



Study on the Impacts on Low Carbon Actions and Investments of the Installations Falling Under the EU Emissions Trading System (EU ETS)

Final Report

February 2015



EUROPEAN COMMISSION

Directorate-General for Climate Action

Unit B2 – Benchmarking

BU-24, 2/20

B-1049 Brussels/Belgium

Contact: Mr Ismo Ulvila

E-mail: ismo.ulvila@ec.europa.eu

**Study on the Impacts on Low
Carbon Actions and
Investments of the Installations
Falling Under the EU Emissions
Trading System (EU ETS)**

Final Report

**Europe Direct is a service to help you find answers
to your questions about the European Union.**

Freephone number (*):

00 800 6 7 8 9 10 11

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

LEGAL NOTICE

This document has been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

More information on the European Union is available on the Internet (<http://www.europa.eu>).

Luxembourg: Publications Office of the European Union, **2015**

© European Union, **2015**

Reproduction is authorised provided the source is acknowledged.

Table of Contents

Abstract	9
Executive Summary	10
Impact of EU ETS on low carbon actions	10
What factors influence low carbon action and the role of EU ETS as a driver?	11
Which low carbon investments and operational decisions have been implemented in EU ETS sectors and what were the factors affecting decisions?	11
Policy conclusions	12
What do companies consider to be the main benefits of the EU ETS?	12
What do companies consider to be the main issues and challenges of the EU ETS?.	13
1 Introduction	15
1.1 This report	15
1.2 Objectives of project.....	15
1.3 Structure of this report	16
2 Company and installation case studies.....	17
2.1 Introduction	17
2.2 Identification of case studies.....	17
2.3 Company and installation case studies	21
2.4 Summary	81
3 Sector case studies	95
3.1 Power Sector	95
3.2 Cement Sector	120
3.3 Steel Sector.....	138
4 Country case study	158
4.1 Introduction	158
4.2 Methodology.....	158
4.3 Analysis	160
5 Literature review.....	171
5.1 Review of literature sources.....	171
5.2 References	177
6 Overall conclusions	179
6.1 Impact of EU ETS on low carbon actions.....	179
6.2 Policy conclusions.....	181

Table of tables

Table 1 Data sources used	18
Table 2 Final set of company / installation case studies	21
Table 3 Low carbon investments in SCA case study.....	25
Table 4 Summary of energy and environmental impacts of SCA's investments	28
Table 5 Low carbon investments in installations in Repsol case study	36
Table 6 Environmental impacts of low carbon investments at each refinery	37
Table 7 Summary of energy and environmental impacts of Tata's investments	46
Table 8 Low carbon investments installations in CEMEX case study	54

Table 9 Carbon price increases needed to make ETS top ranked driver of investments	55
Table 10 Summary of energy and environmental benefits of CEMEX low carbon investments:	56
Table 11 Low carbon investments in CEZ case study	76
Table 12 Summary of energy and environmental impacts of CEZ's investments.....	78
Table 13 Approved and confirmed investments of CEZ into chosen low carbon projects	80
Table 14 Case studies reviewed.....	82
Table 15 Internal carbon price assumptions	85
Table 16 Climate policy and energy efficiency targets across companies	86
Table 17 Summary of investments and impacts on cost, GHG emissions and energy consumption	87
Table 18 Panel estimation load factor Coal and Gas power units in UK 2002-2012 with carbon price impact of ETS phase I and II	109
Table 19 Panel estimation load factor inefficient and efficient Coal and Gas power units in UK 2002-2012 with carbon price impact of ETS phase II	111
Table 20 Carbon price elasticities.....	112
Table 21 Impact of EU ETS on CO ₂ emissions in the UK electricity generation sector in Phase 2 of the EU ETS.....	113
Table 22 Absolute and Specific CO ₂ Emissions from the German Cement Sector (VDZ, 2013).....	128
Table 23 Sample structure - Small and Large Emitters as well as Small and Large Enterprises	159
Table 24 Sector classification of surveyed companies	159
Table 25 Overview of studies, empirical basis and results	175

Table of Figures

Figure 1 Pulp and paper production in Europe	22
Figure 2 Fossil CO ₂ emissions intensity at SCA installations in this case study	29
Figure 3 Allowances, emissions and ratio of surplus allowances to emissions for Ortviken	30
Figure 4 Allowances, emissions and ratio of surplus allowances to emissions for Ostrand	30
Figure 5 Allowances, emissions and ratio of surplus allowances to emissions for Munksund.....	30
Figure 6 Allowances, emissions and ratio of surplus allowances to emissions for five Repsol installations	40
Figure 7 Fossil CO ₂ emissions intensity at Tata Steel Port Talbot.....	48
Figure 8 Allowances, emissions and ratio of surplus allowances to emissions Port Talbot	49
Figure 9 Evolution of fossil fuel consumption per ton of product at studied CEMEX installations	57

Figure 10 Allowances, emissions and ratio of surplus allowances to emissions for the CEMEX installations.....	57
Figure 11 CO ₂ emissions intensity at Nestlé installations covered by this case study..	64
Figure 12 Allowances, emissions and ratio of surplus allowances to emissions for Rosières installation, Nestlé	64
Figure 13 Allowances, emissions and ratio of surplus allowances to emissions for Fawdon installation, Nestlé	65
Figure 14 CO ₂ emissions intensity at the CEZ Tusimice installations covered by this case study	79
Figure 15 Free allowances, emissions and ratio of surplus free allowances to emissions for Tusimice installation, CEZ	80
Figure 16 Fuel input prices for power generators, 1990-2013 (nominal prices)	97
Figure 17 Illustrative merit order for the GB electricity system (2012).....	98
Figure 18 Coal and gas prices, with/ without the cost of CO ₂ emissions, per unit of fuel input.....	99
Figure 19 Illustration of marginal generation costs of a typical coal and gas fired power plant.....	100
Figure 20 Illustration of expected fully levelled costs of generating electricity of power units over their lifetime (source: DECC 2012d).....	101
Figure 21 ETS CO ₂ prices at the spot market.....	103
Figure 22 Panel estimation load factor Nuclear, Coal and Gas power units in UK 2002-2012.....	108
Figure 23 Cement and economic activity in Germany and the EU as a whole on a 2003 basis (Prodcom, 2013)	120
Figure 24 Net exports of cement products in Germany and the EU27 to the rest of the world (Prodcom, 2013).....	121
Figure 25 Absolute carbon emissions index of cement sectors in Germany, EU27 and US; year 2000 index=100 (WBCSD, 2012)	122
Figure 26 Specific CO ₂ emissions of cement industries in selected developed and developing countries or regions from 2000 to 2010 (WBCSD, 2012)	123
Figure 27 Clinker share in final cement products in Germany, the EU 27 and USA from 2000 to 2010 (WBSCD, 2012).....	124
Figure 28 Specific energy consumption of cement sectors in Germany, EU and the US between 2000 and 2010 (WBSCD, 2012).....	125
Figure 29 Share of alternative fuels and biomass fuels in cement sector fuel consumption in Germany, the US and the EU 27 (WBCSD, 2012)	126
Figure 30 German cement industry's specific CO ₂ -emissions resulting from process, fuels or electrical power need (tCO ₂ /t produced cement) (VDZ, 2013).....	128
Figure 31 Thermal energy consumption by source for the German cement sector since 1990 (RWI, 2013)	129
Figure 32 Thermal energy consumption and intensity in the German cement industry (VDZ, 2013)	130
Figure 33 Electricity consumption intensity of the German cement industry 1990 – 2012 (VDZ, 2013)	131

Figure 34 GDP and crude steel production index in selected OECD countries on a 2000 basis (OECD 2014, Worldsteel 2012).....	138
Figure 35 Steel use index in Germany, Japan, EU 27 and the US on a 2002 basis (Worldsteel, 2012).....	139
Figure 36 Net exports of semi-finished and finished steel products in selected OECD countries (Worldsteel, 2012)	140
Figure 37 Absolute and specific CO ₂ emissions (direct and indirect) of steel sectors in Germany, US and Japan (based on IEA and Worldsteel data)	141
Figure 38 BOF production share in Germany, Japan and US steel sector (Worldsteel, 2012).....	143
Figure 39 Total and fuel SEC of the steel industry in Germany, Japan and the US (based on IEA and Worldsteel data)	144
Figure 40 German crude steel production in Mt (RWI, 2013)	145
Figure 41 Absolute and specific CO ₂ emissions (direct and indirect) of the German steel industry (RWI, 2013).....	146
Figure 42 CO ₂ emissions sources in the German steel sector (IEA, 2013) (Worldsteel, 2012).....	147
Figure 43 Steel production by production route in Germany (RWI, 2013).....	148
Figure 44 Specific consumption of reducing agents in Germany (VdEh, 2011)	149
Figure 45 Energy need by resource in German steel industry (RWI, 2013)	150
Figure 46 Assessment of abatement potentials and abatement costs.....	161
Figure 47 Abatement activities	162
Figure 48 Abatement activities over time	163
Figure 49 Strategies to reduce carbon emissions	163
Figure 50 Main vs. side effect (Was carbon abatement the main reason or a side effect?)	164
Figure 51 Drivers for carbon abatement measures	164
Figure 52 Main cost factors of firm's economic efficiency	165
Figure 53 Factors influencing the strategic location decision	166
Figure 54 Price expectations for EUAs in 2013 (inflation adjusted)	167
Figure 55 Short and long term price expectation over time	167
Figure 56 Allowance trading frequency (EUA, CER, ERU).....	168
Figure 57 Trading Frequency broken down by Number of Employees and Emissions	169
Figure 58 Main Factors Influencing Firm's Inactivity Regarding Allowance Trading...	169

Abstract

The objective of this study is to document whether the European Union Emission Trading Scheme (EU ETS) has had an impact on low carbon investment and operating decisions by industry and electricity producers covered by the EU ETS and if so the nature and extent of that impact. The study is primarily based on case studies. It includes installation, company, sector and country level case studies.

Our evidence shows that carbon abatement and the carbon price were not the primary driving factors for most companies and sectors to invest in carbon efficient solutions. Instead, the main impetus came from the need for companies to reduce energy and raw material costs and their broader strategic turn toward sustainable production, based on increasing environmental awareness of stakeholders and consumer markets.

Nevertheless, the EU ETS – especially in its early phases, based on higher actual and expected carbon prices – seems to have played a supportive role in many decisions. This has been through its contribution to minimise energy costs, improved financial viability and profitability, awareness raising for climate issues at the management level and among employees, and capacity building for more accurate monitoring and reporting of emissions creating a better understanding of the potential for efficiency solutions.

Executive Summary

The objective of this study is to document whether the European Union Emission Trading Scheme (EU ETS) has had an impact on low carbon investment and operating decisions by industry and electricity producers covered by the EU ETS and if so the nature and extent of that impact. The study is based on case studies rather than very accurate empirical evidence. We include installation level, company level and sector level case studies.

The case studies were chosen and developed to be realistic, credible and to unpick the low carbon investment and operating decisions – including the investment appraisal process – and the extent to which the EU ETS and other climate and energy policies acted as drivers for these decisions.

The results and key findings from the case studies are highlighted in the summary below.

Impact of EU ETS on low carbon actions

Carbon abatement and the carbon price were not the primary driving factors for most companies and sectors to invest in carbon efficient solutions.

Instead, the main impetus came from the need for companies to reduce energy and raw material costs and their broader strategic turns toward sustainable production, based on increasing environmental awareness of stakeholders and consumer markets.

Nevertheless, the EU ETS – especially in its early phases, based on higher actual and expected carbon prices – seems to have played a **supportive role in many decisions**. This has been through its contribution to **minimise energy costs, improved financial viability and profitability, awareness raising for climate issues at the management level and among employees, and capacity building for more accurate monitoring and reporting of emissions** creating a better understanding of the potential for efficiency solutions.

Furthermore, **indirect costs resulting from the EU ETS (e.g. through higher electricity prices) seem to have played a role in investment decisions**, in particular during the later phases of the EU ETS. Some industry experts also highlighted the EU ETS's positive **innovation impact through access to finance, either for low carbon investments** in the European market (NER300¹) or in developing and transition countries through the flexible mechanisms (CDM/JI).

Along with the falling prices for emission allowances the **overall impact of the EU ETS on low carbon actions generally decreased from the first trading period (between 2005 and 2007) to the second (between 2008 and 2012) and early in the third trading period**. Over these years, improvements in the overall efficiency of production processes seem to have become an even more important driver of low carbon activities.

Companies' future **carbon price expectations** remain at relatively low levels in **the short term** and only rise moderately by the end of 2014. By the end of 2020,

¹ The aim of NER 300 is to establish a demonstration programme comprising the best possible CCS and RES projects and involving all Member States. NER 300 funding programme is so called because it is funded from the sale of 300 million emission allowances from the New Entrants' Reserve (NER).

however, **interviewed companies expect a substantial increase with average price expectations of around €15/tCO₂ by end of 2020.**

What factors influence low carbon action and the role of EU ETS as a driver?

Our interviews provide anecdotal evidence that the following factors played a positive role in companies' decisions to invest in low carbon technologies: high energy costs, global competitiveness, available capital (for companies with high margins), higher awareness for sustainability issues at the board level and in consumer markets, and cheap abatement potential. Companies operating with these characteristics see the EU ETS as an additional means to gain competitive advantage in the European market. Conversely, for companies with high perceived carbon leakage risks, a lack of capital (for companies with low margins), low carbon/climate awareness at the board level or among consumers, and with technical limitations to reduce emissions, the EU ETS does not appear to have incentivised investments.

The level of GHG abatement and the EU ETS role in low carbon investment decisions **varies across sectors**. However, our analysis suggests that there are **increasing differences in carbon abatement within single sectors**: some of the companies interviewed appear to act as front-runner companies achieving ambitious carbon abatement, while others struggle to implement reform and feel threatened by ambitious targets.

Furthermore, our survey data for a country case study on Germany shows that **decisions to reduce carbon emissions depend on the size of the firm as measured in terms of emissions and number of employees**. Large enterprises and emitters are generally more active with respect to carbon abatement compared to Small and Medium Sized Enterprises (SMEs) and small emitters. Finally, the country data provides evidence that an established **Environmental Management System (EMS) increases the abatement activity**.

Which low carbon investments and operational decisions have been implemented in EU ETS sectors and what were the factors affecting decisions?

There is a **consistent trend in companies and sectors regulated by the EU ETS towards energy efficiency and low carbon investments in the last two decades**. Based on ZEW/KfW survey data for Germany we find that a relatively high proportion of companies (77 per cent) carried out investments or made changes in their production processes in 2013 that reduced their GHG emissions. However, decisions were primarily driven by the objective to reduce energy costs, with carbon dioxide reduction as a welcomed side effect.

Asked about their abatement strategies, 71 per cent of the active respondents in the German case study stated to use process optimizations in order to reduce their carbon emissions. The second most important measure (67 per cent) is the **investment in energy efficient machinery**.

Our case studies for the **cement and steel sectors in Germany** highlight that the **use of alternative fuels, substitution of carbon intensive raw materials, energy efficiency measures, and the shift from the Blast Furnace/Basic Oxygen Furnace (BF/BOF) process route to the Electric Arc Furnace (EAF) process route in the case of the steel sector contributed to emissions reductions. In recent years, however, both sectors seem to have reached**

technological barriers to further efficiency improvements in their production routes that they will not easily overcome without breakthrough technologies.

Power sector companies have implemented more proactive and innovative short- and long-term climate strategies during the first decade of the 2000s. This was primarily achieved by **investment in new power stations (switching from coal to gas powered plants)** as well as by investing in **modernisation/retrofitting of old plants to increase efficiency**.

The decision-making process at the company level varies across the case studies we analysed, but there are **certain principles and procedures that seem to guide investment decisions across the board**. The procedure generally followed is: based on management-driven company internal energy efficiency targets or energy cost reduction schemes, technical experts identify a list of possible projects and measures and, in close coordination with installations identify priority investments. Feasibility studies are carried out, taking into account the legislative environment, cost assessments and technological potential. Criteria assessed for each investment proposal include best available technologies, internal rate of return, payback period, technology maturity and environmental co-benefits.

Consistent with the driving intention to reduce energy costs highlighted by most companies, findings clearly indicate that **investments have been (or are expected to become) beneficial for the companies in that energy savings soon made up for the upfront costs**. Though exact payback periods have not been disclosed by the companies due to confidentiality of data, there is an indication that the **approximate payback periods of energy efficiency investments in the case studies range from two up to seven years**. Energy savings have been considerable for most of the investments though this does not always translate into the equivalent energy intensity reductions related to direct CO₂ emissions, mainly due to variations in production volume, interaction between electricity and fuel consumption and changes in emissions coverage under the EU ETS during Phases I, II and III at the installation level.

Policy conclusions

Companies interviewed for this study highlighted benefits as well as issues and challenges in relation to their compliance under the EU ETS. Their feedback hints at some **important lessons learned for enhancing low carbon action via the EU ETS and for increasing stakeholder acceptance**. Companies also provided input on how issues and challenges could be minimised or mitigated. A summary of company feedback is provided below and conclusions are drawn regarding policy options for the European Commission.

What do companies consider to be the main benefits of the EU ETS?

ETS benefits highlighted by companies can be summarised as follows:

- The EU ETS offers compliance flexibility and emissions can be managed and reduced at a fairly modest cost.
- Tighter emission caps, and in particular the new allocation rules within the ETS taking into account sectoral benchmarks, provide a direct competitive advantage to more efficient operators, and thus represent an additional driver to improve energy efficiency in operations.

- Some companies that were driven by the ETS in its early years took decisions to invest in low carbon processes which now provide them with a competitive advantage on the global markets.
- New GHG emissions reductions mechanisms (e.g. such as CDM, NAMAs) and new trading markets are perceived as an opportunity by some to minimise costs and to spur innovation on the global market.
- The EU ETS has played an important role in making low carbon investments more financially viable. In most cases, the need for the investments has been instigated by other drivers (such as cost reductions or sustainability objectives) but the EU ETS through valuing of carbon reductions provided the additional income source to swing the balance in favour of making the investments feasible.
- Similarly the EU ETS is seen as a supporting factor in companies' considerations to turn to more energy efficient production routes and has created attention for these concerns in company boardrooms.
- Some companies highlight that obligations under the EU ETS led to investments in additional capacities for monitoring, reporting and verification (MRV) of emissions which increased understanding on the issues and potentials for emissions reductions.

These **highlighted benefits emphasise the positive impact the ETS has had (and can have in the coming years) for companies** if they decide to commit to a low carbon pathway and **should be integrated into the Commission's Communication strategy for the EU ETS and its reform.**

It becomes clear from the interviews however that **scale-up of positive examples of low carbon action under Phase III of the EU ETS and beyond will need a sufficiently high and stable carbon price with clear rules and mechanisms for compliance.**

The maintenance and further upscale of flexible offset mechanisms, possibly under the label of New Market Mechanisms, NAMAs or Framework for Various Approaches can be important for companies to support low carbon investments and innovation in third countries.

Our case study on Germany also highlights that a minority of surveyed companies (only 38 per cent of the firms surveyed in 2013) are fully aware of costs and benefits of potential technical and organisational solutions for CO₂ abatement. The **provision of further incentives and additional support in setting up knowledge sharing mechanisms, with a particular focus on small and medium sized companies to review emissions and abatement options** could be helpful to achieve awareness and enhance low carbon action.

What do companies consider to be the main issues and challenges of the EU ETS?

Key issues and challenges that companies highlighted include the following:

- Frequent modifications to the implementation details and uncertainties regarding the carbon price are criticised as they create disincentives for long term investments. To provide a clear and ambitious price signal some companies indicated the need for EU ETS reform with a **more ambitious medium term reduction target and an effective supply adjustment mechanism as well as greater simplicity in the regulations.**

- The **absence of a global carbon market to create a level field** for European operators and the risk for carbon leakage and loss of competitiveness is highlighted by many of the energy intensive companies. Some of these companies regard their sector benchmarks as 'unrealistic' or 'aggressive' threatening their competitiveness internationally due to increasing operational and CO₂ compliance costs.
- The indirect costs created by the EU ETS (e.g. through higher electricity prices) are seen as an additional burden by some companies as there is no harmonised compensation scheme for indirect costs.
- The **surplus of allowances in some sectors is criticised to create an unfair competitive advantage** for companies in these sectors as they can create profit through the sale of surplus allowances on the market. Suggestions to solve this included flexible allocation with regard to changes in actual production (moving away from an allocation based purely on historic production levels), as is for instance done in the new Australian ETS.

The criticism highlighted above clearly points to **companies' need for a longer term perspective and planning security regarding policy design and implementation, and carbon pricing within Europe and internationally**. It will be important for the EU to provide this stability, insofar as is possible, and to set a sufficiently tight cap when developing the policy framework for the period 2020-30 in order for companies to maintain and enhance their efforts.

Furthermore, **supporting the development of a global carbon market**, through an ambitious 2015 international agreement and the development and implementation of new market mechanisms (e.g. through sectoral crediting and trading), and linking carbon markets globally will be important in the long run to maintain support from energy intensive sectors such as steel and cement. With a longer term perspective, resistance in those sectors could also be reduced through **stronger support of research into innovative and breakthrough technologies to overcome limits in current technologies**. It will be important that sectoral definition and classification under ETS does not act as a barrier to innovative process routes. It will also be important to **further analyse how the new allocation system based on benchmarks affects industry across sectors and countries** and to **consider compensation and other support mechanisms to avoid loss of competitiveness for specific sectors**. The above suggestions for the introduction of a harmonised compensation scheme for indirect costs across Member States and the flexible allocation of allowances based on changes in actual production (moving away from an allocation based on historic production levels) are examples of types of options that should be explored and tested against key criteria of maximising the efficiency and effectiveness of EU ETS beyond 2020

1 Introduction

1.1 This report

This is the Final Report submitted under contract CLIMA.B.2/ETU/2013/0014 for the "Study on the Impacts on Low Carbon Actions and Investments of the Installations Falling Under the EU Emission Trading System (EU ETS)".

This report presents the details of the analysis and findings for each of the tasks undertaken, following the methodology outlined in the Inception Report which was submitted in November 2013.

The project has been led by ICF working in partnership with SQ Consult, CE Delft and ZEW.

1.2 Objectives of project

The objective of this study is to document whether the EU ETS has had an impact on low carbon investment and operating decisions by industry and electricity producers covered by the EU ETS and if so the nature and extent of that impact. The study is broadly descriptive in nature and focuses on selected case studies on the installation, company, sector and country level.

More specifically, the study aims to:

- analyse the impact of the EU ETS on low carbon investments and operating decisions by operators covered by the EU ETS;
- quantify, to the extent possible, the impacts of such actions;
- present different case-studies (for singular installations / companies or sectors) of the ETS-induced low carbon investments across multiple Member States and analyse the lessons learned. Such analysis takes into account the economic and technological factors affecting investment decisions and analyses in detail the operators' assessments;
- quantify, to the extent possible, how much of the low carbon investment was introduced with a primary goal of improving energy efficiency to reduce energy costs; and
- describe the technological options and choices behind the investment decisions.

The case studies chosen are realistic and credible, and examine the low carbon investment and operating decisions including the investment appraisal process and the extent to which the EU ETS and other climate / energy policies acted as drivers for these decisions.

The case studies can be seen as illustrative of the impacts of EU ETS within the respective sectors, given the similar way in which the EU ETS affects companies in each sector and the other similar external drivers impacting these companies (including policy, economic, consumer behaviour etc.). However, certain factors (e.g. cost and availability of low carbon fuels, process technology, raw materials, corporate strategy etc.) will be company- and installation-specific, and hence will limit the ability of 'scaling up' the findings.

1.3 Structure of this report

This report is structured as follows:

Section 2 presents the company and installation case studies, including the approach for identifying these case studies and a comparative analysis. This report includes seven company and installation case studies (SCA – paper; Tata – steel; Repsol – refinery; Cemex – cement; CEZ – power; Akzo Nobel – chemicals and Nestle – food). Supporting information behind the selection of case studies is given in Appendix A, and the completed interview questionnaires are included in Appendix B.

Section 3 presents the three sector case studies (power, cement and steel), including findings from interviews with HeidelbergCement (cement) and Salzgitter (steel). Supporting information is given in Appendix C.

Section 4 presents a country case study, focussing on Germany.

Section 5 presents a brief review of selected relevant literature to help provide a wider context for the case study findings.

Section 6 presents the overall conclusions.

Each of Sections 2 to 4 finishes with a summary of key points.

2 Company and installation case studies

2.1 Introduction

This chapter covers the company and installation level case studies that have been carried out. It includes:

- In section 2.2, the process undertaken to identify and shortlist the case studies; and
- In section 2.3, summaries of company and installation case studies looking at the low carbon investments made at single or multiple installations.
- Section 2.4 summarises and compares the case studies.

The case studies were conducted either face-to-face or by phone and followed an agreed topic guide. The company's responses to the topic guide questions asked are documented in Annex 1.

The case studies reflect the views of the companies interviewed and provide additional comments by the authors of this study where seen as appropriate.

2.2 Identification of case studies

The identification of case studies followed an agreed process of:

- a) Determine sectors to focus on, based on selection criteria
- b) Identify through literature search a list of installations or companies that :
 - have demonstrated significant GHG emissions intensity reduction and / or are a top (decile) performer
 - have a strong storyline
 - are willing to co-operate with the study
- c) Prioritise the list of companies or installations within each sector, based on comparative review of the data gathered and professional judgement
- d) Invite companies to participate.

These steps are described in subsections below.

2.2.1 Sector selection

Five attributes for sectors were investigated in order to prioritise them for inclusion as case studies. These attributes were:

- a) **Total sectoral GHG emissions.** This was assessed on the basis of ranked EU27 CO₂ emissions for the period 2005 to 2012, drawn from the ETL/CITL database. (These totals only included installations for which data in the ETL/CITL databases were available for every year between 2005 and 2012.)

- b) **Sectoral GHG emissions intensity reduction.** This was assessed on the basis of ranked annual improvement in CO₂ emissions intensity. This is expanded further below.
- c) **Carbon leakage rankings.** This confidential list of sectors was provided by the Commission and included relative rankings of sectors in terms of €/GVA (gross value added).
- d) **Sector views on EU ETS.** This was assessed on the basis of analysis of public statements / position papers made by sector associations and categorisation of support/opposition.
- e) Whether choosing the sector would enhance **coverage compared to previous case studies.**

2.2.1.1 Sectoral GHG emissions intensity reduction

Sectors that show a large decline in sectoral emission intensity may be indicative of sectors where CO₂-reduction investments have taken place.

To identify such sectors that have invested in carbon saving technologies, a quantitative analysis was undertaken from the EUTL/CITL data, combined with economic data on production, so as to arrive at an indication of which sectors have achieved considerable emission reductions relative to their production volume over the time frame 2005 to 2012.

The indicator of emission intensity (expressed in tCO₂/€) for each sector is equivalent to:

Direct CO₂ emissions

Production value ÷ producer price index

Production volume is here defined as the production value (turnover) of a sector, deflated by sectoral producer price indices. This gives a proxy of the development of physical production of a sector. If the production value increases because of price increases of the products of a sector, this is counteracted by a corresponding increase in the producer price index. Therefore, as observed in CE Delft (2008), this indicator gives a more robust explanation of the relationship between CO₂ emissions and output, than the commonly used indicator of CO₂ emissions over GVA.

We conducted this analysis for the 40 sectors with the highest CO₂ emissions over the period 2005 to 2012 at the level of EU27. In order to facilitate the analysis we only included installations for which data in the ETL/CITL databases were available for every year between 2005 and 2012.

The following table summarises the data sources used for this analysis.

Table 1 Data sources used

Data	Data source
Direct CO ₂ emissions	EUTL/CITL
Production value	Eurostat SBS Statistics
Producer price index (Output prices)	Eurostat SBS Statistics

With each of these data sources there have been some well-known issues, as follows:

- The sectoral classification in the EUTL/CITL database has been based on the sectoral classifications that have been made in 2009 for the carbon leakage list. Afterwards, some installations have changed sectoral classifications or have provided additional information to the EC regarding their sectoral status. This newer information has not been included, with a few exceptions of installations in the Netherlands and Slovakia, for which we have used more recent data. However, it was outside the scope of the present project to update this information in all EU member states. Moreover, there has been a change in definition for some installations from Phase I to Phase II. Especially in the chemical industries, there has been an extension of the scope of EU ETS from purely CHP-based allocation in Phase I to include more thermal processes in Phase II. When we suspected that the scope of individual permit-IDs had changed between Phase I and Phase II (for example evidenced by a sudden high increase in allocated permits that could not be justified by looking at the verified emissions in 2007) we excluded that installation from the analysis.
- With respect to the production values, two breaks in series have emerged between 2005 and 2012. First, the update in sectoral classification from NACE Rev 1.1 to Rev 2.0 took place in 2008. While we have tried to accommodate this using concordance tables, for some sectors we observed strange unexplainable results. In this case we have limited the analysis to the years for which we have had most observations.

The tables in Annex 1 include firstly the sectors with the highest cumulative emissions over the period 2005-2012, and these cumulative emissions include only installations that had emissions in each of these years². This shows that the refining and cement sectors had the highest emissions in the period 2005-2012, equivalent to around 1Gt of CO₂ each. Iron and steel, which has been split in various sub-sectors (2710 as main sector but with important components in 2700 as well and 2751) is also a very important emitter of CO₂ emissions.

When we investigate the development of their emission intensity, we see that the sectors with the highest absolute CO₂ emissions have not necessarily reduced their emission intensities. In this analysis, shown in Annex 1, both the cement and refining sectors actually showed increasing emission intensities over the period considered. This is most likely due to the fact that utilisation rates were, due to the economic crisis, lower in the last years compared to 2005. Since energy consumption is degressive with utilisation capacity, they tend to show a deterioration in their emission intensities, which may not adequately be reflected by the actual state of technology in these sectors. However, it should be noted that most of the sectors have nowadays lower capacity utilisation rates than in 2005 so the "ranking" of the sectors may be more appropriate than the absolute numbers. Also, in comparison, the iron and steel sector (NACE codes 2700 and 2710) has shown declining utilisation rates but showed a small improvement in emission intensities. The most improvement in emission intensities could be observed for the sectors manufacture of concrete products for construction productions, pharmaceuticals and the manufacture of other (non-basic) chemical products. Improvements in the fertiliser sector could be due to the capture of CO₂ from the NH₃ production process which has been delivered to the soda-drinks industry and used for urea production within the sector. Also pulp production is an interesting case in this respect, as CEPI has been very active in reducing costs for

² Therefore the summed emissions in these sectors will not match up to the totals that have been published on other studies since these will contain new entrants, installations that have been expanded in coverage of activities, or installations that have ceased production. Such installations are excluded in this table.

European paper industry by rationalising on energy consumption³. In addition, the sector used in 2005 relatively high amounts of oil which may have been substituted for natural gas and biomass and thus have resulted in lowered CO₂ emissions.

Although interesting, such results must be interpreted with care. The quantitative analysis here suffers from data problems as described above. A more general problem is that not all installations in a sector, or all activities at an installation level, fall under the ETS, while the production value refers to all companies in this sector. This may not be a problem if the share of ETS-activities and non-ETS activities is similar between 2005 and 2012. However, if the non-ETS companies are capable of expanding their production more than the ETS-companies, the analysis will show an improvement in the emission intensities which is in fact not due to the installing of low carbon technologies. This may especially be the case for sectors like pharmaceuticals for example. However, it goes beyond the present analysis to have a careful investigation of the share of ETS companies in the total production value of sectors.

Coverage compared to previous case studies

A literature survey was undertaken, including of case studies previously undertaken by ICF, SQ, CE Delft and ZEW, to identify existing case studies on ETS installations. The list of literature is included in Appendix A.

Overall selection of sectors

Based on the rankings, categorisation and coverage against each of the five criteria as tabulated in Table 29 in Annex 1, the sectors that were selected for installation or company level case studies were as follows:

1. Petroleum refining (NACE code 2320)
2. Iron and steel, including coke ovens (NACE codes 2310, 2710)
3. Non ferrous metals (NACE code 2700)
4. Cement (NACE code 2651)
5. Lime (NACE code 2652)
6. Chemicals, including both organic and inorganic (NACE codes 2413, 2414, 2415, 2466)
7. Pulp and paper (NACE codes 2111, 2112)

These prioritised sectors are in addition to the three sector level case studies (power, cement and steel sectors) described in chapter 3.

2.2.2 Identifying and prioritising a list of potential case studies

The list of possible case studies for each of the seven considered sectors (petroleum refining, iron and steel, non-ferrous metals, cement, lime, chemicals and pulp & paper) is presented in Annex 1. The potential case studies were assessed through literature search of publicly available information, knowledge of the project team and any recommendations from MS competent authorities, industry associations and other sources for the potential strength of storyline (high / medium / low and unknown) and perceived likely willingness to cooperate (high / medium / low / unknown).

³ See for example CEPI (2011) The Forest Fibre Industry 2050 Roadmap to a low carbon bio-economy. <http://www.unfoldthefuture.eu/uploads/CEPI-2050-Roadmap-to-a-low-carbon-bio-economy.pdf>

Based on these assessments, the potential case studies were ranked as a means to prioritise for contacting for the shortlist.

The Appendix also includes a table of further possible case studies identified in sectors other than the agreed seven sectors. These were not ranked.

2.2.3 Final selection of company and installation case studies

Following ICF's contact with the companies in the list, and their agreements to participate, the final set of case studies covered in this study are summarised in Table 2.

Table 2 Final set of company / installation case studies

Sector	Company	Member State(s)	Installation(s)
Petroleum refining	Repsol	Spain	Puerto Llano, Tarragona, A Coruña, Cartagena, Petronor
Iron and steel	Tata Steel	United Kingdom	Port Talbot
Cement	CEMEX	Poland	Chelm
		Germany	Kollenbach
		United Kingdom	South Ferriby
		Latvia	Broceni
Chemicals	Akzonobel	Denmark	Mariager facility
		United Kingdom	Ashington facility
Pulp and paper	SCA	Sweden	Munksund, Östrand Ortviken
Power	CEZ	Czech Republic	Tusimice, Počerady, Ledvice, Prunerov
Food	Nestlé	EU-wide / France, United Kingdom	Fawdon, Rosieres

2.3 Company and installation case studies

2.3.1 Pulp and paper – SCA

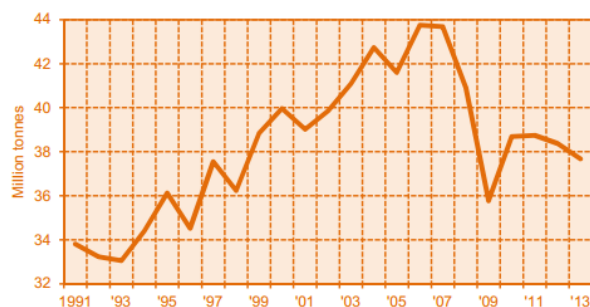
2.3.1.1 Sector background

Europe's annual production of approximately 40 million tonnes pulp represents around 22 per cent of the global pulp production (JRC, 2012). There are five main process routes for the production of pulp: Kraft (or sulphate) pulping, sulphite pulping, mechanical pulping, semi-mechanical pulping and recycled fibre processing. Pulp may be produced from virgin fibre (via chemical or mechanical process routes) or from repulping recovered paper. **Sweden and Finland dominate EU pulp production**, with other significant pulp production in Spain, Portugal, Germany, Austria and France.

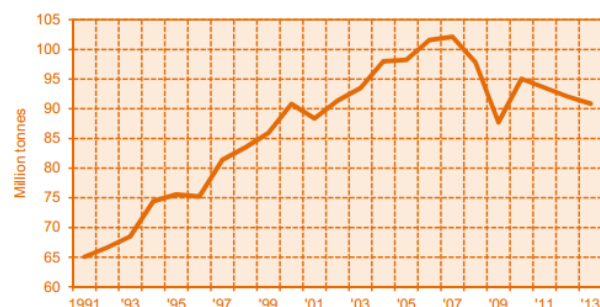
The pulp and paper sector has faced a **decline in production since 2007**, as shown in Figure 1. As well as the economic recession, there have been **structural changes in the industry over recent years** with decline in newsprint demand, and a rise in packaging demand associated with increased online shopping.

Figure 1 Pulp and paper production in Europe

Production of pulp in CEPI countries 1991 - 2013



Production of paper and board in CEPI countries 1991 - 2013



Source: CEPI (2014) Preliminary statistics, 2013 estimated figures ⁴

2.3.1.2 Company details and its products

SCA Group is a multinational pulp and paper company. In 2011, SCA Group operated 250 production facilities (45 larger pulp and/or paper mills), in 60 countries, and sold its products in more than 100 countries. Europe represents an important market approximately €7.2m of SCA sales, which in 2013 represented 73 per cent of total net sales (SCA 2013). The Swedish market made up around 10 per cent of the European market in 2013 in terms of sales (fifth largest market). SCA's competitors are both local in the Nordic region and global.

SCA has three business groups: tissue paper, personal hygiene and forest products. **The Forest Products business area is the focus of this case study, specifically its operations within Sweden.** Forest Products comprises publication papers, kraftliner (packaging papers), pulp, solid-wood products and renewable energy.

All of SCA Forest Product's production of paper, pulp and solid-wood products is concentrated in northern Sweden, close to SCA's forest holdings. Aside from the installations that are the subject of this case study, SCA Forest Products also operates packaging operations: the Obbola mill in Sweden, de Hoop in the Netherlands, Aschaffenburg and Witzenhausen in Germany, and Lucca in Italy.

SCA Forest Products owns and operates integrated pulp and paper mills as well as producing market pulp, and operates both chemical and mechanical pulp mills. The business unit has several EU ETS installations in Sweden, including paper mills, pulp mills, integrated pulp/paper mills (all under ETS Annex I category 'Production of pulp from timber or other fibrous materials' or 'Production of paper or cardboard with a production capacity exceeding 20 tonnes per day') and one saw mill that exceeds the 20 MWth combustion installation threshold. Other non-ETS operations include further saw mills to produce solid wood products, forestry operations (SCA is Europe's largest private forest land owner) and forest based biofuel production. **The specific installations focussed on in this case study are the integrated pulp and paper mill at Munksund, the Östrand pulp mill and Ortviken paper mill:**

Ortviken is SCA's largest paper mill, producing coated and uncoated publication paper. The production capacity is 890 kt paper per year, which makes Ortviken the sixth largest publication paper mill in the world. The installation also includes a thermo-

⁴ http://www.cepi.org/system/files/public/documents/publications/statistics/2014/Preliminary_per_cent20Statistics_per_cent202013_per_cent20Final.pdf

mechanical pulp mill producing 900 kt p.a., which represents 8 per cent of the total EU mechanical pulp production (CEPI, 2013).

- The Östrand pulp mill produces 425 kt p.a. bleached kraft pulp (half for SCA's own manufacturing of publication papers and hygiene products, half for external sale) and 95 kt p.a. of chemical thermo mechanical pulp (CTMP). The kraft pulp production at Östrand represents around 2 per cent of total EU chemical pulp production; the CTMP production around 1 per cent of total EU mechanical/semi-chemical (CEPI, 2013).
- Munksund is an integrated pulp and paper mill in which the paper mill consumes 100 per cent of the produced unbleached pulp to produce containerboard.

2.3.1.3 Strategic considerations

Climate change is high on the agenda of SCA's stakeholders; **achieving a low GHG emissions intensity is important for the business now and has been for some time.** The company was one of the first compared to its competitors to have set internal carbon targets. The company has been engaged in discussions on improving energy efficiency since the 1980s, with GHG emissions reduction identified as a target by SCA before the introduction of the EU ETS. The company has a sustainability strategy that includes targets for CO₂ emissions, and energy efficiency – further details provided in the box below. Therefore, at this high level, **the EU ETS acts to support pre-existing SCA priorities;** SCA expects nevertheless that it would still have similar corporate carbon intensity targets for products even if the EU ETS hadn't been introduced. However this does not mean to say that the EU ETS hasn't been a secondary driver for the investments as described below.

SCA's customers request information on the carbon intensity of products, due to their own concerns for environmental issues, which has led SCA to complete life cycle analyses on many of its products. Consequently, **SCA views achieving low GHG emissions intensity as a high priority in order to be competitive.**

The company is seen as seeking innovative carbon reducing solutions and is a sector leader for making these investments. For example, SCA has been the first Swedish paper company to install biomass fired lime kilns instead of either oil-fired kilns or gasifiers. Since their first installation in 2011 (Östrand, see below) of a new lime kiln, they have observed other pulp mills in Sweden following this leadership. SCA considers their internal policies on climate and carbon to be class leading. Since the 1970s the company has reduced its annual oil consumption by more than 94 per cent in Swedish mills.

Out of the two drivers for low carbon investment of energy cost savings and meeting consumer demand for low carbon products, the energy cost saving is more easily quantifiable, but SCA considers that **their low carbon profile provides them with business opportunities that they wouldn't otherwise have.**

Box 1 SCA's sustainability strategy aims and achievements:

1. Reduce CO₂ emissions from fossil fuel use and purchase of electricity and heating by 20 per cent by 2020 compared to 2005 levels.
2. Triple production of biofuels from SCA's own forests by 2020, with 2010 as reference year.
3. Increase production of wind power on SCA forest land to 5 TWh by 2020.
4. 14 per cent improvement in specific energy use between 2010 and 2020

Achievements (from SCA's 2013 Sustainability report unless otherwise stated⁵):

5. CO₂ emissions per tonne of product have reduced by 4.2 per cent between 2005 and 2010⁶. At the end of 2013, CO₂ emissions per tonne of product had declined by 11.8 per cent compared to 2005 levels.
6. In 2013, energy production from SCA's forest-based biofuels was 909 GWh (870 GWh in the reference year 2010).
7. Wind energy generated from SCA forest land totalled 0.75 TWh in 2013. The target of 5 TWh is substantial when compared to the current SCA Forest Products electricity consumption of 2.8 TWh and total SCA Group electricity consumption of circa 7 TWh. The wind power target is not set in order to be self-sufficient in wind-generated power; this is an independent investment that SCA has undertaken.

Although addressing its climate impact is important *for SCA Group as a whole*, legislation on climate change is not seen as a significant strategy risk so far, rather it is considered to be of neutral impact, i.e. neither a risk nor opportunity, most likely because the legislation does not require SCA to deviate from its existing environmental actions. *For SCA Forest Products* however, responding to climate change policy set by the EU is seen as an opportunity to gain competitive advantage. This is not only through utilising SCA's forest assets and raw materials, which are certified by the Forest Stewardship Council and considered 100 per cent renewable, but also through the energy-based low carbon innovative investments they have been making, as described in this case study. Also for SCA Forest Products, **EU climate change policies produce a risk to the electricity-dependent mechanical mill at Munksund of high electricity prices.**

SCA's recent investments and divestments have concentrated its Forest Products operations close to its forest assets, and ensured good integration across the supply chain. This level of integration has supported the low carbon investments through the availability of local biofuel to the company. The access to biofuel is a competitive advantage held by virtue of location, and will continue to be a competitive driver for SCA's use of biofuels and diversification of use of forest assets.

SCA's primary sources of CO₂ emissions stem from use of fossil fuel and purchased electricity, followed by transport activities. For SCA Group as a whole, the business unit with highest CO₂ emissions from fossil fuel is tissue production – below 10 per cent comes from production of publication papers, pulp and sawn timber. Transport activities account for approximately half of SCA's CO₂ emissions. European operations of SCA Group make up 75 per cent of group-wide energy use (fuel, heat and electricity) (SCA 2012).

⁵ http://www.sca.com/Documents/en/Annual_Reports/SCA-Annual-Report-2013.pdf?epslanguage=en

⁶ <http://www.tosca-life.info/wp-content/uploads/2012/02/BroschurePDF.pdf>

2.3.1.4 Low carbon investments

Description

This case study covers three low carbon investments as described in Table 3. **In all three cases the investments involve the replacement of oil-fired plant with biofuel fired plant.**

Table 3 Low carbon investments in SCA case study

#	Site location, country	Year of decision	Year of implementation	Brief technical and operational details about the low carbon investment or operational decision
1	Ortviken / Östrand	December 2012	Commissioned December 2013 (Rapid timetable)	<p>BioCoop energy project: Redesign and conversion of two boilers at Ortviken paper mill, enabling them to be fuelled with wood pellets, and connecting Östrand pulp mill to the Sundsvall district heating grid for peak load (winter) supply. Heat supply designed at 40 GWh per year (winter), in first unusually mild winter the scheme only sold 3 GWh of heat.</p> <p>The technical installation introduced new pipes, pumps and heat exchangers for more efficient recovery of secondary heat at SCA Östrand and thus now able to recover heat from six different points in the factory. For the production of primary heat, new fuel stores, mills, powder silos, pellet burners in Boiler 2 and Boiler 3, pipes, electrostatic filters, pumps and heat exchangers were installed.⁷</p>
2	Östrand (kraft pulp mill)	2009	2011	<p>Installation of a new lime kiln fuelled with pulverised sawdust pellets (biofuel). New kiln of capacity replaces two pre-existing oil-fired kilns of previous combined capacity 420 kt p.a. and has a capacity twice that of the combined old kilns' capacity.</p> <p>At the same time three new pulverised burners were installed in an existing bark boiler in order to reduce the amount of oil needed for co-firing.</p>
3	Munksund kraftliner mill	2012 (following 1 year operating Östrand)	2014	<p>Similarly to the Östrand installation, a new biofuel fired lime kiln. The new kiln is fuelled with biofuels, in contrast to the old kiln that was oil fired.</p>

⁷ <http://brightmarketinsight.com/headlines/sca-heats-things-up-in-sundsvall/>

As identified by Gulbrandsen & Stenqvist (2013), biofuel lime kilns are recognised by CEPI in their roadmap to a low carbon bio-economy⁸ as one of the long-term solutions up to 2050. To this extent, **the investments at Östrand and Munksund are leading innovative technologies.**

2.3.1.5 Decision process

For **investment 1** (as listed in Table 3), the decision making process involved an external organisation: SCA's mills already exported heat to the Sundsvall district heating grid and they were aware of the local district heating company's proposal for local heat delivery improvements. As a first step SCA saw an opportunity to provide the additional heat output to the district heating network for a lower cost than the local district heating company's proposal. SCA identified the two options available to it – a more expensive investment into a bark boiler, coupled with cheaper ongoing fuel costs, or a less expensive upfront investment cost into a pellet fired boiler but which has a higher ongoing fuel cost – and used internal analysis and expertise to appraise the two options. The internal cost-benefit analysis using net present valuation (5 per cent discount rate) identified, taking into account future expected heat incomes and carbon prices, that SCA could propose a project of around half the cost than that proposed by the district heating company (circa €55m) using the pellet fired boiler option. The project was proposed to the local district heating provider and negotiated. SCA financed the investment internally, so avoided the need to obtain external funding; the district heating company also made investments. SCA took into account the company's local availability of biofuel pellets as the fuel source. Contract negotiations with the local district heating company were important for this investment decision: a 15 year contract of heat supply was negotiated with the district heating company. The timeframe from decision to commissioning was very short, at just 12 months.

For **investment 2** of a new lime kiln at Östrand, the company considered multiple options through assessing and evaluating existing technologies used at other mills in Sweden and Finland, and also considering the more innovative solution of sawdust biofuel pellet-fired kiln. Other mills in Sweden and Finland had achieved 50 per cent oil reduction using gasifiers, but this was insufficient oil reduction for SCA compared to the 95 per cent oil consumption reduction offered by the investment that was made. The sawdust biofuel pellet-fired kiln solution is an appropriate investment for SCA because SCA is a producer of sawdust biofuel pellets, and adding a year-round demand for the pellets (including in summer time) helps to even out production variations. It was particularly efficient to use the sawdust pellets in this case because the same trucks that brought sawdust from the mill to the pelleting plant could bring pellets back to the pulp mill to avoid empty runs.

The criteria that SCA used to evaluate the options available was principally a cost basis, as well as reliability. For example, the alternative option of a bark boiler was discarded due to cost reasons (requires additional drying and gasification, i.e. investments) and reliability (to achieve high availability with bark boilers require powder burners, i.e. additional investments). In summary the process followed was:

- Objective and identification of investment priorities
- Identification of options, including of competitors

⁸ Unfold the Future: The Forest Fibre Industry 2050 Roadmap to a low carbon bio-economy. 2011. Available at http://www.cepi.org/system/files/public/documents/publications/environment/2011/roadmap_fi_nal-20111110-00019-01-E.pdf

- Evaluation of options (cost and reliability)
- Proposal, appraisal and decision
- Implementation

The decision process for **investment 3** of a new lime kiln at Munksund was similar to the process followed for the kiln at Östrand. The key difference is that the one year of operation at Östrand was used as part of the evidence base, rather than the analysis of competitors' investments, for assessing the similar solution at Munksund.

Drivers

The original driver **for investment 1** came from the district heating company. For SCA, the drivers for this investment (which may differ from other investments, and for the wider company perspective) ranked in descending order of importance were:

- Energy costs
- EU ETS
- Corporate GHG emissions policy

For **investment 2**, the main driver for making *an investment* at the plant was to increase production volumes through improving the operational efficiency. More specifically, the existing lime kilns frequently interrupted production leading to them acting as a bottleneck (the recovery boiler was no longer a bottleneck following a previous investment in 2004-2006). The driver for making the investment *a low carbon investment* was primarily the high and volatile energy (fuel oil) costs. The driver for choosing *this particular low carbon investment* was the availability of biofuels within SCA (on a fuel cost and availability basis, plus benefits to biofuel pelleting plant in evening out production) and carbon prices.

There were two drivers for making *an investment* at the Munksund mill (investment 3): firstly, Munksund was seeking efficiency gains, as the existing mill needed to debottleneck and achieve sufficiently low downtime, and secondly, the plant had high dust levels, which was a cause for concern by the local health and safety authority. The drivers for making a low carbon investment, and choosing the particular low carbon investment, were as for investment 2.

Considerations of EU ETS

For all three investments, SCA used the market price of carbon at the time of the decision together with an assumption that the carbon price would rise by 2 per cent per annum (considered by the interviewee to be conservative). With this valuation of carbon, the **EU ETS formed a secondary economic driver after energy prices** (price of oil compared to biomass).

SCA has not analysed for any of these investments the price that carbon would need to have to make it a top-ranked driver.

Energy and environmental impacts

All three investments lead to reductions in oil consumption, hence reductions in fossil CO₂ emissions and small reductions in SO₂ emissions (oil has maximum 0.4 per cent sulphur content according to local regulations). Biogenic CO₂ emissions increase through the use of SCA-produced biofuel pellets. The oil and CO₂ savings of the investments are summarised in Table 4.

Table 4 Summary of energy and environmental impacts of SCA's investments

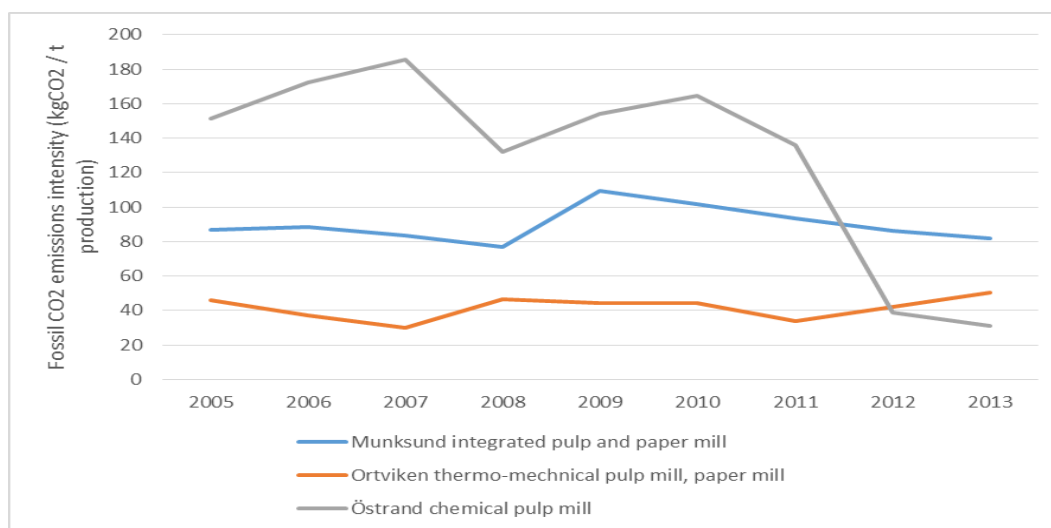
Investment; location	Oil saving (000 m ³ p.a.)	Fossil CO ₂ emissions saving (kt/annum)	Other impacts
1; Ortviken / Östrand (Note 1)	<ul style="list-style-type: none"> ▪ SCA Ortviken: 4 (~5 per cent total fuel consumed at Ortviken) ▪ Sundsvall Energi: 20 	<ul style="list-style-type: none"> ▪ SCA Ortviken: 10 ▪ Sundsvall Energi: 50 	<ul style="list-style-type: none"> ▪ (ICF estimate): 25t SO₂ emission reduction at SCA Ortviken ▪ (ICF estimate) 125t SO₂ reduction at Sundsvall Energi
2; Östrand	<ul style="list-style-type: none"> ▪ 17 (~5 per cent total fuel consumed at Östrand) 	<ul style="list-style-type: none"> ▪ 50 (~80 per cent of site fossil CO₂) 	<ul style="list-style-type: none"> ▪ (ICF estimate): 105t SO₂ reduction. ▪ Small reduction in NO_x and dust emissions (not accurately quantified) ▪ 5kt p.a. pulp production increase
3; Munksund	<ul style="list-style-type: none"> ▪ Not provided 	<ul style="list-style-type: none"> ▪ 20 (~75 per cent of site fossil CO₂) 	<ul style="list-style-type: none"> ▪ Minor SO₂, NO_x and dust emission reductions

Note 1: Investment 1 has not had any measurable impact to date, as the heat demand for its first winter of operation was exceptionally low.

The CO₂ emissions intensity (direct fossil CO₂ only, i.e. excluding reported indirect grid electricity CO₂ and direct biogenic CO₂) of each of the three installations over the period 2005 to 2013 is shown below in Figure 2.

Despite variability in earlier years, the impact of the 2011 investment at Östrand is visible from year 2012. The impacts of the other installations' investments which were implemented in years 2013 and 2014 are not yet visible.

Figure 2 Fossil CO₂ emissions intensity at SCA installations in this case study

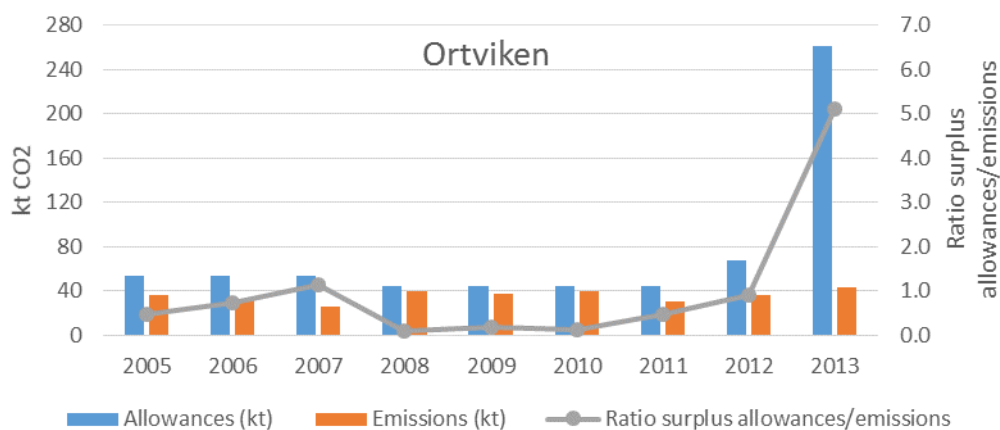


The three figures below summarise the EU ETS allowances, verified emissions data and the ratio of the surplus of allowances to the emissions at each installation, over the period 2005 to 2013.

Figure 3 and Figure 5 for Ortviken and Munksund respectively both show sharp increases in the allowances going from Phase II to III in 2013, with associated rises in the ratio of surplus allowances to emissions. The emission reductions from the low carbon investments described for these installations would be expected to be visible from 2014 or 2015 and would be expected to reduce emissions and so increase further the ratio of surplus allowances to emissions. In Phase II of the ETS, the allocation of free allowances was on the basis of grandfathering (historic results), which led to low amounts of emission allowances for Nordic mills since they have been low CO₂-emitters for a long time due to their use of biomass. The benchmark model for allocation of emission allowances in **Phase III has in general resulted in a substantial increase of emission allowances for Nordic mills** as compared to other mills across the EU they have very low emissions, again due to their use of biomass. This is the case for Ortviken and Munksund.

Figure 4 for Östrand also shows in general the installation's allowances exceeding the CO₂ emissions. In contrast to Munksund and Ortviken, the benchmarking method of allocation of allowances for Phase III did not favour the chemical pulp production at Östrand compared to the grandfathering method, and SCA Östrand received a lower allocation of emission allowances for Phase III than Phase II. The impact of **the low carbon investment at Östrand from 2012 onwards acts to increase the ratio of surplus of allowances to emissions.**

Figure 3 Allowances, emissions and ratio of surplus allowances to emissions for Ortviken



Note that Ortviken received an additional allocation of emission allowances in 2012 from the new entrants reserve following increases in production.

Figure 4 Allowances, emissions and ratio of surplus allowances to emissions for Östrand

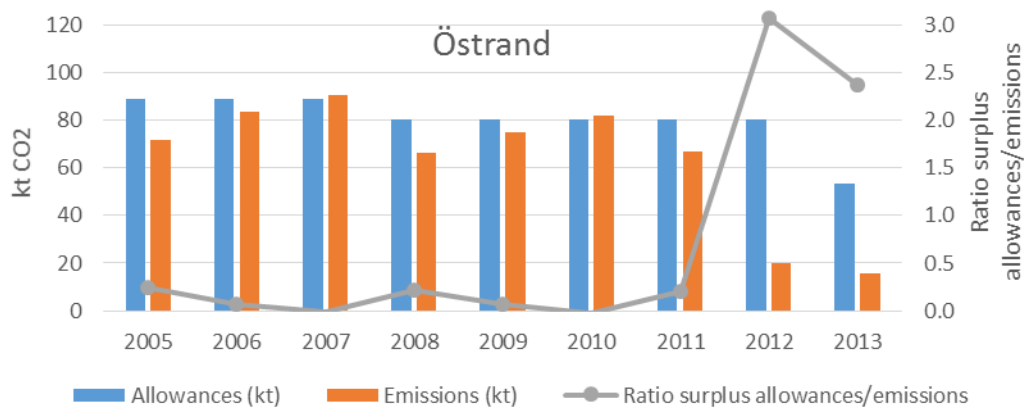
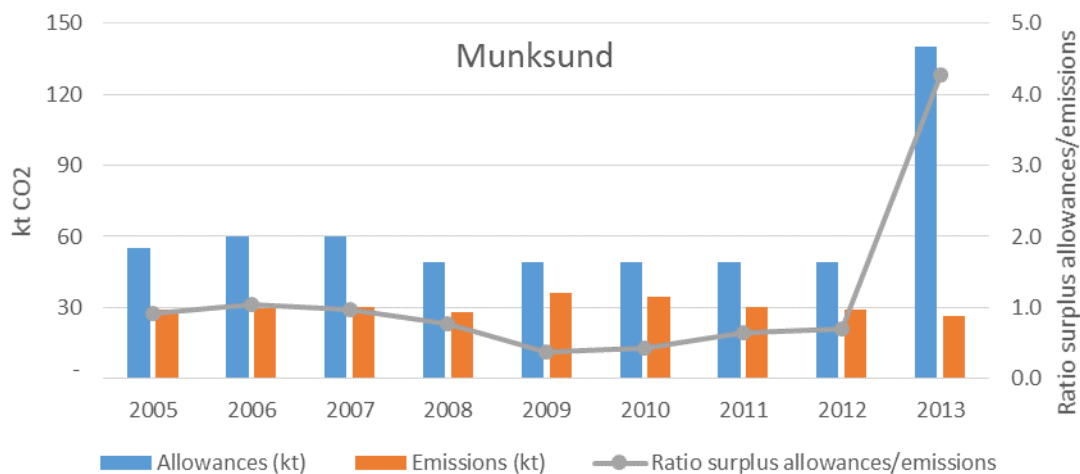


Figure 5 Allowances, emissions and ratio of surplus allowances to emissions for Munksund



Cost impacts

The investment costs for the three low carbon actions are as follows:

- Investment 1: ~€42m (plus local district heating company investment of ~€11m), for total of 24,000 m³ p.a. oil substitution
- Investment 2: ~€50m, for 17,000 m³ p.a. oil substitution
- Investment 3: ~€50m, and circa €7m p.a. cost savings. Oil substitution quantities not provided.

The payback periods for these investments have not been provided, although for investment 3 it would appear to be around seven years. The annual operating savings for investments 1 and 2 are confidential to SCA but are principally driven by the reduction in oil consumption; the energy input is replaced with SCA's own sourced biofuels, so the annual operating savings will be approximately the cost difference between oil and biofuel.

