Europe's low-carbon transition:

Understanding the challenges and opportunities for the chemical sector

European Climate Foundation

MARCH, 2014

PREFACE

An intense debate is taking place about the future competitiveness of European industry, fuelled by high energy prices as well as the economic downturn in many markets. In this context, growing concerns are being voiced that ambitious European climate policies could endanger European industry's competitiveness. The specific situation of energy intensive industries is at the very center of these concerns, as these industries are, by definition, disproportionally affected by increasing energy costs vis-à-vis the US or other geographies. In this debate long-term benefits to society are often contrasted with short-term negative effects for single companies or sectors. This conflict and tradeoff are taken for granted by many, but the implication is instead that Europe should try to find a route by which decarbonization and resource efficiency could be combined with and support a competitive European industry.

That is why the ECF has undertaken a pilot study of the transition dynamics of an especially important energy intensive industry, the chemical industry. The aim is to assess and analyze what the competitive dangers are, and to explore how to turn the challenge of reducing carbon emissions into an advantage for Europe's chemical industry.

To put it differently, the question is: could Europe achieve its triple objectives of competitiveness, sustainability, and security of supply, and what actions and solutions could contribute to strengthening all of these objectives? And could this be done in a situation where there is no global carbon price, where Europe's economy is struggling for growth, and where European industry is suffering from factor cost disadvantages on energy and labor?

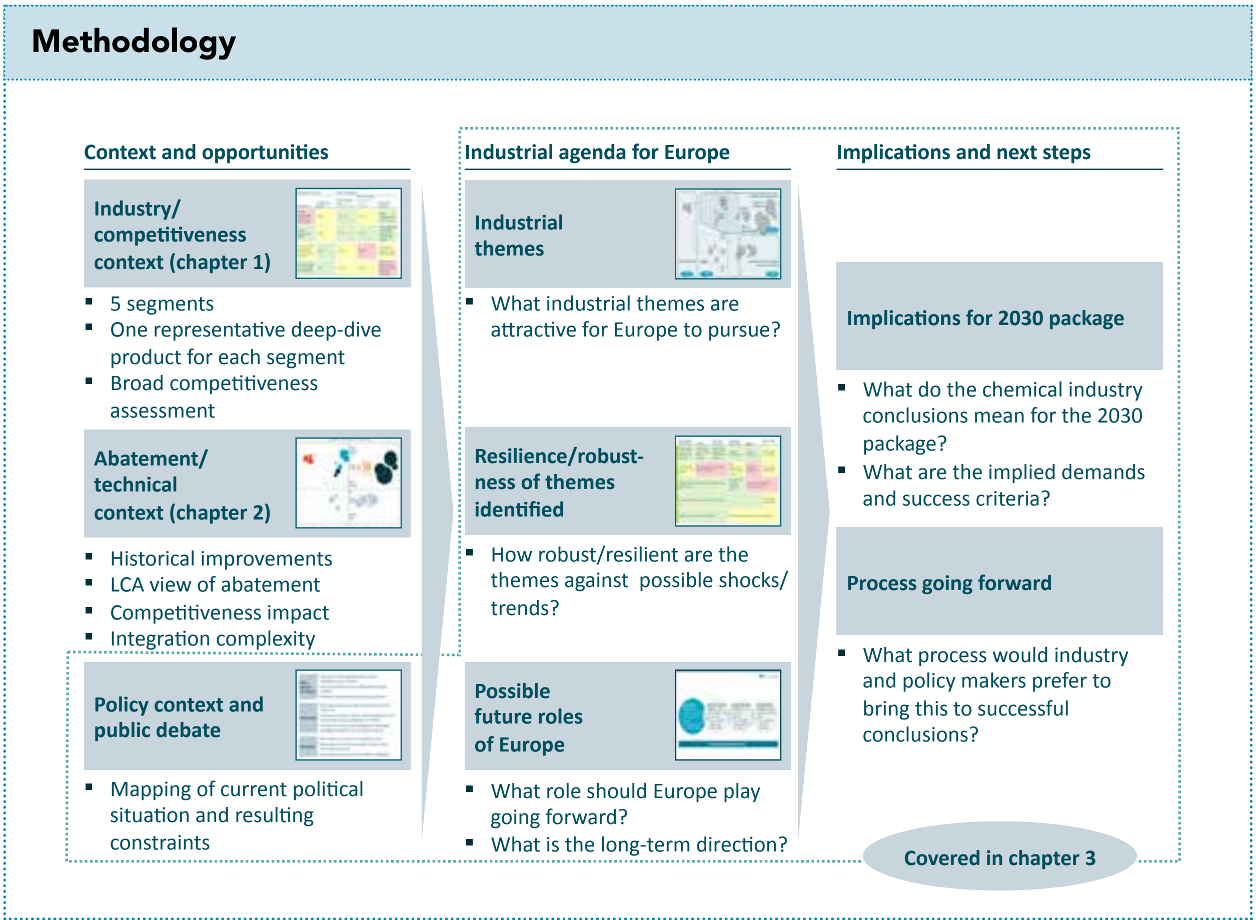
The study suggests that these three goals do not need to be in conflict with each other, but can in many cases be complementary also in the near term. The study gives reasons to be confident that the chemical industry could combine ambitious CO_2 reductions with competitive advantage. It also explores potential transition dynamics in the chemical industry in order to get a better grip on what sort of actions and solutions could contribute to strengthening competitiveness, sustainability, and security of supply.

For sure, it would be in nobody's interest for Europe to set so ambitious climate objectives that they would end up delivering a more or less pronounced deindustrialization, job losses, and economic recession. In fact, a successful economy in many ways enables climate policies, as a growing economy offers resources to be spent on climate friendly investments. This elementary observation holds true across industries, including energy intensive ones.

The report follows the methodology outlined in Figure 1. The first step – 'context and opportunities' – maps out the competitive situation of Europe's chemical industry overall and by segment, and explores key emission reduction opportunities with a life cycle approach. The second step – 'industrial agenda for Europe' – then addresses the question of what overarching industrial themes Europe could pursue and what role Europe could play in the fight against global warming. Finally, in the third step – 'implications and next steps' – we ask what implications this may have for the political dialogue and process in Europe. While the industry/competitiveness and abatement/technical contexts are covered in Chapters 1 and 2, the other topics are discussed in Chapter 3.

Dr. Johannes Meier, CEO European Climate Foundation

FIGURE 1



Acknowledgements and disclosure

The European Climate Foundation aims for the necessary and efficient transition to a low-carbon economy, in order to avoid the high risks for humanity from climate change. To that end, we collaborate with all stakeholders to shape the European context for ambitious and effective climate and energy policies.

The study is fully funded by the ECF, which itself is funded solely from private philanthropic organizations. The ECF does not have financial ties to political bodies or to businesses.

Many industry and policy experts, consulted in interviews and seminars, contributed to this study. McKinsey & Company, a management consulting firm, provided analytical support to the ECF on this project. The ECF is solely responsible for the scope of the study and its conclusions. The ECF wishes to warmly thank all the experts who provided invaluable input to this study; their generous willingness to help throughout the project should not be interpreted as agreement with any of the ECF's assumptions or conclusions.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Could Europe achieve its triple objectives of competitiveness, sustainability, and security of supply, and what actions and solutions could contribute to strengthening all of these objectives? And could this be done in a situation where there is no global carbon price, where Europe's economy is struggling for growth, and where European industry is suffering from factor cost disadvantages on energy and labor? This is the key question that the ECF asked itself in a pilot project looking at the relationship between emission reductions and competitiveness, using the European chemical industry as a case.

The central conclusion of the pilot project is that yes, there seems to be significant opportunities to further reduce emissions – enough to keep the industry on its fast historic improvement trajectory, and enough to keep the industry *'on track'* for an 80 to 95 percent emission reduction by 2050 – while at the same time maintaining or increasing competitiveness. However, an increasing share of the emission reduction opportunities seem to lie in cross-company and cross-sector areas, such as increased circularity, further integration, and further innovation to reduce emissions for other industries and world regions. Exploring ways to accelerate the capture of such more complex opportunities in cost-effective ways, in cooperation between industry and policy makers, seems like a promising way forward for Europe – a way forward which is consistent with the European chemical industry's historical sources of competitive advantage, which center around technological leadership, innovation, and integration. However, there are significant segments within the chemical industry – primarily bulk-oriented segments – where the factor cost disadvantage from high energy and feedstock prices is so high that European companies in these segments struggle in the face of lower-cost providers. While large abatement opportunities exist also for these segments, a much more selective prioritization of opportunities will be needed.

Europe's chemical industry has, up to now, managed to cope comparatively well with high and rising energy and feedstock prices. Since the early 2000s, electricity prices for Europe's industry indeed have more or less doubled, and today electricity prices in Germany are more than twice as high as in the US. The cost of natural gas has been five to ten times higher than in the Middle East at least since 1990, and recently the shale gas boom has lowered US gas prices to less than half of European levels. Notwithstanding these factor cost disadvantages, indicators suggest that the chemical industry as a whole has stayed competitive, despite undeniable challenges. The European chemical industry has grown at about the same rate as the whole European economy since the mid-90s, and the export surplus with the rest of the world has risen. Also, the total shareholder return ('TSR') of the European chemical industry has been close to 12 percent per year on average between 1994 and 2013, compared to a TSR of 8 percent per year for the overall European market index. The German Chemical Industry Association, VCI, describes its own sector today as one of the most vital branches of the German economy, as well as an important driver of innovation for other branches, although Germany has had ambitious environmental and climate policies for many years.

Clearly, this past and current performance does not guarantee that energy prices and regulations in the EU have not reached a level where competitive disadvantages start to become a true problem. Indeed, investments in new capacity are low, and the European chemical industry is largely in a mode of maintenance of existing capacity. Employment is slowly decreasing, by approximately one percent per year, since productivity improvements are outstripping growth, and the gap between European and US energy prices has widened in the past few years and is likely to remain significant for years to come. For the energy and feedstock intensive bulk chemicals, the cost disadvantage is now so high that there is a risk of certain assets closing down. Also, the industry worries that a historically important export market is disappearing, as China is becoming increasingly self-sufficient.

However, history shows that energy and feedstock prices are only one part in explaining the industry's competitiveness, and that competitiveness has to be defined in a broader and more complex way. Looking into the details of the European chemical sector, the development can only be explained by also considering other factors such as access to qualified labor, mature and depreciated assets, integration benefits in clusters, the overall business climate, and the participation of European companies in overseas growth through joint ventures or FDI.

Here lies what could be one of the biggest opportunities for Europe and its energy intensive industries. The study suggests that there are smart and ambitious climate strategies that could have a positive impact by reducing emissions while at the same time stimulating Europe's industrial competitiveness. This would mean that well-designed climate policies and competitiveness do not have to be contradictory, but can be complementary.

In fact, the overall success of the chemical industry during the last decade has been achieved by leveraging the multitude of competitive advantages mentioned above. This has been a successful strategy as is shown by the significant export surplus in trading of specialty chemicals. At the same time, Europe's chemical industry has nearly halved its greenhouse gas scope 1 emissions[1] compared to 1990[2], while in the same timeframe increasing production volumes by around 20 percent, producing ever more and better products than before. This translates to a reduction of emission intensity by 4 percent a year on average, and also means that the industry has 'over delivered' compared to the average industry improvement pace that Europe needs to follow to meet its objectives of reducing emissions by 80 to 95 percent by 2050.

Looking forward, the CEFIC sector roadmap[3] from 2013 has, for the European chemical industry as a whole, identified a 40 to 50 percent[4] emission reduction potential by 2030 compared to the frozen technology baseline. In contrast, this report does not look at the industry overall, but instead analyzes five chemical products in depth throughout their value chains. For these chemicals a 50 to 75 percent scope 1 and 2 abatement opportunity[5] has been identified of which 60 to 70 percent appears to have a neutral to positive impact on competitiveness. Hence, while this project has not modeled the total emission reduction opportunity for the industry, the results of the five life cycle assessments are broadly consistent with the CEFIC roadmap. On top of the scope 1 and 2 potential, these five products also possess a substantial scope 3 opportunity[6] by enabling emission reductions in other sectors and world regions.

For sure, these improvements will not come automatically. In addition to further intra-company process and energy efficiency improvements, the potential lies largely in cross-company and cross-sector optimization opportunities with high integration and governance complexity (see Figure 2). These include increased circularity (recycling and re-use), advanced materials innovation, and cross-sector collaboration to enable emission reductions in other sectors. The latter proves to be very large, maybe larger than the opportunity for the chemical industry itself.

1 Scope 1 emissions, i.e., direct GHG emissions from sources that are owned or controlled by the entity

2 Greenhouse gas emissions, measured in CO_2 equivalents. Around two-thirds of the improvements come from the phase-out of N_2O and approximately one-third from CO_2

3 European chemistry for growth, Unlocking a competitive, low carbon and energy efficient future, CEFIC, 2013

4 Different reduction rates in four different scenarios. Also, the absolute production baseline varies by scenario due to different assumptions on, e.g., competitiveness, innovation, and development of EU chemical production (a more detailed comparison in Chapter 2)

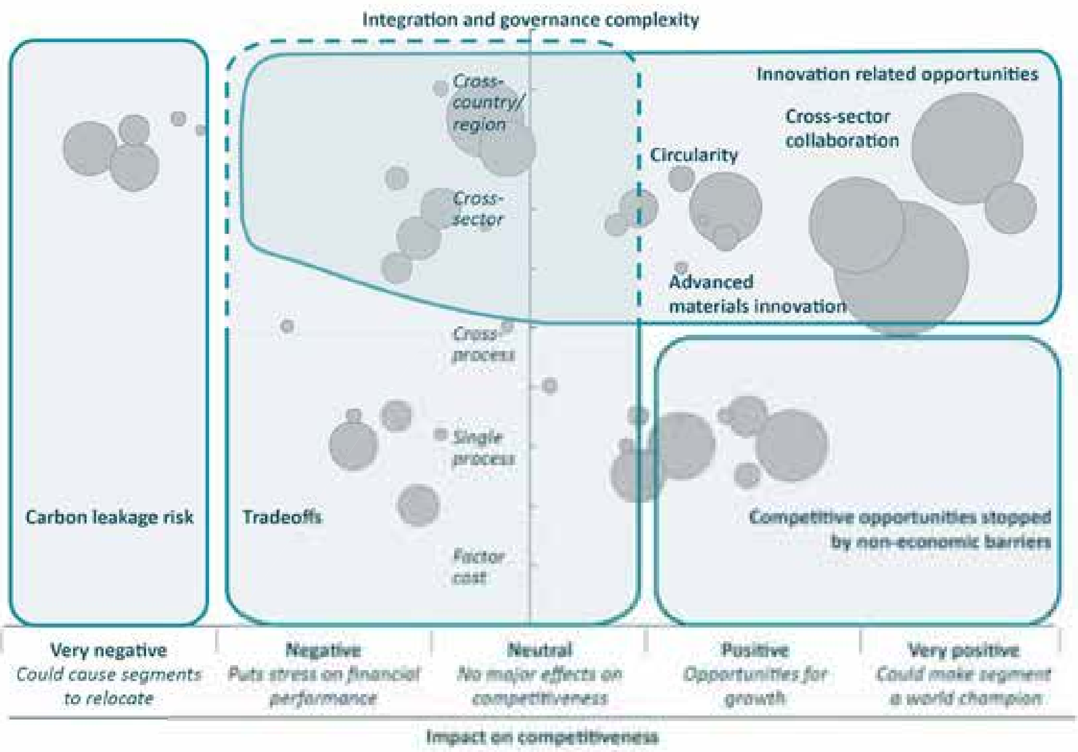
5 Scope 1 and 2 emissions together (Scope 2 emissions are indirect GHG emissions resulting from the generation of electricity, heating and cooling, or steam generated off site but purchased by the entity)

6 Scope 3 emissions include indirect GHG emissions from sources not owned or directly controlled by the entity but related to the entity's activities, e.g., use of sold products

The fact that so much of the opportunity relies on cross-sector and innovation related actions is an important insight, and calls for a broad lens when discussing Europe's ambitions going forward. Moreover, to the extent the European industry could develop solutions that could be applied globally, there is also a potential multiplier effect since Europe constitutes less than 15 percent of global emissions. Such global effects could be unlocked either by establishing advanced markets for innovators (compare to the EU fuel efficiency standards for cars), or by exporting innovative solutions (e.g., attractive circularity solutions, new materials, or solutions for process integration).

FIGURE 2

Industrial themes for the chemical industry



The results leave us with two tentative conclusions regarding what kinds of emission reduction opportunities Europe could choose to pursue, and regarding the role Europe could play in the global transition to a low-carbon economy:

- First, it seems natural for Europe – industry as well as policy makers – to look into what can realistically be done to accelerate the abatement themes identified; circularity, cross-sector collaboration, and advanced material innovation are sometimes heard in the European debate, but receive a low share of attention, financial support, political capital, and metrics or follow-up. Based on the product value chain analyses conducted, they seem to provide a promising path forward, one that can allow the industry to keep up its high pace of emission reductions while at the same time maintaining or increasing competitiveness. But to capture them will likely require new types of cross-sector cooperation, policy, and public-private partnerships.
- Second, Europe could consider a broader set of roles in the global struggle to reduce greenhouse gas emissions than it currently does. The ECF's impression is that a very high share of Europe's attention is focused on reducing the emissions in Europe's current industry structure relying on a sector-by-sector approach. Going forward, the ambition of Europe could also be to help to reshape the industrial system towards more circularity and cross-sector collaboration, to provide markets for advanced low-carbon solutions, and to develop global solutions through more innovation oriented policy.

Europe's opportunity, and challenge, will be to redefine the debate in which, up to now, ambitious climate objectives and competitiveness are much too often assumed to be in conflict. We need a fundamental rethinking of the underlying drivers of success for Europe. And we need to expand the solution space to balance competitiveness, sustainability, and security of supply in European industry. In essence, we need a broader notion of competitiveness to reflect the dynamics and potential of Europe profiting from the challenges of the transition.

The chemical industry has successfully reduced emissions in the past, and there seems to be substantial scope for further success. The opportunity will be to capture the large and promising cross-process, cross-company, cross-sector, and cross-country abatement opportunities – in addition to continuing to improve process and energy efficiency – and to explore the innovative potential that lies in the transition to a low carbon economy. If Europe succeeds in this, its history of ambitious climate objectives could turn into a major economic opportunity and advantage.

