

PRICES AND COSTS OF EU ENERGY

Annex 5 Industrial Case Studies



PRICES AND COSTS OF EU ENERGY

Annex 5 Industrial case studies

By: Nele Friedrichsen, Andrea Herbst

Date: 31 March 2016

Reviewer: Ann Gardiner

*This study was ordered and paid for by the European Commission,
Directorate-General for Energy,*

SERVICE CONTRACT

CONTRACT NUMBER — ENER/A4/FV-2015-395/SER/SI2.712709

All copyright is vested in the European Commission.

DISCLAIMER

The information and views set out in this study are those of the author(s) and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use which may be made of the information contained therein.

A cooperation of:

Ecofys

Fraunhofer ISI

CASE

Glossary

Definitions

Price of energy: The amount of money for which an amount of energy is sold at the wholesale or retail market

Price components: Retail prices for energy consist of three components: energy, network and taxes/levies.

Cost of energy: Energy price multiplied by energy consumption.

Direct impact: This refers to those taxes and levies as well as policies requiring the delivery of certificates, which change the retail prices for energy directly.

Indirect impact: Several policies affect the generation mix, supply routes and energy market systems. These will also ultimately affect the retail price but in a more indirect way, for example by changing the wholesale price.

Abbreviations

EC	European Commission
ETS	Emission Trading Scheme
EU	European Union
GDP	Gross domestic product
JRC	Joint Research Centre
LME	London Metal Exchange
NACE	Statistical Classification of Economic Activities in the European Community – From the French, Nomenclature Statistique des activités économiques dans la Communauté européenne
OECD	Organisation for Economic Co-operation and Development
RCA	Revealed comparative advantage, calculated as $RCA_{ij} = (E_{ij}/I_{ij}) / (\sum_j E_{ij} / \sum_j I_{ij})$ with i = country, j = technology, E = export, and I = import The RCA describes the ratio of export to import of a country for a product group compared to the ratio exports to imports of a country as a whole. An RCA above 1 indicates a relative export advantage of the regarded product group.

Table of contents

Definitions	4
Abbreviations	4
Introduction	1
Case study 1: Crude steel	3
Product description	3
Product cost structure	3
Market situation	7
International competitiveness	10
Case study 2: Paper	14
Product description	14
Energy mix and product cost structure	16
Market situation	20
International competitiveness	25
Case study 3: Aluminium	28
Product description	28
Product cost structure	28
Market situation	31
International competitiveness	33
Case study 4: Hollow glass	36
Product description	36

Product cost structure	36
Market situation	40
International competitiveness	43
Case study 5: Chlorine	46
Product description	46
Product cost structure	46
Market situation	48
International competitiveness	49
References Cost structure case studies	52

Introduction

The following case studies refer to 5 sectors on NACE4 level and partially focus on specific products respectively production routes with the aim to provide an overview on the importance of energy costs and other factors for the competitive position of European industries. The respective sectors are:

- C2410 - Manufacture of basic iron and steel and of ferro-alloys, focus crude steel
- C1712 - Manufacture of paper and paperboard
- C2442 - Aluminium production, focus primary aluminium
- C2313 – Hollow glass, focus container glass
- C2013 - Manufacture of other inorganic basic chemicals, focus chlorine

The selected sectors have relatively high energy costs per production value, a relatively high trade intensity¹ and have importance for the economy measured as share of GDP. The sectors above fulfil the following criteria: energy intensity above 7%, trade intensity of more than 10% and a share of GDP greater than 0.02%.

For each of these sectors, the case studies give a brief product description and then describe the cost intensities of energy, labour and other cost, market situation and international competitiveness. Detailed information about energy consumption of subsectors in European Member States is only partly available at national level. It was therefore agreed to focus the detailed analysis on the countries that contribute the largest shares to value added and together cover more than 50% of European value added within the respective sector.

The following table shows the main contributors to value added per chosen NACE 4 sector based on Eurostat data. The analysis shows that in most cases more than 50% of the value added of a branch is generated by only three countries and Germany, France and Italy are present very often among the sample.

Table 11: Country ranking 2013: share of value added in EU28² value added on NACE 4 level

	Manufacture of paper and paperboard		Manufacture of other inorganic basic chemicals		Manufacture of hollow glass		Manufacture of basic iron and steel and of ferro-alloys		Aluminium production	
Country 1	Germany	22%	France	26%	France	25%	Germany	31%	Germany	34%
Country 2	Finland	16%	Germany	19%	Germany	17%	Italy	9%	Greece	9%
Country 3	Sweden	15%	UK	12%	Italy	16%	Austria	8%	France	8%
Country 4							France			

¹ The trade intensity is assessed by dividing the sum of imports and exports of a product to and from the EU in total by the size of the market represented by the sum of production value and imports.

² If EU28 not available then the sum of the available countries have been used as basis.

To calculate energy cost intensities, the energy consumption per energy carrier is multiplied by prices per energy carrier as calculated using the industrial energy prices tool. For each case study, the typical prices of electricity and natural gas for companies within the NACE 4 sectors have been based on specific assumptions concerning annual energy consumption, consumer class, sector type, installed capacity and level of grid connection (main technical assumptions see below). For oil the spot-price for crude brent and for coal the NL cif ara price as provided from task 1 were used.

Steel: For the steel industry average energy carrier prices have been calculated assuming an annual electricity consumption of 1600 GWh/a of which 90% self-generation, i.e. an annual electricity demand from the grid of 160GWh/a and an annual gas consumption of 130 GWh/a. This roughly corresponds to the oxygen steel production route.

Aluminium: A fictional primary aluminium smelter is modelled based on the average technical production data of European cabins (electricity consumption in 1950 GWh/year, no self-generation, 244 MW power supply, 8000 full load hours, 15.000 kWh/t specific energy consumption) and an annual gas demand of 1170 GWh/a.

Paper: A paper mill was assumed with an annual natural gas consumption of 1200 GWh/a and 400 GWh/a annual electricity consumption without self-generation of electricity and a connected capacity of 80 MW in power supply.

Glass: A fictional glass production plant was assumed with an annual electricity consumption of 25 GWh/a without self-generation of electricity and an annual natural gas consumption of 100 GWh/a.

Chlorine: A fictional chlorine production plant was assumed with an annual electricity demand of 650 GWh/a and an annual gas demand of 1625 GWh/a.

For a detailed description of the methodology used to generate price data per country and product see section 5.1.4. of the main report. In addition, a detailed description on energy carrier prices for industry and its estimation can be found in the main report sections 5.1.2 and 5.1.3.

Case study 1: Crude steel

Product description

Crude steel is an energy intensive bulk product that can be produced via two major production routes in Europe:

- Primary production in the basic oxygen furnace (BOF), which uses iron ore and coke as main inputs.
- Secondary production in the electric arc furnace (EAF), which uses steel scrap and electricity as major inputs.

In 2013 the iron and steel industry was responsible for 18% on the industrial energy demand (10% of industrial natural gas demand, 11% of industrial electricity demand) (Eurostat 2016). Oxygen steel production (BOF) is much more energy intensive than electric steel production (EAF). The most energy-intensive step in this process is the reduction of iron ore to iron in the blast furnace. The BOF energy demand is met by fossil fuels (coal, coke). In the EAF route the most energy-intensive step is the melting of scrap using mostly electricity. Based on Arens et al. 2012 and Fleiter et al. 2013, we estimated a specific energy consumption level by process as follows: EAF 3.26 GJ/t (2.28 GJ/t electricity, 0.98 GJ/t fuels), BOF 12.24 GJ/t (0.6 GJ/t electricity, 11.64 GJ/t fuels). The data needed to separate out the energy product purchases for EAF and BOF routes is not available in the statistics so the case study covers both together.