2.3.1.6 Broader observations and conclusions

As reported in SCA's 2013 sustainability report, **across SCA's 37 EU ETS installations, SCA overall has an annual surplus of emission allowances:** SCA Forest Products installations "will continue to produce a surplus, while its operations in the rest of Europe will have a certain deficit. The balance provides an annual surplus of about 200,000 [tonnes] of carbon dioxide equivalents [in 2013], which is lower than in the past." In 2013, SCA sold 410,000 emission allowances. The influence of the EU ETS on the paper industry has come at a time of structural changes demanded by 7 per cent annual declines in newsprint demand across the EU due to digitalisation and packaging demand increases. SCA considers 100 per cent free allocation for the paper sector to be important to retain against the backdrop of demand decline, even if these are not linked. Mechanical pulp mills (e.g. Ortviken) are large consumers of electricity leading to a high cost compared to allowances in the Nordic region due to the impact of the ETS on power sector and its electricity prices charged to consumers.

As described above, the **EU ETS has played a role for the described investments of improving financial viability of investments. The ETS has been factored into all decision making and this can swing the decisions with the pricing of carbon and consequent on-going annual revenues from EUAs. In most cases, the initial driver for investments as can be expected has been energy costs, together with the need to improve efficiency / debottleneck.** This conclusion is similar to that of Gulbrandsen & Stenqvist (2013)⁹ based on a 2011 interview with SCA. The investments also sit comfortably alongside an established company sustainability policy (which is supported by but not driven by the EU ETS) and to meet customer-driven market demand.

At Östrand and Munksund, SCA has invested in leading innovative technologies. With these investments (and others not described), SCA Forest Products considers its own mills to be the most efficient in Sweden (and **among the most efficient in Europe and globally**). The *increase* in allowances afforded Ortviken and Munksund under the benchmark allocation method of Phase III compared to the grandfathering allocation method of Phase II demonstrates that **the mills have been low CO₂ emitters for a long time**. SCA have indicated that more

⁹ Lars H Gulbrandsen and Christian Stenqvist: The limited effect of EU emissions trading on corporate climate strategies: Comparison of a Swedish and a Norwegian pulp and paper company. Energy Policy, published 06.02.2013.

recently, the EU ETS has overall not been of benefit for them due to the increased electricity costs which at the Ortviken mechanical pulp mill have outweighed by an estimated five times the value of the ETS allowance surplus for that mill.

For future investments at other SCA plants which do not have other local triggers for investments (e.g. production bottlenecks, health and safety etc. as described above), energy costs will remain as primary driver, and **ETS and climate concerns will continue to be secondary drivers**. Specifically for tissue paper mills which are currently fuelled by natural gas, with enough financial incentive, SCA have indicated that there may be an option to convert to biomass firing, although the sourcing of this biomass may be uncertain. Regarding the future role of EU ETS in investments, EU ETS may play a larger role at financing future investments due to increasing carbon prices, depending on the changes to fossil energy prices and SCA's dependency on fossil energy.

2.3.2 Petroleum refining – Repsol

2.3.2.1 Sector background across the EU and in country of case study

Growth in European refinery output has been well below the average of the rest of the world over the last 20 years. This trend is expected to continue, with growth in demand in Europe expected to be even lower in the future (Purvin & Gertz Inc., 2008)¹⁰. The EC (2010)¹¹ forecast of 21 per cent reduction in transport gasoline demand by 2030 may need divestments and shutdowns of European refineries.

Looking forward, the commercial environment facing the EU refining industry is likely to continue to be difficult. Cheaper substitutes for fuel oil – coal and natural gas – have become available for power generation, and tighter fuel standards in shipping have led to a long-term shift in maritime demand from fuel oil into diesel. Reduced prices for fuel oil, when combined with the relative lack of upgrading capacity in Europe and strong capacity growth in nearby markets, such as the Middle East, means that refining margins are likely to be, on average, low in future years. The delay in some investments may also affect competitiveness expected for the sector. Further, saturated personal mobility markets coupled with improving vehicle efficiency have led to structurally-declining demand of fuels in the sector, a new feature of land transport fuel markets after a century of growth. The declining demand has been dictated by increased use of biofuels, mandatory standards for improved vehicle fuel efficiency and, in the future, the possible partial electrification of the vehicle fleet. From a policy perspective, looking beyond the EU ETS, further pressure on refinery sector margins may occur from the presence of mandatory regulations for refinery energy management including the cogeneration of heat and power as well as the capture and storage of CO₂ emissions.

This case study covers Repsol's five refineries in Spain. These five refineries are fully interconnected through pipelines and therefore operate as one single refining system.

2.3.2.2 Company details and its products

Repsol is a Spanish energy company that started its operations in 1927 under the name of CAMPSA. It carries out upstream and downstream activities in Spain and in

¹⁰ Purvin & Gertz Inc., 2008. *Study on oil refining and oil markets. Prepared for European Commission.*

¹¹ European Commission, 2010. *SEC(2010) 1398 final. Commission Staff Working Paper on Refining and the supply of Petroleum Products in the EU.*

the past decade expanded to the markets in Latin America, North America, Africa and Russia.

Repsol's interconnected refineries in Spain considered for this case study are:

- a) **Puerto Llano:** Refining capacity of 150,000 barrels/day. Activities: extraction, refining, chemical and LPG.
- b) **Tarragona:** Refining capacity of 186,000 barrels/day. Activities: extraction, refining, chemical and LPG.
- c) **A Coruña:** Refining capacity of 120,000 barrels/day. Activities: extraction, refining and LPG.
- d) **Cartagena:** Refining capacity of 220,000 barrels/day. Activities: extraction, refining and LPG.
- e) **Petronor:** Refining capacity of 220,000 barrels/day. Activities: extraction, refining and LPG.

Repsol's integrated refining system in Spain operates as one single refinery in practice. Repsol has therefore a unique logistical advantage and access to the two largest European distribution hubs: the Atlantic Ocean (from the A Coruña and Bilbao complexes) and the Mediterranean Sea (from Cartagena and Tarragona complexes). In addition, the Puertollano refinery is located near Madrid, the area with the greatest oil demand in Spain.

Recent investments of €3.1 billion in the Cartagena industrial complex and €1 billion in the Petronor industrial complex have made them be among the most energy efficient refineries in Europe.

The integrated production of petroleum products in all five interconnected refineries consists of:

- Motor gasoline, unleaded
- Light naphtha (light distillate used as feedstock in the petrochemical industry)
- Kerosene-type jet fuel and other kerosene (petroleum distillate, 150°C to 300°C, used in aviation turbines and in sectors other than aircraft transport)
- Diesel fuel (diesel for engine road vehicles, petroleum distillate, 180 °C to 380 °C, used in road/rail transport)
- Heating gas-oil Medium naphtha (medium distillate used as feedstock in the petrochemical industry)
- Lubricating oils (liquid distillates, weight of petroleum oils \geq 70 per cent, extracted by distillation of crude oil; including motor oils, industrial oils and lubricating greases)
- LPG (mixture of light hydrocarbons, maintained in the liquid state by increased pressure used as a power or heating fuel)
- Petroleum coke (black solid product obtained mainly by cracking and carbonising residue feedstock, mainly 90 to 95 per cent of carbon)
- Petroleum bitumen (black or dark brown solid and semi-solid thermo-plastic material with waterproofing and adhesive properties).

2.3.2.3 Strategic considerations

Business impact of EU climate policy

Repsol considers carbon pricing as one of the main tools to fight climate change globally. Repsol supports EU-ETS as a pillar of the EU climate policy. However, the company considers that in the absence of international agreements, the EU-ETS poses a significant risk for global competitiveness. A high CO₂ price could result in a competitive disadvantage with respect to sector companies not affected by comparable regulations.

In the opinion of Repsol, free allocation should be designed to mitigate the risk of carbon leakage. However, Repsol considers that the benchmark imposed on the sector is aggressive. This, together with the linear reduction factor, and the indirect cost of CO₂ emissions represent in their opinion an increasing burden to their installations in Europe.

Furthermore, Repsol sees the updating of the carbon leakage list as a large risk. Repsol's free allocation would vary depending on whether the refining and chemicals sector are maintained in the list or not. If excluded, Repsol considers that their facilities would be subject to a risk of loss of competitiveness due to increasing operational and CO₂ compliance costs. Additionally, Repsol considers the option of backloading or the proposed MSR for the next EU-ETS Phase (2020-2030) as factors of additional uncertainty.

While Repsol is committed to reduce its energy consumption and its GHG emissions, it argues that the latter is not necessarily a competitive advantage against imports from producer regions outside the EU-ETS. A level playing field in Europe can only be achieved if imports of refinery products are also included in the EU-ETS,

Multiple targets derived from the Renewable Energy, the Fuel Quality, and the Energy Efficiency Directives create a complex regulatory framework with additional risks for competitiveness and uncertainties in Repsol's views. On the other hand, Repsol considers new GHG emission reductions mechanisms and new trading markets as opportunities. New allocation rules within the EU ETS that take into account sectoral benchmarks provide a direct competitive advantage to more efficient operators, and thus, represent an additional driver to improve energy efficiency in Repsol's operations. Repsol implemented a company plan in the period 2006-2013 that resulted in the reduction of more than 3 million tonnes of CO₂ (MtCO₂) per year from implemented activities. Repsol has established a new plan for the period 2014-2020 with the objective to reduce an additional 1.9 MtCO₂tonnes per year.

Reducing GHG emissions intensity and competitive advantage

Energy consumption is a critical factor for the competitiveness of the refining sector. Energy costs represent about 60 per cent of overall production cost in a refinery. Reducing energy consumption leads to a direct reduction of GHG emissions. Therefore, low GHG emission intensity is key to the competitiveness of Repsol.

Each of Repsol's refining and chemical installation has an indicator of GHG intensity, and there is a path to reduce the intensity yearly. The indicator used is based on the EU ETS benchmarking methodology so Repsol has a baseline to compare with competitors operating under the ETS. Furthermore, Repsol participates in the Solomon Benchmark study which takes place every two years. Specific targets are set for each installation based on its capabilities and potential to reduce GHG. The reduction is tracked on a monthly basis and communicated to the board. Targets are part of the

strategic planning and are directly linked to employee bonuses. Repsol uses GHG emissions, fuel consumption, and energy efficiency as regular metrics to monitor its competitiveness against other European refineries and importers.

Reducing GHG emissions intensity and corporate image

Repsol is fully aware of the potential consequences of climate change; according to our interviewees the company is committed to be part of the solution. Consequently, Repsol supports research, new technologies and innovation that are key for the development of a sustainable energy supply for the future. Repsol also expresses publicly its will to contribute to the compliance of international commitments, specifically with the Kyoto protocol and following developments.

European climate policy and company policy

Repsol's Business Strategy is defined in 5-year strategic plans. These plans are reviewed periodically taking into account climate change risks and opportunities that may impact Repsol's competitiveness and its strategic lines of action.

Repsol's Carbon Strategy aims at reducing the carbon footprint, improving the energy efficiency of processes and developing new low carbon business lines via the Repsol's Emerging Businesses Direction and Repsol's R&D Department. All of Repsol's business units and the Environmental Footprint and Carbon Unit Directorate participate in setting Repsol's Carbon Strategy. **Repsol's Strategy is particularly influenced by the EU-ETS, the EU Energy Efficiency and Renewable Energy Directives.**

Some of the most relevant elements influenced by climate change in Repsol's strategy are:

- a) Participation in the carbon market to maximise the value of allowances and reduce the cost of compliance.
- b) Promotion of energy efficiency in operations. Organisational and operational changes like the implementation of ISO 50001 certification for Energy Management Systems has been carried out.
- c) Repsol sets annual targets for emissions reductions which are linked to Repsol's strategic long term objective. Repsol's objective to reduce its emissions by 2.5 million tonnes from 2006-2013 compared to a "business as usual" scenario was surpassed one year ahead of time, and a total reduction of more than 3 million metric tonnes per year was finally achieved. Repsol has set a new target of 1.9 million tonnes of CO₂ reduction by 2020.
- d) Internalise carbon as input in the development of projects by establishing a carbon price on Repsol's emissions.
- e) Develop new low carbon business opportunities in fields such as renewable electricity generation, electrification of transport or renewable energies use in general.

Company's climate change and GHG emissions policy in comparison with competitors

Repsol is well positioned in comparison to its direct competitors. Repsol is leading the Climate Disclosure Leadership Index (CDLI, 2012), comprising the best 50 international companies in communication and transparency regarding climate change.

In terms of emissions performance, according to the Climate Performance Leadership Index (CPLI, 2012), Repsol (together with Spectra Energy, BG Group and Chevron) is one of the companies from the energy sector with the highest score in this field.

2.3.2.4 Low carbon investments

Description

Investments in Repsol's five refineries in Spain are presented in Table 5 below:

Table 5 Low carbon investments in installations in Repsol case study

No	Site location, country	Year of decision	Year of implementation	Brief technical & operational details about the low carbon investment or operational decision
1	All five refineries in Spain	2011	2012-2016	Optimisation of the use of installations: Reduce steam consumption in equipment, heat integration
2	All five refineries in Spain	2011	2012-2016	Operational improvements: Improve heater efficiency, operation improvement of diverse equipment such as columns, pumps, compressors, steam traps, etc.
3	All five refineries in Spain	2011	2012-2016	Update of operational criteria: Replacement of old steam turbines by new engine, replacement of liquid fuels by less CO ₂ intensive fuels, new criteria for stand-by equipment.
4	All five refineries in Spain	2011	2012-2016	Update of equipment: New furnace preheaters, better efficiency equipment, new steam traps.

Decision process

Strategic decisions and lines of action on climate change are established at the company's Executive Committee, which also approves the multiannual strategic objectives and the corresponding annual emission reduction targets.

The Executive Committee and the Audit and Control Committee of the Board of Directors review quarterly the execution of Repsol's Climate Change Strategy. The Environmental Footprint and Carbon Unit (under the Corporate Environment and Safety Direction) coordinates the actions with all business units involved.

Additionally, Repsol's scorecard includes conducting a quarterly report of CO₂ emissions for the Executive Director Strategy and Control.

For all four investments presented in this case study, the decision process was the same. First, Repsol defined a global target based on the benchmark results. Then a list of possible actions (investments, operational improvements, etc.) that could result in reductions of CO₂ was identified. A cost effectiveness evaluation was performed for all options on this list and their time line for implementation was also evaluated. Finally a ranking was established and decisions were made based on this ranking. The time frame for the overall implementation process is 2011-2016.

Drivers

The drivers for all four low carbon investments in order of priority were:

- Energy costs is by far the most important driver in the refinery sector
- Energy efficiency policy, especially due to the consequences it may have in lowering energy consumption and consequently energy costs
- Corporate GHG emissions policy, which is related to the objective of the company to reduce its emissions and also to indirectly reduce energy consumption
- EU ETS
- Energy security

Considerations of EU ETS

Energy costs are and will continue to be the main driver for decision making within Repsol. Energy costs represent 60 per cent of the total refining costs; this cost is so high that the carbon price appears minor in the ranking of drivers for investments. **The carbon price currently only plays a supporting role in the refining industry.**

As the EU-ETS is not directly relevant for low carbon decisions, Repsol does not hold internal carbon price estimations. **They usually work with carbon price forecasts from market consultants, such as Bloomberg and Point Carbon-Reuters.** These prices under different assumptions vary between €25/t and €40/t by 2025. These are the prices that Repsol considers in its analysis.

Energy and environmental impacts

Repsol has achieved a 15 per cent overall GHG emission reduction since 2010. Moreover, in the period 2006-13, Repsol has achieved more than 3 million tonnes of CO₂ abatement per year in all their activities. Every refinery follows a roadmap to reduce GHG emissions and keeps record of its GHG intensity indicator.

The emission reductions are tracked on a monthly basis and communicated to the Company Board. The indicator used is called IRCO₂ (CO₂ reduction indicator) and it is based on the benchmarking Concawe methodology, using 2010 as a baseline year: IRCO₂ = CO₂ emissions/CWT (CWT or Complexity Weighted Tone is proportional to CO₂ emissions at equal performance). This indicator measures the CO₂ intensity and allows a consistent comparison of results across years and between different sites. Specific reduction targets are set for each installation based on its capabilities and potential.

The energy and environmental impacts of the investments for each refinery has been different though. The results are presented in Table 6.

Table 6 Environmental impacts of low carbon investments at each refinery

No	Refinery name	Environmental benefits
1	Puerto llano	<ul style="list-style-type: none"> ▪ A reduction of 12.9 per cent of CO₂ emissions per unit of product was achieved in 2013 referred to 2010 baseline. The evolution of the CO₂ Emissions reduction index (IRCO) shows this reduction:

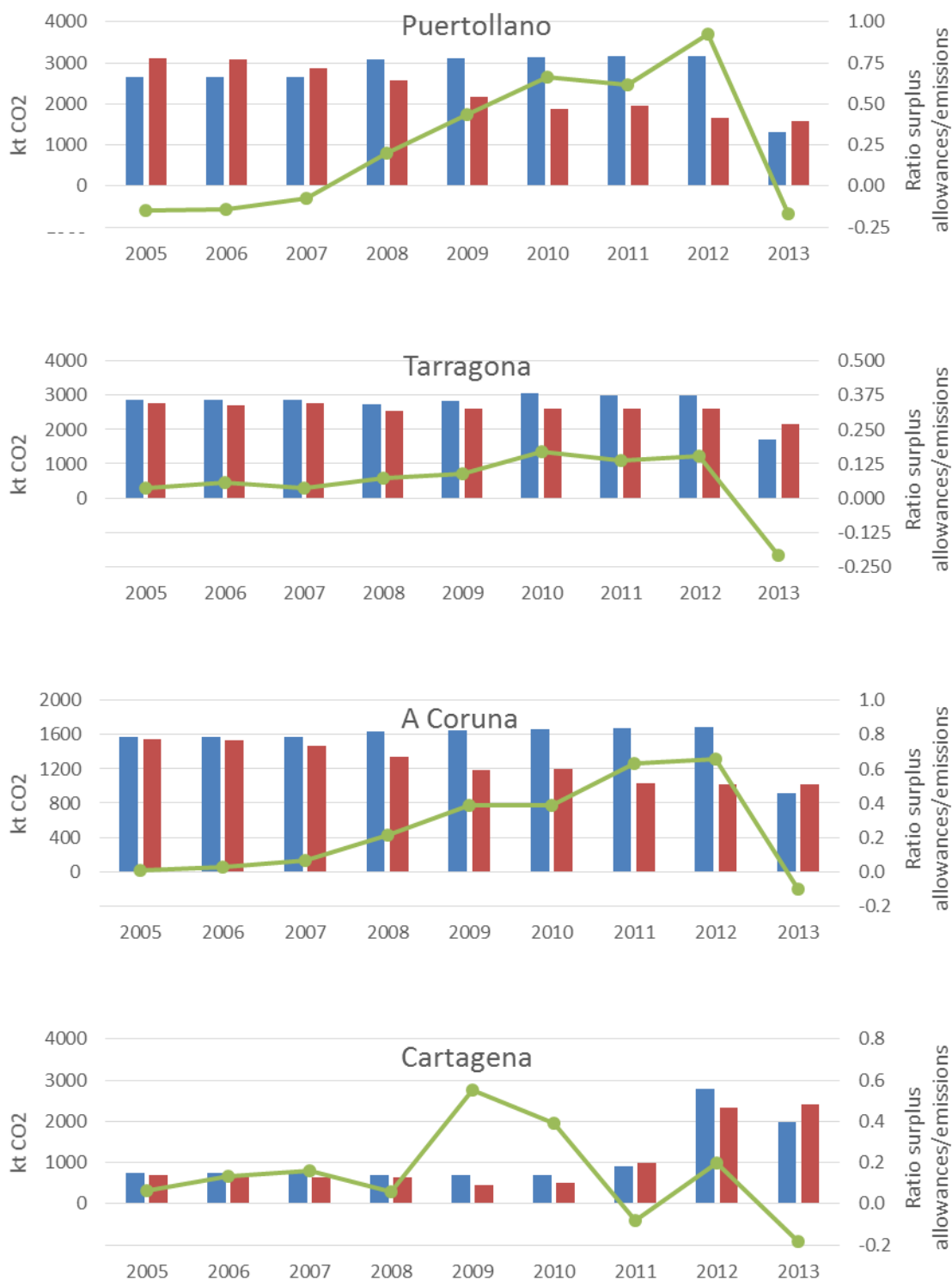
		<ul style="list-style-type: none">- IRCO 2010: 36.41- IRCO 2011: 34.66- IRCO 2012: 32.35- IRCO 2013: 31.72 <ul style="list-style-type: none">▪ Part of these emission reductions are certificated according to ISO 14064 standards. The total amount of CO₂ emissions reduction that were certificated by an external consultant was:<ul style="list-style-type: none">- ISO 14064 reductions 2011: 14,620 t CO₂- ISO 14064 reductions 2012: 32,937 t CO₂- ISO 14064 reductions 2013: 56,556 t CO₂▪ Replacement of liquid fuels by natural gas has resulted in the reduction of other pollutants into the atmosphere such as SO₂ or particulates.
2	Tarragona	<ul style="list-style-type: none">▪ A reduction of 25.5 per cent of CO₂ emissions per unit of product was achieved in 2013 referred to 2010 baseline:<ul style="list-style-type: none">- IRCO 2010: 43.52- IRCO 2011: 42,.13- IRCO 2012: 35.53- IRCO 2013: 32.43▪ Part of these emission reductions are certificated according to ISO 14064 standards. The total amount of CO₂ emissions reduction that were certificated by an external consultant was:<ul style="list-style-type: none">- ISO 14064 reductions 2011: 17,519 t CO₂- ISO 14064 reductions 2012: 96,207 t CO₂- ISO 14064 reductions 2013: 110,492 t CO₂ <p>Replacement of liquid fuels by natural gas has resulted in the reduction of other pollutants into the atmosphere such as SO₂ or particulates.</p>
3	A Coruña	<ul style="list-style-type: none">▪ A reduction of 13.5 per cent of CO₂ emissions per unit of product was achieved in 2013 referred to 2010 baseline.<ul style="list-style-type: none">- IRCO 2010: 37.90- IRCO 2011: 35.16- IRCO 2012: 34.20- IRCO 2013: 32.79▪ Part of these emission reductions are certificated according to ISO 14064 standards. The total amount of CO₂ emissions reduction that were certificated by an external consultant was:<ul style="list-style-type: none">- ISO 14064 reductions 2011: 44,436t CO₂- ISO 14064 reductions 2012: 57,199 t CO₂- ISO 14064 reductions 2013: 11,193 t CO₂▪ Replacement of liquid fuels by natural gas has resulted in the reduction

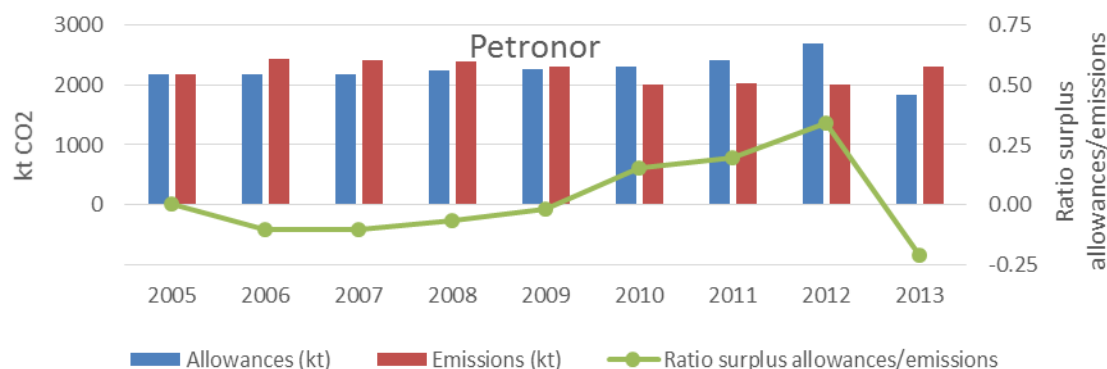
		of other pollutants into the atmosphere such as SO ₂ or particulates.
4	Cartagena	<ul style="list-style-type: none"> ▪ A reduction of 38.1 per cent of CO₂ emissions per unit of product was achieved in 2013 referred to 2010 baseline: <ul style="list-style-type: none"> - IRCO 2010: 47.38 - IRCO 2011: 42.87 - IRCO 2012: 29,59 - IRCO 2013: 29.35 ▪ Part of these emission reductions are certificated according to ISO 14064 standards. The total amount of CO₂ emissions reduction that were certificated by an external consultant was: <ul style="list-style-type: none"> - ISO 14064 reductions 2011: 21,975 t CO₂ - ISO 14064 reductions 2012: 113,019 t CO₂ - ISO 14064 reductions 2013: 76,085 t CO₂ ▪ Replacement of liquid fuels by natural gas has resulted in the reduction of other pollutants into the atmosphere such as SO₂ or particulates.
5	Petronor	<ul style="list-style-type: none"> ▪ A reduction of 3.6 per cent of CO₂ emissions per unit of product was achieved in 2013 referred to 2010 baseline: <ul style="list-style-type: none"> - IRCO 2010: 35.59 - IRCO 2011: 35.72 - IRCO 2012: 34.36 - IRCO 2013: 34.30 ▪ Part of these emission reductions are certificated according to ISO 14064 standards. The total amount of CO₂ emissions reduction that were certificated by an external consultant was: <ul style="list-style-type: none"> - ISO 14064 reductions 2011: 109,804 t CO₂ - ISO 14064 reductions 2012: 122,447 t CO₂ - ISO 14064 reductions 2013: 45,642 t CO₂ ▪ Replacement of liquid fuels by natural gas has resulted in the reduction of other pollutants into the atmosphere such as SO₂ or particulates.

Regarding energy consumption, there is no energy consumption indicator defined in a consistent manner that allows comparison between different years and sites.

Figure 6 summarises the verified EU ETS CO₂ emissions, allowances per installation per year 2005 to 2013, and the ratio of surplus allowances to emissions. When considering the production volumes too (as included in the Annex 2, these figures show that in years 2012 and 2013, the allowances sharply decreased despite an increase in the production of the interconnected refineries. In year 2011 the total allowances were 11,148 ktCO₂; in 2012, 13,372 (+20 per cent); and in 2013 7,762 (-42 per cent). On the other hand, production in 2011 was 27.9 Mtoe; in 2012, 33.3 Mtoe (+19 per cent); and in 2013, 35Mtoe (+5 per cent). I.e. despite allowances reduced by 30 per cent between 2011 and 2013 the production of the refineries increased by 25 per cent.

Figure 6 Allowances, emissions and ratio of surplus allowances to emissions for five Repsol installations





The production data provided by Repsol is aggregated for the five refineries as one system. No disaggregated production data is provided per refinery due to the commercial sensitivity of this information. Therefore it is not possible to show the evolution of the CO₂ emissions intensity per refinery. Note, that it is not appropriate to plot the CO₂ emissions intensity for the refining system as a whole. This is because of the difficulty to assign CO₂ to every fuel produced in a refinery. Therefore years are comparable only when the share of different fuels is similar across the years, which is not the case because production of different fuels depends on market demand and dynamics.

Cost impacts

For each investment, Repsol estimates the variable/operating costs and fixed costs, and evaluates the savings related to energy reductions and CO₂ emissions reduction.

No individual results were provided by Repsol in the interview. Investment costs are considered as commercially sensitive information.

2.3.3 Iron and steel – Tata Steel

2.3.3.1 Company details and its products

The combined Tata Steel group is one of the world's largest steel producers, with an aggregate crude steel capacity of more than 29 million tonnes and approximately 80,000 employees across four continents.

The European operations of Tata Steel's main steelmaking sites are in the UK and the Netherlands. Tata Steel in Europe is Europe's second largest steel producer. They supply steel and related services to construction, automotive, packaging, rail, lifting & excavating, energy & power, aerospace and other markets worldwide.

Tata Steel Europe's main products can be classified into three subsets with different components, namely flat products (such as packaging steels, narrow strip), long products (such as tubes, rail and rod) and construction products and systems (such as structural steels, walls and roofs) (for further information see Annex 2).

This case study covers the Port Talbot integrated steelworks in Wales, UK. Port Talbot Works makes liquid steel, which it and Llanwern Works in Newport roll from slab into strip.

2.3.3.2 Strategic considerations

Broadly speaking, Tata Steel sees fuel/energy taxes, regulatory uncertainty and changes in consumer behaviour as key risks related to climate change. These, in combination with supply chain risks and the physical risks to assets, mean that climate

change has been moving up the hierarchy of strategic considerations. Achieving a low level of GHG emissions and energy intensity (per unit production) is seen as important to gain competitive advantage by the company and is primarily driven through energy costs and product sustainability. For a growing number of customers, and indeed sectors, provision of a sustainable product is becoming a 'must', according to Tata.

Tata Steel as part of Tata Group is following certain environmental and climate related principles and commitments: according to the Group's sustainability policy, the group and its subsidiaries are committed to play a leadership role in climate change by adopting environmentally friendly technologies, business practices and innovation. Companies will furthermore measure their carbon footprint and will strive to be the benchmark in their segment of industry on the carbon footprint, for their plants and operations.

Tata Steel has its own carbon strategy which includes the following key areas/commitments:

- Reduce carbon emissions based on best practices and the sector benchmarks (as recognised by the industry)
- Employee engagement with focus on energy efficiency improvements
- Research into new carbon efficient technologies (mid to long-term perspective)
- Focus on improving products' life cycle energy intensity
- Work jointly with other steelmakers on the international level to promote climate policies that are less detrimental to European Steel makers
- A Europe wide internal emissions monitoring and benchmarking tool was developed (this was also rolled out to India, Singapore and the USA).

According to the company, the targets for emissions reductions (installation and company-wide) are currently under revision and cannot be published at this point. According to Tata Steel they are aiming to strengthen energy and CO₂ performance through this revision. Every installation / steelmaking site has targets on CO₂ and energy efficiency. Downstream operations have energy targets only. Tata furthermore has internal targets to improve the life cycle performance of final products (e.g. cars) they are producing. There is a strong focus on products as the capacity to reduce emissions over their complete life cycle here is much higher.

According to our interviewees, the approaches and limitations are broadly similar in the sector. Some companies have slightly more 'progressive' approaches. Voestalpine, for example, is seen as the EU benchmark. Except for Korea and Japan there are countries outside the EU where companies show advances in this area, according to our interviewees. Chinese steel companies are, however, starting to invest into emissions reductions technologies given recent pressures based on the piloting of emissions trading schemes in certain provinces and cities.

The company sees **little scope to implement further efficiency improvements in the steel production process**. A switch in production route from the blast furnace/basic oxygen furnace (BF/BOF) process to the Electric Arc Furnace (EAF) process could reduce emissions considerably (see also the steel sector case study in section 3.3). However Tata Steel highlights key factors limiting the potential for such substitution, namely the quality of the crude steel and availability of scrap¹² (this is

¹² Tata argues that EAF it is not a wider option for the world and cannot replace BOF technology. According to our interviewees 2/3 of the worldwide steel demand has to be covered by new steel (BOF), only 1/3 can be covered by scrap (EAF). This argumentation is building on the

also broadly confirmed by our steel sector case study in section 3.3. though no detailed data is available to confirm the availability of scrap in different EU countries, including the UK).

Our interviewees further argue that for historic reasons the EU28 has a higher ratio of EAF to BF production than Tata Steel has as a company. In the UK and for the Port Talbot plant specifically the expansion of EAF technology is difficult due to the high electricity prices (process costs would be too high). Tata argues that the investments highlighted in this case study were by far the largest carbon reduction options with reasonable payback schemes for Port Talbot. Other technologically achievable schemes under the BOF route, according to the interviewee, are much less effective in reducing emissions, and in the majority of cases do not meet payback criteria.

The European Commission's reference report "Best Available Techniques (BAT) Reference Document for Iron and Steel Production"¹³ provides insights on BAT conclusions for the BOF-Route. The BATs identified¹⁴ include the gas recovery system that Tata implemented under the described investments at Port Talbot.

Though this is outside the scope of this study, the specific case of Tata Steel would have to be assessed in greater detail to understand the economic viability of different abatement options for the plant. Interestingly, the Salzgitter AG case study under section 3.3 highlights similar technological changes to their production facilities as the most cost efficient and technologically viable option.

The box below provides an overview of potential abatement options within the EU more broadly.

European Steel Association – Eurofer position outlined in its publication "A Steel Roadmap for a Low Carbon Europe 2050"

¹³ http://eippcb.jrc.ec.europa.eu/reference/BREF/IS_Adopted_03_2012.pdf

¹⁴ The four BATs identified in the report include (1) Collect, clean and buffer BOF gas for subsequent use as a fuel; (2) reduce energy consumption by using ladle-lid systems; (3) optimise the process and reduce energy consumption by using a direct tapping process after blowing; and (4) reduce energy consumption by using continuous near net shape strip casting, if the quality and the product mix of the produced steel grades justify it.

Box 2 Technical review by the Boston Consulting Group and the Steel Institute VDEh of steel's CO₂-abatement potential in the EU

Looking at an independent assessment, this recent study assumes as a starting point that from an economic point of view, an absolute CO₂ reduction of about 10 per cent from 1990 levels is a realistic target for the steel industry outcome.

The authors argue that the latter objective can be achieved by an improvement in current production routes and an additional shift (from 41 per cent to 44 per cent) toward more Scrap-EAF steel. Depending on the scenario, by 2050 the average specific emissions per tonne of crude steel could be reduced from 1990 levels by between 14 per cent and 48 per cent.

Using carbon capture use and storage (CCS) in addition to other technologies could bring absolute emissions down by almost 60 per cent of 1990 levels per cent. But economic practicalities and uncertainty over the availability and public acceptance of CCS render this option highly speculative.

Looking also at how the steel industry can make a real difference as a mitigation enabler, the authors found that, with its strength and durability, steel enables savings in other industries. Their assessment of case studies shows that CO₂ savings in other industries can outweigh the emissions created by the production of the necessary steel at a ratio of 6 to 1—resulting in net savings of around 370 Mt CO₂ per year by 2030.

Source: Boston Consulting Group and the Steel Institute VDEh (2013): *Steel's Contribution to a Low-Carbon Europe 2050: Technical and Economic Analysis of the Sector's CO₂ Abatement Potential*

2.3.3.3 Low carbon investments at Port Talbot Plant

Description

Tata chose to reflect on three investments undertaken at the Port Talbot Plant:

Investment 1: Installation of a gas recovery system in 2010 to re-use gases produced at the Port Talbot plant to create electricity equivalent to 10 per cent of its needs.¹⁵

Investment 2: Introduction of a new cooling system at the BOF plant (waste heat recovery) in 2012, which reduced the amount of power Tata had to buy externally by 10MW (additional generation capacity installed as part of the scheme). Investment 2 enabled investment 3.

Investment 3: Extra investment into additional capacity for heat recovery in 2012, generating 1 MW of additional generation capacity installed as part of the scheme. By investing more than was strictly necessary in investment 2 it allowed Tata to undertake project investment 3.

Decision process

The decision making process was similar for all three investment decisions (and would also be a similar mandatory process for all investments over £1m). Decisions are based on an internal emission monitoring and benchmarking process that is

¹⁵ Described in local media bulletins at <http://businesscasestudies.co.uk/tata-steel/business-ethics-and-sustainability-in-the-steel-industry/making-ethical-and-sustainable-decisions.html#axzz3084iyMWy> and at <http://www.walesonline.co.uk/news/wales-news/corus-delivers-ambitious-project-reuse-1897589>

implemented in all installations. The company has developed detailed cost curves on central measures to achieve the benchmarks as defined by the industry.

Key steps include:

- Installations identify a list of possible projects and have to do a first round of prioritisation based on assessment by R&D departments and engineers
- Before a proposal is put to management it has to meet a number of criteria. Criteria include access to engineering expertise, how the project fits in with R&D priorities, internal rate of return, payback, and technological maturity. It takes installations up to a year to get an idea ready for approval.
- There is an annual round for approvals and these have to match and fit into the 5 year investment plan priorities and magnitude.
- For the largest investment proposals decisions are taken on the Group level, thus outside of EU.

Overall it was highlighted that decisions on capital investment proposals are competing with a variety of proposals:

- The mandatory schemes (based on national/local legislation etc.) have priority
- Essential replacement schemes come second
- Additional energy efficiency investments come third

Drivers

Primarily, Tata Steel was “unhappy at what it saw as wasteful flaring off of excess gas, especially at a time of rising gas prices”. Key drivers for all three decisions were:

- high energy costs and the need for energy security and independence
- internal company drivers such as the Tata Group’s objectives on climate change and sustainability
- low carbon products are highly demanded
- costs are key for any decisions. Sometimes a slightly longer, e.g. three to four year, payback period can be considered if a project has environmental elements.

The company argues that the EU ETS and carbon prices did not play a major role in these decisions. This is most likely due to the fact that during the time of decision making (in early 2009) the company had a high surplus of allowances and hence was not considerably affected by carbon prices under Phase II of the EU ETS. As mentioned by the interviewees, the carbon price only impacted indirectly, e.g. through the higher electricity prices. Indirect costs of the EU ETS have in the most recent past been a bigger issue for Tata than direct costs, but as the surplus of allowances in Phase II turns into a deficit in Phase III (due to the impact of benchmark-based allocations) for the company the direct impact of the carbon price will rise.

Considerations of EU ETS

Even though the company has benefited from over allocation of allowances in Phase I and II of the EU ETS¹⁶, company representatives highlighted that the allowance deficit under Phase III is putting increasing financial pressure on

¹⁶ http://www.sandbag.org.uk/site_media/pdfs/reports/losing_the_lead.pdf

the firm due to the need to purchase a growing amount of allowances on the market. Our interviewees declined to disclose future projected deficit figures for allowance allocations under EU ETS Phase III due to commercial confidentiality.

The internal carbon price at Tata is treated as confidential. The short to mid-term outlook is reviewed on a monthly basis. In this period the carbon price is perceived as relatively low. In the longer term (2020 and beyond) the price assumed has always been higher than the short-term view, and is factored into longer term strategic decisions.

Tata's longer term strategic directions also take the following factors into account:

- post-2020 – assumptions (EU ETS Phase IV)
- 2030 EU climate package
- progress on the global climate agreement

Energy and environmental impacts

Investment 1:

According to Tata Steel, the investment helped to save nearly 300 kt CO₂ per year from 2010. Note that the level of allowance allocation for the plant was 7.8 Mt CO₂ in the years 2008-12, with actual emissions reducing from 7.3 Mt CO₂ in 2010 to 6.6 Mt CO₂ in 2011 and 5.1 Mt CO₂ in 2012 making the approximate proportion of emissions reduction at the plant considerably higher, based on emissions covered under the EU ETS. Tata Steel indicates a 1 per cent reduction of overall emissions resulting from the low carbon investment though this cannot be independently confirmed based on the data available¹⁷. The investment has reduced the need for natural gas for power. Additional benefits were reduced emissions of dust particles by 40 tonnes a year.

Investment 2:

Tata installed 20 MW capacity, but 10 MW for 8000 hrs/yr is the reduction in external purchase.

Investment 3:

This scheme used some of the remaining capacity installed as part of scheme 2 to save a further 1 MW for 8000 hrs/yr.

All three investments at Port Talbot led to reductions in energy consumption, hence reductions in fossil CO₂ emissions. The CO₂ savings of the investments are summarised in Table 7.

Table 7 Summary of energy and environmental impacts of Tata's investments

Investment; location	Energy Savings (electricity)	Fossil CO₂ emissions saving (kt/annum)	Other impacts
---------------------------------	---	--	----------------------

¹⁷ The impact of the economic downturn in 2008/09 on emissions would need to be disaggregated to get a clearer picture isolating actual emissions savings resulting from the investment separately from impacts of the economic downturn.

Port Talbot 1	Savings are calculated at 10 per cent of current demand for electricity at the plant, coming close to 14 MW	Helped to save nearly 300 kt CO ₂ per year.	This has reduced the need for natural gas for power. Reduced emissions of dust particles by 40 tonnes a year
Port Talbot 2	Tata installed 20MW capacity; 10MW for 8000hrs/yr is the reduction in external purchase of electricity.	42.4kt CO ₂	
Port Talbot 3	Scheme used some of the remaining capacity installed as part of scheme 2 to save a further 1MW for 8000hrs/yr electricity.	4.24kt CO ₂	

The CO₂ emissions intensity (kg CO₂/t crude steel production) of Port Talbot over the period 2005 to 2013 is shown in Figure 7. **The small impacts of the investments are masked in the graph by dominant activity-based drivers and scope-related aspects:**

- **Activity.** There were lower production volumes during the economic downturn (fall-off began Q4 2008) that led to an energy intensity increase, though higher production volumes in 2013 did not lead to a lowering of energy intensity. Activity levels (and emission intensity) were also impacted by the restart of a furnace. This process re-development (one BF at Port Talbot was taken off-line for refurbishment during 2012 and did not restart until part-way through 2013) affects emissions intensity as it took approximately 6 months to fully commission the refurbished furnace and get it operating optimally.
- **Scope.** Changes in ETS scope led to an apparent 'rise' in emissions (and emissions intensity) in 2008 and 2013, according to the company¹⁸. This has a noticeable impact in the plot in Figure 7. This is due to the fact that additional processes at the installation level became covered by the EU ETS at the start of both Phases II and III, which, for a given production level and without technology change, leads to a rise in intensity.

¹⁸ A comparison of the Annex I from first ETS Directive and the 2009 revision shows that the additional coverage is "Production or processing of ferrous metals (including ferro-alloys) where combustion units with a total rated thermal input exceeding 20 MW are operated. Processing includes, *inter alia*, rolling mills, re-heaters, annealing furnaces, smitheries, foundries, coating and pickling" although previously, combustion installations over 20MWth were already included. So the difference here could be additional combustion units, or the named processes.

Figure 7 Fossil CO₂ emissions intensity at Tata Steel Port Talbot

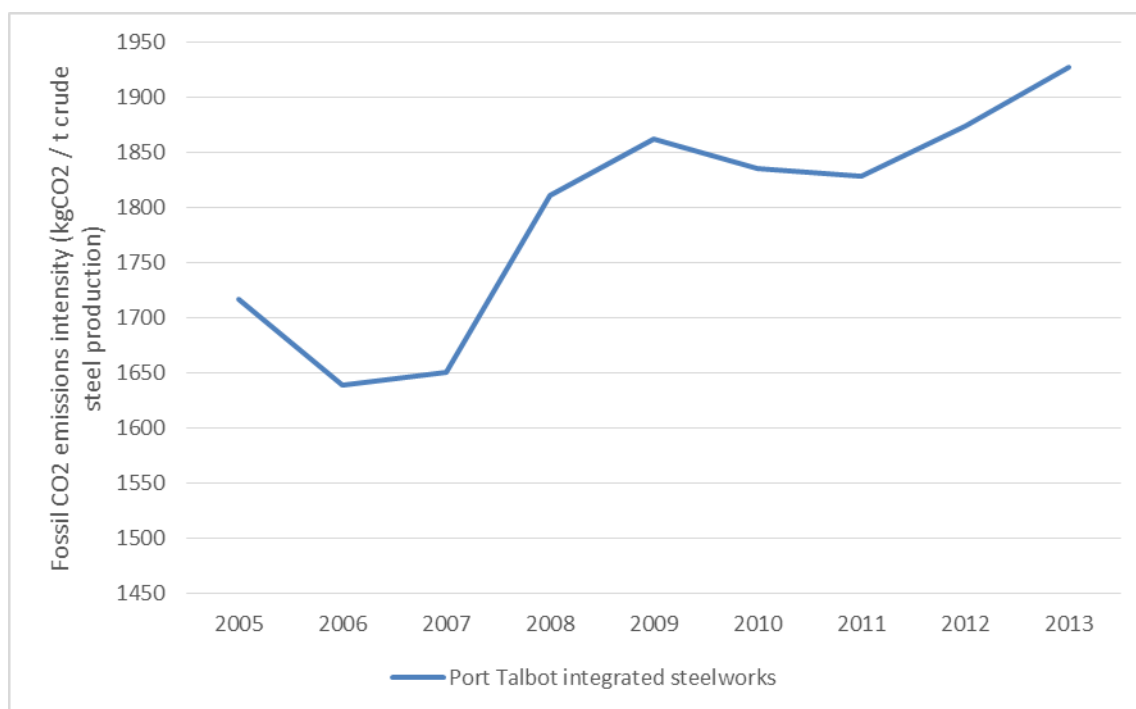
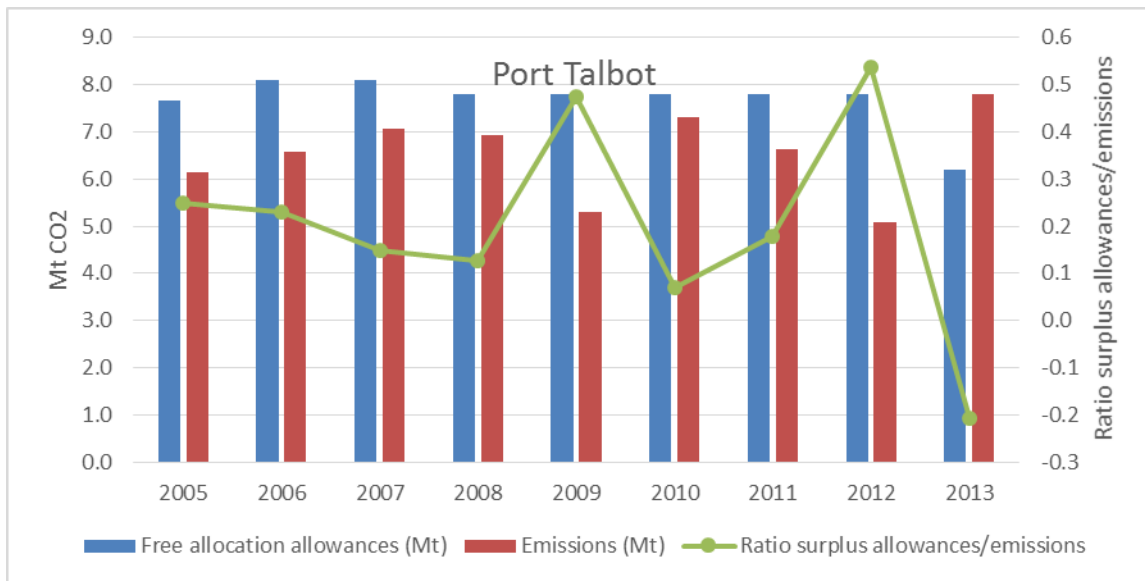


Figure 8 below summarise the EU ETS allowances, verified emissions data and the ratio of the surplus of allowances at Port Talbot, over the period 2005 to 2013.

This shows high levels of surplus allowances throughout Phases I and II, with a steep rise in the ratio of surplus allowances to emissions between 2008 and 2009 due to the economic downturn, followed by a subsequent fall of the ratio between 2009 and 2010. The emission reductions from investment number 1 described above would be expected to be visible from 2010 onwards with a subsequent reduction of emissions and an increase of the ratio of surplus allowances to emissions. The graph below (0) supports this interpretation. From 2013 however there is a turn in the ratio with emissions being clearly higher than allocated allowances. This is partly due to the change in rules for the allocation of free allowances based on best practice benchmarks, derived from the 10 per cent highest performers of steel producers in the EU. At the same time, emissions increased from 5 to almost 8 MtCO₂, which comes close to a 60 per cent increase. As before, the company argues that the step up in total emissions is mainly due to the restart of a furnace as well as additional on-site processes being covered by the ETS scheme in Phase III. Thus, if the years 2009 (financial downturn) and the 2012 (blast furnace off-line) would be taken out of the equation, the 'surplus' of allowances would have started to decrease since 2008, eventually leading to a deficit in 2013 which the company expects to become larger year on year up from 2013 onwards (Phase III).

Figure 8 Allowances, emissions and ratio of surplus allowances to emissions Port Talbot



Cost impacts

Investment 1:

The overall investment cost Tata £60m. Local press reports suggest that the energy saving brought about by the technology change means the investment will pay back within two years.¹⁹

Investment 2:

Overall costs for this investment were £53m.

Investment 3:

The investment costs were £2.5m.

Actual payback periods for the above investments were not disclosed by Tata Steel due to confidentiality of financial data. Tata Steel commented however that payback periods for these type of investments are expected to last in between two to four years (sometimes a slightly longer payback period, e.g. three to four years, can be considered if a project has environmental elements).

2.3.3.4 Broader observations and conclusions

From Tata's perspective, the first Phase of the EU ETS focused the attention of many companies onto CO₂ (as well as energy). However, the company emphasises that there is a clear limit in the short and medium term to how much more the steel industry can achieve in terms of GHG emissions reductions. Tata argues that a higher carbon price (as pursued in Phase III) will not make a difference in how much the company can reduce emissions. This is the case at least until late 2020s when breakthrough technologies currently researched under the UCLOS research programme (to which Tata Steel is a contributing partner, see text box below), such

¹⁹ <http://www.walesonline.co.uk/news/wales-news/corus-delivers-ambitious-project-reuse-1897589>

as the Blast Furnace with Top Gas Recycling (ULCOS-BF), Bath smelting (Hlsarna), Direct Reduction (ULCORED), or Electrolysis (ULCOWIN)²⁰, could become available.

Box 3 The Ultra-Low CO₂ Steelmaking (ULCOS) Research Programme

The ULCOS programme was launched in 2004 with the support of the EU provided by the 6th Framework and the Research Fund for Coal and Steel programmes. It's first Phase, called ULCOS I, ran until 2011, with a €75 million budget and EU support at the level of 40 per cent through four different coordinated projects, the remainder being financed directly by the project partners, including Tata Steel. The first objective of the ULCOS programme was to identify steel production process routes, which could robustly deliver cuts in CO₂ emissions of more than 50 per cent per tonne of steel. The breakthrough routes were worked out and demonstrated at a scale deemed sufficient for eventual commercial deployment. After benchmarking, modelling, laboratory, bench scale and pilot tests, four routes were selected in a final shortlist. Three of them rely on the use of carbon in coal, coke or natural gas, and thus also on Carbon Capture and Storage (CCS), in a way that has been tailored to the needs of steel production; a fourth process uses electricity directly and thus no direct carbon. A second Phase, ULCOS II, is now under way and should eventually lead to the development of all of these processes to commercial scale, if their technical feasibility is proved and if economic conditions are right.

Sources:

http://ec.europa.eu/research/infocentre/article_en.cfm?id=/research/star/index_en.cfm?p=ss-ulcos&item=Infocentre&artid=26913; Eurofer "A Steel Roadmap for a Low Carbon Europe 2050"

As made visible in the above figures, Tata Steel's allowances allocation is reducing in Phase III of the EU ETS. The need to buy additional allowances combined with the economic downturn since 2009 are perceived as an existential threat to the company. Following Tata's argumentation:

"In a low margin sector (and for many steel companies during the financial crisis this has been 'no margin') even a low cost of carbon results in a significant risk of loss-making on each tonne of steel produced. Such businesses are generally also highly capital constrained. Carbon costs directly impact by both reducing internal funds for capital projects, and increasing the risk level seen by potential external providers of capital. The deployment of available capital is therefore necessarily prioritised towards mandatory and essential replacement schemes, followed by product enhancement and cost reduction, e.g. energy efficiency schemes. To date carbon costs have therefore only indirectly affected investment decision-making. In the future (and with an annual deficit of allowances), the impact will increase. However, and returning to the margin issue, the risk is that investments will not be made within the EU."

This assessment should, however, be seen with caution given that the (currently low) carbon price is seen as a small factor in the equation, with profit margins being mainly influenced by the capacity utilisation ratio of steel producers.

²⁰ For an overview of technologies see Eurofer's "A Steel Roadmap for a Low Carbon Europe 2050"

In summary we understand from the case study that **during Phase I and II of the EU ETS Tata Steel was allocated a considerable amount of surplus of allowances taking away any pressure to invest in efficiency improvements based on carbon price.** The EU ETS seems however to have had an **indirect influence during Phases I and II as it provided a signal to company management that low carbon actions could be beneficial in the medium to long term future. Phase III of the scheme for the first time resulted in a deficit of allowances for the company that is predicted to increase in the following years.** Tata highlights the **higher carbon price to impact negatively on their competitiveness within and outside Europe and on their ability to invest in longer term efficiency options with high upfront costs.** The company stresses that there are prevailing technological limits in achieving further emission reductions with reasonable payback periods.

Despite this, the case of Port Talbot shows that **Tata Steel went ahead with major energy efficiency investments, driven primarily by the need for cost reduction and the broader impetus for sustainability improvements.** It is the consultant's view that the presence of the EU ETS and predictions for a rising carbon price must have improved financial viability for these investments.

2.3.4 Cement – CEMEX

2.3.4.1 Sector background across the EU and in country of case study

As will be noted in Chapter 3, demand for cement products, which is directly related to the construction sector, was strongly impacted by the 2008-09 economic crisis. After production peaked in 2007, and sharp drops in 2008 to 2009, 2010-12 levels of production stabilised at levels 30 per cent to 35 per cent lower than in 2007. Another key trend is that cement production in different EU Member States operates at varying levels of substitution of Portland cement with other cement products.

Cement products produced within the EU are for the most part consumed within the EU; very low quantities are traded outside the EU. The financial downturn of 2008-09 led to increases in exports in order to overcome the sharp fall in the internal demand.

This case study covers four CEMEX investments that aim at facilitating the substitution of fossil fuels with alternative fuels in their cement (clinker) production kilns. The investments highlighted in this case study have been made in production facilities of CEMEX operations in Central and Eastern Europe, including Poland, Germany, the UK and Latvia.

2.3.4.2 Company details and its products

CEMEX is a global player in the production and commercialisation of building materials. CEMEX is the world's leading supplier of ready-mix concrete, and one of the world's largest suppliers of aggregates.

CEMEX was founded in Mexico in 1906 and began its expansion into Europe in 1992. Today, CEMEX is a company that produces, distributes, and sells cement, ready-mix concrete, aggregates, and related building materials around the globe. The annual sales of CEMEX in 2013 amounted to US\$15.23 billion, and its operating EBITDA was US\$2.64 billion. Currently it employs more than 43,000 employees worldwide.

CEMEX is present in more than 50 countries throughout the Americas, Europe, Africa, the Middle East, and Asia. The global cement production capacity of CEMEX is 94 million tonnes in 61 plants. 27 per cent of total CEMEX sales are in Northern Europe, and 10 per cent in the Mediterranean region.

CEMEX is the leading provider of building materials in the four countries mentioned in which the investments took place. Some highlights of CEMEX operations in these countries are presented below:

- **Poland:** Focus on cement and concrete production.
- **Germany:** CEMEX plants are a top performer in the use of alternative fuels (82.6 per cent in 2013). CEMEX also offers a variety of special, innovative concrete products such as acid-resistant concrete for the construction of cooling towers and energy projects.
- **United Kingdom:** CEMEX in the UK is an important supplier of concrete block paving, roof tiles, flooring systems and sleepers for rail infrastructure.
- **Latvia:** Production expansion in 1 million tonnes per year with the construction of a new kiln at the Broceni cement plant in 2009.

2.3.4.3 Strategic considerations

Business impact of EU climate policy

According to CEMEX the **carbon price is not taken into account as a main decision factor for investments** any longer. It is seen as an **extra factor that can support decisions in favour of low carbon investments by improving marginally the business case**. CEMEX considers the current EU ETS policy as both a risk and an opportunity.

Risk:

CEMEX considers that the cap on the number of free EU-ETS allowances allocated to the cement industry should be based on a sectoral bottom-up analysis. This analysis would in their view be better done by the cement sector itself and audited by the EC. Sectoral caps within the EU-ETS would enable the cement industry to plan more realistic investments in GHG emissions reductions. In the same way the annual reduction factor should correspond to a sectoral roadmap that could then also be audited by the EC. **In CEMEX's view the risk of the current EU-ETS is that the technological limit for low carbon improvements could be reached too soon and any benchmarks set beyond these limits would considerably harm the European cement industry.**

This risk is currently mitigated somehow by the economic crisis. The economic crisis has caused a reduction of cement production and therefore of emissions. This results in the need for less CO₂ allowances to be bought on the market or in some cases a surplus of free allowances. But the risk will re-occur after economic recovery.

Another risk in CEMEX's view is the carbon price: if the price is too low (e.g. current prices), then it does not contribute to its objective of incentivising low carbon investments. If it is too high then the risk of becoming non-competitive increases.

Opportunity

CEMEX explains that if the carbon price is adequate (which they see at the level of 16-18 EUR/t CO₂) it is possible to invest in reducing CO₂ and still be competitive. With current low prices though (3-5 EUR/t CO₂), and depending on the price of fossil fuels, it may be more economically attractive to combust pet coke instead of alternative (low carbon) fuels.

Reducing GHG emissions intensity and competitive advantage

Within the EU market it is important for CEMEX's competitive position to make all feasible efforts to reduce the level of GHG emissions intensity. **Thanks to its investment programme for GHG emissions reductions, especially related to fuel substitution, CEMEX has gained a competitive advantage on other ETS participants, and so needs to buy fewer allowances than its European competitors.**

However, CEMEX has concluded that reducing GHG emissions within the EU-ETS is not a competitive advantage against cement importers. A level playing field in Europe can only be achieved if importers are also included in the EU-ETS. CEMEX suggests that considering all importers as one single production plant would make them compete in equal conditions and with a dynamic allocation of free allowances as well.

CEMEX regularly uses GHG emissions, fuel consumption, and energy efficiency as metrics to monitor its competitiveness against European producers and importers. As CEMEX does not have access to confidential information of its competitors, CEMEX uses CSR public reports from other companies to compare against. CEMEX also uses the Cement Sustainable Initiative (CSI) bi-annual publication with CO₂ emissions per tonne of product (global, per company, per region).

Reducing GHG emissions intensity and corporate image

Achieving a low level of GHG emissions intensity is important for CEMEX's image and profile. CEMEX is not only interested in reducing the CO₂ emissions of its production processes, but is actually more interested in producing cement and other building materials that can reduce the full lifecycle CO₂ emissions in the built environment. CEMEX highlights that it was the first global company in its sector that published the carbon footprint for all its products. Reducing the carbon footprint of its products has become the main driver for constant improvement within the company.

European climate policy and company policy

CEMEX highlights that climate policy is a crosscutting priority in the company, led from the top management by a global Vice President and manager on corporate environmental affairs. A sustainability policy, including climate change related objectives, is implemented throughout the company and communicated in the annual CSR report.

CEMEX has global targets on CO₂ reduction and energy efficiency. These targets are defined for the year 2015, compared to a baseline year of 1990. Regarding CO₂, CEMEX has committed to a global 25 per cent reduction in CO₂ emissions by 2015 compared to 1990 emissions. The installations presented in this case study have achieved fossil fuel substitution rates of up to 75 per cent.

Company's climate change and GHG emissions policy in comparison with competitors

Regarding climate change commitments, CEMEX sees itself performing at the same level compared to the rest of large European competitors. In topics like CDM though, CEMEX is more advanced and has developed more initiatives than its European competitors.

2.3.4.4 Low carbon investments

Description

Four installations in four different countries are presented in this case study. All installations are involved in the treatment, storage and feeding of alternative fuels, mainly Refuse Derived Fuel (RDF) from Municipal Solid Waste (MSW) to the clinker kilns. These installations and their description are presented in Table 8 below:

Table 8 Low carbon investments installations in CEMEX case study

No	Site location, country	Year of decision	Year of implementation	Brief technical & operational details about the low carbon investment or operational decision
1	Chelm, Poland	2006	2007	<p>Actions for the substitution of fossil fuel by alternative fuels:</p> <p>Refuse Derived Fuel (RDF) storage and feeding installation with trammel for drying the RDF before pre-calcination.</p> <p>Additionally, CEMEX has co-invested in an RDF treatment and preparation plant next to the cement plant. The plant is not operated by CEMEX.</p>
2	Kollenbach, Germany	2010	2011	<p>Actions for the substitution of fossil fuel by alternative fuels:</p> <p>Jäckering Mill. It included an RDF preparation plant, mill and dryer.</p>
3	South Ferriby, United Kingdom	2005	2006	<p>Actions for the substitution of fossil fuel by alternative fuels:</p> <p>Introduction of Climafuel - a RDF produced from commercial waste streams into the cement kilns. Burning of the fuel commenced in 2006 and complemented the use of Secondary Liquid Fuel (SLF) – waste solvents which was implemented in 2002 to replace the burning of solid fuels which consisted of a mixture of 90 per cent petroleum coke and 10 per cent coal.</p>
4	Broceni, Latvia	2006	2009	<p>Actions for the substitution of fossil fuel by alternative fuels:</p> <p>New alternative fuel feeding line to one kiln. New facilities are designed to achieve up to 80 per cent of fuel substitution. Alternative fuels used are RDF mainly from MSW, waste woodchips, shredded tires and milled rubber</p>

Decision process

CEMEX has a central planning department that takes the main role in the decision making process for all investments worldwide. This is supported by country specific resources and capabilities to perform feasibility and market studies, and to evaluate

the commercial and other benefits of strategic investments, as well as the interrelation of national investments with other needs at global level. There is also a global trading Division in CEMEX that has a say in any investment.