Chapter 1:

CURRENT COMPETITIVENESS OF THE EUROPEAN CHEMICAL INDUSTRY

Europe's chemical industry has, up to now, managed to cope comparatively well with high and rising energy and feedstock prices. The industry has grown at about the same rate as the whole European economy since the mid-90s, and the export surplus with the rest of the world has risen. Also, the total shareholder return ('TSR') of the European chemical industry has been close to 12 percent per year on average between 1994 and 2013, compared to a TSR of 8 percent per year for the overall European market index. Clearly, this past and current performance does not guarantee that energy prices and regulations in the EU have not reached a level where competitive disadvantages start to become a true problem. Indeed, investments in new capacity are low, and the European chemical industry is largely in a mode of maintenance of existing capacity. Employment is slowly decreasing since productivity improvements are outstripping growth, and the gap between European and US energy prices has widened in the past few years and is likely to remain significant for years to come. For the energy and feedstock intensive bulk chemicals, the cost disadvantage is now so high that there is a risk of certain assets closing down. Also, the industry worries that a historically important export market is disappearing, as China is becoming increasingly self-sufficient. However, history shows that energy and feedstock prices are only one part in explaining the industry's competitiveness, and that competitiveness has to be defined in a broader and more complex way. Looking into the details of the European chemical sector, the development can only be explained by also considering other factors such as access to qualified labor, mature and depreciated assets, integration benefits in clusters, the overall business climate, and the participation of European companies in overseas growth through joint ventures or FDI.

INTRODUCTION TO THE INDUSTRY

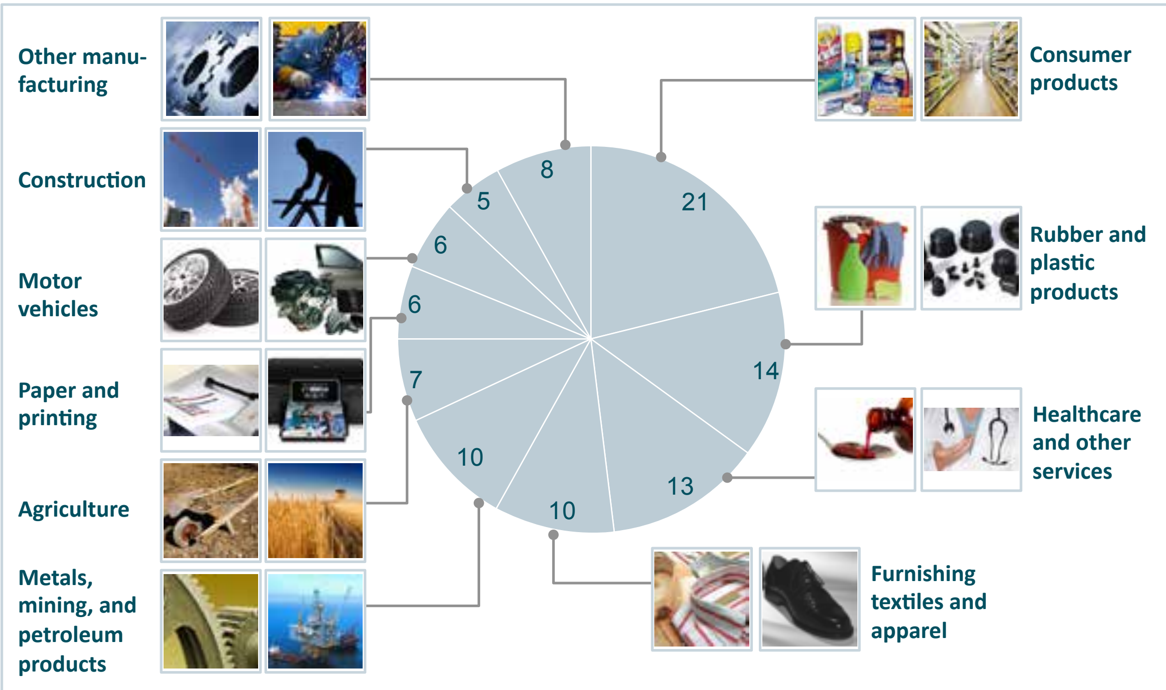
The chemical industry comprises thousands of products that end up in a very broad range of end-user applications in most other sectors of the economy. Examples span from day-to-day consumer products, e.g., packaging, detergents, and various plastics, to highly specialized products, e.g., electronic chemicals, catalysts, and mining chemicals (see Figure 3). This means that there is often a strong correlation between the overall economic growth of a region, and the growth of the chemical industry.

The industry plays a large and important role in Europe's economy, with 1.2 million full-time employees (excluding outsourcing and purchased services) and 2.2 percent of Europe's gross output (see Figure 4). The largest country is Germany, followed by France, Italy, and the UK. These four countries together make up 56 percent of the gross output[7] and 62 percent of the labor force.

FIGURE 3

End-user applications of chemical products

Percent



SOURCE: CSFB research

7 Value of production within the corresponding geographical area

FIGURE 4

Key activity metrics for the chemical industry

1 Total chemical industry excluding pharmaceuticals; 2 Data for 2010; 3 Includes scope 1 and 2 emissions
SOURCE: IHS Economics; Eurostat; EEA; CEFIC

HISTORICAL PERFORMANCE AND TRENDS

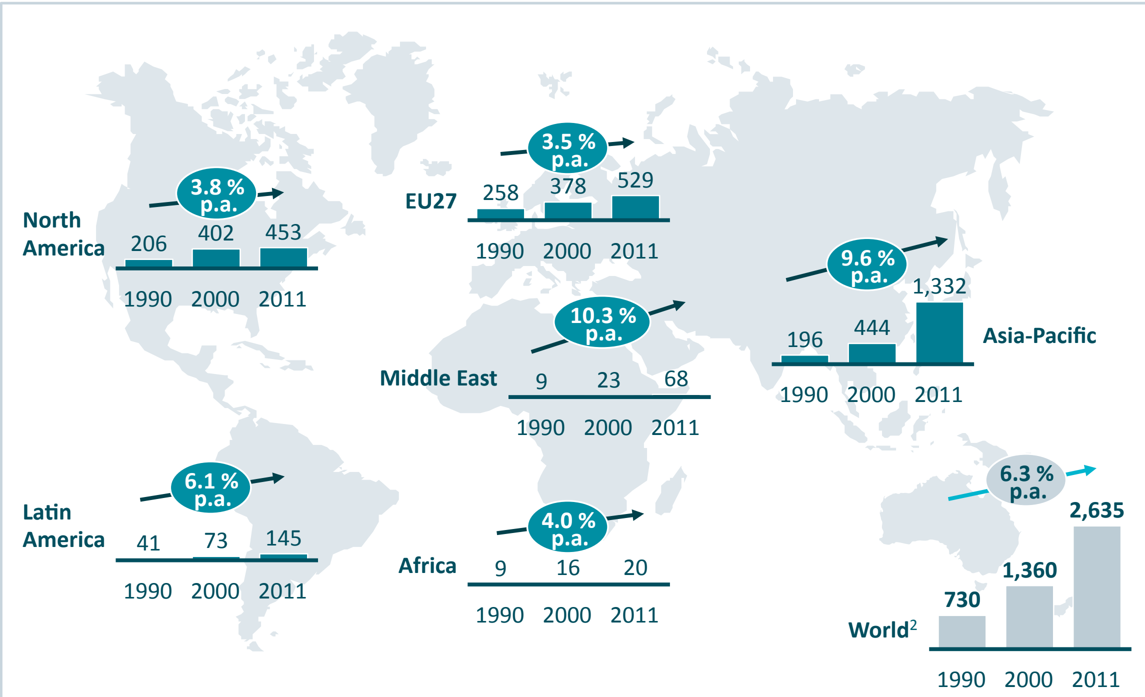
Production growth

Over the last 20 years, the global chemical industry has gone through a fundamental shift. From very low activity in 1990, the Asian countries have increased their gross output to a level that in 2011 exceeded that of Europe and North America combined (see Figure 5).

FIGURE 5

Historical growth of the chemical industry across regions

Total gross output[1], EURbn, nominal



1 Total chemical industry excluding pharmaceuticals; 2 Also includes European non-EU27 countries (not shown on page)
SOURCE: IHS Economics

Despite the strong Asian production growth, the European chemical industry has successfully maintained a stable growth trajectory and kept supplying the European market. Part of the explanation is that China for many years has faced challenges to meet its own demand, and Europe has had an opportunity to export large volumes. Figure 6 compares the chemical industry growth and Europe's economic growth more broadly. As can be seen, the chemical industry's gross output has grown by 3.7 percent per year between 1995 and 2011 in nominal terms, compared to a nominal European GDP growth of the exact same 3.7 percent. In other words, the industry revenues generated in Europe have grown in line with the overall economy. Part of the nominal revenue growth has been driven by higher inflation in the chemical industry than in the economy more broadly, due to the dependence on rising feedstock and energy prices. Hence, in real terms the industry has grown somewhat slower – by 0.4 percentage points – than GDP overall[8]. Moreover, the increasing feedstock and energy prices, which the chemical industry has only partially been able to pass on to customers, have resulted in a gross value add ('GVA') growth of 2.0 percent per year, i.e., a somewhat slower growth than in gross output.

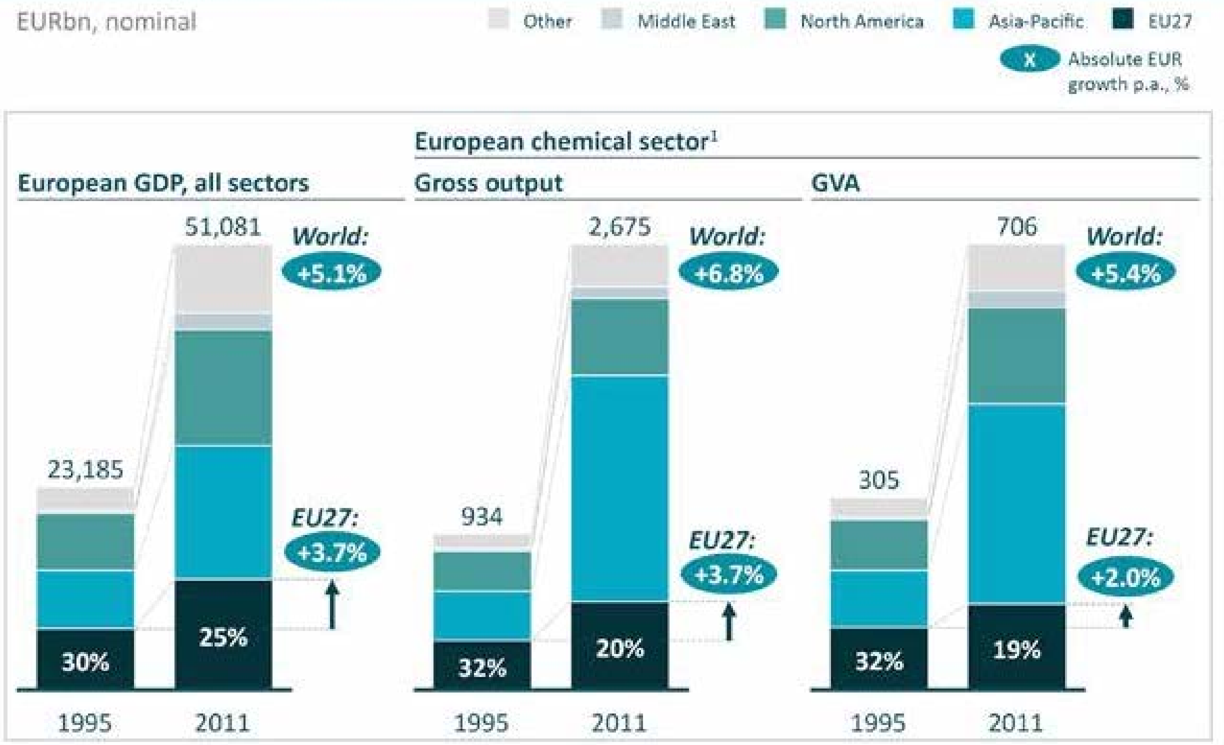
8 Based on data from Eurostat

As discussed above, the Asian chemical industry has grown by an extraordinary 9 to 10 percent per year during this period, which has resulted in a decreasing global market share of Europe's chemical industry, from 32 percent in 1995 to 20 percent in 2011. In a way, such a development is to be expected; most of our industry discussion partners agree it is natural to locate new capacity in geographies with strong local demand growth.

To put the numbers in Figure 6 in context, a cross-sector comparison with other energy intensive industries is shown in Figure 7. The European chemicals sector has grown faster than pulp & paper, cement, concrete & lime, and iron & steel sectors. Moreover, only the pulp & paper sector has marginally maintained a global market share better than the chemicals sector. Both the cement and iron & steel sectors have seen their market shares decrease to approximately half in this time frame.

FIGURE 6

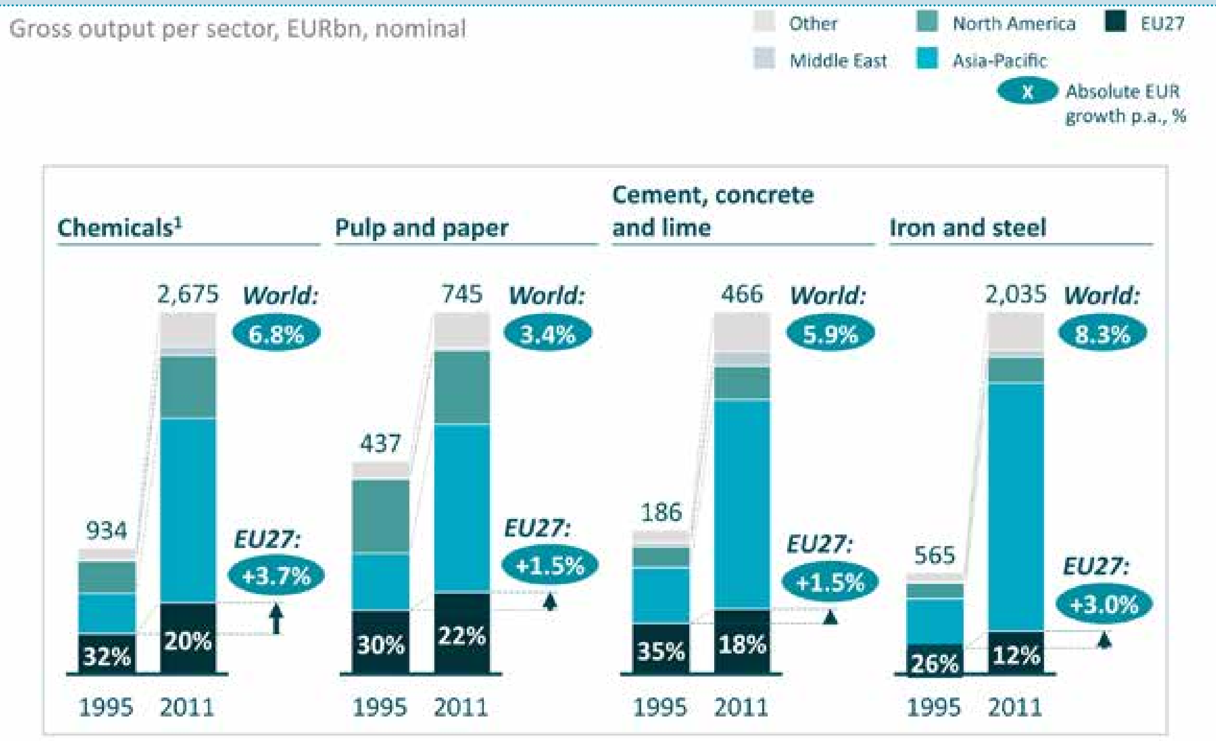
Growth comparison with GDP



1 Total chemical industry excluding pharmaceuticals
SOURCE: IHS Economics

FIGURE 7

Growth comparison with other sectors



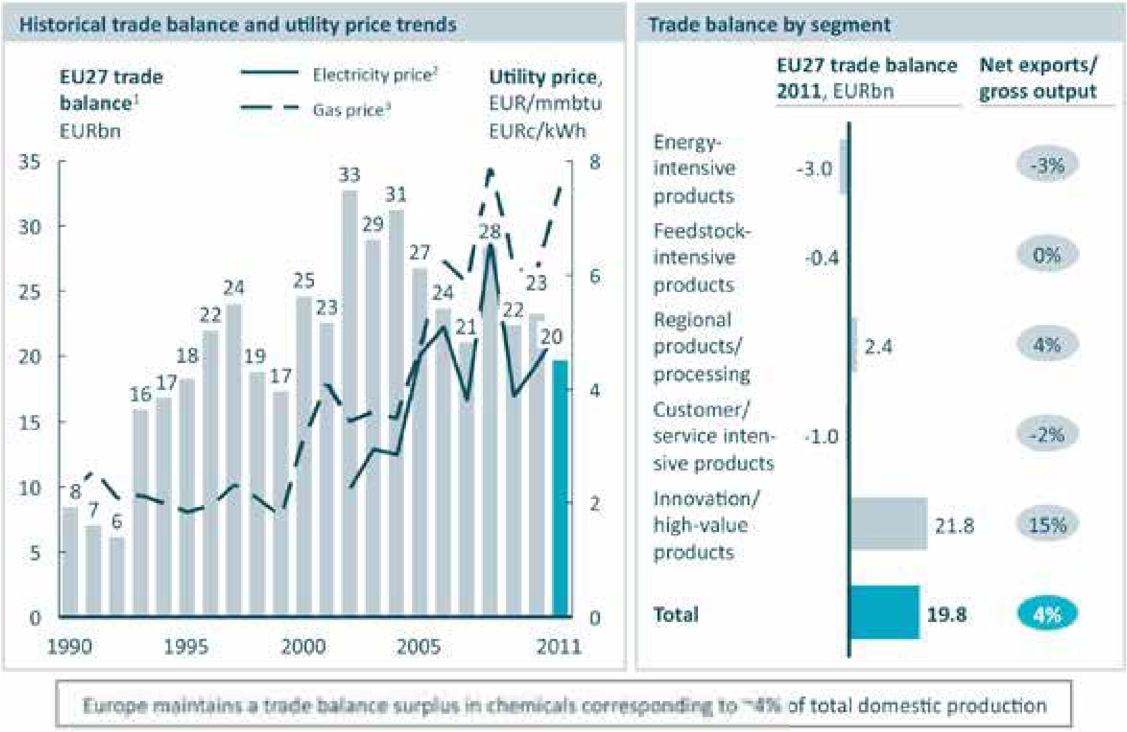
1 Total chemical industry excluding pharmaceuticals
SOURCE: IHS Economics

International trade

Looking at international trade, Europe is the only world region that has sustained a positive trade balance for chemicals over the last decades, despite rising factor costs. Based on data from IHS Global, Europe has a trade surplus for chemicals of approximately 20 billion Euros, or 4 percent of gross output. As Figure 8 shows, this surplus is almost exclusively driven by different innovation/ high-value specialty products and indicates that Europe has been and still is one of the strongest world regions in terms of innovative and high-value specialties.