Product cost structure

Comparing the Austrian, German and Italian (major value added contributors of the EU28) production cost structure shows, that while Austria and Germany have a rather similar magnitude of intensity of energy product costs to production value between 2008 and 2015 (0.14 €/€ Austrian average and 0.10 €/€ German average), the average Italian energy product costs intensities are significantly lower at 0.05 €/€ (Figure 1). The main reason for this difference is likely to be the type of production used in the different countries. While in Germany and Austria the share of BOF-produced steel is still very high, Italy has a much higher share of the less energy intensive EAF-production route (EAF production shares in 2013: AT 8%, DE 32%, IT 72% (Steel Statistical Yearbook 2014)).

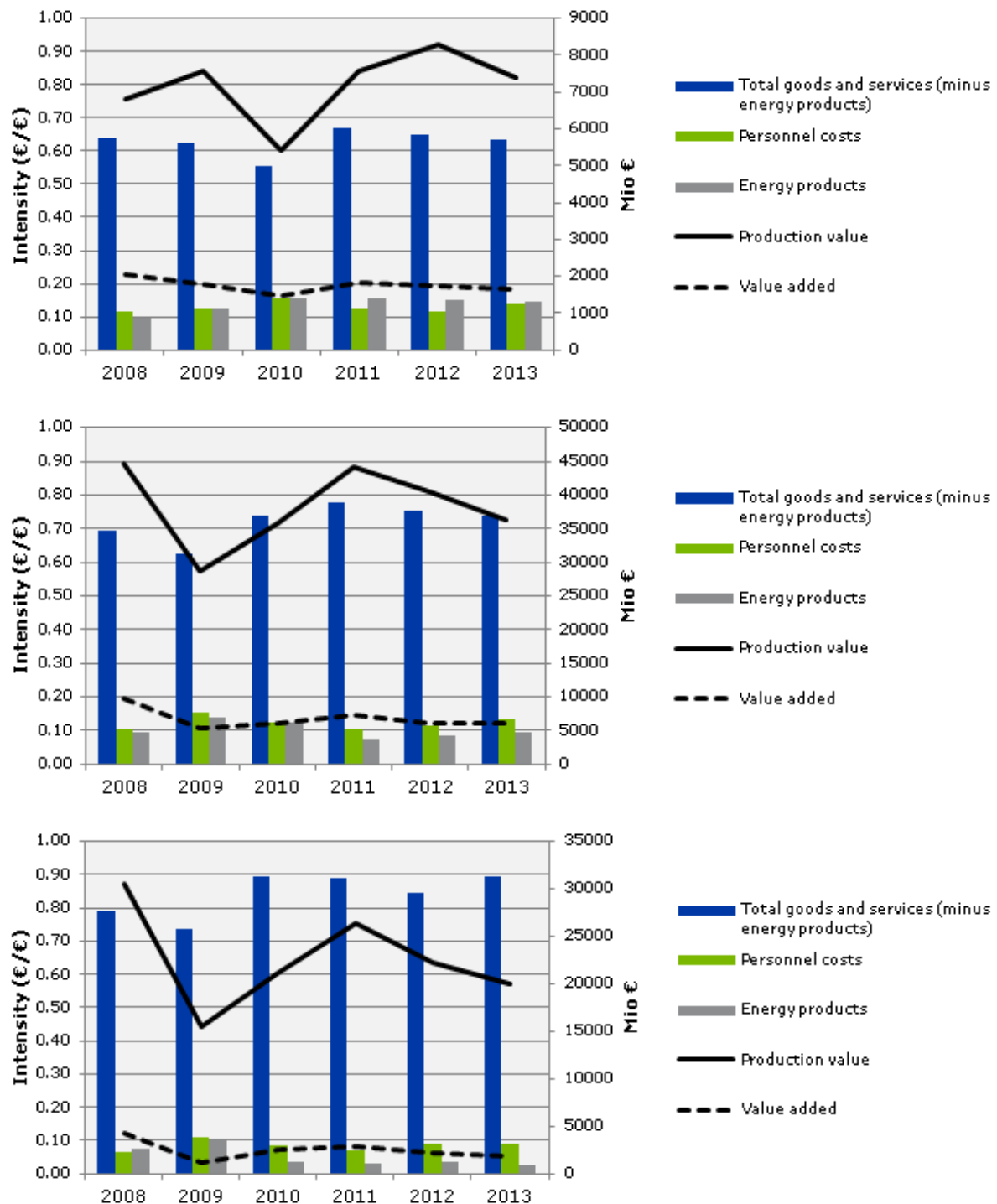


Figure 1: Production cost structure (total goods & services, personnel costs, energy products), production value, and value added NACE 2410 for Austria (top), Germany (middle), Italy (bottom)

Source: own illustration of Eurostat Structural Business Statistics (2015)

Despite the high share of EAF steel production and the comparatively high average electricity prices in Italy, the actual electricity procurement price for large Italian companies is not completely transparent. Via a special provision they have access to the interconnector capacity to other countries and thus can obtain electricity at the wholesale prices of neighbouring countries, however quantification of this effect in earlier studies has not been possible (Grave et al. 2015). This special provision paired with the high EAF production share is likely to be the main reason for the relatively low energy product purchase intensities in Italy compared to Germany and Austria. Based on energy consumption and energy prices, a bottom-up calculation of energy cost by energy carriers has been realised for European Member States.

The calculated energy cost intensities³ by energy carrier on production value show the highest intensity for electricity costs in the three focus countries followed by gas cost intensities (Figure 2). The German electricity cost intensity is higher than in Austria reflecting slightly higher prices. But this might not be the only reason for these differences in intensity. The different production structure between these two countries might also be a reason for the difference in electricity cost intensities. BOF steel production is less electricity intensive than EAF production. Having an above average BOF steel production share – around 90% - Austria's steel production is less electricity intensive while Germany with more EAF production needs more electricity per production value. The electricity cost intensity for Italy is much higher than in Germany and Austria caused by its very high proportion of EAF steel production and slightly higher prices.

From 2010 the electricity cost intensities in Austria and Italy more or less reflect the developments of the underlying electricity prices. The year 2009 represents an exception, especially in Italy and Germany where lower electricity prices are paired with higher electricity costs. One reason for this development might be “take or pay” contracts – at lower production levels, companies need less energy than expected in the years before. If a company agreed to a minimum level of energy delivery, it has to cover the costs also in times of lower demand. Especially big integrated steel plants with high heat demand reduced production in the time of the financial crisis, which increased the relative share of the more flexible electric arc furnace route in crude steel production.

³ Energy cost intensity: Energy cost intensity is understood as total energy costs (by energy carrier) compared to net production value (see chapter 5 main report) [energy carrier costs (energy consumption / energy carrier * energy carrier price) divided by production value].