For all four installations in this case study, the decision process was following a similar structure. The timeline for decision processes depends on the specific project, but on average it takes half a year between conception and decision making.

- CEMEX informs itself about different options for investments and actions through market research, best practice sharing within the company and attending specialised technical conferences;
- CEMEX evaluates and selects candidate investment options with the help of financial indicators (IRR, NPV, ROCE), qualitative considerations like CSR factors, and different sensitivity analysis.

2.3.4.5 Drivers

CEMEX states that the drivers for all four low carbon investments in order of priority were:

- Energy costs, which is by far the main driver;
- EU ETS. While the benefits of the EU-ETS in incentivising low carbon actions is currently small, the scheme is considered as a supporting factor for all low carbon investments
- Energy efficiency policy as per their possibility of facilitating investments in energy efficiency that would result in lower energy costs
- Renewable energy policy

Considerations of EU ETS

CEMEX does not have carbon price expectations for the future. However, at the time of the decision making for the investments in this case study, CEMEX assumed for all four investments a carbon price of €15.5/t in 2013, €16.5/t in 2014, and €17.5/t in 2015 and onwards. The valuations for all four investments were prepared for the standard period of 10 years, considering benefits from 2013 onwards.

The carbon price for which EU-ETS would have become the top ranked driver for each investment has been different as presented in the following table.

Table 9 Carbon price increases needed to make ETS top ranked driver of investments

No	Site location, country	Carbon price that would have make EU-ETS the top ranked driver for each investment
1	Chelm, Poland	The carbon price would need to triple vs original assumptions for CO ₂ savings to be the main financial contributor – so approx. 45-50EUR/t of CO ₂ would be required
2	Kollenbach, Germany	Not the main factor for this decision
3	South Ferriby, United Kingdom	It would now be the cost of Climafuel per tonne as there is a CO ₂ saving because of its biomass content (typically 75 – 80 per cent)
4	Broceni, Latvia	The carbon price would have to meet the electric power cost at 73.9 EUR/MWh

Energy and environmental impacts

The energy and environmental impacts for each investment have been different. They are presented in Table 10.

Table 10 Summary of energy and environmental benefits of CEMEX low carbon investments:

No	Site location, country	Energy and environmental benefits
1	Chelm, Poland	<p>5 per cent of CO₂ reduction measured across the installation</p> <p>47 kt CO₂ reduced annually</p> <p>GHG emissions intensity (per tonne of product) is 38</p> <p>3 per cent reduction of electricity measured (4463 MWh/year)</p>
2	Kollenbach, Germany	<p>4.2 per cent (26,800t / 633,500t) of CO₂ reduction measured across the installation</p> <p>26.8 kt CO₂ annually</p> <p>31.3 kg CO₂ / t clinker</p> <p>Actual values of CO₂ emissions related to this project are not representative. This is due to the fact that various other factors have an impact on total CO₂ emission.</p> <p>No other environmental benefits have been reported.</p>
3	South Ferriby, United Kingdom	<p>For 2013, the site verified a total of non-biomass CO₂ equal to 283,208 t of CO₂ with a total biomass equal to 28,902 t of CO₂, or a total CO₂ of 312,110 t of CO₂.</p> <p>For the kiln only, using Waste Derived Fuel (WDF) it produced a total (including biomass) of 103,932 t of CO₂ or total non-biomass of 75,030 t of CO₂ and total biomass only is 28,902 t of CO₂. For solid fuels only the kiln would produce 138,075 t of CO₂ which would increase the installation production of CO₂ to 346,253 t. Clinker production for 2013 was 339,337 t.</p> <p><u>Reductions :</u></p> <p>per cent CO₂ reduction across installation = 10 per cent measured</p> <p>Annual emissions saving = 34 kt CO₂</p> <p>Intensity reduction per tonne of product = 0.1006</p> <p>Another environmental benefit has come in air emissions. NO_x has reduced by 80 per cent and SO₂ by 75 per cent compared to burning solid fuels.</p>
4	Broceni, Latvia	<p>The investment allowed CEMEX to increase alternative fuel usage rates from 70 per cent to 75 per cent for this installation. No other environmental benefits have been reported.</p>

Investments to substitute fossil fuels have given good results to CEMEX. Figure 9 shows the fossil fuel intensity along the period of study. The use of alternative fuels

varies year to year according to economics of conventional fuels and availability of alternative fuels.

Figure 10 shows for the four CEMEX installations the allowances, verified CO₂ emissions and the ratio of surplus allowances to emissions.

Figure 9 Evolution of fossil fuel consumption per ton of product at studied CEMEX installations

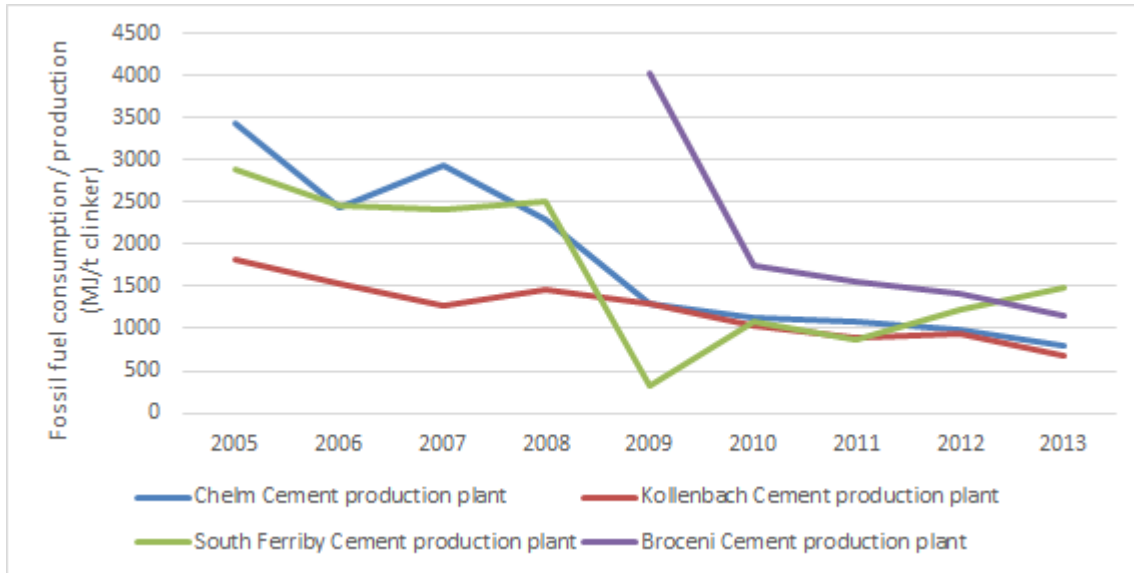
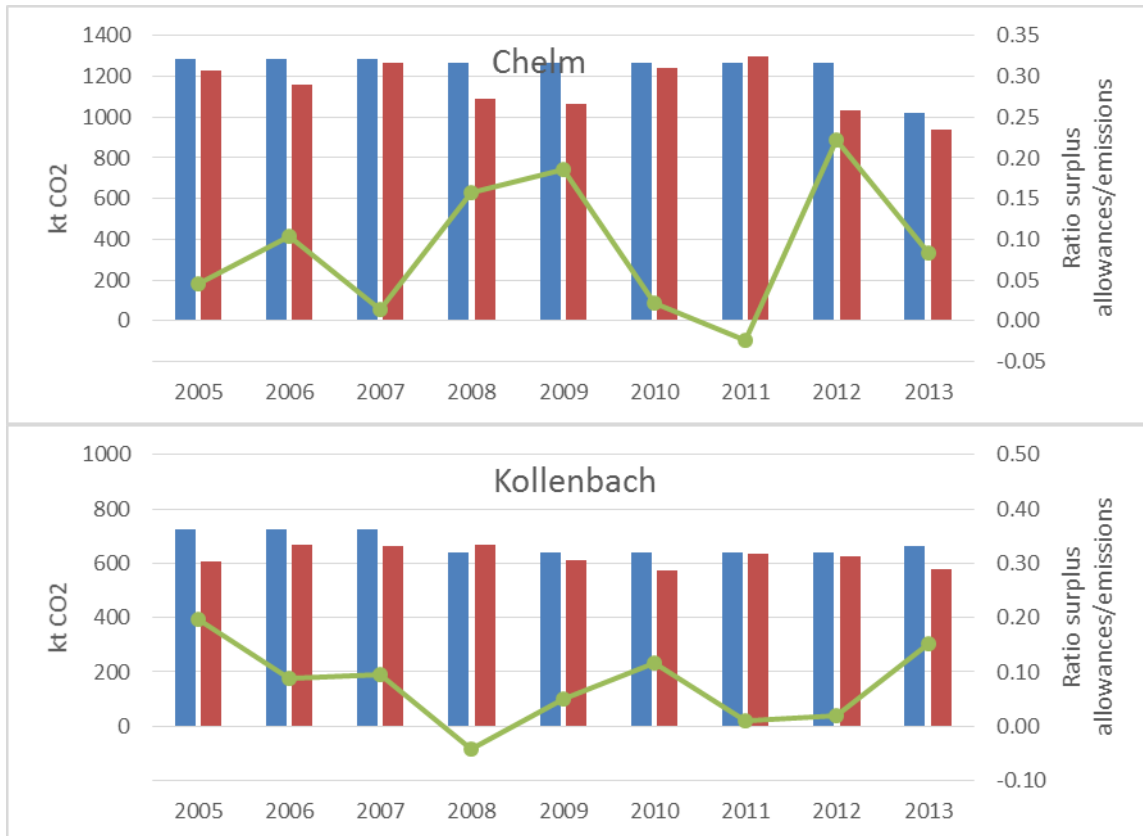
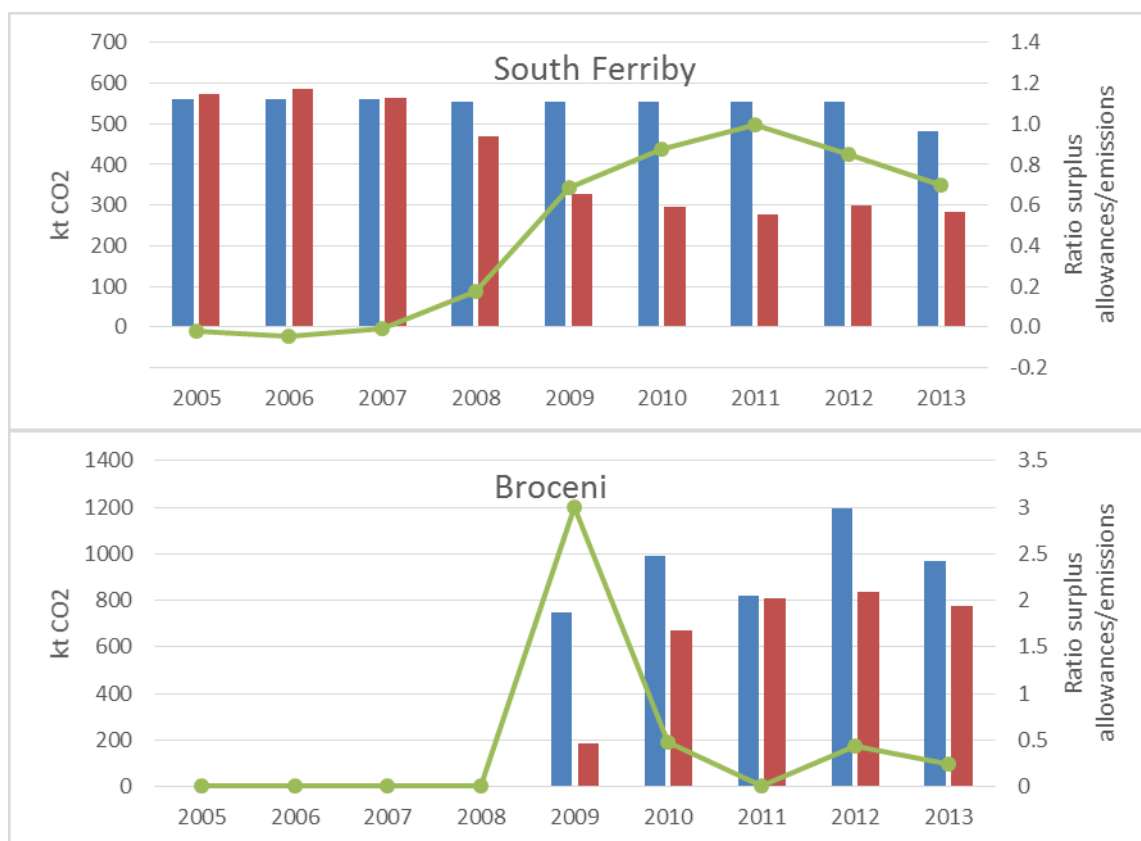


Figure 10 Allowances, emissions and ratio of surplus allowances to emissions for the CEMEX installations





2.3.5 Food – Nestlé

2.3.5.1 Company details and its products

Originating in Switzerland in 1866, Nestlé today has 447 factories in 86 countries around the world, with about 333,000 employees selling its products in 196 countries. Nestlé has a portfolio of more than 2,000 global and local brands²¹.

The main EU Member States in which Nestlé has EU ETS installations are Germany, France, UK and Spain. Out of 150 installations in EU, in 2013 nineteen were in the ETS.

Key Nestlé products include powdered and liquid beverages, water, milk products and ice cream, prepared dishes and cooking aids, confectionery and pet care²².

Nestlé's business principles take into account environmental sustainability such as natural resource efficiency, sustainably managed renewable resources and zero waste²³.

2.3.5.2 Strategic considerations

Climate change poses both risks and opportunities for Nestlé. In Phase III of the ETS Nestlé will have to undertake significant emissions reductions and / or buy allowances. This is seen as a cost (with uncertainty) and hence as a risk. The potential for emissions reductions and energy consumption savings more broadly are seen as an

²¹ <http://www.nestle.com/>

²² Nestlé's Annual Report 2013

²³ Source: Carbon Disclosure Project, CDP 2011 Investor CDP 2011 Information Request: Nestle

opportunity as they could provide competitive advantage for the company. Other important considerations regarding the impacts of climate change include water availability.

Nestlé is implementing projects under its Energy Target Setting Programme to reduce GHG emissions by:

- improving energy efficiency;
- switching to cleaner fuels; and
- investing in renewable sources.

Investments at Nestlé are assessed using different scenarios and including a range of factors. Environmental considerations (including water, environment, and climate change) play an important role in investment decisions and the company is undertaking efforts to introduce improvements where possible. The corporate sustainability profile is important to Nestlé. Decisions are based on longer term strategic assessments rather than on supply chain pressures.

Nestlé's Policy on Environmental Sustainability²⁴ identifies air emissions reductions and climate change adaptation as key focus areas. The company argues that it has a holistic approach towards climate change, because considering GHG emissions in isolation may have a detrimental impact on other environmental aspects, such as water. Nestlé is committed to phasing out hydrofluorocarbons (HFCs) and replacing them with safe and more environmentally sustainable alternatives, although expanding the deployment of freezers using natural refrigerants beyond Europe will require an appropriate maintenance network. The company regards biofuels as a major climate change challenge and, through its commitment on biofuels, Nestlé aims to take all possible and practical measures not to use liquid biofuel from first-generation agricultural products in their operations.

In 2012, the company renewed their emissions reductions and energy intensity targets, including among others:

- **By 2015** – Nestlé will reduce direct greenhouse gas (GHG) emissions per tonne of product by 35 per cent compared to 2005 levels, resulting in an absolute reduction of GHG emissions.
- **By 2015** – Nestlé will reduce energy consumption per tonne of product in every product category to achieve an overall reduction of 25 per cent compared to 2005.

As of 2013 Nestlé had reduced direct GHG emissions per tonne of product by 35.4 per cent since 2005, resulting in an absolute GHG emission reduction of 7.4 per cent (direct GHG emissions declined 14 per cent between 2005 and 2012, while production increased by 31 per cent). This means that the company achieved the objective it set itself in 2012 two years early. Nestlé has phased out 93 per cent of its industrial refrigerants with high global warming and ozone-depleting potential (2012: 92 per cent), and 18,000 of new ice cream chest freezers are using natural refrigerants.

Results from the Carbon Disclosure Project (CDP) indicate that Nestlé compares well against other multilateral companies: under the CDP Climate Performance Leadership Index Nestlé was rated in 2012 and 2013 as 'Best Performer'.

Company level performance is tracked under different zones: **Zone Europe** has defined targets for 2020 though these were not disclosed by the company. The

²⁴ <http://www.nestle.com/csv/environmental-sustainability/climate-change>

targets are defined by country /market and include energy efficiency, GHG reductions, water withdrawal, waste generation etc.).

2.3.5.3 Low carbon investment 1: Energy Target Setting Programme: Covering all the sites, covering 80 per cent of energy consumption in Europe.

Description

This company wide initiative started with Nestlé's ambition to reduce impacts while running a growing business with quite energy intensive products. The initiative was introduced in 2009 and has the following elements:

- Ten to 20 environmental experts (i.e. energy and water) go to each site for 2 to 3 weeks to review the energy and water mapping of the installation and based on latest technology and best practices they identify gaps and opportunities for improvements. Potential improvements related to water usage /GHG emission reductions are important in these assessments.
- A resource/energy reduction target is defined for each project to be implemented.
- There is a tracking tool with each project in the system to identify targets and current levels of implementation using a star system.

Initial results of the Energy Target Setting Programme:

- The Energy Target Setting Programme has shown that the company can enhance energy efficiency improvements considerably in each factory. Potential is between 10-20 per cent if no major investments have been implemented before.
- Best practices were shared among installations through an electronic system and the R&D department.
- The programme has also been used to optimise the operational processes in each installation.

Decision process

Within the EU 35-40 sites were assessed under the programme since 2009. Around 100 potential improvements projects were identified at these sites as a long-list. A selection process with specialists was undertaken to identify 20 to 30 of the most relevant projects and financial commitments were given to implement the projects on this basis.

The company is now focusing on the implementation of the identified projects and takes them into account in its yearly investment cycles to make decisions to invest.

Drivers

As part of the corporate strategy, broader sustainability considerations were driving the decision to introduce an internal Energy Target Setting Programme. According to Nestlé, the EU ETS played a minor role in this process. Every project under the programme has different dimensions and reasons (including but not limited to environmental reasons). For the below listed installation based investment key factors were highlighted separately. Key factories have targets of emission levels they want to reduce to each year.

There is a combination of reasons for taking investment decisions on resource efficiency improvements: Nestlé benchmarks factories. There are some companies

that perform better in energy use and have hence lower costs. The company tries to identify quick wins (5-10 per cent); the subsequent 5-10 per cent reductions are labelled as bigger investments for which the company and installation situations need to be taken into consideration).

Energy and environmental impacts

The Energy Target Setting Programme aims to improve the environmental performance of Nestlé's factories based on a thorough assessment of baseline energy and water consumption.

Under a business as usual (BAU) scenario 1-2 per cent improvements every year would be expected to occur. The Energy Target Setting Programme and projects identified under this framework deliver over 2-3 per cent per year over the BAU.

In 2013, on a global scale²⁵, the scheme identified 610 projects, expected to deliver annual energy savings of about 2 million GJ and 229,000 tonnes of CO₂e and 2.6 million m³ of water in the coming years. Nestlé internally tracks the savings delivered for each implemented project under the scheme. For the year 2013 annual savings amounted to 1 million GJ of energy, 3.6 million m³ of water and 68,800 tonnes of CO₂.²⁶

An example for a project in Europe identified through the scheme is the installation of a new evaporator at the Nescafé factory in Mainz, Germany, which is expected to save 19 million kWh, 70,000 m³ of water and more than 3,800 tonnes of CO₂ annually. Another example is provided below.

Cost impacts

For the 610 projects identified in 2013 on a global scale²⁷ Nestlé invested about CHF 61 million (about €50m).

2.3.5.4 Low carbon investment 2 - Wood fired boiler in Rosières, France

Description

Nestlé has recently invested in 3 sites in France to replace coal and gas boilers by energy efficient wood-fired boilers that are estimated to result in a reduction of approximately 30 per cent CO₂ of emissions. This section describes one of those three investments, identified under the Energy Target Setting Programme: the 1st wood-fired boiler was commissioned in 2012 in Rosières.

Decision process

The decision making process was broadly structured along the lines outlined under Investment Decision 1, Energy Target Setting Programme (see above).

The following considerations influenced the decision for this particular investment:

²⁵ Figures were only provided on the global level (disaggregation for the EU level is hence not possible)

²⁶ These savings resulted from projects identified before 2013 though no baseline year was provided by the company

²⁷ Figures were only provided on the global level (disaggregation for the EU level is hence not possible)

1st: Capacity increase was required in the factory; the old boiler was a bottleneck for production and needed to be replaced.

2nd: The company was looking for new sustainable fuel sources for their production facilities in France as part of their broader sustainability agenda.

3rd: The respective local authority in France issued certain subsidies for investments to create employment.

4th: Nestlé also evaluated that the site was key for Nestlé and it would be there for the next 10-15 years. That was the baseline for decision.

Drivers

The global sustainability plan and its priority to reduce emissions were the key drivers. An additional driver was the need to debottleneck: the boiler was old and inefficient.

Considerations of EU ETS

The effects of the EU ETS through the income generated by the sale of surplus allowances were considered as an additional benefit (worth €0.25m/year) but since the carbon price is difficult to estimate it was not a driving factor. Hence, this was a small factor in the cost estimate and was not the reason why Nestlé invested.

Nestlé have indicated that carbon prices below €15/t do not lead to significant impact on low carbon investments. **Carbon prices of around €30/t would, according to Nestlé, make the industry think differently about investment decisions.**

Energy and environmental impacts

The investment has led to a reduction of CO₂ emissions by 6 per cent or 25,000 tonnes per year on this site (compared to 400,000 tonnes overall emissions at the plant).

Cost impacts

The total investment cost for this improvement was €15m, of which €8-9m was funded by Nestlé and the remainder by the local authority as a job creation subsidy (see *Decision Process* above). This seems a sizable subsidy, and clearly exceeds the cost impact of the EU ETS.

2.3.5.5 Low carbon investment 3 - Anaerobic digestion plant in Fawdon, UK

Description

Nestlé UK have invested in an anaerobic digestion plant in Fawdon, UK that will recover energy from waste in the form of biogas. The plant converts trade effluent and residual confectionery ingredients into renewable energy. The electricity generated from biogas is used in the confectionery production processes, cutting energy and disposal costs and reducing the site's carbon footprint. This plant is representing a pilot site for sustainability improvements.

Decision process

The decision making process was broadly structured along the lines outlined under Investment Decision 1, Energy Target Setting Programme (see above).

In addition, the following considerations also influenced the decision for this particular investment:

The plant is acting as a pilot plant in the UK and internationally where the company implements and tests technologies to understand what can be achieved in line with Nestlé UK roadmap for low carbon development (see below). The technology is hoped to provide a blueprint for sustainable manufacturing. Benefits for Nestlé will include: Generation of renewable energy that can cover and exceed the energy needs at the plant, reduced energy consumption, lower waste and energy charges, revenues generated through feeding surplus energy into the grid, and the reduction of the on-site carbon footprint.

Drivers

The main driver was the sustainability roadmap that Nestlé UK has developed (for the company's operations in the UK) which includes an absolute GHG emissions reduction target of 30 per cent by 2020 from 2006 levels. Other targets they have set include zero waste to landfill, reduction in water production, establishment of nature reserve (Biotopes) on the site (to promote local flora and fauna conservation etc.). According to Nestlé, these targets are also driven by a high consumer expectations for sustainable production standards in the UK.

Although the factory is in the EU ETS, the level of emissions is around 6,000 to 7,000 tonnes of CO₂ per year, which is low compared to other Nestlé sites, and the ETS was not a driving factor in selecting this investment.

Considerations of EU ETS

See above.

Cost impacts

The investment costs were £4m. Payback periods have not been provided by the company.

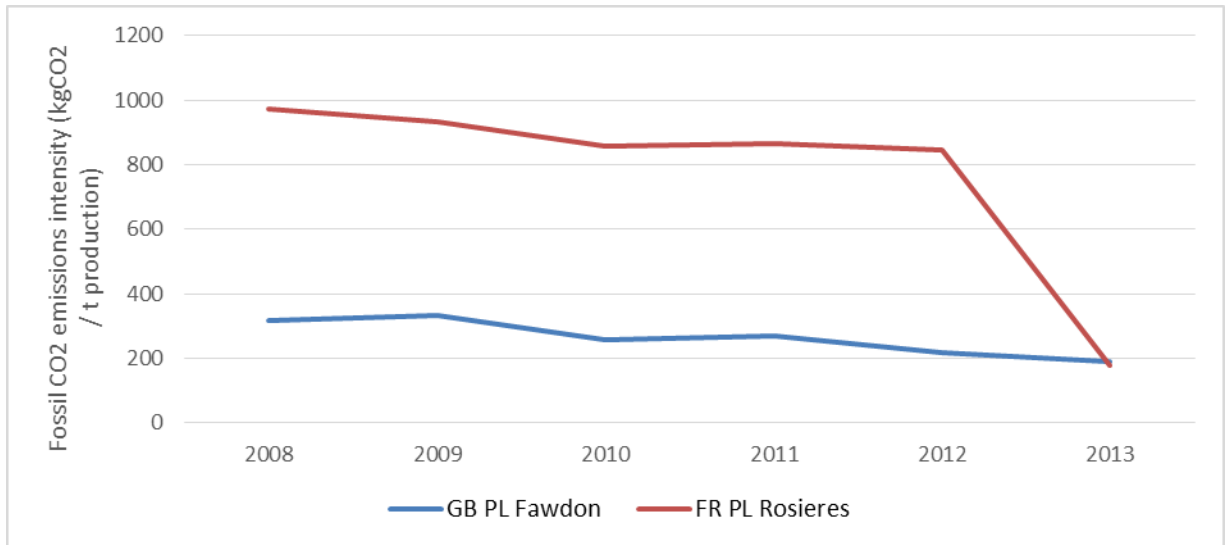
Energy and environmental impacts

When the anaerobic digestion plant is fully operational, it is expected to generate 300kW of green electricity that will be used in the factory, with any surplus power being exported to the grid²⁸.

2.3.5.6 Energy and environmental impacts of Rosières and Fawdon investments for Nestle

²⁸ <http://www.clearfleau.com/news/clearfleau-commissions-anaerobic-digestion-plant-for-nestle->

Figure 11 CO₂ emissions intensity at Nestlé installations covered by this case study



The investments described seem to have had a significant influence on the CO₂ emissions intensity at the two installations highlighted by Nestlé (Figure 11). In particular, the introduction of the wood fired boiler at Rosier results in large emissions intensity decreases as a result. The two figures below summarise the EU ETS allowances, verified emissions data and the ratio of the surplus of allowances to the emissions at each installation, over the period 2007 to 2013. Following the emissions reductions achieved through the investment at Rosières the allowance surplus increased significantly in 2013.

Figure 12 Allowances, emissions and ratio of surplus allowances to emissions for Rosières installation, Nestlé

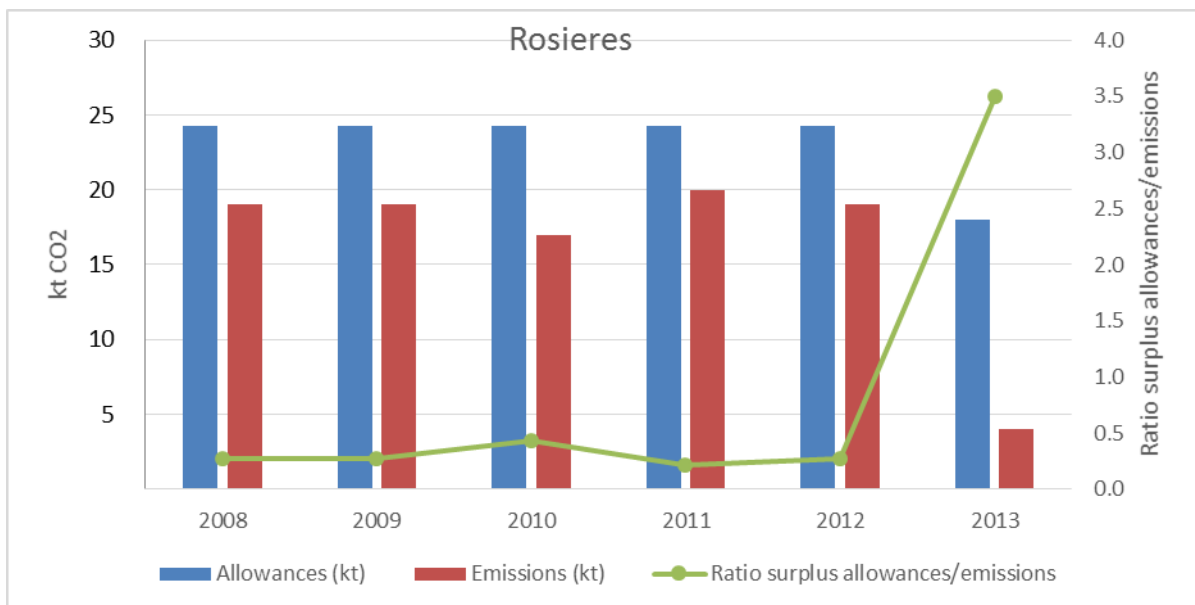
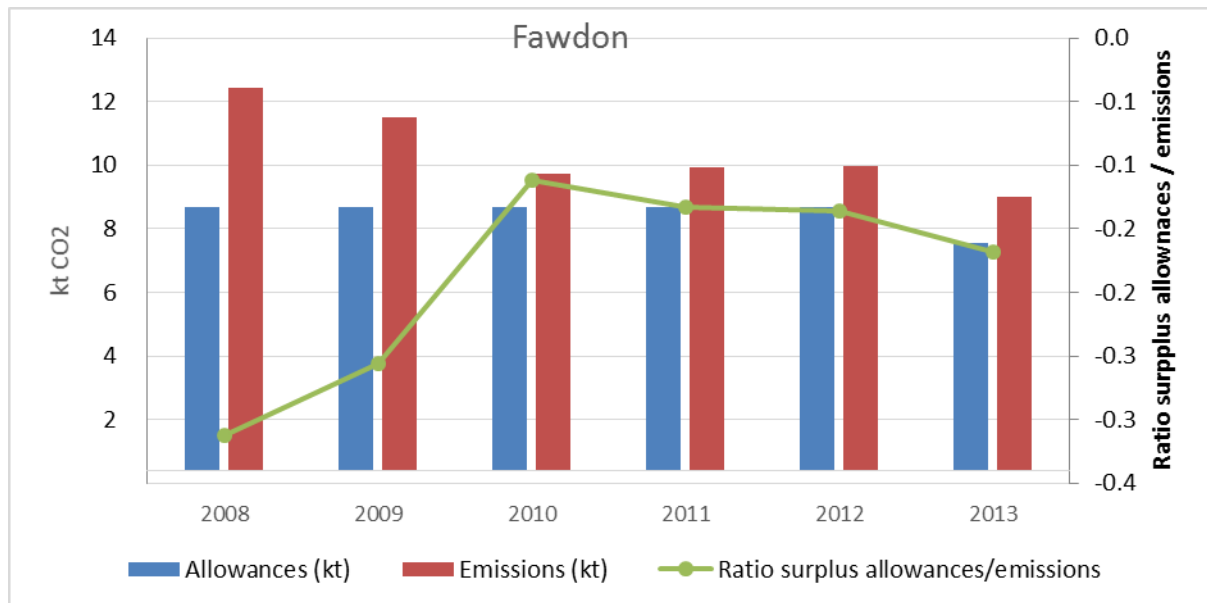


Figure 13 Allowances, emissions and ratio of surplus allowances to emissions for Fawdon installation, Nestlé



Broader observations and conclusions

According to Nestlé, EU ETS was not a key driver in the above mentioned decisions. It did play a role in discussions at the company management level during the first years after the EU ETS introduction but the decision to become more resource efficient was much broader and there were multiple benefits attached to this decision. The company's sustainability agenda, thinking of new solutions to reduce impact of the company on the environment and communities, was an important driver. **The EU ETS during Phase I and II acted as a supporting factor in the company's decisions to invest into sustainable and low carbon production facilities but Nestle has not changed their planning based on the policy.** For the time being the **carbon price is so low it has no impact on the decision.** If carbon costs would become significantly higher they would, Nestle argues, play a more important role. **A price of €30/t CO₂ or more could become an interesting point when companies start to think differently on the decision to include carbon in their considerations.**

Nestlé argues that there is a clear need to find solutions to improve emissions and there should be an efficient policy scheme to support this. **The interviewees argue that the EU ETS has the potential to act as a driver for significant emissions reductions but it needs to be reformed and become more rigid to perform this role.** Nestlé does highlight that the **EU ETS creates publicity and encourages discussions around the sustainability and low carbon issue on the board level.** Another benefit the company sees is that the **ETS has created visibility and awareness on the potential investments that need to be implemented**, e.g. through the necessary reporting of emissions reduction potential on the installation level. **No negative competitive impacts from the EU ETS are predicted at this point.**

From Nestlé's perspective, the EU is not sufficiently ambitious about the EU ETS. The company feels that it can gain a competitive advantage if it invests early. They can only make full use of this advantage if the price of carbon increases dramatically. The company furthermore argues that tighter caps for

some sectors and installations under Phase III of the EU ETS will not have sufficient impact. Current overload of credits **will** continue to be available later (2018).

Reflecting on Nestlé's assessment regarding the impact of the EU ETS on investment **decisions**, it is the consultant's view that, given that the company will be required to purchase a considerable amount of certificates for its emissions from concerned factories during EU-ETS Phase III, **the EU ETS must have played a bigger role in decision making processes on the company level during recent years than indicated during the interview for this case study**. This assumption is supported by a report of 2011 the company submitted to the Carbon Disclosure Project²⁹ highlighting that the EU ETS has played a major role in the development of an emissions reduction strategy in Europe. The report states:

"Nestlé will be required to purchase certificates for its emissions from concerned factories during EU-ETS Phase III. The cost of allowances is expected to rise as demand increases and the amount of allowances available on the market decreases due to carbon leakage measures benefiting large emitters. It might impact the production costs in factories participating in the scheme and affect their competitiveness (...). It might also impact consumer decision if costs of products manufactured in those factories are higher than competition."³⁰

In the report the company also highlights the opportunities and competitive advantage it associates with the increased compliance costs:

"The fact that Nestlé will probably have to buy EU ETS credits from 2017 (forecast) generates an additional motivation to reduce the total CO₂ emissions in order to reduce as well the total costs of credits which will have to be bought. The new technologies we are implementing and the experience acquired to reduce GHG emissions in EU will also be implemented in our others worldwide factories, and this will be clearly an additional competitive advantage where other countries will put in place GHG emissions reduction mechanisms (like Australia)."³¹

Most likely the carbon price crash following the economic down turn in Europe must have contributed to Nestlé's reassessment of the situation in 2014.

2.3.6 Chemicals – AkzoNobel

2.3.6.1 Company details and its products

AkzoNobel is a leading global paints and coatings company and a major producer of specialty chemicals. The company supplies industries and consumers worldwide with innovative products. The portfolio includes well-known brands such as Dulux, Sikkens, International and Eka. With headquarters in Amsterdam, the Netherlands, AkzoNobel has operations in more than 80 countries, with a staff of 50,000 people around the world.

²⁹ Investor CDP 2012 Information Request submitted by Nestle: http://www.nestle.com/asset-library/Documents/Creating per cent20Shared per cent20Value/Performance/CDP_Investor_2011_Final.pdf

³⁰ Ibid

³¹ Ibid.

2.3.6.2 Strategic considerations

AkzoNobel is a company that is highly resource- and energy-intensive. The potential impact of resource scarcity, energy costs and wider CSR risks are seen as the most significant risks for the company. Consequently, according to the company, sustainability targets and associated KPIs are on an equal footing with financial targets and associated KPIs in the business strategy; business operations are organised accordingly.

The company's strategy is based on the following six ambitions:

1. Achieve return on sales (operating income/revenue) of 9.0 per cent by 2015;
2. Achieve return on investment (operating income/average over 12 months invested capital) of 14.0 per cent by 2015;
3. Maintain net debt/EBITDA lower than 2.0 by 2015;
4. Increase revenue from downstream eco-premium solutions to 20 per cent of revenues by 2020;
5. Reduce carbon emissions through the value chain (excluding Scope 4) by 25 to 30 per cent per tonne by 2020 (2012 base);
6. Improve resource efficiency across the full value chain measured by a new KPI, a Resource Efficiency Index.

AkzoNobel has a long-standing reputation as a leader in the field of sustainability, evidenced by its consistently high ranking on the Dow Jones Sustainability Index. The benchmarking of these performance indicators is the tool used by AkzoNobel for comparison with competitors.

2.3.6.3 Carbon policy

During the early years of EU ETS preparation and implementation, AkzoNobel anticipated that a world-wide carbon market would evolve and that carbon would become an important driver for innovation and for investment decisions. The company established as internal policy to consider a carbon price in investment decision making that would reflect the costs of innovations required to drive down CO₂ emissions. After a few years into the EU ETS the company reassessed these assumptions and the internal policy was changed: CO₂ is now seen as an additional tax on energy and no longer as an explicit factor in the investment decision making process. The internal cost factor currently used is about €50/t CO₂e.

AkzoNobel claims to have fully integrated its sustainability strategy, which also includes a carbon policy, into its core business strategy. This stems from the recognition that the effects of climate change are likely to have fundamental impacts on the global environment, society and the economics of its own corporate activities and all other activities in their value chains. AkzoNobel has moved its sustainability engagement beyond controlling emissions from own operations towards managing the strategic risks from dependence on fossil fuels and fossil based raw materials throughout the company's product chains. The company has committed to develop eco-efficient solutions for customers, acknowledging the societal imperative as well as the business opportunity of managing its carbon footprint in the value chain through innovative products, technology and energy management.

AkzoNobel manages climate impact along the value chain and consequently measures and reports its carbon footprint. From 2009 to 12 this was done on a *cradle-to-gate*

basis³²; from 2012 this was changed to a *cradle-to-grave* basis³³. Target setting in 2012 (for 2020) was consistently adapted based on new figures on the actual carbon footprint. The measurement is based on key value chains (376 in 2013) which represent the company's main products or product groups and over 80 per cent of its sales. The company uses this information to identify improvement opportunities and to help customers reduce their footprints. All measurements are based on life cycle assessments and reporting is done in accordance with the Greenhouse Gas Protocol.

AkzoNobel has defined the following specific sustainability targets:

- **Specific target for GHG emissions (own operations scope 1 and 2) per tonne of product:** 245 kgCO_{2e} per tonne of production by 2015, which is a 10-15 per cent reduction compared to 2009. The target has been achieved by 2013 (verified by third-party auditing)
- **Absolute target for GHG emissions (own operations scope 1 and 2):** less than 4.6 Mt CO₂(e), which were emissions in 2008
- **Overall target of 25-30 per cent carbon reduction over the whole product value chain during the period 2012-2020.** This target is achieved through a combination of reductions in own emissions (scope 1 and 2), scope 3 downstream emissions and scope 3 upstream emissions. AkzoNobel's carbon footprint currently includes 4 Mt GHG emissions (calculated in CO₂ equivalents) in scope 1 and 2 emissions, 12 Mt in scope 3 downstream emissions and 11 Mt in scope 3 upstream emissions (Ref: AkzoNobel Report 2013 p 174).
- **Eco-premium solutions with customer benefits should reach 20 per cent of turnover by 2020.** The Eco-premium solutions concept was created as part of AkzoNobel's drive to translate the eco-innovation challenge into an operational target.
- **Targeted share of renewable energy of 45 per cent by 2020.** This is one of the contributing factors to the overall company carbon footprint target. The improvements will include purchased electricity and heat from renewable sources as well as on-site generation. One of the routes identified to increase the share of renewable electricity is to participate in cost-attractive large energy ventures. AkzoNobel aims to continuously grow its share of purchased renewable electricity stemming from projects where the company is either involved in the development process or owns part of the venture.

Throughout the company each Business Unit Manager is responsible for developing and implementing a Carbon Management Plan in line with the company's carbon framework policy. Based on this Carbon Management Plan targets are set at Business Unit level, which lead to the overall corporate sustainability targets. Carbon management is embedded into routine business management processes and achievements are verified by the company's external Auditor.

Given the strategic impact of climate change and carbon pricing the Board of Management of AkzoNobel has explicit oversight responsibility for the company's carbon policy. The Carbon management and innovation programs are reviewed by the Sustainability Council and the Executive Committee of the company.

³² Cradle-to-gate is a product Life Cycle Assessment from manufacturing of the product ('cradle') to the factory gate, i.e., before it is transported to the consumer. This means that the use phase and disposal phase of the product are omitted. Cradle-to-gate assessments are also used for environmental product declarations (EPD) in the scope of the ISO 14040 series of standards,

³³ Cradle-to-grave is the full product Life Cycle Assessment from manufacturing of the product ('cradle') to its use phase and disposal phase ('grave').

2.3.6.4 Monitoring and reporting

Through the value chain focus in their strategy, company targets and product development, AkzoNobel aims to use raw materials produced in energy and material efficient processes to produce products which are resource efficient for customers. AkzoNobel has developed quantified carbon management plans which identify specific improvement opportunities and programs. This requires the valuable input from comprehensive life cycle assessments.

The basis for all life cycle assessment calculations is the ISO standard 14040-14044. In addition to this, AkzoNobel has been involved in the development of carbon footprinting standards. AkzoNobel served as a pilot company in the development of the GHG Protocol Scope 3 guidelines and follows this Protocol and applicable ISO standards for their yearly carbon reporting. The division of emissions in different scopes (1, 2 & 3) originates from the GHG Protocol. Lifecycle thinking is the basis for all of AkzoNobel's sustainability work. It is included in many of their processes, including product development and eco-premium solution assessment, carbon footprint assessment, marketing propositions, and investment decisions.

Each Business Unit (BU) within AkzoNobel calculates its carbon footprint and reports on an annual basis. In this reporting, every BU has to document the basis for specific decisions taken regarding significant issues for that BU in a "BU carbon reporting documentation". The BU then reports on carbon emissions on the basis of sold product volumes outside the BU. Volumes of by-products and steam are excluded from this carbon reporting. The AkzoNobel carbon footprint is obtained from the sum of all BU carbon footprints.

- Calculate the carbon footprint for Key Value Chains (KVC) – cradle to grave.
- Calculate the carbon footprint for a Raw Material basket (covering at least 80 per cent of the raw material volumes) and add manufacturing site emissions and the emissions from key customer activities and end of life processes.

The AkzoNobel carbon reporting (2009-2012) included cradle to gate emissions. The "gate" is defined as the company's gate in those cases the company delivers 'ex works', i.e. when sales agreements include product delivery at the gate of AkzoNobel. The "gate" is defined as the customer's gate in those cases AkzoNobel has delivered that product at customer's gate.

For AkzoNobel the impact related to raw materials and products are of major importance in comparison to some other scope 3 emissions mentioned in the GHG Protocol. The company's current target is to reduce their cradle-to-grave carbon footprint of its combined emissions per tonne of sales for scope 1, 2 and 3 by 25-30 percent between 2012 and 2020. Reductions are pursued and realised in all parts of the value chain.

2.3.6.5 Low carbon achievements

The AkzoNobel Report 2013, page 205 reports low carbon achievements since 2009.

	Unit	2009	2010	2011	2012	2013	Target 2015	Target 2020
Energy intensity (own operations direct and indirect)	GJ/tonne of production	5.7	5.7	5.7	5.7	5.6	--	--

	Unit	2009	2010	2011	2012	2013	Target 2015	Target 2020
CO ₂ emissions intensity (own operations direct and indirect)	kg/tonne of production	272	267	256	257	222	245	
CO ₂ emissions intensity <i>cradle to grave</i> (reported from 2012, includes VOC emissions)	kg/tonne of product				1,700	1,600		-25-30 per cent
CO ₂ emissions intensity <i>cradle to gate</i> (reported up to 2012)	kg/tonne of product	980	960	950	950		10 per cent	

Although AkzoNobel has also actively monitored and reported data in earlier years, the company has chosen to only include data from 2009 onwards in its formal reporting due to large structural company changes including the sale of materials and pharmaceutical businesses taking place in 2008. These include the acquisition of Imperial Chemical Industries (ICI) for €10.66 billion. Following this important acquisition, the company has restructured its activities. The new structure was communicated on 2 January 2008, after which the company was rebranded in April of the same year including a small change in the company's name to AkzoNobel.

2.3.6.6 Investments considered for this case study

Three types of low carbon investments have been considered for this case study:

- **Installation of a biomass boiler in the Mariager facility in Denmark.** The boiler is fed with locally produced woodchips and has a production capacity of 17.4 MW of steam and 4 MW of hot water.
- **Construction of a new decorative paints facility in Ashington, United Kingdom.** This facility is being built according the latest state-of-the-art technologies. The facility is to replace current production sites and manufacturing operations elsewhere in the UK. The new factory will reduce energy consumption per litre of paint produced by 60 per cent compared to today's operations.
- **Use of the first biocide-free foul release fluoropolymer technology Intersleek.** The Intersleek technology is an AkzoNobels's eco-premium solution that has an improved static resistance to fouling growth that addresses the significant issue of slime fouling on ship hulls. It can save up to 9 per cent of the ship's energy consumption.

Other comparable investments include:

- **Upgrade of the chlorine facility in Frankfurt am Main, Germany.** Upgrade of the installation to use the latest membrane technology and to increase the production capacity by 50 per cent. This installation produces chlorine, caustic soda and chlorinated methane for the manufacturing of specialty chemicals and pharmaceuticals.

- **Use of Epicerol propylene to replace oil-based epichlorohydrin in coating products.** Epicerol is based on the use of natural and renewable glycerin (by-product obtained in the production of biodiesel) as a raw material, which has a substantially lower carbon footprint than fossil fuel-produced epichlorohydrin which is based on propylene, an oil derivative. Compared to the traditional manufacturing process, the production of Epicerol reduces GHG emissions by 27 per cent, biogenic CO₂ capture by 34 per cent, non-renewable energy consumption by 57 per cent and also significantly reduces the consumption of water and chlorine. By 2016, AkzoNobel aims to source 20 per cent of its total epichlorohydrin demand as Epicerol.

Additionally, it is worth mentioning AkzoNobel's efforts to develop eco-premium solutions that improve the carbon footprint in the application of their products. Besides the Intersleek technology and the use of Epicerol as mentioned above, other eco-premium solutions include:

- **Dulux Weathershield Sunreflect, an exterior paint with a solar reflectance index double that of regular exterior paints.** The paint can result in up to 15 per cent energy savings resulting from lower needs for air conditioning.
- **Dulux Light & Space, interior paints produced with LumiTec technology that reduce the amount of light that the painted surfaces absorb.** This can result in 20 per cent energy savings for lighting of the room.
- **Peridur, an organic binder based on a renewable raw material** that allows for production of iron ore pellets with superior metallurgical and chemical qualities. **Use of Peridur reduces slag waste and CO₂ generation throughout the iron and steel production chains.**
- mTA-salt, an industrial salt that increases the eco-efficiency of chlorine production by allowing up to 5 per cent energy savings. The entirely biodegradable product also enhances the safety of chlorine liquefaction by reducing the formation of the hazardous nitrogen trichloride.

2.3.6.7 Low carbon investment 1: Installation of a biomass boiler in the Mariager facility in Denmark

Description

Installation of a boiler with production capacity of 17.4 MW of steam and 4 MW of hot water. This boiler is fuelled with locally produced woodchips – transported around 70 km on average – complying with the Sustainable Forestry Directive introduced by the Danish Government and complying with EU directives.

Decision process

This investment was an OPEX driven decision fitting into the company's production concept of using mainly thermal energy (steam). As gas prices remained high and electricity prices kept falling due to increases in wind power capacity, CHP production based exclusively on natural gas became too expensive. The new boiler diversified the fuels used by the company by switching to a renewable fuel. The time period from decision to construction was slightly longer than one year.

Drivers

OPEX driven decision combined with the fact that AkzoNobel could sell the surplus of free allocations to help the investment.

Considerations of EU ETS

A price around € 23 per tonne of CO₂ was used in the calculations to make a decision for this investment. **EU ETS was not regarded as a key investment decision factor. This would have only been different at prices of approx. € 75 per tonne of CO₂.**

Energy and environmental impacts

Total GHG emissions reduction of 50 per cent has been achieved. For this calculation, woodchips have been considered carbon neutral as established by European regulations.

Cost impacts

The installation of this boiler included an initial investment of €8m, with an annual recurring running cost of €122,000. The annual savings in steam cost reached €2m. The overall internal rate of return (IRR) was 8 per cent.

2.3.6.8 Low carbon investment 2: Construction of a new decorative paints facility in Ashington, United Kingdom

Description

AkzoNobel is building a new paint facility in Ashington, UK which will become the new home to the company's UK Decorative Paints operations. The facility is to replace the current site in Prudhoe and its manufacturing operations in Slough, both in the UK. The Ashington plant is due to open in 2015. With the introduction of new building and process technology AkzoNobel aims to deliver a more efficient production with cost savings from reduced material and energy consumption per tonne of product.

Decision process

The investment decision was taken based on the opportunity to reduce energy and resource costs. For this plant specifically very high reductions in energy consumption are expected, estimated to be 60 per cent compared to current consumption levels.

Drivers

As with all investment decisions and operational decisions the main drivers for this specific investment were energy and resource costs.

Considerations of EU ETS

The EU ETS was not regarded as a key investment decision factor. The full evaluation process of all major investment decisions – and also for this specific investment decision – applies carbon costs as a cost plus factor on top of energy costs.

Energy and environmental impacts

The new factory will reduce energy consumption per litre of paint produced by 60 per cent compared to today's operations. Consequently the GHG emissions corresponding to the energy use for production of paint will also be reduced by over 60 per cent. Additional environmental benefits will be achieved from reductions in the use of building materials, annual fresh water usage and waste disposal. These benefits result from the fact that the plant is being built with cutting edge manufacturing technology

as well as the latest in building design whilst also making large sustainability improvements by recycling and reusing waste and water.

Cost impacts

Total investments for the new facility are approx. £100 million. Annual energy costs savings are predicted to be 60 per cent.

2.3.6.9 Low carbon investment 3: Use of the first biocide-free foul release fluoropolymer technology Intersleek

Description

AkzoNobel's Marine Coatings business has developed the Intersleek technology. This is the shipping industry's first biocide-free foul release fluoropolymer technology. The technology has an improved static resistance to fouling growth that addresses the significant issue of slime fouling on ships hulls. Compared to regular coatings ships can save on average 9 per cent of energy consumption by applying the Intersleek coating.

Intersleek technology was first developed in 1970 but was not commercialised until 1996. The technology has undergone further development through the years with commercialisation of products that increased the types of vessels which could use this technology. The first product, Intersleek 425, was for fast craft only (speed > 25 knots). Intersleek 700, launched in 1999, widened the vessel types to include deep sea liner trades. The first fluoropolymer coating, Intersleek 970, was launched in 2007 and further widened the vessel types to include slower bulk carriers. As the latest revision, Intersleek 1100SR specifically targets the on-going issue of slime allowing foul release technology to be used on virtually all vessel types.

Decision process

The continued development of Intersleek is part of the eco-premium solutions innovation solutions programme. The decision process for its use follows the plan to achieve AkzoNobel's targets.

Drivers

According to AkzoNobel, the main business driver was innovation and the company's strategy to bring sustainable value and benefits to its customers. The customer benefit is twofold:

- Customers can increase operational, environmental and energy efficiencies, which reduces fuel costs and emissions.
- AkzoNobel has developed a methodology by which the fuel and emission savings generated through using Intersleek technology can be translated into voluntary carbon credits from the Gold Standard Foundation which can be sold on the carbon market. AkzoNobel will give all of the net value of the credits to the customers applying Intersleek to help customers invest in these carbon reducing technologies.

Considerations of EU ETS

According to AkzoNobel, the EU ETS has not been part of the investment decision since it does not have an impact on AkzoNobel's direct emissions.

Energy and environmental impacts

AkzoNobel refers to various studies to estimate that the coating can result in a decrease of energy consumption of the ship of 9 per cent which translates directly into a 9 per cent reduction in GHG emissions.

Currently the effects of slime potentially costs the shipping industry 44 million extra tonnes of bunker fuel, which results in 134 million tonnes of CO₂ emissions every year. These GHG reductions are assessed on the basis of a peer-reviewed methodology developed by AkzoNobel and certification company The Gold Standard.

Intersleek technology has also been shown to have a significantly reduced environmental footprint compared to traditional fouling control technologies through a detailed eco-efficiency analysis verified by the Swedish Research Institute.

Cost impacts

At current bunker prices, the effects of slime on increasing fuel consumption cost the shipping industry around \$28.6 billion in additional fuel costs. Intersleek can save up to 9 per cent of these costs.

Broader observations and conclusions

AkzoNobel currently views the EU ETS as an add-on to energy costs and not as an explicit factor in the investment decision making process. In the first years of EU ETS preparation and implementation, AkzoNobel considered ETS as a major element in investment decision making, including a carbon price that would reflect the costs of innovations required to drive down CO₂ emissions. After a few years into the EU ETS AkzoNobel concluded the EU ETS did not live up to the company's expectations and the company consequently changed its internal carbon policy. **CO₂ is now seen as an additional tax on energy at a level of about €50/tCO₂e.**

AkzoNobel has a fully integrated carbon management system. Given the company's high resource- and energy-intensity AkzoNobel sees the potential impact of resource scarcity, energy costs and wider CSR risks as a most significant risk for the company. Consequently **sustainability targets and KPIs are at an equal footing as financial targets** and KPIs in the business strategy and the business operations are organised accordingly. **The carbon management activities are embedded in each of the company's Business Unit and in all routine business management processes. Achievements are externally verified. Given the strategic impact of climate change and carbon pricing the Board of Management of AkzoNobel has explicit oversight responsibility for the company's carbon policy.**

AkzoNobel manages climate impact along the value chain and consequently measures and reports its carbon footprint. From 2009-12 this was done on a cradle-to-gate basis; as of 2012 this was changed to a cradle-to-grave basis. The measurement is based on key value chains (376 in 2013) which represent the company's main products or product groups and over 80 per cent of its sales. The company uses this information to identify improvement opportunities and to help customers reduce their footprints. **All measurements are based on life cycle assessments and reporting is done in accordance with the Greenhouse Gas Protocol.**

An important element of the company's implementation strategy is the development of eco-efficient solutions for customers that **help improve managing the carbon footprint in the value chain through innovative products, technology and energy management.**

2.3.7 Power – CEZ

2.3.7.1 Sector background

The power industry is the largest single major emitter of greenhouse gases (GHGs) in the EU and the largest sector under the EU ETS system, with approximately 60 per cent of total emissions covered by the system (Eikeland, 2013). CO₂ is the major emitted GHG originating from combustion of fossil fuels in heat and electricity generation.

The power industry differs from other industries in the overall higher deficit of allowances allocated as compared to actual emissions throughout all trading periods (Ibid.). It differs also in that the carbon leakage problem associated with the EU ETS – relocation of production to non-ETS areas – has been seen as less relevant for the power sector given the limited opportunities for trade outside the EU ETS area due to limitations in existing transmission capacities (Ibid.).

2.3.7.2 Company details and its products

CEZ is a subsidiary of CEZ Group that operates power plants solely in the Czech Republic. CEZ Group also operates six other installations in the Czech Republic and is active in other EU countries including Romania, Bulgaria and Poland, and also in Turkey. The company primarily generates, distributes, purchases and sells electricity.

This case study focuses on CEZ (the subsidiary of CEZ Group) installations operated in the Czech Republic. With an installed capacity of 13,000 MW, CEZ owns 72 per cent of the market share in the Czech Republic (gross electricity generation).

2.3.7.3 Strategic considerations

In its first phase the EU ETS was seen as an opportunity by CEZ as the company felt it could gain competitive advantage through key investments in carbon reductions. However, given the current low carbon prices on the market, CEZ are not able to operate their newly refurbished low carbon plants on a profitable basis. Their operation only makes sense under the assumption of a high carbon price.

Given the current uncertainty about the future of the EU ETS, the policy is perceived as a strategic risk. Under high market prices (above €30/t) low levels of emissions intensity would be a competitive advantage, but under low prices this is not the case. This particularly applies to CEZ's new CCGT plant at Počerady. Under the current circumstances, running this plant and thus decreasing GHG intensity, would result in losses for the company.

According to CEZ, other European power sector installations are facing similar problems. There are a lot of newer (and lower carbon) gas-fired plants whose operations are currently stalled; whereas existing coal and lignite sources have been kept running as they have cheaper operating costs.

Compared to their competitors in Europe, CEZ has a medium CO₂ intensity (0.39 tCO₂/MWh), which is below the average of major European price setting power plants (with the emission factor of 0.8 t/MWh in 2012)³⁴.

³⁴ Presentation by CEZ representative Barbora Vondrušková (Nov 2013): LOW CARBON TRANSITION: CEZ GROUP AS AN EARLY GOER

Low carbon ambitions are part of CEZ's profile. However, CEZ highlights that there is a need to distinguish between the overall European market and the Czech reality. CEZ argues that in many European markets a low carbon profile will be essential to gain consumer approval. The Czech Republic market, on the other hand, is a more price-driven market, with low carbon only being important for a handful of consumers.

An Action Plan on emissions reductions was adopted by CEZ's Board of Directors in 2007 which included a target of 15 per cent emissions intensity reduction by 2020 compared to 2005 levels. The target at the company level is supported by targets on the installation level. Each specific installation has its own efficiency target and is responsible to implement measures to meet the target. CEZ has invested more than 120,000m Czech Crowns (approx. €4,370m) in low carbon so far which it sees as a substantive effort.

Our interviewees stressed that the company climate change policy is to a large extent dependent on the external economic drivers, among them the EUA price. Further CO₂ reductions will depend on the development of these drivers and actual economic incentives. The company has additional gas projects in the pipeline which they could further develop and implement if the carbon market provides sufficient incentives in the future. As with other competitors, CEZ has been forced to write-off part of the value of its CCGT plants (see description for Počerady below for further information) because of unfavourable market conditions.

2.3.7.4 Low carbon investments

Description

This case study covers four low carbon investments as described in Table 11. Three of those investments have yet to enter their operational phases (based on the low carbon price their active operation might not be financially viable). All of these investments have taken place in the Czech Republic.

Table 11 Low carbon investments in CEZ case study

#	Site location	Year of decision	Year of implementation	Brief technical & operational details about the low carbon investment or operational decision
1	Tusimice 2	2007	2012 (full operation)	Comprehensive refurbishment of coal-lignite plant. Four units were renewed and the power plant's efficiency increased by 6 percentage points (from 33 per cent to 39), saving 14 per cent of fuel per MWh produced. The refurbishment extends the plant life to 2035.
2	Počerady	2008	2016 (start of operation is unclear because of low price of power and EUA)	Počerady CCGT (steam-gas source with total generating capacity of 841MW _e , excluding heat output) is the first project of its kind in the Czech Republic. Installation is located in the area of the existing power plant at Počerady. Expected net efficiency is 57.4 per cent and service life is 30 years.
3	Ledvice 4	2007	2018 (full operation)	Coal power plant Ledvice with new supercritical unit (1 x 660 MW _e).

			Advance construction of the power plant structures, main focus on the boiler, T24 grade high pressure steel used. Planned net efficiency 42.5 per cent, service life 40 years.
4	Prunerov 2	2007	2018 (full operation)
			Investment represents complex renewal (3 units x 250 MW _e) of the coal power plant Prunerov. Net efficiency will increase to above 39 per cent (or 42 per cent if heat supply included).

Decision process

For **all investments**, CEZ follows a standardised decision making process. This includes six steps:

- A team of experts observes the environment and market conditions to get an idea of all the options that exist across all of Europe for the sector to identify what is feasible for specific locations.
- Based on this initial review, the costs and benefits are calculated: the price of the investment (including price of electricity, price of fuels and then price of CO₂ allowances and their development into the future) and net value of each project is calculated.
- In-house analysis with external consultants and financial advisors to identify risks and opportunities for each of the projects including policy impact assessment (forecasts with data from Eurostat, Entso-e etc.)
- Assessment of information and analysis from stages 1-3 in the framework of a feasibility and business potential analysis of each project to find out if and how conditions have changed, taking into account legislation, technology as well as economics (net present value, NPV).
- The Board of Directors decides on further investments based on these initial steps.
- Then practical preparations start (contracts with resource and technology suppliers).

In each phase the company adds details, e.g. through feasibility studies. The further the proposition advances the higher the probability of a project's realisation.

Usually, the phase of preparation takes 2-3 years and realisation 5-6 (in terms of coal fired) or 3-4 (in terms of CCGT) years.

