels, based on current technical expertise, emissions from the steel sector in 2030 would still be around 60% higher than in 2005. Another large shift in location is anticipated in the Middle East, CIS, and Latin America as they have lower overall costs in processing steel and also access to raw material (both energy and iron ore). The discovery of shale gas in the US may also revive their steel industry. There are plans to build five new DRI plants, which use gas instead of coal to purify iron used in steel production[15].

Around 40% of global steel production is traded. The largest exporters are Russia, CIS, Europe and Asia and the largest importers are Africa, the Middle East, Europe and North America. This dynamic may change over time though, as production capacity increases, particularly in the Gulf and parts of Asia where there are discussions around the construction of plants with a production capacity of 6Mt per annum; double the historical levels of output from BOF[16] mills.

The steel sector has high upfront capital costs. Plants operate for approximately 40 years and strongly benefit from economies of scale, particularly BOF plants which can be built as integrated steel mills; a plant with all functions for primary steel making. These plants cost around €1.5bn to build on greenfield sites. EAF plants are typically smaller and therefore have smaller sunk costs[17]. The steel industry is highly cyclical, with rapidly rising and falling demand in response to broader economic growth and activity. This, combined with the high capital costs associated with steel infrastructure investment, results in considerable volatility in profits against a relatively fixed asset cost base. In addition to physical factors such as proximity to end consumers, proximity, cost of inputs and level of transport infrastructure, regulation (both current and anticipated) relating to energy and emissions play an important role in the production location decision of a plant.

3.1.1 Cost impacts from carbon pricing

Carbon pricing has the potential to be a significant contributor to the steel sector's cost schedule. The exact carbon cost impact on steel is largely dependent on the type of product, the production process used, the plant efficiency and the amount of scrap used. A few analyses have been undertaken to estimate the carbon cost impact. Wooders et al. (2009) estimated that for a carbon cost of €30/tCO_2, long products showed a 30% price increase whereas flat products showed a cost increase of 15%. An analysis by McKinsey[18] estimated combined direct and indirect carbon costs in flat steel, i.e. higher quality steel, from a €20/tCO_2 price for the BOF route to be an additional 17.3% on top of existing costs, and 2.9% for steel from EAF.

The EC[19] identified steel as being at risk of carbon leakage in Phase III of the EU ETS because both trade intensity (32.3%) and total carbon costs as a percentage of sector GVA (10.6%) exceed the thresholds stipulated in the EU ETS legislation (10% and 5% respectively). The increase in direct costs is calculated at 6.5% compared to 3.6% in indirect costs (see European Commission 2009b). In Australia, both the manufacture of carbon steel (non stainless steel) and integrated iron and steel manufacturing are identified as highly emissions intensive trade exposed activities eligible for a high (94.5%) but declining rate of free allowances. This is in addition to a $300m steel transformation plan to assist them with the transition to a

[14] World Steel Association (see www.worldsteel.org)
[15] Bloomberg (2012b)
[16] Wooders et al. (2009)
[17] Wooders et al. (2009)
[18] MEPS Steel Review, McKinsey Metals & Mining Practice; McKinsey analysis
[19] European Commission (2009b)

low carbon future. Similarly, the US Environment Protection Agency (EPA)[20] identified the steel sector as presumptively eligible for remedial assistance as an energy-intensive, trade exposed sector under the American Power Act. A study by Linares and Santamaria (2012) highlights the different effects of a carbon price on BOF and EAF technologies in Spain, where EAF production dominates. While BOF production stops being competitive at a carbon price of €12/tCO_2, EAF technology is domestically used up to €20/tCO_2. Both, the low emission factor for the Spanish electricity sector, and the high share of EAF facilities in Spain significantly reduces the risk of carbon leakage due to import competition.

3.1.2 Determinants of cost pass-through ability

Although there are some speciality steels which allow for price differentials, steel is a commodity with a single global price for each product. Prices are extremely responsive to the economic climate and downstream pro-cyclical changes in demand, whereas costs remain constant. Profit margins therefore fluctuate greatly, as was seen in the economic downturn where steel prices almost halved. Even recently, when there is relatively more economic stability, steel prices fluctuated by around US$200/t between April 2010 and April 2011[21] and by around €100/t by the end of 2012. These factors indicate that a cost pass-through is difficult if products compete at the international level. Such competition is more often found for long products, while higher quality steel products are subject to long-standing integration of suppliers with end-users which will likely makes pass-through easier. The car industry is often cited as an example of a consumer of speciality steel. In general, steel demand is not very price elastic, meaning that a change in prices of steel products does not trigger a decline or increase in demand which is equivalent to the range of the price change.

Alongside energy and raw materials, transport costs are a significant cost component in the steel sector. Sea-borne transport costs have been rising recently in response to rising demand for commodities in emerging economies but are changeable on a yearly basis, as are the price of raw materials. The Baltic Dry Index, an indicator of seaborne transportation costs for bulk materials, experiences short-term fluctuations but has fallen by an average 26% in the past year (May 2012-May 2013)[22]. Traditionally, the access to cheap and high quality raw material (iron ore, coal) defined national comparative advantages for steel locations, but as trade costs decline and trade volumes expand, new competitors can enter the market. Japan is an example of this. Although there are no domestic raw materials, Japan ranks amongst the top steel producers, not least due to its state-of-the-art steel plants. However, access to raw materials remains important as a determinant of plant location.

3.1.3 Abatement options

Given the long lifetime of a plant, investment in abatement needs a long-term carbon price signal, as it needs to pay off over periods up to the lifetime of a steel plant. Despite fierce opposition against carbon cost and tougher mitigation targets, the European steel industry collectively works on responses to this challenge (e.g. the ULCOS initiative for ultra low carbon dioxide steelmaking, a consortium of 48 EU steelmakers). Wooders et al. (2009) point out that there are few abatement opportunities available in the short-medium term, which are able to significantly reduce CO_2 emissions in the steel sector due to existing high levels of energy efficiency during production. Nevertheless, there are potential abatement options over mid- to long-term to minimize carbon costs: closing inefficient high polluting plants, improving energy and carbon efficiency at existing plants, ensuring plants are built using BATs and increasing the use of scrap. Amongst the technical improvements are top gas recycling (TGR), a method to recycle gases with high CO_2 share and to reduce coke input by improving the reduction processes, or use of "biocoke" (i.e. coke from biomass such as wood).[23]. There is the need for additional breakthrough technologies, including CCS, which would require high investment and most likely supporting innovation policies from governments in the very near term. The IEA[24] suggests that large-scale deployment of CCS technology for new builds and retrofitting in the steel sector by 2030 would require innovation and demonstration to occur between now and 2020.

[20] EPA (2009)
[21] Steel on the net (see http://www.steelonthenet.com/prices.html)
[22] Bloomberg (2013) (see http://www.bloomberg.com/quote/BDIY:IND/chart)
[23] See The Committee of Climate Change (2010)
[24] IEA (2010)

3.2 Cement

The cement sector is identified as having a high carbon cost exposure in all carbon cost impact studies.[25] Cement production is highly emissions intensive per tonne of output, particularly with respect to direct CO_2 emissions from processing. These currently account for approximately 25% of industrial CO_2 emissions and 6% of total global emissions[26]. The creation of clinker is the most emission intensive part of the cement production process, accounting for around 60% of direct emissions[27]. Emissions arise during the chemical reactions which occur in the clinker production process, around 35% stem from fuel combusted in the kiln during the processing of limestone and 5% are indirect emissions from electricity use. Developing countries have the largest, and growing, share of cement sector emissions. China alone contributes to half of the world's cement emissions, reflecting the importance of cement in developing infrastructure during rapid economic growth.