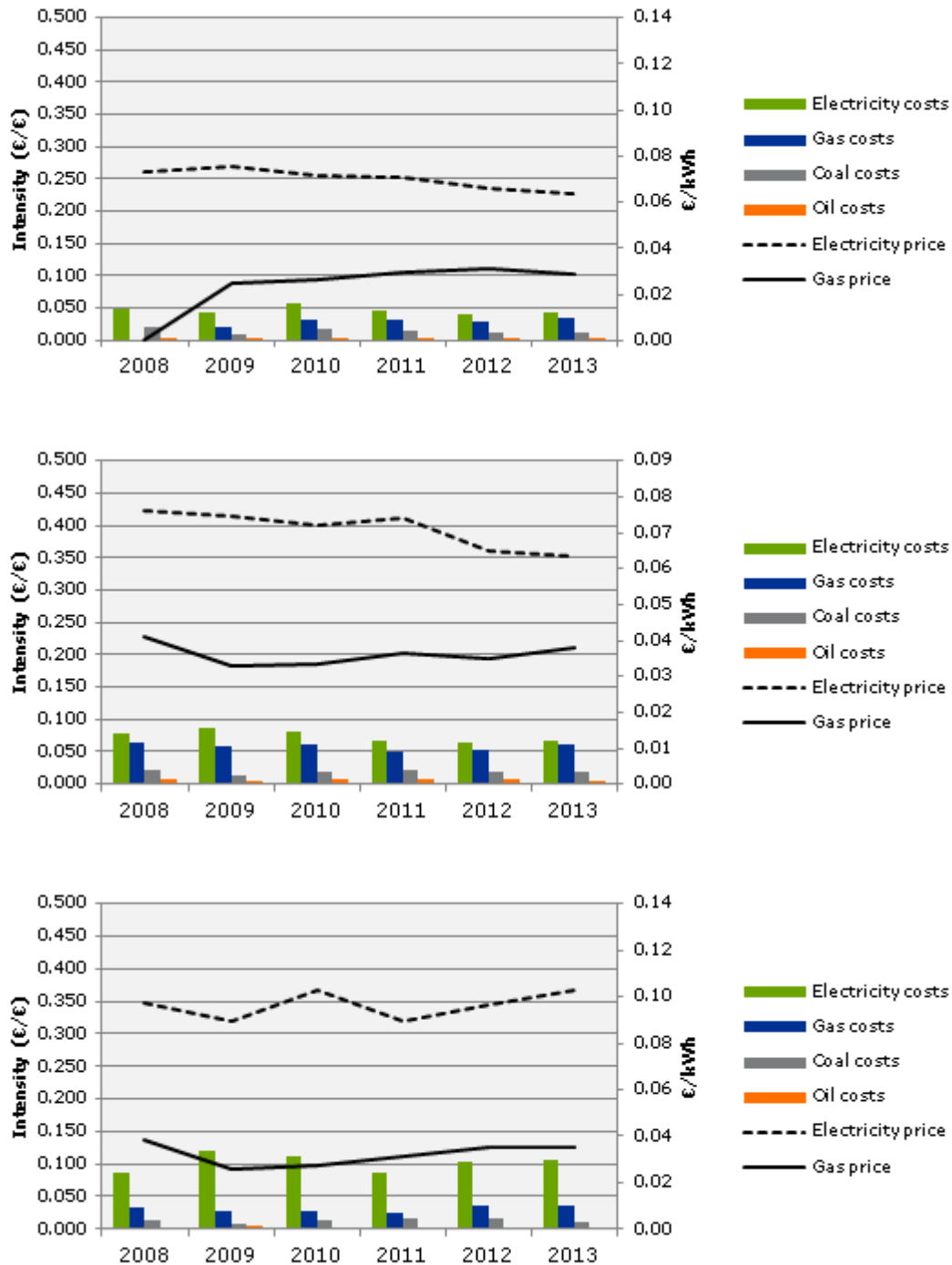


Figure 2: Energy cost intensity by energy carrier on production value steel industry (2008-2013) for Austria (top), Germany (middle), Italy (bottom) (including own generation)

Source: own elaboration of Eurostat Structural Business Statistics and task1 results

In this context: when interpreting the numbers shown in Figure 2 it is necessary to note, that these calculated costs include own generation of electricity and fuels as well as price uncertainties (end use prices were calculated for a typical firm - larger companies might have access to lower prices) and for this reason can be higher or lower than the available statistical information on energy product purchases from Eurostat. In 2013 in Germany, the sector 2410 supplied approximately 35% of its electricity demand from self-generation (DESTATIS).

A differentiation of the shown information between primary (BOF) and secondary (EAF) production is not possible, as statistical data on energy product purchases as well as energy consumption by energy carrier is not available on process level in current statistics.

We use physical production data, specific electricity demand and electricity prices for a rough, top-down estimation of electricity cost for the two production routes (EAF and BOF) for the year 2014 in the three focus countries. Physical production data is taken from World steel Association (2015). Average electricity demand for electric arc and blast oxygen furnace steel is assumed to be for EAF: 2.28 GJ/t electricity, 0.98 GJ/t fuels and for BOF 0.6 GJ/t electricity, 11.64 GJ/t fuels (based on Arens et al. 2012 and Fleiter et al. 2013). Based on these assumptions, electricity costs per tonne of BOF crude steel have been estimated to be around 10€/tonne for Austria and Germany and about 14€ per tonne for Italy, while EAF crude steel electricity costs have been estimated to be approximately 37 € per tonne in Austria, 39 € per tonne in Germany and 54 € per tonne in Italy (year 2014). We note that these results represent averages based on the assumptions described. In reality, company specific energy consumption per tonne of physical product will vary depending on the local conditions of the production site, product portfolio as well as its electricity costs (depending on supply contracts, company size, etc.)

In comparison, Renda et al. (2013) estimated production cost shares for BOFs making flat products and EAFs making long products. They estimate electricity costs of 26\$ (approx. 20€) per tonne of HRC (hot rolled coil) and 44\$ per tonne of CRC (cold rolled coil) in Eastern Europe, and 19\$ (15€) per tonne of HRC and 33\$ per tonne of CRC in Western Europe as an approximation for BOF electricity costs. For natural gas they estimated costs of 48\$ (CRC) (37€) and 77\$ (HRC) in Central Eastern and 43\$ (33€) and 68\$ in Western European integrated plants (Renda et al 2013). For wire rod production Renda et al. 2013 estimate expenditures for electricity in Central Eastern companies of 78\$ (61€) per tonne and for natural gas of 15\$ (12€) per tonne. For Russia they calculated the lowest costs per tonne both for electricity and gas.

Market situation

The European Union is, after China, one of the most important global steel producers (outer circle in top Figure 3).