Drivers

At the time of decision making, the main driver for all investments was the expectation that CO₂ prices would rise and low carbon investments would increasingly provide a competitive advantage. The EU Council Conclusions in 2007 and the Commission's proposal from 2008 were used to form these assumptions. CEZ also ran an impact assessment with the carbon price scenarios given by the Commission.

The second priority driver was market competition with CEZ observing that similar projects (like CCGTs) had been implemented by competitors (big energy utilities) in Spain, Germany and the UK.

Considerations of EU ETS

For all four investments, the carbon price outlook from the EC's impact assessment provided the basis for CEZ's calculations. The price estimated for 2020 was €30/tCO₂. CEZ ran several scenarios. Even their scenario with the lowest assumption assumed a higher price on carbon than the current market price of permits. Price expectation at the time of the investment decision were above €20/tCO₂.

Energy and environmental impacts

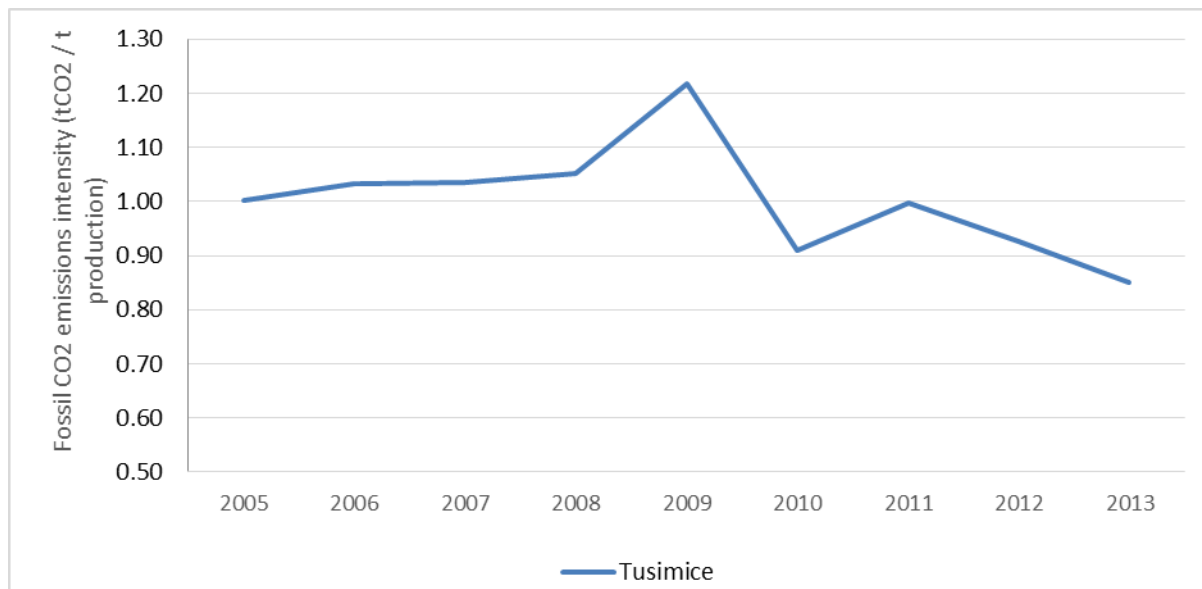
Table 12 Summary of energy and environmental impacts of CEZ's investments

Investment location	Fossil CO₂ emissions saving (kt/annum)	Other impacts
Tusimice 2	Expected reduction of 960 ktCO ₂ /year. Expected decrease in emission intensity by 31 per cent.	Emissions of nitrogen oxides decreased by 70 per cent, sulphur dioxide by 79 per cent and dust by 87 per cent. (However, emissions decreased in 1990s by more than 90 per cent).
Počerady	Estimated annual reduction is 2,800 ktCO ₂ . <i>Note 1</i>	Not available yet.
Ledvice 4	Expected reduction of 1,140 ktCO ₂ /year. Emission intensity should decrease by 31 per cent	Not available yet.
Prunerov 2	Expected reduction of 960 ktCO ₂ /year. Expected decrease in emission intensity by 31 per cent.	The emissions of nitrogen oxides decreased by 59 per cent, sulphur dioxide by 57 per cent and dust by 39 per cent. (However, the power plant underwent its first efficiency improvements in the 1990s when its emissions were decreased by more than 90 per cent).

Note 1: CEZ has been forced to write-off part of the value of its CCGT Počerady because of unfavourable market conditions, namely EUA price).

The CO₂ emissions intensity of the Tusimice plant is shown below in Figure 14. The intensities for the other sites are not shown as their effects are not yet (in 2013) observable.

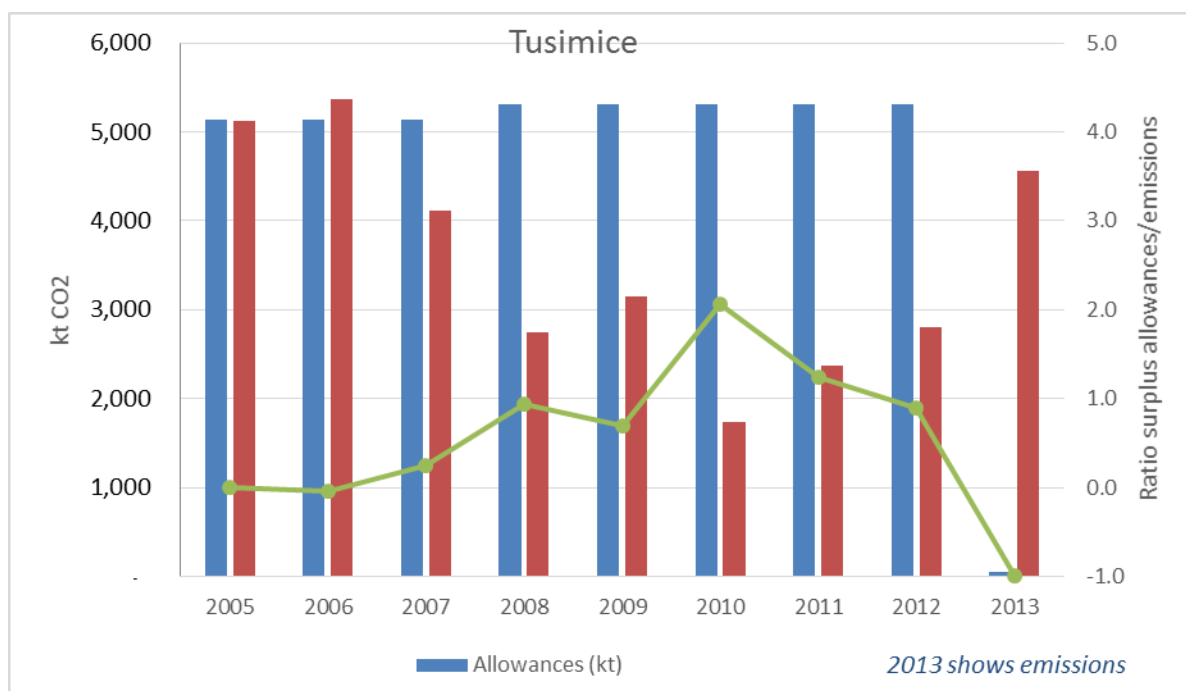
Figure 14 CO₂ emissions intensity at the CEZ Tusimice installations covered by this case study



The above figure (Figure 14) shows the improvement in energy efficiency achieved at the Tusimice plant between 2009 and 2013, which is attributed to the described investment, and which contributes to fuel consumption reductions of 14 per cent per MWh produced.

This is also visualised through the graph below (Figure 15) which shows the ratio of surplus allowances to emissions from 2005 to 2013. In 2007 the ratio is clearly increasing with an increasing number of surplus allowances and decreasing emissions at the plant. The phase II allocation of allowances for the plant ends after 2012 because in phase III from 2013 power companies have to purchase all allowances on the market. As a reason for the sharp increase in production in 2013 CEZ stated that the plant was put into full operation the year after the complex refurbishment initiated at 2007.

Figure 15 Free allowances, emissions and ratio of surplus free allowances to emissions for Tusimice installation, CEZ



Note that 2013 shows emissions allocated under Article 10a of EU ETS Directive

2.3.7.5 Cost impacts

The following investment cost information was provided by the company:

Table 13 Approved and confirmed investments of CEZ into chosen low carbon projects

	Permit ID	Total investment (CZK million)	Total investments (approx. EUR m equivalents)
Tušimice 2	CZ-0209-05	26,400	962
Počerady	CZ-0478-12	16,500	601
Ledvice 4	CZ-0447-11	40,500	1,476
Prunéřov 2	VZ-0207-05	32,200	1,173

CEZ highlighted that data on payback periods is confidential and that changing market conditions make it difficult to assess the pay-back. CEZ did however indicate that the investments' payback periods now look more negative than at the time the investment decisions were made.

Broader observations and conclusions

Early in the ETS, CEZ Group had high expectations on the carbon price and hence invested in the new CCGT project and coal fired retrofits.

In the current climate however the impact of the carbon price is almost negligible. CEZ estimates that to initiate coal- to gas switching on a larger scale the carbon price would need to rise to around €30/t (this is also due to the coal price decreasing significantly during past two years).

Based on these realities their low carbon gas plant(s) currently are planned to end-up in the cold reserve, i.e. not operational. If carbon prices increase CEZ will consider connecting them to the grid.

CEZ has been critical of the current oversupply of allowances. As a consequence, the price of the allowances is around €5/t, despite the fact that **there is no installation with marginal abatement costs of €5/t, so allowances selling at €5/t have no effect. The low carbon prices do not only imply that low carbon plants cannot be operated at reasonable costs, but carbon intensive plants are being put back into operation** (see the recently increased emissions in Germany in both relative and absolute terms). This is not only the case for CCGT but also for other low carbon technologies in the power sector. These technologies can only be profitable if there is a reasonable (higher) carbon price.

CEZ stresses however that the malfunctioning of the EU ETS has significant consequences for the future as it impedes gradual deployment of low carbon plants. This means a risk for security of supply as well as inefficiency and ineffectiveness in terms of costs (i.e. the EU ETS is not enabling the choice of the most cost efficient measures to tackle emissions).

CEZ furthermore sees a threat that the increased deployment of renewables, based on a non-market approach and relying on national support schemes, conflicts with the EU ETS as it creates emission buffers in the ETS with absolute targets. Moreover, CEZ argues that the expected capacity mechanism can hamper the completion of the internal market, if not fully harmonised at the EU level.

EU ETS reform suggestions

CEZ argues that structural reform of the EU ETS should be implemented quickly and should be ambitious enough to create a clear price signal. The Post 2020 Framework should correspond to the 2050 Roadmap targets, meaning a 40 per cent reduction target should be included (35 per cent from CEZ's perspective only means the continuation of the present trend). CEZ suggests furthermore that **a supply adjustment mechanism should be introduced. A market stability reserve is perceived as positive but its modalities should be changed compared to what is currently proposed (external economic trigger to adjust the supply and initiate the reserve instead of the band-based mechanism).**

CEZ is expecting higher simplicity and for the rules not to change beyond current proposals for legislation.

2.4 Summary

This section brings together the key results from company/installation case studies conducted for this project, adding additional relevant results from case studies from

external projects, including the DG CLIMA Communications on ETS Design project led by ICF, where available. Case studies included are listed in the table below:

Table 14 Case studies reviewed

Sector	Company	Source
Pulp and Paper	SCA	This study
Pulp and Paper	Norske Skog	Other literature sources
Cement	CEMEX	This study
Cement	Heidelberg Cement AG	This study
Cement	Holcim	Other literature sources
Steel	Tata Steel	This study
Steel	Salzgitter AG	This study
Steel	Celsa	Other literature sources
Refineries	Repsol	This study
Refineries	Shell	Communications on ETS Design
Refineries	Exxon Mobil	Other literature sources
Chemicals	AkzoNobel	This study
Chemicals	Borealis	Communications on ETS Design
Power	CEZ	This study
Power	Drax	Communications on ETS Design
Chemicals	DSM	Communications on ETS Design
Tyres	Michelin	Communications on ETS Design
Food	Nestle	This study
Food	Suiker Unie	Communications on ETS Design
Aviation	Virgin Atlantic	Communications on ETS Design

Results of the collation and comparison are summarised for each of the key questions for the study. Through the comparative analysis we attempt to identify key factors influencing companies' decision making for low carbon investments and their perspective on the EU ETS as a driving factor for those decisions.

2.4.1 Climate change policies and companies' strategic considerations

Is the potential business impact of climate policy seen as a significant strategic risk or opportunity to companies?

Companies provided a varied picture on how they assessed risks and opportunities resulting from climate policies on the EU level. Key factors that determined companies' overall assessment of risks and opportunities related to the EU ETS included:

- *Allocation of allowances, ETS defined benchmarks and cap setting:* A **tighter cap for installations under Phase III and additional costs** that resulted from the need to purchase allowances were highlighted by some of the companies interviewed. This includes energy intensive companies such as Tata (steel) and CEMEX (cement) but also less energy intensive ones such as Nestle (food).

Both Tata and CEMEX highlighted **'unrealistic benchmarks' for the steel and cement sector under Phase III** and the **technological limits their sectors are reaching regarding efficiency improvements (in the short and medium term)** as major risks. Both companies suggested bottom-up benchmarks defined by the industry as a more realistic solution.

"CEMEX considers that the cap on the number of free EU-ETS allowances allocated to the cement industry should respond to a sectoral bottom-up analysis. This analysis would be better done by the cement sector itself and audited by the EC. Sectoral caps within the EU-ETS would correspond to the real capacity of the cement industry to invest in GHG emissions reductions. In the same way the annual reduction factor should correspond to a sectoral roadmap that can also be audited by the EC. The risk of the current EU-ETS is that the technological limit for low carbon improvements could be reached too." (CEMEX)

The **change in allocation of allowances based on sector specific benchmarks was perceived as positive by other companies, often those operating on lower energy and carbon intensity levels already (Salzgitter, Borealis etc.)**, providing them with competitive advantage on the European market.

- *Price of carbon:* Some of those companies that invested in energy efficiency early on and had ambitious emission reduction policies and targets (e.g. CEZ) highlighted that the **currently low carbon prices reduced attractiveness of low carbon investments and to some extent created a risk for their installations as costs encountered did not pay off (fast enough)**. Other (energy intensive) companies, such as Tata steel, argued that **carbon/allowance price in Phase III would be too high and, given low margins for the sector, would impact negatively on international competitiveness** as well as on their companies' ability to invest in low carbon solutions.
- *Companies' overall level of sustainability policies and ambitions:* As to be expected, ambitious sustainability policies at the company level seem to correlate positively with the view that proactive climate policies are an opportunity rather than a risk for businesses (Nestle, AkzoNobel, DSM etc). **Early movers felt that investments into low carbon processes and products would create competitive advantage** due to, e.g. resource efficiency in their operations and increasing consumer demand of energy efficient products, though it is important to note that the **low carbon prices resulted in fewer incentives for these companies to continue on the low carbon pathway** (see CEZ above as an example). However, broader strategic decisions (e.g. broader sustainability considerations or energy costs) or longer term scenarios assuming a higher carbon price from 2020 often made them continue to invest in low carbon solutions.
- *Global competition and carbon leakage:* Most companies interviewed operate on a global market and are hence exposed to high levels of international competition. **Companies from sectors with high leakage risks (Tata, CEMEX, Repsol) highlighted the competitive disadvantage caused through unilateral policies on the European level.** Almost all companies emphasised that a global agreement on caps and targets would be crucial for a level field.

The impact of indirect costs caused through the ETS and the absence of harmonised compensation for companies incurring these costs were highlighted as increasing risks for leakage by electricity intensive companies such as Repsol, CELSA and to some extent Tata Steel.

Is achieving a low level of GHG emissions intensity (per unit production) important to competitive advantage? If so, to what extent?

Almost all companies covered by this study highlight **that low levels of energy and GHG intensity are crucial for industrial competitiveness on the European (and to some extent also the international) markets, with the primary reason being high energy costs.** But for most interviewees, **wider resource efficiency and stakeholder and consumer preferences for more sustainable products** are also playing a role for their competitiveness on the global market. **Carbon costs are often seen as a risk of market distortion on the global market rather than a reason for increasing competitiveness, though frontrunners do benefit from low GHG intensity as they can trade over-allocated allowances or do not have to buy additional ones on the market.**

"Energy efficiency and the resulting emission reductions have become crucial for surviving in the global sugar market. Our product is a commodity in a global market. We are competing with companies in Brazil, Thailand, and elsewhere. In the Netherlands we usually use natural gas for our energy needs, which is more expensive than lignite (used in Germany, France, Italy, Eastern Europe) and natural gas in the US, which is approximately one third of the EU price. So energy efficiency brings down costs, and ETS helps us to confirm the urgency." (Suiker Unie)

CEMEX highlighted though, that low levels of GHG are not a competitive advantage against cement importers.

Is achieving a low level of GHG emissions intensity important to corporate profile / image? What are the drivers for this (e.g. supply chain pressure, company values, innovation, etc.)

As above, most of the companies assessed highlight low carbon policies as part of their corporate image. Our findings indicate that **for a growing number of companies and sectors, provision of a sustainable product is becoming a 'must' in the competition for consumers.** Higher consumer awareness in Europe in comparison to other parts of the world was highlighted by some interviewees. But even within Europe, differences in consumer preferences seem to prevail with CEZ (power) highlighting that in the Czech Republic energy costs are still the driving factor for consumers with low carbon energy suppliers being made responsible for higher costs. The company argues that, unlike in many Western European markets, only a handful of consumers are interested in low carbon energy sources in the Czech Republic.

How are climate change and GHG emissions policy embedded in company policy? Do companies have specific targets on CO₂ reduction, energy efficiency, etc.?

It seems that **most of the companies included in the sample have integrated GHG reduction policies into their business strategies and companies' sustainability policies** though there is a considerable variety on the details of plans and targets.

There are companies (such as Nestle, Repsol, AkzoNobel, Michelin, Salzgitter, Tata) that have mainstreamed energy efficiency and GHG considerations into

their operations and products and are proactively providing installations with a toolset to assess emissions, reduction potential as well as plans for concrete emissions reduction initiatives. Nestle’s Energy Target Setting Policy is a case in point: the expert teams from within and outside the company are working with installations to identify emissions reductions potential (based on detailed energy intensity comparisons and benchmarking across their installations) and measures to implement these. Most promising suggestions are then integrated into the business’s investment plans. Michelin (tyres) are undertaking 3-yearly energy audits to identify emissions reduction potentials and to define an action plan to reduce energy consumption for key sites. Another example for a comprehensive programme is Salzgitter Flachstahl GmbH's Energy Efficiency Program aiming at identifying and implementing energy saving potentials. The programme has so far lead to 118 measures aiming at reducing energy costs, and avoiding 150,000 tonnes of CO₂ emissions.

Companies such as Tata Steel and Heidelberg Cement invest heavily into research to identify breakthrough technologies in the medium to long-term (e.g. clinker substitutes). This seems to be driven by the technological limits they are reaching regarding emissions reduction potential in the short to medium term. Payback on energy efficiency investments seems to be the stronger factor in these considerations given uncertainties in the carbon market.

Many of the companies have integrated an internal carbon price up to 2020 and beyond into their strategic investment considerations. Companies used to work with higher internal carbon prices during the early years of the EU ETS, but since the crash in carbon prices most of them have lowered their assumptions considerably up to 2020 as there seems to be a general feeling that carbon prices will stay low for a long period of time. The table below provides insights into internal carbon price assumptions based on information assembled in the case studies.

Table 15 Internal carbon price assumptions

Carbon price assumptions	2012	2013	2014	2015	2020	2027	2030	
Nestle	Nestle does not set a company internal carbon price							
SCA	€5-8/t in 2012	Calculations for subsequent years assumed that the carbon price rose 2 per cent per annum				€7-11/t	€8-23/t	
CEMEX		€15.5 EUR	€16.5	€17.5				
Tata Steel	The internal carbon price at Tata is treated as confidential. The short to mid-term outlook is reviewed on a monthly basis. In the short to medium term the carbon price is perceived as relatively low.				In the longer term (2020 and beyond) the price assumed has always been higher than the short-term view, and is factored into longer term strategic decisions			
Shell	Shell's assumptions on carbon price used for investment decisions took a value of \$40/t (approximately €32/t) in 2010 and 2011 drawn from long term scenario development, rather than the actual current price.							

Further to this, most companies have set internal targets for emissions reductions. These are summarised for key companies in the table below.

Table 16 Climate policy and energy efficiency targets across companies

Company	GHG target	Energy efficiency target
Nestle	By 2015 Nestle wants to reduce CO ₂ emissions by 35 per cent in absolute terms (absolute energy reduction) compared to a 1990 baseline	
SCA	Reduce CO ₂ emissions from fossil fuel use and purchase of electricity and heating by 20 per cent by 2020 compared to 2005 levels.	14 per cent improvement in specific energy use between 2010 and 2020
CEMEX	CEMEX has committed to a global 25 per cent reduction in CO ₂ emissions by 2015 compared to 1990 emissions.	
Tata Steel	The targets for emissions reductions (installation and companywide) are currently under revision and cannot be published at this point. They are aiming to strengthen energy and CO ₂ performance. Every installation / steelmaking site has targets on CO ₂ and energy efficiency. Downstream operations have energy targets only.	In the Netherlands, Tata Steel signed a voluntary agreement with the Dutch government to achieve a year-on-year improvement in energy efficiency of 2 per cent, including downstream product life cycle benefits, at the facility in IJmuiden, through both processes and products.
Repsol	Repsol sets annual objectives for emissions reductions linked to its strategic long term objective. Repsol's objective to reduce its emissions by 2.5 million tonnes from 2006-2013 related to a "business as usual" scenario was surpassed one year ahead, and a total reduction of more than 3 million metric tonnes per year was finally achieved. Repsol has set a new target reduction of 1.9 million tonnes of CO ₂ by 2020.	
CEZ		An Action Plan on emissions reductions was adopted by CEZ's Board of Directors in 2007 which included a target of 15 per cent emissions intensity reduction by 2020 compared to 2005 levels.

2.4.2 Low carbon investments and operational decisions

What low carbon investments and operational decisions have been implemented? What has been the impact of these on GHG emissions and costs?

Carbon investment and operational decisions that were reported by companies cover a range of measures summarised in the below list of categories:

- Investment in qualitative processes to assess emission reduction potential and to identify suitable measures for improvements (e.g. Nestle, Michelin, Salzgitter, Tata)
- Research into breakthrough technologies (e.g. Tata, Heidelberg Cement)
- Modernisation/retrofitting of old plants to increase energy efficiency (e.g. Tata, CEZ)
- Construction of efficient new plants (e.g. Celsa)
- Investigating Carbon Capture and Storage (CCS) and Carbon Capture and Usage (CCU) (e.g. Heidelberg Cement, Shell, Drax Power Station)
- Fuel switching: from coal to biomass (e.g. Nestle's woodfired boiler), from coal to gas (e.g. CEZ power plant), from oil to biofuels (e.g. SCA, Virgin),
- Gas and heat recovery systems, such as waste heat recovery / waste to energy (e.g. Tata), CO₂ for greenhouse gases (Shell)
- Fuel efficiency and lighter materials (e.g. Virgin, Tata, Heidelberg Cement)
- On-site renewable energy installations (e.g. Michelin)

Table 17 Summary of investments and impacts on cost, GHG emissions and energy consumption

Company	Low Carbon Actions	Cost impacts	GHG reductions achieved	Energy consumption reduction achieved
Nestle	Investment in three wood-fired boilers (1st one commissioned in 2012) thus switching from coal combustion to renewables	€15m	The three boilers have resulted in 25 per cent CO ₂ savings overall for Nestle France ³⁵	
SCA	1) Redesign and conversion of two boilers to biomass firing (wood pellets) at Ortvikén paper mill, and connecting Östrand pulp mill to Sundsvall district heating grid for peak load (winter) supply.	~€42m	60kt fossil CO ₂ emissions savings per year	24,000 m ³ of oil savings per year

³⁵ Nestle Creating Shared Value Full Report, 2013:
http://storage.nestle.com/Interactive_CSV_Full_2013/index.html#266

*Study on the Impacts On Low Carbon Actions and Investments of the Installations
Falling Under The EU Emissions Trading System (EU ETS)*

Company	Low Carbon Actions	Cost impacts	GHG reductions achieved	Energy consumption reduction achieved
	2) Installation of a new lime kiln fuelled with pulverised sawdust pellets (biofuel). New kiln replaces two pre-existing oil-fired kilns, and doubles capacity.	~€50m	~80 per cent reduction of site fossil CO ₂ per year	No change to total energy consumption. Oil consumption is reduced by 17,000 m ³ per year, replaced by biomass consumption.
	3) New biofuel fired lime kiln replacing old oil fired kiln.	Capex ~€50m ~€7m annual cost savings	75 per cent reduction of site fossil CO ₂ per year	No major energy consumption impacts
CEMEX	1) Refuse Derived Fuel (RDF) storage and feeding installation with trammel for drying the RDF before pre-calcination. RDF treatment and preparation plant next to the cement plant (co-investment).	Capex €3.2m; Opex ~€204k/yr; Annual cost savings ~€2.5m/yr	5 per cent of CO ₂ reduction measured across the installation 47 kt CO ₂ reduced annually	4463 MWh or 3 per cent reduction in energy consumption per year
	2) Jäckering Mill invested in an RDF preparation plant, mill and dryer	€1.5m (actual CAPEX amount)	27kt CO ₂ annually, which is ~4.2 per cent of installation emissions	
	3) Introduction of Climafuel - a RDF produced from commercial waste streams- into the cement kilns from 2006. Climafuel complemented the use of Secondary Liquid Fuel – waste solvents which was implemented in 2002 to replace the burning of solid fuels (primarily pet coke).	Capex £2m; Opex £200k/yr; Cost savings £1.5m/yr compared to burning solid fuels	10 per cent reduction of CO ₂ across the installation 34 kt CO ₂ in annual emissions saving 0.1 reduction of carbon intensity per tonne of product	

*Study on the Impacts On Low Carbon Actions and Investments of the Installations
Falling Under The EU Emissions Trading System (EU ETS)*

Company	Low Carbon Actions	Cost impacts	GHG reductions achieved	Energy consumption reduction achieved
	4) New alternative fuel feeding line to one kiln. Alternative fuels used are Refuse Derived Fuel (RDF) mainly from MSW, waste woodchips, shredded tyres and milled rubber	Capex €270k; Annual savings €70,000/yr		The investment allowed CEMEX to increase alternative fuel usage rates from 70 per cent to 75 per cent for this installation.
Tata Steel	1) Installation of a gas recovery system to re-use gases produced at the Port Talbot plant	Capex £60m; Pay-back < 2 years	300 kt CO ₂ /yr, equivalent to 1 per cent of installation emissions.	
	2) New cooling system at the BOS plant (waste heat recovery), enabling investment 3	£53m capital costs		Electricity savings of 80GWh
	3) extra investment into additional capacity for heat recovery	£2.5m capital costs		Electricity savings of 8GWh.
Repsol	1) Optimisation of the use of installations 2) Operational improvements: Improve heater efficiency, operation improvement of diverse equipment: columns, pumps, compressors, steam traps. 3) Update of operational criteria: Replacement of old steam turbines by new engine, replacement of liquid fuels by less CO ₂ intensive fuels, new criteria for stand-by equipment. 4) Update of equipment: New furnace preheaters, better efficiency equipment, new steam traps	Investment costs are considered commercially sensitive information	Reductions ranging from 3.6 per cent to 38.1 per cent of CO ₂ emissions were achieved across the five installations considered in the case study in 2013 compared to 2010 baseline.	

Company	Low Carbon Actions	Cost impacts	GHG reductions achieved	Energy consumption reduction achieved
Salzgitter	"Salzgitter Flachstahl GmbH's Energy Efficiency Program", launched in 2009, to identify and implement energy saving measures. So far 118 measures for energy reductions carried out. Won the Energy Efficiency Award 2013 by the German Energy Agency.	€39m of annual cost savings due to the measures	150 kt of CO ₂ emissions since its implementation	
CEZ	Tusimice 2 - Comprehensive renewal of coal-lignite plant. Four units were renewed.		Expected reduction of 960 ktCO ₂ /year.	Expected decrease in emission intensity by 31 per cent.

To what extent was EU ETS a driver for this low carbon action? What internal carbon price was assumed? What were the other drivers and what was the relative importance of the EU ETS in comparison to the other drivers?

Almost all firms highlight the **reduction of energy and electricity costs as the key factor** for their decisions, followed by **external drivers** such as the **EU ETS** and market drivers such as **consumer demand preferences** as well as **internal drivers** such as **sustainability policies and targets**. Additional EU ETS linked **funding schemes or** national incentive schemes were named as drivers for specific investment decisions in the field of CCS and CCU (Heidelberg Cement, Drax , Shell). Furthermore **local incentive** schemes that reduced investment costs were also mentioned, e.g. by Nestle (wood fired boiler in France).

The **EU ETS seems to have spurred innovation in quite a few of the companies we have reviewed**, both within and outside the EU. For example, SCA's investments at **Östrand and Munksund (biofuel fired lime kilns) represent leading innovative technologies**. With these investments (and others not described), SCA Forest Products was then able to consider its own mills to be the most efficient in Sweden (and **among the most efficient in Europe and globally**).

Repsol and DSM also highlight **market and innovation opportunities through the CDM and (in the future) new market mechanisms**.

"The structure of the EU ETS can provide a cost-effective platform for international businesses to set up CDM projects in qualifying countries. In such a way, the EU ETS allowed DSM to finance a CDM project in China. The project demonstrated a new technology that significantly reduces emissions of N₂O from caprolactam; this would not have been possible without the finance from the offset credits. This trial demonstrated that such technology could be installed successfully in many other facilities, reducing emissions and bringing other benefits. DSM is now investigating how to expand the use of this technology to other parts of the world, including Europe." (DSM)

Most companies **currently (i.e. at the transition between phase II and phase III) assess the EU ETS and the price on carbon as a minor driver for low carbon investment decisions**. As Salzgitter GmbH (steel) highlights:

"Due to low and volatile carbon prices in the past and uncertainty associated with future outcomes of climate policy, the EU ETS only played a minor role in the firms production and investment decisions. This also holds for the launch of the energy efficiency program." (Salzgitter)

The EU ETS and assumptions on the carbon price seem to have played a **more important role for investment decisions in the early phases of the EU ETS when a higher carbon price for the short to medium term future was assumed** (e.g. CEZ, AkzoNobel, and Heidelberg Cement for example).

Some companies however are **looking at the EU ETS in a more long-term way assuming a higher carbon price for the period post 2017/20 and under this outlook are integrating the carbon price in their investment calculations** (e.g. Shell, Suiker Unie). Shell, for example, takes a long term view on carbon, with the carbon price used for investment decisions being a value of \$40/t (approximately €32/t) drawn from long term scenario development, rather than the actual current price.

2.4.3 Companies' assessment on the impacts of the EU ETS on their operations and broader observations of the EU ETS

Though there was criticism regarding the functioning and implementation details of the ETS (its current ineffectiveness to encourage emissions reductions and the negative impacts on competitiveness on a global level) **most companies included in the analysis do see emissions trading as the most cost effective tool to cut emissions in comparison e.g. to carbon taxes**. This was proactively highlighted in the Sustainability Winter 2011/2012 Report by Virgin Atlantic Airways

"Cap and trade is known to be an environmentally-effective, market based measure (MBM) for reducing carbon emissions – whereby fuel efficiencies are further incentivized and the funds collected can be used for both climate change mitigation (reducing greenhouse gas emissions) and adaptation schemes (helping countries to adapt to the rigors of climate change, particularly developing countries). Cap and trade is much more environmentally effective and cost efficient than simple taxation matters. The latter are much less effective in achieving carbon reductions and funds tend to be used in general national government accounts, rather than for carbon reduction initiatives." (Virgin Atlantic 2012)

To what extent has EU ETS supported low carbon investments and operational decisions? To what extent has this varied over the life of EU ETS to date?

There is a **range of companies highlighting in their evaluation that the EU ETS encouraged investment and innovation in low carbon technologies in its early phases of the ETS**, but that the **price fall in recent years and the uncertainties in policies has dis-incentivised investments**:

"Especially in the early days the expected impact of the ETS spurred investments. The system however failed to create a robust price signal. The oversupply of emission allowances, mainly caused by the economic recession, caused the carbon price to crash. The current market price alone would not justify certain investment decisions that were possible in the past". (Drax)

"Stable regulatory conditions are one of the key factors to determine the profitability of a project. However, the EU ETS has been characterised by frequent modifications of its framework, so it has become more complicated to compute investments profitability. Therefore, it may have hampered incentives to invest". (Salzgitter GmbH)

Other companies, especially those from the steel, cement and refining sectors, highlighted **technological limits to efficiency improvements** (in the short to medium term) as reasons for the failure of the ETS in Phase III to spur further investments:

"The initial phase of the EU ETS did focus the attention of many companies onto CO₂ (as well as energy). Until the end of Phase II the carbon price has responded as it should and therefore driven the appropriate actions. However, there is a clear limit in the short and medium term to how much the steel industry can achieve, i.e. Phase III will see steel companies taking up (last of) the available energy efficiency options open to them. Breakthrough technologies are required to address significant direct carbon reductions." (Tata Steel)

What do companies consider to be the main benefits of the EU ETS?

David Hone, Senior Climate Change Advisor for Shell summarises some of the key benefits from the ETS:

"The EU ETS offers compliance flexibility and cost management, given that they have to manage their CO₂ emissions and do nothing is not an option. Emissions can be managed and reduced and at a fairly modest cost." (Shell)

There were many additional benefits highlighted by companies:

- **Tighter emission caps**, and in particular the new allocation rules within the ETS taking into account sectoral benchmarks, **provide a direct competitive advantage to more efficient operators**, and thus, represent an additional driver to improve energy efficiency in their operations (e.g. Repsol, Salzgitter, Nestle)
- A sufficiently high price on carbon would lead to lower fuel consumption and higher energy efficiency as a direct effect for companies (CEZ)
- Further to this, some companies driven by the ETS in its early years took decisions to invest in low carbon processes which now provides them with a **competitive advantage on the global markets** (Suiker Unie)
- **New flexible crediting mechanisms** (e.g. such as CDM, NAMAs) and **new trading markets are perceived as an opportunity by some to minimise costs and to spur innovation on the global market.** (Repsol, DSM)
- **EU ETS has played an important role for making low carbon investments a reality in terms of financial viability / profitability.** In most cases, the need for the investments has been instigated by other drivers (such as cost reductions or sustainability objectives) but the EU ETS through valuing of carbon provided the additional income source to make the investments feasible (SCA).
- Similarly the **EU ETS is seen as a supporting factor in companies' considerations to turn to more efficient production routes** and has **created attention for those concerns in company boardrooms (Suiker Unie, Nestle, Drax, Borealis)**
- Furthermore companies mentioned the fact that obligations under the EU ETS lead to **investments in additional capacities for monitoring, reporting and verification of emissions and hence to more understanding of the issues and potentials for emissions reductions** (e.g. Exxon Mobile, SCA, Norske Skog)

What do companies consider to be the main issues and challenges of the EU ETS?

Key issues highlighted by many companies included:

- **Frequent modifications to the implementation details and uncertainties regarding the carbon price** are criticised as they **create disincentives for long term investments**

"The EU ETS has brought uncertainty in the investment process. Uncertainty with respect to the legal conditions (free allocation) reduces the willingness to run ambitious long-run projects" (Heidelberg Cement)

- The **absence of a global carbon market to create a level field** for European operators and the risk for carbon leakage and loss of competitiveness is highlighted by many of the energy intensive companies. SCA and Norske Skog (pulp and paper) also highlighted the need to review leakage risk for newly added sectors given that the perspective of a global climate agreement is bleak.
- There are diverging views on whether the EU ETS is setting too ambitious or too loose caps for specific sectors:
- Many companies (including Nestle, Heidelberg Cement AG) highlighted that the **carbon prices were too low in recent years to create incentives for low carbon investments**: *"The European Community is not sufficiently ambitious about the EU ETS. Nestle feels that it can gain a competitive advantage if it invests early. We can only make full use of this advantage if the price of carbon would increase dramatically. Globally a high price on carbon could develop into a win-win situation."* (Nestle)
- Other companies, including Tata and Repsol **criticised their allocations and regard the associated benchmarks as 'unrealistic' or 'aggressive' threatening their competitiveness on the global markets due to increasing operational and CO₂ compliance costs**. *"In phase III of the scheme, the steel industry is short of allowances and the need to buy allowances combined with the economic downturn since 2009 is becoming an existential threat for the industry. The higher carbon price for steel producers is taking away the margins. (...) Any imposed costs by the EU ETS will take away money for investments into low carbon technologies and research."* (Tata)
- The **current low carbon costs have significant consequences for the future as they practically lock gradual deployment of low carbon plants**. This means a risk for security of supply as well as inefficiency and ineffectiveness in terms of costs (CEZ). CEZ explained their situation as follows: *"In a sharp contrast to what was expected, i.e. higher competitiveness of the company based on lower emission intensity of the production, the competitiveness decreased compared to companies from third countries (in terms of equity and rating (...)). This has a negative impact on the future development of the company's business activities (the lower the equity or rating, the higher cost of capital, more difficult access to finance etc.). As for CEZ specifically, the Investment division was cancelled (and the staff fired) as no investments are now planned."*
- The **indirect costs created by the EU ETS (e.g. through higher electricity prices) are seen as an additional burden** by some companies (e.g. Repsol, Tata Steel, Celsa) as there is no harmonised compensation scheme for indirect costs (Borealis)
- DSM highlighted **concerns that the reserve of allowances for new entrants and capacity extensions can be depleted**, it is not clear what will happen after 2020 and the system does not properly account for the usual ramp-up of debottlenecking or new capacity.
- The **surplus of allowances in some sectors is criticised as creating disadvantages for others**. This could be structurally solved if the allocation would become flexible with regard to changes in actual production (moving away

from an allocation based on historic emissions), as is for instance done in the new Australian ETS (DSM, Holcim)

- Borealis furthermore highlights that the **EU ETS forms barriers for growth due to its allocation rules for new installations and increases in capacity and production.**

2.4.4 Overall summary

In summary, the case studies show that the EU ETS is a marginal supporting factor for low carbon investments and operating decisions. It is not currently the strongest or decisive factor, but it still plays a positive role. Energy cost reductions might have acted as the dominant driver in this trend but the EU ETS, especially in its early phase (based on higher actual and expected carbon prices), seems to have had a supportive influence in many decisions. In most recent years, due to the fall of the carbon price and uncertainties on climate policies on the EU and global level, the ETS seems to have weakened its effect on investment decisions and other factors such as cost minimisation and broader resource efficiency concerns have driven the low carbon agenda for companies.

The EU ETS has acted as a driver for investments (both inside and outside Europe) through its incentive to minimise energy costs, its support for low carbon investments in providing them with additional financial viability and profitability, awareness raising for climate issues at the management level and among employees, and capacity building for more accurate monitoring and reporting of emissions creating a better understanding of the potential for emissions reductions. Furthermore, indirect costs resulting from the EU ETS (e.g. through higher electricity costs), seem to be playing a role in investment decisions, in particular during the later phases of the EU ETS. Some industry experts also highlighted its indirect impact through access to finance, either for investments in the European market (NER300) or in developing and transition countries through the flexible mechanisms (CDM/JI). Through these channels and the carbon price incentive the EU ETS also seems to have spurred innovation in quite a few of the companies we have reviewed, both within and outside the EU.

Factors that seem to have played a positive role in companies' decisions to invest in low carbon technologies, particularly given the higher carbon price assumptions in the early years of the EU ETS, are high energy costs, global competitiveness, available capital (for companies with high margins), higher awareness for sustainability issues at the board level and in consumer markets, and cheap abatement potential. Companies operating with these characteristics saw the EU ETS as an additional means to gain competitive advantage in the European market. Conversely, for companies with high carbon leakage risks, a lack of capital (for companies with low margins), low carbon/climate awareness at the board level or among consumers, and with technical limitations to reduce emissions, the EU ETS does not appear to have incentivised investments.

Key challenges companies are encountering related to the EU ETS are frequent modifications to its implementation framework, uncertainties regarding the carbon price outlook, the absence of a global carbon market to create a level field for European operators, low prices discouraging investments or, conversely, too high costs threatening competitiveness and no harmonised compensation across the EU for indirect costs.

3 Sector case studies

3.1 Power Sector

3.1.1 Introduction

This section presents a case study on the impact of the EU ETS on operational decisions in the UK power sector. This is based on an ex-post evaluation of the impact of EU Emissions Allowance (EUA) prices on the generation mix considering different fuel types and electric efficiencies.

If econometric analysis establishes that the introduction of carbon pricing due to the EU ETS leads to market outcomes with lower CO₂ emissions, then this is in itself a valuable insight. Furthermore, if operational decisions are influenced consistently, then an impact on investment decisions is ultimately likely.

3.1.1.1 Approach

We analysed, ex-post, the impact of EUA prices on production decisions of individual installations using econometric analysis based on monthly data for individual power units.

We tested for two separate effects:

1. Fuel substitution effect – can a changeover from high carbon (coal) to low carbon (natural gas) fuels be observed in the study period? (Note: for a switchover to biomass, see below.)
2. Efficiency effect – can we observe the switch to more efficient power plants due to the EU ETS?

These effects can be answered by regression analysis of the influence of the ETS price on power generation. Regression analysis is a technique for using data to identify relationships among variables and use these relationships to make predictions. Regression analysis sets the relationship between a dependent variable and a range of predictor variables. In this research, the actual output of generation units will be the dependent variable, the predictor variables can then be a number of relevant factors: e.g. prices of fuel input (without and with a time lag to capture the role of forward contracts and coal storage); the EUA price (with and without time lag); forward prices of fuels and CO₂; generation from renewables, import and export volumes; total demand and others. By doing so the influence of the EUA price on revealed production decisions (e.g. the production in units with varying CO₂-content) can be assessed and from this it can be quantitatively estimated to what extent the EUA price has resulted in CO₂ savings by producing relatively more in units with lower CO₂-emissions.

Fuel substitution effects can occur due to changing dispatch of different generating units with different primary fuels, and can occur within a single generating unit if it is able to utilise multiple fuels. An example of the second kind is a coal fired unit that can also co-fire biomass (and/or different other fuels). It would be interesting to test whether CO₂ price developments impacted biomass co-firing, however in this study we are unable to do this due to a number of reasons, primarily a lack of time series data on biomass energy input (and cost) to different generating units in the study period. Therefore the scope of analysis refers to the substitution effect on the unit level.

3.1.1.2 Selection of country

This case study was performed on the United Kingdom. From all EU28 Member States, the United Kingdom was selected for this case study for a number of reasons:

- The UK has a fully liberalised electricity market with well-functioning power markets, meaning:
 - prices are established in the market by supply and demand
 - dispatch of power generating units is determined by prices (both short and long term)
 - prices are transparent for both suppliers and demand
 - there is sufficient liquidity, meaning actual dispatch follows prices and strategic bidding is uneventful
- Limited effects of import and exports (i.e. import and exports are to EU countries), because this can alter market prices
- It has a generating portfolio that mixes generating units with high and low CO₂ emissions (enabling meaningful analysis)
- It has a generating portfolio combining older and newer units, where it is possible for changes in the marginal cost of production to lead to a different ordering of units on the supply curve
- A stable regulatory situation in the study period
- It has a sizeable market with sufficient power generating stations and units to dispatch. This is a requirement to do meaningful statistical analysis with a sufficiently large sample size. In the UK data set we have monthly data on dispatch of 320 units, which is a sufficient number to conduct the regression analysis and be able to draw conclusions.
- In principle, any EU28 member state can be analysed in a meaningful way, if the above requirements can be sufficiently met.

Great Britain (England, Scotland and Wales) has a single electricity market. Northern Ireland connects to the Republic of Ireland and shares its electricity market with Ireland. This analysis focuses on the electricity market of Great Britain (England, Scotland and Wales).

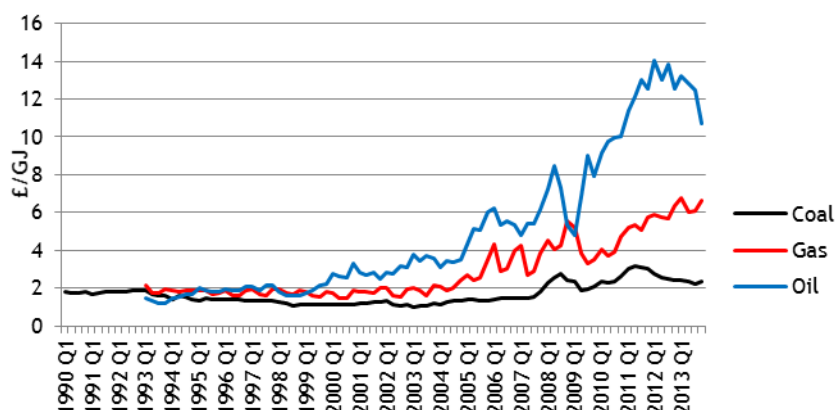
3.1.2 Impacts of environmental policies and fuel prices on production decisions

Renewable energy policies and CO₂ policies can have an impact on production decisions of power generation companies. CO₂ prices can, along with the prices of the different fuels, influence which power plants are running. In this section we will discuss these effects theoretically. We start with the developments of the fuel prices in the study period, then detail how operational decisions come about and then detail the effects of fuel price and CO₂/environmental policies on the operational decisions.

3.1.2.1 Fuel prices

The choice for a fuel for power generation is influenced by the fuel price. Figure 16 shows the relative prices of fuels for power generation, expressed per unit of input energy (GJ fuel value). In the time period of the graph, coal has seen very modest price increases, whereas prices of gas and, to a much greater extent, oil, have seen larger increases.

Figure 16 Fuel input prices for power generators, 1990-2013 (nominal prices)



Source: DECC quarterly energy prices

3.1.2.2 Operational decisions: dispatch of units

Dispatch of units is determined by a number of factors including the price of fuels and the relative efficiency (heat rate) of the plant. A firm with a mixed generating portfolio (nuclear, coal, gas and/or dual fuel fired units and renewables) will try to meet its commitments (the volumes sold) at least possible cost. Accordingly, dispatch of its production facilities is driven by minimisation of the operating costs unless market offerings provide a lower cost alternative. Assuming competitive markets, the resulting overall system allocation then aligns with overall cost minimisation as well (see for example Scheppe et al. (1988) "Spot Pricing of Electricity"; and Stoft and Steven (2002) "Power System Economics").

The minimisation of operating costs imposes a well-established optimisation problem on the planning and scheduling of production facilities at the core of the operations of a utility, referred to as the unit commitment and economic dispatch problem. It is resolved through scheduling production at least marginal cost, while respecting a series of operating, technical, system, commercial, and environmental constraints.

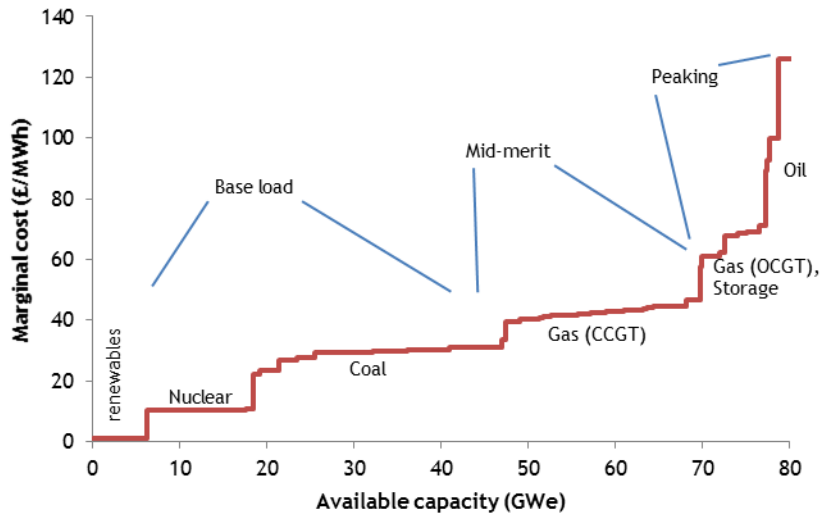
Merit order

A simplified model for least-cost dispatch is offered by the merit order model. The approach disregards temporal constraints and simplifies the cost structure, but offers a basic understanding of the order of dispatch, and as such offers a stylised representation of the cost-structure of production.

The merit order models marginal cost of production as a stepwise increasing marginal cost curve, ordering facilities from low to high marginal cost.

Given the level of system demand to be served, the lower section of the curve represents the segment of the system to be dispatched in order to meet demand at least cost. Generally speaking, the merit order discloses the cost structure in segments characterised by fuel and technology, as the structure of system marginal cost is largely driven by the underlying fuel costs and the efficiency of conversion. The demand levels provide for a rudimentary categorisation of dispatch. Here one may distinguish a number of categories: renewables with no fuel cost; base-load facilities; 'mid-merit' facilities; and the peak-load facilities and storage. See Figure 17.

Figure 17 Illustrative merit order for the GB electricity system (2012).



The basics of dispatch may be described in more detail as follows:

1. First renewables with very low marginal cost of production are dispatched. These are units with no (or little) cost for fuel: wind, solar, run of the river hydro. Dispatch of these units is generally determined by technical availability and meteorological conditions, and not by market prices.
2. Then, base load units are dispatched. These generating units (jointly) meet the lower levels of demand and are essentially always producing. These thermal power plants use combustion heat or heat from nuclear fission to generate steam that drives a turbine-generator. Examples are nuclear reactor, pulverised coal, gas steam boiler, gas turbine with combined steam cycle, and dual-fuel power plants such as coal/biomass. Individual power plants are operated within different technical/economic boundaries and have different conversion efficiencies. Production levels are quite stable. Base-load plants achieve typically a high number of full load hours per year, they have lower variable (marginal) costs compared to other plants, and less flexibility to run at reduced output for prolonged periods of time. For nuclear, downtime is more influenced by maintenance and fuel cycles, than due to market prices.
3. Then the so-called 'mid-merit' facilities are dispatched. These are the facilities that show somewhat higher marginal cost of production and that are dispatched to meet the higher load levels during hours of higher demand. These facilities may have a number of stops and starts per week, and are more flexible in running at reduced output.
4. Lastly the highest marginal cost, or peaking units are operated. These units are dispatched only during high-demand periods, such as peak-hours during working days in winter. This category is made up of very flexible power plants that omit a steam cycle, for example the open cycle gas turbine (OCGT), which is usually gas-fired (not coal). In these peaking plants, natural gas is combusted and the combustion heat drives a gas turbine generator directly. The exhaust gases still contain a lot of valuable heat which is not used, meaning a penalty on electric efficiency is incurred. The advantage is that the unit is very flexible: it can start up quickly meeting a spike in demand, and

these units are the least expensive to build, maintain and have on reserve/standby. Another category here are old generating units that might be not so flexible in the short run (but can be restarted in reasonable time), and are kept in stand by reserve. An example is an oil-fired unit. Although these units have high marginal costs, they are kept as a standby-option in order to meet demand in critical situations.

3.1.2.3 Impact of CO₂ prices on power generating units

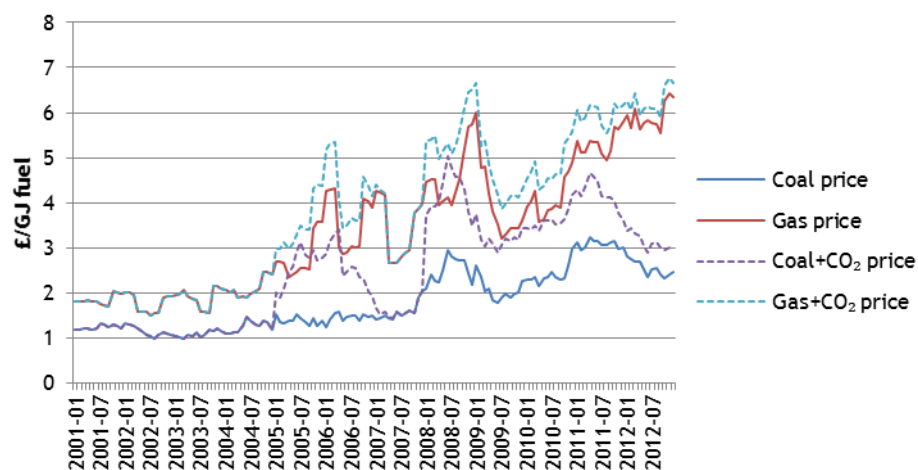
The impact of EUA/CO₂ prices on the operation of power plants relates to the impact these prices have on the marginal cost of production. The CO₂ prices are an additional marginal cost factor for CO₂-emitting generation.

If there is a price for CO₂ emissions, a power plant may decide not to operate and to sell the emission rights (EUAs), even if it has had a free allocation for the EUAs in the first place (see Figure 18). If EUAs need to be purchased, then it is clearer to see that it is a cost factor.

Specific CO₂ emissions per MWh of electricity generated vary (strongly) between fuels. Coal is a fuel with a high mass fraction of the element carbon (~90 per cent) and a low fraction of the element hydrogen (~4 per cent). Natural gas is a hydrocarbon fuel with a far higher mass fraction of hydrogen and far lower carbon. This means that when it burns, it releases less CO₂ per unit of heat energy. The consequence of the chemical composition is that if CO₂ is priced, and prices are substantial, this drives up the marginal generating cost of coal fired plants more than the marginal cost of efficient gas fired plants.

Using average emission factors for combustion of coal and natural gas, one can add the CO₂ prices to the prices of the fuel to combustion and thus get a new cost figure. Expressed in £ per GJ of energy content (fuel value), this yields Figure 18.

Figure 18 Coal and gas prices, with/ without the cost of CO₂ emissions, per unit of fuel input

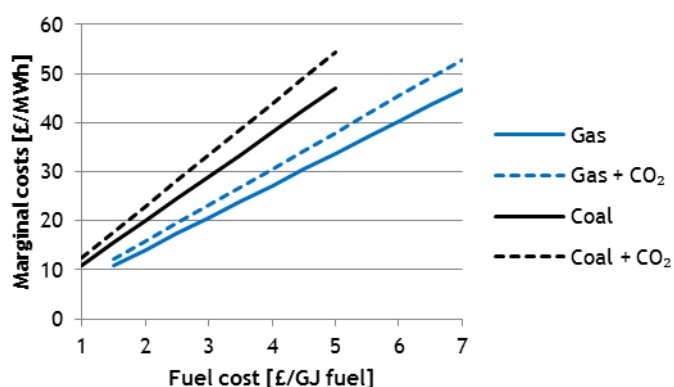


In the figure one can observe a number of things: firstly, coal has in the time period always been cheaper than gas. However, secondly, if the cost of CO₂ emissions is added to the fuel cost, then during the periods where ETS prices have been relatively high (e.g. >15 £/t) there have been moments when coal was almost as expensive as natural gas per unit of fuel input.

The UK's combined cycle natural gas fired power plants generally offer a substantially higher conversion efficiency of fuel energy content to electricity than coal fired units.

Figure 19 illustrates the marginal cost for a typical coal fired and a typical gas fired combined cycle plant.

Figure 19 Illustration of marginal generation costs of a typical coal and gas fired power plant³⁶



Combining figures, we see that there have been moments in time when gas fired power had lower marginal costs than coal fired generation. Indicatively, this holds for the time period 2005/06 and 2008 (2008-2010). This is the fundamental reason why an analysis of the effect of CO₂ prices on production decisions in UK power stations is interesting to undertake.

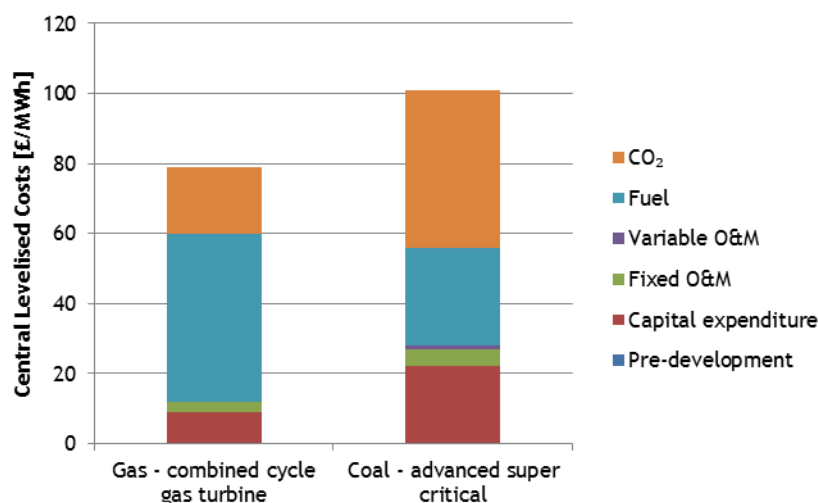
3.1.2.4 Investment decisions

In general, there is not much scope for investments in energy efficiency improvements on existing installations in the power sector. Investments may rather take the form of new production capacities, either to satisfy growing demand (especially until 2009), or to replace older inefficient units.

A firm contemplating the construction of new power plant capacity makes an assessment of the future expected revenues and the costs needed to generate those revenues. Typically these assessments involve at least basic net present value (NPV) calculations and generally more advanced methods based on real-options approaches. An example of such a valuation method is the levelised costs of generating electricity, given in Figure 20 for two power stations. It shows significant shares of CO₂ and fuel costs. While the levelised costing method is a useful tool in comparing average cost levels, the ex-ante cost prediction is inherently highly uncertain. Predictions are strongly dependent on expected lifetime fuel/CO₂ costs, load hours per year, and technical and regulatory lifetime.

³⁶ For two theoretical plants with conversion efficiencies of 40/55 per cent (coal/gas) respectively, and CO₂ priced at 15 £/tonne. The approximation is with average emission factors of fuels and ignores load-related changes to marginal cost.

Figure 20 Illustration of expected fully levelled costs of generating electricity of power units over their lifetime (source: DECC 2012d)



Methods of valuation in a liberalised framework impose additional complexities due to the impact of competitors' (expected) investments on future revenue streams. Valuation therefore covers the assessment of (future values of):

- sale prices of electricity
- market demand
- other revenue streams e.g. capacity payments
- investments by other generation companies
- future fuel costs
- future costs of CO₂-emissions/EU emission allowance costs

Given the nature of the cost structure of the industry, being CAPEX intensive, and the technical lifetime of facilities spanning several decades, investment cycles may extend over a decade or more.

Next to the aspects indicated above, a series of additional considerations can be considered to be relevant for the decision to invest in a specific technology, like company specific aspects such as company values, strategies and specific experience with technologies, but also public pressure and energy policy.

As such, investment dynamics are driven by a complex interplay of known, uncertain and unknown factors, allowing for differing degrees of quantification if at all. Combined with the limited number of investments since the introduction of market mechanisms in the sector, quantitative assessments of investment dynamics should be expected to be myopic at best. Against this background, EUA/CO₂ pricing should be expected to render carbon-intensive technologies less attractive than would be the case in absence of such pricing mechanisms.

3.1.2.5 The impact of the EU ETS on power production decisions

Since 2005 the entire power sector falls under the EU ETS. This means that for individual power producers emissions are valued and may be taken into account in production decisions. The EU ETS is characterised by three distinct phases: Phase I (2005-07); Phase II (2008-12) and Phase II (2013-20).

In order to understand the results from the ex-post evaluation it is important to understand the differences between these phases. The main differences are:

- Different set of allocation rules to the UK power sector
- Different price developments in the ETS markets and possibility of hedging strategies

Allocation rules and impact on power production

In the trial Phase I, which ran from 2005-2007, UK power producers received allowances for free.³⁷ In Phase I, the UK had a huge deficit in allocated allowances to cover their emissions (Ellerman and Buchner, 2008). The UK short position was mainly explained by a lack of allowances distributed to the power sector (McGuinness and Trotignon, 2007). Therefore, despite the freely obtained allowances, the UK power sector had to buy a substantial amount of their allowances (about 30 per cent) on the CO₂-exchange. This was more than any other country participating in the EU ETS.

In phase II (2008-12), a small share of emissions (7 per cent) to UK power producers were being auctioned. Furthermore, a system of differentiated benchmarks was introduced to guide allocation. The UK power sector also was net short on emission allowances. In Phase III (2013-20), power producers in the UK fall under a 100 per cent auctioning regime.

The EU ETS implies that power producers face a cost of emitting carbon. In economic theory, this price signal is similar under a system of free allocation or auctioning. The reason is that even freely obtained allowances would still constitute an opportunity cost to the power producer. Power producers may decide not to use the allowances by switching to low carbon generation capacity which would yield them the profit of selling the un-used allowance on the ETS markets. In the reality of the UK-allocation to power producers, it implied that the power producers would be less short on their EUA positions and would have to buy fewer additional allowances on the market. This would also imply that power producers would pass through the full opportunity costs of their freely obtained allowances in product prices. Sijm *et al.* (2005, 2006) produced empirical evidence that power producers in the Netherlands and Germany did pass through the costs of freely obtained allowances in the spot market power prices during Phase I. For the UK, Zachmann (2007) and ECN (2008) found similar results for the UK. Point Carbon (2008) has concluded that windfall profits were being made in the power sector.