Sector characteristics

There are two types of cement plants, integrated plants producing both clinker and cement, and cement mills which produce cement, using clinker from other plants. The most common type is Portland cement[28] used as a standardised ingredient for concrete or mortar. Only 6-7% of total world clinker and cement production is traded globally. Markets are segmented at the national level and internationally and cement prices differ across regions in one particular country as well as between different countries.

Cement production is highly cyclical. Demand is closely linked to economic growth and activity within the construction industry - which depends upon public finances, infrastructure expenditure, residential and commercial building activity and interest rates. Following decreasing activity in the construction sector since 2009, cement production volumes have declined in most developed economies, in particular within Europe. World cement production in 2011 was estimated at around 3.6 billion tonnes, indicating a steady recovery from the economic downturn when output was closer to 2.8bn tonnes. This increase in output is largely driven by demand in China and other developing Asian countries. China reached a record 58% of global production in 2011, an annual increase of 17.9%, while in the US and Japan, cement production fell to 1.9% and 1.2% of the global total respectively. Cement production in the EU27 represented around 7.6% of the total global production, and still has not recovered to pre-recession levels.[29]

Demand for cement largely originates from the construction industry and is very pro-cyclical. China and other developing Asian countries accounted for two thirds of all demand in 2009[30]. It is proposed that cement demand can peak once a country reaches a certain level of economic development, as such the IEA forecasts a flat projected demand for OECD countries[31]. Globally, demand is forecasted to rise to around 3,100 Mt per annum in 2015 and 4,100 Mt in 2050[32], reflecting rapid economic development in an increasing number of non-OECD countries.

For European cement firms, the start of the economic crisis occurred in the middle of an investment phase. The industry has responded with debt reduction and cost-cutting plans. There have also been a number of plant closures, particularly in Europe and North America and some company credit ratings within the

[25] E.g. Carbon Trust (2004), Hourcade et al. (2007), Houser (2008), Graichen et al. (2008) and de Bruyn et al. (2008) Monjon and Quirion (2009) show that under the most stringent condition of full auctioning in Phase III of the EU ETS, the European cement sector could face a leakage-to-reduction-ratio in 2016 only by relocation of cement production, 16% due to relocation of clinker production alone.
[26] Gielen (2008)
[27] Boston Consulting Group (2010)
[28] Portland cement is a standardized cement. The standardized proportion of gypsum to clinker is approximately 5%.
[29] CEMBUREAU, Cement Industry – Key facts & figures (See http://www.cembureau.be/about-cement/key-facts-figures)
[30] CEMBUREAU, Cement Industry – Main Characteristics (see http://www.cembureau.eu/about-cement/cement-industry-main-characteristics)
[31] IEA (2008)
[32] Gielen (2008)

industry have been downgraded, resulting in a higher cost of borrowing. High priority is being given to securing liquidity, refinancing and extending terms of existing debt.[33]

Transport poses a significant barrier to international trade because cement and clinker are heavy commodities with respect to their value per tonne of product. For example, shipping costs for reported cement trades between EU and North Africa for 2007 were around $44/tonne; between China and the US, $54/tonne and between China and Europe, $59/tonne[34]. These costs fall within the same range as some European cement prices, and help to explain the relatively low volume of international trade within the sector, compared to other EII trade. These high transport costs act as barriers to entry and markets.[35] The increasingly long trade routes for cement can be explained by a number of factors, including overcapacities due to regional decline in demand, by relatively low input costs, in combination with high demand and prices in some of the importing countries (e.g. Spain until 2008)[36]. Although international trade is rising, its share is still much lower than in other EIIs relative to overall production levels. In Europe, the largest importers of non-EU cement and clinker are the coastal regions, in particular Spain and Italy. The average low levels of international transport were reflected in the European Commission's carbon leakage assessment for Phase III of the EU ETS, which estimated extra-EU trade intensity to be around 6.8%[37].

3.2.1 Cost impacts from carbon pricing

When calculating the value at stake at a €30/tCO_2 price, the European Commission (2009b) identified the cement sector to be third highest out of all sectors being at risk of leakage in Phase III of the EU ETS. The calculated cost increase as a percentage of GVA is 45.5%, while the increase in direct costs amounts to 41.1% and indirect costs is 4.4% (see European Commission 2009b)[38]. This is broadly in accordance with an estimate by the IEA[39] in 2005 for a carbon price of €20/tCO_2 leading to a cost increase expected to be around 25% of the product price[40]. Linares et al. (2012) estimate for Spain, that a cost increase due to a carbon price of more than €18/tCO_2 already leads to a full substitution of domestic coastal clinker production by imports. Only when carbon prices are low, domestic production can keep its competitiveness.

In general, sunk costs in the cement sector differ across technologies and regions. According to CEMBUREAU, the European Cement Industry Association, for Europe they are in the order of €150m per million tonnes of annual capacity. The cost of a new cement plant is equivalent to around three years of turnover[41], which indicates high capital intensity. Sunk costs will however differ across regions. Cook (2011a) suggests construction costs for a new 'greenfield' dry process integrated cement plant typically range between around US$150-200/t cement capacity in developing and emerging economies, and between $250-300/t cement in OECD regions[42]. Aside from differences in construction costs, the differences in costs are due to quality, which will impact on the likely lifespan of the plant and the level of maintenance required. Upgrades of plants are relatively cheaper then newly built ones but still costly in absolute terms. The long and lumpy investment schedule in the cement sectors means that investment decisions are very forward-looking and policy uncertainty is particularly undesirable.

3.2.2 Determinants of cost pass-through

The cement industry is split into two types of plants with different abilities to pass through CO_2 costs. Those competing with overseas producers, using shipping as transport mode, are prone to carbon leakage as soon

[33] Cook (2011a)
[34] Cook (2011a)
[35] Cook (2009) and Cook (2011a)
[36] Linares (2012)
[37] European Commission (2009b)
[38] European Commission (2009b)
[39] Reinaud (2004)
[40] With €20/tCO_2 the incremental allowance cost would be €17.4 per tonne of cement. In 2005, the price of Portland cement in Europe was approximately €70.4/tonne.
[41] CEMBUREAU, Cement Industry – Main Characteristics (see http://www.cembureau.be/about-cement/cement-industry-main-characteristics)
[42] Assuming a plant size of around 1.5 million tonnes per annum (Mta)

as they pass through a CO_2 cost as this makes imports more competitive. The sale of clinker and cements from installations with overcapacities has shown in the past how access to coastal infrastructures determines competition. For producers situated close to shipping hubs, the CO_2 cost can make the crucial difference for the profitability of cheaper imports. Those operating in local, mostly landlocked, markets will not be confronted with such competition and a cost pass-through of the CO_2 price does not lead to import competition. The specific situation for this sector with respect to its location is reflected in the different cement prices across regions. In 2006, the average price of cement in Germany was $71/tonne, in Canada it was $66/tonne whilst Chinese cement was sold in the order of $32/tonne[43]. The industry is fairly concentrated too, reflecting the high sunk costs associated with building new plants. The largest five multi-national cement companies (Holcim, Lafarge, Cemex, HeidelbergCement and Italcementi) account for around 30% of the global market (CemNet, 2008)[44]. The cement industry is therefore usually characterised as being a network of regional oligopolies[45].