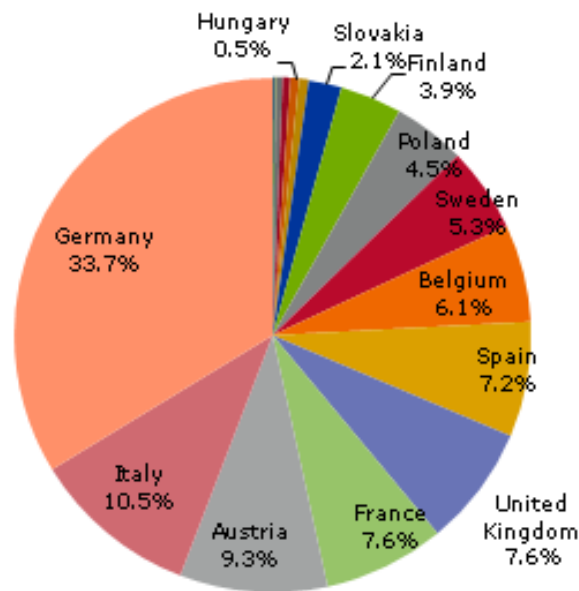
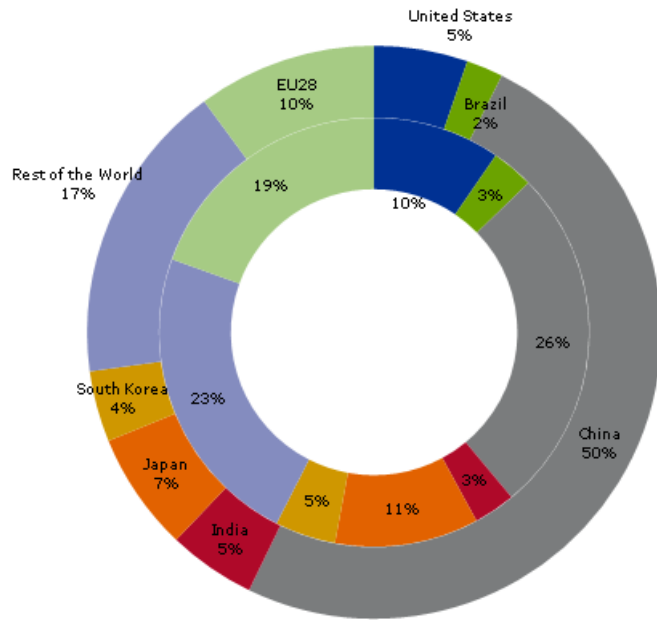


Figure 3 Global crude steel production shares 2004 (inner circle) and 2013 (outer circle) (top), EU28 iron and steel value added distribution (bottom) 2013

Source: own illustration of Worldsteel Statistical Yearbook (2014) & Eurostat Structural Business Statistics

Within nearly ten years China has nearly doubled its share in world production (26% in 2004, inner circle Figure 3). Especially the EU28 but also the rest of the world are losing market shares compared to China. In terms of value added contribution Germany, Italy and Austria are the top three countries. In terms of physical production volume in tonnes France, Spain, and the United Kingdom are producing more steel than Austria (but lower value added products).

The European steel market is a more or less saturated market, where no significant increases in domestic steel demand per capita can be expected. Since 1974 the apparent steel use per capita (crude steel equivalent) of selected European countries has already shown a slightly decreasing trend (Figure 4).

A decreasing apparent steel use per capita could indicate that important infrastructures in the big industrialised European countries have already been built and that living standards are relatively high (e.g. current average density of cars per persons is 505 cars per 1000 inhabitants in the EU15 in 2010, OECD 2012). For the long-term (2050/2100) this could mean that a saturation phase of in-use steel stocks per capita might be possible in these countries. Pauliuk et al. (2013) estimated the in-use stocks of iron for 200 countries and showed that *“the industrialized countries with the longest tradition in steel making showed the highest stock levels, which in most cases have reached a state of slow growth, saturation, or even decline”*. With two life-time-modelling approaches they revealed that the stocks in *“Australia, Canada, the former Czechoslovakia, Finland, France and Benelux, Germany, Japan, Norway, Sweden, Switzerland, the UK, and the U.S. were between 10 and 16 tons/capita in 2008, and the stock curves tended toward saturation, had already saturated, and some were even declining”* (Pauliuk et al. 2013).

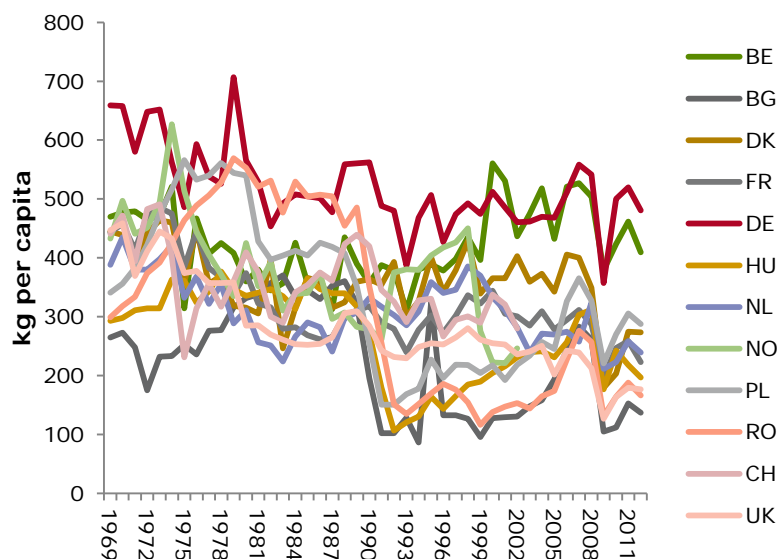


Figure 4: Apparent steel use since 1969 (kg per capita crude steel equivalent)

Source: own illustration of Worldsteel Statistical Yearbook (2014)

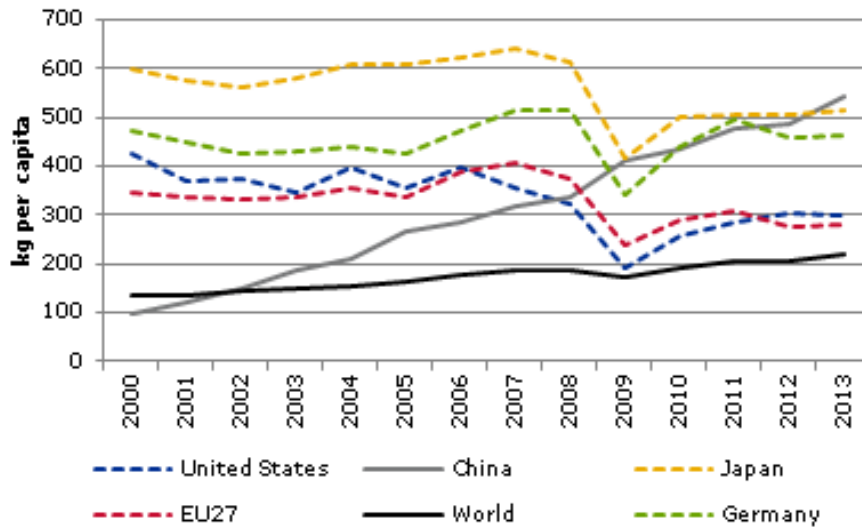


Figure 5: Apparent steel use (kg per capita finished steel equivalent)

Source: own illustration of Worldsteel Statistical Yearbook (2014)

Emerging countries, like for example China, have had an increasing steel use per capita but in recent years economic growth has slowed down and there are increasing overcapacities in the global steel market. These overcapacities have put additional pressure on the competitiveness of European steel industry.

International competitiveness

The major trading partners of steel products of the EU28 are China, Russia, United States, and Turkey. EU28 is a net exporter of steel products to the United States and Turkey. EU28 is a net importer of Chinese and Russian steel products (Figure 6).