Research on the impact of the EU-ETS on fuel switching is scarcer. Tauchmann (2006) found no impact of the carbon price on fuel switching in the UK during ETS Phase I, whereas McGuinness and Ellerman (2008) found large impacts.³⁸

So while allocation rules differed between Phase I and Phase II, this did not change pricing behaviour and it may not have had an impact on the actual supply decision of power producers.

³⁷ Unused emission credits from the New Entrant Reserves would be auctioned under Phase I in the UK.

³⁸ Tauchmann based his conclusion on annual rather than monthly or daily data, hence discarding a lot of temporal variation in fuel switching, whereas McGuinness and Ellerman based their conclusion on a regression analysis which seems fundamentally flawed. The latter explain the intended load factor of coal and CCGT power units based on total electricity demand, generation by nuclear plants, the spread between the coal and gas price and the carbon price. Differences between coal and CCGT are catered for by interaction terms. The carbon price has fallen almost uniformly in the investigated period (see figure 13) while CCGT generation has risen vis-à-vis coal generation, so that the estimated carbon impact could be due to spurious correlation. Furthermore, the dependent variable enters the regression on the right-hand side albeit in a different shape: as the sum of generated power by individual coal and CCGT units minus nuclear generation (i.e. total demand).

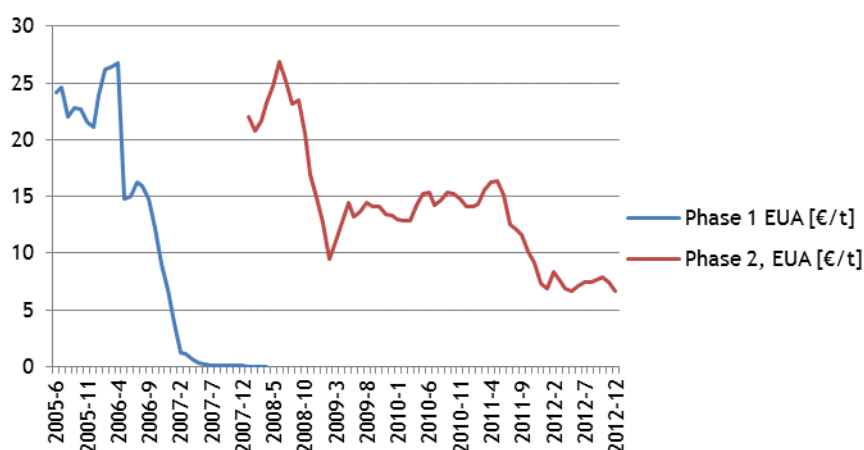
Price developments

Monthly CO₂ prices as established by the EU ETS are given in Figure 21. Initially in Phase I, prices were much higher than expected. Reasons are, amongst others (see Ellerman and Joskow, 2008), the relatively cold winter in the beginning 2005, a dry summer in Southern Europe and the lack of liquidity in the market as the supply of allowances from companies that had long positions was insufficient. After the publication in April 2006 of the verified and surrendered emissions from 2005, it became apparent that much more allowances were issued than needed and prices started to drop rapidly as most participants decided to sell these allowances immediately.

In Phase II, prices remained stable until the start of the economic crisis which caused prices to collapse to around €15/t. In 2011 it became apparent that there was a substantial oversupply of allowances to the market which caused prices to fall even further.

Figure 21 gives the spot market prices of EUAs. It is important in this light to notice that power companies use hedging strategies for future delivery of power by covering them with forward EUAs. This practice was different between Phase I and Phase II, because allowances obtained in Phase I could not be transferred to Phase II. However, power producers could buy forward Phase II allowances during Phase I. Therefore, since April 2006, forward and spot market prices of EUAs tended to differentiate in Phase I. In Phase II, there was a close link between both forward and spot prices.

Figure 21 ETS CO₂ prices at the spot market



3.1.2.6 Other environmental policies

In addition to the EU ETS there are also other environmental policies that impact on production decisions.

Prior to the EU ETS, the UK established a voluntary emission trading scheme, the UK Emission Trading Scheme, which ran from 2002 and ceased when the EU ETS Phase I started. However, the power sector was excluded from this emission trading scheme since it fell under different environmental regulations. Under the United Kingdom's Climate Change Programme from November 2000, the power sector was affected by the renewables obligation from 2002, which requires all electricity suppliers who supply electricity to end consumers to supply a set portion of their electricity from eligible renewables sources. The proportion was a 3 per cent requirement in 2002-03 and increased each year towards a 10.4 per cent target for 2010-2012, a 15.4 per cent target by 2015-2016 and a 20 per cent target by 2020-2021. These mandatory proportions could be traded using Renewable Obligation Certificates.

Another relevant piece of legislation is the Electricity Market Reform (EMR). The EMR includes three initiatives to encourage decarbonisation of electricity generation: A Carbon Price Floor to complement the European Union Emissions Trading Scheme (EU ETS); Feed-in tariffs (Contracts for Difference) which will eventually replace the Renewables Obligation; and an Emissions Performance Standard to restrict future use of the most carbon intensive forms of generation. However important for the future development of the power sector, it is less important for the ex-post analysis of effectiveness of the EU ETS (2005-12) that is the main focus in this chapter. The full details of the EMR were not known to market parties until 2011/12.

3.1.2.7 Conclusions from qualitative analysis

From the preceding sections we conclude the following:

1. The UK has a liberalised electricity market where prices are set by market parties, and a number of integrated and independent power producers are active. Together they own and control a large number of generating units that have wide range of fuels: coal, natural gas, uranium, wind.
2. Dispatch of these generating units is governed by marginal cost of the generating units (given a number of constraints).
3. The fuel prices development has seen a number of moments in the study period (2002-2012) where prices of natural gas and coal have converged so that a switchover effect possibly can be observed between some generating units.
4. The introduction of the EU ETS was essential in giving CO₂ a price that is felt by generating companies.
5. Assessing historic EUA prices, we conclude that some switchover from coal to gas use for generation can theoretically be expected due to the combination of fuel & CO₂ emission costs being higher per unit of electricity produced.

The last hypothesis will be quantitatively tested using econometric analysis in the following section.

3.1.3 Ex-post evaluation of effects EU ETS on power production

In this section, we present results of a model for electricity generation by coal, gas and nuclear power units in the UK (excluding Northern Ireland) in the period 2002-2012. Data obtained from Platts, the World Bank and the DECC are used to assess the impact of the EUA and of other factors (e.g. gas and coal prices, other electricity generation) on the load factor per unit. This is done in order to check whether the carbon price has influenced the fuel mix and the efficiency of power generation in the UK.

3.1.3.1 Potential impacts

Based on the discussion in previous sections, we surmise that the EUA price may have had an impact on generated output of coal and gas power plants through a fuel substitution and/or an efficiency effect.

Fuel substitution effect

A higher carbon price lessens the spread between the costs of gas and coal and should result in a drop in coal power generation and increase in gas power generation. A fall in the load factor (ratio of generated power with maximum capacity in MWh) of coal

powered units should coincide with a rise in the load factor of gas powered units in order to match demand.

As described in previous sections a substitution effect to biomass (increasing co-firing of biomass instead of coal in coal power stations (e.g. Drax) due to CO₂-pricing) is not an effect we were able to test for.³⁹

Other factors may also impact the load factor. First of all, differences per unit arise from differences in technology (gas turbine, steam turbine or combined cycle, cogeneration, capacity, conversion efficiency, etc.), efficiency in operations, plant location (transport costs of fuels (changes in delivered prices), grid connectivity, yearly average temperature etc.), and other things.

Differences in the load factor over time are caused by seasonal and other fluctuations in demand, power generated by other sources (renewables, waste incineration, co-generation and imports), seasonal maintenance schedules, and the dynamics of input fuel prices.

An increasing gas price should have a negative impact on gas power generation, whereas an increasing coal price should impact positively on it. Impacts should have the exact opposite sign for coal power generation: an increasing gas price should have a positive impact on coal power generation, whereas an increasing coal price should impact negatively on it. Nuclear power, which is near the bottom of the merit order curve, is expected to be far less price-sensitive than gas or coal power.

Efficiency effect

Less efficient coal plants run at higher marginal costs and, depending on prices and the time of day or season, compete with the more efficient gas plants on the merit order.

Hence, the electricity generation of less efficient coal plants should be more responsive to the generation of power by other sources and the prices of fuel input than electricity generation by the more efficient coal plants. Likewise, more efficient gas plants should be more responsive to changes in demand and fuel prices than less efficient gas plants.

If sensitivity to the carbon price proves higher for inefficient coal plants and efficient gas plants, then the falling EUA price in Phase II of the ETS may have caused the decline of an efficiency effect.

What we then observe is, in the period of falling EUA prices, that generation by less efficient coal power units increased and generation by efficient gas plants fell. A subsample of inefficient and efficient plant units (for both coal and gas) will be selected to test for an efficiency effect.

Box 4 Efficiency effect in a period of falling EUA prices

The estimation of the 'efficiency effect' is undertaken to test whether, within the samples of coal and gas power plants, a switchover to more efficient generating units due to the carbon prices established by the ETS, can be observed. This requires us to

³⁹ For the specific regression analysis problems are a lack of time series data on biomass fuel use per generating unit, the fact that biomass co-firing is uncompetitive economically without a number of specific policies (renewables obligation, the price levels of renewable obligation certificates, and so on.)

create subsamples: 'efficient coal'; 'inefficient coal'; 'efficient gas' and 'inefficient gas'.

In a period with high EUA prices, the relative profitability of generating units in the two 'inefficient' subsamples is less than that of units in the 'efficient' subsamples: the inefficient units have higher marginal cost of generation. Therefore we would expect to see an increase in the generation by the efficient subsamples and a decline of generation by the inefficient subsamples.

Adversely, in a period with falling or low EUA prices, the relative profitability of the efficient subsamples compared to the inefficient subsamples declines. This is expected to lead to a relative increase in generation by the inefficient subsamples, and a decrease in generation by efficient subsamples.

The period of falling and low EUA prices coincided with the trend of declining coal prices. Given the typical position of inefficient coal and efficient gas units on the merit order curve, a combined efficiency effect can also be observed in a switchover from efficient gas to inefficient coal. The inefficient coal units have high specific CO₂ emissions per unit of output, meaning changes in EUA prices are expected to strongly influence these units' marginal generating cost. In the regression analysis we will show the effects of both the relative fuel and the EUA prices on the generation by the units in the different samples.

In order to assess both the fuel substitution and efficiency effect, time-series data have to be available that allow enough observations to empirically estimate the relationships. Times series data are required to analyse the impact of the price development of carbon in the EU ETS. In addition, individual plant data allow for the testing if more efficient power plants have been favoured over less efficient power plants due to the EU ETS.

In this research time series/cross-sectional data (panel data) of the production of individual power generation units have been used to observe the production output of each individual installation over time. As such data do not exist in public sources, we have obtained from Platts monthly observations on the generated electricity, capacity and characteristics of gas, coal and nuclear power units at 69 power plants in the UK in 2002-2012. The full dataset consists of over 18,000 observations. These data have been matched with the aid of Platts to the verified emissions of power production from the EUTL in the UK between January 2005 to December 2012 and combined with DECC data on prices of fuel inputs, aggregated monthly power generation by source and monthly CO₂-prices in the period 2005-2012.⁴⁰

3.1.3.2 Model selection

The model which runs the regressions for each fuel type j (j =gas, coal or nuclear) is defined as:

$$LF_t^{ij} = \alpha^{ij} + \sum_j \sum_m \beta_m^j \ln(L^m P_{t-m}^j) + ETS \gamma_{co}^j \ln(P_t^{CO2}) + MONTH + \delta^j OTH_t + \varepsilon_t^j$$

$$\varepsilon_t^j = \sum_n \rho^n L^n \varepsilon_{t-n-1}^j + u_t^j$$

⁴⁰ Quarterly fuel price data from the DECC has been interpolated to monthly figures with the aid of commodity price data from the Worldbank. Prices used were Brent Crude oil, European Natural Gas and the South-African Coal price. CO₂ prices have been obtained from BlueNext and Sendeco2.

The load factor (LF) of each unit i and fuel type j in time t equals generated electricity in MWh divided by the maximum capacity in MWh per month.

The a^{ij} are cross-sectional fixed effects for each unit. They control for all differences in the average load factor per unit due to differences in technology, age, capacity, heat efficiency, location etc.

The prices P^j of gas and coal in £ per GJ fuel input (nuclear power is assumed to run at zero marginal costs) have been transformed into logarithms and will enter the model in current and/or in values from previous months at the appropriate lag length m . The lag length reflects the use of long-term contracts on fuel delivery on the supply-side and electricity generation on the demand side and, in the case of coal, storage facilities.

The carbon price PCO_2 in £ per tonne CO_2 is also transformed into a logarithm and appended to the model (lagged values have been neglected here, as none proved significant in the regressions). The carbon price is multiplied by a dummy variable ETS which takes on the value 1 if the observation period falls inside the range of the ETS, the ETS-I or the ETS-II (depending on the tested assumption) and 0 elsewhere.

Monthly dummies are appended to the model to control for seasonal fluctuations in power generation.

Electricity generated by other sources (OTH consisting of imports, cogeneration, waste incineration, administrative differences etc.) enters the model as a fraction of domestic demand and exports of electricity.

An autoregressive structure is imposed on the error term ε at the appropriate lag length n (i.e. the model contains a Moving Average term). This Moving Average (1)-term corrects for temporary shocks in the data.

The above model is regressed for operational coal, gas and power units to test for a fuel substitution effect. Plants or units that were inactive for more than three months during intermittent periods were also left out of the regressions.

In the test for an efficiency effect a subsample will be drawn from among coal and gas power units. Unit selection is based on the ratio of verified emissions in tonne CO_2 divided by generated electricity in MWh per year during the period 2006-2012. Coal and gas units with inexplicably low or high emissions were left out of the subsample.⁴¹ As fixed emission factors are applied to fossil fuels, we used the CO_2 emission rate as a proxy for the fuel use per amount of generated electricity.

3.1.3.3 Results

Fuel substitution effect

The first set of regressions are meant to convey the role of the EU ETS in the substitution between nuclear power, gas power and coal power generation. Variation around the load factor of each unit is explained by unit-fixed effects, monthly

⁴¹ To do this analysis, we had to match entries from the Platts monthly dataset on the unit level with data from the EU emissions registry on site level. This posed a number of data problems, amongst others that we do not know the amounts of biomass that was used by some coal power units, we can only guess from inexplicably low emission figures that biomass use may have been the cause for low emissions, but other factors (poor reporting, poor data, exemptions) could have been just as responsible. In the analysis we only incorporated sanity-checked data.

dummies to catch seasonal variation, past and current prices of fuel input and CO₂ and the share of electricity generated by other sources. All regressions are based on an unbalanced panel data estimation (i.e. time series of different lengths on individual power units) with robust standard errors and carried out in EViews software.

The results of the regression analysis are shown in Figure 22 below. From this table the following observations can be made:

- The overall fit of the model is reasonable for both coal and gas and the coefficients on the explanatory variables have sensible values and are of the correct sign. Various lags on the price data were considered, but only lags with significant coefficients or lags deemed relevant to the storyline were retained.
- Nuclear power performs more poorly in this model. It seems that nuclear power is not affected much by generation of other power sources or the prices of coal, gas and CO₂. This is unsurprising as nuclear power comes first in the merit order and serves basically base-load against which coal and gas do not compete – even though the current gas price seems to be negatively correlated with nuclear power generation.
- The seasonal variation in coal power generation was large; the load factor was up to 12.5 per cent lower in August than it was in December and January. Seasonal fluctuations in nuclear and especially gas power generation are much smaller. Generation of power by other sources (including renewables) seemingly reduced coal and gas power generation, but the impact on coal power was substantially larger.
- Both current and past prices of the fossil fuels have had an impact on coal and gas generated power, but the gas price seems to have been more important for both gas and coal power generation.
- Next the price impact of the EU ETS is considered. We may note that the carbon price has had a significant (at 99 per cent confidence interval) negative impact on coal power generation and similarly so a significant (at the 99 per cent level) positive impact on gas power generation. This is fairly conclusive evidence for a fuel substitution effect of the carbon price on gas and coal power generation.
- The -0.016 coefficient value on the carbon price in the estimation for coal means that a **doubling of the current carbon price from € 5 to € 10 per tonne CO₂ would lead to a fall in the average load factor of coal units from 48 per cent to 46.4 per cent.** It corresponds to a carbon price elasticity of coal generation of -0.033, or, in other words, a doubling of the carbon price would lead to a reduction of coal generated electricity by -3.3 per cent. In turn, the 0.013 coefficient on the carbon price in the estimation for gas corresponds to a price elasticity of 0.025. Hence, a doubling of the current carbon price would increase the average load of 52 per cent to 53.3 per cent and would lead to an increase in electricity generation from gas of 2.5 per cent.

Figure 22 Panel estimation load factor Nuclear, Coal and Gas power units in UK 2002-2012

	Nuclear		Coal		Gas	
	Coef.	t-value	Coef.	t-value	Coeff.	t-value
Price coal	0.047	0.83	-0.075**	-2.41	0.137***	4.73
Price coal lagged 1 month			-0.044	-1.42		
Price coal lagged 2 months			-0.123***	-3.87		
Price gas	-0.106*	-1.88*	0.108***	2.68	-0.111***	-2.70

*Study on the Impacts On Low Carbon Actions and Investments of the Installations
Falling Under The EU Emissions Trading System (EU ETS)*

Price gas lagged 1 month			0.137***	3.15	-0.069*	-1.65
Price gas lagged 2 months			0.074*	1.95	-0.110***	-3.05
Price Carbon	-0.003	-0.50	-0.016***	-4.57	0.013***	3.75
Other sources	-0.315	-1.03	-0.944***	-6.64	-0.655***	-4.70
Unit-fixed effects	Yes		Yes		Yes	
Month effects	Yes		Yes		Yes	
MA(1)-term	0.630***	38.71	0.567***	50.56	0.634***	54.18
No of observations	2,775		7,289		6,920	
No of units	29		67		71	
R ²	0.49		0.61		0.68	
Adjusted R ²	0.48		0.60		0.67	
F-statistic	59.26		129.62		161.37	
Prob(F-statistic)	0		0		0	
Durbin Watson	1.88		1.94		2.01	

) significant at 90 per cent *) significant at 95 per cent ***) significant at 99 per cent*

The impact of the EU ETS on the fuel mix is elaborated further in the regressions in Table 18. Here, the spot market carbon price impact is estimated for both the first phase (2005-2007) and second phase (2008-2012) of the ETS. This is done with the aid of interaction dummies for observations that fell in the defined periods.

It becomes clear from this set of regressions that the fuel substitution effect observed above was largely due to developments during the second Phase of the ETS: the magnitude of the coefficient is large for ETS Phase II, and is significant at the 99 per cent level. For Phase I the spot market CO₂ prices seemed to be insignificant. This situation does not change when we use forward prices for Phase II during the time period in Phase I.⁴²

Table 18 Panel estimation load factor Coal and Gas power units in UK 2002-2012 with carbon price impact of ETS phase I and II

	Coal		Gas	
	Coef.	t-value	Coef.	t-value
Price coal	-0.021	-0.64	0.063*	1.93
Price coal lagged 1 month	0.015	0.44		
Price coal lagged 2 months	-0.061*	-1.87		
Price gas	0.091**	2.24	-0.100**	-2.42

⁴² A re-assessment of the results in Phase I using forward prices of EUA2008 showed only marginally different results. CO₂ prices were not significant at the 5 per cent level for both coal and gas. Using a 10 per cent confidence level would imply that CO₂ emissions did reduce the demand for coal but did not result in an increase in the demand for gas. We therefore concluded not to take this estimate into account in the analysis.

Price gas lagged 1 month	0.110**	2.54	-0.059	-1.40
Price gas lagged 2 months	0.061	1.60	-0.130***	-3.61
Price carbon in ETS I	-0.004	-0.92	0.001	0,14
Price carbon in ETS II	-0.054***	-6.96	0.041***	5.78
Other sources	-0.908***	-6.43	-0.713***	-5.10
Unit-fixed effects	Yes		Yes	
Month effects	Yes		Yes	
MA(1)-term	0.560***	49.65	0.629***	53.21
No of observations	7,289		6,921	
No of units	67		71	
R ²	0.61		0.68	
Adjusted R ²	0.60		0.67	
F-statistic	129.03		160.30	
Prob(F-statistic)	0		0	
Durbin Watson	1.94		2.00	

) significant at 90 per cent **) significant at 95 per cent *) significant at 99 per cent*

3.1.3.4 Inefficiency effect

Next, subsamples are drawn from coal and gas power units based on a higher or lower than average efficiency (tonne of CO₂ emissions per generated power in MWh per year) according to the emission registry office data. We split the coal units in an inefficient and efficient sample, and the gas units similarly so. All units of coal and gas plants that had a higher than average CO₂ emission factor (for coal and gas respectively 0.904 and 0.397 t CO₂/MWh) are placed in the less efficient sample, those with lower emission rates are placed in the efficient sample.

We focus this analysis only on Phase 2 since we observe a clear link between ETS prices and power production decisions in Phase 2. The samples are much smaller than the original dataset, as the Platts data and the registry office data do not fully match and a number of observations had to be excluded. In the final sample constructed, ten units are in the efficient coal sample against six units in the inefficient coal sample, whereas 21 units are in the efficient gas sample and 18 units in the inefficient gas sample. Notable differences between efficient and inefficient plants are that the former tend to be larger and run at much higher loads.⁴³

The regressions for the subsamples of coal and gas power plants are shown in 0

First it should be noted that despite the small samples for coal units (and hence the poorer fit of the model) more efficient units are less responsive to generation by other sources and the price of gas than inefficient units. For gas units the signs of the impacts are reversed. This gives some confidence that the sampling method reflects the placement of units on the merit order curve.

⁴³ The average loadfactor was 0.63 vs 0.46 for efficient and inefficient gas plants and 0.54 vs 0.36 for coal plants.

*Study on the Impacts On Low Carbon Actions and Investments of the Installations
Falling Under The EU Emissions Trading System (EU ETS)*

The carbon price impact is significant in both coal samples and larger for inefficient coal power units. This implies that the EU ETS has resulted in an efficiency gain in the sense that the more efficient coal fired power stations had a competitive advantage over the less efficient coal fired power stations due to the existence of a price for carbon. For gas power generation the sign of the coefficients is the other way round but the conditions are similar. The carbon price has impacted more heavily on efficient units than on inefficient ones, so the efficient units have a competitive advantage. Whether these absolute differences will also translate into relative differences is also dependent upon the load factors.

Table 19 Panel estimation load factor inefficient and efficient Coal and Gas power units in UK 2002-2012 with carbon price impact of ETS phase II

	Coal				Gas			
	Efficient		Inefficient		Efficient		Inefficient	
	Coef.	t-value	Coef.	t-value	Coef.t	t-value	Coef.t	t-value
Price coal	-0.093	-1.14	-0.082	-0.80	0.142**	2.31	0.023	0.46
Price coal lagged 1 month	-0.003	-0.03	-0.002	-0.02				
Price coal lagged 2	0.007	0.09	0.020	0.19				
Price gas	0.024	0.24	0.261**	2.04	-0.138*	-1.79	-0.091	-1.36
Price gas lagged 1 month	0.195	1.73	0.089	0.64	-0.034	-0.43	-0.048	-0.70
Price gas lagged 2 months	-0.005	-0.06	-0.037	-0.31	-0.155**	-2.25	-0.153**	-2.62
Price carbon in ETS II	-0.053***	-2.97	-0.066***	-3.08	0.060***	4.63	0.039***	3.54
Other sources	-0.610*	-1.76	-1.542***	-3.42	-1.038***	-3.92	-0.721***	-3.12
Unit-fixed effects	Yes		Yes		Yes		Yes	
Month effects	Yes		Yes		Yes		Yes	
MA(1)-term	0.558***	20.10	0.510***	13.25	0.626***	32.28	0.616***	30.34
No of observations	1,249		693		2,210		2,198	
No of units	10		6		21		18	
R ²	0.57		0.58		0.51		0.69	
Adjusted R ²	0.56		0.57		0.51		0.68	
F-statistic	53.64		35.66		60.32		134.68	

	Coal				Gas			
	Efficient		Inefficient		Efficient		Inefficient	
Prob(F-statistic)	0		0		0.00		0.00	
Durbin Watson	2.00		1.79		2.03		2.02	

*) significant at 90 per cent **) significant at 95 per cent ***) significant at 99 per cent

Carbon elasticities of power generation (the percentage change in power generation as a result of a one percent rise in the carbon price) can be calculated by division of the coefficient on the carbon price by the average load factor as the capacity of units remains unchanged. For coal, the load factor of efficient plants in the efficient sample was about 50 per cent higher than that of inefficient plants in the inefficient sample. The carbon price elasticity was then about 87 per cent higher (in absolute terms) for inefficient units than for efficient units (see Table 20).

For gas, the load factor of efficient units was about 35 per cent higher than that of inefficient units. As a result of this the carbon price elasticity was only about 13 per cent higher for efficient units. However, the carbon price elasticities for the sampled units exceed the estimate for the entire sample, so the evidence for a relative efficiency effect is less conclusive for gas power generation than it is for coal power generation.⁴⁴

Table 20 Carbon price elasticities

	Coal			Gas		
	All	Efficient	Inefficient	All	Efficient	Inefficient
ETS I	-0.00833*			0.001923*		
ETS II	-0.1125	-0.09815	-0.18333	0.078846	0.096	0.084783

*) Insignificant

3.1.3.5 Interpretation of results

The main results of the regression can be summarised as follows:

- There is clear evidence for a fuel substitution effect due to the carbon price in the EU ETS. The carbon price impacts negatively on the load factor of coal power plants and positively on that of gas power plants in the UK. Therefore we conclude that the EU ETS did result in CO₂ savings in the UK power sector.
- This carbon price impact was very significant in Phase 2 of the EU ETS. However, in Phase 1, we did not find a significant impact of the price of carbon in production decisions in the UK power market (see below for discussion).

⁴⁴ It should also be noted that we compare units that are less or more efficient than the average, rather than units that are at the opposite end of the spectrum.

- There is also evidence for an efficiency effect of the EUA price, most notably for coal power generation. A higher carbon price should lead to a shift in power generation from coal plants with a lower conversion efficiency to a higher efficiency and – to a much smaller extent – from less to more efficient gas plants as well.

While we do find an impact of the carbon price in the EU ETS on production decisions in the UK power sector in Phase 2, we did not find this impact in Phase 1. There could be a number of reasons for this difference. First, power producers may have had to learn from the EU ETS and the way it would impact on power production decisions. Since Phase 1 was a trial phase in the EU ETS, participants were also learning how to cope with the price signal in the EU ETS. Second, power producers do not sell their power only on the spot markets but also through contracts. Contracts signed prior to mid-2004 will not have factored in the carbon costs and thereby not influenced the production decisions. It may be the case that a lot of power delivered between 2005 and 2007 was in fact contracted before mid-2004 thereby neglecting the influence of the EU ETS for individual power companies. Third, Phase 2 contained a small share of emissions to the power sector which fell under an auctioning regime while all remaining emissions in Phase 1 were grandfathered. While traditional economic theory predicts that different allocation methods (e.g. auctioning versus grandfathering) have no impact on production decisions, others (e.g. Baumol and Oates, 1988) have pointed at the information content that economic instruments can pertain. In this line of reasoning, companies may be more influenced by taxes than by subsidies because the fact that they have to pay for pollution has a psychological impact different from a subsidy (see also Kahneman & Tversky, 1979).

Despite the absence of an impact in Phase 1, the significant impact of the CO₂ price in Phase 2 shows that the EU ETS has resulted in CO₂ savings. The total impact of the EU ETS for emissions of the UK electricity generation sector can be quantified based on the estimates from table 3.5. Data from DECC on electricity generation and of the emission factors on fuels from DECC were multiplied by emission factors on fuels to obtain estimates of the carbon emissions for coal and gas power generation. This quantification is a rough approximation because we place the results from the sample (a sample based on PLATTS data) to the total UK power generation sector to estimate the total impacts. Also the eventual impact of CO₂ prices on biomass-co-firing at coal power stations has not been taken into account due to the lack of availability of data on biomass co-firing at individual power stations.

The mean load factors of coal and gas power units and coefficients on the carbon price were applied to derive the carbon price impacts on emissions and the cumulative savings in emissions. **According to this simple calculation, savings during the second phase of the EU ETS amounted to more than 35 Mt of CO₂ or about 4.5 per cent of total emissions by the UK electricity generation sector.**

Table 21 Impact of EU ETS on CO₂ emissions in the UK electricity generation sector in Phase 2 of the EU ETS.

	Emissions (Mt CO ₂)			Carbon price impact (Mt CO ₂)		
	Coal	Gas	Total	Coal	Gas	Cumulative savings
2008	103	63	166	-15.8	7.3	-8.4
2009	85	59	145	-11.2	6.0	-5.2
2010	89	63	152	-12.1	6.5	-5.6
2011	90	51	141	-11.4	5.0	-6.4

2012	131	35	166	-12.6	2.6	-10.1
2008-2012	500	271	771	-63.0	27.4	-35.7

Note: totals may not add up due to rounding.

3.1.3.6 Sensitivity analysis of the regressions

The regressions were checked for a number of well-known problems in estimation such as auto-correlation in the error terms, heteroscedasticity, multicollinearity and endogeneity.

- First, while the error terms of the estimated equations are reasonably well behaved in terms of first order autocorrelation (Durbin Watson statistic always close to 2), mean and standard deviation, some autocorrelation remained present in the equations for coal and gas. This can be attributed to correlated errors at the fourth time lag. We re-estimated the models using an additional MA(4)-term on the error term. Autocorrelation at the fourth lag could either be due to yearly variations in the load factor (four being the first divisor of twelve with zero remainder not covered by the lags) or the lag structure of the model (three lags on prices plus one lag on the error). Running the equations with an AR(4)-term on the errors removed the remaining autocorrelation, but did not alter the parameter estimates on the other explanatory variables.
- Heteroscedasticity, a higher or lower variation in the load factor or in the explanatory variables, for instance for units with high and low capacities, is already controlled for by using White's robust standard errors in all regressions. Hence, the estimates in the tables already account for this problem in estimation.
- Multicollinearity between the prices of fuel inputs is to some extent present as both the price of coal and natural gas were highly correlated until 2010. However, afterwards, prices do not correlate giving some confidence that estimates of the carbon prices in the second phase of the ETS are less plagued by multicollinearity.
- Parsimony is used in the number of dummy variables. It is for instance known whether some units can use biomass as a secondary fuel, but not to what extent they actually did this over time, nor whether cogeneration and heat delivery was possible and to what extent. Technological impacts were not analysed as they interact with other dummy variables. However, all unit-based differences in the load factor (both observed and unobserved) are accounted for in the unit-fixed effects and do not affect the parameter estimates on other explanatory variables.
- Endogeneity, a non-causal circular relationship between power generation and prices, should not be a problem in the regressions, as the influence of each individual unit on the demand for and price of fossil fuels and overall electricity demand is negligible. Likewise, the production cost of the marginal producer (linked to the gas or coal price) may also impact on the price of carbon, yet the decision of the marginal producer in the UK should not impact too heavily on a European-wide carbon price.

3.1.4 Uncertainties

Aside from the estimation problems, which can be covered to a reasonable degree, there are some potential shortcomings of the approach, which warrant attention.

First, we have used monthly data which neglects day to night patterns in electricity demand, load hours and spot prices. As such, our estimates may be biased to some extent. The loss of variation due to aggregation across time periods may lead to under- or overestimation of impacts – one cannot say *a priori* which impact this has had on the final estimation results.

Next, we have not taken account of 'regime changes'. For instance during periods of exceeding low demand, low coal prices and high availability of coal power generation capacity, coal power stations are expected to be (mostly) the marginal units in the supply curve. In these cases, impacts of carbon and coal prices on the level of coal generation should be larger, and impacts of gas price should be lower. During periods of high demand, closure of coal fired capacity (or unavailability due to e.g. downtime) and comparatively low gas prices, the situation should be reversed.

Furthermore, carbon prices have fallen almost uniformly over the second phase of the ETS period, a period in which also the spread between coal and natural gas prices increased. Hence, our estimates were dependent upon a period when coal generation increased. The regression model need not necessarily reflect the situation if a reversal in the spread and/or carbon price would occur. These uncertainties limit the extent to which the regression results can be generalised to future time periods and other power markets. It would be interesting to repeat the regression exercise in a number of years, to find out what the CO₂ impact is with a period of a higher spread between CO₂ and gas prices.

Finally, we have limited the analysis to coal and gas powered units, neglecting the role of biomass in fuel-switching (other than through the exogenous impact of generation by other sources). Biomass co-firing is an additional impact on fuel switching and on emissions for which we could not account. Despite primarily being stimulated through other policies, biomass co-firing does become more attractive under CO₂ pricing, so our quantification of the effects of the EU ETS is presumably a lower limit.

3.1.5 Summary

As the EU ETS impacts on the marginal costs of power production, we have tested in this research the hypothesis that the EU ETS has resulted in a switchover from coal to gas use for electricity generation. Using a dataset giving monthly data on production of 320 generating units (coal, gas and nuclear) between January 2002 and December 2012, and by linking these to the EUTL registry and statistical information from DECC on prices and capacities, we have conducted regression analysis to investigate this hypothesis.

From the regression analysis we conclude that the EU ETS has affected operational decisions in the UK power market which resulted in lower CO₂ emissions. We have identified three mechanisms through which the CO₂ prices have impacted on power decisions in the UK market.

First, we find quite strong evidence that due to the carbon price in the EU ETS load factors of gas fired power stations increased while load factors of coal fired power stations decreased. This result especially holds in Phase 2 of the EU ETS (2008-12). According to our estimates, a doubling of the carbon price would reduce the average load of coal power plants in the UK from 48 per cent to 43 per cent whereas the average load of gas power plants would increase from 52 per cent to 56 per cent. Therefore, the strength of the CO₂ price signal matters for the amount of CO₂ reductions that will be realised. In Phase 2, the carbon price signal resulted in total a CO₂ emission saving of 35Mt, or about 4.5 per cent of emissions in the UK power sector over the period 2008-2012.

In Phase 1 such an impact was not observed which may be due to learning effects for power production operational managers and/or the fact that a substantial part of the power delivered during Phase 1 was already contracted prior to the existence of the EU ETS. Also the allocation method was different between Phase 1 and Phase 2 as more allowances were auctioned in Phase 2. This may have acted as a psychological

stimulus to more carefully plan power production. However, more research is needed to explain the difference in results between Phase 1 and Phase 2.

Second, there is evidence **that due to the existence of a carbon price, operational managers favoured more efficient coal power stations over less efficient power stations**, although the subset through which we have derived this result is relatively small. The carbon price elasticity was about 87 per cent higher (in absolute terms) for inefficient units than for efficient units implying that due to the EU ETS, less efficient coal power stations lowered their load factors more than efficient units. Such impacts could, to a lesser extent, also be found for natural gas generating units.

A potential *third* effect is that due to the carbon price signal biomass co-firing became more attractive. However, this impact was not tested due to lack of data. We also observe that auxiliary renewable energy policies may have stimulated the demand for biomass co-firing.

While the results are in line with what is expected from the literature on economic dispatch of power generation assets, this analysis using an econometric model for carbon pricing in power systems, with monthly data, has yielded **statistically significant results**.

The strength of the model lies in the significance of the observed coefficients that their signs are in accordance with what can be expected from literature, with no significant coefficients that are unexplained. Limitations of the accuracy of the regression model are:

- We did not take actual biomass co-firing in coal plants into account due to lack of data.
- Temporal variations on the time scale hour/day/week are neglected, which could be an important driver for monthly load factors of flexible generation. The size of these effects are hard to quantify, and will depend on the installed capacities of e.g. intermittent renewable electricity (solar-PV and wind). Whilst solar-PV has specific hourly patterns impacting flex units most (e.g. gas generation), wind energy output is more stochastic in nature, and can impact any generating unit.

A number of factors are important for the extent to which the results in this analysis can be generalised. These factors must be taken into account when this study is repeated for other energy systems or EU Member States.

The developments of relative prices of fuels, in relation to the carbon price, is an important factor in the results. The level of carbon pricing needed should in essence be influenced by price levels of high carbon vs. low carbon fuels. In the study period, the UK has seen comparatively low gas prices, increasing coal prices and (by today's standards) mostly high EUA prices. The current trend is that gas prices have increased more so than coal prices, since 2012 EUA prices are rather low, which **leads to reduced competitiveness of efficient plants compared to inefficient ones**.

- For the fuel substitution effect to be not only significant but also of sizeable volume, there has to be a sufficiently large generation portfolio with ample reserve capacity.
- As electricity is a unique commodity; ideally temporal variation on all relevant time scales (hour/day/week/month/season) should be in the regression model. This would be even more important in energy systems with a larger share of intermittent generation (solar/wind), and/or storage capacity. In the largest part of

the study period, the UK had only limited intermittent renewable generation capacity.

- By comparison the UK electricity market has weak interconnection, so price levels on other EU countries are of limited influence to UK dispatch. In analysis of other countries, price levels in surrounding markets can and do influence dispatch, and should be estimated in the model. Therefore, whereas the approach to be followed is transposable to other markets, the results from the UK electricity market analysis are not directly transposable to other markets.

3.1.6 References

Baumol W.J. and Oates W.E. (1988) *The theory of environmental policy*, Cambridge University

DECC (2012b) *Renewables Obligation: Statistics*

DECC (2012c) *Table of past and present UK nuclear reactors*

DECC (2012d) *Electricity generation costs*

DECC (2013) *Energy statistics, Electricity historical data*

DECC (2013b) *Electricity Market Reform delivery plan*

DECC (2014) *The Renewables Obligation*
<https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-low-carbon-technologies/supporting-pages/the-renewables-obligation-ro>

DECC (2014b) *Policy – Maintaining UK energy security – Electricity Market Reform*
<https://www.gov.uk/government/policies/maintaining-uk-energy-security--2/supporting-pages/electricity-market-reform>

DECC (2014c) *Energy trends, March 2014*

Sijm J.P.M., Hers S.J., Lise W. and Wetzelaer B.J.H.W, ECN (2008) *The impact of the EU ETS on electricity prices; Final report to DG Environment of the European Commission Brussels, December 2008*

Ellerman, A. Denny and Barbara Buchner (2008) *Over-allocation or Abatement: A Preliminary Analysis of the EU ETS based on the 2005-06 Emissions Data*, "Environmental and Resource Economics, 2008, V.39

Ellerman, A. Denny and Joskow, Paul L. (2008) *The European Union's Emissions Trading System in perspective. Report prepared for the Pew Center on Global Climate Change. May 2008.*

European Commission (2013). *State aid SA. 34947 (2013/C) (ex 2013/N) – United Kingdom Investment Contract (early Contract for Difference) for the Hinkley Point C New Nuclear Power Station C (2013). 9073 final*

IEA (2012). *Energy Policies of IEA Countries: The UK*, Paris: International Energy Agency (IEA), 2012

IEA (2012b). *IEA Statistics: Natural gas information*, Paris: International Energy Agency (IEA), 2012

- IEA (2012c). IEA Statistics: Oil information Paris: International Energy Agency (IEA), 2012
- IEA, (2012d). IEA Statistics: Coal information Paris: International Energy Agency (IEA), 2012
- IEA (2013). Electricity Information 2013 Paris: International Energy Agency (IEA), 2013
- Kahneman D. and Tversky A. (1979). Prospect theory: an analysis of decision under risk In: *Econometrica*, vol. 47, no. 2, (1979); p.263-292
- McGuinness M. and Ellerman, A. Denny (2008). CO₂ Abatement in the UK Power Sector: Evidence from the EU ETS Trial Period Boston Mass.: MIT, CEEPR, November 2008
- McGuinness M. & Trotignon R. (2007). "Technical Memorandum on Analysis of the EU ETS Using the Community Independent Transaction Log," Working Papers 0712, Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research.
- NAO (2003). The New Electricity Trading Arrangements in England and Wales Report by the comptroller auditor general HC 624 Session 2002-2003: 9 May 2003 London: The Stationery Office
- Platts (2014) Powervision dataset
- Platts (2014) Platts, from BM reports, Dataset power unit generation levels (monthly data)
- Point Carbon (2008). EU ETS Phase 2 – The potential and scale of windfall profits in the power sector: A report for WWF. Point Carbon Advisory Services, March 2008
- Sijm J.P.M., Bakker S.J.A., Chen Y., Harmsen H.W., and Lise W., (2005). CO₂ price dynamics: The implications of EU emissions trading for the price of electricity Petten : Energieonderzoek Centrum Nederland (ECN)
- Sijm J., Neuhoff K., Chen Y. (2006). CO₂ cost pass through and windfall profits in the power sector. In: *Climate Policy*, vol. 6 (2006); p. 49-72
- Sijm J., Hers S., Lise W., Wetzelaer B. (2008). The impact of the EU ETS on electricity prices Petten: ECN
- Slijm J., Chen Y., Hobbs F. (2009). The impact of power market structure on the pass-through of CO₂ emissions trading costs to electricity prices – A theoretical approach, paper presented at the 17th Annual Conference of the European Association of Environmental and Resource Economics (EAERE), Amsterdam, June 24-27, 2009
- Schweppe Fred C., Caramanis, Michael C., Tabors, Richard D., Bohn, Roger E (1988). *Spot Pricing of Electricity*
- Stoft and Steven (2002). *Power System Economics* May 2002
- Harald Tauchmann (2006). Firing the furnace? An econometric analysis of utilities' fuel choice
- Energy Policy* vol 38, No. 18, December 2006.

Zachmann (2007). A Markov Switching Model of the Merit Order to Compare British and German Price Formation DIW, Berlin: July 2007

3.2 Cement Sector

3.2.1 Introduction

This section presents an analysis of the impact of the EU ETS on low carbon actions in the cement sector, as well as the broader economic, technical and energy context. The analysis covers data from Germany, EU and the USA, and also includes the findings of an interview with the German cement company HeidelbergCement.

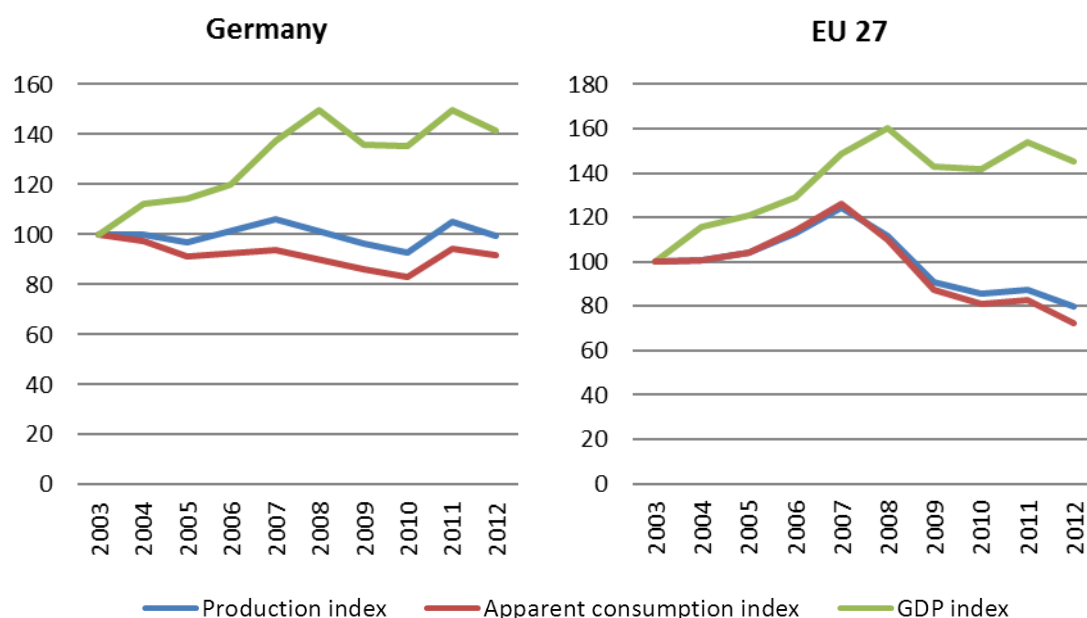
3.2.2 Data analysis

3.2.2.1 Economic Performance

This section aims at identifying the main trends in the economic performance of cement production. We consider cement volumes as an aggregate of cement, clinker and other cements as published by the Eurostat Prodcom database.

In Figure 23 cement production is approximated as the amount of cement products issued in the studied region in one year. The aggregate *cement products* include data for Portland cement, the most common type of cement; cement clinker as a semi-finished product and other types of cement, which aggregate the remaining production of the cement industry. Subtracting net exports from production allows us to compute the apparent national consumption. We also added the national GDP as a proxy for overall aggregated demand. All data is indexed to 100 in year 2003. This allows us to describe the relationship between the cement supply and the overall demand as well as cement specific demand.

Figure 23 Cement and economic activity in Germany and the EU as a whole on a 2003 basis (Prodcom, 2013)



In the EU as a whole, the consumption of cement products has been influenced by the overall economic demand since 2003. This indicator is closely related to the construction sector, which has been strongly impacted by the 2008 economic crisis. Hence, after having reached a peak in 2007, the European cement production dropped sharply by 40 percentage points. Similarly, the production stabilised as the economy started to recover in 2010, decreasing once again in 2012.

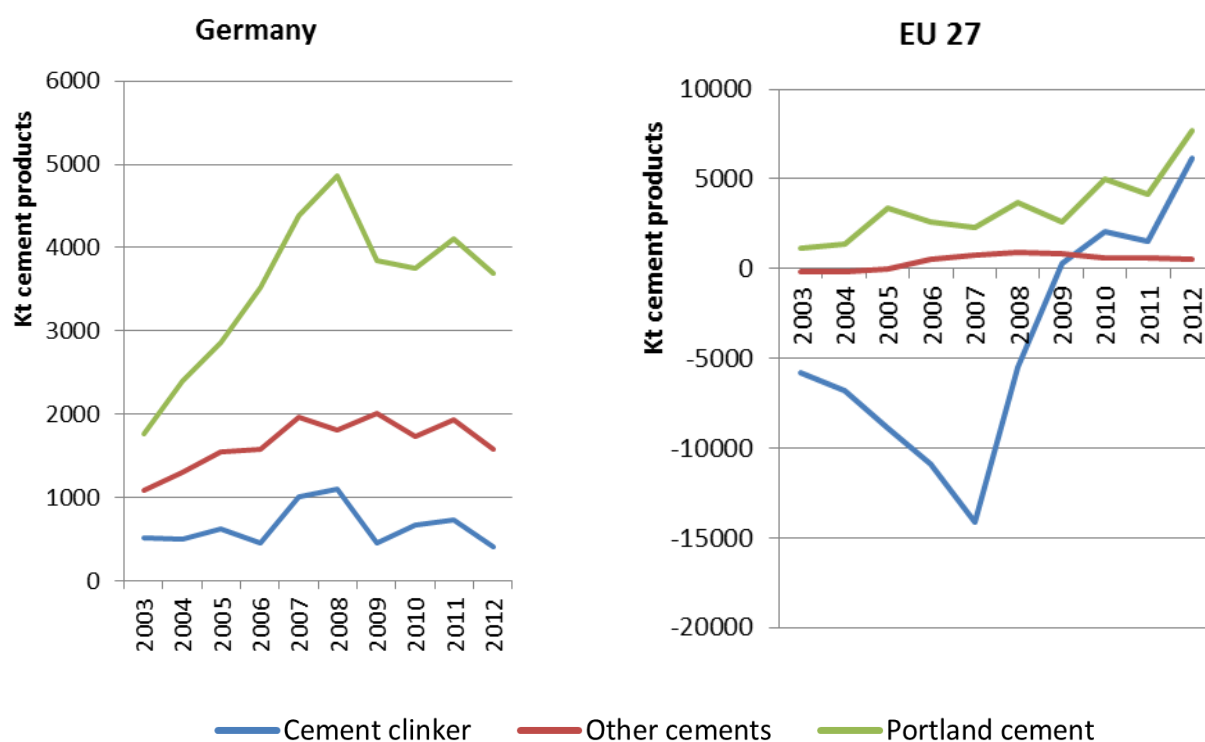
These effects have been less stark in Germany; cement production only dropped by 10 percentage points. Since 2003, demand for cement products seems to have become less affected by the level of aggregated demand, as the above figure shows. While GDP increased by roughly 40 per cent over the period 2003 to 2007, cement consumption dwindled by some 5 per cent in Germany and the cement industry did not recover before the economy as a whole did in 2010.

It is also worth noticing that, while respective shares of Portland cement, clinker and other cements have remained stable in the EU 27 over time, Portland cement has been progressively substituted by other types of cement products⁴⁵ in Germany. Its share in the total production of cement products dropped from roughly 70 per cent in 2000 down to 45 per cent in 2010 (Prodcum, 2013).

3.2.2.2 Trends in Trade

As the first section presented the relationship between cement production and national/EU wide demand, we focus next on the impact of external demand on the shape of trade trends. Figure 24 summarises export trends of the past decade based on Prodcum data. Data for Portland cement, cement clinker as a semi-finished product and other types of cement are aggregated under the term *cement products*.

Figure 24 Net exports of cement products in Germany and the EU27 to the rest of the world (Prodcum, 2013)



Trade allowed the German cement sector to partly overcome the decrease in its internal demand for cement. As the national consumption decreased softly over the past 12 years, net exports rose. As a consequence the production of cement within the

⁴⁵ Aside of Portland cement (CEM I), four other main types of cement are to be distinguished. Their physical characteristics depend on the amount of clinker substitutes they contain, mainly slag sands and ashes, but also natural raw materials such as pozzolan.

country has remained relatively stable over time. As in many other sectors, trade has become a structural feature of the cement industry in Germany. In gross terms, 25 to 45 per cent of the German cement production was annually exported over the 2000-2010 period (Procom, 2013).

The absolute amount of cement products traded outside the EU remains very low though. As the graph shows, most of the cement produced in Europe is consumed by member states. After the 2009 crisis, most countries tried to massively export their cement in order to overcome the sharp fall in the internal demand. Net exports soared by 250 per cent. Nevertheless, no more than 5 per cent of the EU cement production has been exported to the rest of the world since 2003. This highlights the fact that cement is mostly traded within a restrictive geographical market, due to the heavy and bulky nature of cement, as summarised by Cembureau (2014): “*Land transportation costs are significant and it used to be said that cement could not be economically hauled beyond 200 or at most 300 km*”.

It should be noted that clinker was imported into the EU before the economic downturn. The clinker production of several countries in southern Europe was insufficient to cover the demand until 2007 (Climate Strategies, 2014).

From these observations and the results of the above mentioned Climate Strategies report (2014) the following main conclusions can be drawn:

- Trade flows are driven by the difference between cement production and domestic demand. In Germany, the demand for cement decreased over the last decade, and German cement producers have been exporting a large share of their production. Before 2008, countries in southern Europe have in particular met their net cement demand by importing clinker. After the economic downturn these countries became net exporters in order to compensate for the significant drop in internal demand.
- The relatively low share of cement exported outside the EU emphasises the regional character of cement markets. Due to the high transportation costs of cement, most cement production plants have been built strategically between raw material quarries and demand spots, hence clustering the market into regional areas.

3.2.2.3 Overview of Carbon Emissions

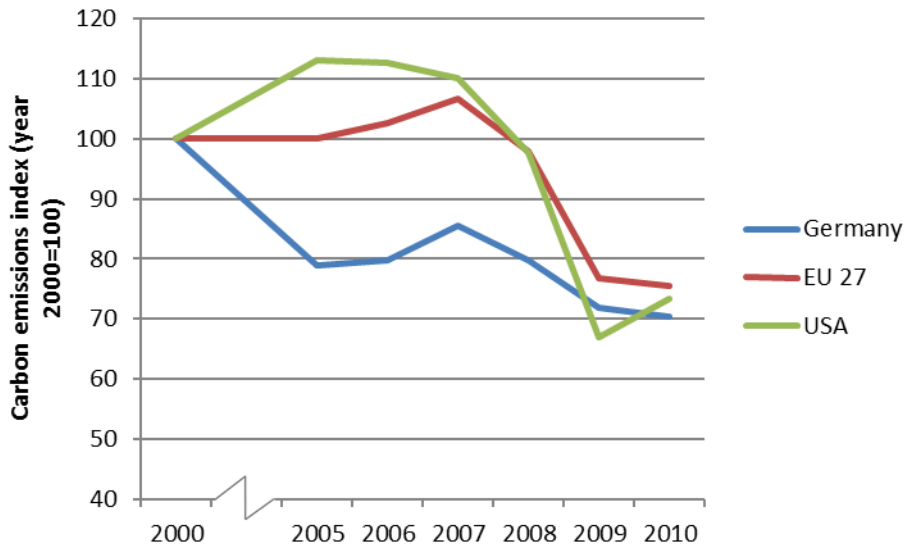
In the first two sections, we described the demand structure of the cement industry. This helped us to identify the economic drivers of the cement production. In this section we focus on the carbon emissions trends.

Absolute Carbon Emissions

Figure 25 shows the development of absolute CO₂ emissions from the cement sector from 2000 to 2010 for Germany, the EU27 and the USA. Data used have been retrieved from the WBCSD GNR⁴⁶ database. Cement data refers to cement-aggregate, which corresponds to our cement product indicator of the previous section.

Figure 25 Absolute carbon emissions index of cement sectors in Germany, EU27 and US; year 2000 index=100 (WBCSD, 2012)

⁴⁶ World Business Council on Sustainable Development, Getting the Numbers Right



Until 2007, absolute CO₂ emissions have followed very different trends in the EU, the US and Germany. While emissions from the cement sector in Germany have reduced by 20 per cent between 2000 and 2005, EU emissions remained stable between 2000 and 2005. In the US, carbon emissions have risen by more than 10 per cent over the same period.

All these trends have been affected by the economic downturn in 2008/2009. Absolute carbon emissions decreased in all three regions. This might suggest that the decrease in absolute carbon emissions was largely driven by the fall in demand rather than by investments in carbon abatement measures. This hypothesis is assessed by the analysis of the specific carbon emissions. Specific carbon emissions or *carbon intensity* describes the amount of CO₂ emitted per tonne of cement produced.

Figure 26 Specific CO₂ emissions of cement industries in selected developed and developing countries or regions from 2000 to 2010 (WBCSD, 2012)

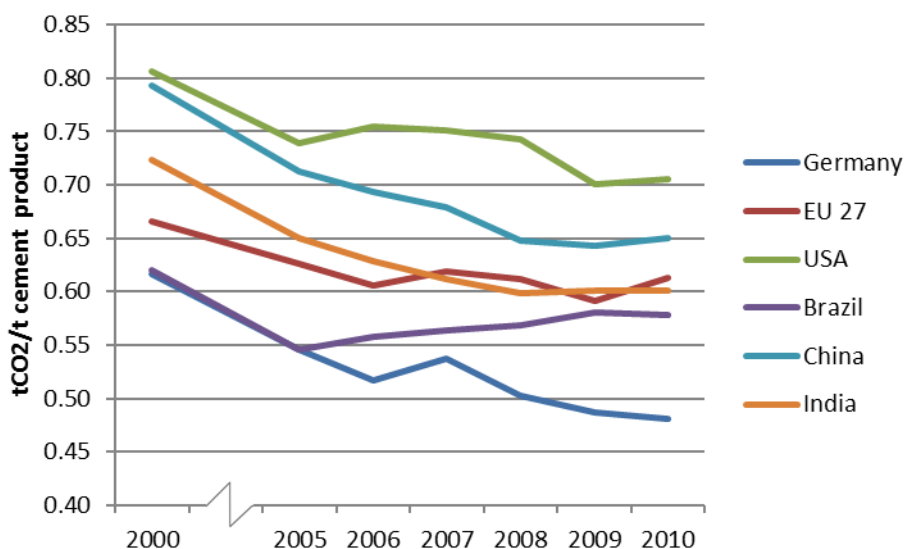


Figure 26 visualises the specific CO₂ emissions from 2000 to 2010. In Germany, the specific CO₂ emissions of the cement industry decreased between 2000 and 2005. Thereafter, a period of only minor reductions in specific CO₂ emissions followed. This holds true for the European level as well, though in a less substantial manner. The US cement industry has lowered its specific CO₂ emissions until 2005, stabilizing

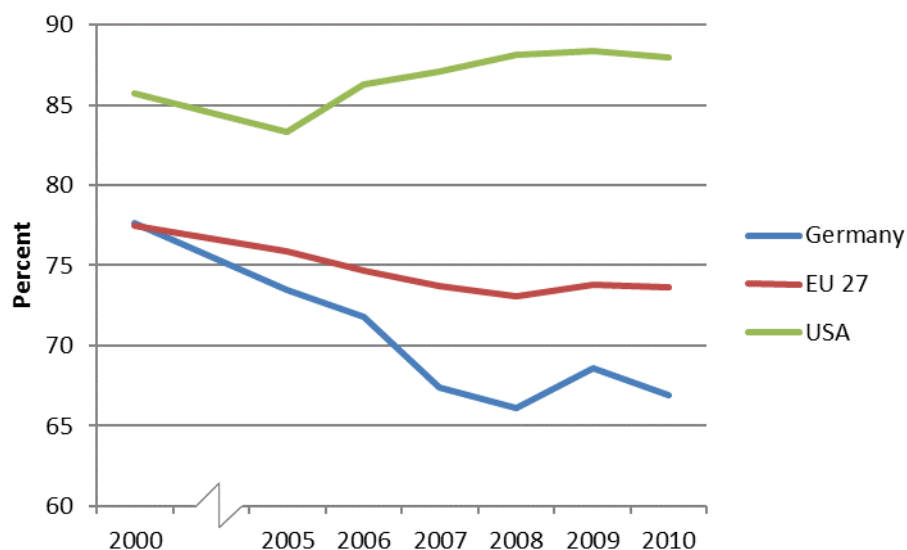
afterwards at a 0.7t CO₂/t cement level, whereas the EU and Germany managed to reach some 0.6t and 0.5t levels, respectively. Similar trends are observable in developing countries, except for Brazil. In Brazil specific emissions increased after 2005 despite primary substantial improvements. Reasons for the general slowdown in carbon abatement pace are to be found in the ever more expensive and technically intense marginal CO₂ reductions.

Production Process and Carbon Emissions

This section identifies drivers for the observed trends in specific carbon emissions, with a primary focus on carbon emissions caused by the production process itself. Most CO₂ emissions of the cement industry are related to the acidification of clinker. Hence, a way to decrease emissions is to use a lower share of clinker in the production process of cement. Most cement producers have consequently used a larger share of alternative raw materials in their production mix.

Figure 27 shows that this trend holds for the EU27 and Germany from 2000 until 2008 with the clinker share stabilising afterwards. The observation however does not hold for the US. In the US the share of clinker does not show a general downward trend and increased from 83 per cent in 2005 to 88 per cent in 2010. These observations are related to the trends in the product mix. As stated previously, the share of Portland cement has been decreasing over time in Germany. Its alternatives feature a lower share of clinker. Similarly, the small decrease of Portland cement in the EU cement product mix over the decade since 2000 can explain the observed trends in clinker share. The decrease in the clinker share in the EU and Germany is directly related to the increasing use of slag sand as a clinker substitute. In the US the relative scarcity of alternative raw materials is responsible for a comparably high clinker share (US GS, 2014).

Figure 27 Clinker share in final cement products in Germany, the EU 27 and USA from 2000 to 2010 (WBSCD, 2012)



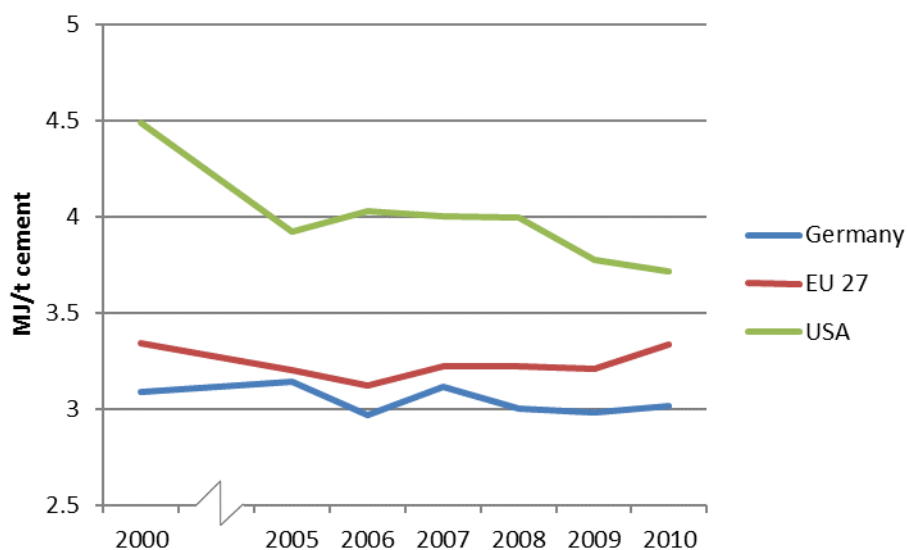
The stabilisation of the clinker share in cement is due to the basic features of its substitutes. Those are either waste streams of the steel industry such as slag or fly ash, or other natural raw materials such as limestone or pozzolan. Both types of products are limited in their availability due to either economic or geological constraints. Moreover, their preparation as substitutes for clinker requires some technological changes to the production process. The costs of these changes may limit the rates at which substitutes are adopted in cement production (Climate Strategies, 2014).