There are a number of studies that have isolated the impact of carbon prices on the industry and identified the cost pass-through rate. The Carbon Trust (2010)[46] suggests that the pass-through rate with free allocation of allowances is between 33- 90% of opportunity costs, dependent on market structures and location. Sijm et al. (2008)[47] estimate cost pass-through rates for cement in the area of 33-50%. Others have estimated higher rates: for example Demailly and Quirion (2006)[48] assume a pass-through rate of 75% and Oxera (2004)[49] 83%. These pass-through rates suggest a genuine risk of windfall profits in the industry under free allocation but do not offer any insights into differences between coastal and non-coastal regions. Given the regional price differences amongst land-locked cement plants, the pass-through in such markets can be assumed as being much easier due to the transport cost prevalent for long-distance cement transport costs. Moreover, cement has no obvious large-scale substitutes in building, industrial and infrastructure applications (see below). As such, cement has a relatively low price elasticity of demand.[50]

3.2.3 Abatement options

The cement industry has introduced a number of initiatives to reduce the emissions intensity of production since 1990. The World Business Council for Sustainable Development (WBCSD) has noted that the emission intensity of cement production has fallen by around 14% between 1990 and 2009[51]. However, further significant emissions reductions in the sector are constraint by current available technologies and processes related to clinker.

There are three technologies to produce clinker: wet, semi-dry and dry, depending on the moisture of the raw materials, mainly limestone and clay and the drier the input, the more efficient the processing.[52] New cement types such as 'geopolymers',which have lower process emissions are still in the early phases of development.

Thus the short-term options to reduce emissions relate to the processing of clinker, using clinker as an input and to the use of energy. Chemical additives can reduce CO_2 emissions in processing clinker, while the clinker content can be reduced, e.g. by using slug ash. However, there are physical limitations on the amount of such substitution. The limitations can be the regional availability of substitutes, increasing prices of substitution materials, the properties of substitution materials, intended application of cement, national standards for cement, and not least, common practice and acceptance of the composite cements by construction contractors and customers[53].

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43 Selim and Salem (2010)
44 CemNet (2008) and Cook (2011a)
45 Ghemawat and Thomas (2008)
46 Carbon Trust (2010)
47 Sijm, J.P.M. et al. (2008)
48 Demailly and Quirion (2006)
49 Oxera Consulting (2004)
50 La Cour and Mollgaard (2002) suggest a demand-price elasticity coefficient of -0.27; Demailly and Quirion (2006) assume an elasticity of -0.2. See also Cook (2011a).
51 World Business Council for Sustainable Development, Cement Sustainability Initiative (2008)
52 In Europe 75% of total production is based on dry technology. See Linares and Santamaria (2011)
53 World Business Council for Sustainable Development, Cement Sustainability Initiative & IEA (2009)

The industry can continue to make marginal improvements in the emissions-intensity of production. This is especially important from a climate policy perspective given the forecasted increase in production capacity between now and 2050. Globally, installations differ in terms of the production technology used (e.g. dry kiln technologies for clinker production uses 40% less energy than wet ones), the fuel used (e.g. alternative fuels such as tires have lower emissions than traditional fuels) and the blending rates of cement. 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[54], suggesting some energy efficiency gains and associated abatement potential exists if all plants are using BATs, and also indicating different ranges of marginal abatement cost. Cook (2011a) notes that these options are likely to translate into cost-savings too, suggesting that variations in energy performance between different cement production technologies are a key factor driving production costs and competitiveness in the industry.

CCS is also being explored as a breakthrough technology for reducing emissions in the cement sector but will be a costly option. According to the IEA, and depending on technology, CCS would need a CO_2 price signal of between US$ 31 and 90/tCO_2.[55] The IEA[56] 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, the IEA sees the application of CCS as essential for reducing cement sector emissions below current levels by 2050. In order to achieve this there would need to be a rapid roll out of demonstration projects starting in 2015 to allow for commercial viability by 2030 and large scale roll out (to around 40% of plants) by 2050.

3.3 Aluminium

The aluminium sector belongs to the sectors at a high risk of carbon leakage[57], particularly when taking into account the indirect cost impact of carbon pricing. Indirect emissions from electricity production can have a share of up to 75% of overall emissions in the sector. The aluminium sector accounts for around 1 % of global GHG emissions according to the Carbon Trust (2011) and regional differences in emissions levels per tonne of output are principally due to the carbon intensity of fuel sources in the region where the production takes place[58]. Emissions per tonne of output range between 1tCO_2/t for recyclate, to 3tCO_2/t for BAT smelters using hydro-powered electricity, and up to 20tCO_2/t for less modern technology powered by coal-based electricity[59].

Sector characteristics

The production of aluminium can take two different routes, a primary and a secondary one.[60] The former relies on the production of alumina out of the raw material bauxite and its subsequent reduction to primary aluminium via smelting. The latter is based on the use of recycled aluminium scrap. In particular the primary route is very energy intensive by using large amounts of fuels in the alumina production (Bayer process) and of electricity for smelting (Hall-Heroult process).[61] Due to a lower melting temperature necessary, the secondary route requires less energy input and leads to fewer CO_2 emissions than the primary route. Recycling of aluminium is rising, in particular in China (but from a low level); however, it depends on the stage in the business cycle, demand and availability. Around 77% of total aluminium production is traded globally.[62]

[54] IEA (2007)
[55] IEA (2006)
[56] IEA (2010)
[57] E.g. Carbon Trust (2004), Hourcade et al (2007), Houser (2008), Graichen et al. (2008) and de Bruyn et al. (2008)
[58] Sinden et al. (2011); Carbon Trust (2011)
[59] Carbon Trust (2011) and Sinden (2011)
[60] Healy and Schumacher (2011a)
[61] Healy and Schumacher (2011a)
[62] Reinaud (2008)

Aluminium products are relatively homogenous. Both semi-finished products (e.g. bars, profiles, wires, sheets, foils, tubes, pipes) and speciality products (e.g. powders, special alloys) can be made from recycled and virgin aluminium and will be indistinguishable in terms of their quality. Demand for aluminium comes from a number of downstream sectors including transportation, packaging, machinery and construction. Aluminium consumption is forecasted to quadruple between now and 2050, principally in emerging economies; China's consumption grew at an average 10% per annum between 1980 and 2007. Demand for aluminium may increase in more developed countries between now and 2050 as an input into 'green growth' projects[63].