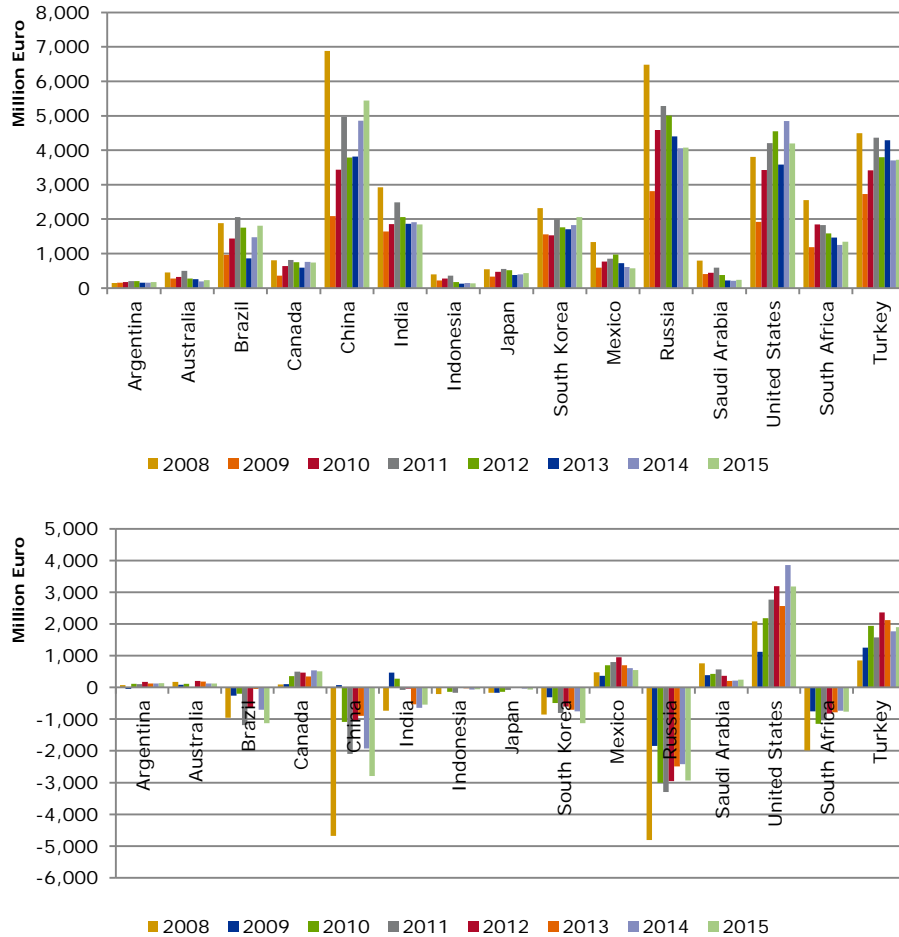


Figure 6 Total trade value (top) and net exports (bottom) of the European Union (EU28) NACE 2410 (2008-2013)
 Source: own illustration of Eurostat EU Trade since 1988 By CPA_2008 (DS-057009)

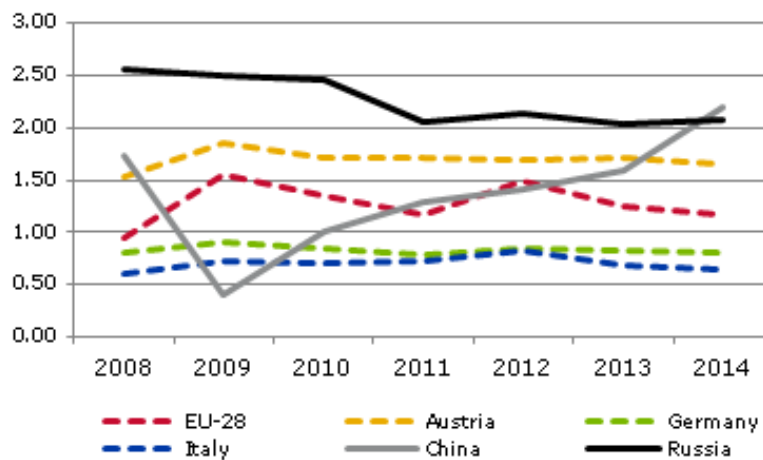
Analysing the UN comtrade trade data for the iron and steel industry (HS2007: 72 Iron and steel) calculating the RCA (Revealed comparative advantage)⁴ of the branch for selected focus countries shows that Russia in particular seems to have a comparative advantage in this industry (Figure 7, high RCA in comparison with the other focus countries). The relatively low gas and electricity prices in Russia contribute to this advantage shown in Figure 7.

Chinas electricity and gas prices seem to be surprisingly high in comparison with Italy and Germany and the fact that the EU is a net importer of Chinese steel products. Despite rather high and

⁴ $RCA_{ij} = (E_{ij}/I_{ij}) / (\sum_j E_{ij} / \sum_j I_{ij})$ with i = country, j = technology, E = export, and I = import (Gerspacher et al. 2011) The RCA describes the ratio of export to import of a country for a product group compared to the ratio exports to imports of a country as a whole. An RCA above 1 indicates a relative export advantage of the regarded product group.

increasing (electricity) prices, China's RCA is strongly increasing in the last years and has already overtaken Russia's comparative advantage (Figure 6). Part of the apparently high price may relate to the exchange rate for China as discussed in the main report. High global steel overcapacities lead to high exports- especially in China where economic growth is weaker than in the past 20 years - consequently China tries to sell its products in non-domestic markets – often using very low prices and governmental subventions.

Figure 7: RCA⁵ 72 Iron and steel for selected countries (2008-2014)



Source: own illustration of United Nations UN comtrade data

This development supports the subject, that the competitiveness and trading advantages of a country depend on a variety of different factors and not only energy prices and consequently energy costs. To give a reliable assessment on the competitiveness of a country or region all those competitiveness and location factors (economic, governmental, infrastructure, research/development/innovation, product portfolio, etc.) have to be analysed jointly and not individually.

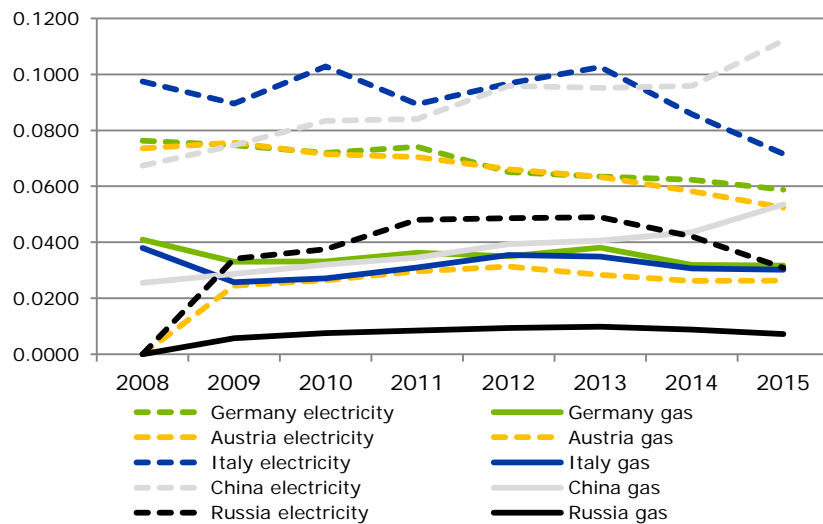
Until 2014 the EU28 were still net exporters of semi-finished and finished steel products (Figure 9). While long and flat products have been net-exported on average between 2008 and 2014, simple steel products like ingots and semis have been net imported. Facing global overcapacities, pressure on the European steel industry - especially in the simple steel sector (e.g. construction steel/profiles) - has risen. Countries like China, which support their steel industry with state-interventions or subsidies, enter the market with very low prices, and mergers and site relocations in the steel industry might be a future consequence.

⁵ not considering re-imports & re-exports.