Finally, cement production has to consider market acceptance and specific needs. The building industry – the primary user of cement products – uses a wide variety of cements. Each of these cements features a precise set of properties, which partly depends on the quality and share of clinker in cement. However, some products may meet the physical requirements but may not be accepted by the market. In the cement sector, the resistance of the market to new products is particularly strong. The reason is that the products have to last decades, if not centuries. Building companies do not want to take the risk of using products that have not been proved to be effective. The rate at which clinker is substituted in cement is therefore hampered by proof (and perception) of quality as well as technical restrictions (Climate Strategies, 2014).

Energy Consumption and Carbon Emissions

Apart from the decrease in the clinker share, energy efficiency is also an important driver of low carbon activities in the cement industry. The following section aims at identifying trends in the cement production's energy efficiency. Figure 28 describes the development of the specific energy consumption (i.e. energy intensity) of cement production in Germany, the EU27 and the US from the year 2000 to 2010. After a period of improvements, especially in the US, the specific energy consumption of the cement sector stabilised around its 2005 level. For example, the German cement industry reached a 3 MJ/t cement level in 2006 and has not experienced further improvements since then.

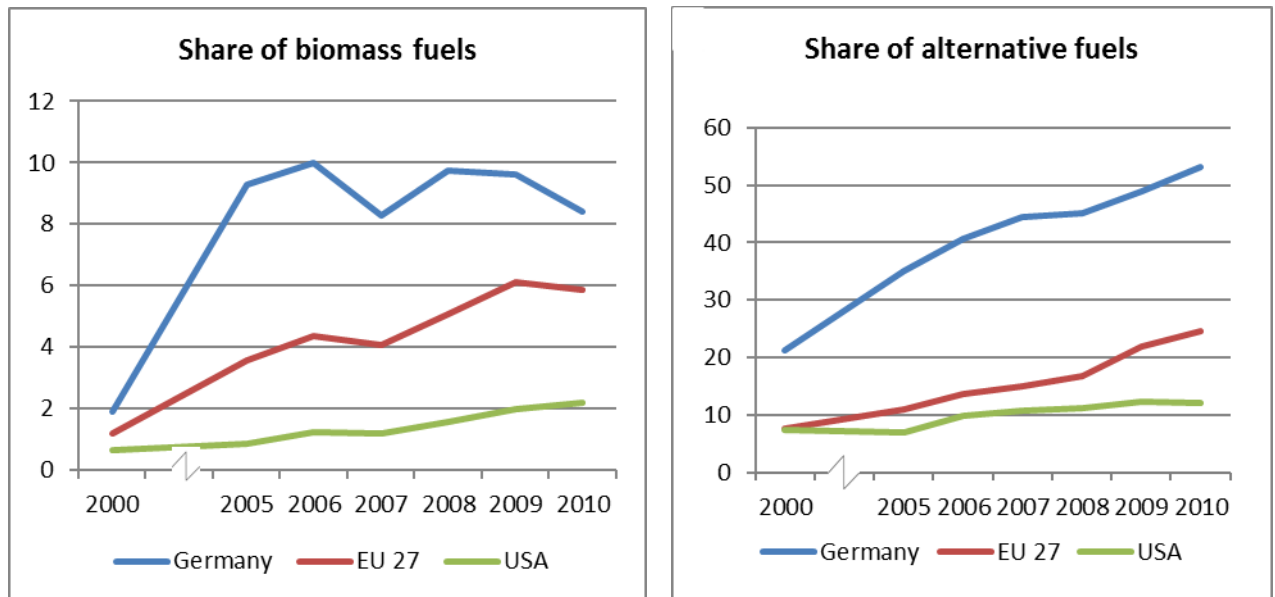
Figure 28 Specific energy consumption of cement sectors in Germany, EU and the US between 2000 and 2010 (WBCSD, 2012)



One driver of past improvements in energy efficiency was that, aside from fossil fuels, the cement industry started to use alternative fuels in 1990 and has significantly increased their usage since then. These are mostly wastes from other industries or municipalities⁴⁷. They have become an important source of thermic energy in the German cement sector representing roughly 50 per cent of the fuel consumption in 2010. As one can observe in Figure 29, similar trends have occurred in the EU and the US. However, the increase in the share of alternative fuels has been far less significant, since they respectively reach some 25 and 12 per cent of the total fuel consumption (WBCSD, 2012).

⁴⁷ According to the VDZ, waste used in the cement industry mainly consists of tyres, oil waste, industrial waste such as paper, packages, plastics, textile waste, meat, bone meal, wood waste, dissolver products, clay and industrial sludge (VDZ, 2013).

Figure 29 Share of alternative fuels and biomass fuels in cement sector fuel consumption in Germany, the US and the EU 27 (WBCSD, 2012)



Alternative fuels are considered as carbon neutral by the cement industry (VDZ, 2013). The EU ETS however only considers biomass fuels as carbon neutral. Their importance in the fuel mix of cement production has also been growing since 2000. Especially in Germany, biomass fuels have increased to represent roughly 10 per cent of fuel thermal input in cement production since 2000 (WBCSD, 2012).

The sector's thermal energy efficiency has changed following the shift to alternative fuels: it has slightly improved between 1990 and 2000. Thermal energy efficiency has however stabilised around 80 per cent of the 1990 level in all countries studied. The electricity intensity of the cement industry has decreased in the 1990s and has remained stable until 2005. This decline was mostly due to improvements in energy management. Since then however, electricity intensity has started to rise again. The reason for that is the introduction of clinker substitutes. These require a supplementary electricity-intensive preparation phase, hence increasing electricity consumption (WBCSD, 2012).

Despite this recent increase, electricity consumption represents a rather low share of the cement industry's total energy consumption. Germany, the EU as well as the US use less than 12 to 14 per cent of electricity in their energy mix. Variations in electricity intensity therefore cannot explain energy efficiency improvements.

As a conclusion, most of the energy savings occurred between 1990 and 2005. Since then specific energy consumption trends have been smoothing as depicted in Figure 29. This indicates the existence of a structural barrier to more substantial energy efficiency gains.

As suggested by the literature, reasons for this smoothing trend are the decreasing potential of energy savings and other carbon abatement processes. As the carbon intensity decreases the marginal abatement potential also decreases, so it is more difficult (costly) to drive further improvements. In order to overcome this limit, investments in breakthrough low carbon technologies would be required.

3.2.2.4 Trends in Low carbon Activities and Investments

This section aims to identify common trends in low carbon activities and investments among German firms in the cement sector and to understand to what extent the EU ETS has had an impact on the low carbon activities and investments. The analysis is

based on business and sustainability reports as well as carbon monitoring reports of the German cement industry (VDZ, 2013).

Brief Technical Introduction

In this section we will provide some insights on the general framework as well as technical features of cement production in Germany.

The total number of German cement companies has decreased from 25 companies in 2003 to 22. These 22 companies currently operate 54 cement plants in Germany, the majority of which produce between 0.2 and 1 million tonnes of cement per year for domestic purposes. In total 33.3 million tonnes of cement were produced by them in 2012. Domestic cement production has been quite constant in absolute terms since 2005 (when it was 32.8 Mt). The German cement sector employed 7,371 workers in 2012 and generated a total turnover of €2.2 billion (VDZ, 2014).

Cement is the result of a complex production process. It basically consists of two steps:

- Clinker is produced from a mixture of raw materials (calcium oxide (65 per cent), silicon oxide (20 per cent), aluminium oxide (10 per cent) and iron oxide (5 per cent)) by grinding, heating and hydration.
- Cement is produced by adding cementitious materials (blast furnace slag, coal fly ash, natural pozzolan, etc.) or inert materials (limestone) to the clinker and grinding the output

Each of these production phases produces CO₂ in a different manner. During the first phase, CO₂ is produced and emitted through chemical reactions due to the drying process. This represents roughly 50 to 70 per cent of the cement industry's carbon emissions, whereas the combustion of fuel generates most of the rest. Electric energy is needed to grind the output in both phases, while the first phase mostly relies on fossil and alternative fuels to heat the raw materials within kilns (CEMBUREAU, 2014).

Kilns can either be designed to process wet or dry materials. Their energy efficiency can be improved through the use of precalciners and preheaters. The current Best Available Technique (BAT) consists of a dry kiln equipped with a multistage preheater and precalciner. This BAT is currently used in roughly 45 per cent of European clinker production. The use of this technology allows lower CO₂ emissions since wet kilns need more fuel to evaporate water from the raw materials. For instance, a wet kiln requires around 50 per cent more energy than a dry BAT-kiln (Climate Strategies, 2014).

Whereas process CO₂ emissions amount to approximately 530kg CO₂/t clinker, fuel emissions vary between 220 and 500kg CO₂/t clinker (depending on thermal energy efficiency of cement kiln and fuel type). Moreover, the consumption of electric power results in indirect CO₂ emissions (Cembureau, 2014).

Fuel-related emissions can be reduced by substituting traditional fuels by alternative ones such as waste or biomass that emit (or are classified as emitting) less CO₂/MJ. Thermal energy efficiency improvements by using optimal technology/operating practices represents another possibility. Process-related emissions can be reduced by means of substituting clinker for other mineral components in cement while maintaining its physical properties. In addition, Carbon Capture and Storage (CCS) as well as Carbon Capture and Utilisation (CCU) techniques are considered abatement measures in terms of process and fuel-related CO₂ emissions. By improving the electric energy efficiency of clinker and cement production installations, indirect emissions of CO₂ could also be mitigated (Climate Strategies, 2014).

Specific Carbon Emissions

In light of the technical insight of the previous section, we will now describe the carbon emissions trends of the German cement sector. Table 22 summarises the development of CO₂ emissions in the German cement industry (absolute and specific).

Table 22 Absolute and Specific CO₂ Emissions from the German Cement Sector (VDZ, 2013)

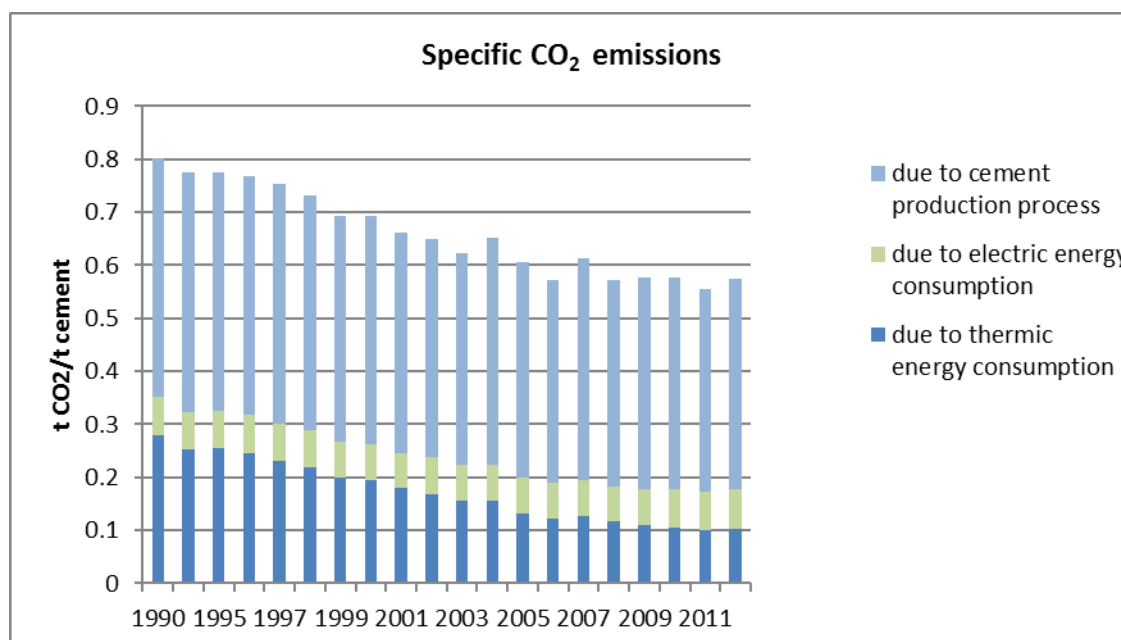
	Absolute CO ₂ emissions (in Mt/y)					Specific CO ₂ emissions (in t CO ₂ /t cement)				
	1990	2010	2011	2012	Evolution ⁴⁸	1990	2010	2011	2012	Evolution ⁴⁹
Energy	12.19	5.42	5.92	5.82	-52.3	0.346	0.178	0.173	0.177	-48.8
Of which thermal ⁵⁰	9.73	3.19	3.41	3.39	-65.2	0.275	0.104	0.1	0.103	-62.5
Of which electricity	2.46	2.23	2.51	2.43	-1.2	0.072	0.074	0.073	0.074	2.8
Process emissions	15.64	12.19	13.13	13.03	-16.7	0.442	0.398	0.383	0.398	-10.0
Total	27.83	17.61	19.05	18.84	-32.3	0.787	0.575	0.556	0.575	-26.9

Since 1990, the overall CO₂ emissions of the German cement industry have decreased, from 27.83 to 18.84 Mt/year in 2012.

This represents a decline of roughly 30 per cent in absolute CO₂ emissions, primarily due to reductions in emissions from thermal energy consumption (-65.2 per cent 1990 to 2012). As an analysis of specific emissions reveals, the decline in absolute emissions was caused by efficiency modifications within the production process (e.g. alternative fuels) (VDZ, 2013).

The specific CO₂ emissions per tonne of cement have also decreased since 1990. They dropped from 0.787 tCO₂/t cement in 1990 to 0.575 tCO₂/t cement in 2012. Figure 30 provides a more detailed (annual) overview of the development of specific CO₂ emissions in the German cement sector since 1990.

Figure 30 German cement industry's specific CO₂-emissions resulting from process, fuels or electrical power need (tCO₂/t produced cement) (VDZ, 2013)



⁴⁸ In percent, 1990 base 100

⁴⁹ In percent, 1990 base 100

⁵⁰ Without alternative fuels

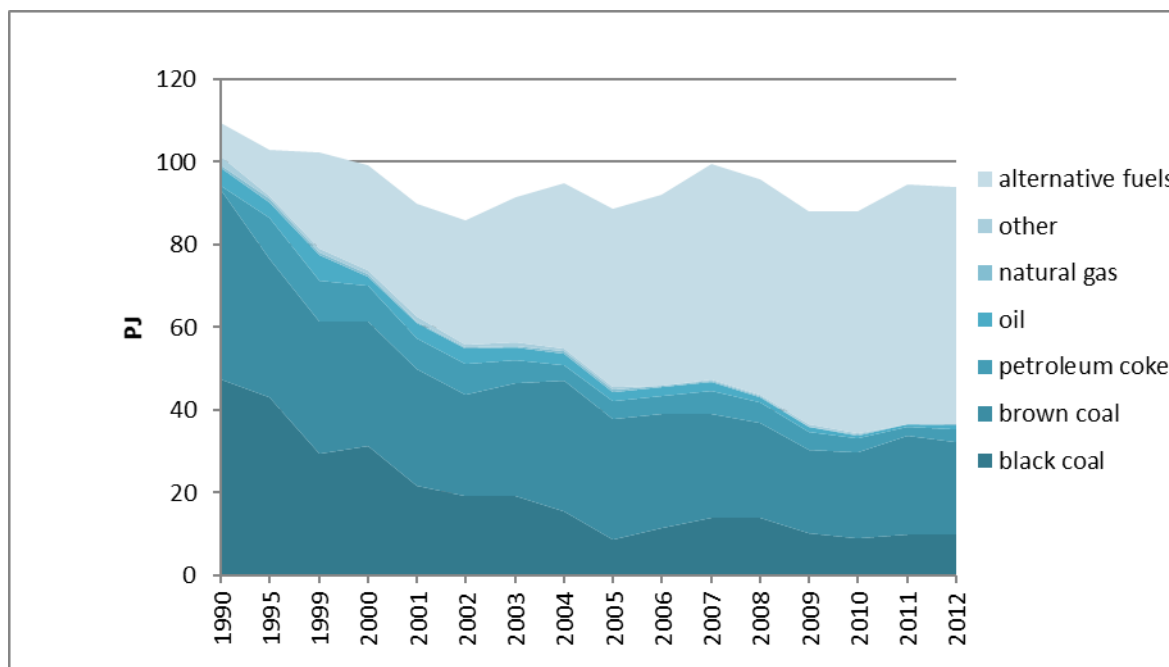
The figure clearly shows that the decline in specific emissions is mostly due to 60 per cent reduction in emissions intensity of thermal energy consumption CO_2 . Reductions of process emissions intensity have fallen by roughly 15 per cent over this same 1990 to 2012 period, while the (indirect) CO_2 emissions intensity of electricity consumption has remained approximately constant. The declines have for the most part taken place between 1990 and 2006. Since 2006, emissions have been slightly fluctuating around 0.55 tCO_2/t cement produced (VDZ, 2013).

Low carbon Activities and Investments

The previous section showed that most carbon abatement has occurred due to a decrease in emissions from thermal energy consumption and to a lesser extent from production process modifications. The following part sheds light on these findings, especially breaking down these improvements with respect to the technical features of the cement industry in Germany. Trends in fuel, electric and process emissions, as well as the development of new technologies are successively addressed⁵¹.

Figure 31 depicts the type and amount of **thermal** energy consumed by the German cement industry since 1990. Historically, the German cement industry relied mostly on fossil fuels, particularly brown coal (lignite) and stone coal (anthracite). Since 1990 however, new fuels have become more important: the combustion of alternative fuels nowadays amounts to around 60 per cent of the thermal energy consumption of the German cement industry (7 per cent in 1990). This encompasses a large mix of wastes (tyres, industrial waste, bone meal, biomass fuels, etc.). Since the cement industry, which publishes the data, considers these alternative fuels as carbon neutral⁵², their increased use has led to a sharp decline in thermal energy carbon emissions.

Figure 31 Thermal energy consumption by source for the German cement sector since 1990 (RWI, 2013)

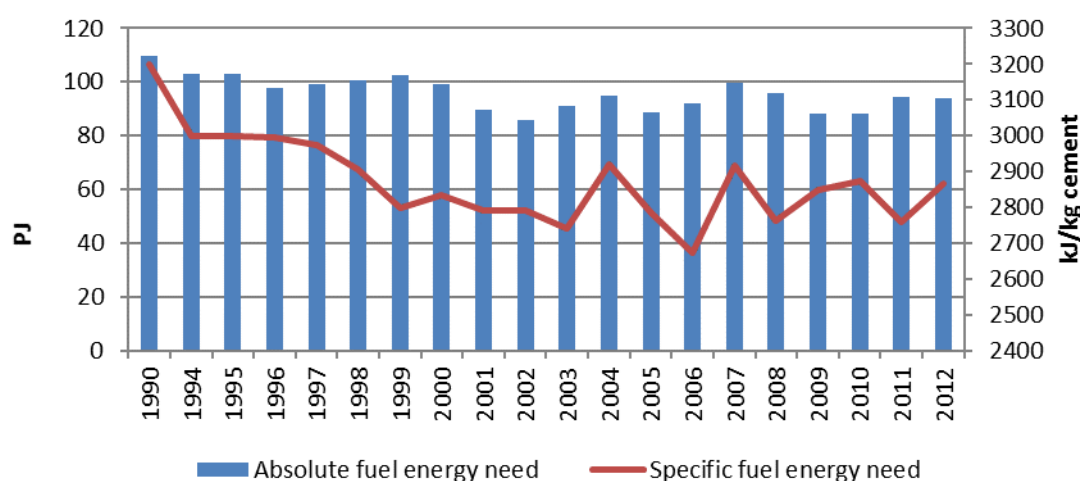


⁵¹ For an overview of specific carbon abatement measures of the German cement producers, please refer to Table 1 in the appendix.

⁵² They argue that waste incinerated or buried would have anyway released the carbon it contains. Since the beginning of the third phase of the EU ETS, the EU considers only biomass fuels as neutral, the rest is being accounted in the allowance calculation.

The energy efficiency of the thermal combustion process (including alternative fuels) also improved between 1990 and 2002, allowing the thermal energy intensity per tonne cement to be cut by 11 per cent. Since then however, no further improvements in terms of energy efficiency are observable, but an increasing volatility is recognisable (Figure 32). As a whole, the specific energy consumption of the German cement industry decreased from 3,200 kJ/kg cement in 1990 to 2,866 kJ / kg cement in 2012 (Figure 32).

Figure 32 Thermal energy consumption and intensity in the German cement industry (VDZ, 2013)

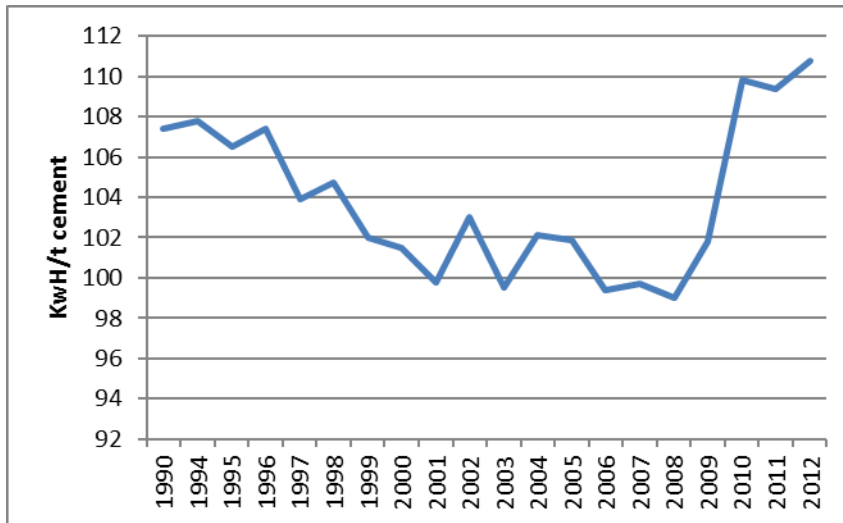


These results suggest that the substantial reduction in CO₂ emissions from thermal fuel combustion have mostly been driven by the mean of fuel substitution since 1990. If compared to the increasing share of alternative fuels, energy efficiency improvements do not account for much in the thermal energy carbon abatements.

The replacement of inefficient kilns has also had an impact on the specific energy consumption (essentially thermal). The EU average thermal energy efficiency of cement kilns remained stable at 3,730 MJ/tonne between 2000 and 2011, exceeding the Best Available Technology (BAT) level by some 20 per cent. This BAT currently stands for dry kilns with multistage preheater and precalciner and nowadays represents roughly 45 per cent of European clinker production (Climate Strategies, 2014). In Germany however, all production uses dry kilns, of which 96 per cent feature a precalciner (VDZ, 2013). This means, energy efficiency improvements through kiln replacement is about to reach its full potential in the German cement sector.

Figure 33 shows the specific electricity consumption of the German cement sector from 1990 to 2012. Improvements in energy efficiency led to a 6 per cent reduction in electricity consumption intensity between 1990 and 2009. However, since 2009, the electricity consumption intensity has increased to above 1990 levels due to the substitution of clinker with a large mix of alternative raw materials. These alternative raw materials require electricity intensive pre-treatment (e.g. drying and shredding). CO₂/tonne In addition, depending on the use of alternative raw materials, the final product features have different physical properties than Portland cement.

Figure 33 Electricity consumption intensity of the German cement industry 1990 – 2012 (VDZ, 2013)



Through the acidification of raw materials, clinker making releases huge amounts of CO₂, representing the most important part of the cement industry emissions (around 70 per cent in 2012). Thus, carbon abatement measures may be very effective in this sector. New types of cement with a lower clinker share, despite increasing electricity need, reduce the amount of carbon dioxide emitted during the drying phase. The clinker share is reduced by adding more new materials, especially slag sand issued by the steel industry. This approach is nevertheless limited by a minimum clinker share within the cement, as well as the availability of the substitutes⁵³ (VDZ, 2013).

These new types of cement containing a lower share of clinker (CEM II and III) together represented a 70 per cent share of the market in 2012 (36 per cent in 1990). According to VDZ, the main reason for this product substitution has been the effort put in place by the cement industry to foster their acceptance on the market. In the meantime, process emissions per tonne cement have been cut by 10 per cent. With respect to the extent to which the market has been shifting from one type of cement to another, we can consider the raw-materials-based abatement as relatively low. Moreover, this mitigation option is close to its full potential. In 2010 the clinker-share in Germany was approximately 66.9 per cent. Based on a calcination reaction of limestone some 294 kg CO₂ will be theoretically emitted when producing one tonne of cement⁵⁴. The chemical boundaries are therefore near to be reached considering real-raw material emissions of 398 kg CO₂ in 2010 being 35 per cent higher than theoretical emissions. Thus, developing a new type of clinker is the only way to significantly reduce raw material-related emissions.

Firms in the cement sector are currently developing new cement mixes which may allow them to fully replace clinker in their final cement products. One of these projects is the on-going research on Belite Calciumsulfoaluminate Ternesite (BCT) Cement by HeidelbergCement. Its aim is to develop an alternative to clinker. The product releases lower process emissions and also needs less thermal energy to be heated in kilns. The use of such a substitute should allow reductions in carbon emissions of 30 per cent

⁵³ For instance, the availability of slag sand (as a by-product of the steel industry) depends on steel production levels.

⁵⁴ Calcination: CaCO₃ -> CaO + CO₂
 $m_{CO2} = \text{clinker-share} * m_{Cement} * (M_{CO2}/M_{CaCO3})$
 $= 0.669 * 1000\text{kg} * (44.01/100.09)$
 $= 294.16 \text{ kg}$

compared to Portland clinker. Nevertheless, as the Climate Strategies report (2014) points out, these new types of cement may face the absence of market demand, and suffer therefore from very low economic incentives. The main reasons for this are the high costs associated with the introduction of new products into the cement market; and customers need to be convinced about the adequacy of their long-term properties.

Carbon Capture and Storage (CCS) as well as Carbon Capture and Utilisation (CCU) are two further trends in low carbon activities in the cement sector. CCS is an abatement option capturing CO₂ from the installations' flue gases, liquefying and transporting it for storage. This investment-intensive technology is fostered and tested for applicability by the European Cement Research Academy (ECRA). Although CCS directly leads to lower emissions of CO₂, indirect emissions might increase as applying the technology results in higher energy consumption. Societal acceptance is still unclear particularly considering the difficulties underground storage of atomic waste still creates and the corresponding level of contempt of communities. Yet, European environmental organisations generally promote CCS in sectors where few other abatement options exist. CCS is still considered very expensive and therefore industry-wide application is not yet feasible (Climate Strategies, 2014).

Another research project led by ECRA concentrates on using renewable energy to convert captured CO₂ into hydrocarbons such as methanol rather than just storing CO₂ underground. The method is called Carbon Capture and Utilisation (CCU) and converts the captured CO₂ into a fuel or resource for industry.

3.2.3 In-Depth Study - HeidelbergCement AG

This section aims to illustrate the trends observed within the cement sector by providing concrete examples of low carbon activities and investments undertaken by HeidelbergCement and assessing the EU ETS influence on these processes.

3.2.3.1 Introduction

HeidelbergCement is Germany's largest producer of cement, aggregates and ready-mix-concretes and is one of the world's market leaders in this sector. In 2012 the company produced around 89 million tonnes of cement. It employs some 53,000 people at 2,500 locations in more than 40 countries with an annual turnover of approximately €11 billion (HeidelbergCement, 2013).

Since 1990, HeidelbergCement has, as revealed by Table 3 in Annex 3, reduced its absolute carbon emissions by 8 per cent, and its carbon intensity tonne by 18 per cent, compared to the sectoral averages of 33 per cent and 27 per cent respectively⁵⁵.

Since the implementation of the EU ETS (2005), the absolute CO₂ emissions of HeidelbergCement have been increasing by 18 per cent while the specific emissions have been decreasing by 6 per cent. The absolute and specific energy needs of the firm have been respectively falling by 13 per cent and 25 per cent since 1990.

⁵⁵ One must however be careful with these data, since we do not know whether the sustainability report includes alternative fuels within its emissions panel. The VDZ report does not, so this methodological imprecision can change the HeidelbergCement results with respect to the sectoral average.

Furthermore, the HeidelbergCement report data concerns the whole firm, including foreign installations, whereas it is not defined in the VDZ report whether the data solely entails the German sector.

3.2.3.2 Energy Efficiency, Alternative Fuels and Raw Materials

HeidelbergCement have implemented the typical carbon abatement methods for the sector: they substituted fossil fuels for alternative fuels (of which one third biomass, up from 9 per cent in 1990) by up to 21 per cent of the thermal energy consumption. The energy tonne intensity has been reduced by 23 per cent since 1990 (including alternative fuels). The shift to a less clinker-intensive mix has also been an important feature of the HeidelbergCement strategy, decreasing the share of clinker in the final cement product between 1990 and 2012 from 84 per cent to 75 per cent. This substitution process has however stabilised since 2010. (HeidelbergCement AG, 2013)

3.2.3.3 Lighthouse Projects

This section aims to identify and present possible low carbon lighthouse projects at HeidelbergCement. Currently HeidelbergCement is conducting research on two topics in order to investigate and evaluate further CO₂ abatement potential.

Firstly, represented by their Norwegian subsidiary Norcem, HeidelbergCement launched a CCS project in Brevik, Norway in 2013 and which aims to complete in 2016. The project aims to clarify how and by what amount excess energy from the cement production process can be used to capture CO₂ (transport and storage are not tested). Moreover, it shall provide knowledge in terms of different post combustion capture technologies and compare to CO₂ capture at power plants, for instance. CO₂The total cost of this project is approximately €12 million, the majority of which is paid by the Norwegian government. The entire project comprises four subsidiary and more detailed projects conducted by different technology-supplying firms:

- absorption process using amine solvent by Aker Solutions in mobile test unit
- membrane test unit using gas separation membranes by a consortium led by DNV
- solid sorbent process using fluidised bed technology by RTI International
- hot carbonate looping process by Alstom (at University of Darmstadt)

Aker Solutions will execute long-term and large-scale testing in their Mobile Test Unit of which solvents to use. The mobile unit can be regarded as a CO₂ capture plant. An advanced amine solvent specifically optimised for flue gases from cement plants will be applied in this context. The Mobile Test Unit has been constructed in 2008 and was initially used on gas-fired turbines in Norway. It can capture up to 0.7 million tonnes of CO₂ on an annual basis. The corresponding results of the testing will deliver information for future decisions on CO₂ abatements and might predict the feasibility of large-scale and industry-wide CCS. Although the intellectual property rights will stay with the suppliers, the most important outcomes will be proposed to other European cement producers, as the project was endorsed by the European Cement Research Academy (ECRA) (Akersolutions, 2014).

A second strand of research relies on the decrease of process-related carbon emissions released by clinker acidification. The use of alternative raw materials such as slag sand is limited, not only by their availability but also by the required quality of the cement products. At constant technological level, it has become complicated to further substitute clinker in cement without affecting its quality (VDZ, 2013). BCT (Belite Calciumsulfoaluminate Ternesite) aims at overcoming this technological barrier by providing a less carbon-intensive alternative to clinker. It is a combination of calcium sulfoaluminate cements and belite, a chemical element of classical Portland clinker. The cement produced out of this mix is as strong and long lasting as classical cement but is far less carbon intensive. It allows reducing process emissions by 30 per cent compared with classical Portland clinker. It also requires lower kiln heating

temperatures as well as less intensive grinding. Hence it enables reducing the fuel consumption by 15 per cent and the electricity need by 10 per cent (ZKW, 2014).

3.2.3.4 Interview

3.2.3.5 Sector and Company Details

The company confirmed the findings in the overall trends in production and emissions of the cement industry. Energy efficiency measures, the use of alternative fuels and the decrease of the clinker share in cement products have been widely used. In industrialised countries, the cement industry is close to reaching technology limits considering carbon abatement and future measures will bring only minor incremental improvements. The ongoing competition for raw materials like biomass fuels and clinker substitutes such as slag sands was confirmed. It was emphasised that the European emission reductions targets (43 per cent CO₂ emissions compared to 2005 by 2030) will not be reached at current technological levels.

3.2.3.6 Low carbon Actions and Drivers

Three different low carbon activities at HeidelbergCement were highlighted: the modernisation of existing plants and construction of efficient new ones, Carbon Capture and Storage (CCS) as well as Carbon Capture and Usage (CCU) projects, and research activities concerning alternative binders in order to substitute conventional clinker.

Firstly, from 2004 to 2012, HeidelbergCement has been investing throughout Europe in the modernisation of existing plants as well as in the construction of new ones, which has led to carbon reductions. In the first years of the EU ETS with carbon prices at around €30/tCO₂ the investments were *driven* by the carbon prices. Since the carbon market crashed, the main drivers for investing in incremental improvements have been trends in the cement market as well as energy savings, but carbon savings still occurred. For example, HeidelbergCement has built new plants in Poland and the UK as they expected demand to increase in these markets. Similarly they have been trying to diversify their energy mix mirroring the trends in the power market.

Secondly, low HeidelbergCement is developing a clinker substitute called BCT (see section 1.4.3 and 2.3). Research on the development of clinker substitutes is common in the cement industry and should allow cutting process emissions. Greener new cement products such as the BCT are seen as a niche product at HeidelbergCement. If marketable, the product would be oriented toward a precise type of client. Moreover, energy savings have been considered in the BCT investment decision, since this new type of product should allow producing cement at a lower kiln temperature.

Thirdly, HeidelbergCement is supporting different CCS and CCU projects. For example, the CCS project in Brevik, Norway is part of a larger portfolio of research investments. Furthermore, HeidelbergCement is currently experimenting a CCU technology in Cupertino (California). By means of microbes, raw material for further products might be created using the emitted CO₂ by the cement production. These projects are designed to reveal new technologies so as to reduce CO₂ emissions. Experimenting in this field allows HeidelbergCement to determine which technologies are conceivable as future carbon mitigation solutions.

3.2.3.7 Broader Observations on the EU ETS

From 2005, when the EU ETS was implemented, the carbon price was taken into account in low carbon investment decisions at HeidelbergCement. However, since the

carbon market crashed, its influence has been decreasing. The EU ETS has had no significant effect on investment decisions over the last three years.

In addition, the EU ETS has brought uncertainty into the investment process. Uncertainty of allocation reduces the willingness to run ambitious long-term projects. Uncertainty is however not the only drawback of the EU ETS identified by HeidelbergCement. The lack of a global ETS system that includes international competitors might lead to competitive disadvantages and carbon leakage. So far, low EUA prices have been keeping away the fear of international competition imbalances due to the carbon market. Bearing carbon costs would not be a problem for HeidelbergCement if the international competition were also regulated, e.g. if cement producers outside the EU would also pay for CO₂ when they trade with the EU.

HeidelbergCement critically scrutinised the EU ETS and differentially evaluates the European carbon market. The EU ETS is perceived as a theoretically functioning instrument for addressing international climate protection targets and generating incentives for firms to implement low carbon measures. However, due to the persistently low prices in the European carbon market, uncertainties with respect to the legal conditions and the international climate negotiations, the EU ETS generates only weak incentives for taking measures to reduce carbon emissions.

3.2.4 Summary

Different trends in low carbon activities have caused the reduction of carbon intensity of cement production in Germany. **The use of alternative fuels, energy efficiency measures, and the decrease of the clinker share in the production have been widely used.** Fuel-related emissions have been reduced by **substituting traditional fuels by alternative fuels like waste or biomass.** Furthermore, **improvements in terms of energy efficiency have been made since 1990.** For example, the energy intensity of the thermal combustion process per tonne of cement has been cut by 11 per cent and the replacement of inefficient kilns and improvements in processes using electricity have been made and reduced the energy consumption per tonne of cement. Finally, process emissions have been reduced by means of substituting mineral components for clinker and with respect to these measures the cement industry is about to reach its technological frontier.

Taking HeidelbergCement as a typifying the German cement market, we conclude, that during the early years **of the EU ETS cement companies in Germany considered the carbon price in their decision-making and investment decisions. With carbon prices of around €30/tCO₂ these low carbon activities were – at least partially – driven by the EU ETS.** The EU ETS is perceived as an appropriate instrument to encourage low carbon activities and investments. However, **along with decreasing carbon prices the EU ETS lost its influence. The decrease in carbon prices reflects the oversupply of emission allowances due to the economic crisis which per se caused strong emission reductions and the extensive use of emission credits for compliance under the EU ETS. Instead of the EU ETS other aspects like energy prices and general market conditions became higher priority. Energy and raw material costs became top drivers of CO₂ abatement measures.** In addition, the cement sector expects an increasing political and public focus on the environmental compatibility of construction materials. This has also steered the innovation of the cement sector towards resource saving products.

We identified important and relevant **low carbon trends in the cement sector: the development of alternative binders in order to substitute conventional clinker and CCS as well as CCU projects. Substituting clinker by other mineral components is limited by a minimum clinker share within the cement, as well**

as the availability of the substitutes. Greener new cement products aim to overcome this technological barrier by providing less carbon intensive alternatives to clinker. One example (BCT) is cited that reduces process emissions by around 30 per cent compared to conventional clinker. **Fuels and energy costs can be considered important drivers of this particular low carbon trend.**

CCS as well as CCU projects aim at reducing process and fuel-related CO₂ emissions.

Against the backdrop of the in-depth interview, the impact of the EU ETS on the identified low carbon trends, i.e. BCT and CCS as well as CCU, can be considered to be moderate. BCT allows producing cement at lower kiln temperatures compared to conventional production processes and therefore reduces the energy consumption significantly. Increasing energy prices can be considered as the main driver for this and CO₂ reductions remain a side effect. By exploring CCS and CCU technologies, the cement sector investigates future far-reaching CO₂ abatement measures. **The investment decisions take the carbon price into account, but – at the moment – it is not expected that the price for CO₂ will increase sufficiently to make these technologies profitable.**

3.2.5 References

Akersolutions. (2014). *Aker Solutions to perform world's first tests for capture of CO₂ from cement industry*. Retrieved 03 30, 2014, from akersolutions.com: [http://www.akersolutions.com/en/Global-menu/Media/Press-Releases/All/2013/Aker-Solutions-to-perform-worlds-first-tests-for-capture-of-CO₂-from-cement-industry/](http://www.akersolutions.com/en/Global-menu/Media/Press-Releases/All/2013/Aker-Solutions-to-perform-worlds-first-tests-for-capture-of-CO2-from-cement-industry/)

Buzzi Unicem (Dyckerhoff AG) . (2013). *Sustainability Report: Länderbericht Deutschland 2012* .

Carbon Trust. (2010). *Tackling Carbon Leakage: Sector specific solutions for a world of unequal carbon prices*.

Cembureau. (2014). *Cement industry - main characteristics*. Retrieved April 4, 2014, from Cembureau.be: <http://www.cembureau.be/about-cement/cement-industry-main-characteristics>

Cemex Deutschland AG. (2013). *Nachhaltigkeitsbericht – Zwischenbericht 2012*.

Climate Strategies. (2014). *Carbon Control and Competitiveness Post 2020: the Cement Report*.

Co, PHOENIX Zementwerke Krogbeumker GmbH &. (2014). *Umwelt*. Retrieved from phoenix-zement.de: <http://www.phoenix-zement.de/umwelt/umwelt.html>

Heidelberg Cement. (2013). *Annual Report 2012*. Heidelberg.

Heidelberg Cement AG. (2013). *Annual Report 2012*. Heidelberg.

HeidelbergCement AG. (2005). *Nachhaltigkeitsbericht 2004-2005*.

HeidelbergCement AG. (2007). *Nachhaltigkeitsbericht 2006-2007*.

HeidelbergCement AG. (2008). *Nachhaltigkeitsbericht 2007*. Heidelberg.

HeidelbergCement AG. (2010). *Nachhaltigkeitsbericht 2009*. Heidelberg.

HeidelbergCement AG. (2011). *Nachhaltigkeitsbericht 2009-2010*. Heidelberg.

Holcim Süddeutschland GmbH. (2013). *Umweltbericht 2012: Umweltmaßnahmen des Zementwerks Dotternhausen.*

IEA, & WBSCD. (2009). *Cement Technology Roadmap 2009.*

Lafarge. (2012). *Sustainability Report 2011.*

Märker. (2014). *Umwelt.* Retrieved 02 25, 2014, from maerker-gruppe.de:
<http://www.maerker-gruppe.de/typo3/index.php?id=71>

Portlandzementwerk Wittekind Hugo Miebach Söhne . (2014). Retrieved from
wittekindzement.de: <http://www.wittekindzement.de/>

Prodcom. (2013). *Statistics on the production of manufactured goods.*

RWI. (2013). *Die Klimavorsorgeverpflichtung der deutschen Wirtschaft -
Monitoringbericht 2011 - 2012 .*

Schwenk Zement KG. (2014). *Umwelt und Emissionsmanagement.* Retrieved from
schwenk-zement.de: 2014

VDZ. (2013). *Verminderung der CO₂-Emissionen – Beitrag der deutschen
Zementindustrie." 11.aktualisierte Erklärung zur Klimavorsorge, Monitoring-
Abschlussbericht 1990 – 2012.* Düsseldorf.

WBSCD. (2012). *GNR database.* Retrieved February 27, 2014, from
wbscdcement.org: [http://www.wbscdcement.org/index.php/key-issues/climate-
protection/gnr-database](http://www.wbscdcement.org/index.php/key-issues/climate-protection/gnr-database)

Zement- und Kalkwerke Otterbein GmbH & Co. (2014). *Umwelt.* Retrieved 02 25,
2014, from zkw-otterbein.de: <http://www.zkw-otterbein.de/index.php?id=22>

ZKW. (2014). *Umwelt.* Retrieved 03 30, 2014, from zkw-otterbein.de:
<http://www.zkw-otterbein.de/index.php?id=22>

3.3 Steel Sector

3.3.1 Introduction

This section presents an analysis of the impact of the EU ETS on low carbon action in the steel sector, as well as of the broader economic, technological and energy context. The analysis covers data from Germany, the EU, USA and Japan. The German steel industry is a particular focus of the study and we also included the findings of an interview with the German-based steelmaker Salzgitter.

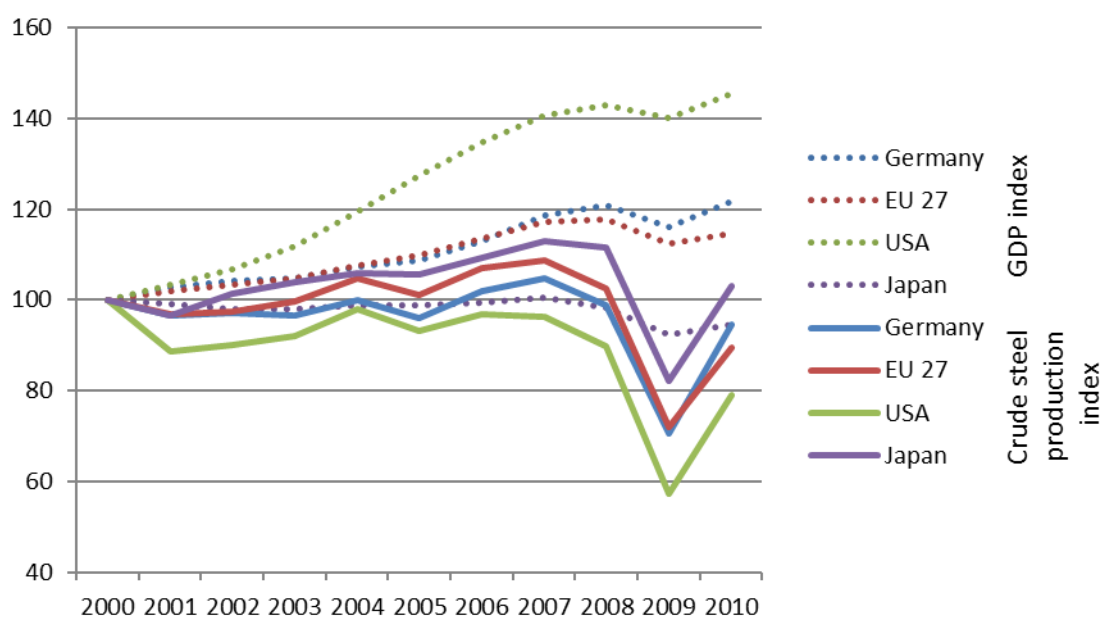
3.3.2 Data analysis

3.3.2.1 Economic Performance

This section aims at analysing economic performance and trade indicators, especially in order to identify the main trends in the steel production.

Figure 34 describes the development of national GDP as well as of crude steel production in selected countries from 2000 to 2010. The latter is the aggregate production of steel ingots, continuously cast steel as well as liquid steel for castings as described in the Worldsteel database (2012)⁵⁶. This allows us to analyse the relationship between the aggregated national demand and the production level of the steel industry.

Figure 34 GDP and crude steel production index in selected OECD countries on a 2000 basis (OECD 2014, Worldsteel 2012)



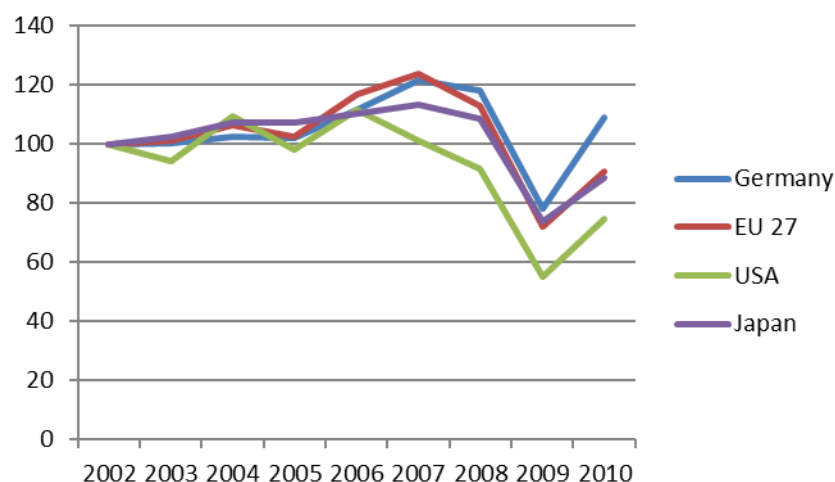
In the 2000-2008 period, the aggregated demand for steel was increasing in most of the countries. While GDP has increased by 40 per cent in the US and 20 per cent in the EU, the steel production in the respective countries has only increased by some 10 per cent before 2009. In 2009, the aggregated demand slightly decreased due to the

⁵⁶ In the studied countries, most of the production relies on continuously cast steel, other semi-finished products ingots and liquid steel representing a very low share of the crude steel production (for example respectively 3.8 and 0.25 per cent of the German crude steel production in 2011).

economic downturn in all countries whereas the crude steel production dropped by 30 to 40 per cent. The aggregated demand as well as the crude steel production began to recover in 2010 (Worldsteel, 2012). In all studied countries, steel production has remained rather constant until 2008. For example, Germany produced 46.376 Mt crude steel in 2000, 45.833 Mt in 2008 and returned to similar levels after the crisis, namely 43.830 Mt in 2010. The crude steel production has slumped in lockstep during the 2009 economic downturn, so that countries on average experienced a 20 per cent decrease in steel production.

Trends in steel production have followed those of the aggregated demand over the last decade. This is because the steel production is mostly driven by the domestic demand. We consider the latter as the apparent steel use within the studied country, as computed by Worldsteel (2012). The domestic demand is determined mostly by the activity of the steel downstream industries. These include the automotive and construction sectors, but also packaging, durable consumer goods and mechanical engineering industries. Their steel consumption can be depicted by the apparent steel use, as shown in Figure 35.

Figure 35 Steel use index in Germany, Japan, EU 27 and the US on a 2002 basis (Worldsteel, 2012)



Downstream industries, especially the construction sector, have been growing between 2005 and 2007 in Europe. As a consequence, the apparent steel use boomed with a 20 per cent increase in the EU and Germany, whereas it had remained stable before 2005. This additional need for steel has however been satisfied through intensified imports as section 1.2 will highlight. In Japan, the apparent steel use increased progressively, while in the US it suddenly dropped down in 2006.

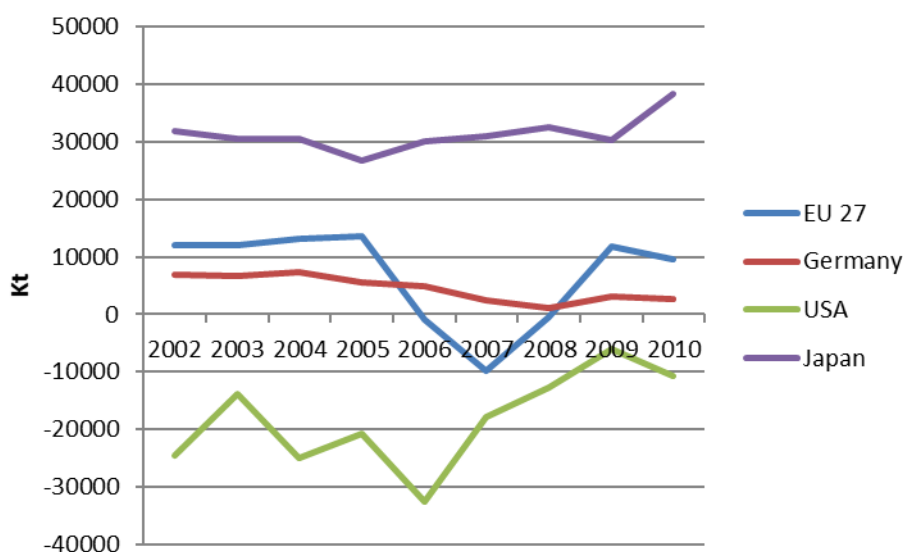
The 2009 economic downturn strongly impacted steel's downstream industries. Automotive and construction sectors were particularly affected so the domestic demand for steel decreased. Between 2008 and 2009 the apparent steel use fell by 40 per cent in Germany and the EU and by roughly 30 per cent in the US and Japan. As a consequence steel producers had to cut down their production by some 20 per cent (Worldsteel, 2012). As this section describes trends in the domestic demand for steel, the next one shall provide some insights on the trade flows of the steel industry.

3.3.2.2 Trends in Trade

Most of the steel traded is related to finished products, i.e. in the form of tubular, long or flat products. Altogether they represented more than 85 per cent of the imports and

more than 90 per cent of the exports in 2010 in the studied regions (Japan being the exception with respectively some 98 and 88 per cent share). The distribution of these products differs by country, but flat products are the most broadly traded. As a consequence, semi-finished products (such as all kinds of crude steel) and ingots represent a rather low share of the steel trade. Furthermore, the distribution of trade flows with respect to the steel product mix has remained stable over time. That is, the relative share of long, flat and tubular products has not changed much since 2000 in all studied countries (except for US imports which have been progressively shifted toward tubular products).

Figure 36 Net exports of semi-finished and finished steel products in selected OECD countries (Worldsteel, 2012)



The importance of the domestic consumption in the crude steel production is confirmed by analysing the net exports⁵⁷ (see Figure 36). As crude steel is marginally traded, trade flows are presented as an aggregate of semi-finished and finished products. As the consumption sunk in 2009, net importers such as the EU or the US became net exporters in order to compensate the lack of domestic demand. Exports decreased dramatically at that time, but less so than imports. Similarly, since 2002 Japanese steel producers have been compensating the poor evolution in crude steel national consumption by exporting their output, hence becoming important structural net exporters. In Germany, steel-intensive industries have been increasingly looking for supply outside German borders.

To summarise some key characteristics of the steel industry:

- The steel production of a country is mainly driven by trends in domestic demand. The major outlets of the steel industry are downstream industries such as the automotive or the construction sector. The close relationship between those industries makes the location of steel plants a strategic factor. The steel needs of those industries explains the trend of the steel production in the studied countries.
- Steel related trade flows are generally driven by the domestic demand. In 2005, Germany and the EU handled their soaring domestic demands by importing steel from outside their borders. After the 2007 financial crisis, the EU and the US compensated the drop in their domestic demands by increasing their net exports.

⁵⁷ Volume of exports minus volume of imports

- Steel trade relies on finished products: tubular, flat and long products. These products' relative shares in the trade flows have remained stable over time.

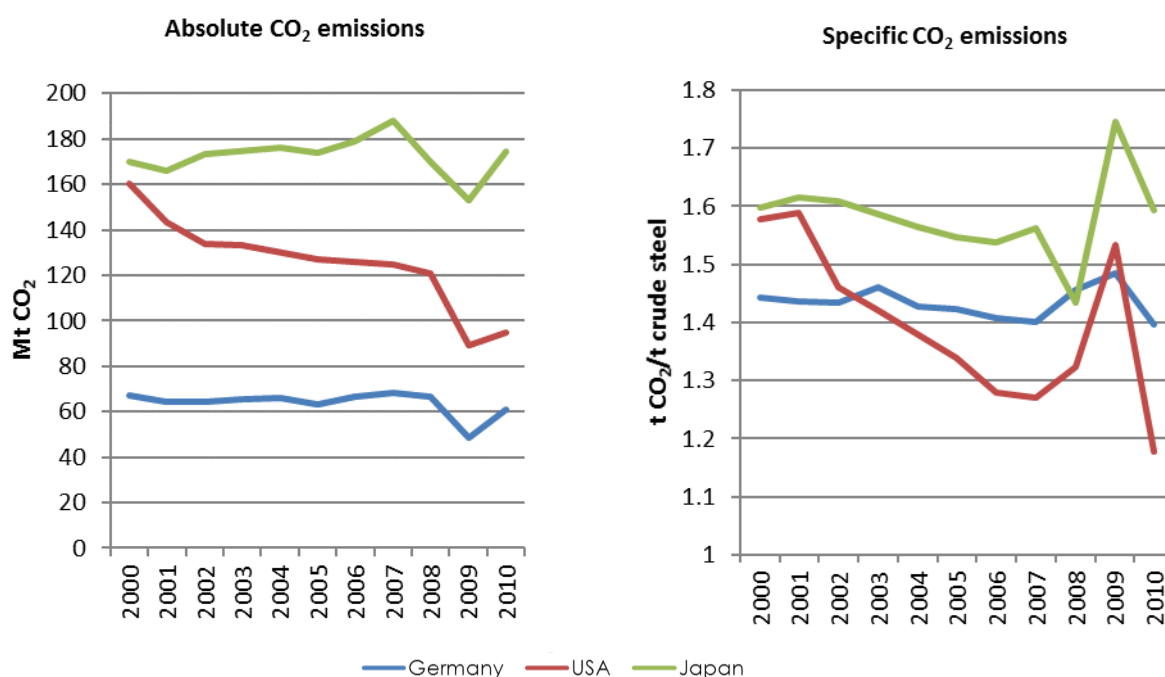
3.3.2.3 Overview of Carbon Emissions

In the first two sections, we described the demand structure of the steel industry. This helped us identify the economic drivers of the steel production. We can now focus on the trends in carbon emissions.

Absolute and Specific Carbon Emissions

Figure 37 depicts the development of both absolute and specific CO₂ emissions (emissions per tonne crude steel) over the 2000-2010 period. Our computations do not include EU figures as IEA data for the European aggregated level were not available.

Figure 37 Absolute and specific CO₂ emissions (direct and indirect) of steel sectors in Germany, US and Japan (based on IEA and Worldsteel data)



In Germany and Japan, absolute carbon emissions from the steel sector have remained stable over time, reaching respectively 61 and 174 Mt CO₂ in 2010. Due to the economic downturn and the consequent decrease in the steel production the absolute carbon emissions dropped in 2009. In the US the absolute carbon emissions have dropped steadily from roughly 160 Mt CO₂ in 2000 down to 95 Mt in 2010, a decrease of around 40 per cent. With respect to the specific carbon emissions, no significant reduction has occurred in Germany and Japan in the 2000-2007 period. Specific emissions have been stabilizing respectively at around 1.4 and 1.6 t CO₂/t crude steel. In contrast, the specific carbon emissions in the US decreased from 1.6 in 2000 down to 1.3 t CO₂/t crude steel in 2007.

Specific emissions have however been upwardly affected by the 2008-2009 demand shock. This is particularly true for the US and Japan whose carbon intensities have been soaring by respectively 50 and 30 per cent points in 2009. The same holds for Germany, but to a more limited extent, as its specific emissions only increased by 5 per cent at that time. This is to be explained by the extremely scaled structure of the steel production: running a plant at a lower production level increases the marginal, and therefore the specific carbon emissions of steel making.

Carbon emissions can be broken down into fuel, electric and process-related⁵⁸ emissions. As expected, no substantial change happened in the German and Japanese steel industries over the 2000-2010 period. The share of fuel emissions has remained rather stable at around 65 per cent in Germany, respectively 70 per cent in Japan. Similarly, process emissions have stabilised at a 15 per cent level in both countries. This analysis is much more relevant in the case of US CO₂ emissions. While electric carbon emissions have remained rather stable, process- as well as fuel-related emissions have been slightly sinking since 2000. This holds for specific as well as absolute emissions. For example, the US steel sector's fuel intensity has fallen by roughly 55 per cent between 2000 and 2010 (IEA, 2013) (Worldsteel, 2012).

3.3.2.4 General Carbon Abatement Drivers

The last sections highlighted the trends in carbon emissions in Germany and Japan compared to the US over the last decade. Now we analyse the main features of the steel production in order to identify the underlying technical drivers for these trends.

Steel making roughly consists of substituting the oxygen contained in the ferrous raw materials (iron ores or ferrous scraps) by carbon. The alloying of carbon and iron contributes to the solidity property of steel. To perform this process, different methods are available (Flues et al. (2013) and BCG, 2013):

- Two techniques require first to reduce raw materials into iron, using either a Blast Furnace converter (BF), or a Smelting Reduction converter (SR). The output, called pig iron, is in both cases melted into steel through a Basic Oxygen Furnace (BOF). These methods are carbon intensive since they make use of a lot of fossil raw materials (mostly coke and coal) as iron-reducing agents, and as fuels to feed the furnace.
- Another route for steel production is by means of an Electric Arc Furnace (EAF). In this case, iron ores stay solid rather than being melted, and the oxygen is removed by a chemical reaction with hot reducing gas. Steel is then produced by feeding an Electric Arc Furnace with the Direct Reduced Iron, hence this route is named Direct Reduced Iron Electric Arc furnace (DRI-EAF). This method is less carbon-intensive than the BOF since it does not make use of fossil fuels to reduce iron, and proceeds with gas as a reducing agent. Mostly the emissions of this route are considered as indirect, coming from the production of electricity, and not directly from the process or firing of the plant. Recycling is exclusively performed by this method. It simply consists in melting ferrous scraps into steel within an EAF (Scrap-EAF). As the iron reduction phase is spared, this is the least CO₂-emitting method.
- Once crude steel is out of the furnace, a casting and rolling phase is still necessary to give the metal its flat, long or tubular shape. This process is entirely performed with electric energy. The BOF route allows blast furnaces gases to be turned into electricity and heat power. Therefore, a subsequent part of the electric energy need of this route is provided by internal production. Integrated plants are then those which make use of their waste gas recycling full capacity, so that they reach a state of electric self-sufficiency at which they can autonomously run their steel casting and rolling without the need for external electricity delivery. This does not hold for the EAF however, since the usage of EAFs mainly leads to indirect, electricity related emissions.

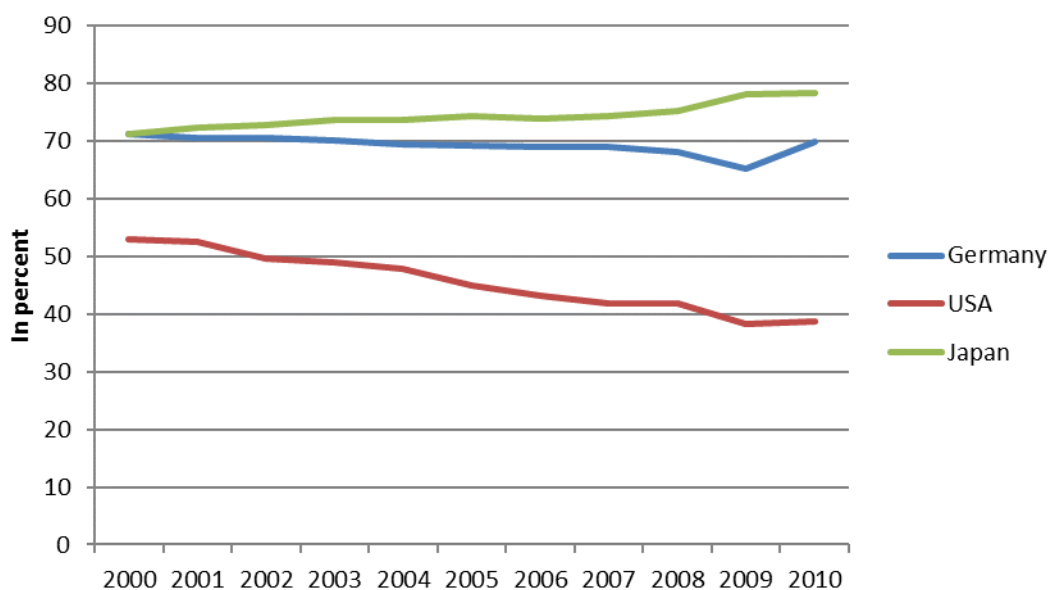
Considering the production route is very important to understand CO₂ emissions in the sector. In Europe and most industrialised countries, steel is almost entirely produced

⁵⁸ Process-related emissions are those released due to the chemical process of pig iron making, namely heating carbon intensive raw materials such as coke with ferrous minerals.

by the Blast Furnace-Basic Oxygen Furnace (BF-BOF) or the Scrap-Electric Arc Furnace (Scrap-EAF) route. Figure 38 depicts the evolution of the BOF share in the total crude steel production, the remaining share being exclusively EAF produced.