Energy costs will clearly determine future investment decisions in the sector. In Europe and in Australia, the sector is included in the ETS from 2013 (EU) and from 2012 (Australia) onwards and also will have to carry indirect carbon costs from ETS auctioning in the power sector (EU). While in the first EU ETS phase (2005-2008) the sector was still partly shielded from the impact by longer term energy supply contracts, new power supply contracts and a steep rise in primary energy prices between 2005 and 2008 have reduced the competitiveness of the EU aluminium industry in global markets. Market shares have increased for those with cheap electricity access, in particular from hydro-power (Brazil, Norway, Iceland), but also in locations with cheap gas (e.g. Qatar, USA)[64], provided this is reflected in power contracts for smelters. Long-term electricity contracts thus are a tool to secure the competitive position of aluminium producers, given the global price determinants. The sunk costs in the aluminium industry depend on the degree of vertical integration of production. The higher the integration with extraction of bauxite, alumina production and smelting, the higher the investment needs.[65] The IEA[66] notes that transport costs are a very small component in the overall cost schedule. Thus new markets could be also be served from existing plants worldwide as aluminium products in general are highly traded commodities.

Nevertheless, the demand trend in combination with the availability of cheap energy will determine the location of new production capacity. Aluminium production is concentrated in a few regions at less than 300 sites globally[67]. China and Russia account for around 50% of global production and both provide power from carbon-intensive sources or from nuclear plants. Production capacity in primary aluminium production is growing most quickly in China (its share in global production rose from 24% in 2005 to 35% in 2009)[68] and The Middle East (increase by 40% 2005 to 2009, equivalent to a share of 3% in 2009); likely due to their proximity to downstream demand and comparative advantage in production. According to the Carbon Trust (2010)[69] costs of production are already around 40% lower in the Middle East than in Europe. In this instance, carbon cost differentials between the two regions widen the gap in production costs further and passing through CO_2 costs will become impossible for EU producers. Recycling rates in China have increased by 60% between 2005 and 2009, but mainly using imported scrap. The absolute level of recycled aluminium in China, however, is still low compared to other regions, given that China is using a lot of aluminium for infrastructure development and that this has only recently being incorporated in capital formation.

3.3.1 Cost impacts from carbon pricing

The European Commission's assessment[70] of the CO2 cost impact identified aluminium as being at risk of carbon leakage in Phase III of the EU ETS because both trade intensity (35.9%) and total carbon costs as a percentage of sector GVA (14.0%) exceed the thresholds (10% and 5% respectively). The increase in direct costs was estimated to be 1.7%, whereas indirect costs may increase by 10.3% (see European Commission 2009b) reflecting the majority of the carbon cost exposure comes from electricity consumption. Data for the US industry show similar results: the trade intensity of aluminium refining is 70% and of primary aluminium production it is 64%, while the energy intensity is 21% and 20% respectively. In Australia, aluminium

[63] Carbon Trust (2010)
[64] Sartor (2011)
[65] Ranges discussed in 2011 for a project in Malaysia were US$4 bn for a yearly capacity of 750,000t aluminium in The National 2011, Abu Dhabi in $4bn aluminium plant deal (see http://www.thenational.ae/featured-content/home/middle-headline-teaser/abu-dhabi-in-4bn-aluminium-plant-deal)
[66] Reinaud (2008)
[67] Carbon Trust (2011)
[68] According to USGS (2011)
[69] Carbon Trust (2010)
[70] European Commission (2009b)

smelting and production of aluminium rolls are both identified as being highly emissions intensive and eligible for a high proportion of their emissions to be covered by free allocation.

3.3.2 Determinants of cost pass-through ability

The cost pass-through of aluminium producers is very limited. The global price of aluminium is determined on the London Metals Exchange and the Shanghai Futures Exchange and can be characterized as being very volatile in recent years[71]. Producers are essentially price takers and so the profitability of operations is highly dependent on production costs and the global prices. This in particular limits the pass-through ability of the sector. Moreover, most aluminium products do not compete based on their quality and the lack of differentiation hinders pass-through of additional costs.

The high share of energy costs for aluminium production is a crucial factor for investment decisions and determines the competitive position of producers. Those regions with cheaper sources of energy have a natural comparative advantage against competitors who face higher costs. With rising oil prices and an increasing number of countries introducing carbon pricing policies (EU, Australia, South Korea or China), locations with low carbon energy such as hydroelectricity may be more favourable from both an environmental and economic standpoint. Electricity prices will likely continue to be the main determinant of investment location decisions for the industry. This puts the production in Europe in particular at a disadvantage and explains they high sensitivity of the sector towards a CO_2 cost.

3.3.3 Abatement potential

The abatement potential in the aluminium industry depends on the energy use and recycling rates. Using recycled scrap is one way of reducing emissions in the aluminium production process. Secondary smelting of aluminium only requires roughly 5% of the energy of primary smelting due to the relatively low melting temperature of 700-800 °C[72]. Recycling rates are very high in the USA and Europe and growing in China. The International Aluminium Institute estimates global recycling rates to be at approximately 60% but in some countries like Brazil, Norway and Japan this is closer to 90%. The Carbon Trust (2011) estimates that if all countries increased their recycling rates to this level, the sector could cut its global emissions by around 5%[73].

There is also a range of measures to further reduce the direct and indirect emissions from producing aluminium. Primarily, the type of electricity for melting and primary aluminium production is the key factor for lowering emissions associated with production. This differs considerably from region to region, e.g. China with the highest share of coal-based electricity and Latin American producers using mainly hydropower and natural gas. The processing of primary aluminium, following the extraction of bauxite, applies the so-called Bayer process. The Bayer process is very energy intensive consuming on average 13% and 85% of total electricity and fuel use for the production of primary aluminium respectively (Worrell et al., 2007). Different anodes could be applied in this process to lower direct emissions during primary smelting[74] and CCS technologies applied to power generation would significantly reduce indirect emissions associated with production.

3.4 Basic Chemicals

The chemical industry produces a diverse range of products and there is a high integration of processing within and across the industry. In 2005, the chemicals sector contributed approximately 5% of global GHG emissions[75].

Sector characteristics

The chemicals sector can be categorised into five groups or subsectors based on their chemical composition: (i) petrochemicals, (ii) basic inorganics, (iii) polymers, (iv) specialities and (v) consumer chemicals. The first

[71] Reinaud (2008)
[72] Worrell et al. (2007)
[73] Carbon Trust (2011)
[74] Schumacher and Healy (2012)
[75] Based on data from the ICCA (2009) and WRI's Climate Analysis Indicators Tool (see http://cait.wri.org)

three subsectors (i)-(iii) constitute the group of basic chemicals, which together had a share of around 57% of total chemicals sales in the EU in 2005[76]. Although there are differences in the production techniques and associated emissions between products, the chemicals subsectors share a number of similar market characteristics, such as quality competition for speciality products for the categories (iv) and (v). There are multiple steps in the production process and a number of different chemical compounds can be produced in high volumes. For example, a chemical compound produced in one sub-sector may provide the feedstock for further processing in another chemical subsector. An important link across sectors exist with refining from which feedstock is provided for chemical plants.

Due to the high integration between chemical subsectors and a specific minimum size requirement, chemical plants are capital intensive and large in size. While incumbent plants in Europe have an average size of 450,000 tons/year, new basic petrochemical plants (crackers) built in India, China and the Middle East have a typical capacity of over one million tonnes a year.[77] The trend in overall global chemical sales shows a strong shift towards Asia, in particular China (up from 5.8% to 22.2%), between 1990 and 2009[78] at the expense of sales in the EU (32.1% to 24%) and the US (28% to 21.2%). In recent years the US has seen a resurgence in its chemicals industry due to the availability of cheap shale gas both as a feedstock and power source for the industry. The American Chemical Association anticipates that the use of shale gas could lead to a 5% expansion in chemicals production by 2015[79].The German chemicals producer BASF has indicated concerns over the relative competitiveness of their European plants due to the opportunities presented by low US gas prices and plan to expand the capacity in two of their US operations[80].