In addition, the economic growth in emerging countries like China, India, Brazil, etc. will also have major impacts on the European steel industry. The net-exports of European steel products are, amongst others, also influenced by the international demand for steel containing products (e.g. vehicle construction, engineering). In the recent past slower growth than expected in China and other emerging countries, geopolitical tensions and high uncertainties might have damped international demand for consumptions (e.g. cars) and investment goods (e.g. machinery).

A future option that is discussed for the European steel industry is to shift more production to more specialised, knowledge-intensive and customised steel products (e.g. shorter process chains/ increasing proximity of value chains, near-net-shape casting, and improved measurement technologies). Nevertheless, a significant market for commodity steel will still be needed⁶.

Figure 8: Electricity and gas prices for selected countries (2008-2015)



Source: own illustration of price data task 1 and IEA database on energy prices and CEIC data

⁶ For further discussion of the challenges with this option please see for example ThyssenKrupp <http://www.stahl-online.de/index.php/hiesinger-zu-industrie-4-0/>. <https://shop.stahleisen.de/magazine/stahleisen/stahl-und-eisen/stahl-und-eisen-heft-3-2016/a-1010/>

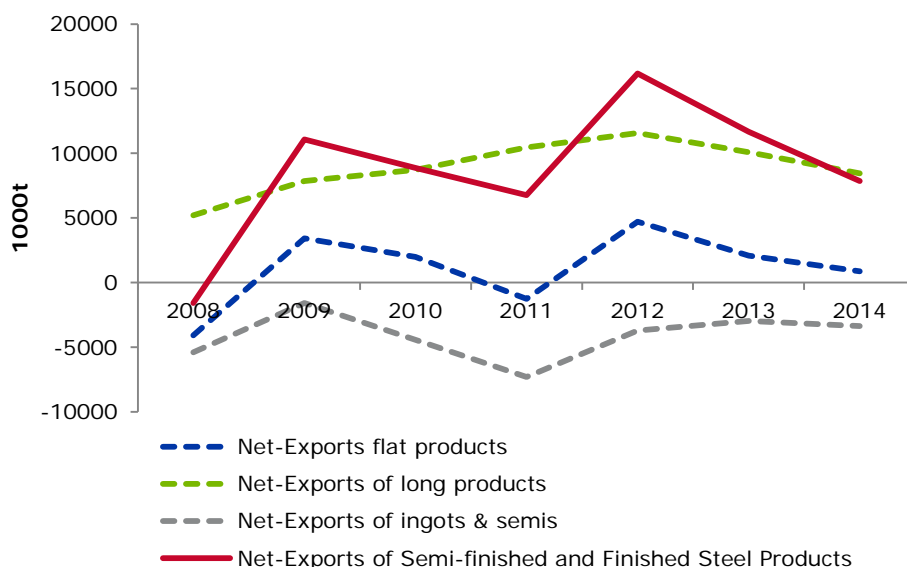


Figure 9 EU28 Net-Exports of selected steel products (2008-2014)

Source: World Steel Association 2015

Case study 2: Paper

Product description

Papermaking requires the production of either mechanical or chemical pulp or alternatively the use of recycled fibres. Mechanical pulping separates fibres mechanically by grinding the wood. Mechanical pulp still contains lignin and paper made from mechanical pulp is called “wood-containing” while paper made mostly from chemical pulp is called “wood-free”. Chemical pulping separates fibres by cooking woodchips with chemicals under high pressure. The lignin is separated and can be burnt to replace other fuel. Modern pulp mills are energy self-sufficient or even have surplus electricity or heat that can be exported or used in adjacent facilities (e.g. if the pulp mill is integrated with papermaking). In non-integrated mills, pulp or recovered fibre is purchased from the market.

The fibrous material is dispersed in water and mixed with additives to improve the characteristics of the paper. The mix of raw materials (e.g. fibrous material, mineral fillers, coating) is important for the product quality but has also a major effect on total production costs and the environmental impact of the process. Depending on the desired final characteristics of the product further steps are integrated such as bleaching or refining, with refining being the most important electricity use.⁷ In

⁷ For most papers refining requires around 10 kWh/t to 500 kWh/t of electricity energy but up to 3 000 kWh/t for speciality papers. Refining thus represents the most important use of electricity in papermaking (in non-integrated mills, mechanical pulp production would also be electricity intensive).

the paper machine, water is removed from the fibrous mixture on a colander and a paper web forms. The paper web is further drained mechanically in a press section and through vacuum sections. Finally it is dried thermally (JRC 2015).

Typically four main paper and board grades are differentiated:

Table 1: Main grades of paper and paperboard (based on JRC 2015)

<p>Graphic papers</p>	<p>Newsprint: paper mainly used for printing newspapers. Produced mainly from mechanical pulp and/or paper for recycling. Commodity product. Mostly produced in mills with a large paper machine capacity (roughly 300 000 tonnes/year).</p> <p>Uncoated mechanical: paper for printing or other graphic purposes with less than 90 % chemical pulp fibres. Typically produced in large-scale integrated mills (250 000 tonnes/ year, integrated wood pulp production).</p> <p>Uncoated wood-free: paper for printing or other graphic purposes with at least 90 % chemical pulp fibres, free of wood-particles and lignin. Includes most office papers. Wood-free graphical papers are typically produced in machines with a capacity of 150 000 tonnes/year.</p> <p>Coated papers: all paper suitable for printing or other graphic purposes that is coated on one or both sides.</p>
<p>Sanitary and Household</p>	<p>Tissue and other hygienic papers. Parent reel stock made from virgin pulp, recovered fibre or a mixture.⁸</p> <p>Machine capacity on average 30 000 – 60 000 tonnes/year. Additionally, many small privately or family owned businesses with a production of up to 10 000 tonnes/year.</p>
<p>Packaging</p>	<p>Case materials: papers and boards mainly used in manufacture of corrugated board. Made from a mix of virgin and recovered fibres.</p> <p>Cartonboard: paper with good folding properties, stiffness and scoring ability. made from virgin and/or recovered fibres. Typically, smaller size of paper machine with 33 000 tonnes/year. Mills in Finland and Sweden are relatively big with 100 000 – 150 000 tonnes/year.</p> <p>Wrappings</p> <p>Other papers mainly for packaging purposes: all paper and board mainly for packaging purposes other than those listed above. produced mainly from</p>

⁸ Sanitary paper is reported in the production statistics at parent reel weight that is before the conversion to final products while import and export statistics account for trade of parent reels AND finished products.

	recovered fibres.
Special (Other)	Other paper and board for industrial and special purposes: e.g. cigarette papers, filter papers, thermal paper, self-copy paper, sticking labels as well as gypsum liners and special papers for waxing, insulating, roofing, asphaltting, and other specific applications or treatments.

Energy mix and product cost structure

The sector NACE Rev 2 1712 Manufacture of paper and paperboard accounted for roughly 7% of industrial electricity consumption and 8% of industrial natural gas consumption (based on 2009 data for Germany as the latest available year without lacking data). Compared to a share in total industrial value added of slightly below 1%, this implies that papermaking is relatively energy intensive. According to CEPI, energy accounts for 21% of production cost (JRC 2015)..