In Germany, the share of BOF produced steel has remained stable at a 70 per cent level over the 2000-2010 period. In the same time, Japan has slightly increased its BOF share up to 80 per cent. The US seems to be a structural scrap user. In 2000, already 50 per cent of its steel production was EAF-based, and this share has kept increasing up to 60 per cent in 2010 (Worldsteel, 2012).

Figure 38 BOF production share in Germany, Japan and US steel sector (Worldsteel, 2012)

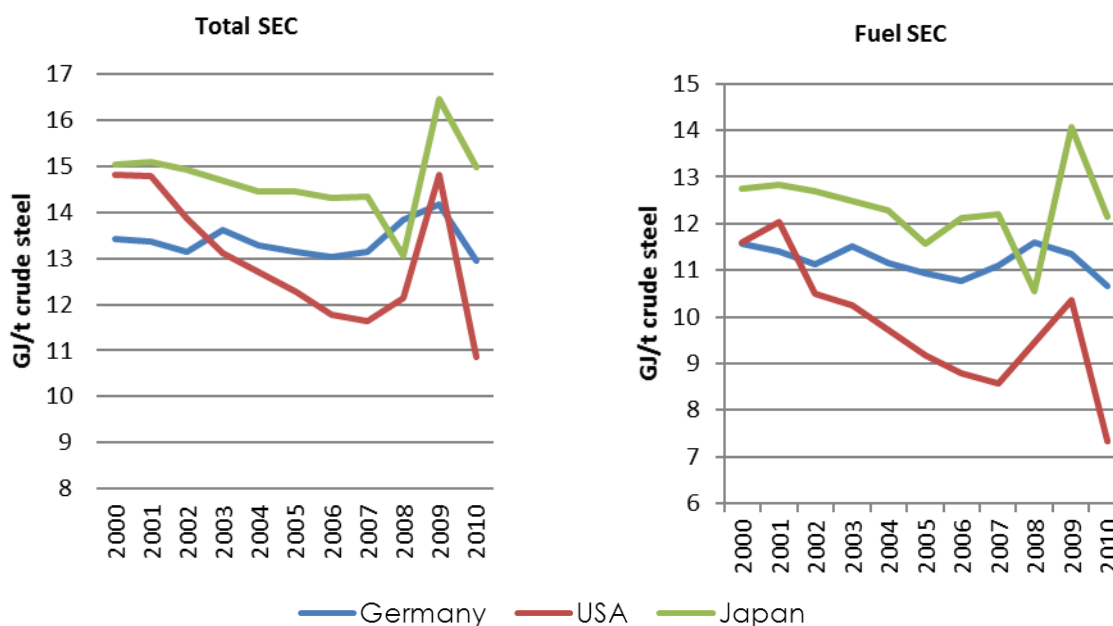


This substitution influenced their carbon emissions since 2000. Within the EAF route ferrous scraps are not required to be reduced into iron once again, as it would be the case with ferrous raw materials. Thus, carbon emissions are spared by skipping the iron reduction phase in a blast furnace, which is highly carbon intensive. Second, the steel making from reduced iron is far less energy intensive within the EAF than the BOF route. From a technological point of view, the energy efficiency potential of the EAF is higher as well.

In Germany and Japan, such a route shift has not happened (at least not since the year 2000). This route shift has proven to be efficient at decreasing the energy intensity of steelmaking. Figure 39 depicts the evolution of the energy intensity over the 2000-2010 period. As a consequence, while the US energy intensity has slightly improved between 2000 and 2010, cutting their Specific Energy Consumption (SEC) down to 11 GJ/t crude steel, Germany's and Japan's steel industries have both experienced poor improvements. As EAF plants only require electrical power to be used, the fuel intensity of the US industry has been falling since 2000. Germany however experienced very flat fuel intensity trends, with exception of the economic downturn (Worldsteel, 2012) (IEA, 2013). Scale effects have a substantial impact on the fuel intensity. A drop in the production implies higher marginal energy consumption and therefore higher specific carbon emissions (see Figure 3.23 below). Interesting remains the soaring SEC during the 2009 economic downturn. Japanese and American energy efficiencies have particularly been affected by the slump in their respective steel production. This suggests the presence of scale effects in the

production of steel, namely strong marginal energy efficiency potential. A more in-depth analysis of these results **shows that these trends have mostly been driven by the fuel SEC with electric SEC being rather unaffected by the production level.** Germany has experienced an upward trend of SEC in 2009 too. However its SEC only rose by 1 GJ/t crude steel while Japan and the US were experiencing some 3 GJ/t crude steel increases.

Figure 39 Total and fuel SEC of the steel industry in Germany, Japan and the US (based on IEA and Worldsteel data)



Trends in the German steel production's fuel mix have also remained rather stable since 2000 with coal products accounting for 73 per cent, natural gas for 21 per cent and oil products for 5 per cent in 2010. Japan and the US have also kept a similar fuel mix, though the first makes use of coal products mostly, whereas the second makes use both of coal fuels (roughly 50 per cent) and natural gas (at least 40 per cent). In 2000, the fuel specific carbon emissions of the US and Germany were at similar levels (IEA, 2013).

Our findings highlight some important features of the steel industry regarding carbon emissions:

- Carbon emissions trends are mostly driven by the route used in the production. The EAF scrap route, aside of its absolute energy savings with respect to the BOF route, has more energy efficiency and carbon abatement potential, although there can be significant 'indirect' GHG emissions from electricity production required to operate the EAF. Nevertheless, Germany has not been experiencing any shift towards this technology. Scrap availability and quality are structural limits of the scrap share in the steel production. Since we do not have data on any of these, comparison with other countries must be handled carefully.
- Improvements in energy efficiency as well as changes in the fuel and reducing agents mix may also help reducing CO₂ emissions of the steel production when using the BOF route. These improvements however remain incremental and they are limited in capacity by the technological frontiers of the current production facilities.

- Stabilizing trends in the German steel sector suggest that it has reached its scrap route upper limit capacity, and that incremental improvements are no longer efficient in cutting carbon emissions. This statement shall be confirmed by the next sections. These will also highlight what solutions are currently available or under development to overcome the technological frontiers of the steel industry.

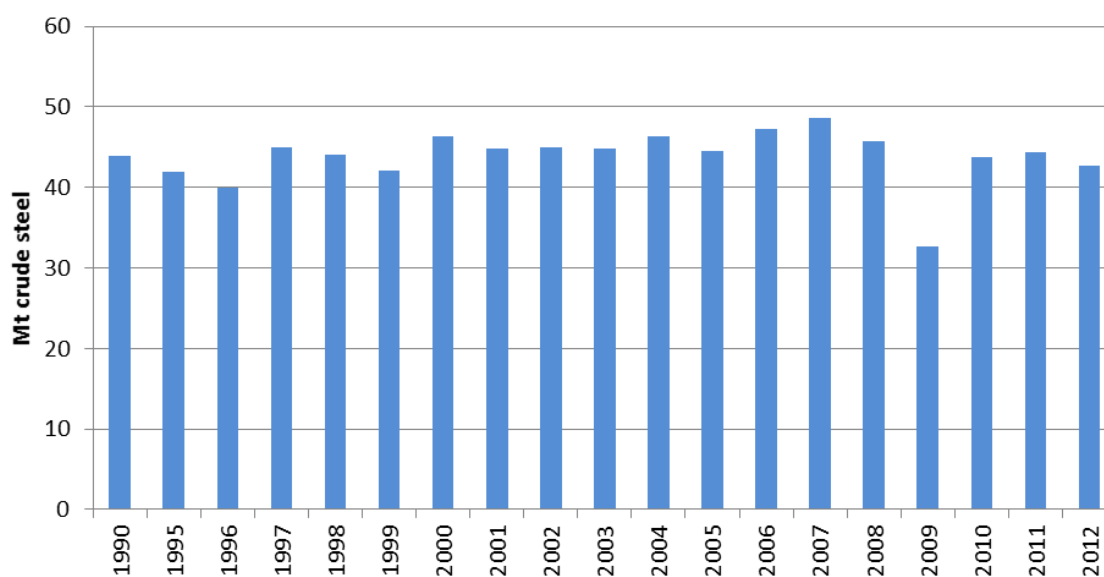
3.3.2.5 Trends in Low carbon Activities and Investments in Germany

This section aims at identifying common trends in low carbon activities and investments among German firms in the steel sector and to understand to which extent the EU ETS has had an impact on the low carbon activities and investments. The analysis is based on business and sustainability reports.

Brief Technical Introduction

The goal of this section is to briefly review the main economic and technical features of the German steel production. A total of 75 companies were producing steel in Germany in 2012 employing some 98,749 people (BMW, 2014). Altogether, they produced 42 Mt crude steel in 2012. 0 describes the German crude steel production evolution over the past 20 years. The German steel sector production has remained rather stable since 1990. Especially since 2000, the German steel production has been ranging from 43 up to 49 Mt/year, except for 2009's economic downturn which cut the steel production by one third (RWI, 2013).

Figure 40 German crude steel production in Mt (RWI, 2013)



As mentioned previously, the EU crude steel production is almost entirely divided between the BF-BOF and the Scrap EAF routes. In 2010, BF-BOF accounted for 59 per cent of the EU-27 production and Scrap-EAF for the remaining 41 per cent, respectively 68 and 32 per cent in Germany. Scrap-EAFs have become more and more important, as their 1990 level was at around 18 per cent of the crude steel production in Germany (BCG, 2013).

As we observed in the previous section, most of the steel production results in finished products. That is, crude steel shaped into flat, long and tubular products. For example, it represented 96 per cent of the sector's production in 2011. Semi-finished products

such as steel ingots and liquid crude steel have remained slightly marginal since 2000.⁵⁹

Three main sources of carbon emissions can then be identified. Process emissions as a result of the reduction of ferrous and carbon raw materials into pig iron; fuel emissions, principally emitted through the firing of blast furnaces (BF-BOF); and indirect emissions issued by the generation of electricity necessary for steel casting and rolling, as well as for EAF steel making.

Carbon Emissions

As we determined the main sources of carbon emissions of the steel industry, we shall now quantify them in a more in-depth analysis. In 2012, the German steel industry emitted some 57.8 million tonnes of CO₂ while producing 42.7 million tonnes of crude steel. Therefore specific emissions amounted to 1.356 t CO₂/t crude steel, which represents a 15 per cent decline since 1990. Back then, 1.594 t CO₂ were emitted by producing one tonne of crude steel. Figure 3.25 gives an overview of the specific and absolute CO₂ emissions of the German steel sector. Most of the reduction took place between 1990 and 2003. Thereafter the trend has stabilised around 1.35 tCO₂/t crude steel (RWI, 2013).

The steel sector agreed within the framework of the Declaration of German Industry on Climate Care to reduce specific energy consumption and CO₂ emission. In particular, the steel industry in Germany committed to reduce specific CO₂ emissions down to 1.243 tCO₂/t crude steel by 2012 but failed to accomplish its goal by only managing 68 per cent of the desired reduction compared to 1990 (VdEh, 2011).

Figure 41 Absolute and specific CO₂ emissions (direct and indirect) of the German steel industry (RWI, 2013)

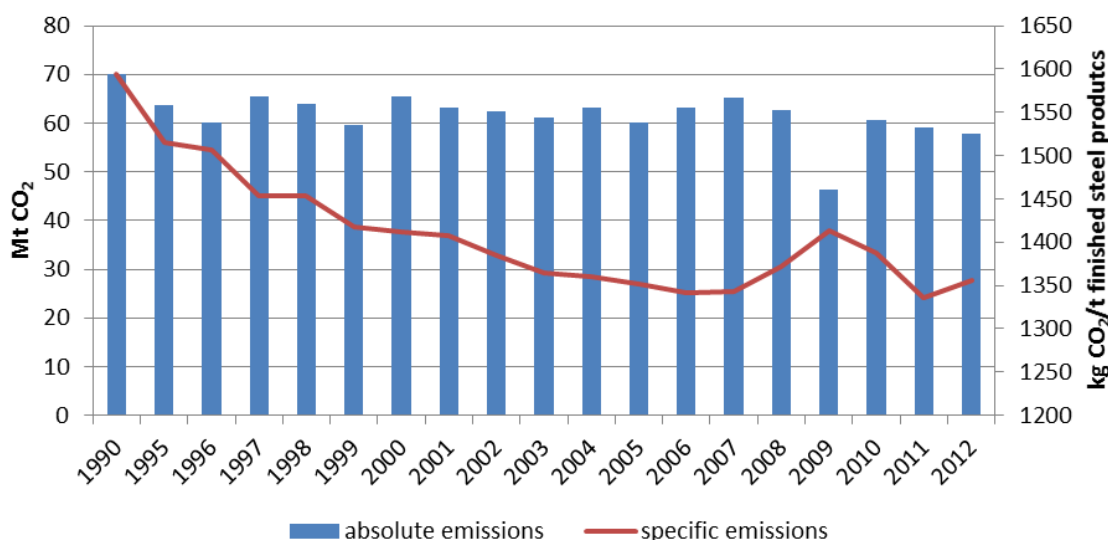


Figure 42 depicts the evolution of the specific CO₂ emission sources since 2000. Since integrated energy plants also produce heat as a source of energy⁶⁰, electricity and heat are regrouped under *electricity and heat*, hence representing the indirect

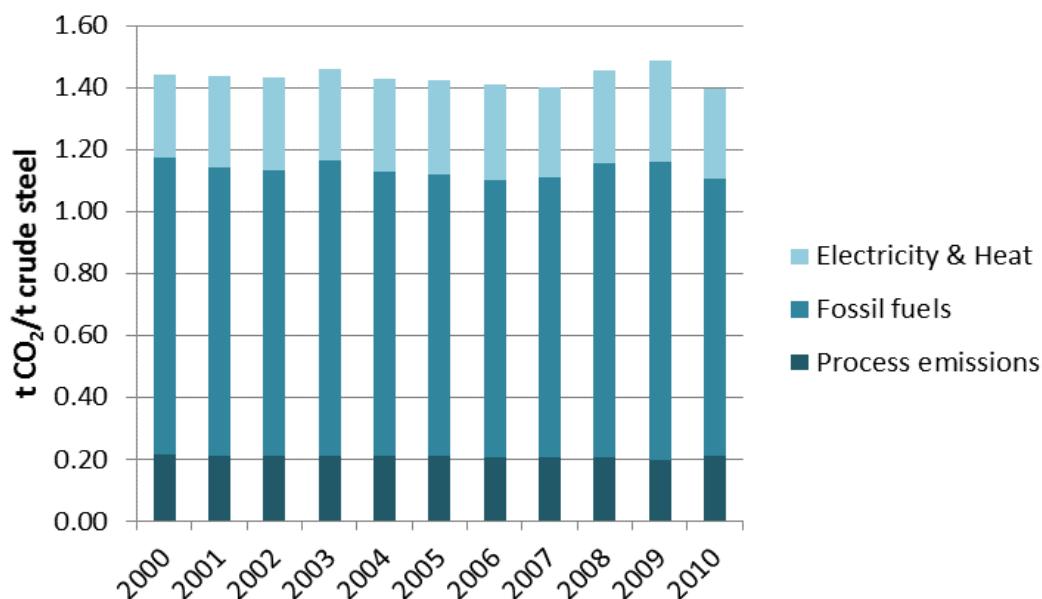
⁵⁹ We follow the distinction of Worldsteel (2012) between ingots, liquid steel for casting and continuously cast steel.

⁶⁰ These are known as Co-integrated Heat and Power (CHP) plants, namely „plants which are designed to produce both heat and electricity, sometimes referred to as cogeneration power stations“ (IEA, 2014).

emissions stemming from the production of energy. *Fossil fuels* describe the emissions directly emitted by steel production plants while using thermic energy. Finally, process emissions are those released by the chemical reaction necessary for the iron reduction.

Roughly 65 per cent of the yearly specific emissions stem from the combustion of fossil fuels. The shares of electric and process emissions have also remained stable, respectively around 20 and 15 per cent. As technical insights suggest (see section 3.3.2.3), process and fuel emissions are mostly to be related to the BOF route, while most of the electric ones should be considered EAF-based⁶¹.

Figure 42 CO₂ emissions sources in the German steel sector (IEA, 2013) (Worldsteel, 2012)



As Figure 41 points out, the specific emissions of the German steel industry have decreased by roughly 15 per cent during the 1990's. Since 2000 however, no subsequent trend in terms of CO₂ emissions of German steel industry appears, except for the drop in absolute emissions following the economic downturn. The shares of fossil, indirect and process emissions remained stable since then, in absolute as well as in specific terms. No change is to be identified after 2005, indicating the EU ETS has had a poor impact on German steel producer's specific emissions. Especially in the period after the economic downturn in 2009, one reason could be the decrease in carbon prices.

An additional factor that might have diminished the incentives created by the EU ETS might have been the high free allocation of European Union Allowances (EUAs) for installations in the steel sector. Results from the KfW/ZEW CO₂ Barometer show that firms that profit from high shares of free allocation are less active in the carbon market (KfW/ZEW CO₂ Barometer 2013). In the second phase of the EU ETS, between 2008 and 2012, installations that belong to the iron and steel production in Germany have accumulated a surplus of emission allowances of roughly 77,000 ktCO₂ (KfW/ZEW CO₂ Barometer 2009, 2010, 2011, 2012 and 2013).

⁶¹ The reduction from iron ores to pig iron releases process emissions and makes use of fossil fuels as source of energy. The steel melting phase also features fuel emissions. Electricity-based emissions within the BOF route are slightly marginal and partly autonomously produced out of waste gases. On the contrary, the EAF route relies exclusively on electric energy.

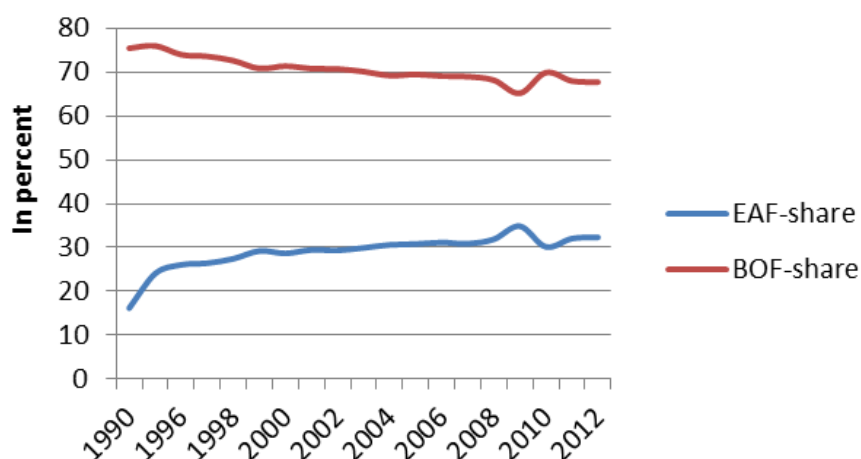
Past Low carbon Activities and Investments in Germany

This section aims at identifying drivers of the carbon intensity improvements as well as providing an overview of the ongoing developments which shall help overcoming the current stabilization in specific CO₂ emissions. The shift from BOF to EAF steel making is analysed at first. Thereafter improvements in energy efficiency as well as in the mix of reducing agents and fuels are successively addressed.

Figure 43 shows the relative importance of the BOF and EAF routes in Germany since 1990. We consider here BOF as the blast furnace (BF-BOF) route and EAF as the scrap route (Scrap-EAF) since other production routes are slightly marginal in Germany. In 2012, about 32 per cent of the steel produced in Germany was made by using an EAF. This represents a 16 per cent increase in EAF-application compared to 1990 (RWI, 2013).

The shift from primary to secondary steel making (recycling) should be considered an important factor of the carbon emissions reduction. In particular, the production of steel using the BOF-route theoretically leads to approximately 1.35 t CO₂/t steel, whereas applying an EAF would diminish emissions down to 0.35 t CO₂/t steel (RWI, 2008). This is mostly due to the fact that the EAF is almost exclusively used for the proceeding of ferrous scraps in Germany. Hence, the very carbon intensive pig iron making phase is spared.

Figure 43 Steel production by production route in Germany (RWI, 2013)



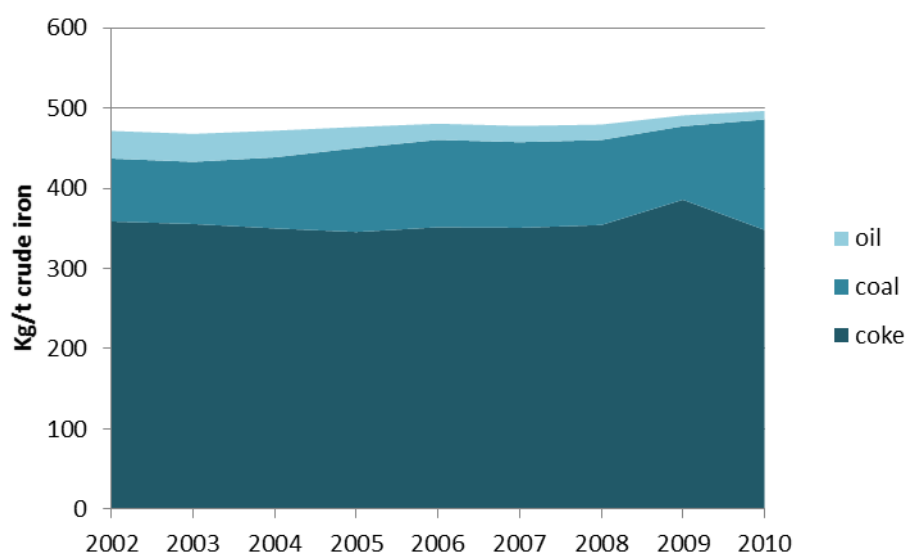
Moreover carbon abatements of scrap-EAF plants have been reinforced by their higher efficiency potential. According to BCG (2013), efficiency gains have caused 32 per cent of CO₂ emissions reductions of the EAF route since 1990, respectively 14 per cent at the sector level. Most of these improvements came from the drop in carbon intensity of the electric power feeding the EAF route. Indirect emissions stemming from the use of external electric power have decreased from 585g CO₂ /KWh in 1990 to 429g CO₂ /KWh in 2010.

However, the use of scrap in the steel production is limited by two factors: firstly, the amount of scrap available cannot meet the overall demand for raw materials; secondly, its quality is not sufficient for the production of high-quality steels (BCG, 2013). This can partly explain the end of the production route shift since 2000.

Since 2002, roughly 15 per cent of the specific carbon emissions of the German steel industry as a whole stemmed from the iron reducing process exclusively through the BOF route (BCG, 2013). Therefore, the reducing agent mix is an important factor to deal with regarding BOF carbon abatement potential. Figure 44 gives an overview of

the trends in the reducing agent mix of the German steel making during the 2002-2010 period.

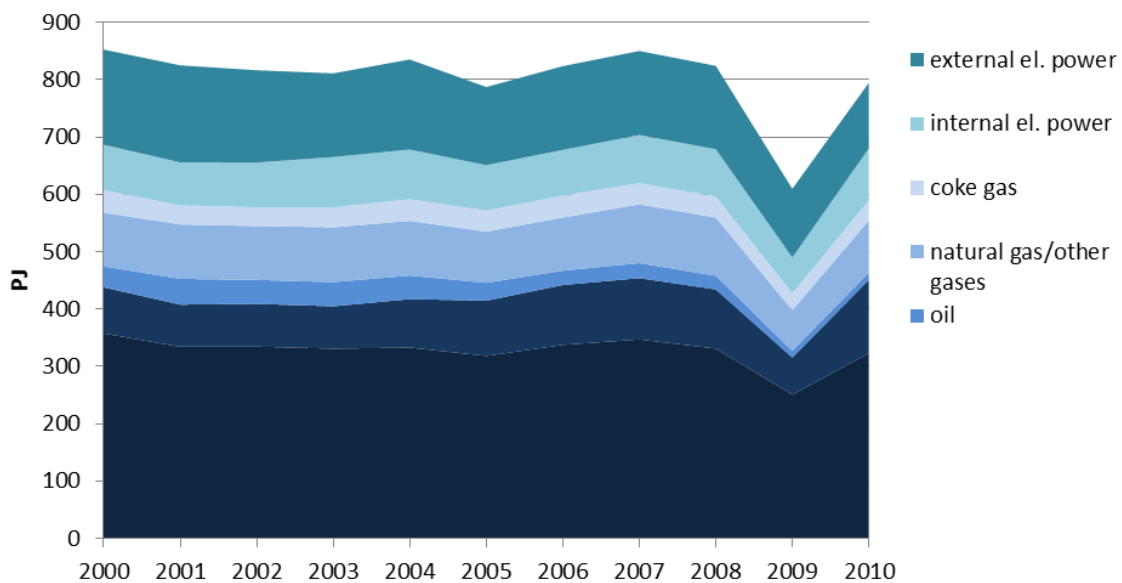
Figure 44 Specific consumption of reducing agents in Germany (VdEh, 2011)



Coke-related emissions have declined by 2 per cent since 2002, whereas coal-related emissions increased from 9 to 15 per cent throughout this period. This coke-substitution by coal as revealed in Figure 44 is an explaining factor for the decreasing total specific emissions as the carbon content of coke (0.83 kg C/kg) is much higher than coal's carbon content (0.67kg C/kg) based on IPCC data for steel production (IPCC, 2006). Moreover, the oil share declined as well, further reducing total CO₂ emissions, since its carbon content is: 0.86 kg C/kg. To conclude, increasing the usage of coal and decreasing all other shares has led to decreasing specific emissions when producing steel. However, these fossil raw material substitutions did not have a very meaningful impact on the German steel industry's carbon emissions.

The carbon emissions' stabilizing trend is also reflected in the energy mix of the German steel industry. Figure 45 gives an overview of this mix. The share of fossil fuels in the energy mix has remained stable at a 70 per cent level. The only change was the substitution of oil by coal. Similarly, the respective shares of internal (10 per cent) and external (20 per cent) electric power in the overall energy mix did not massively evolve since 2000.

Figure 45 Energy need by resource in German steel industry (RWI, 2013)



The iron making phase generates process- or blast furnace-gases which have sufficient calorific value for producing electricity or heat. This amount of energy in turn supplies the casting and rolling machines of the steel making plants. Since 1990, the use of these gases for producing energy has been growing. This has allowed the German steel industry to become less dependent on external power supply. In 2012, 44.2 per cent of the electricity used was internally produced, compared to 32.7 per cent in 1990. Over this period, the use of electricity has become more efficient since the specific consumption (GJ/t crude steel) decreased by 16 per cent (VDEh, 2013). However, the share of internal electric power has been stabilizing since the beginning of the 2000's. Moreover, carbon abatements stemming from improvements in the use of electric energy are limited as electric power represents roughly a 15 per cent share of the BOF route's energy need. BCG (2013) expects improvements in gas reuse to cut down BOF CO₂ emissions by 6.7 per cent of the current level by 2050.

Since 2000, the impact of the usual carbon abatement drivers of the German steel industry (route substitution, energy efficiency, incremental improvements) has been decreasing. Stabilizing trends in carbon abatement suggest that German steel production plants have reached their technological frontier. Concerning the use of energy, their performance are according to Worell et al. (2007) indeed very close if not equal to those of the Best Available Technologies benchmarks issued by the EU (Joint Research Centre of the European Commission, 2013). **Carbon abatement potential at the current technological level can hence be considered rather limited. Therefore, substantial investment in breakthrough technologies must be made to continue tackling carbon emissions.** The next section shall provide an overview of future developments in low carbon investments.

Future Low carbon Activities and Investments in Germany

Our previous findings have highlighted the limited carbon abatement potential given a constant EAF share in the production and current technological level. We will now briefly summarize the German steel industry's future emission reduction potential.

BCG (2013) suggests that the substantial CO₂ abatement required to reach the European emission reduction targets should come from both incremental

improvements and a massive shift from a BF-BOF based production to a DRI-EAF production (less carbon intensive and electrically supplied). As in the cement sector, most abatement has been performed by substitutions of raw materials and in energy efficiency (incremental improvements). IISD (2012) suggests that DRI technologies are a niche, which are likely to prevail only in localized markets. Only breakthrough technologies will be able to subsequently decrease CO₂ emissions of the steel industry. This is particularly true for Germany since its producing capital already features best available techniques and production methods and makes a large use of scrap. Hence the marginal CO₂ abatement potential is being more difficult to realize. This explains the stabilization in the specific emissions trends we observed before. Incremental improvements have allowed steel producers to get a high carbon abatement potential out of their production plants. According to representatives of the sector, they eventually reached their technological frontier so that further significant abatements cannot take place without a shift in the production technology. To overcome this technical limit, investments in ambitious breakthrough technologies must be made (IISD, 2012).

As a consequence, some German steel producers⁶², along with other European firms, universities, research centres, and the European Commission have launched the ULCOS⁶³ project (ULCOS, 2013; see also chapter 2 of this study, case study on Tata Steel). This R&D program aims at developing breakthrough, low carbon technologies to allow the steel industry to overcome its current technical limits. They rely either on the development of new steel technologies, which should allow alternatives to the BOF route, or on improvements to the existing process, including Carbon Capture and Storage (CCS) technology. CCS enables the capture of the carbon dioxide, transporting and storing it underground in depleted oil and gas fields or deep saline aquifer formations (CCSa, 2014). More explicitly, four process improvement projects are to be examined with a projected CO₂ abatement potential of more than 50 per cent.

- Hlsarna smelter technology combines coal preheating and partial pyrolysis in one reactor where ore melting and therefore iron production occurs reducing the coal usage and thus CO₂ emissions. Applying CCS to Hlsarna will furthermore result in a significant emissions reduction.
- ULCORED is based on direct reduction of solid iron ore by a reducing gas produced from natural gas. The solid iron then needs to be melted using electric energy, i.e. an Electric Arc Furnace. On the one hand, this method is very expensive, demands high-quality iron ore to be used and a considerable amount of electric energy. On the other hand, it removes the need for coke ovens and emitted CO₂ will be stored underground as well (CCS).
- The ULCOWIN project is studying alkaline electrolysis as a way to reduce CO₂ by transforming the iron ore into metal and oxygen (O₂) requiring electrical energy only. No direct CO₂ would be emitted applying this technology, which is still in a development phase. Although iron is not yet produced by electrolysis on an industrial basis, many other similar metals as zinc, aluminium and nickel are.
- The latest project, UlcOs-BF, at Florange has been withdrawn by ArcelorMittal in late 2012 due to "technical reasons", yet might be conducted in the future. Its core characteristics are the recycling of top gases, which are then used as reducing agents, as well as the underground storage of CO₂ (CCS).

Against the backdrop of analysing past and possible future low carbon activities we conclude that since 2000, the German steel industry has come

⁶² Among them: ArcelorMittal Deutschland, ThyssenKrupp, Saarstahl.

⁶³ Ultra Low Carbon Dioxide Steelmaking

closer to its technological frontier. This statement is sustained by the very marginal improvements in energy efficiency as well as in the reducing agents and fuel mix or in the share of scrap used in steel products. Most of these solutions have been taken to their full emissions reduction capacity or close to it, so that further subsequent improvements would require either a massive shift towards EAF route production or the implementation of potential breakthrough technologies. An interesting range of low carbon research projects is currently being run, especially in shape of the ULCOS project⁶⁴. Their implementation is however extremely expensive, so strong economic incentives need to arise to shift towards these technologies. The EU ETS might have triggered interest for research in low carbon technologies, but CO₂ prices are currently too low to make them economically viable.

3.3.3 In-Depth Study – Salzgitter AG

3.3.3.1 Introduction

Salzgitter AG is a steel producer composed of 100 associated companies. It produced some 7.647 Mt of crude steel in 2012 with a €2,655m⁶⁵ turnover while employing 25,541 people.

The firm emitted 8.211 Mt CO₂ in 2012, of which 7.944 Mt were subject to the EU ETS. Since 1990, the firm has cut its absolute and specific carbon emissions by respectively 22 and 25 per cent. Most of these abatements have taken place during the 1990's (Salzgitter AG, 2010). Since 2000, the absolute carbon emissions trend shows a relatively slow increase (5 per cent between 2006 and 2012), solely interrupted by the 2009 economic downturn.

3.3.3.2 Energy Efficiency, Alternative Fuels and Raw Materials

Like most steel producers, Salzgitter AG has been implementing incremental improvements to cut energy costs. The use of blast furnace waste gas has been increasing and investments for further improvements in this direction have been made.⁶⁶ Moreover, the use of reducing agents has been decreasing. The firm has mostly relied on improvements concerning the reducing agents mix and energy efficiency measures to achieve carbon abatements. No switch in the fuel mix seems to have taken place. The share of scraps used in the production has been increased, so that another EAF oven has been implemented along with the first one in Salzgitter (Peine Träger) in 2010.

3.3.3.3 Lighthouse Project

Salzgitter is running the "Salzgitter Flachstahl GmbH's Energy Efficiency Program", which was launched in 2009. The project aims at identifying and implementing energy saving potentials and leads to 118 measures aiming at cutting down energy costs. The program was recently awarded the Energy Efficiency Award 2013 by the German Energy Agency and has already prevented carbon emissions of up to 150,000 tonnes.

For instance, Salzgitter AG has developed expansion turbines generating electricity by using the pressure issued by the release of blast furnaces gases. Furthermore, they invested in torpedo ladles leading to energy savings and therefore cost savings as

⁶⁴ Not only EU steel producers are investing in such research projects, according to IISD (2012): „ CO₂ Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50 (COURSE50) is a Japanese research program investigating innovative technologies for the reduction of carbon emissions in steelmaking.“

⁶⁵ Turnover of the steel sector only

⁶⁶ No data has however been published concerning these improvements

well. In addition, some substantial investments have been made in the casting-rolling facility, implementing a new type of strip casting technology. This system should allow cutting CO₂ emissions by 40 per cent compared with the previous one. Similar plant modernizations have driven energy efficiency improvements, with carbon emissions reduction being a side effect.

In general, most of these measures **aim at optimizing existing plants in terms of energy consumption**. Salzgitter AG established a database which contains all ideas, detailed information and descriptions and serves for a structured administration of the single measures. Thereby workers get informed about the current progress of the individual measures as well as encouraged to contribute their own ideas. Until March 2013 some 234 ideas were listed in the database of which 118 have been implemented. There is a remarkably high degree of variety in this database. Due to the energy efficiency program the Salzgitter Flachstahl GmbH was able to save some 580 GWh/year which accounts for 29 per cent of their total energy need and some €39m.

Sector and Company Details

Our broader findings regarding emissions reduction potential in the German steel industry were confirmed in the interview, i.e. that there is little carbon abatement potential left based on the current technological level. The last decade has been characterised by the active implementation of energy efficiency measures. The main goal was to cut energy and therefore production costs. The reduction of carbon emissions has remained a side effect only. Energy efficiency measures have particularly taken place in terms of blast furnace gases recycling. This has allowed steel producers to spare some use of external electric energy.

Low carbon Actions and Drivers

As part of the above mentioned Energy Efficiency Programme, investment decision making is primarily performed by small groups including co-workers in charge of technical maintenance, production and energy. Their conclusions are discussed with other departments. Pursuing this bottom-up process allows Salzgitter to select the technically and economically best measures to be implemented.

Since the steel production process is very energy intensive, the main driver of Salzgitter' investment decisions has been the reduction of energy costs.

It was stressed that such energy efficiency measures do not solely decrease energy costs but have also positive side effects, such as an increasing general productivity, saving of carbon emissions or reducing local pollution. Following this argument, the sustainability of the products is becoming increasingly important. Moreover, **the awareness of politicians and the general public regarding the environmental compatibility of products can be considered as a motivation to lead to low carbon activities and investments**.

Due to low and volatile carbon prices in the past and uncertainty associated with future outcomes of climate policy, the EU ETS only played a minor role in the firms production and investment decisions. This also holds for the launch of the energy efficiency program.

Broader Observations on the EU ETS

Stable regulatory conditions are one of the key factors to determine the profitability of a project. However, the EU ETS has been characterised by frequent modifications of its framework, and as a consequence it has become more complicated to compute

investments' profitability. This may have hampered incentives for the company to invest. For example, energy prices are influenced by a wide set of market variables in the short run but can be roughly forecasted on the long run. In contrast, the EU ETS is influenced by many political considerations which are perceived as being likely to change often and in opposite direction over time. The changing political signals and regulations make it impossible for steel producers to decide whether investing in low carbon plants would be profitable in the end. As a consequence energy prices have driven the low carbon investments at Salzgitter, whereas carbon prices were too low and too volatile to trigger low carbon activities and investments.

It is the company's view that price stability and better incentives can be achieved by changing the allocation mechanism. Allocation according to past emissions values set wrong incentives in the past. As an improvement starting from the third trading period, allocation now follows benchmarks. Having the right incentives, low carbon investment depends on the availability of cost-effective abatement technologies. Besides the price-uncertainty, adverse effects of unilateral climate policy on competitiveness are seen as a major problem.

Based on the interview with our contact person at Salzgitter we conclude that the company is very critical of the European carbon market. Unstable regulatory conditions and volatile carbon prices are perceived as the main problems. Nevertheless, appropriate changes in the regulatory framework, e.g., allocation through benchmarking, are seen as first steps in order to improve the EU ETS and to increase the incentives for taking measures to reduce carbon emissions.

3.3.4 Summary

The yearly production of steel in the selected countries/regions (US, Germany, Japan and the EU) has been quite stable in absolute terms since 2000 with only one brief contraction for the economic crisis of 2009. As consumption fell short in 2009, net importers such as the EU or the US became net exporters in order to compensate the lack in domestic demand.

The steel sector's absolute and specific **CO₂**-emissions in Germany have remained almost stable over the last decade whereas the US steel sector has managed to drastically decrease its absolute as well as its specific emissions in the same period. This is due to the fact that they conducted a major shift in production processes. In 2000, more than 50 per cent of US steel was produced by applying the BOF-route and in 2010 this share was below 40 per cent, i.e. the EAF-route gradually substituted the original BOF-route. Due to the economic downturn in 2009, the European steel sector experienced a drop in production and absolute emissions. However, the specific emissions increased since the steel production process shows substantial scale effects with respect to energy efficiency and specific CO₂ emissions.

Steel making consists of substituting the oxygen contained in ferrous raw materials (iron ores or ferrous scraps) by carbon. Different methods are available for this process with major differences in carbon abatement potential. In particular, the production of steel using the BOF-route theoretically and with best available technologies leads to approximately 1.35 t CO₂/t steel, whereas applying an EAF would diminish emissions down to 0.35 t CO₂/t steel. However, the implementation of EAF plants is very much depending on the availability and quality of scrap.

Most of the carbon emission reduction in the steel sector was achieved prior to the implementation of the EU ETS. In the framework of the Declaration of German Industry on Climate Care the steel sector committed to reduce its specific energy consumption and CO₂ emissions in 1995-2005. Nevertheless, inducing a price on carbon emissions set further incentives for abatement measures. Against the backdrop

of the in-depth interview we conclude that the introduction of the EU ETS brought carbon dioxide emissions and the associated externalities to boardrooms and decision makers. Especially during the early years of the EU ETS CO₂ costs were considered in the decision-making and investment process of regulated firms. Later, when uncertainty about post Kyoto climate policy increased and prices collapsed due to the oversupply of emission allowances, the EU ETS became less important.

However, energy prices were and are more important for companies belonging to the steel sector, as the production is very energy-intensive. Besides energy costs, the sustainability of the products can be considered a driver for low carbon activities and investments. The awareness of politicians and the general public regarding the environmental compatibility of their products is monitored closely by companies of the steel sector. Based on the interview, the impact of the EU ETS on CO₂ abatement measures could be further enhanced by reducing policy uncertainty and price volatility of carbon prices, as it would make the profitability of long-term investments predictable and would reduce risks.

Furthermore, our findings show that incremental improvements in the industry led to a technological frontier and further significant emissions reductions can only be achieved through breakthrough technologies.

3.3.5 References

ArcelorMittal. (2013). Steel: The fabric of sustainable growth - Corporate responsibility 2012 summary report.

Badische Stahlwerke GmbH. (2013). Umwelterklärung 2013.

Boston Consulting Group (BCG). (2013). Steel 's contribution to a low carbon Europe 2050. Stuttgart.

Bundesministerium für Wirtschaft und Energie (BMWI). (2014). Stahl und Metall. Retrieved May 16, 2014, from [www.BMWI.de](http://www.bmwi.de):
<http://www.bmwi.de/DE/Themen/Wirtschaft/branchenfokus,did=171736.html>

Carbon Capture & Storage Association (CCSa). (2014). What is CCS? Retrieved 05 13, 2014, from <http://www.ccsassociation.org/>: <http://www.ccsassociation.org/what-is-ccs/>

Deutsche Edelstahlwerke GmbH. (2013). Bericht zur nachhaltigen Entwicklung 2012.

ESF Elbe-Stahlwerke Feralpi GmbH. (2013). Erste Umwelterklärung 2012.

Flues, F., Rübhelke, D., & Vögele, S. (2013). Energy Efficiency and Industrial Output: The Case of the Iron and Steel Industry. ZEW Discussion Paper No. 13-101, Mannheim.

Georgsmarienhütte GmbH. (2014). Technologie. Retrieved May 16, 2014, from www.gmh.de: <http://www.gmh.de/de/technologie/energiemanagement.html>

International Energy Agency (IEA). (2013). World energy balances, IEA World Energy Statistics and Balances (database). doi: 10.1787/data-00512-en. Retrieved May 16, 2014, from http://stats.oecd.org/BrandedView.aspx?oeid_bv_id=enestats-data-en&doi=data-00512-en

International Energy Agency (IEA). (2014). Combined Heat and Power Plants. Retrieved May 16, 2014, from www.iea.org: <http://www.iea.org/stats/defs/origins/chp.asp>

International Institute for Sustainable Development (IISD). (2012). Energy-Intensive Industries: Decision making for a low carbonFuture - The Case of Steel., Winnipeg.

Intergovernmental Panel on Climate Change (IPCC). (2006). Guidelines for National Greenhouse Gas Inventories - Chapter 4.

Joint Research Centre of the European Commission. (2013). Best Available Techniques (BAT) Reference Document for Iron and Steel Production.

KfW/ZEW CO₂ Barometer 2009. "Leaving the Trial Phase behind – Preferences & Strategies of German Companies under the EU ETS."

KfW/ZEW CO₂ Barometer 2010. "Effizienzpotenziale des Emissionshandels noch nicht ausgeschöpft – Strategien und Management deutscher Unternehmen".

KfW/ZEW CO₂ Barometer 2011. "Hoher Anpassungsbedarf im EU-Emissionshandel ab 2013 – deutliche Defizite bei der Vorbereitung in den Unternehmen".

KfW/ZEW CO₂ Barometer 2012. "Anreizwirkung des EU-Emissionshandels auf Unternehmen gering – Klimapolitische Regulierung wenig relevant für Standortentscheidungen".

KfW/ZEW CO₂ Barometer 2013 – Carbon Edition. "The EU Emissions Trading Scheme: Firm Behaviour During the Crisis".

Lech-Stahlwerke GmbH. (2013). Umweltbericht 2012/13 .

Organisation for Economic Co-operation and Development (OECD). (2010). "Structural Business Statistics" Structural and Demographic Business Statistics (database) c . Retrieved May 16 2014, from <http://www.oecd-ilibrary.org/>.

Rheinisch-Westfälische Institut für Wirtschaftsforschung (RWI). (2008). Der Klimaverpflichtung der deutschen Wirtschaft monitoringbericht 2003-2004..

Rheinisch-Westfälische Institut für Wirtschaftsforschung (RWI). (2013). Die Klimavorsorgeverpflichtung der deutschen Wirtschaft - Monitoringbericht 2011 - 2012 .

Saarstahl AG. (2013). Geschäftsbericht 2012.

Salzgitter AG. (2010). Beständigkeit durch Fortschritt- Corporate Responsibility-Bericht 2009. Salzgitter.

ThyssenKrupp Steel AG . (2010). Nachhaltigkeitsbericht 2009.

Ultra Low Carbon dioxide Steelmaking (ULCOS). (2013). www.ulcos.org. Retrieved February 25, 2014, from About ULCOS: www.ulcos.org/fr/about_ulcos/home.php

UN Comtrade. (2014). United Nations Commodity Trade Statistics Database. Retrieved May 16, 2014, from <http://comtrade.un.org/db/>

Verein Deutscher Eisenhüttenleute (VdEh). (2011). CO₂ -Monitoring-Fortschrittsbericht der Stahlindustrie in Deutschland Berichtsjahr 2010., Düsseldorf.

Verein Deutscher Eisenhüttenleute (VdEh). (2013). Beitrag der Stahlindustrie zu Nachhaltigkeit, Ressourcen- und Energieeffizienz.

Worell, E., Price, L., Neelis, M., Galitsky, C., & Nan, Z. (2007). World Best Practice Energy Intensity Values for Selected Industrial Sectors. Lawrence Berkeley National Laboratory.

Worldsteel. (2012). Steel Statistical yearbook 2012. Brussels.

4 Country case study

4.1 Introduction

The objective of this section is to provide an analysis of the impact of the EU ETS on low carbon decisions, activities and investments at a country-wide level in Germany. The results give a broad picture on German companies' activities and decisions under the EU ETS and help to interpret the results of the installation and sector case studies under Section 2 with this broader context in mind.

4.2 Methodology

This section provides a short introduction to the methodology applied. This includes a brief overview of the database, the KfW/ZEW CO₂ Barometer, as well as a technical note on the constructed data set.

The KfW/ZEW CO₂ barometer

The empirical evidence is based on survey data collected in the framework of the KfW/ZEW CO₂ Barometer. The KfW/ZEW CO₂ Barometer – developed as part of a cooperative project of KfW Bankengruppe and the ZEW – has been analysing the situation of German companies regulated under the EU ETS on an annual basis since 2009⁶⁷. The objective of the study is to closely monitor company behaviour in carbon markets. The underlying annual survey addresses a broad spectrum of topics related to company behaviour in carbon markets such as expectations regarding commodity and carbon prices, carbon trading strategies and abatement activities. For that purpose, all German companies regulated under the EU ETS are invited to participate in the survey each year.

The data set

Table 23 summarises the number of respondents per year classified with respect to the number of employees and verified emissions. On average, approximately 20 per cent per cent of the invited companies responded to the survey per year and topics covered by the survey changed from year to year. The data set is constructed as a repeated cross-section since the year 2009. The analysis in this section is primarily based on the results of the most recent survey conducted in 2013 and combines the results of the surveys conducted between 2009 and 2012 as far as possible.

The following analysis will give a differentiated view on the behaviour of small and large emitters as well as small and medium-sized enterprises (SMEs) and large enterprises. Small emitters are defined in the survey as firms that emit less than 25,000 t CO₂, firms that emit 25,000 t CO₂ or more are large emitters. Furthermore, we classify respondents in SMEs and large enterprises. SMEs are defined as enterprises with fewer than 250 employees. Accordingly, large enterprises are defined as companies with at least 250 employees.

The majority of the participating companies are classified as large enterprises or large emitters. Over the years, approximately 57 per cent of the respondents are large emitters, 64 per cent are large size enterprises, and 41 per cent of all respondents are both large enterprises and emitters.

⁶⁷ The Centre for European Economic Research (ZEW) is a non-profit and independent research institute. It is one of Germany's leading research institute addresses on decision-makers in politics, business, and administration, scientists in the national and international arena as well as the interested public. The Kreditanstalt für Wiederaufbau (KfW) is a German development bank owned by the Federal Republic of Germany and the Federal States of Germany.

Table 23 Sample structure - Small and Large Emitters as well as Small and Large Enterprises

Small and Large Enterprises			
Year	Large Enterprises	SME < 250 employees	Total
2009	n=56 (50 per cent)	n=56 (50 per cent)	n=112 (100 per cent)
2010	n=95 (80 per cent)	n=24 (20 per cent)	n= 119 (100 per cent)
2011	n=77 (55 per cent)	n=64 (45 per cent)	n=141 (100 per cent)
2012	n=103 (65 per cent)	n=55 (35 per cent)	n=158 (100 per cent)
2013	n=105 (70 per cent)	n=45 (30 per cent)	n=150 (100 per cent)
Small and Large Emitters			
Year	Large Emitters > 25,000 t CO ₂ p.a.	Small Emitters < 25,000 t CO ₂ p.a.	Total
2009	n=58 (52 per cent)	n=54 (48 per cent)	n=112 (100 per cent)
2010	n=62 (52 per cent)	n=57 (48 per cent)	n= 119 (100 per cent)
2011	n=86 (61 per cent)	n=55 (39 per cent)	n=141 (100 per cent)
2012	n=94 (59 per cent)	n=64 (41 per cent)	n=158 (100 per cent)
2013	n=85 (57 per cent)	n=65 (43 per cent)	n=150 (100 per cent)

Table 24 summarises respondents' sector affiliation. The results show that on average 39 per cent of the surveyed companies per year belong to the energy sector. The second most common sector in the sample with an average of 19 per cent is the manufacturing of non-metallic mineral products, followed by the paper industry (10 per cent), the chemical industry (7 per cent) and the food industry (6 per cent) and the steel sector (5 per cent).

Table 24 Sector classification of surveyed companies

Sector	Nace-Rev.	Share Per Year				
		2009	2010	2011	2012	2013
Energy and / or heat generation (e.g. power supply companies)	40.1	-	42 per cent	39 per cent	41 per cent	34 per cent
Food and animal feed, beverage industry	15	-	7 per cent	7 per cent	5 per cent	7 per cent

Sector	Nace-Rev. Share Per Year					
		2009	2010	2011	2012	2013
Textile, clothing, leather and leather goods	17, 18, 19	-	0 per cent	1 per cent	0 per cent	0 per cent
Pulp and paper, paper products, printing and publishing	21, 22	-	9 per cent	10 per cent	11 per cent	10 per cent
Manufacture of coke, refined petroleum products and nuclear fuel	23	-	4 per cent	2 per cent	1 per cent	1 per cent
Chemical industry	24	-	5 per cent	7 per cent	4 per cent	14 per cent
Rubber and plastic products	25	-	1 per cent	1 per cent	1 per cent	1 per cent
Manufacture of other non-metallic mineral products (glass, ceramics etc.)	26	-	20 per cent	20 per cent	20 per cent	18 per cent
Steel and non-ferrous metal production	27	-	3 per cent	5 per cent	5 per cent	7 per cent
Metal products	28	-	1 per cent	0 per cent	1 per cent	0 per cent
Manufacture of machinery and equipment	29	-	0 per cent	1 per cent	0 per cent	1 per cent
Automobile industry (incl. automobile suppliers)	34, 35	-	1 per cent	0 per cent	1 per cent	1 per cent
Office machinery, computers, electrical and optical equipment	30 - 33	-	1 per cent	0 per cent	0 per cent	0 per cent
Other	-	-	7 per cent	7 per cent	9 per cent	8 per cent
Total*			100 per cent	100 per cent	100 per cent	100 per cent

* Percentages may not total 100 due to rounding.

4.3 Analysis

Based on the constructed repeated cross-section data set we use descriptive statistics to show how the firms answered the questions related to the impact of the EU ETS on low carbon decisions, activities and investments as well as on broader observations on the EU ETS.

4.3.1 Abatement potentials, cost and activities

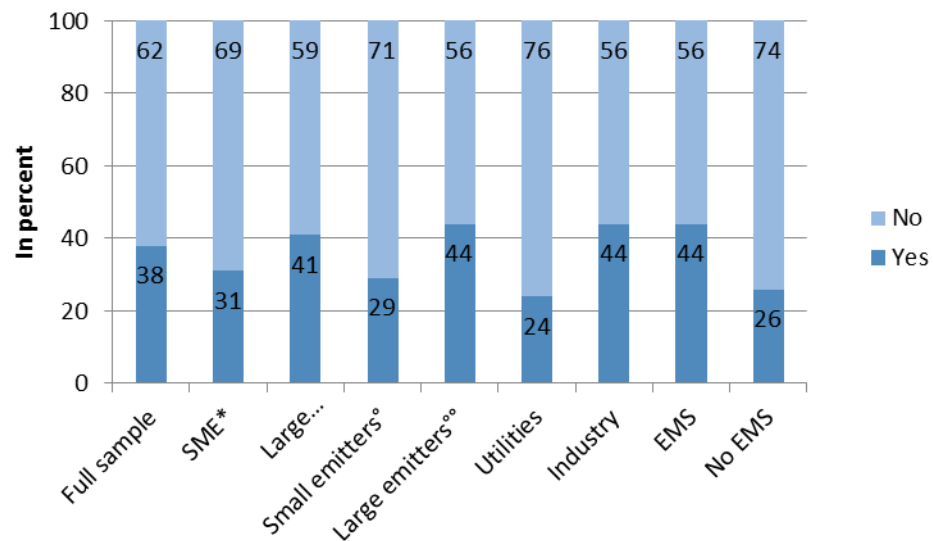
In this section we analyse the awareness of companies regarding their individual CO₂ abatement potentials and the corresponding costs. Furthermore, we investigate the share of firms that actively abate CO₂ emissions over time and describe which low

carbon activities were implemented. For this purpose, we analyse questions asked within the framework of the KfW/ZEW CO₂ Barometer 2013.

Figure 46 illustrates that only 38 per cent of the firms surveyed in 2013 are fully aware of costs and benefits of potential technical and organisational solutions for CO₂ abatement. In other words, 62 per cent of the respondents so far have neither assessed their individual abatement potential nor the associated costs. Differentiating between large and small emitters as well as enterprises reveals that large enterprises and large emitters are more active in assessing carbon abatement than SMEs and small emitters. 31 per cent of SMEs and 29 per cent of small emitters stated they had conducted an assessment of their individual abatement potential and the associated costs. In contrast, 41 per cent of large companies and 44 per cent of large emitters reported to have made an assessment of their abatement potentials and the associated costs.

Furthermore, an established environmental management system (EMS) increases the level of awareness with respect to potential CO₂ abatement options. An EMS develops, implements and maintains policies for environmental protection within a company. We find that 44 per cent of the respondents with an established EMS reported conducting an analysis of their carbon abatement options and the associated costs. In contrast, only 26 per cent of the companies without an established EMS have so far assessed their CO₂ abatement potentials.

Figure 46 Assessment of abatement potentials and abatement costs



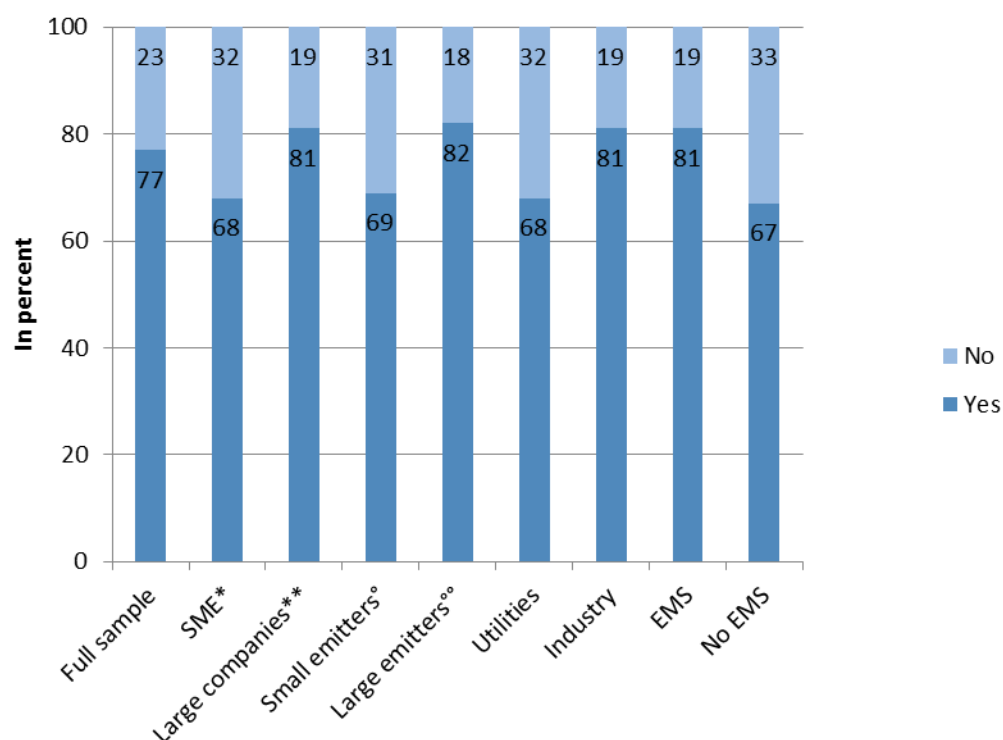
Source: KfW/ZEW CO₂ Barometer 2013 – Carbon Edition

*Note: * < 250 employees, ** ≥ employees, ° < 25,000 t CO₂ (2012), °° ≥ 25,000 t CO₂ (2012)*

Figure 47 shows that 77 per cent of the surveyed companies in 2013 have intervened in the production process or invested in order to reduce their CO₂ emissions. Furthermore, the decision to reduce carbon emissions depends on the size of the firm in terms of emissions and number of employees. Large enterprises as well as large emitters are more active with respect to carbon abatement compared to SMEs and small emitters. 81 per cent of large companies and 82 per cent of large emitters stated to intervene in the production process or invested in order to reduce their carbon emissions. In contrast, 68 per cent of SMEs and 69 per cent of small emitters stated to actively abate CO₂ emissions.

Furthermore, we find the sectoral affiliation to influence the abatement activity. 81 per cent of the companies belonging to the industrial sector have conducted carbon abatement measures. In contrast, only 68 per cent of the utilities have intervened in the production process or invested in order to reduce carbon emissions. Finally, an established EMS increases the abatement activity. 81 per cent of the companies with an established EMS have conducted abatement measures. In contrast, only 67 per cent of the companies without an EMS have been active.

Figure 47 Abatement activities

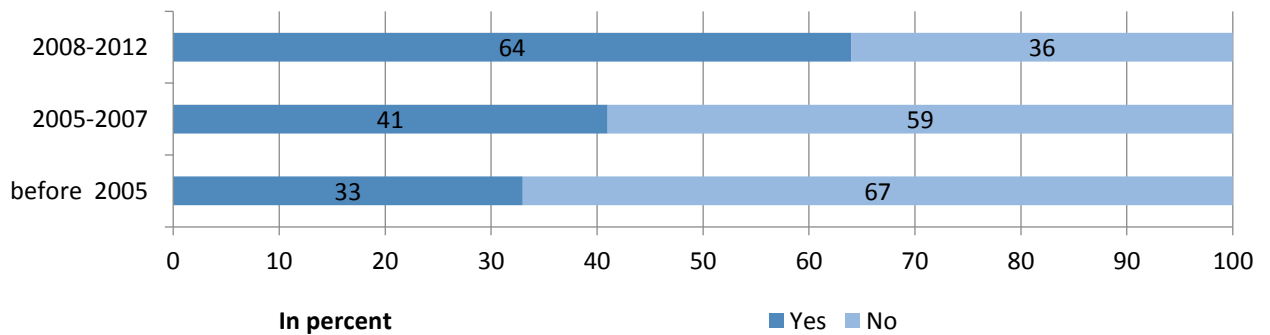


Source: KfW/ZEW CO₂ Barometer 2013 – Carbon Edition

Note: * < 250 employees, ** ≥ employees, ° < 25,000 t CO₂ (2012), °° ≥ 25,000 t CO₂ (2012), year = 2013

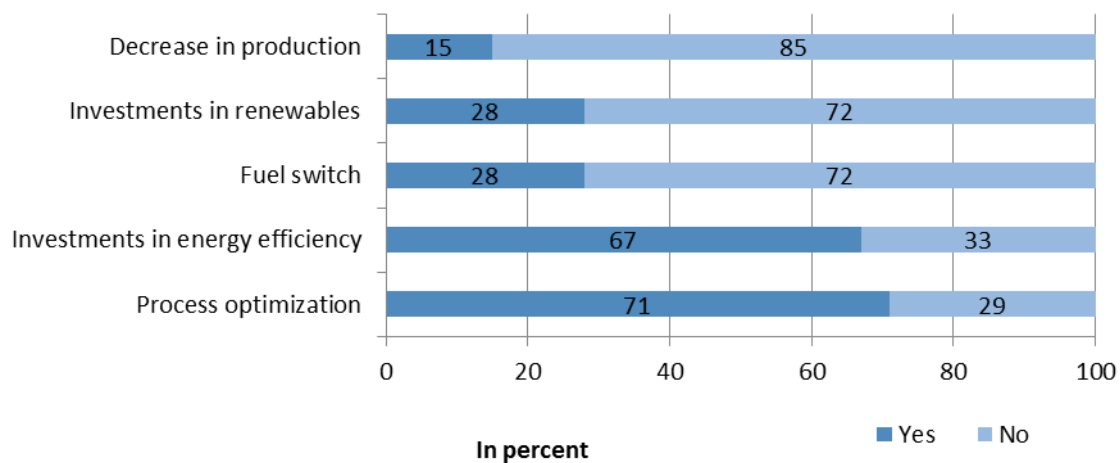
By analysing data on the implementation of carbon abatement measures we find that abatement activities of the surveyed companies increased over time (Figure 48). Asked about the date of the implementation of carbon abatement measures, 33 per cent of the surveyed companies stated in 2013 that they have already conducted abatement measures before the implementation of the EU ETS in 2005. 41 per cent have been active during the first phase of the EU ETS (between 2005 and 2007) and 64 per cent realized abatement solutions during the second phase of the EU ETS (between 2008 and 2012).