FIGURE 8

Trade balance of European chemical industry by value



1 Total chemical industry excluding pharmaceuticals; 2 Wholesale price for Germany; 3 Average German import price
SOURCE: IHS Economics; Enerdata

While an export surplus may be the result of a weak domestic demand, the fact that chemical exports from Europe in themselves are in a strong position is also supported by estimates of the European Commission on the relative comparative advantages of different industrial sectors. Following these estimates, the European chemical industry has succeeded in keeping a higher proportion of total manufacturing exports than other important competitor countries.

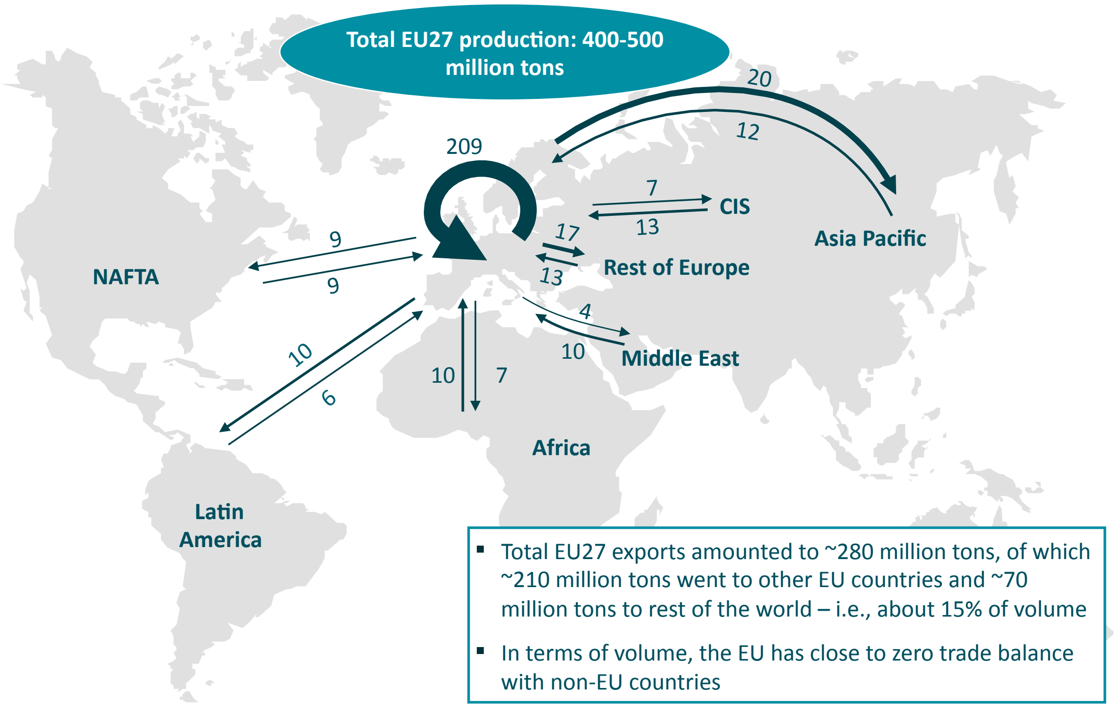
In addition to the value trade balance above, which is the most relevant trade metric to analyze, Figure 9 depicts Europe's trade flows by volume. As can be seen there is intense trade of chemicals within the EU – about half of the produced volume crosses at least one border. In terms of extra-EU trade, the numbers are smaller. Approximately 15 percent of the EU's production volume is exported to other world regions, primarily Asia and other European non-EU countries. Nonetheless, EU inflows are equally small, making the net volume trade balance close to zero. Although higher, similar numbers can be seen for the US. In 2011, approximately 20 percent of the US production volume was exported and the country had a volume trade surplus of about 5 percent.

9 European Competitiveness Report 2013, Towards Knowledge Driven Reindustrialisation

FIGURE 9

Trade flows of European chemicals by volume

Million tons, 2011



- Total EU27 exports amounted to ~280 million tons, of which ~210 million tons went to other EU countries and ~70 million tons to rest of the world – i.e., about 15% of volume
- In terms of volume, the EU has close to zero trade balance with non-EU countries

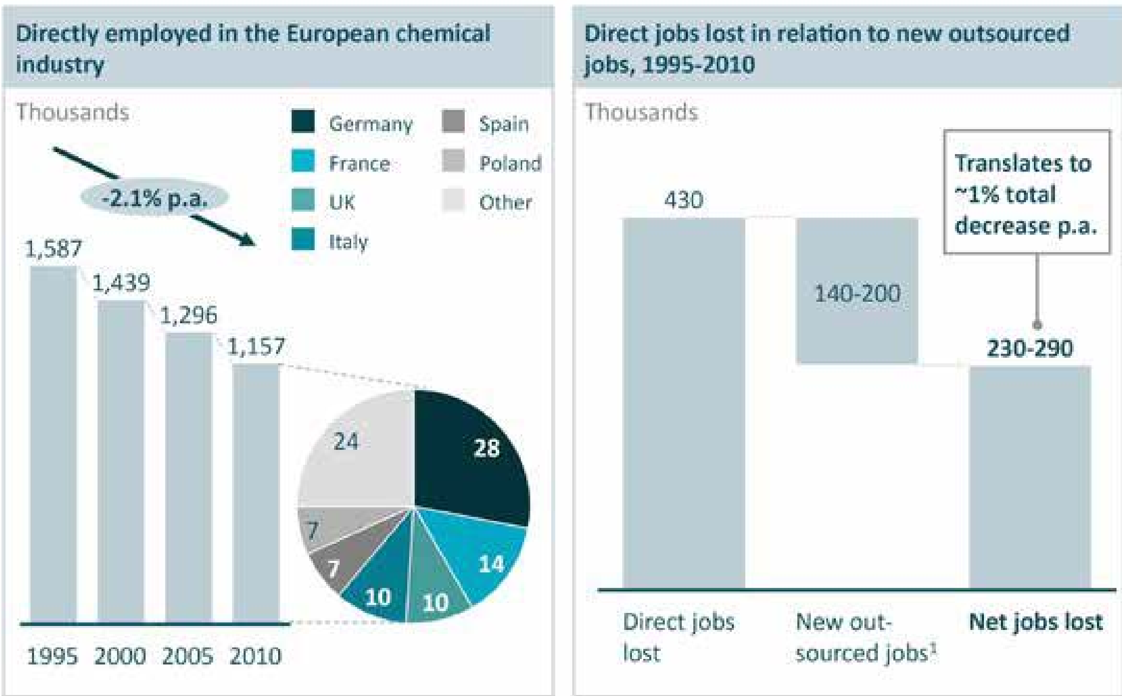
NOTE: Analysis based on imports by country broken down by trade partner. Includes all chemical subsegments
SOURCE: UN Comtrade

Labor trends

Between 1995 and 2010, there has been a 2 to 3 percent decline per year of employees directly employed by the chemical industry (see Figure 10). When accounting for the shift towards outsourcing and different forms of hired labor, which are estimated to have increased by 140 to 200 thousand employees during the period, the net effect on the chemical sector labor force is a decrease by approximately 1 percent per year. While productivity improvements have been important during a period of steep cost increases, this negative employment trend is another sign that most of today's production growth takes place overseas.

FIGURE 10

Employment trends in the European chemical sector



1 Estimate based on OECD STAN Input-Output data of value and labor numbers for service sectors vs. chemical industry
SOURCE: CEFIC Chemdata International; Eurostat; OECD

COMPETITIVENESS BY SEGMENT

Segmentation

To create a fair assessment of Europe's competitiveness relative to other regions, this report looks into five different chemical segments, which are distinctly different from a competitive dynamics and sustainability point of view: energy intensive bulk products, feedstock intensive bulk products, regional products/processing, customer/service intensive products, and innovation/high-value products. As Figure 11 shows, the segments are created based on a product feature mapping.

The European industry is present in all of these segments, with an approximately equal split between bulk and non-bulk segments. From an emission point of view, the bulk segments dominate with 55 to 65 percent of total emissions. The segments are presented more in depth in Figure 12 and Figure 13.

FIGURE 11

Definition of segments based on product feature mapping

Segment	Sub-segment	Product	Trade intensity	Feedstock intensity	Energy intensity	R&D intensity	Value density
Bulk	Energy intensive products	Inorganics	Global	Low	High	Low	Low
		Chlorine-based polymers	Global	High	High	Low	Low
		Chlorine-based chemicals	Global	Medium	High	Low	Low
		Industrial gases	Regional	Low	High	Low	Low
		Pigments	Global	Low	High	Low	Low
	Feedstock intensive products	Petrochemicals[1]	Global	High	Medium	Low	Low
		Polymers and additives	Global	High	Medium	Medium	Low
		Rubber elast. & chem.	Global	High	Medium	Low	Low
		Textile chemicals & dyes	Global	High	Medium	Low	Low
		Industrial cleaners	Global	High	Low	Low	Low
		Imaging chemicals	Global	Medium	Medium	Low	Low
Regional pro-ducts/ processing		Paints, coatings and inks	Regional	High	Low	Medium	Low
		Construction chemicals	Regional	High	Medium	Low	Low
Customer/service intensive products		Water chemicals	Regional	Low	Medium	Medium	Medium
		Oil field chemicals	Regional	Medium	Medium	Medium	Medium
		Specialty paper chem.	Regional	Low	Medium	Medium	High
		Mining chemicals	Regional	Medium	Medium	Medium	Medium
		Synth. lubricants & additives	Regional	Medium	Low	High	High
Innovation/high-value products		Specialty agrochemicals	Global	Low	Low	Medium	High
		Pharma fine chemicals	Global	Medium	Low	High	High
		Food/ feed ingredients	Global	Low	Low	High	High
		Catalysts	Global	Low	High	High	High
		Functional materials	Global	Low	High	High	High
		Functional specialties	Global	High	Low	Medium	Medium
		Electronic chemicals	Global	Low	Medium	High	High
		Enzymes	Global	Low	Low	High	High

1 Petrochemicals can be split into more subcategories

FIGURE 12

Description of segment characteristics

Segment		Characteristics
Bulk	Energy intensive products	▪ Globally traded bulk commodities, typically with low value density ▪ Energy intensive production process, e.g., involving electrolysis ▪ Low differentiation potential from technological advantages
	Feedstock intensive products	▪ Globally traded bulk commodities, typically with low value density ▪ Feedstock intensive processes, giving Europe large cost disadvantage ▪ Similar to other bulk chemicals, low technological differentiation possible
Regional products/ processing		▪ Typically regional reach, e.g., due to short lifetime or high transport costs ▪ Likely to stay in Europe in near future, i.e., relatively low carbon leakage risk ▪ Generally low value density – other product characteristics vary
Customer/ service intensive products		▪ Typically regional market reach – importance of customer cooperation ▪ Generally high value density (key differentiation vs. 'regional products') ▪ Medium/high R&D intensity, both in new products and business models
Innovation/ high-value products		▪ Globally traded high-value products ▪ High level of R&D and innovation ▪ Large opportunity to help other sectors develop and reduce emissions

FIGURE 13

Key metrics by segment

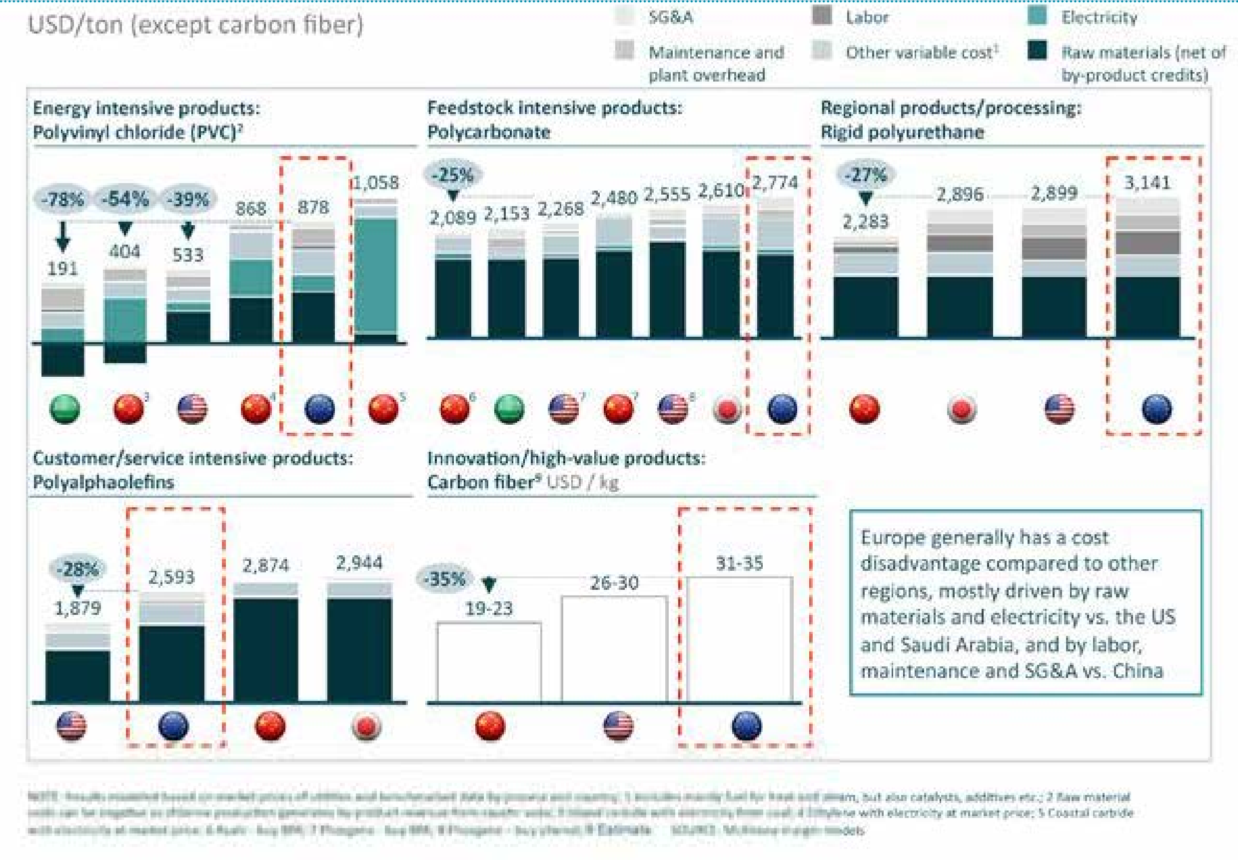
1 Total chemical industry excluding pharmaceuticals; 2 Data for 2010; 3 Includes scope 1 and 2 emissions. The split by segment is calculated, due to lack of official data source using this segmentation
SOURCE: IHS Economics; Eurostat; EEA; CEFIC

Factor cost analysis

As Figure 14 shows, Europe has a substantial production cost disadvantage across all the five segments. Based on the example products studied for each segment (these products will be presented more in depth in Chapter 2), the disadvantage versus the lower cost countries is approximately between 25 to 75 percent for the two bulk segments, and 25 to 35 percent for the non-bulk segments.

FIGURE 14

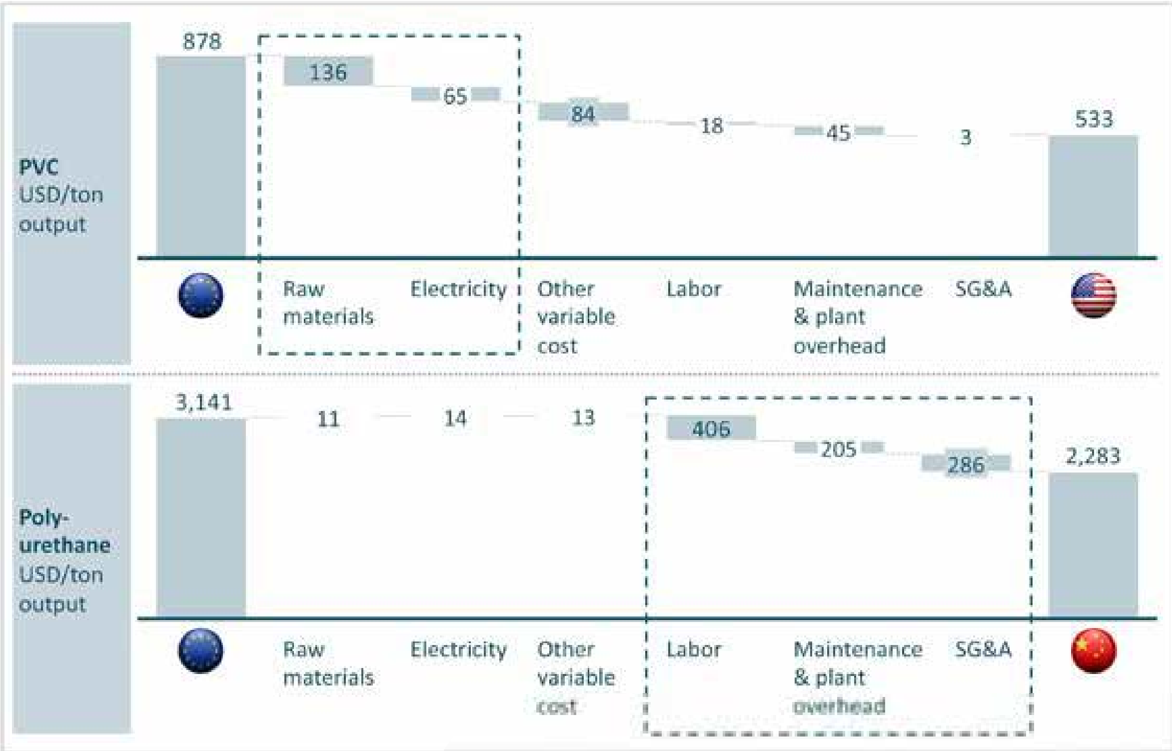
Production cost comparison



The main drivers behind these disadvantages vary by region. Higher feedstock (e.g., natural gas) and electricity prices are generally the key drivers of Europe's cost disadvantage versus the US and Saudi Arabia. Higher labor costs, capital costs, and other fixed costs are the main disadvantages versus China (see Figure 15 which outlines the differences for two products). Additionally, there are also different production processes used in different regions of the world. In PVC production, for example, most regions rely on ethylene based production. In China, however, carbide technology is frequently used. If located in the inland close to a coal mine, the cost advantage can become significant with own electricity production (from coal) leading to low cost chlorine electrolysis and caustic soda as by-product that can be sold at very competitive rates. With electricity purchased at market prices (typically for ethylene based plants or old coastal carbide plants) the Chinese cost becomes in line with, or even higher than, the production cost in Europe.