The typical electricity consumption of modern paper mills ranges from 450- 850 kWh/t (JRC 2015). The specific consumption depends on the paper grade (higher grammage has lower specific consumption), raw material mix (coatings reduce specific consumption because they are easier to dry) and size and speed of the paper machine. Fuel consumption for steam generation and sheet drying also varies. Example values are around 4600 to 7180 MJ/ t.⁹

As described in the introduction, the energy consumption and cost structure analysis focuses on the three countries with the largest shares in value added of European Papermaking (NACE Rev. 2 Code 1712). These are Germany, Sweden and Finland.

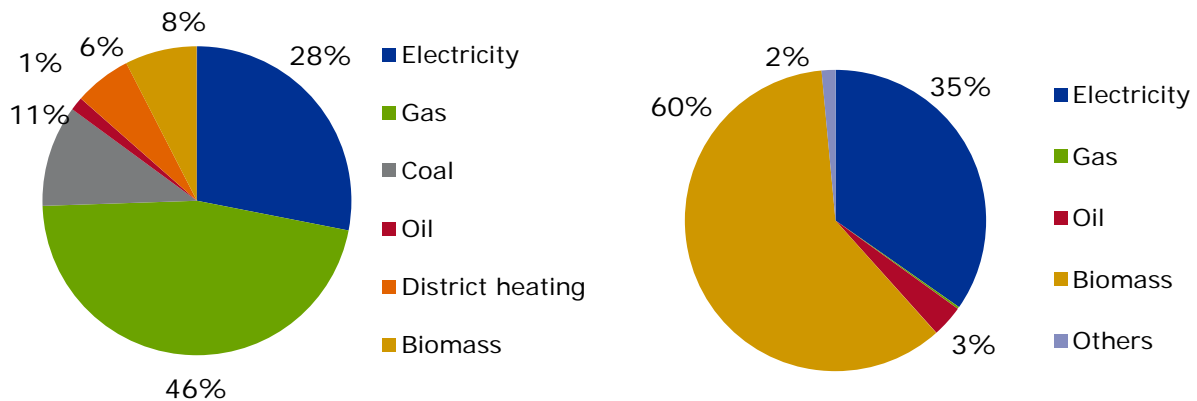
The biggest share of energy consumed in Papermaking in Germany is natural gas with nearly 50%, followed by electricity with slightly more than a quarter and coal which accounts for roughly 10% (see Figure 10). There is an indication that the use of brown coal products increased in Germany paper making indicated by a higher number of cases, but consumption data is confidential. The driving factor behind use of brown coal and pulverized brown coal is likely low and stable prices of the domestically available energy carrier. In a press release from 2008 10-year guaranteed prices for the coal supply contract are mentioned that are said to be well below natural gas supply price for the paper mill.¹⁰In Sweden, relative electricity consumption is slightly higher with over one third, but the dominant energy input is from biofuels with 60%. In Germany, biomass and other renewable energy only made up roughly 7% in 2009. The difference is likely rooted in the different sectoral structure:

⁹ Specific consumption may be even much higher when special techniques such as through-air drying are applied which would increase typical consumption to 3100 kWh/ t (electricity) and 21 000 MJ/t (fuels).

¹⁰ <http://www.bankkaufmann.com/a-156370-Wirtschaftliche-Energie-Rheinischer-Braunkohlenstaub-ist-eine-interessante-Option-fuer-die-Papierindustrie.html>, for technical details of a mill that has been equipped with a CHP using pulverized brown coal and oil see also: http://www.getec-heat-power.de/upload/dokumente/produkte_leistungen/Industrie_PapierfabrikHainsbergFreital_hp.pdf

Sweden is the biggest pulp producer in Europe (followed by Finland) and roughly two thirds of its pulp production is chemical pulp which allows for the use of black liquor to generate heat and power.

Figure 10: Energy mix in papermaking (NACE Rev 2 1712, Germany 2009 left and Sweden 2011 right)



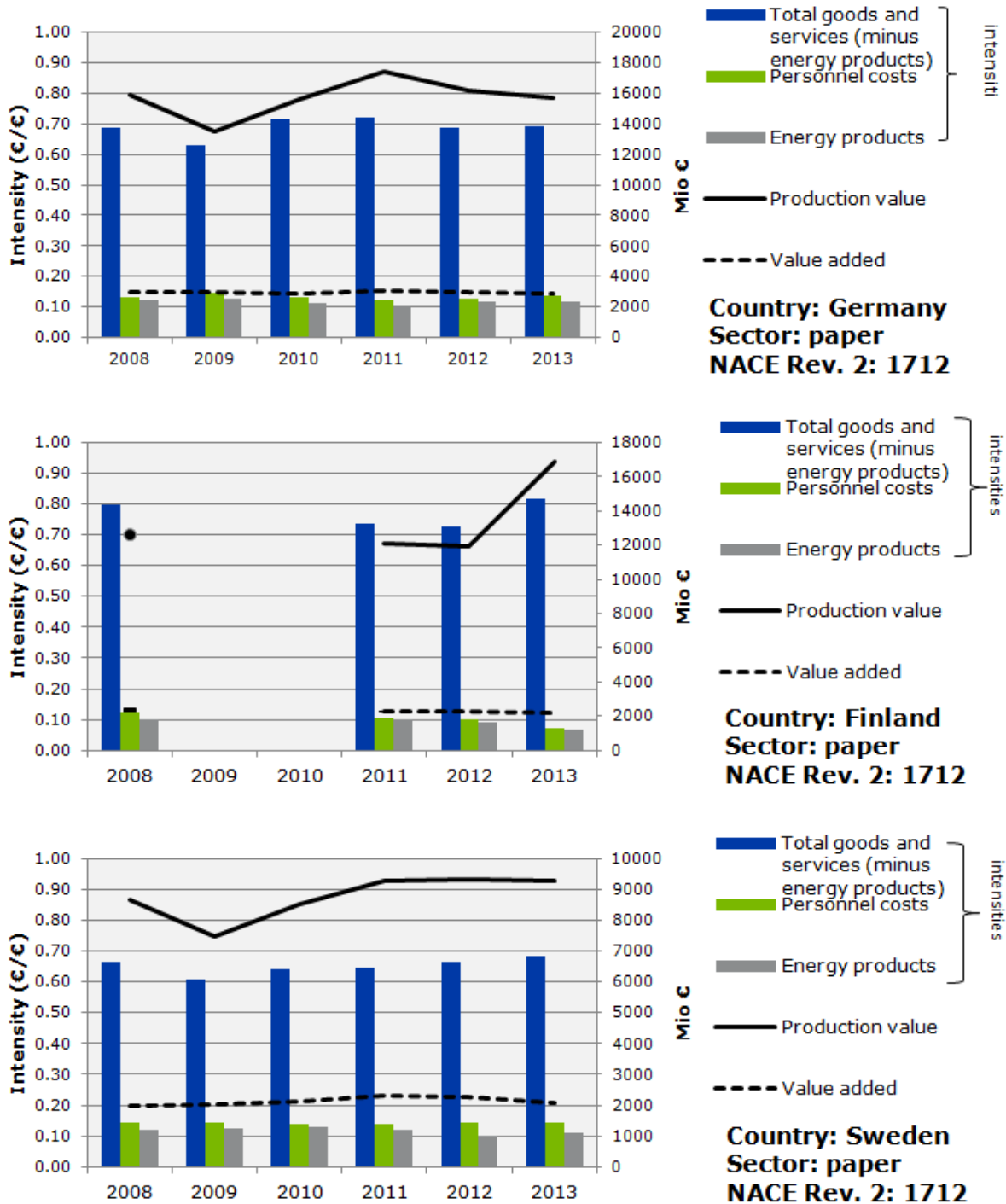
source: own illustration based on EUROSTAT, DESTATIS and www.scb.se

Concerning the cost structure in the different countries (see Figure 11), both in Sweden and in Germany, energy purchases are roughly 0.12€/€ of production value. In Sweden this value has been decreasing slightly to ca. 0.1€/€ over the past years. In Finland, energy purchases make up only around 0.08€/€ of production value. Personnel cost intensity (per production value) is around 0.15€/€ in Sweden, 0.14€/€ in Germany and 0.09€/€ in Finland. In 2015 the cost intensities of papermaking in Finland decreased mainly because of an increase in production value. A notable exception is purchases of goods and services (excl. energy) which remains high at 0.8€/€ in Finland 2015. In Germany and Sweden, goods and services (excl. energy) are in the order of 0.7€/€ (per production value). The high share of purchases for goods and services points to the importance of raw material cost such as wood, (chemical) pulp or recycled paper.