Petrochemicals, basic inorganics and polymers are produced in large integrated plants whilst more specialities and consumer chemical require more complex production techniques and (e.g. dyes and pigments, paints and inks) are usually produced in small and medium enterprises[81]. The former grouping represents commodities and compete globally. The latter currently enjoys relatively more product and service differentiation. This is reinforced by higher expenditure on research and development, particularly in emerging fields like biotechnology and nanotechnology[82]. Established markets such as those in Europe are still facing increasing competition as workers in emerging economies become better educated, building capacity for more technical and specialised chemical production.

The production location of the chemicals industry has been changing rather dramatically during the last decade. Historically, the high degree of technical specialism required in production has led to the concentration of the chemicals industry in high-income areas of the world such as West Europe. However, in recent years, both China and the Middle East have seen a rapid expansion in chemicals production capacity fuelled by domestic policies and demand[83]. China has a government directive to become self-sufficient in chemicals production and the Middle East enjoys favourable regulatory conditions as well as an abundance of gas which is a feedstock into the production of a number of chemicals, thus given them a competitive advantage over their European counterparts. This is mirrored in a change of trade patterns and the commodity markets. According to a sector study by KPMG (2010), the Middle East has emerged as a major competitor for the European chemical industry, while a decade ago North America was the main global exporter of basic chemicals, used as raw materials, such as polypropylene or polyolefins, and supply and demand was balanced in Europe. Although the Middle East continues to be a large producer, the accessibility of shale gas has led to resurgence in chemicals production in the US which may mean reverting back to previous trade dynamics.

Transport costs in the chemicals sector vary depending on the product. Hazardous materials require specially designed transportation which raises the costs significantly and may limit the distance over which the chemical is transported[84]. Therefore, some chemicals plants are located very close to downstream end-

[76]European Commission (2007)
[77] European Commission (2007)
[78] ICCA (2010)
[79] Royal Society of Chemistry (2013)
[80] Washington Post (2013); Bloomberg (2012a)
[81] European Commission (2009a)
[82] European Commission (2007)
[83] KPMG (2010)
[84] European Commission (2009a)

users, leading to agglomeration of industry. Just under half of global production in the chemicals sector is traded and trade is growing faster than production levels[85]. In multi-nationals, there is intra-firm trading of chemicals to allow for access to more markets globally. Operating in a global market will encourage firms to consider global cost differentials when deciding on the location of production issues. In addition to subsidized feedstocks, plants in the Middle East enjoy lower transport costs to emerging markets in Asia than for their European counterparts due to proximity.

3.4.1 Cost impacts from carbon pricing

In the EU assessment of industries prone to carbon leakage, the impacts from a CO_2 price on the chemical industry were calculated for each subsector separately. Different regions categorise the sector and subsectors in different ways but a number of subsectors are often defined as being energy intensive and trade exposed[86]. The European Commission[87] identified six basic chemical subsectors to be at risk of carbon leakage in Phase III of the EU ETS. The US assessment lists ten subsectors, partly overlapping with the EU NACE codes (these are listed in Table A1). Australia identified five chemical subsectors as being at high risks but these were at a higher level of sectoral disaggregation. All six subsectors listed by the EU have in common a relatively high trade intensity, which ranges between 25 and 50%. The increase in direct costs is particularly high for fertilizers and nitrogen compounds, synthetic rubber and other inorganic basic chemicals. The latter also face a relatively high increase in indirect costs and hence in total costs. Due to indirect process emissions, the increase in total costs of carbon pricing for fertilizers and nitrogen compounds was estimated at around 70.2%, which is the largest value for all analysed subsectors.

3.4.2 Determinants of cost pass-through ability

In the chemicals industries, diversity in the market characteristics of basic chemicals and speciality products reflects different degrees of cost-pass-through ability, as the type of product, its uses and the demand elasticities related to a price increase determine the competitive pressure.

The high degree of technical specialisation required to generate certain chemicals gives the producers some control over the prices and potentially allows for a significant cost pass-through. In Europe, the European Chemical Industry Council (CEFIC)[88] assert that the ratio of gross operating profits to sales in the chemicals sector is ranked second highest out of all European manufacturing sectors and is also ranked second in terms of "value added per employee", 84% higher than the combined average of all manufacturing sectors. Although profit margins will of course depend on the relative costs of other production inputs, there is a significant return on labour as a factor of production. There are chemicals with specific characteristics and uses which are therefore hardly substitutable with any other manufacturing sector's products.

However, there are also some applications of chemicals, for which alternatives exist. In some instances, chemicals are substitutable within the industry, in particular, basic chemicals which act as a feedstock into more complex chemical processes, such as developing chlorine via electrolysis which is used as an input for 55% of all chemical processing in the European chemicals industry[89]. Feedstocks, e.g. gas, are substitutable between firms across regions, but more complex chemical compounds may require specific technical expertise and production processes that are not so readily substitutable within the industry. This reduces the flexibility of the sector to compensate CO_2 costs through substitution and related cost savings. In general, the lower the degree of substitutability the more likely that costs can be passed through.

3.4.3 Abatement options

The production of basic chemicals depends on energy and this also determines the CO_2 emissions performance. The chemicals industry uses energy products both as a source of energy and as an input into their products. Historically, the industry has had a high reliance on fossil fuel hydrocarbons, however in

[85] European Commission (2009a)
[86] For example Carbon Trust (2004), Hourcade et al. (2007) Houser et al. (2008), Graichen et al. (2008), de Bruyn et al. (2008)
[87] European Commission (2009b)
[88] CEFIC (see http://www.cefic.org/Facts-and-Figures/Profile-of-the-Chemical-Industry/Added-value-in-EU-chemicals-and-other-manufacturing-sectors/)
[89] Eurochlor (2002)

some regions like Europe, a number of producers have begun to expand their feedstock base to include the use of alternatives such as bio-based renewable raw materials[90]. This is to limit their (carbon) cost exposure, but also to follow customer demand for higher environmental standards from chemical producers. In Europe, around 8% of feedstock sources are derived from biomass sources, and this will likely increase in forthcoming years but will be somewhat dependent on the level of rival demand for these inputs from other sectors, e.g. the use of biomass to produce energy and heat, and their associated prices[91]. Policies such as the EU Biofuels Directive creates demand over the short-to-medium term, which is unlikely to be met domestically. Therefore, the chemicals sector will be in competition for bio-based feed-stock that will increasingly be sourced internationally, potentially raising costs. For fertilisers, abatement options include improving process efficiency, using CHP or making nitrogen fertiliser from gas rather than coal. CCS may also be well suited to ammonia production due to the high concentrations of waste gas produced during the manufacturing process. Moreover, altered fertiliser application rates could reduce NOx emissions from fields, and thus reduce demand for fertiliser.

Understanding the real mitigation potential in the chemicals sector will require further analysis into the specific products and processes in the sector.