FIGURE 15

Examples of cost differences between Europe and other regions



SOURCE: McKinsey margin models

This European cost disadvantage is not new. Countries in the Middle East have enjoyed substantially lower gas prices for decades, and electricity prices have been lower in both the Middle East and the US for a long period of time. Still, the difference has become even more accentuated in the last few years when the US shale gas revolution has dramatically lowered US feedstock and electricity prices and has strengthened US cost competitiveness.

Other competitiveness dynamics

While Europe clearly suffers from a significant factor cost disadvantage, there are several lines of defense that limit the competitive impact on parts of the European industry:

- **Transportation costs:** For chemicals, international trade is generally held back by relatively high transportation costs. Overseas transportation costs are often in the range of 100 to 200 US dollars per ton of product, which typically represents 5 to 10 percent of the production cost for the energy intensive and feedstock intensive bulk segments. For the higher value customer/service intensive and innovation/high-value products, however, the transportation costs are lower in relative terms and other localization criteria (e.g., access to skilled labor or proximity to customers) are often more important than cost. Finally, the regional products have physical characteristics (e.g., short life-time or low value density) which effectively prevent them from extensive overseas shipping (see Figure 16).
- **Integration:** Vertical integration is typically advantageous as it reduces transaction and intermediate transportation costs. It also yields cross-process and by-product benefits that improve the average business case of the products produced. Europe is strong in this respect, making it less attractive to offshore or import single products or processes.

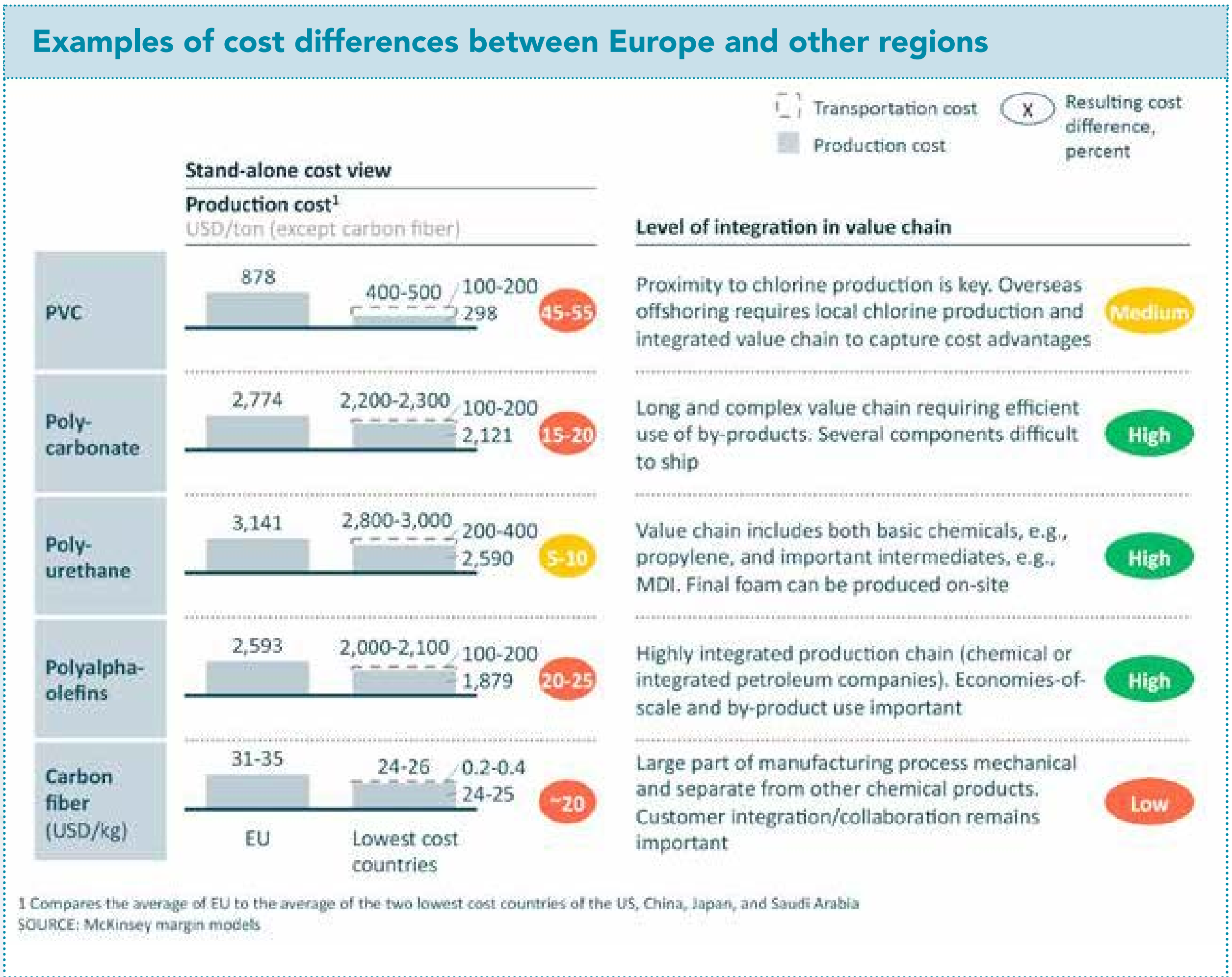
- **Depreciated assets:** Many plants in Europe have been operating for a long period of time, and are largely written off. Continuous operations help to maintain profitability, as the replacement value is often significantly higher than book value.

- **Exit costs:** Closing down a plant is often associated with significant exist costs. These include redundancy costs, dismantling costs, and the risk of environmental restoration costs. The exit costs act as another barrier against offshoring.

Even if European companies would want to import certain products despite the above effects, it is not necessarily possible. In the case of PVC for example, US companies currently make a larger profit by selling excess PVC to Asia and the Middle East, effectively outcompeting Europe in export markets.

In addition to the lines of defense, Europe also possesses several important competitive advantages. The good access to highly skilled labor allows advanced research and product development. The chemical infrastructure is well-functioning and has been developed, integrated, and increasingly optimized for decades. For instance, there is a cluster of competitive chemical companies along the Rhine valley. Moreover, compared to some of the fast growing markets, Europe has a relatively favorable business climate with a low degree of corruption and a reasonably high ease of doing business. All of these aspects are important to consider in addition to the factor cost challenge when assessing competitiveness.

FIGURE 16



Resulting competitiveness by segment

To summarize, the notion of competitiveness needs to be seen in a broader context than just cost. There are several other factors, in particular local demand trends, business climate, degree of integration, and access to skilled labor, that also play a large role and sometimes are equally important as cost. Hence, as Europe aims to maximize its competitiveness, all of these factors should be addressed.

In Figure 17, Europe is mapped against the US, China, and Saudi Arabia with respect to these dimensions. While Europe clearly struggles with higher costs, Europe also has a number of strengths. On aggregate level, Europe appears to come out on a similar level of competitiveness as China and Saudi Arabia, whereas the US demonstrates strong competitiveness across most dimensions.

Given large differences across chemicals, Figure 18 goes one step deeper and assesses Europe's competitiveness by chemical segment. A mixed picture emerges with the two bulk segments being under high competitive pressure, and a more favorable outlook for the three non-bulk segments:

- For energy and feedstock intensive bulk products, Europe has a clear challenge, mainly driven by slower demand growth than in other parts of the world, as well as a significant cost disadvantage compared to other regions. Production of many products within these segments currently stays in Europe mostly due to significant relocation and exit costs.
- For regional products/processing, there is – by definition – less competitive pressure from other regions. Moreover, for the example chemical studied in this report (rigid polyurethane foam) a robust growth of approximately 5 percent per year is expected in Europe going forward. One worry could be more imports of intermediaries, but so far this is limited.

FIGURE 17

Assessment of competitiveness by region

Level of competitiveness: High Medium Low

	Conventional economics		Other crucial factors		
Region	Cost position	Local demand growth[1]	Access to skilled labor, skilled labor[2]/ education[3]	Business climate, ease of doing business[4]/ corruption[5]	Integration/ resilience
EU27	25-50% disadvantage compared to other regions	1-3%	17 / 14	21 / 12	Overall, highly integrated and mature industry
US	10-40% advantage vs. Europe	2-4%	6 / 25	4 / 19	Highly integrated and mature industry, new investments ongoing
China	Higher cost than EU for some products, up to 50% lower cost for others	>10%	44 / 54	96 / 80	Less mature industry, not yet fully optimized
Saudi Arabia	Cost advantage (up to >50%) for bulk chemicals	~8%	31 / 39	26 / 63	Less mature industry, more narrow range of chemicals produced

NOTE: Europe represented by Germany in rankings; 1 Calculated as production minus net exports between 2011-2016 using data from IHS Economics; 2 Rank in "Availability of scientists and engineers", World Economic Forum (WEF); 3 Rank in "Quality of the Educational System", WEF; 4 Rank in the World Bank's ease of doing business index 2013; 5 Rank in Transparency International's corruption perception index 2013
SOURCE: World Bank Doing Business 2014; IHS Economics; WEF Global Competitiveness Report 2013-2014; Transparency International

- For customer/service intensive chemicals, Europe's cost position appears relatively better than for the bulk segments and there is a large benefit of access to skilled labor and proximity to customers. Likewise, for innovation/high-value products, Europe has traditionally been strong with a persistent trade surplus. For certain products the cost situation is challenging, however, this tends to be relatively less important for this kind of specialty products with a high dependence on innovation and knowledge.

FIGURE 18

Assessment of Europe's competitiveness by segment

Europe's competitiveness: High Medium Low

	Conventional economics		Other crucial factors		
Chemical/ segment	**Cost position**	**Local demand growth**[1]	**Access to skilled labor,** skilled labor[2]/ education[3]	**Business climate,** ease of doing business[4]/ corruption[5]	**Integration/ resilience**
PVC (energy intensive)	US ~40%, China ~50%, Middle East ~80% lower cost	Europe and US 2-3%, China and Middle East 5-6%			Mature industry, strong value chain integration
Poly-carbonate (feedstock intensive)	5-25% lower cost in other regions	Europe 1-2%, other regions 3-5%			Strong integration into BPA in Europe and in the US
Polyurethane (regional)	5-10% lower cost in US and NEA, 25-30% in China	Europe ~5%, US 2-3%, China and Middle East 5-7%	17 / 14	21 / 12	Similar across regions
PAO[6] (customer/ service intensive)	~30% lower cost in the US, but China and NEA more expensive	Europe ~2%, US 3-4%, China and Middle East 4-6%			Integrated into oil cracking, where EU lacks advantage
CFRP[7] (innovation/ high-value)	15-40% lower cost in other regions	Europe, US and China all 10-12%			More integration into end-product manufacturers
Average EU27	**Europe generally most expensive, especially in bulk**	**Generally positive growth but slower than other regions**	**Highly skilled labor force**	**Generally a safe and attractive business climate**	**Overall, highly integrated and mature industry**

NOTE: Europe represented by Germany in rankings; 1 Expected consumption growth between: 2010-2016 (PVC), 2012-2017 (PC and PU) 2011-16 (PAO) and 2012-2018 (CFRP); 2 Rank in "Availability of scientists and engineers", WEF; 3 Rank in "Quality of the Educational System", WEF; 4 Rank in the World Bank's ease of doing business index 2013; 5 Rank in Transparency International's corruption perception index 2013; 6 Polyalphaolefins; 7 Carbon fiber reinforced plastic
SOURCE: World Bank Doing Business 2014; WEF Global Competitiveness Report 2013-2014; IHS Economics; Enerdata

Capital markets perspective

Between 1994 and 2013, the total shareholder return ('TSR') for the European chemical industry was close to 12 percent per year on average. This return should be compared to that of the European market index of 8 percent per year[10]. Importantly, this trend has been persistent even in the last few years. Between 2009 and 2013 the European chemical industry TSR was 25 percent per year compared to 15 percent per year for the market as a whole.

Part of the explanation for this strong development is that European companies are trying to capture some of the growth overseas. As an example, more than 50 percent of BASF's planned capital expenditures over the next five years will be directed outside of Europe[11], e.g., in China and the US. As an example, the company is about to open a new plant for emulsion polymers in Texas[12], a decision likely spurred by low-cost natural gas. Similarly, AkzoNobel is pursuing investments in both China and Brazil[13].

10 Sourced from Datastream
11 Financial Times, "BASF to focus investments outside Europe", February 25, 2014
12 https://www.basf.com/group/corporate/en/news-and-media-relations/news-releases/news-releases-usa/P-12-225. March 5, 2014
13 https://www.akzonobel.com/news_center/news/news_and_press_releases/2013/akzonobel_plans_further_investment_in_china.aspx. March 5, 2014 http://www.akzonobel.com/news_center/news/news_and_press_releases/2012/akzonobel_invests_80_million_to_supply_new_suzano_pulp_mill_in_brazil.aspx. March 5, 2014

Often, European investments in Asia and the Middle East take the form of local joint ventures ('JVs'). A current example of successful presence in the Middle East is the Borouge JV (owned by Borealis and Abu Dhabi National Oil Company) that was established in 1998. In the last few years, Borouge has contributed to the majority of Borealis' net profit and its operations are to be expanded in 2014, and will become the world's largest polyolefins site with 4.5 million tons of annual capacity.[14]

Given the fast growth overseas, these kinds of international expansions could have positive indirect effects on Europe's economy, as they contribute to better competitiveness and financial performance of the European companies than if no foreign investments were made.

As the German Chemical Industry Association, VCI, states, "the chemical industry is not only one of the most important but also one of the most vital economic sectors in Germany"[15].

FUTURE OPPORTUNITIES AND CHALLENGES

Going forward, the European chemical industry faces a set of opportunities and challenges:

- A large future opportunity lies in innovation. As will be discussed further in later chapters, accelerating innovation in products, processes, and business models could offer large and partly new opportunities both for the chemical industry and beyond. Specifically, Europe could aspire to take the lead in the development of advanced materials, which could strengthen both competitiveness and sustainability.

- Another related opportunity – partly driven by innovation and partly by increased use of chemicals – is to continue enabling emission reductions in other sectors of the economy. Based on ICCA, the chemical industry has large enabling effects already today, with a gross savings ratio of 2.1 to 2.6 tons CO_2e for every ton emitted by the chemical industry. More use of certain chemicals, as well as new products, could bring very positive impact on both competitiveness and sustainability. Europe and the chemical industry could also pioneer the transition towards the 'circular economy' with large scale re-use, recycling, and resource efficiency. This would not only imply new business models and profit pools, but would also pave way for innovative solutions to reducing greenhouse gas emissions.

- When it comes to investments, the picture is mixed and offers challenges in Europe and opportunities abroad. While Europe has been approximately on par with the US over the last years, European investments are expected to fall well behind the US over the next years (see Figure 19). Large investments in new petrochemical capacity in the US are under construction or announced, as a result of the access to low-cost gas feedstock and energy following increased shale gas exploration. Likely, the difference will be smaller for many other chemical segments than petrochemicals, however, this is undoubtedly a development that does not act in Europe's favor, and will lead to increased competition both in Europe and in export markets. As discussed earlier, however, European companies are taking the opportunity to invest abroad to participate in the strong overseas growth.

- Another challenge for Europe is a risk of structural oversupply in the coming years. Although higher development and living standards in emerging markets increase the demand for specialty chemicals – an area where Europe is strong – countries like China are now becoming increasingly self-sufficient after many years with significant imports. This could ultimately cause European exports to decrease. Also, the US is expected to take a larger role in supplying the world, which could cannibalize on European exports further. These effects, together with continuous process improvements and capacity creep expansions in Europe, could pose a challenge.

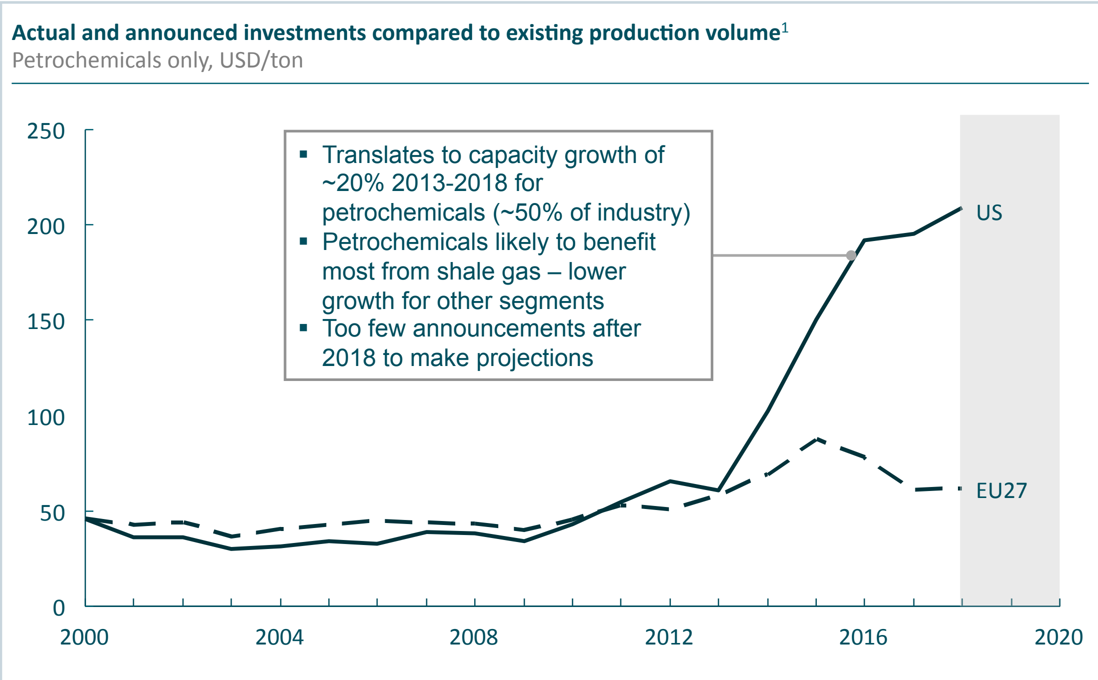
14 www.borealisgroup.com; www.borouge.com. March 5, 2014

15 https://www.vci.de/Die-Branche/Seiten/Uebersichtsseite.aspx. February 13, 2014

- Finally, the European cost challenge has led to a growing concern among some industry experts around possible ripple effects if some of the major European assets would in fact start shutting down. Indeed, the industry is heavily integrated, and such tipping points could in the worst case lead to a downward spiral.

FIGURE 19

Investment trends for Europe and the US



1 Data for petrochemicals only, excludes inorganics and specialties. Includes new investments and maintenance capex (maintenance calculated as 1.5% of replacement value), excludes cost of plant conversion (Europe has heavily converted chlorine plants and the US has converted crackers)
SOURCE: McKinsey models

Chapter 2:

WHAT COULD BE DONE TO REDUCE GREENHOUSE GAS EMISSIONS WHILE MAINTAINING OR INCREASING COMPETITIVENESS?