Figure 48 Abatement activities over time



Asked about their abatement strategies, most respondents stated to conduct process optimisations and investments in energy efficiency measures (Figure 49). 71 per cent of the active respondents stated to use process optimisations in order to reduce their carbon emissions. The second most important measure (67 per cent) is the investment in energy efficient machinery.

Figure 49 Strategies to reduce carbon emissions



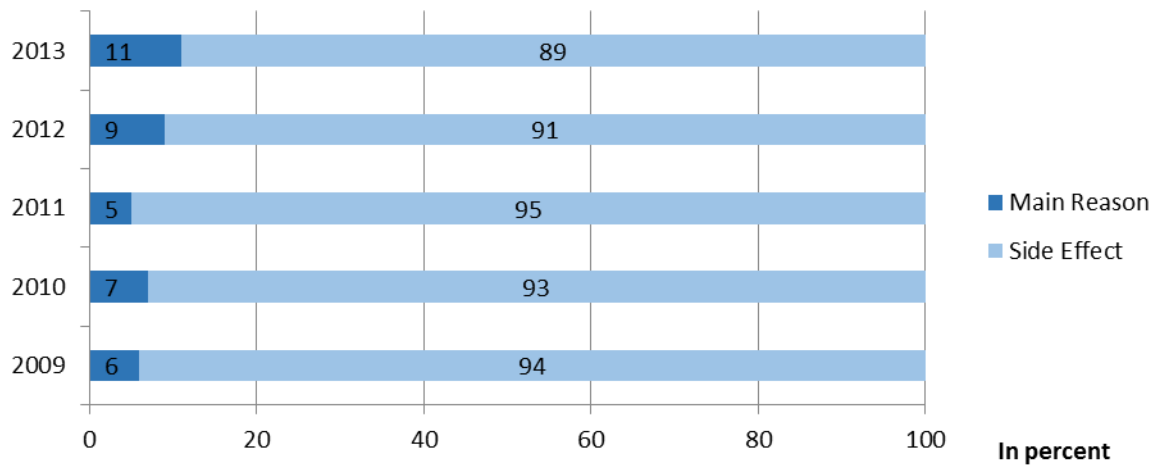
Source: KfW/ZEW CO₂ Barometer 2013 – Carbon Edition

4.3.2 Drivers for low carbon activities

This section aims at identifying the main drivers of the low carbon actions described in the previous section. We analyse which role the abatement of CO₂ emissions played in the decision-making and investment process. For this purpose, we rely on questions asked within the framework of the KfW/ZEW CO₂ Barometer 2010, 2011, 2012 and 2013.

Despite the fact, that most (77 per cent) of the companies surveyed in 2013 have conducted CO₂ abatement measures in the past, **we find that in most cases the abatement of CO₂ was not the main driver for the decision.** Figure 50 summarises whether respondents over the years stated that CO₂ abatement was the main driver for the abatement measure. In 2013, for the first time, more than 10 per cent of the surveyed companies stated that carbon abatement was the main reason for the measure to be conducted.

Figure 50 Main vs. side effect (Was carbon abatement the main reason or a side effect?)



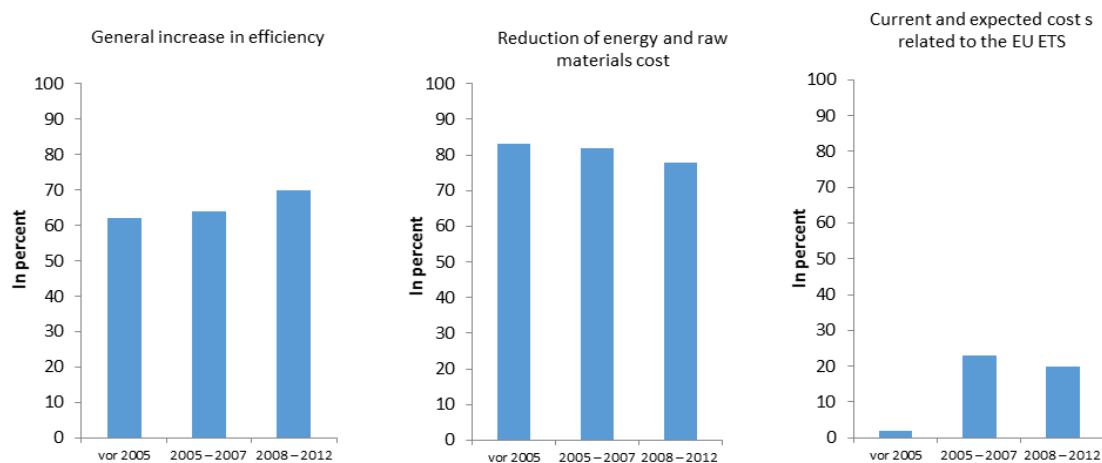
Source: KfW/ZEW CO₂ Barometer 2009, 2010, 2011, 2012, 2013

Against the backdrop that in the most cases the abatement of CO₂ was not the main driver for low carbon activities and investments, in 2012 surveyed companies were asked to indicate the main drivers for actions that involved CO₂ abatement.

Figure 51 summarises our main findings. **We find that surveyed companies stated that the reduction of energy and raw material costs as well as general increases in efficiency were the main drivers for low carbon activities over the last years. Costs caused by the EU ETS as well as expected costs of the EU ETS in the future played only a subordinate role.**

Along with the falling prices for emission allowances the impact of the costs caused by the EU ETS on low carbon actions decreased from the first trading period (between 2005 and 2007) to the second (between 2008 and 2012). The importance of energy and raw material costs also decreased over the same period. Over the years, improvements in the general efficiency of the production process have become an even more important factor for low carbon activities. This confirms our previous observation: **CO₂ reduction remains a side effect of other efficiency measures.**

Figure 51 Drivers for carbon abatement measures



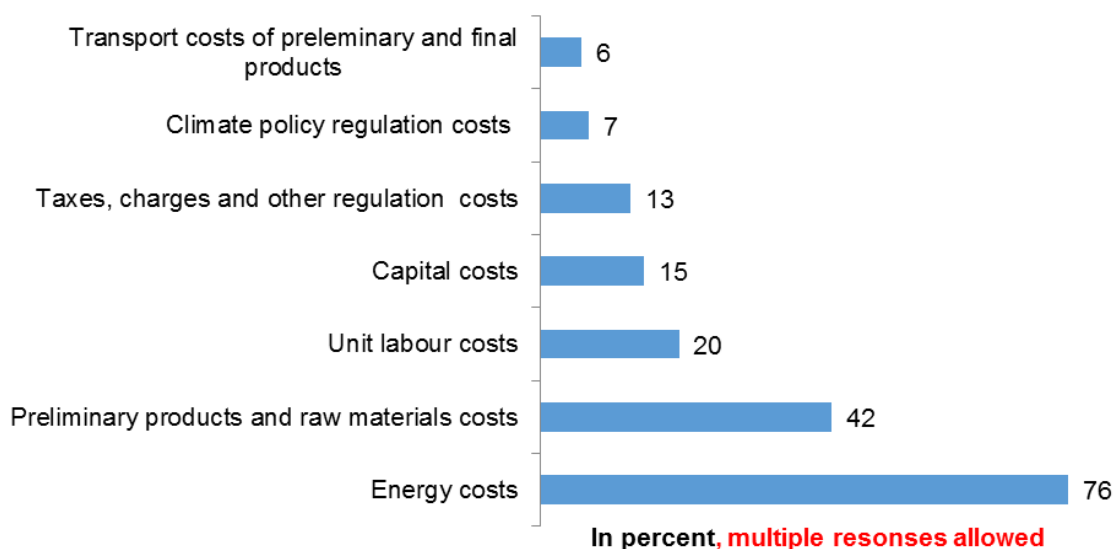
Source: KfW/ZEW CO₂ Barometer 2012

4.3.3 Competitive situation

This section aims at analysing the most important factors that influence companies' production costs as well as decisions on strategic location. Finally, we evaluate the relevance of costs associated with climate policies and especially the EU ETS for the strategic location decision. This subsection is based on questions raised within the framework of the KfW/ZEW CO₂ Barometer 2012.

Figure 52 summarises the most important factors that influence company's production costs. More precisely, surveyed companies were asked to indicate the two most important factors regarding the economic efficiency of their products. **For 76 per cent of all surveyed companies in 2012 energy costs are the most important factor for their economic efficiency concerning production of their main products.** Further important factors are the costs **for input goods and raw materials**. In contrast, costs associated with climate policy regulations played a subordinate role. Only 7 per cent of the surveyed firms stated that the costs associated with climate policy regulations are an important factor of the economic efficiency of their production.

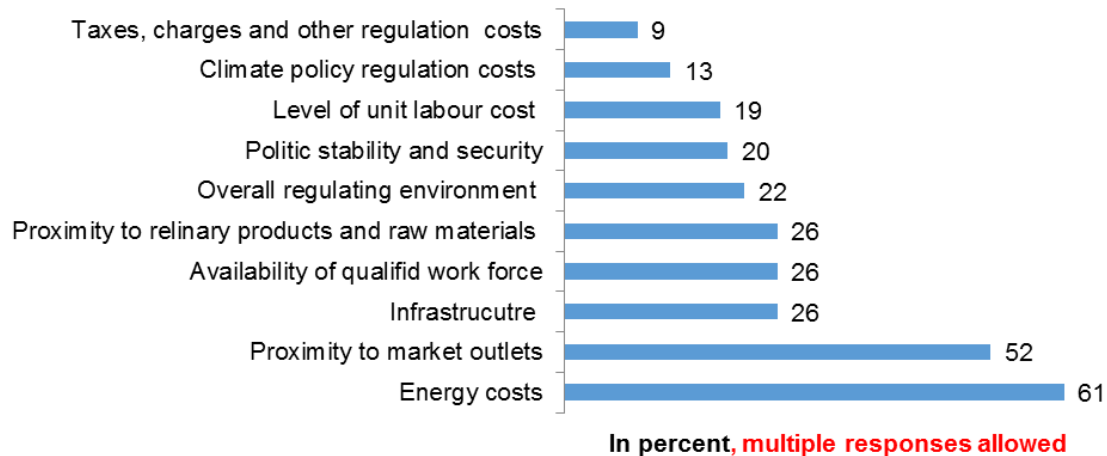
Figure 52 Main cost factors of firm's economic efficiency



Source: KfW/ZEW CO₂ Barometer 2012

In the next step, we are interested whether the costs associated with climate policy regulations have had an impact on companies' strategic location decision. In 2012 surveyed companies were asked to state the three most important factors for their strategic location decision. Figure 53 summarises the main results. **We find that the costs for climate policy regulations do not influence companies' strategic location decision at a significant level.** Only 13 per cent of the respondents in 2012 stated that the costs associated with climate policy regulations are an important factor for their location decision. **Furthermore, we find that energy costs and the proximity to the sales market are the most important.**

Figure 53 Factors influencing the strategic location decision



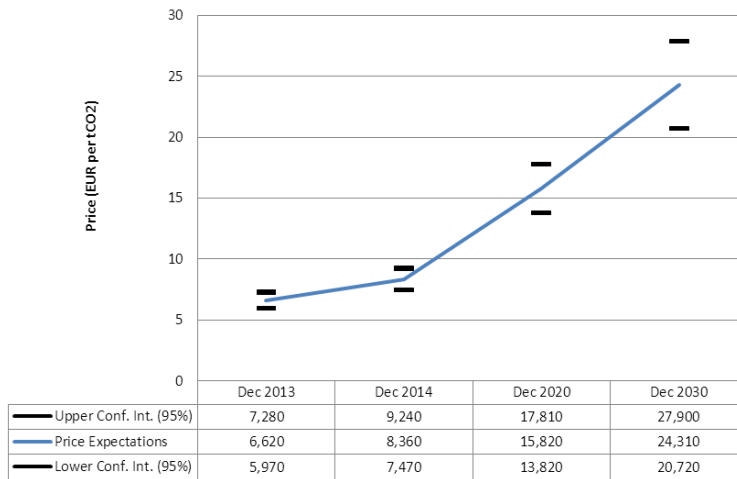
Source: KfW/ZEW CO₂ Barometer 2012

4.3.4 Carbon Prices and Trading Behaviour

Finally, we will complete this step by analysing broader observations on the EU ETS. We analyse CO₂ price expectations, trading frequencies as well as its determinants in order to analyse firm behaviour in the EU ETS. This analysis is based on questions raised within the framework of the KfW/ZEW CO₂ Barometer surveys of 2010, 2011, 2012 and 2013.

Figure 54 summarises the price expectations of surveyed companies in 2013. In the short run, companies expected carbon prices to remain at relatively low levels and to rise only moderately until the end of 2014. Surveyed companies' expectations for the end of 2014 are on average EUR 8.36 per tCO₂. By the end of 2020, respondents expect a substantial increase to have taken place. On average they expect by December 2020, a price of EUR 15.82 tCO₂. Surveyed companies expect this positive trend in carbon prices to continue even in the long run after the end of the third trading period of the EU ETS. On average, they expect a price of EUR 24.31 tCO₂ at the end of 2030.

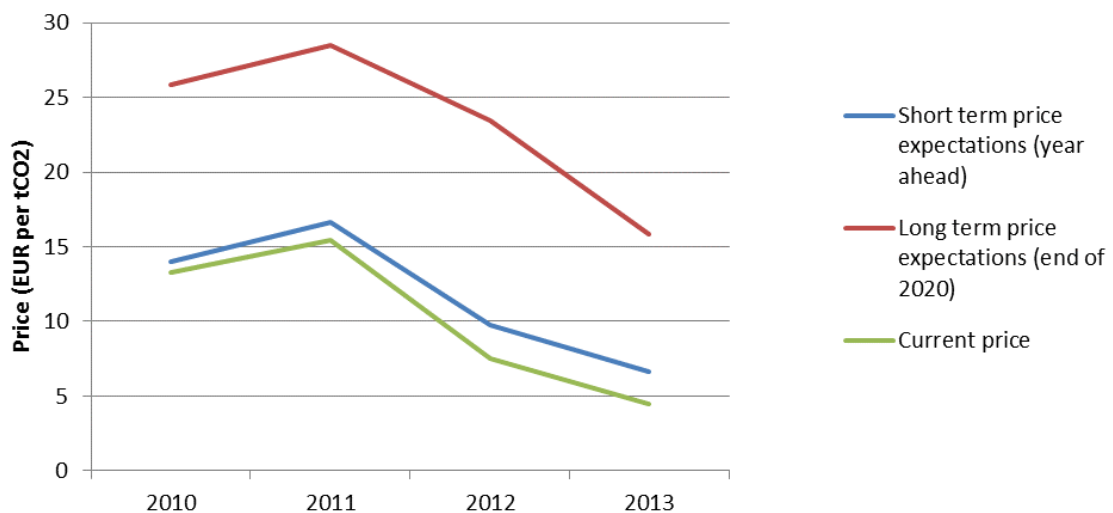
Figure 54 Price expectations for EUAs in 2013 (inflation adjusted)



Source: KfW/ZEW CO₂ Barometer 2013 – Carbon Edition

Figure 55 summarises the development of respondents short- (year ahead) and long-term (end of 2020) price expectations in comparison to the current carbon price since 2009. **We find surveyed companies to expect increasing carbon prices in the short as well as in the long term, but they adjust their price expectations to the current market situation.** Since 2011, respondents have revised their price expectations strongly downward. The long-term carbon price expectation at the end of 2020 has decreased from EUR 25.87 tCO₂ to EUR 15.82 tCO₂.

Figure 55 Short and long term price expectation over time



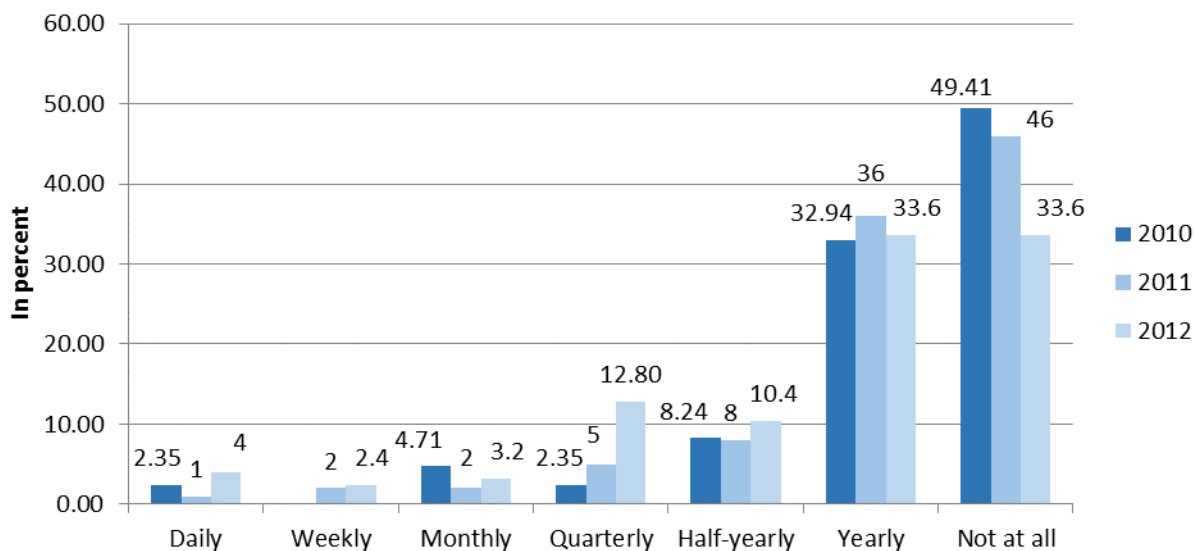
Source: KfW/ZEW CO₂ Barometer 2010, 2011, 2012, 2013

Note: In 2010, the current price during the time the survey was conducted was EUR 13.30 tCO₂ and respondents expected a price of EUR 13.96 tCO₂ at the end of 2011 and of EUR 25.87 tCO₂ at the end of 2020.

Figure 56 summarises companies trading frequency between 2010 and 2012. **We find that a substantial portion of the surveyed companies are not actively participating in the carbon market.** Over the years on average 43 per cent of the respondents stated they had not been trading emission allowances or credits (EUAs, CERs or ERUs) in the last year. Furthermore, most of the active companies stated to merely trade on an annual basis. Over the years on average 34 per cent of the surveyed companies stated to trade emission allowances only once a year.

Nevertheless, **we find that the proportion of companies that participate actively on the carbon market increased over the years.** For example in 2012, 66 per cent of all surveyed companies stated they had been trading emission allowances or credits. This corresponds to an increase of almost 10 percentage points compared to the active companies in 2011.

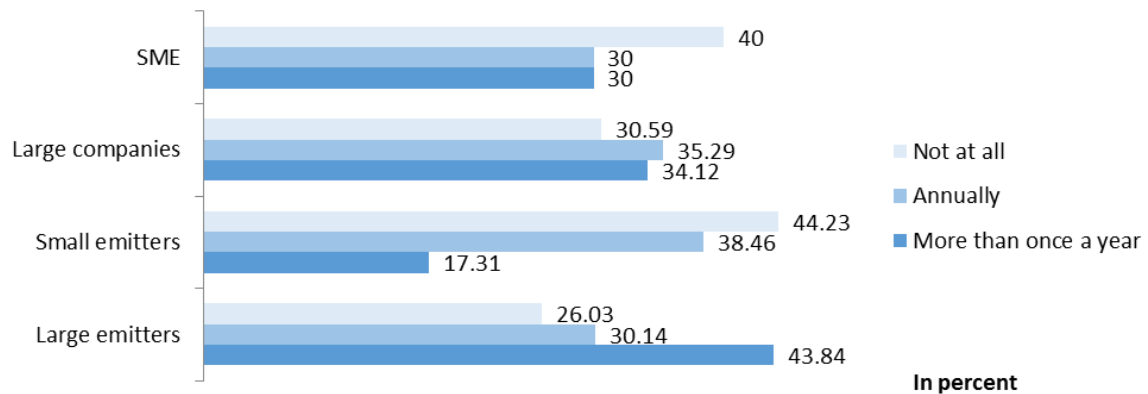
Figure 56 Allowance trading frequency (EUA, CER, ERU)



Source: KfW/ZEW CO₂ Barometer 2010, 2011, 2012

Figure 57 reveals that the decision to actively participate in the carbon market as well as the trading frequency depends on the size of the company. Large companies with at least 250 employees are more likely to participate actively in the carbon market than SMEs with less than 250 employees. In 2013, 40 per cent of the small firms surveyed stated that they had neither traded emission allowances nor credits (EUAs, CERs or EURs) in the last year. In contrast, only 31 per cent of the large firms stated that they did not actively participate in the market during the same time. **By classifying respondents in small and large emitters, we find that large emitters are significantly more active in the carbon market than small emitters.**

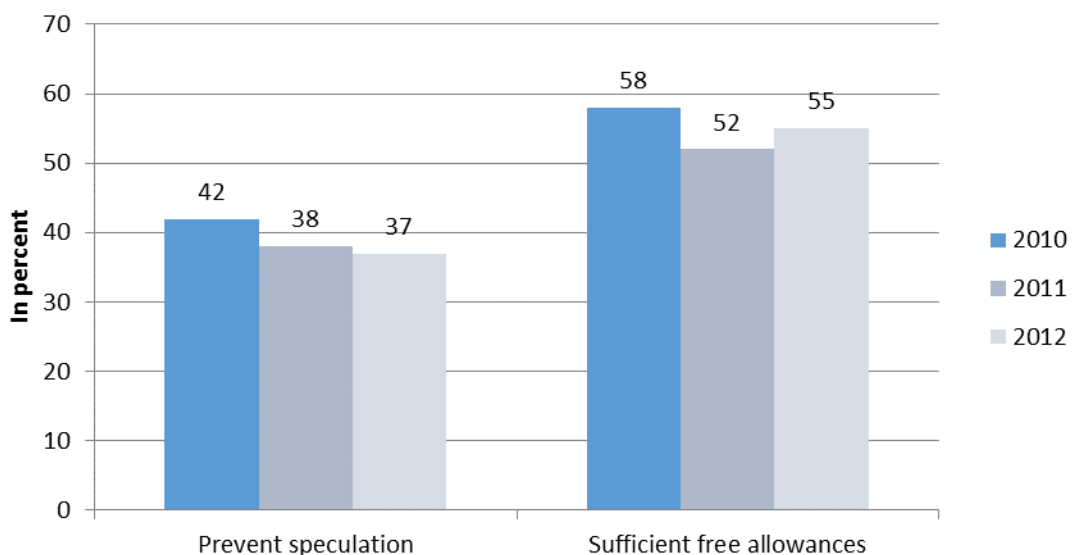
Figure 57 Trading Frequency broken down by Number of Employees and Emissions



Source: KfW/ZEW CO₂ Barometer 2013 – Carbon edition

According to our analysis there are essentially two reasons for firms not to participate actively in the carbon market: A sufficiently large free allocation of emission allowances and regulatory limits on speculation. On average 55 per cent of the inactive respondents stated that they received a sufficiently large amount of free allowances to ensure compliance (Figure 58) and that they therefore do not see the need to actively engage in the market. Furthermore, on average 39 per cent of inactive companies mentioned restrictions on speculation as a reason for not actively participating in the carbon market. These companies stated that they cannot be involved in transactions not belonging to their core business activities or transactions they regard as speculative businesses.

Figure 58 Main Factors Influencing Firm’s Inactivity Regarding Allowance Trading



Source: KfW/ZEW CO₂ Barometer 2010, 2011, 2012

4.3.5 Summary

Based on survey data used for this study we find that a **relatively high proportion of the surveyed companies have carried out investments or made changes in the production process that have caused a reduction of their CO₂ emissions.** Based on the most recent survey conducted in 2013 we find that 77 per cent of all respondents intervened in the production process or invested in order to reduce their carbon emissions. Furthermore, we find that the **size of the company in terms of emissions and number of employees influences the decision to reduce carbon emission. Large companies and large emitters are more active with respect to low carbon actions in comparison to SMEs as well as small emitters.** With respect to concrete CO₂ abatement options, **process optimisations and investments in energy efficiency measures are the most frequently used options.**

Despite the fact that a high proportion of the surveyed companies has conducted CO₂ abatement measures by now, **we find that in most cases the actual carbon abatement was not the underlying motive. Costs caused by the EU ETS played only a side-effect and the main impetus came from the objective to reduce energy and raw material costs and company internal targets related to efficiency of the production process.** We find that **energy costs are the most important factor for economic efficiency and the strategic location decision of the respondents.**

Furthermore, we find that a **substantial amount of the surveyed companies is not actively participating in the carbon market.** During the last years, however, the regulated companies increased their CO₂ allowances trading activity. Again, especially large firms and large emitters are active in the carbon market. **We find that the main reason for regulated companies not to actively participate in the carbon market is a sufficiently large free allocation.**

Finally, we find the respondents to expect increasing carbon prices. They adjusted their price expectation to the current situation at the carbon market (dictating a low price), but expect carbon prices to increase in the short and in the long run.

4.3.6 References

KfW/ZEW CO₂ Barometer 2009: "Leaving the Trial Phase behind – Preferences & Strategies of German Companies under the EU ETS".

KfW/ZEW CO₂ Barometer 2010: "Effizienzpotenziale des Emissionshandels noch nicht ausgeschöpft – Strategien und Management deutscher Unternehmen".

KfW/ZEW CO₂ Barometer 2011: „Hoher Anpassungsbedarf im EU-Emissionshandel ab 2013 – deutliche Defizite bei der Vorbereitung in den Unternehmen“.

KfW/ZEW CO₂ Barometer 2012: „Anreizwirkung des EU-Emissionshandels auf Unternehmen gering – Klimapolitische Regulierung wenig relevant für Standortentscheidungen“.

KfW/ZEW CO₂ Barometer 2013 – Carbon Edition. "The EU Emissions Trading Scheme: Firm Behaviour during the Crisis".

5 Literature review

This section is to provide some broader context to this study through an overview of key studies (quantitative and qualitative) conducted between 2009 and 2013 looking at the impact of the EU ETS on investment and innovation at the company level. It is not intended as a detailed discussion or critique of the latter.

5.1 Review of literature sources

Since the EU ETS's inception in 2005 a considerable amount of *ex-post* evaluation studies within the environmental economics literature have been produced. Studies have focused on assessing the ETS performance on a variety of aspects including:

- its contribution towards emissions reductions;
- its impact of the EU ETS on profits and product prices;
- its ability to incentivize investment in low carbon technology.

On the later one, disentangling the effects of the EU ETS from a multitude of factors including the global recession and investments into newer technologies that would have taken place despite the regulatory environment has proven difficult. The main focus of research has hence not been on the production of counterfactual scenarios, but more on surveying decisive actors and their attitudes, such as managers of major utilities and industries. The below section is summarizing major findings from the recent literature, focusing on innovative studies and the emergence of new survey data on a European and country level with a focus on post 2009 publications.

In summary, many of the reviewed studies conclude **that although the EU ETS has been instrumental in moving the discussion on low carbon strategies into the boardroom, thus becoming a factor in decision-making, it is not providing sufficient incentive for an overall strategy change towards low carbon production. The lack of a clear price signal from the EU ETS has undermined the overall objectives of the scheme and has questioned its effective functioning without fundamental reform.**

Taking a comparative approach across the oil, pulp and paper, steel, electric power and cement sector, primarily based on case study analysis, Birger, Skjærseth et al (2013) find that the electric power sector has been the most proactive in response to or anticipation of the EU ETS. The energy-intensive industries have also taken low carbon actions, however, investments have been less significant and are less common in the sector. Generally, the study finds that the EU ETS has shifted the climate and environmental strategies of companies towards innovations. Furthermore, the EU ETS has led to increased industrial collaboration across industry in search of innovative pathways for carbon reductions. Some interesting results from the sector based case studies are summarised below.

- For the cement sector, Christensen (2013) bases her assessment on in-depth case studies into Holcim and Heidelberg Cement specifically, but also takes overall sectoral developments into account. She observes that climate related actions in the cement sector have become more frequent between 2000-10, but with inter-company differences in strategic responses. According to the author, the EU ETS in its early phases has not been able to provide strong economic incentives for strategic changes in the cement sector, due to significant over-allocation of allowances and low carbon prices. Expectations of a more stringent ETS in the near future however underpin the companies' increasingly proactive long-term climate strategies. The trading scheme has put carbon on the corporate agenda, and has contributed to a rethinking of long term strategies in the sector. The author finds indications that the ETS has directed company attention to previously underexplored technology solutions – like energy efficiency investments, clinker substitution and CCS technologies.

- In comparing a Swedish (SCA) and a Norwegian pulp and paper company (Norske Skog), Gulbrandsen and Stenqvist (2013) find limited effect of the EU ETS on the low carbon investment and operational decisions of these companies. While the EU ETS has pushed up prices for electricity, thus having an indirect effect, neither SCA nor Norske Skog have actively looked to develop or implement low carbon actions as a direct result of the EU ETS. However, the EU ETS successfully triggered a reinforcement of the companies' commitment to more stringent climate change and environmental strategies. The latter is manifested in more efforts to monitor emissions and account for CO₂ prices. The study also highlights the importance external factors play in influencing whether or not a company invests in low carbon measures. SCA for example has broadened its product portfolio whereas Norske Skog has contracted and had to grapple with financial difficulties. This resulted in SCA investing more in low carbon actions than Norske Skog.
- The steel sector, according to Wettestad and Arntzen Løchen (2013), has been critical of the EU ETS from the start and has distanced itself from the ETS by introducing industry defined benchmarks. Nevertheless, interesting industry developments towards low carbon actions have taken place. Looking at ThyssenKrupp and SSAB, the authors observe new monitoring and reporting tools, investments in energy efficiency and increased attention toward CCS. The authors argue that the EU ETS has been a driver in getting the ULCOS (Ultra-low carbon dioxide steelmaking) research programme off the ground. Their overall assessment hence provides a mixed picture on the impacts of the EU ETS in the steel sector. They highlight the ETS's impact on corporate leaders' thinking and awareness as the most significant effect.
- Regarding the oil sector, Skjærseth (2013) investigates climate strategies of oil companies included in the ETS (Total, ENI, Shell, ExxonMobil, Repsol and BP) and the position of the European industry association Europaia before looking at ExxonMobil and Shell in more detail. The author finds that the EU ETS has succeeded in bringing companies to factor in carbon pricing into their longer-term strategies.
- Eikeland (2013) finds empirical evidence for the EU ETS impacting significantly on corporate strategies in the power sector through various mechanisms. Most notably, the EU ETS stimulated new strategies of learning at the industry and company levels whereby companies collectively agreed on a strategy for decarbonizing energy supply in Europe by 2050. The author highlights however, that the EU ETS did not evolve in a regulatory vacuum, however, and other EU and national policies also influenced companies' behaviours.

A leading European project conducted in 2009-10 (Neuhoff 2011), including research institutes such as the Climate Policy Initiative (CPI), the London School of Economics, DIW Berlin, ETH-Zürich, ISI-Fraunhofer, Universidad Carlos III de Madrid and University of Erlangen-Nürnberg, brought together a variety of data sets and research methods to provide robust insights on some of the issues raised above.

The project concluded that the EU ETS had a moderate impact on decision making on the managerial level but is still a less important factor in investment decisions than other aspects, such as access to fuel and public perception, as well as other technology specific incentive schemes (Rogge et al 2011). Uncertainty about the level of the future carbon price and the lack of stringency in the ETS have been identified as some of the major reasons: About 40 per cent of companies reported that the generous allocation of allowances in Phase 2 allowed them to continue business as usual. For Phase 3 this share declined to 10 per cent - illustrating increased stringency of EU ETS post 2012. Moreover, the share of companies that expected fundamental change in their operations and investment increased from 4 per cent to 10 per cent between Phase 2 and Phase 3I (Martin et al 2011). Elements of the scheme such as the inclusion of international credits from the CDM contributed to undermine some of

the stringency set by the cap and the clarity of the policy. The analysis points to the importance of combining long-term climate policy targets (as expressed in emission targets, renewable targets, and the EU ETS cap), economic incentives created by carbon prices emerging from EU ETS, and tailored technology support schemes, to encourage low carbon investment (Neuhoff 2011).

One of the contributing studies for the project, Rogge et al (2011), also looked at the relative impact and correlation of the EU ETS with other EU and national climate policies and found different results for different industries. For power generators the relevance of long-term climate policy targets for innovation and investment activities is highly correlated with the relevance of the EU ETS: For producers of renewable energy technologies, technology specific support schemes are important for decisions about investments and innovation. Relevance of technology specific support schemes is in turn highly correlated with both long-term targets and EU ETS.

The study also finds that current and future price expectations are an important investment decision factor: The expected carbon prices by power generators were much higher for 2020 than for 2012. However, firms assign much uncertainty to the 2020 price expectations. The differences in their carbon price expectations and their certainty about the later, correlated with the relevance level assigned to the EU ETS for investment decisions regarding the adoption of new plants and RD&D. That is, power generators with higher long-term CO₂ price expectations and a higher certainty about these expectations emphasised the importance of the EU ETS for investment decisions on new plants.

Another contributing study, Martin et al (2011), conducted a survey of almost 800 manufacturing companies across six European countries, exploring the impact of the EU ETS on low carbon innovation. The study looked at both, product innovation and process innovation to reduce carbon impact, finding that more than 60 per cent of firms have pursued measures to reduce GHG emissions, primarily relating to their manufacturing or core processes. Firms require on average a payback time of four years for investment in energy-saving measures. However, this figure varies widely between firms and countries. The study also finds that 30 per cent of firms under the EU ETS only passively participate in the market; i.e. they do not consider carbon allowances as a financial asset providing opportunities. Based on survey results, firms start to sell allowances only if they have an excess supply of 5,000 to 10,000.

The study also looked more specifically at low carbon investment in R&D. 70 per cent of companies were engaged in R&D, with the aim of curbing emissions and/or energy consumption ("clean process innovation"). A smaller proportion (40 per cent) were also pursuing "clean product innovation"; i.e. R&D with the aim of developing products that can help customers to reduce their emissions. There are significant differences between countries when it comes to clean innovation. According to the study, most active on product innovation is Germany, on process innovation is France with lowest levels of innovative activities observed in Hungary and Poland. Finally, the study finds a significant positive association between the expectations firms hold about the future stringency of their cap and "clean" innovation.

Rogge and Hoffmann (2010) analyse potential changes in the sectoral innovation system for power generation technologies which have been triggered by the EU ETS. Based on 42 exploratory interviews with German and European experts they find that, although overall impact on innovation has been limited, corporate CCS research and investments into efficiency improvements and retrofitting of coal plants has increased. Furthermore, carbon has become an integrated factor in investment appraisal of power sector construction. In conclusion they argue that the EU ETS' impact on corporate CO₂ culture and routines may prepare the ground for the transition to a low carbon sectoral innovation system for power generation technologies.

Hervé-Mignucci (2011) surveyed corporate investor communications for the five most carbon constrained European utilities (RWE, E.ON, EDF, Enel and Vattenfall) in order

to investigate the incentive that the EU ETS has created to invest in low carbon generation. The survey found that in the early years of the EU ETS, European utilities investments were considerably more influenced by non-climatic considerations, notably (1) the strategic repositioning of the industry towards a regional energy utility business and (2) environmental and competition-related regulations. Tighter constraint in ETS Phase 2 and expectation regarding Phase 3 triggered investments in favour of low carbon solutions: highly carbon-emitting plants were cancelled in favour of plants emitting less CO₂. The tighter caps also resulted in increased use of offset project mechanisms to foster investments in lower carbon power plants. Whether this trend has continued in the wake of the financial crisis is difficult to assess from this work as the time period covered is from 2004-2009 (Laing 2013).

Using a newly constructed data set recording patenting activities, key firm characteristics, and regulatory status with respect to the EU ETS, Caley and Dechezleprêtre (2012/13) investigated the EU ETS impact on the development of low carbon technology patents with results showing that the EU ETS between 2005 and 2009 has encouraged innovation in clean technologies among regulated companies. The authors identified over 5500 firms operating more than 9000 installations regulated under the EU ETS, accounting for over 80 per cent of EU ETS-wide emissions. The authors found that the EU ETS has increased low carbon innovation measured in terms of patenting activities among regulated firms by as much as 10 per cent, while not excluding patenting for other technologies. There is furthermore evidence that the EU ETS has not impacted patenting beyond the set of regulated companies. These results would imply that the EU ETS accounted for nearly a 1 per cent increase in European low carbon patenting compared to a counterfactual scenario.

Lofgren et al (2013) use Swedish firm level data to conduct an econometric ex-post evaluation of the impact of EU ETS on both small and large investment decisions. Their results show that the introduction of the EU-ETS does not seem to have had a significant effect on firm investment decisions in carbon dioxide reducing measures. Rather, the decision to make *large* investments seem to be determined primarily by firm characteristics such as the energy intensity of the firm's production, earlier investment in green R&D and earlier investments related to the environment. For *smaller* investments, basically the same firm characteristics are of importance. The authors explain the limited impact of the EU ETS through the generous cap during the first and second trading periods and overall economy wide changes.

Anderson et al (2011) surveyed Irish EU ETS firms to study the occurrence and determinants of CO₂ emissions friendly technological change during the pilot phase of the scheme (2005-2007). They found that despite declining emissions prices and policy related uncertainty, 48 per cent of responding Irish firms (27 responding firms) employed new machinery or equipment, 74 per cent made process or behavioural changes, and 41 per cent switched fuels to some degree that contributed to emissions reductions during the pilot phase. The authors highlight that the effect of rising energy prices on these emissions and energy saving actions should be taken into account when interpreting the results. They conclude that that the EU ETS was effective in stimulating moderate technological change and also raising awareness about emissions reduction possibilities.

The below table gives an overview of literature results.

Table 25 Overview of studies, empirical basis and results

Study	Empirical base	Results
Anderson B, Convery F, Di Maria C, 2011, "Technological Change and the EU ETS: The case of Ireland", IEF Working Paper No. 43	Survey of Irish EU ETS firms (based on survey responses by 27 firms with EU ETS installations in Ireland)	Find that EU ETS had been successful in stimulating moderate technological change
Calel R and Dechezleprêtre A (2013). Environmental Policy and Directed Technological Change: Evidence from the European carbon market. EUI Working Paper RSCAS 2013/09	Patenting data by the EPO covering 5'500 firms operating more than 9'000 installations regulated under the EU ETS	Find that the EU ETS accounts for nearly a 1 per cent increase in European low carbon patenting
Hervé-Mignucci M, 2011, "Operating and financial investments by European utilities over 2004-2009: what role for European mitigation policies?" CDC Climat Research Working Papers 2011-9	Surveyed corporate investor communications for the five most carbon constrained European utilities (RWE, E.ON, EDF, Enel and Vattenfall).	Find that tighter constraint in ETS phase II and expectation regarding phase III triggered clearer investment-related in favor of low carbon solutions
Kenber M, Haugen O, Cobb M (2009): "The Effects of EU Climate Legislation on Business Competiveness", GMF Climate and Energy Paper Series 09, Washington DC	Survey of 9 companies with installations directly covered by the EU ETS or others that expect indirect effects.	Company decision-making has taken carbon pricing on board, but climate legislation has not led to fundamental shifts in strategy.
Laing, T; Sato, M; Grubb M, Comberti C (2013): Assessing the effectiveness of the EU Emissions Trading Scheme, Centre for Climate Change Economics and Policy Working Paper No. 126	Bringing together results from different studies (see above)	Concludes that EU ETS has been integrated into firms strategic decision-making on investments, but not on the scale required to meet EU long-term targets and to incentivise the type of innovation required to bring down costs for low carbon transition.
Löfgren A, Wråke M, Hagberg T, Roth S (2013). The Effect of EU-ETS on Swedish Industry's Investment in Carbon Mitigating	Use Swedish firm level data to conduct an econometric ex-post evaluation. Dataset consisted of 229 firms	Found no significant impact of EU ETS on neither small nor large scale investment decisions

Study	Empirical base	Results
Technologies. WORKING PAPERS IN ECONOMICS No 565 Department of Economics School of Business, Economics and Law at University of Gothenburg	included in the ETS, with a total of 932 observations.	
Martin R, Muûls M and Wagner E (2011): Climate Change, Investment and Carbon Markets and Prices - Evidence from Manager Interviews	Conducted a survey of almost 800 manufacturing companies across six European countries	Find considerable amount of firms have pursued measures to reduce GHG emissions with a significant positive association between the expectations firms hold about the future stringency of their cap and "clean" innovation.
Neuhoff K (2011) "Carbon Pricing for Low carbon Investment: Executive Summary" Climate Policy Initiative and Climate Strategies	Bringing together results from 3 constituent surveys (see above)	EU ETS had some impact on decision making on the managerial level but is still a less important factor in investment decisions than other aspects of the business environment
Rogge, K. S. and V. H. Hoffmann (2010). "The impact of the EU ETS on the sectoral innovation system for power generation technologies – Findings for Germany." Energy Policy 38(12): 7639-7652.	42 exploratory interviews with German and European experts in and outside the power sector	Find overall impact on innovation to be limited, but an increase in corporate CCS research and investments into efficiency improvements and retrofitting of coal plants could mark transition point for low carbon investment trend.
Rogge, K; Schmidt, T; Schneider M (2011): Relative Importance of Different Climate Policy Elements for Corporate Climate Innovation Activities: Funding for the Power Sector	European survey amongst power generators regulated under the ETS and power generation technology providers (65 utilities and 136 technology providers)	For power generators the relevance of long-term climate policy targets for innovation and investment activities is highly correlated with the relevance of the EU ETS. For producers of renewable energy technologies, technology specific support schemes are important for decisions. Current and future price expectations are an important investment decision factor in the equation.
Rogge, K. S., J. Schleich, et al. (2011): The role of the regulatory framework for innovation activities: the EU ETS and the	Survey and case studies among German paper producers and their	Findings suggest that innovation activities are mainly governed by market factors and (as yet) are hardly affected by the European Emission Trading System and

Study	Empirical base	Results
German paper industry. International Journal of Technology, Policy & Management 11(3/4): 250-273.	technology providers	other climate policies
Jon Birger Skjærseth and Per Ove Eikeland (eds) (2013): Corporate Responses to EU Emissions Trading: Resistance, Innovation or Responsibility? Farnham (UK), Ashgate, pp. 253-282	In-depth case studies and other data review	The study finds that the EU ETS has shifted the climate and environmental strategies of companies for the short- and long-term towards innovations. Furthermore, the EU ETS has led to increased industrial collaboration across industry in search of new reduction measures

5.2 References

Anderson B, Convery F, Di Maria C, 2011, "Technological Change and the EU ETS: The case of Ireland", IEF Working Paper No. 43.

Christensen, Anne Raaum. 2013. 'Cement Industry'. In Jon Birger Skjærseth and Per Ove Eikeland (eds), *Corporate Responses to EU Emissions Trading: Resistance, Innovation or Responsibility?* Farnham (UK), Ashgate, 2013, pp. 165-208.

Eikeland, Per Ove. . 2013. 'Electric Power Industry'. In Jon Birger Skjærseth and Per Ove Eikeland (eds), *Corporate Responses to EU Emissions Trading: Resistance, Innovation or Responsibility?* Farnham (UK), Ashgate, 2013, pp. 45-97.

Gulbrandsen, L.H. and Stenqvist, C. (2013). The limited effect of EU emissions trading on corporate climate strategies: Comparison of a Swedish and a Norwegian pulp and paper company. *Energy Policy*, 56: 516–525.

Hervé-Mignucci M, 2011, "Operating and financial investments by European utilities over 2004-2009: what role for European mitigation policies?" CDC Climat Research Working Papers 2011-9.

Hoffmann, V. H. (2007). "EU ETS and Investment Decisions: The Case of the German Electricity Industry." *European Management Journal* 25(6): 464-474.

Kenber M, Haugen O, Cobb M, 2009, "The Effects of EU Climate Legislation on Business Competiveness", GMF Climate and Energy Paper Series 09, Washington DC.

Laing, T; Sato, M; Grubb M, Comberti C (2013): Assessing the effectiveness of the EU Emissions Trading Scheme, Centre for Climate Change Economics and Policy Working Paper No. 126.

Löfgren A, Wråke M, Hagberg T, Roth S (2013). The Effect of EU-ETS on Swedish Industry's Investment in Carbon Mitigating Technologies. WORKING PAPERS IN ECONOMICS No

565 Department of Economics School of Business, Economics and Law at University of Gothenburg.

Martin R, Muûls M and Wagner E (2011): *Climate Change, Investment and Carbon Markets and Prices - Evidence from Manager Interviews*.

Neuhoff K, 2011, "Carbon Pricing for Low carbon Investment: Executive Summary" Climate Policy Initiative and Climate Strategies.

Petsonk, A. and Cozijnsen, J., 2007, "Harvesting the Low Carbon Cornucopia: How the European Union Emissions Trading System (EU ETS) Is Spurring Innovation and Scoring Results, Environmental Defense.

Rogge, K. S. and V. H. Hoffmann (2010). "The impact of the EU ETS on the sectoral innovation system for power generation technologies – Findings for Germany." *Energy Policy* 38(12): 7639-7652.

Rogge, K; Schmidt, T; Schneider M (2011): *Relative Importance of Different Climate Policy Elements for Corporate Climate Innovation Activities: Funding for the Power Sector*

Rogge, K. S., J. Schleich, et al. (2011). "The role of the regulatory framework for innovation activities: the EU ETS and the German paper industry." *International Journal of Technology, Policy & Management* 11(3/4): 250-273.

Skjærseth, Jon Birger, 2013. Oil Industry. In Jon Birger Skjærseth and Per Ove Eikeland (eds), *Corporate Responses to EU Emissions Trading: Resistance, Innovation or Responsibility?* Farnham (UK), Ashgate, 2013, pp. 99-125.

Skjærseth, J. (2013). "Governance by EU emissions trading: resistance or innovation in the oil industry?" *International Environmental Agreements: Politics, Law & Economics* 13(1): 31-48.

Skjærseth, Jon Birger, Per Ove Eikeland, Anne Raaum Christensen, Lars H. Gulbrandsen, Arild Underdal and Jørgen Wettestad. 2013. 'Comparative Analysis'. In Jon Birger Skjærseth and Per Ove Eikeland (eds), *Corporate Responses to EU Emissions Trading: Resistance, Innovation or Responsibility?* Farnham (UK), Ashgate, 2013, pp. 253-282.

Wettestad, Jørgen and Liv Arntzen Løchen. 2013. 'Steel Industry'. In Jon Birger Skjærseth and Per Ove Eikeland (eds), *Corporate Responses to EU Emissions Trading: Resistance, Innovation or Responsibility?* Farnham (UK), Ashgate, 2013, pp. 209-252.

6 Overall conclusions

This chapter brings the different strands of research, analysis and literature review conducted for this study together and attempts to provide an integrated perspective on the key questions of the project.

6.1 Impact of EU ETS on low carbon actions

Overall, the results from the case studies (both on the company and sectoral level) and the country wide analysis on impacts of the EU ETS on German companies support each other and provide a common ground on the major questions looked at for this study. Many of our findings are in line with the broader literature (see section 5 of this report) though there are also some new insights and perspectives on companies' decision making coming out of the case studies.

To what extent is EU ETS a driver for low carbon investment and operational decisions? How does the EU ETS influence decision making? To what extent has this varied over the life of the EU ETS to date? What were the other drivers and what was the relative importance of the EU ETS in comparison to the other drivers?

Based on our case studies and interviews it becomes clear that carbon abatement and the carbon price were not the primary driving factors for most companies and sectors to invest in carbon efficient solutions. Instead, the main impetus came from the need for companies to reduce energy and raw material costs and their broader strategic turn toward sustainable production, based on increasing environmental awareness of stakeholders and consumer markets.

Nevertheless, the EU ETS especially in its early phases (based on higher actual and expected carbon prices), seems to have played a supportive role in many decisions. Our interviews highlighted that the EU ETS has provided a supporting factor in low carbon investments through its ability to minimise energy costs, provision of additional financial viability and profitability, awareness raising for climate issues at the management level and among employees, and capacity building for more accurate monitoring and reporting of emissions creating a better understanding of the potential for emissions reductions. Furthermore, indirect costs resulting from the EU ETS (e.g. through higher electricity prices), seem to have played a role in investment decisions, in particular during the later phases of the EU ETS. Some industry experts also highlighted the EU ETS indirect impact through access to finance, either for low carbon investments in the European market (NER300) or in developing and transition countries through the flexible mechanisms (CDM/JI). Through these channels and the carbon price incentive the EU ETS also seems to have spurred innovation, both within and outside the EU.

Along with the falling prices for emission allowances the overall impact of the EU ETS on low carbon actions generally decreased from the first trading period (between 2005 and 2007) to the second (between 2008 and 2012) and early in the third trading period. However, within sectors the distribution of cost impact varies according to the allocation methodology, with the Phase 3 benchmark-based allocation methodology for free allowances increasing costs for less GHG emissions efficient installations compared to the previous allocation methodologies, thus increasing the focus on low carbon actions. The importance of energy and raw material costs also increased over the same period. Over the years, improvements in the general efficiency of the production process have become an even more important driver of low carbon activities.

Companies' future carbon price expectations remain at relatively low levels in the short term and only rise moderately by the end of 2014. By the end of 2020, however, respondents expect a substantial increase. The German case study indicates an average price expectations of around EUR 15 tCO₂ by end of 2020). Companies expect this positive trend in carbon prices to continue beyond 2020 (with our case study for Germany indicating an average price expectation of around EUR 24.00 tCO₂ at the end of 2030). Some companies are influenced by this long-term perspective when planning strategic investment steps.

What factors influence low carbon action and the role of EU ETS as a driver?

Our interviews at the firm level provide anecdotal evidence that the following factors played a positive role in companies' decision to invest in low carbon technologies, particularly given the higher carbon price assumptions in the early years of the EU ETS: high energy costs, global competitiveness, available capital (for companies with high margins), higher awareness for sustainability issues at the board level and in consumer markets, and cheap abatement potential. Companies matching these conditions saw the EU ETS as an additional source of competitive advantage in the European market. Conversely, for companies with high carbon leakage risks, a lack of capital (for companies with low margins), low awareness of climate related issues at the board level and/or among consumers and technical limitations to reduce emissions, the EU ETS does not appear to have incentivised investments.

The level of GHG abatement and of EU ETS role in low carbon investment decisions **varies across sectors**. However, our analysis suggests that there are increasing differences within single sectors: some of the companies interviewed appear to act as front-runner companies achieving ambitious carbon abatement, while others struggle to implement reform and feel threatened by ambitious targets.

Furthermore, our survey data for the German case study shows that the decision to reduce carbon emissions depends on the size of the firm as measured in terms of emissions and number of employees. Large enterprises as well as large emitters are generally more active with respect to carbon abatement compared to SMEs and small emitters.

Finally, the country data provides evidence that an established Environmental Management System increases the abatement activity.

To what extent have low carbon investments and operational decisions been implemented in EU ETS sectors? What were the economic and GHG emissions impacts of such low carbon actions? What economic and technical factors affected decisions? How much does investment in energy efficiency projects contribute simultaneously to low carbon objectives?

Our findings show a consistent trend in companies and sectors regulated by the EU ETS towards energy efficiency and low carbon investments in the last two decades or so. Based on ZEW/KfW survey data for Germany we find that a relatively high proportion of companies (77 per cent) carried out investments or made changes in their production processes in 2013 that reduced their GHG emissions. However, decisions were primarily driven by the objective to reduce energy costs, with carbon dioxide reduction as a welcomed side effect. Only a share of 11 per cent of surveyed companies indicated to conduct measures that aim primarily at curbing carbon dioxide emissions.

Asked about their abatement strategies, 71 per cent of the active respondents stated to use process optimisation in order to reduce their carbon emission. The second most important measure (67 per cent) is the investment in energy efficient machinery.

Our sector case studies for the cement and steel sector highlight that the use of alternative fuels, substitution of carbon intensive raw materials, energy efficiency measures, and **the shift from the BOF-process route to the EAF-process route in the case of the steel sector contributed to emissions reductions. In recent years, however, both sectors seem to have reached technological barriers to further efficiency improvements in their production routes** that they will not easily overcome without breakthrough technologies.

For the power sector data indicates that electric power companies have implemented more proactive and innovative short- and long-term climate strategies during the first decade of the 2000s. This was primarily achieved by investment in new production facilities (switching from coal to gas powered plants) as well as by investing in modernisation/retrofitting of old plants to increase efficiency.

Decision making process at the company level varies across the case studies we analysed, but there are certain principles that seem to guide investment decisions across the board. The procedure followed was: Based on management driven company internal energy efficiency targets or energy cost reduction schemes, technical experts identify a list of possible projects and investments and, in close coordination with installations, do a first round of prioritisation based on assessment by R&D departments and engineers. Feasibility studies are taking into account legislative environment, economics and technological potential. Criteria assessed for each investment proposal include a. o. how the project fits in with R&D, internal rate of return, payback period, technology maturity, environmental co-benefits etc

For the low carbon investments that companies highlighted in the framework of the installation/firm level case studies we have summarised impacts on cost, GHG emissions and energy consumption in section 2 (table 2.17: Summary of investments and impacts on cost, GHG emissions and energy consumption). Consistent with the driving intention to reduce energy costs highlighted by most companies, findings clearly indicate that investments have been (or are expected to become) beneficial in that energy savings soon make up for the upfront costs. Though exact payback periods have not been disclosed by the companies due to confidentiality of data, there is indication that the approximate payback periods range from two up to seven years. Energy savings have been considerable following most of the investments though this does not always translate into the equivalent energy intensity reductions, mainly due to variations in production volume and changes in data coverage and reporting during the covered time period.

6.2 Policy conclusions

Companies interviewed for this study highlighted benefits as well as issues and challenges in relation to their compliance under the EU ETS. Their feedback hints at some important lessons learned for enhancing low carbon action via the EU ETS and for increase of stakeholder acceptance. Companies also provided input on how issues and challenges could be minimised or mitigated. A summary of company feedback is provided below and conclusions are drawn regarding policy options for the European Commission.

What do companies consider to be the main benefits of the EU ETS?

ETS benefits highlighted by companies can be summarised as follows:

- The EU ETS offers compliance flexibility and emissions can be managed and reduced at a fairly modest cost.

- Tighter emission caps, and in particular the new allocation rules within the ETS taking into account sectoral benchmarks, provide a direct competitive advantage to more efficient operators, and thus, represent an additional driver to improve energy efficiency in their operations.
- Some companies that were driven by the ETS in its early years took decisions to invest in low carbon processes which now provide them with a competitive advantage on the global markets.
- New GHG emissions reductions mechanisms (e.g. such as CDM, NAMAs) and new trading markets are perceived as an opportunity by some to minimise costs and to spur innovation on the global market.
- EU ETS has played an important role in making low carbon investments more financially viable. In most cases, the need for the investments has been instigated by other drivers (such as cost reductions or sustainability objectives) but the EU ETS through valuing of carbon provided the additional income source to make the investments feasible.
- Similarly the EU ETS is seen as a supporting factor in companies' considerations to turn to more energy efficient production routes and has created attention for those concerns in company boardrooms.
- Furthermore many companies mention the fact that obligations under the EU ETS lead to investments in additional capacities for monitoring, reporting and verification (MRV) of emissions and hence to more understanding on the issues and potentials for emissions reductions.

These highlighted benefits lend themselves well to emphasise the positive impact the ETS has had (and can have in the coming years) for companies if they decide to commit to a low carbon pathway and should be integrated into the Commission's Communication strategy for the EU ETS and its reform.

It becomes clear from the interviews however that scale up of positive examples of low carbon action under Phase 3 of the EU ETS and beyond will need a sufficiently high and stable carbon price with clear rules and mechanisms for compliance.

The maintenance and further upscale of flexible offset mechanisms, possibly under the label of New Market Mechanisms, NAMAs or Framework for Various Approaches (FVA) will be important for companies to support low carbon investments and innovation in third countries.

The German country case study also highlights that the minority of surveyed companies (only 38 per cent of the firms surveyed in 2013) are fully aware of costs and benefits of potential technical and organisational solutions for CO₂ abatement. In other words, 62 per cent of the respondents so far have neither assessed their individual abatement potential nor the associated costs. This points to the need and potential for enhanced communication, outreach efforts and support measures by both Member States and the Commission to enhance awareness and action on the company level. We find that an established environmental management system (EMS) in companies increases the level of awareness with respect to potential CO₂ abatement options. So the provision for further incentives and additional support in setting up knowledge sharing mechanisms with a particular focus on small and medium sized companies to review emissions and abatement options could be helpful to achieve awareness and enhanced low carbon action.

What do companies consider to be the main issues and challenges of the EU ETS?

Key issues and challenges that companies highlighted include the following:

1. Frequent modifications to the implementation details and uncertainties regarding the carbon price are criticised as they create disincentives for long term investments. To provide a clear and ambitious price signal some companies indicated the need for EU ETS reform with a more ambitious reduction target and an effective supply adjustment mechanism as well as greater simplicity in the regulations.
2. The absence of a global carbon market to create a level field for European operators and the risk for carbon leakage and loss of competitiveness is highlighted by many of the energy intensive companies.
3. There are diverging views on whether the EU ETS is setting too ambitious or too loose caps for specific sectors: Many companies highlighted that the carbon prices were too low in recent years to create incentives for low carbon investments; other companies regard their sector benchmarks as 'unrealistic' or 'aggressive' threatening their competitiveness on the global markets due to increasing operational and CO₂ compliance costs.
4. The indirect costs created by the EU ETS (e.g. through higher electricity prices) are seen as an additional burden by some companies as there is no harmonised compensation scheme for indirect costs.
5. The surplus of allowances in some sectors is criticised to create an unfair competitive advantage for companies in these sectors as they can create profit through the sale of surplus allowances on the market. Suggestions to solve this included flexible allocation with regard to changes in actual production (moving away from an allocation based on historic emissions), as is for instance done in the new Australian ETS.
6. The EU ETS forms barriers for growth due to its allocation rules for new installations and increases in capacity and production.

The issues listed above clearly point to companies' need for a longer term perspective and planning security regarding policy design and implementation, and carbon pricing within Europe and internationally. It will be important for the EU to provide this stability, insofar as is possible, and to set a sufficiently tight cap in developing the policy framework for the period 2020-30 for companies to maintain and enhance their efforts.

Furthermore, supporting the development of a global carbon market, through an ambitious 2015 international agreement and the development and implementation of new market mechanisms (e.g. through sectoral crediting and trading) linking carbon markets globally will be important in the long run to maintain support from energy intensive sectors such as steel and cement. Resistance in those sectors could also be reduced through stronger support of research into innovative breakthrough technologies to overcome limits in current technologies. It will be important that sectoral definition and classification under the ETS does not act as a barrier to innovative process routes. Furthermore, the analysis of the new allocation system based on benchmarks and how it is affecting industry across sectors and countries will be crucial. This could guide considerations on compensation schemes and other support mechanisms to avoid loss of competitiveness for specific sectors. The above proposals for the introduction of a harmonised compensation scheme for indirect costs across Member States and the flexible allocation of allowances based on changes in actual production (moving away from an allocation based on historic emissions) are examples of types of options that should be explored and tested against key criteria of maximising the efficiency and effectiveness of EU ETS beyond 2020.

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

one copy: via EU Bookshop (<http://bookshop.europa.eu>);

- more than one copy or posters/maps:
 - from the European Union's representations (http://ec.europa.eu/represent_en.htm);
 - from the delegations in non-EU countries (http://eeas.europa.eu/delegations/index_en.htm);
 - by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm) or calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

(*)The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (<http://bookshop.europa.eu>).

Priced subscriptions:

- via one of the sales agents of the Publications Office of the European Union (http://publications.europa.eu/others/agents/index_en.htm).