3.5 Pulp and paper[92]

The pulp and paper industry is the fourth largest industrial emitter worldwide. Based on 2005/2006 data, the pulp and paper industry contributed around 202 $MtCO_2$[93], representing approximately 1% of global emissions. In this report pulp and paper are addressed as a single sector, based on their linkage in the production chain – pulp is an input to the manufacture of paper and paperboard products.

Sector characteristics

At the NACE 4 level the pulp and paper industry includes pulp, paper and paperboard, and wallpaper (see Table A1). Nevertheless, both sectors have diverse and differentiated product structures and production routes. Within Europe, the IEA[94] estimated that the sector emitted around 34$MtCO_2$, in 2010. The number of companies and plants in Europe has been decreasing over the last 20 years, with a decline of around 25% over the last decade.[95]

The production of pulp and subsequently of paper is multi-faceted and the exact processes used are dependent on the quality of the final output needed. Pulp can be produced via three main routes: mechanical pulping, chemical pulping (Kraft or Sulfite process) and by using recovered paper.[96] While chemical pulping results in higher quality fibres, it is more energy intensive than mechanical pulping; recovered paper is by far the least energy intensive process.[97] The quality spread is reflected in product prices. Prior to the economic downturn in 2009 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[98].

Similarly, input costs differ, depending on the quality of the output. However, the production process is fundamentally energy-intensive and so carbon pricing, alongside rising fossil fuel prices is of increasing concern for the industry from a competitiveness standpoint. The sector has already begun to respond to these rising energy costs and to CO_2 costs by shifting towards the use of biomass as a fuel source (around

[90] European Commission (2009a)
[91] European Commission (2007)
[92] This section refers mainly to finding on the EU pulp and paper industry.
[93] Miner (2010)
[94] IEA (2010) According to CITL data for 2010: 37Mt CO_2
[95] CEPI (2011)
[96] Healy and Schumacher (2012b)
[97] Healy and Schumacher (2012b)
[98] Bergmann et al. (2007)

50% of the inputs of the European pulp and paper industry relies on biomass) and reducing the energy consumed per tonne of output in recent years. UBS investment research (2008)[99] noted that globally many companies have reported a reduction in the purchased energy per unit of output of 20% or more between the years 1997-2007.

Sunk costs in the pulp and paper sector are high and the period from planning a new site until its operation ends is around 40 years. As pulp and paper plants are nearing the end of their operating life in some OECD countries, there may be an opportunity to improve the emissions efficiency of production over the next few years. In the EU the average age of pulp and paper production facilities is only 15 years, although some mills are close to the end of their lifetime.

Geographically, pulp and paper producers are concentrated in a small number of regions. Over half of the world's paper production originates from the USA, Canada, China and Japan and this looks to rise further as China continues to increase its production capacity. Pulp is similarly concentrated, in 2008, North America and Europe accounted for 72% of total worldwide pulp production[100]. The trade performance of the EU in pulp and paper reveals that exports consist of high value products such as coated paper, but also low value products such as recovered paper. The destination of most low value products is China (recovered paper and paperboard), or India. For higher value products it is rather Russia and the US (coated paper and others). In parallel the EU imports mostly from the US, Russia (low value newsprint paper), or China, with an overall net balance of EU exports in the sector.[101] The demand for pulp and paper products is strongly correlated to a country's income. As per capita income rises, it is expected that demand will increase for printing and writing paper. Thus for emerging economies it is likely that demand for higher quality paper products will increase the coming years, balanced by increasing demand for electronic media, which reduce demand for newsprint.

3.5.1 Cost impacts from carbon pricing

The sector is often classified as being at risk of carbon leakage in modelling studies. In the EU, three pulp and paper subsectors were identified as being at risk of carbon leakage as they exceeded the necessary thresholds for an increase in total costs and trade intensity[102]. These subsectors are: the manufacture of pulp, the manufacture of paper and paperboard, and the manufacture of wallpaper (see Table A1). All three subsectors are characterised by a relatively high trade intensity (above 25%), the impact of carbon pricing on total costs only exceeds the 5% threshold in the paper and paperboard subsector (10.2%). In Australia, newsprint, tissue, packaging and higher quality printing and writing paper and dry pulp manufacturing are al identified as being highly emissions intensive, trade exposed industries. The US data show a slightly different picture, as the subcategories differ. Pulp and newsprint paper is highly traded (90% and 68%) and the range of energy intensity for all subsectors is between 8 and 16%.

3.5.2 Determinants of cost pass-through ability

China's increasing pulp and paper production capacity has led to increased demand for physical inputs which in turn led to higher costs. This is symptomatic of all cost components in the industry. As previously discussed, transport costs, energy costs and input costs have all increased in recent years which has likely led to falling profit margins and a response from industry to increase production efficiency. In some regions, such as Europe, this has led to a contraction in production and employment in the pulp and paper sector. Thus, the ability to pass through additional carbon costs to the final consumer has declined and will most likely not improve given international competition. There are no obvious substitutes for pulp and paper for end users but to save costs (and thus compensate for the CO_2 costs incurred) there is some opportunity to substitute products and processes within the sector e.g. in terms of quality, wood type, and whether or not the material is from recycled sources. These factors will impact on production costs and therefore product prices.

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[99] UBS Investment Research (2008)
[100] Gielen and Tam (2006)
[101] Healy and Schumacher (2011b)
[102] European Commission (2009b)

Transport costs are also a significant cost component in the pulp and paper industry interacting with carbon prices. The exact transport choice is dependent on the quality of the transport infrastructure in the pulp and paper producing region. In Europe, the Confederation of European Paper Industries (CEPI)[103] argues that the current rail network is too fragmented and unreliable to be effectively deployed on a large scale by pulp and paper producers and opts for road transport for the majority of their freight, and this is becoming increasingly costly with higher fuel prices. Similarly, with rising demand for commodities, shipping costs are increasing. CEPI estimates[104] external logistics to already average at around 10% of turnover for the pulp and paper industry.

3.5.3 Abatement options

In some regions there are opportunities for the pulp and paper industry to still increase recycling rates, energy efficiency and shift to alternative fuel sources in order to reduce emissions. One option is to increase the use of recycled inputs which are less emission intensive than virgin inputs. However, fibres can only be recycled 4-7 times before their quality diminishes significantly and virgin fibres are needed as an input. The average recycling rate worldwide is 45%[105] but is higher in some regions such as the EU, the recycling rate rose from 40% in 1991 to around 70% in 2010[106]. Although recycling rates are constrained by the physical availability of recycled materials, the IEA[107] estimates an additional global recycling potential of 35%, with most of the opportunities located in North America and parts of Asia. CEPI[108] estimates that each tonne of recycled pulp used offers a net energy saving potential of up to 10.9Gj/t. However, the impact on an installation's emissions is dependent on the emission intensity of production (determined by fuel source and production process used).

As a reaction to increasing energy prices in recent years, the pulp and paper sector globally has shifted towards more energy efficient practices e.g. chemical pulping uses a third of the energy required in mechanical pulping. However, this shift is not uniform across producer regions. The IEA[109] estimates that Germany is operating close to levels representing BATs, identifying only a 2% improvement potential for energy use, whilst in the UK this was estimated to be at around 28%. There has also been a significant shift towards using more renewable sources. In Europe the industry uses black liquor and other forms of biomass to meet around 55% of their energy requirements using CHP technology. The IPCC[110] estimates that in developed countries, biomass already represents 49% of fuel used in the pulp and paper industry. This may be a practice adopted by more regions as a way of mitigating cost increases and carbon price exposure, but again will be constrained by the physical availability and prices of these alternatives to fossil fuels.