During the last 20 years, the chemical industry has been very effective in lowering its scope 1 emissions, by as much as 49 percent, despite a production growth of more than 20 percent. This means that the industry has 'over delivered' compared to the average industry improvement pace that Europe needs to follow to meet its objectives of 80 to 95 percent emission reductions by 2050. Looking forward, this study has found significant additional emission reduction opportunities, but importantly much of the potential seems to lie in cross-company and cross-industry optimization opportunities with high integration and governance complexity, in addition to further intra-company process and energy efficiency improvements. For the five example chemical products whose life cycles have been analyzed in this study together with the industry, there seems to be 50 to 75 percent additional scope 1 and 2 abatement potential by 2030. 60 to 70 percent of this opportunity could maintain or strengthen European competitiveness, if pursued efficiently. On top of the scope 1 and 2 potential, these five products also possess a substantial scope 3 opportunity by enabling emission reductions in other sectors and world regions.

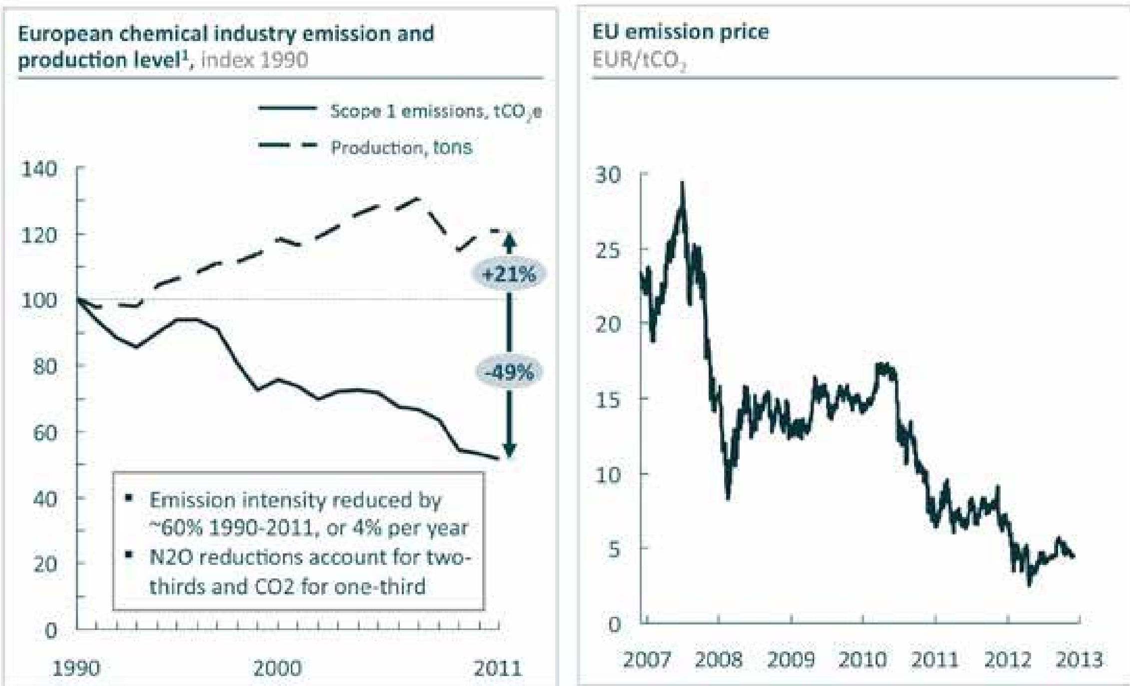
PAST EMISSION REDUCTION ACHIEVEMENTS

During the last 20 years, the chemical industry has been very effective in lowering its emissions (Figure 20). Based on official data from EEA, direct (scope 1) emissions decreased from 292 $MtCO_2e$ in 1990 to 151 $MtCO_2e$ in 2011, a reduction of 49 percent. While the reduction is significant in itself, it should also be noted that production volumes increased by more than 20 percent during the same time period. For the direct emissions, this translates to approximately 60 percent reductions per ton output during the period, or an average of 4 percent per year relative to production.

An important explanation for the achievements of the chemical industry is significant reductions of N_2O, which is a more potent GHG than CO_2. About 70 percent of the abatements were driven by reductions of N_2O. To a large extent, this should be seen as a one-off reduction, not possible to replicate to the same extent in the coming years.[16] The remaining 30 percent of the decrease was due to CO_2 reductions. The CO_2 reduction rate in the 1990 to 2011 period was 23 percent, calling for continuous efforts in the coming decades to bring down those emissions further.

FIGURE 20

Historical GHG emission reduction development



1 Estimated based on petrochemical, ammonia, and nitric acid production
SOURCE: EEA; ICIS ATEC; UNFCCC

16 Based on data from EEA, less than 10 percent of remaining emissions in 2011 are attributable to N_2O

The role of the ETS in achieving these reductions can be debated. On the one hand it was introduced only recently, many chemicals have been excluded, and the carbon price has plummeted. At today's carbon price in the 5 Euro per ton range, and given the fact that ETS participants will receive free allowances for the benchmark emissions between 2013 and 2020, the ETS imposes emission costs of approximately 250 to 300 million Euros per year on the chemical industry.[17] Although this is substantial, other incentives appear to play a larger role. For instance, even if the carbon price would bounce back to 20 Euros per ton, this would still only be equivalent to an 8 Euro increase per barrel of crude oil. With today's high barrel prices, energy cost appears to be a stronger financial incentive for efficiency improvements.

On the other hand, many companies have likely invested in improved energy and process efficiency based on the belief of substantially higher future emission costs.

SCOPE AND METHODOLOGY TO ASSESS FUTURE OPPORTUNITIES

For each of the five segments one representative chemical product has been chosen. For each chemical, a life cycle analysis has been performed to determine the emission baseline today and to create a comprehensive perspective of the abatement opportunities throughout the value chains from cradle to grave. The analyses have been performed together with the industry to stress test and validate assumptions. The five chemicals chosen are shown in Figure 21.

FIGURE 21

Overview of analyzed chemicals

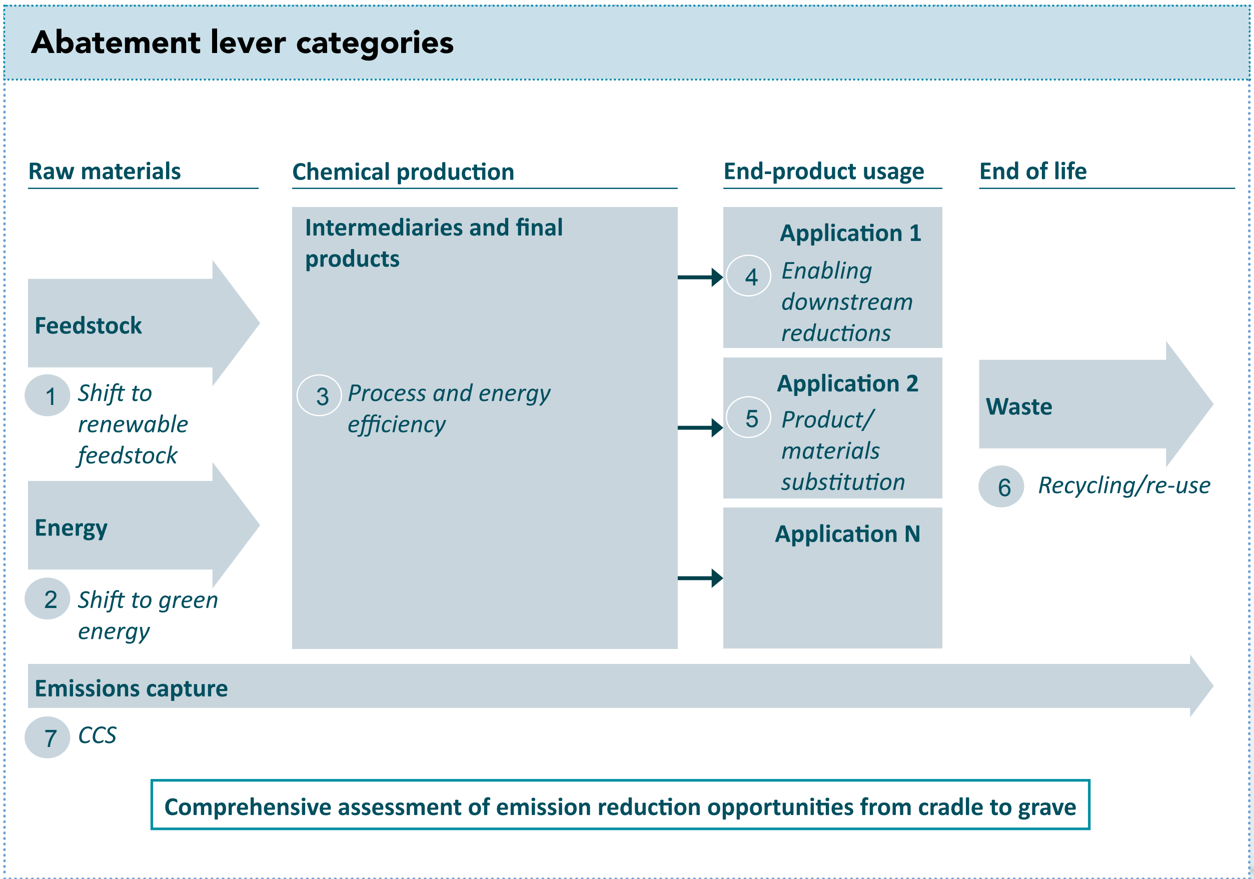
Segment		Chemical	
Bulk	Energy intensive products	**Polyvinyl chloride (PVC)** ▪ High-strength and durable plastic, mainly produced out of ethylene and chlorine ▪ Highly energy intensive due to electrolysis in chlorine production ▪ Large number of applications, mostly in the construction sector	
Bulk	Feed-stock intensive products	**Polycarbonate** ▪ Group of thermoplastic polymers, produced mainly from phosgene and bisphenol A ▪ Features include temperature and impact resistance, and optical properties ▪ Used within building and construction, optical media, electronics, and automotive	
Regional products/ processing		**Rigid polyurethane** ▪ Polymer produced by reacting an isocyanate (MDI) with a polyol ▪ Expensive to ship due to high air content in final foam product ▪ Used in insulation and construction materials	
Customer/ service intensive products		**Polyalphaolefins (PAO)** ▪ Base oil for high performance lubricants, with 5% share of total lubricant market ▪ Mainly used in automotive engines and gearboxes, but also in industrial applications	
Innovation/ high-value products		**Carbon fiber reinforced plastic (CFRP)** ▪ Made from carbon fiber and a matrix material, usually epoxy or polyester ▪ Relatively expensive compared to similar fibers (glass and plastic fibers) ▪ Used in aircraft & aerospace, wind energy, and automotive industries	

17 Under the assumption that all of today's emissions (direct and indirect) are covered by the ETS, the average chemical plant emits 30 percent more emissions relative to its respective benchmark, and the cross-sectoral reduction factor applies. Net costs after 2020 depend on further decisions on 2030 EU climate package

All of the abatement levers found have been grouped into seven overarching abatement lever categories that address different parts of the value chain, including upstream, midstream, and downstream steps (see Figure 22). This set of levers covers both scope 1, 2, and 3 emission reduction opportunities.[18]

The choice to consider the entire value chains is deliberate. The purpose it to paint a complete picture of the opportunity of each chemical in a broader system context. As will be discussed later, the majority of the abatement potential lies in other areas than in the actual chemical production.

FIGURE 22



18 Scope 1 emissions are direct GHG emissions from sources that are owned or controlled by the entity. Scope 2 emissions are indirect GHG emissions resulting from the generation of electricity, heating and cooling, or steam generated off site but purchased by the entity. Scope 3 emissions include indirect GHG emissions from sources not owned or directly controlled by the entity but related to the entity's activities, e.g., use of sold products

Overview of abatement lever categories

- Shift to renewable feedstock: implies replacing fossil fuels with renewable feedstock from Europe. Addresses primarily scope 1 and scope 2 emissions
- Shift to green energy: implies a shift from fossil to green electricity in society as a whole; indirect emissions (scope 2) from the chemical industry would be reduced
- Process and energy efficiency improvements: include various measures to increase yield, energy efficiency, and reduce direct combustion and process emissions (scope 1 and 2 emissions)
- Enabling downstream emission reductions: considers the role of the chemical industry to help other sectors reduce their emissions (scope 3 emissions)
- Product/materials substitution: implies shifting to greener materials, either product components or complete end products. Addresses primarily scope 1 and scope 2 emissions
- Recycling/re-use: implies large-scale circularity opportunities to feed materials back into the value chain and reduce need of virgin materials (mostly scope 1 and 2 emissions)
- CCS: refers to carbon capture and storage technologies (scope 1 emissions)

KEY FINDINGS OF THE LIFE CYCLE ABATEMENT ANALYSES

Summary of findings

For all five chemicals analyzed, abatement opportunities of scope 1 and 2 emissions are in the range of 50 to 75 percent relative to their estimated frozen technology baselines[19] in 2030. Out of this, it is estimated that 60 to 70 percent of the opportunity would have a neutral to positive competitiveness impact. These deep emission cuts appear possible by opening up the solution space and going beyond 'traditional' efficiency improvements and considering broader opportunities along the value chain.

In addition to the scope 1 and 2 opportunities, significant scope 3 reductions of more than 90 $MtCO_2e$ have been identified for these five chemicals alone. This demonstrates the important role of the chemical industry to enable emission reductions in other sectors or geographies. Figure 23 shows a summary of the key findings of the five chemicals.

19 Based on today's emissions and anticipated production growth until 2030

FIGURE 23

Main findings by chemical

PVC	▪ Production in Europe of 6 million tons. Production more than 50% more expensive compared to China, and about 40% more expensive than the US ▪ Abatement potential of 50-60%[1], mainly from ambitious recycling and continuous process and energy efficiency efforts	
Poly-carbonate	▪ European production of 0.8 million tons facing a cost disadvantage of up to 25% ▪ Potential emission reductions of 55-65%[1], driven by improved production efficiency and recycling. Additionally, large opportunity to enable abatements in the transport sector by material substitution to improve light-weight design	
Poly-urethane	▪ About 1.3 million tons of rigid polyurethane produced in Europe. Cost disadvantage in production reduced by relatively high transportation costs ▪ Abatement potential of 55-65%[1] in the chemical sector, but most impactful measure is increased usage of insulation in buildings (40-80 $MtCO_2$ net potential)	
Polyalpha-olefins	▪ Majority of the 213 thousand tons produced used in automotive industry as lubricant. Highly integrated production that is generally cost competitive, with exception for the US ▪ Abatement potential of 55-65%[1]. Further potential in the transport sector from replacing lower grade products with PAO and increasing fuel efficiency	
CFRP	▪ Expensive material early in the life cycle with high expected growth. Europe uncompetitive from a cost point of view, yet more innovation is key ▪ Emission intensive production, yielding 22-25 tCO_2e per ton of CFRP. Reduction potential of 60-70%[1], whereof the key opportunities are recycling and improved production efficiency. Also opportunity to decarbonize the transport sector using light-weight design	

For a large part (approximately 70 to 75 percent) of the total potential, mature technologies exist and would be implementable in the near to medium term. Examples include PVC recycling, retrofit polyurethane insulation in homes and other buildings, more efficient chlorine electrolysis technologies, increased re-refinement rate of polyalphaolefins, and switching to greener foam blowing agents for polyurethane. Nevertheless, remaining 25 to 30 percent of the potential requires more research, wherefore process and technology innovation is and will continue to be important. Moreover, many of the abatement opportunities, including those for which mature technologies exist, are complex and require cross-company or cross-industry action to be effectively captured. This topic will be discussed more in depth later.

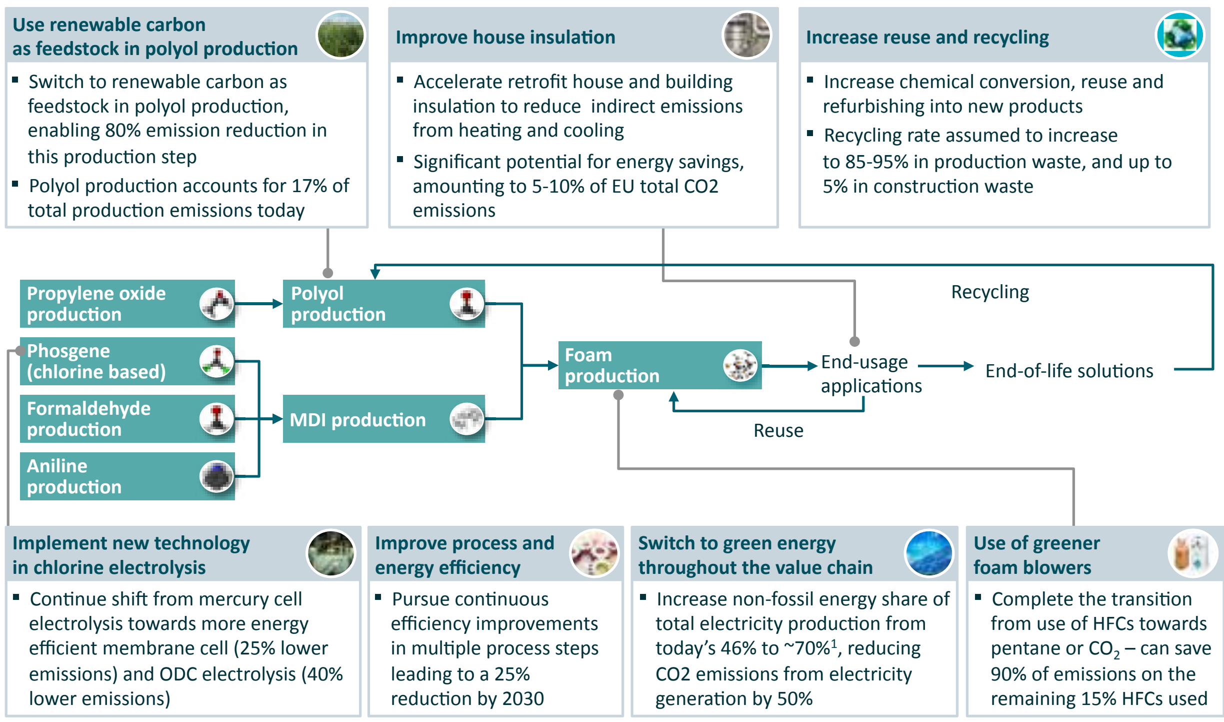
Example of polyurethane opportunity

To provide some examples of the abatement levers identified, the key opportunities for rigid polyurethane foam are discussed below. As with the other chemicals analyzed, the findings have been validated with the industry.