Breakthrough technologies would be another option to abate emissions, particularly for the drying component of the paper production process which accounts for around 70% of total fuel consumed in paper production. According to CE Delft[111] a few technologies, such as airless drying and super heated steam drying, are in the nascent phases of development and have the potential to reduce fuel consumption in the drying component of the paper production process by 70-90%, resulting in an overall reduction in process emissions of up to 60% for paper manufacturers. However, these new processes are unlikely to be commercially viable in the next two decades. Other breakthrough technologies which would significantly reduce the emissions attributable to pulp and paper production are in the early phases of development, such as black liquor gasification with CCS which would have the additional benefit of producing large amounts of biomass as a bi-product of pulp being processed for paper making. This technology is already being trialled in Sweden[112] but faces significant sunk costs and so may require supporting government policies to speed up the innovation process.

[103] CEPI (2008)
[104] CEPI (2008)
[105] Gielen and Tam (2006)
[106] Defined as "recovered paper utilisation plus net trade", compared to paper & board consumption, CEPI (2011)
[107] Gielen and Tam (2006)
[108] CEPI (2006)
[109] IEA (2007)
[110] IPCC (2007)
[111] CE Delft (2010)
[112] CE Delft (2010)

3.6 Summary of insights across the sectors

Following the economic downturn most EIIs went through a phase of overcapacity and market concentrations in Europe while the upward growth trend in Asia was not interrupted. In accordance with this economic growth global demand for steel, aluminium, cement, chemicals and paper products will shift towards Asia and towards emerging countries in Latin America. More mature economies will remain important markets, especially where there is expansion of renewable energy production and high-end products for which speciality steel, aluminium, specific chemicals will be required. A benefit for steel and chemical companies investing in the traditional production sites is to be close to main customers at the higher end of value chain, new light materials development or energy-saving programmes in the building sector. Positive cost effects arise from industry agglomeration and lower transport costs.

New investment in EII plants in countries with CO_2 pricing will depend on a mix of policies and incentive measures to create stable investment environment and to avoid leakage from imports stemming from plants that operate with CO_2-intensive technologies. In particular, more attention should be given to supporting new cross-sector technologies such as CCS for industrial producers including steel, cement and basic chemicals industry as well as sector-specific investment in abatement options around recycling and optimisation processes in steel, aluminium, pulp and paper production. The use of biomass, however, is potentially in conflict with other demand for such sources within the EIIs, but also as part of the energy and transportation sectors.

The (future) pricing of CO_2 in, China, South Korea, or Japan, will fragment the EIIs' global policy environment further. The carbon price thus will also become a cost component for producers outside the EU, emphasising the role of energy supply, energy costs and access as a key determinant of return on investment in EII. The rise of unconventional sources of natural gas in the US is a case in point (natural gas prices in the USA have fallen about 80% during the last four years). Investment in response to lower input prices has already observed for the chemical sectors (e.g. shale gas in the US), in particular refining investments in the Middle East and India, and for the aluminium sector primary production in locations with cheap access to power (mainly from fossil sources). In the light of this development, long investment cycles and the shift in demand for all products from EIIs, a climate policy with a horizon of only eight years (such as the 2020 horizon of the EU) is highly unlikely to be the key factor influencing the industries' next investment considerations.

4. Regulatory and legal framework – issues for energy-intensive sectors

Investment decisions in the energy intensive industries are also made in the light of **long-term expectations** on the regulatory environment in a country or region. This includes inter alia the taxation system, labour market regulations, legal certainty, protection of property rights, or participation in trade agreements. Moreover, regulation has an impact on labour, resource and energy costs. Climate policy adds to this list both with its policy toolkits (emissions standards, prohibitions, taxes or emissions trading), and relative strength compared to other world regions. The carbon leakage discussion in the EU is driven by the expectation of different or no carbon constraint in major trade partner countries of the EU.

Moreover, the **time horizon** foreseeable for a stable regulation environment matters. Investment in EII is locked-in for long periods of 20 to 40 years. This exceeds the current time horizons set up in the EU's ETS directive (2020), while the legal consequences of the EUs 2050 roadmap are not yet specified [113]. The EU has 2020 targets for renewables, energy efficiency and carbon emissions, in addition European EIIs face national regulation which will differ across countries. Compliance with these different pieces of legislation is likely to be costly for EIIs operating across multiple jurisdictions. In its 2013 Green Paper[114], the European Commission recognizes the need to ensure that interactions between post 2020 targets and policies are explicitly understood to preserve their original incentives.

For European EIIs the location decisions need to be based on the actual type of investment for the different markets. Greenfield, i.e. new investment is rather likely to take place in emerging economies to serve increasing demand and likely lower operating costs in terms of both labour and transport, which cannot be covered by exporting from the existing sites. Many EIIs in the EU face the choice of re-investing in their existing plants or to serve the EU markets from abroad in the future, and this investment represents the option to lower the regulated emissions in their operations. In this respect, the unclear time horizon of carbon pricing in the EU adds to the uncertainty inherent to calculating the pay off to such investment decisions.

Energy policy around the world such as fossil fuel subsidies in relevant trade partner countries like China[115] or the drive towards self sufficiency in the US and associated investment in R&D, pipeline infrastructure and regulatory environment[116], will have an impact on future investment decisions and efforts to increase abatement or to divert production abroad. Thus, either access to low-carbon energy sources or fossil fuel subsidies determine for some EIIs whether to invest within or outside the EU.

Long-term energy **contracts** both for gas and electricity in Europe have been subject to ex-post investigation by the DG Competition and antitrust authorities in the US. While such contracts hamper competition and undermine the EU's internal energy market liberalisation project, considerable risks for investments are being created, especially for some EIIs.[117] This is a dominant issue for the aluminium industry with its high dependence on electricity and some compounds in the chemical industry, which are produced by electrolysis.

The analyses of EIIs' carbon cost impacts from auctioning of emission rights shows different effects from the anti-leakage measures available under the revised EU ETS Directive Article 10a.[118] Free allowances, inclusion of importers or indirect cost compensation are meant to serve as a temporary cost relief for industry as the revised EU ETS Directive is guided by the EU climate policy goal of an international commitment to carbon pricing in the future. Free allocation, the default option to address the direct cost increase from carbon pricing, will cushion the carbon price impact for the most efficient plants (10%), and will mean higher cost for those who will not receive the full amount needed (subjected to lower, benchmarked free allocation). As this measure will be scrutinized every five years in order to re-evaluate the list of sectors at risk of carbon

[113] European Commission (2011)
[114] European Commission (2013)
[115] See e.g. Financial Times (2012)
[116] Stevens (2012)
[117] For a discussion of the approach taken by the Commission see Hauteclocque and Glachant (2009).
[118] European Commission (2009c)

leakage, it does not provide long-term reliability; however, as said, this was not the initial idea of the provision.

For higher electricity costs, the revised Directive provides for the possibility for Member States to compensate the most power-intensive sectors for increases in electricity costs resulting from auctioning in the power sector. National governments would need to include industries in their national state aid schemes (Art. 10a(6)). Such payment is subject to state aid rules, which need to be amended accordingly. With respect to the international environment in which EIIs operate, the handling of indirect cost compensation creates uncertainty, because it is unclear how the different member states will make use of such a rule and for how long and this may lead to further competitive distortions in the market.