The main emission reduction opportunities for polyurethane are shown in Figure 24. All together, the identified abatement potential amounts to 55 to 65 percent by 2030, accounting for direct and indirect emission reductions (scope 1 and 2). In absolute terms, this translates to 9 to 10 $MtCO_2e$ compared to a frozen technology baseline of 16 $MtCO_2e$ in 2030. On top of this, there is a 40 to 80 $MtCO_2e$ identified *net savings* potential from increased polyurethane production to improve house and building insulation (scope 3 abatement).

FIGURE 24

Key abatement levers in the value chain of rigid polyurethane



1 Based on Enerdata Emergence Case
SOURCE: Industry reports

- In the early steps of the value chain it is possible to continue the shift towards more efficient technologies for chlorine electrolysis. Given the high energy consumption associated with electrolysis, this would reduce both emissions (primarily indirect scope 2 emissions) as well as energy costs.

- Similarly, continuous process and energy efficiency improvements across other parts of the value chain could reduce both direct and indirect (scope 1 and 2) emissions further. The size of individual improvements varies.

- There are other measures that would address direct (scope 1) emissions very effectively. Using renewable feedstock in polyol production could save as much as 80 percent of emissions in this stage of the production process.

- Likewise, completing the phase-out of fluorochemicals in foam blowers in exchange for pentane or carbon dioxide could save 90 percent of remaining emissions in this production step. Much progress has been done already, but still approximately 15 percent of foam production uses flourochemicals as the foam blowing agent.

- Increased recycling and re-use (mostly in less demanding applications) are generally promising opportunities that would reduce the need for virgin materials. For polyurethane, however, this is more difficult than for other materials where recyclability is higher, e.g., PVC.

- Finally, a very interesting opportunity is to accelerate retrofit insulation of houses and buildings and to scale up production of polyurethane. For every ton of carbon dioxide emitted in polyurethane production, scope 3 savings of at least five tons would be achieved in the residential sector due to improved energy efficiency. This demonstrates an important enabling effect in downstream sectors that will be discussed more later in the report.

PATTERNS IN THE ABATEMENT OPPORTUNITIES

Assessment methodology

As always when a variety of abatement options exist, some are more commercially viable than others. Building on the broader notion of competitiveness in Chapter 1, the 'impact on competitiveness' of every lever is assessed, assuming it would be implemented in the near term. The competitiveness impact is ranked on a five-point scale, ranging from very negative to very positive. While this assessment has been done lever by lever, Figure 25 shows the high-level trends that are seen for the various lever categories.

FIGURE 25

Competitiveness assessment of abatment lever categories

	Conventional economics		Other crucial factors			
	Viability/ impact on cost position	Impact on local demand for the chemical sector	Impact on know-how	Impact on business climate	Impact on integration/ resilience	Total assessment
Shift to renewable feedstock	Generally increased costs for similar products	Higher imports if cost of domestic production increases	Competitive advantage if produced effectively	Limited	More local production and more cross-sector collaboration	
Process and energy efficiency	60-70% neutral to positive, rest negative	Effect on costs passed through to end customers	Limited	Limited	Increases resilience of installed assets	
Recycling/ re-use	Potentially large upside, partly done today	Limited effect from recycling	Uncertain – possibility for technology leadership	Limited	Requires infrastructure and increases stickiness	
Shift to green energy	More expensive today but fast improvement trajectory	Limited effect, only affects energy costs	Some opportunity given certain in-house energy production	Limited	Limited effect in chemical industry	
Product/ materials substitution	Marginal today. Research on promising alternatives	Possible cannibalization of products from other sectors	Could yield competitive edge boosting Europe's competitiveness	Limited	Increased intra-EU collaboration, e.g., through joint customer R&D	
CCS	Significant investments required	Increasing costs, benefiting international players	Uncertain – risk of "wrong" know-how investment	Limited	Investments to raise exit costs	
Enabling downstream reductions	Pull from end user sectors makes business case positive	Pull from end user sectors typically drives up demand	Significant potential for skill leadership	Limited	Increasing integration with other sectors or customers	

In addition to competitiveness impact, a second dimension referred to as 'integration and governance complexity' is introduced. This is an inherent characteristic of each lever and denotes its implementation focus, ranging from factor cost to cross-country/region. For example, most historical abatement efforts have targeted single process optimizations, e.g., sealing leaks, improving yield, or decomposing process gases. More complex abatement opportunities require optimizations across multiple processes, or even companies, sectors, or regions.

Importance of cross-sector action

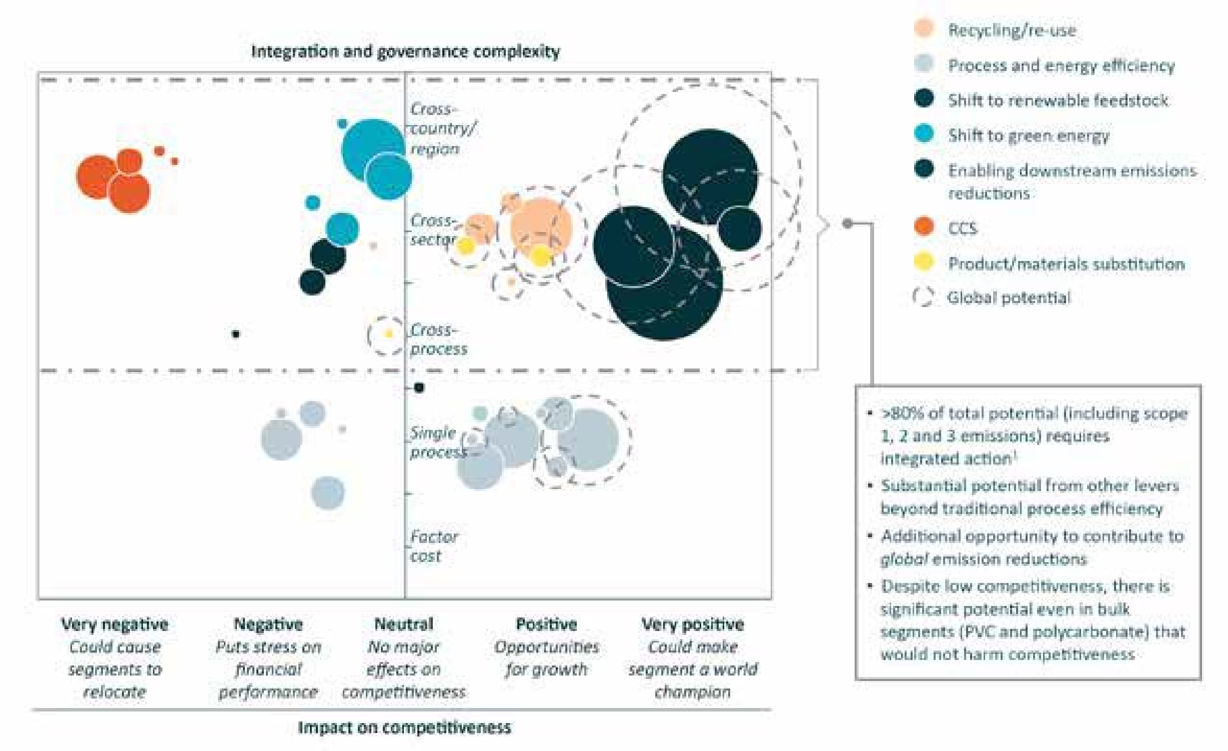
In Figure 26, the two perspectives are combined and all the individual abatement levers from the five chemical value chains are depicted. Interestingly, we find more than 60 to 70 percent of scope 1 and 2 abatement opportunities to have a neutral to very positive impact on competitiveness. The remaining opportunity would have a negative impact on competitiveness, suggesting a more selective implementation. Some levers, for instance CCS, would have such a negative impact on competitiveness that a deliberate choice needs to be made whether to pursue such levers at this point in time.

Considering the integration and governance complexity, as much as 55 to 60 percent of scope 1 and 2 abatements, and more than 80 percent if also including scope 3 abatements[20], requires integrated action with other processes, companies, or sectors. This is an important observation, as capturing these types of opportunities might well require new approaches by the industry as well as policy makers. Most of the historical efforts to bring down emissions have focused on intra-company or even single process improvements. The vast majority of the abatement opportunities found in this report are more complex to identify, address, and capture.

In addition to the high integration complexity, another interesting conclusion from Figure 26 is that several of the levers in the upper right corner have large multiplier effects and could contribute to global emission reductions. For example, if the industry could resolve the scratch issues that today prevent polycarbonate from substituting glass or metal body parts in vehicles, fuel efficiency would improve not only of those vehicles driven in Europe but also of those being exported to or manufactured in other parts of the world. Similarly, in the case of a breakthrough that makes lignin a viable precursor in carbon fiber production, it is likely that all producers would adopt such technology, also outside of Europe. This global multiplier effect does not exist to the same extent for the less complex 'single process' or 'cross-process' levers.

FIGURE 26

Mapping of abatment opportunities by competitiveness impact and complexity



1 Given the highly varying emission baselines for the five chemicals and thus varying absolute abatement potentials for the different levers, the analyses have been normalized to provide indicative ranges of the total opportunity. For the scope 3 opportunity, global multiplier effects are excluded in this calculation

20 Given the highly varying emission baselines for the five chemicals (0.8 to 16 $MtCO_2e$ in 2030) and thus varying absolute abatement potentials for the different levers (ranging from less than 0.1 to more than 40 $MtCO_2e$), these analyses have been normalized to provide indicative ranges of the total opportunity. For the scope 3 opportunity, global multiplier effects are excluded in this calculation

The pattern of the abatement opportunity in Figure 26 is probably a more important insight than the size of the potential itself. This pattern might call for a quite different set of actions and tools than have been relied on historically.

Profile of the abatement levers

Among the abatement opportunities in the upper right corner – i.e., competitive levers with high integration and governance complexity – there are two major lever categories that emerge:

- **Enabling downstream emission reductions.** There are many examples of abatement levers in this category, e.g., applying polyurethane for large-scale retrofit building insulation, constructing light-weight vehicles using carbon fiber reinforced plastic and polycarbonate, and shifting from low-grade lubricants to polyalphaolefins to reduce fuel consumption in engines. Clearly, these enablement opportunities are not only applicable to the innovation/high-value products. Much of the answer is to use existing products more innovatively; either in a greener way or to a greater extent. However, all of these measures to some degree require cooperation with other sectors (in these cases residential and automotive sectors) to be implementable at large scale. Hence, their integration and governance complexity is regarded as 'cross-sector'. While most industries could claim they contribute to some sort of emission reductions in other sectors, the role of the chemical industry appears strikingly large.
- **Circularity (recycling/re-use).** Several circularity opportunities have been identified for these five chemicals. PVC production, as an example, requires energy intensive chlorine electrolysis, and any feedback loops that reduce the need for virgin materials would typically have environmental benefits. PVC can technically be recycled up to seven times, implying a large base of material to be recycled for many decades to come, and some recycling is carried out on commercial terms by certain firms even today. Another interesting recycling opportunity found in this study involves carbon fiber – while more research is necessary to make this viable, the estimated energy savings in production of new carbon fiber could exceed 75 percent if the technology would materialize successfully. Also polycarbonate and polyalphaolefins demonstrate recycling and re-use opportunities, although somewhat smaller than for PVC and carbon fiber. For Europe more broadly, increased chemical recycling and re-use would not only enable emission reductions, but could also reduce the need for imported oil and gas feedstock, make chemical production more resource efficient, and improve security of supply. Nevertheless, to realize these opportunities, cross-sector collaboration would be necessary as it is questionable to what extent the chemical industry could drive circularity efforts at large scale alone.

In the upper middle part of Figure 26, there are three other abatement categories with a high complexity:

- **Product and materials substitution** offer interesting possibilities for the future. Examples in this study include replacing polycarbonate with bio-based plastics, switching from polyalphaolefins to bio-based oils, and replacing PAN with lignin or polyethylene in carbon fiber production. These levers would require collaboration with other sectors to materialize effectively, e.g., engine manufacturers in the case of the lubricating oils.
- A **shift to renewable feedstock** is another promising area, although with a somewhat smaller 2030 potential than some of the other levers. Currently, several challenges are being worked on to make this a larger and more viable opportunity, e.g., to improve economics, technology, and achieve a larger scale. Examples include renewable carbon in polyol production for polyurethane, using bio-ethylene in PVC

production, and replacing phosgene with CO_2 based feedstock in polycarbonate production. While the chemical sector can do much of the research and development, collaboration with other sectors, e.g., agriculture, is needed.

- A society wide **shift to green energy** would reduce scope 2 emissions, and the indirect carbon footprint of the chemical industry would improve significantly. Such a shift is ongoing across Europe, but is primarily a question for the energy sector.

Finally, there are two other lever categories with very different profiles:

- Improved **process and energy efficiency** will continue to play a large role going forward. The industry has been successful in pursuing efficiency improvements in the past, and has the incentives to make further progress. This type of abatement opportunity typically focuses on single or multiple processes within a company, and thus possesses a lower integration and governance complexity to be implemented.
- **CCS**, on the other hand, has not developed as fast as many industry observers believed five to seven years ago. Regulatory issues relating to storage, as well as technological and cost challenges, have led to many demonstration projects being mothballed. Nevertheless, if this opportunity indeed would materialize, it would require some sort of cross-company or cross-sector action.

PUTTING THE ABATEMENT OPPORTUNITIES IN CONTEXT

Reduction rate comparison

The main focus of this report has been to look at the types of abatement opportunities that exist for the chemical industry, and assess how and to what extent they could be captured given the competitive situation in each segment. The total abatement potential of the industry has not been modeled as part of this project.

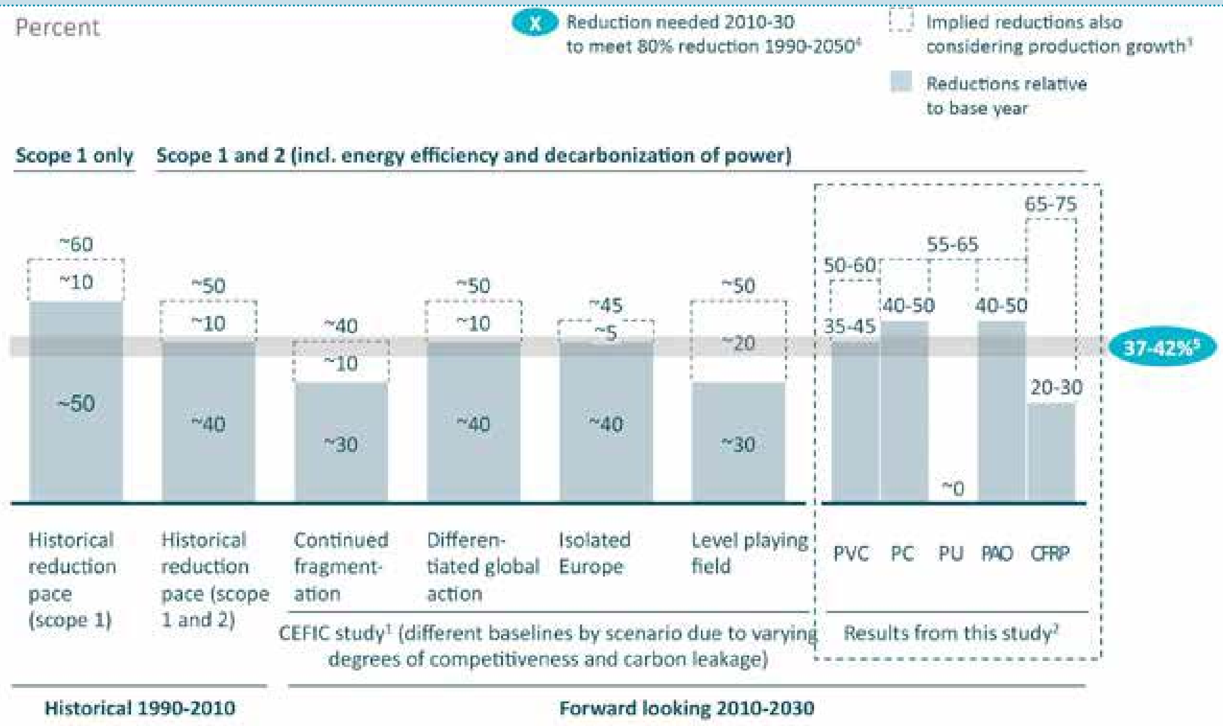
However, to put the findings of the five life cycle analyses in context, Figure 27 summarizes the identified abatement potential and makes three relevant comparisons – to the historical pace of emission reductions in the industry, to the modeled forward-looking opportunities identified by CEFIC in their four scenarios, and to the required trajectory to reach 2050 targets.

First, the identified emission reduction opportunities of the five products – scope 1 and 2 opportunities of 50 to 75 percent until 2030, whereof 60 to 70 percent with a neutral to positive competitiveness impact[21] – are in line with the historical achievements. When accounting for the historical production growth, scope 1 and 2 emissions decreased by approximately 50 percent in the 1990 to 2010 time period. While N_2O abatements accounted for a large part of these reductions, the abatement levers explored in this study have not been employed to the same extent in the past and could offer new opportunities for the future.

21 As discussed above, there is also a material scope 3 opportunity that is not covered here

FIGURE 27

Overview of emission reductions



1 CEFIC report "European Chemistry for Growth" (including scope 1 and 2 emission reductions, decarbonization of power, and different competitiveness and carbon leakage assumptions by scenario); 2 Includes total identified scope 1 and 2 abatement potential, whereof approximately 60-70 percent is estimated to have a neutral to very positive impact on competitiveness. In addition, there is significant scope 3 potential that is not shown on this page; 3 Takes into account the frozen technology emissions growth resulting from increased actual/expected production volumes during the period; 4 Assuming same CAGR 2010-2050; 5 Lower range including scope 1 emissions, higher range including scope 1 and 2 emissions. SOURCE: UNFCCC; CEFIC

Second, the CEFIC sector roadmap from 2013 has, for the industry as a whole, identified a 40 to 50 percent[22] improvement potential by 2030 compared to the frozen technology baseline. The results of the five chemicals analyzed in this report would be very much in line with those of CEFIC, if accounting only for the 60 to 70 percent of the opportunity that seems to have a neutral to positive competitiveness impact. Nonetheless, it is important to emphasize again that the purpose of this study is not to estimate the total potential for the industry as a whole. Only five products representing a small share of the industry have been analyzed, and there is no evidence suggesting that the total opportunity is different from that identified by CEFIC.

Third, the industry appears to be on a good trajectory to reach the 80 to 95 percent reduction target by 2050 relative to 1990. For most of the five chemicals analyzed in this report (with exception of polyurethane and CFRP whose production growths are expected to be high), the identified actual reduction opportunities by 2030 are more than enough to follow the average required trajectory.

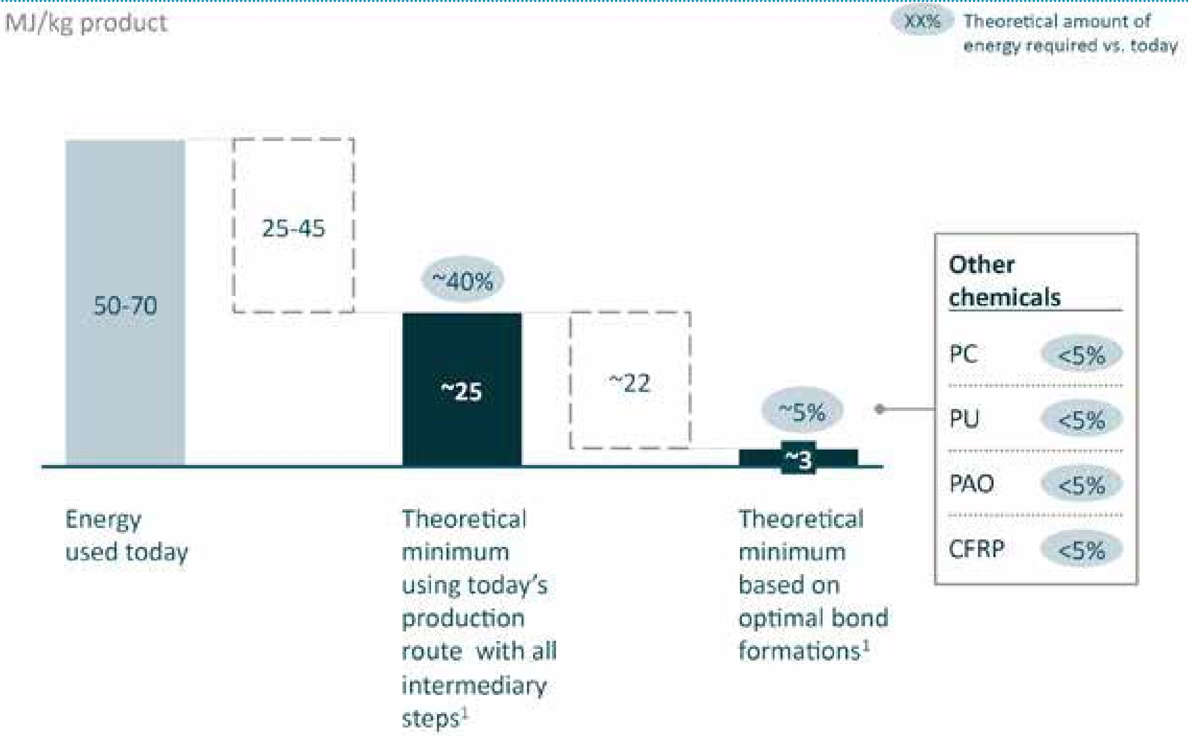
Opportunity for continuous research and development

Another way to look at the improvement potential – both from an emissions and resource efficiency point of view – is to compare current energy usage versus the 'theoretical limit' energy requirements. Such analyses have been conducted for each of the five chemicals.

22 Different reduction rates in four different scenarios. Also, the absolute production baseline varies by scenario due to different assumptions on, e.g., competitiveness, innovation, and development of EU chemical production

FIGURE 28

Estimated theoritical minimum energy requirement — PVC example



NOTE: Numbers based on raw material assumptions – therefore, deviation of +/- 2-3 MJ per kg possible
1 Based on energy requirements for bond cleavages and bond formations
SOURCE: Plastics Europe; Boeing; Springer Report; Norwegian University of Science and Technology; Barcelona Tech

As shown by Figure 28, the theoretically required energy required to produce the five chemicals is less than 5 percent of the energy that is used in today's production processes.[23] Clearly, the theoretical limit pushes the envelope and will never be reached. Nonetheless, the large gap between today's energy intensity and the theoretical minimum demonstrates the abundance of improvement opportunities that are likely to exist, and gives confidence that the industry is not running out of improvement options.

23 Estimate based on energy requirements for bond cleavages and bond formations. In addition, energy to overcome activation barriers needs to be accounted for, wherefore this should be interpreted as *indicative* energy requirements only

Chapter 3: IMPLICATIONS – QUESTIONS FOR EUROPE

Chapter 1 concluded that the European chemical industry overall has managed to grow approximately in proportion to Europe's economic growth. This has been achieved despite persistent factor cost disadvantages since other strengths – notably from innovation and integration – have played in Europe's favor. This calls for a broader notion of competitiveness than just factor cost.

Chapter 2 then demonstrated large opportunities for the chemical industry to continue its successful path towards lower emissions. However, it also showed that the majority of opportunities are cross-sector and innovation oriented, and it highlighted circularity, product/materials substitution, and enabling of downstream emission reductions as important opportunity areas.

What do these findings mean for Europe? Is there a practical way for Europe to realize these emission reduction opportunities while at the same time maintaining or increasing competitiveness? To start this discussion, the paper now turns to the current policy context and public debate, and then moves on to raise a number of key questions regarding a possible industrial agenda for Europe going forward (see Figure 1).

POLICY CONTEXT AND PUBLIC DEBATE

The current European policy context for climate and energy is described in Figure 29. It is characterized by concerns about the European economy and its competitiveness and, in relation to this, questions about the climate change agenda and what level of carbon price Europe can afford without losing competitiveness. Governance-wise, climate and energy topics are also at a breakpoint, given that the 2030 package will be shaped during 2014, and a new European Commission is coming into office.

Specifically for the carbon policy context, the existing system – for industrial emitters – is set up to primarily stimulate emission reductions within each individual company or sector, even though a stable long-term carbon price signal in theory should also stimulate cross-sector abatement. Examples of this include statistics and metrics, industry road maps, and environmental taxes – all of which predominantly focus on each player's or sector's role in reducing its own emissions. Moreover, cost-additive systems – both on EU level and member state level – appear to dominate. For instance, even at today's low carbon price levels, the ETS is expected to generate approximately 10 billion Euros in annual taxation income in the current trading period[24]. Until 2020, this could translate to more than 70 billion Euros, depending on the future carbon price. During the same period of time (2014 to 2020), 6.6 billion Euros is budgeted for non-nuclear energy research in Horizon 2020 (the EU's largest research program). Even if this comparison is simplified and does not capture innovation budgets on member state level, it demonstrates that cost additions are an important cornerstone of today's European policy.[25]

FIGURE 29

Current policy context and public debate

Macro economic environment	▪ Long period of weak/negative economic growth, specifically in southern Europe ▪ Euro crisis and financial stress on both governments and industries ▪ Protection of industries and jobs major policy priorities
Carbon policy	▪ ETS as flagship policy, but publically debated due to the low carbon price ▪ Policy approach (targets, metrics, roadmaps) largely focused on reducing own emissions by adding cost to emitters ▪ For consumer sectors, product standards (e.g., white goods labeling) are examples of non-cost-additive measures
Governance	▪ New European Commission to be appointed in 2014 ▪ National governments play increasingly important role for climate and energy topics ▪ Carbon agenda cuts across responsibilities of multiple DGs

Given this context, it is now a good time for Europe to think through the long-term climate and energy objectives. When doing so, it is important to take into account the abatement themes that could maintain or strengthen Europe's competitiveness, and to consider both the competitive situation that prevails as well as possible competitiveness concerns around previous policies, e.g., REACH.

24 Based on CAN Europe analysis; Assumption of carbon price below 7 Euros per ton

25 There are also non-cost-additive elements of European climate policy. For example, the definition of standards (e.g., for fuel efficiency of cars or white goods labeling) have the role to create criteria for market access and, in many cases, are equivalent to an implicit carbon price. However, these are primarily oriented towards consumer sectors

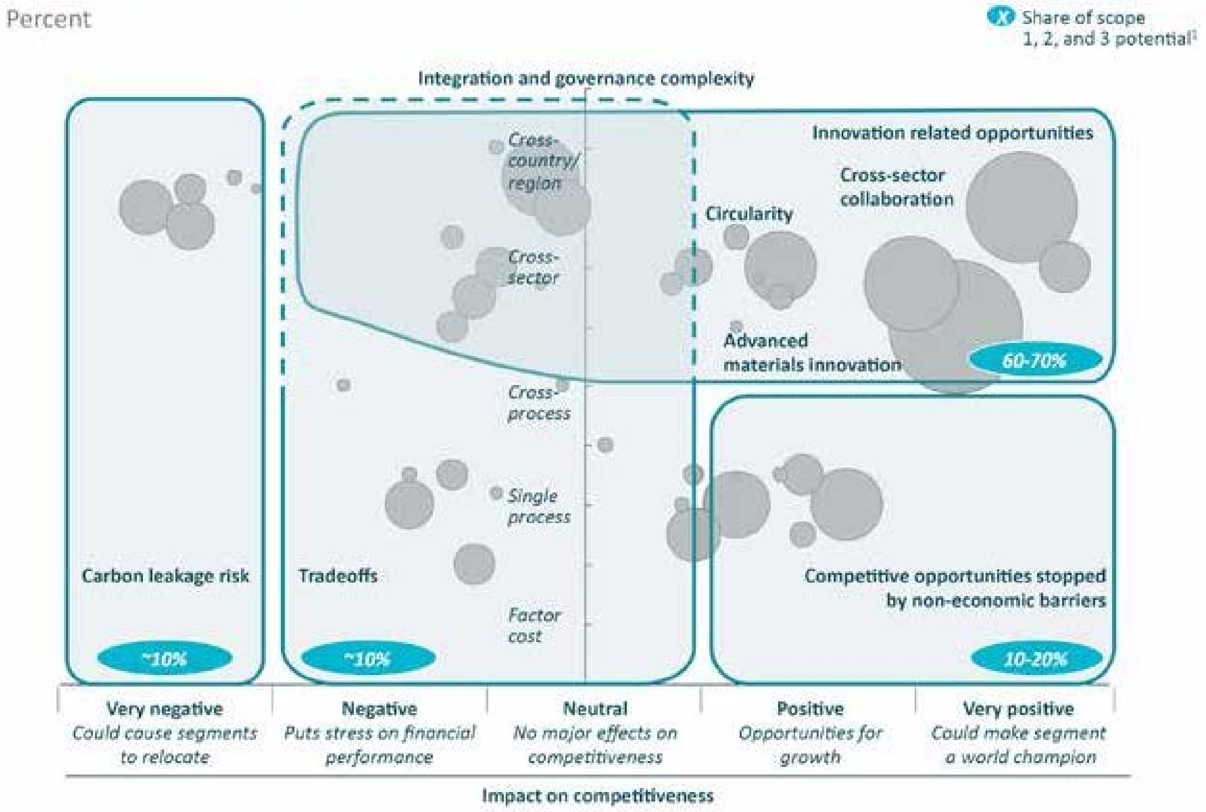
INDUSTRIAL AGENDA FOR EUROPE

Industrial themes to consider

Given the results of the abatement investigation in Chapter 2, it seems natural for Europe – industry as well as policy makers – to investigate whether these findings hold true more broadly, to look deeper into the cross-sector opportunities and determine their attractiveness, and to identify what – if anything – could be done to accelerate their capture. Based on the life cycle value chain analyses conducted, they seem to provide a promising path forward, one that could allow the industry to keep up its high pace of emission reductions while at the same time maintaining or increasing competitiveness. In Figure 30, the identified abatement opportunities are conceptualized into possible industrial themes for Europe.

FIGURE 30

Industrial themes for the chemical industry



1 Scope 3 potential here includes the opportunity from enabling downstream reductions, and excludes the global spillover potential

A large share – 60 to 70 percent – of the total abatement potential (scope 1, 2, and 3) is found in the category 'innovation related opportunities'. For these, the integration complexity is high, and capturing the potential requires coordinated action across processes, companies, sectors, or even countries. Another approximately 10 to 20 percent are considered 'competitive opportunities', 10 percent are 'tradeoffs', and about 10 percent end up in the category 'carbon leakage risk'.

While this analysis is conducted based on five products only, the direction in which these results are pointing is important. Current incentives and policies for emission reductions appear to mostly have an effect on abatement levers with low integration and governance complexity (in the lower part of the chart), and there is an important question of what – if anything – Europe could do to accelerate the much larger innovation related opportunities. Not only is there a large sustainability benefit in addressing such opportunities both for

Europe and the world. They could also bring significant competitive benefits and lay the grounds for European leadership in new technologies, business models, and products.

A closer description of the themes follows below, along with some of the key questions going forward (see Figure 31):

- **Circularity.** A lot of energy goes into the production of materials, and the loss is typically significant if just burning them for heat. A circular system, however, is restorative, retains more materials volumes in the economy, and is overall more resource efficient. A circular system can also create economic value, and – as an analogy – the paper industry nowadays regards recycled paper as a source of competitive advantage. As discussed in Chapter 2, several circularity opportunities have been identified for the five chemicals. For some chemicals there is significant progress already, e.g., recycling of PET bottles, but circularity could apply to many more chemicals. As a first step, the most attractive chemicals for circularity need to be investigated, followed by identification of ways to speed up the development. One way could be through common product standards, e.g., around use of additives in plastics, to increase recyclability and market value of used materials. Nonetheless, the challenges of circularity are the integration efforts required by multiple players, and it is hard for any company to act alone – a system transition is needed.

- **Cross-sector collaboration.** Beyond circularity, which focuses on end-of-life solutions, a large number of cross-sector collaboration opportunities exist to achieve emission reductions. Examples of this include joint product development programs, innovative system solutions, processes, or novel business models. As mentioned before, there are also mature solutions (e.g., retrofit house insulation) where the benefit would be to scale up the current activity level. Often, the industry has business incentives to capture such opportunities, and indeed much of this is happening already. The key question is if there are ways to accelerate this further. Example measures could include public-private partnerships as well as simplified registration, permitting, and patenting processes. Yet, the appropriate mechanism is likely to need to be evaluated on a case-by-case basis together with the industry. Also, there is a fundamental question to investigate whether policy has a role to play to achieve such acceleration.

- **Advanced materials innovation.** As history has shown, e.g., through the phase-out of fluorochemicals, materials substitution could bring about very positive sustainability effects. This field requires continuous product innovation to come up with viable alternatives, and could be seen as an important special case of cross-sector collaboration. Specifically, this study has pinpointed the immense opportunities of advancements in carbon fiber applications as well as for polycarbonate, which both could play a key role in improving light-weight designs. Ways to speed up this development could include R&D grants or advanced market mechanisms to address targeted opportunities. However, there are many open questions, e.g., what innovations to focus on, and how to avoid dictating the day-to-day R&D agenda for the chemical industry.

FIGURE 31

Questions for the key themes

Circularity	▪ What is the attractiveness of a circular system for Europe and the industry? ▪ What chemicals should be prioritized, and how could the transition happen?
Cross-sector collaboration	▪ How could cross-sector collaboration be accelerated further? ▪ Would policy have a role to play to achieve the acceleration?
Advanced materials innovation	▪ What innovations could bring the most value and sustainability impact? ▪ How could policy speed up innovation without undue interference?
Competitive opportunities stopped by non-economic barriers	▪ What are the key barriers that prevent change today? ▪ How could such barriers be removed without excessive policy complexity?

Beyond the innovation themes above, there are also three other major themes emerging:

- **Competitive opportunities stopped by noneconomic barriers.** There is a set of abatement opportunities that would make commercially sense to pursue, and that have a relatively limited integration complexity. Examples include more efficient electrolysis technologies and other energy saving process improvements. However, there are typically non-economic barriers that delay implementation. If Europe would want to take additional action to accelerate execution, example actions could include setting technical norms and standards, building awareness, ensuring sufficient capital supply, or building public-private partnerships. The key question becomes how to accelerate this kind of emission reductions without imposing policy complexity.
- **Tradeoffs.** Another set of levers come at a cost that would make the overall competitive impact negative if pursued by Europe alone. Among other things, this includes more expensive process efficiency improvements. For segments where competitiveness allows, Europe already has the ETS in place to tilt the playing field and increase incentives for implementation. The key question is what tradeoffs are reasonable in different segments, given Europe's current competitive situation.
- **Carbon leakage risk.** Finally, there is a set of abatement levers that are so expensive that pursuing them on a large scale could put Europe's competitiveness at risk, and where the possible outcome could be long-term carbon leakage. The question is whether the most viable option would be to take a passive approach and put such opportunities on hold.

Resilience of themes identified

Given the uncertainty in both the macroeconomic, industrial, and policy environment, the resilience of the results above has been considered. The relevance of each theme, from a competitiveness point of view, has been assessed with respect to five macro shocks relating to fossil fuel prices, economic development, and policy movements. It is important to note that these are hypothetical scenarios, not macro-economic projections.

The results of this assessment are shown in Figure 32. Green cells indicate that the respective abatement lever theme would be at least as relevant to pursue under the corresponding scenario, while red cells indicate lower relevance.

this would also hold true in the event of a prolonged slow economic recovery, or if the rest of the world would increase its climate ambitions. In both cases, innovation could help to drive prosperity and business growth in Europe. Naturally, a prolonged slow economic recovery could have negative consequences for the climate efforts and the corporate willingness to invest would likely decrease, but it would not make the innovation themes less relevant per se. One important shock for which the relevance of the themes could decrease would be steadily falling fossil fuel prices.

FIGURE 32

Robustness of abatement themes in different scenarios

More relevant to pursue[1] | Same relevance to pursue | Less relevant to pursue

		Advanced materials innovation	Circularity	Cross-sector collaboration	Competitive opportunities	Tradeoffs	Carbon leakage risk
Fossil fuel price	Higher fossil fuel prices	Greater incentives to move away from fossil materials	Greater incentives to improve resource efficiency	Greater incentives to move away from fossil materials	Improved business case	Improved business case	On the margin limited effect
	Lower fossil fuel prices	Innovation still viable due to end user pull	Decreased price pressure reduces incentives for action		Most opportunities inherently value creating	Worsened business case	On the margin limited effect
Economy	Prolonged slow economic growth	Competitiveness more important. Innovation could be a vehicle for growth			More important to remove barriers for growth	Less desirable to implement uncompetitive actions	
Policy	Stronger European carbon policy	Increased incentives for abatement action more broadly					On the margin limited effect
	Stronger global carbon policies	Opportunity to export innovations abroad			Mostly intra-Europe levers, few export opportunities		

Pursuing innovation themes and competitive opportunities appears resilient to scenarios

1 The assessments are based on relevance under different scenarios. Willingness to undertake action could, in certain cases, turn out differently

Interestingly, most themes would grow in relevance if the different shocks would materialize. This would hold especially true for the three innovation themes and the competitive opportunities theme. As expected, higher fossil fuel prices or stronger carbon policy (e.g., increased carbon price) would increase relevance. For most themes,

Possible future roles of Europe

The results in Figure 30 suggest to us that Europe could consider a broader set of roles in the global effort to reduce greenhouse gas emissions than it currently does. The ECF's impression is that a high share of Europe's attention is focused on reducing each industry's own emissions in the current industry structure. The broader opportunities highlighted above (e.g., circularity, advanced materials innovation, cross-sector collaboration, and global multiplier effects) are sometimes heard in the European debate, but receive a low share of attention, of financial support, of political capital and of metrics and follow-up. We believe that the results above – where a large part of the opportunity for Europe lies outside the traditional scope 1 and 2 focus in the current industry structure – suggest that Europe should also investigate what impact and attractiveness broader roles could have, for instance reshaping the industrial system towards a more circular and sustainable setup, providing advanced markets for novel low-carbon solutions, or developing global solutions through a more innovation oriented policy (Figure 33). Nothing prevents Europe from playing all four roles at the same time.