The trade-off between transport costs and marginal CO_2 costs is particularly strong in the cement sector, and impacts upcoming investment decisions. If cement importers were to be included in the EU ETS, this would level the competitiveness situation, and secures the success of the EUs climate policy for coastal cement installations. However, currently, this option is not being pursued by the Commission; instead the cement industry will receive free allowances based on product benchmarks. Anticipating that the share of free allowances will decline until or after 2020 due to re-evalution procedures, investments could be delayed by industry.

The specific regulatory environment created by the EU climate and energy package 2008 is not sufficient to provide EIIs with a long-term incentive to invest in the EU territory. However, this never was the original intention of this legislation. Nevertheless, the heavy industries are integral part of a low-carbon economy and thus, policy should set up guidelines and targets to secure innovation activities and investment in these sectors.

While the current approaches to price CO_2 in the EU, Australia, South Korea (and as planned in China and discussed in Japan) create a cost incentive, which will lead to further product innovation and new competition for low-carbon projects amongst the EIIs, it cannot deliver longer-term certainty about the EII returns on investment in the regions. The particular challenge for policymakers comes from the interaction of the climate policy with a set of other regulation, the different responsibilities between member states and Commission in supporting low carbon investment, and the international policy and market trends, in particular the soaring demand for steel, aluminium, cement, and products from EIIs.

5. Conclusions

Emissions pricing plays an important role for energy-intensive industries (EIIs) in Europe and other jurisdictions with carbon pricing policies (e.g. Australia and parts of the US and Canada). This paper summarises the impacts for steel, cement, aluminium, chemicals and pulp and paper according to the findings of the Climate Strategies network. While the short-term implications from both the cost impact and the anti-leakage policy by the EU, benchmarked free allocation, are increasingly understood for these sectors, there is a lack of certainty about the long-term implications.

EIIs in particular are struggling with two impacts from a CO_2 price. One is the marginal impact of the CO_2 price, which can trigger imports if the transport costs have prevented this in the past (especially prominent for clinker production used by the cement industry). The other is the indirect cost impact from electricity prices, which will determine the future operation and investment decisions (particularly for aluminium production, steel from EAF plants and chemical compounds produced via electrolysis). In the short-term, the type of compensation provided under current EU legislation allows EII to manage their direct carbon cost by a mixture of passing costs through, especially for speciality products, importing cheaper inputs from outside the EU, using profits to stabilise final product prices, deploying available technologies to save emissions, or cutting other production costs. For some, the cost pass-through by the power industry since 2005 when the ETS was set up has already created a strong incentive to become more energy efficient, or to reduce their production in the EU.

The competitive position of the EIIs varies along a set of factors: product varieties and differentiation are highest in chemicals, followed by aluminium, steel, or pulp and paper while differentiation is rather low in basic chemicals and very low in cement. The elasticity of demand is rather low for the products serving specialised purposes, such as steel for automobiles, or specialised chemical products and this allows producers to pass through some of the carbon costs. Moreover, the actual potential for price differences differs. Aluminium is traded globally and companies are price takers, while some cement firms dominate the separated regional markets, and thus prices can differ on a regional basis.

Beyond the EU carbon policy, the long-term location of the EIIs across world regions is increasingly risky. While demand projections indicate increasing dynamics in Asian or other regions for all EIIs, this does not wipe out investment risks, which can relate to the political stability in a region (such as the Middle East) or future climate policies (e.g. in China), unanticipated changes in energy supply (e.g. the discovery of shale gas) or the systematic market risks inherent to all long-term decisions. Carbon price developments need to be assessed and managed by companies in addition to assumptions about demand, input costs, business cycles, raw material price volatility etc. While it is an important issue to make climate policy as reliable as possible for the long run, e.g. by a clear commitment to the EU ETS or other measures beyond 2020, this will not reduce or even compensate for other investment risks. The very long-term horizon of EIIs' investment is not and cannot be met with political frameworks of the same dimension. The 2013 Green Paper on a climate and energy strategy by the European Commission proposes targets for 2030. If the targets are addressing the whole range of energy production, use and emissions, and are combined with R&D incentives, this could provide some regulatory certainty for EII's long-term low-carbon investment decisions.

It will remain difficult for policymakers to gain information about future industry trends, especially on technological development, an example is the support for application of CCS in EU member states which hasn't developed at the anticipated pace. Supporting innovation by a mix of policies and incentive measures is the only option, but also could mean losing public money when trying to pick winners. Sustaining a CO_2 price is a way to signal the profitability of emission reductions within the EU territory. Given the climate policy targets of the EU until 2050 under the 2 degrees target stipulated at the UNFCCC level, more consideration needs to be given on how to facilitate low carbon innovation for reducing emissions sources in EIIs.

The market impacts that are being created by a national or regional climate policy, with new climate friendly and resource efficient products, has gained attention from nearly all EIIs. For example, the chemicals industry produces insulation to improve the energy efficiency of buildings and both steel and aluminium are used in the manufacture of wind turbines and solar panels. This creates new opportunities for these industries and may change the demand for these goods further in the future.

From the Climate Strategies analyses it becomes clear that the time horizon of climate policies in Europe and other regions appears too short-lived if measured against the evaluation of the role of EIIs, particularly given that the international efforts to level the carbon playing field are below expectations. As it is unlikely that the legal validity of the EU climate and energy package will be changed, a new chance to provide a longer term policy signal within the EU territory lies with the further development of an EU 2030 climate and energy strategy and the EU's 2050 roadmap, while internationally the focus will lie on the UNFCCC negotiations until 2020, when a new climate deal is anticipated to be finalised.

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Annex 1

Table A1 :European Commission list of subsectors at risk of carbon leakage.
Source: European Commission (2009b)

Sector	Nace-4 Code (Rev. 1.1)	(Sub)sector description	Increase in direct costs/ GVA (%)	Increase in indirect costs/ GVA (%)	Increase in total costs/ GVA (%)	Trade Intensity (%)
Steel	2710	Manufacture of basic iron and steel and of ferro-alloys (ECSC 20)	6.5	3.6	10.6	32.3
Cement	2651	Manufacture of cement	41.1	4.4	45.5	6.8
Aluminium	2742	Aluminium production	1.7	10.3	14.0	35.9
Chemicals	2412	Manufacture of dyes and pigments	0.7	1.4	3.2	43.1
	2413	Manufacture of other inorganic basic chemicals	4.8	6.0	11.9	31.7
	2414	Manufacture of other organic basic chemicals	2.5	2.2	5.4	46.3
	2415	Manufacture of fertilizers and nitrogen compounds	14.0	3.7	70.2	27.4
	2416	Manufacture of plastics in primary form	1.4	1.7	3.0	27.1
	2417	Manufacture of synthetic rubber in primary forms	>5 and <30	<5	>5 and <30	38.1
Pulp & Paper	2111	Manufacture of pulp	2.9	<5	<5	46.1
	2112	Manufacture of paper and paperboard	5.3	4.8	10.2	25.7
	2124	Manufacture of wallpaper	<5	0.9	<5	38.7