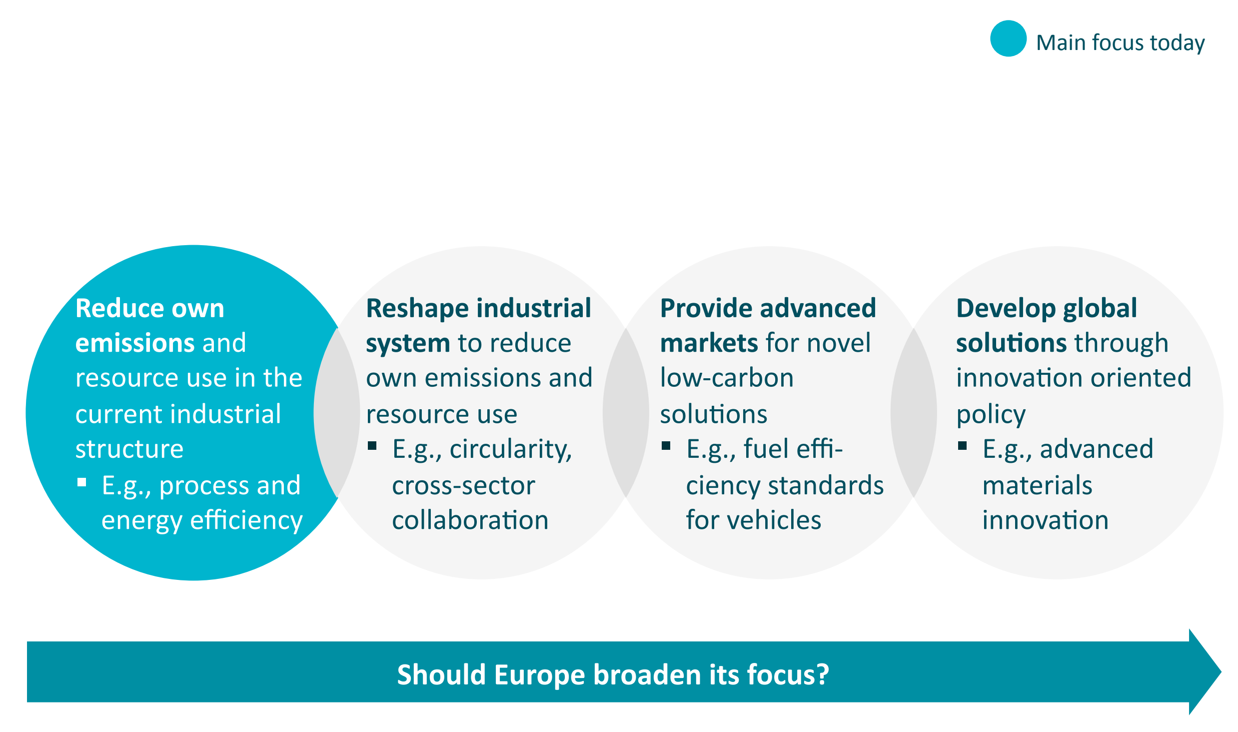
IMPLICATIONS FOR THE PROCESS GOING FORWARD

Europe's opportunity, and challenge, going forward will be to capture the large and promising cross-process, cross-company, cross-sector, and cross-country abatement opportunities – in addition to continuing to improve process and energy efficiency. We need to expand the solution space to balance competitiveness, sustainability, and security of supply in European industry. And we need a fundamental rethinking of the underlying drivers of success for Europe. In essence, we need a broader notion of competitiveness to reflect the dynamics and potential of Europe profiting from the challenges of the transition.

We are well aware that the results in this study rely in part on the findings obtained for a subset of all chemical products, and might not be representative for the whole industry. However, we believe they point to an interesting set of opportunities for Europe to explore further. If these opportunities stand up to scrutiny when more products are analyzed, they provide a promising path forward – as they would allow the chemical industry to continue reducing emissions for itself and for others, while at the same time maintaining or increasing Europe's competitiveness through strengthening its historical competitive advantages.

FIGURE 33

Possible roles of Europe—should Europe consider to broaden its focus?



The ECF would therefore like to invite the chemical industry to further discuss and validate the robustness of these conclusions, and would also like to invite a broader set of stakeholders to a dialogue about the implications of these results. We have to focus on the "how" of Europe's low-carbon transition, and at the heart of the discourse should be the exploration of areas where technical and business model innovations could allow competitiveness and sustainability to be complementary. To explore the solution space in a meaningful way we must look beyond the incremental business-as-usual model and start addressing the need for a sustainable industrial strategy for Europe.

REFERENCES

American Chemistry Council, The Economic Benefits of Polyvinyl Chloride in the United States and Canada, 2008

Azom.com, Polycarbonate (PC) (C15H16O2) Plastic Recycling, 2013, (http://www.azom.com/article.aspx?ArticleID=7963)

Bayer, Bayer's CO_2 Projects - Use of Carbon Dioxide for the Production of Plastics, (https://www.materialscience.bayer.com/~/media/Bms/Documents/Publications/CO2-Projekte_kurz_EN.ashx)

Bayer, Chlorine Production with Much Less Electricity, 2013, (http://www.bayer.be/ebbsc/cms/fr/actualites/actualites/Chlorine_production_with_much_less_electricity.html)

BioBased Economy, Economical Feasibility of the Sugarbeet-to-Ethylene Value Chain in Zuid-West Nederland, 2012

Biosynthetic Technologies, High-Performance Biosynthetic Motor Oil Now Possible as Biosynthetic Technologies Nears Commercial Production, 2013, (http://www.businesswire.com/news/home/20131015005079/en/High-Performance-Biosynthetic-Motor-Oil-Biosynthetic-Technologies-Nears#.UwZYYmJdX9N)

Bisphenol A Europe, Polycarbonate Sustainability Factsheet, 2011

Bluestar, 15th Annual Global Outlook for Carbon Fiber 2012, London, UK, Spinning Wool to Carbon Fiber, Neil Barker, 2012

Boeing, Airplane Recycling Efforts- Benefit Boeing Operators, William Carberry, 2008

British Plastics Federation, PVC-U Plastics Recycling in Action, Some Case Studies

Buildings Performance Institute Europe, Europe's Buildings under the Microscope, 2011

CAN-Europe, CAN-Europe Position Paper: Best use of Auctioning Revenues from the EU Emissions Trading Scheme, 2012

Carleton University, Fire Dynamics II - Lecture # 5 - Chemistry of Room Fire Combustion, 2003

Cefic, European Chemistry for Growth, Unlocking a Competitive, Low Carbon and Energy Efficient Future, 2013

Cefic, Facts and Figures 2012: The European Chemicals Industry in a Worldwide Perspective, 2012

Cefic, The European Chemical Industry: Facts and Figures 2013, 2013

Das, Sujit, Life Cycle Assessment of Carbon Fiber-Reinforced Polymer Composites, International Journal of Life Cycle Assessment, 2011, 16:268–282

Deloitte, PVC Markets of Europe and South-East Asia: Analysis of Profitability and Production Cost, 2010

Dow Chemical Company, Life Cycle Assessment – PVC for Electric Cable Applications, 2008

Ecoshift Consulting, Life Cycle Analysis of Greenhouse Gas Emissions from Biosynthetic Base Oil (BBO) Compared to Poly-Alpha Olefin (PAO) Base Oil, Dustin Mulvaney, 2013

ENI, Diphenylcarbonate DMC-DPC Integrated Process - Proprietary Process Technology, 2009

Entertainment Distribution Company, Saving Costs and Improving the Environmental Impact Through Materials Recycling, Paul Murphy, 2012

Eurima, The Contribution of Mineral Wool and other Thermal Insulation Materials to Energy Saving and Climate Protection in Europe, 2002

European Automobile Manufacturers Association, Cars, Trucks & the Environment, 2010

European Automobile Manufacturers Association, Pocket Guide 2013, 2013

European Commission, Horizon 2020, Work Programme 2014-2015, 10. Secure, Clean and Efficient Energy, 2013, (http://ec.europa.eu/programmes/horizon2020/en/h2020-section/secure-clean-and-efficient-energy)

European Commission, Life Cycle Assessment of PVC and of Principal Competing Materials, 2004

European Diisocyanate and Polyol Producers Association, Polyutherane website FAQ, 2014, (http://www.polyurethanes.org/index.php?page=more-facts-and-figures)

European Environment Agency (EEA), CO2 Emissions per kWh of Electricity and Heat Output, 2011, (http://www.eea.europa.eu/data-and-maps/figures/co2-emissions-per-kwh-of)

European Environment Agency (EEA), EEA Greenhouse gases data, 2013

European Environment Agency (EEA), Most Carmakers Must Further Improve Carbon Efficiency by 2015, 2012, (http://www.eea.europa.eu/highlights/most-carmakers-must-further-improve/)

European Environment Agency (EEA), Vehicle Ownership and Truck Intensity in the EEA, 2010, (http://www.eea.europa.eu/data-and-maps/figures/vehicle-ownership-and-truck-intensity)

Eurostat, Annual detailed enterprise statistics on manufacturing, subsections DF-DN and total, 2014

Eurostat, Greenhouse gas emissions by sector data, (http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tsdcc210)

ExxonMobil, Group IV Basestocks, 2009

Federation of European Rigid Polyurethane Foam Associations, Thermal Insulation Materials Made of Rigid Polyurethane Foam, 2006

Glass for Europe, Life Cycle Assessment of Clear Float Glass for Building Applications, (http://www.glassforeurope.com/en/issues/life-cycle-analysis.php)

GMC2, The Future of Carbon Fiber, Edward G. Carson, 2012

Granta Design, CES Edupack - PC (High viscosity, Molding and Extrusion), 2009

Greenpeace International, How to Limit HFC Emissions?, 1999

Helsinki University of Technology Department of Mechanical Engineering, Treatment and Disposal of Polyurethane Wastes: Options for Recovery and Recycling, Ron Zevenhoven, 2004

ICIS, Mitsubishi Chemical Plans Bio-polycarbonate Pilot Plant, 2009, (http://www.icis.com/resources/news/2009/05/14/9216374/mitsubishi-chemical-plans-bio-polycarbonate-pilot-plant/)

IEA-ETSAP and IRENA, Production of Bio-Ethylene, a Technology Brief, 2012

IHS Global, CEH Marketing Research Report: Plastics Recycling, James Glauser, 2012

IHS Global, CEH Marketing Research Report: Polyurethane Foams, Uwe Löchner, Henry Chinn and Yuko Yamaguchi, 2012

IHS Global, CEH Marketing Research Report: Polyvinyl Chloride, (PVC) Resins, Michael Devanney, 2011

IHS Global, Chemical Economics Handbook: Carbon Fibers, Sebastian N. Bizarri et al, 2013

IHS Global, Chemical Economics Handbook: Linear Alpha-Olefins, Elvira O. Camara Greiner and Milen Blagoev and Yuko Yamaguchi, 2013

IHS Global, Chemical Economics Handbook: Polycarbonate Resins, Henry Chinn, Kevin Smith, Barbara Sestoand Yoshio Inoguchi, 2013

IHS Global, Synthetic Lubricants, Masahiro Yoneyama, Marifaith Hackett, Stefan Müller and Vivien Yang, 2012

International Energy Agency (IEA), World Energy Outlook 2013, 2013

International Organization of Motor Vehicle Manufacturers, CV World Vehicles in Use, 2013

IPCC/TEAP, Special Report: Safeguarding the Ozone Layer and the Global Climate System, 2005

Just Auto, Polycarbonate Auto Glazing Offers Designers New Vision, Matthew Beecham, 2008, (http://www.just-auto.com/analysis/polycarbonate-auto-glazing-offers-designers-new-vision_id94895.aspx)

Lahti University of Applied Sciences, Carbon Footprint of the Raw Materials of an Urban Transit Bus, Päivi Kärnä, 2012

Mitsubishi Chemical, New Bio-based Engineering Plastic "DURABIO", 2005, (http://www.m-kagaku.co.jp/english/products/business/polymer/sustainable/details/1194667_3255.html)

New York State Pollution Prevention Institute, Tools to Measure Sustainability: Life Cycle Assessment, 2012

Oxy, Cracking EDC, (http://www.oxy.com/OurBusinesses/Chemicals/TechnologyLicensing/Pages/CrackingEDC.aspx)

PlasticsEurope, Eco-Profiles and Environmental Product Declarations of the European Plastics Manufacturers: Bisphenol A, 2011

PlasticsEurope, Eco-Profiles and Environmental Product Declarations of the European Plastics Manufacturers: Ethylene, Ethylene, Propylene, Butadiene, Pyrolysis Gasoline, Ethylene Oxide (EO), Ethylene Glycols (MEG, DEG, TEG), 2012

PlasticsEurope, Eco-Profiles and Environmental Product Declarations of the European Plastics Manufacturers: Long and Short-chain Polyether Polyols for Polyurethane Product, 2012

PlasticsEurope, Eco-Profiles and Environmental Product Declarations of the European Plastics Manufacturers: Polycarbonate, 2013

PlasticsEurope, Eco-Profiles and Environmental Product Declarations of the European Plastics Manufacturers: Toluene Diisocyanate (TDI) & Methylenediphenyl Diisocyanate (MDI), 2012

PlasticsEurope, Eco-Profiles of the European Plastics Industry: Acetone, 2005

PlasticsEurope, Eco-Profiles of the European Plastics Industry: Phenol, 2005

PlasticsEurope, Eco-Profiles of the European Plastics Industry: Polyurethane Rigid Foam, 2005

PlasticsEurope, Environmental Product Declarations of the European Plastics Manufacturers - High Density Polyethylene (HDPE), 2012

PlasticsEurope, Plastics – the Facts 2013, An Analysis of European Latest Plastics Production, Demand and Waste Data, 2013

Plastics Today, Green Matter: A Dash of Isosorbide Makes All the Difference, Karen Laird, 2012, (http://www.plasticstoday.com/blogs/green-matter-dash-isosorbide-makes-all-difference-112920121)

Process Engineering, Bayer Process to Shrink Chlorine Production Costs and Emissions, 2009, (http://processengineering.theengineer.co.uk/bayer-process-to-shrink-chlorine-production-costs-and-emissions/1000151.article)

PU Europe, Life Cycle Environmental and Economic Analysis of Polyurethane Insulation in Low Energy Buildings, 2010

PU Europe, Sustainability and Polyurethane Insulation - Today's Solutions for Tomorrow's Needs, 2010

PU Europe, Waste Management and Polyurethane Insulation in the Context of Resource Efficiency, 2013

PVCplus, Everything about PVC from Manufacturing to Recycling, 2012

Shinsuke Fukuoka; Isaburo Fukawa; Masahiro Tojo; Kazuhiro Oonishi; Hiroshi Hachiya; Muneaki Aminaka; Kazumi Hasegawa; Kyosuke Komiya, A Novel Non-Phosgene Process for Polycarbonate Production from CO2: Green and Sustainable Chemistry in Practice, Catalysis Surveys from Asia 14(3):146-163

SRI Handbook, Greenhouses Gases Handbook, Mike Arné and Eric Johnson, 2006

Sustainable Plant, Large-Scale PPC Polyol Run Promises Sustainable Polyurethane from Waste CO_2, 2013 (http://www.sustainableplant.com/2013/02/large-scale-ppc-polyol-run-promises-sustainable-polyurethane-from-waste-co2/)

Swiss Federal Institute of Technology Zurich, Techno-Economic Analysis of Low-GHG Emission Light, Sara Safarianova, Fabrizio Noembrini, Konstantinos Boulouchos and Philipp Dietrich, 2008

The European Council of Vinyl Manufacturers (ECVM) & PlasticsEurope, Eco-Profiles of the European Plastics Industry – Polyvinylchloride (PVC, Bulk Polymerization), 2005

The European Council of Vinyl Manufacturers (ECVM) & PlasticsEurope, Eco-Profiles of the European Plastics Industry – Polyvinylchloride (PVC, Emulsion Polymerization), 2008

The European Council of Vinyl Manufacturers (ECVM) & PlasticsEurope, Eco-Profiles of the European Plastics Industry – Polyvinylchloride (PVC, Suspension Polymerization), 2008

The Truth About Cars, Are You Ready for: Plastic Windows?, Edward Niedermeyer, 2011, (http://www.thetruthaboutcars.com/2011/07/are-you-ready-for-plastic-windows/)

Tom N. Kalnes, David R. Shonnard, Andreas Schuppel, LCA of a Spent Lube Oil Re-refining Process, 2006

Total, Fuel Economy Concept, (http://www.total-fuel-economy-lubricants.com/)

Transparency International, Corruption Perceptions Index 2013, 2013

United States Department of Energy, Oak Ridge National Laboratory, Low Cost Carbon Fiber from Renewable Resources, Frederick S. Baker, 2010

United States Department of Energy, Oak Ridge National Laboratory, Low Cost Carbon Fiber Overview, C. David Warren, 2011

United States Department of the Interior Minerals Management Service Gulf of Mexico OCS Region, Environmental Impacts of Synthetic Based Drilling Fluids, 2000

United States Environmental Protection Agency (EPA), WARM Version 12 – Plastics, 2012

University of Bath, Inventory of Carbon & Energy (ICE), 2008

University of York, The Essential Chemical Industry, 2013, (http://www.essentialchemicalindustry.org/polymers/polyurethane.html)

VinylPlus, Introducing VinylPlus - The New 10-year Voluntary Commitment of the European PVC Industry, Dr. Anahita Williamson, 2011

VinylPlus, Progress Report 2012 - Reporting on the Activities of the Year 2011, 2012

VinyLoop, The VinyLoop Case - How to Shape LCA Tools to Promote the Use of Recycled PVC, Richard Thommeret and Christian Thamm, 2011

World Bank, Doing Business 2014: Understanding Regulations for Small and Medium-Size Enterprises, 2013

World Economic Forum (WEF), The Global Competitiveness Report 2013-2014, Klaus Schwab, 2013

European
Climate Foundation