The sum of the different components is on average 0.94 €/€ in Germany and Finland and 0.91€/€ in Sweden which indicates a slightly better situation for the Swedish industry. Still, in all three countries, the potential profit margin is likely small.

The different cost structure of the three focus countries is likely rooted in a difference in product portfolio and industry structure. In the Nordic countries, fine paper mills have often been built adjacent to a pulp mill (JRC 2015) which allows synergies e.g. through the use of black liquor also visible in the different energy input structure in comparison of Sweden and Germany above. This likely contributes to lower cost for energy products.

Figure 11: production cost structure, production value and value added for NACE Rev. 2 1712 - Manufacture of paper and paperboard Germany (top), Finland (middle), Sweden (bottom)



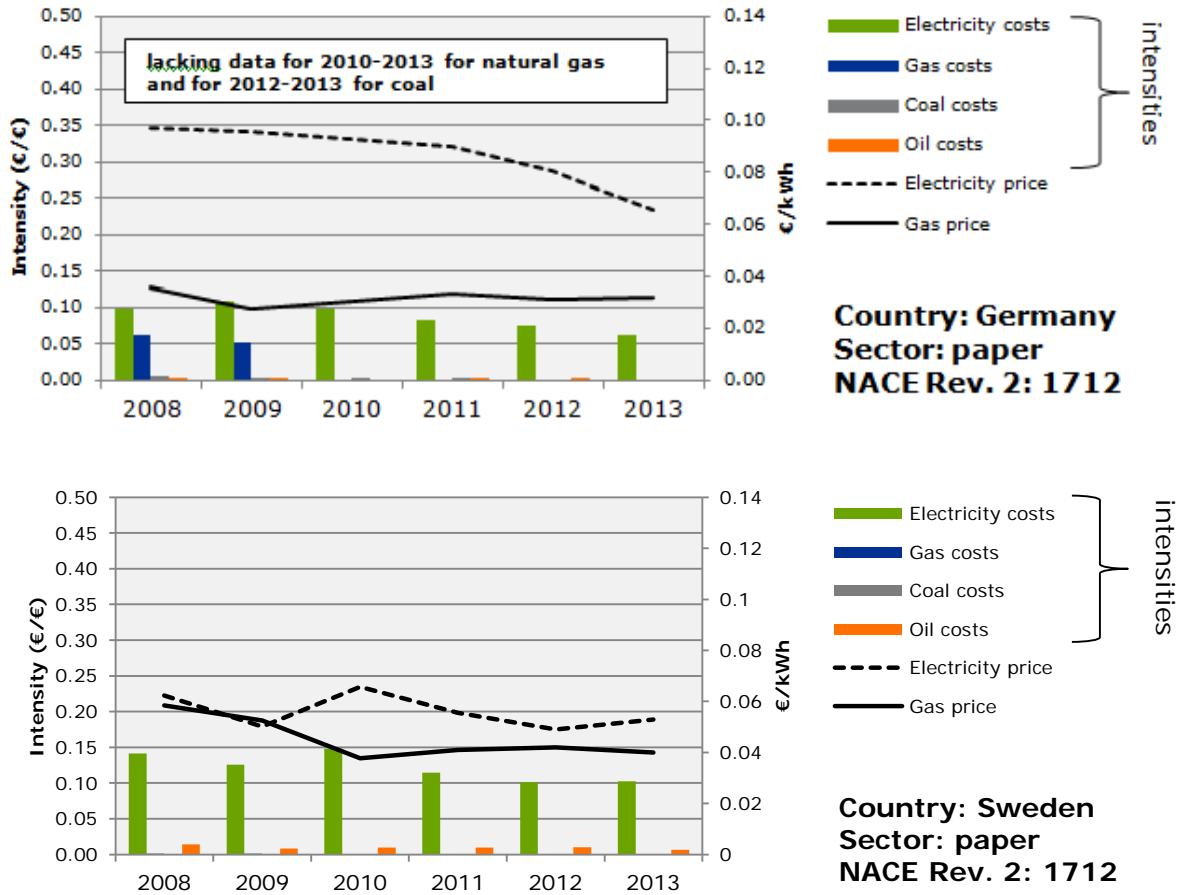
Source: own illustration based on Eurostat Structural Business Statistics

Based on energy consumption and prices, a bottom-up calculation of energy cost by energy carrier was realized for Germany and Sweden (see Figure 12, for Finland energy consumption was not available at NACE 4-digit level).

Electricity cost intensity is estimated at 0.1€/€ in Germany initially and then strongly decreases to 0.06€/€ associated with a decreasing electricity price. Natural gas consumption is only available for 2008-2009 and indicates a cost intensity of 0.05€/€. Coal cost play a minor role. It has to be noted though, that the cost intensities are likely an overestimation. The sum of the bottom-up calculated energy cost (consumption multiplied by prices) for Germany is by 26%-36% higher than the cost for energy purchases given in Eurostat (years 2008 and 2009 only, because of data constraints). One important factor driving this difference is self-generation of electricity. The consumption values include electricity that has been generated on site. In Germany, the sector 1712 supplied 35% of its electricity demand from self-generation. The predominant energy carrier used in self-generation is natural gas with roughly 75% followed by biomass with roughly 25%. Water power has a negligible share of roughly 1% (VDP 2014). At European level, CEPI reports for the pulp and paper industry self-generation of roughly 50%. Hence, a much lower amount of electricity needs to be purchased which would lead to lower electricity cost. The fuel cost (mostly natural gas) are already included. Also high prices could lead to an overestimation of cost. Within an analysis for the German government, the electricity price for paper mills in Germany e.g. has been estimated to be 6.5 ct/kWh for big companies with full privileges (up to 13 ct/kWh for very small companies without privileges) (ISI & Ecofys 2015). Hence, except for 2013, the prices used in this study for German papermaking seem to be rather high and in particular big companies may be able to purchase electricity at lower cost.

In Sweden, the bottom-up estimated energy cost are only 1% to 11% lower than the purchases for energy products given in Eurostat, except for the years 2008 and 2010. In these years, the bottom-up estimated cost in Sweden also exceed the value of energy purchases given in Eurostat by 23-30%. The driving factor are likely alternative fuels such as biomass that is much used in Sweden. These energy carriers have not been considered in the cost calculation because they are diverse and it is unclear at which price they should be included.

Figure 12: energy cost intensity by energy carrier, electricity and gas price for NACE Rev. 2 1712 - Manufacture of paper and paperboard in Germany (top) and Sweden (bottom)

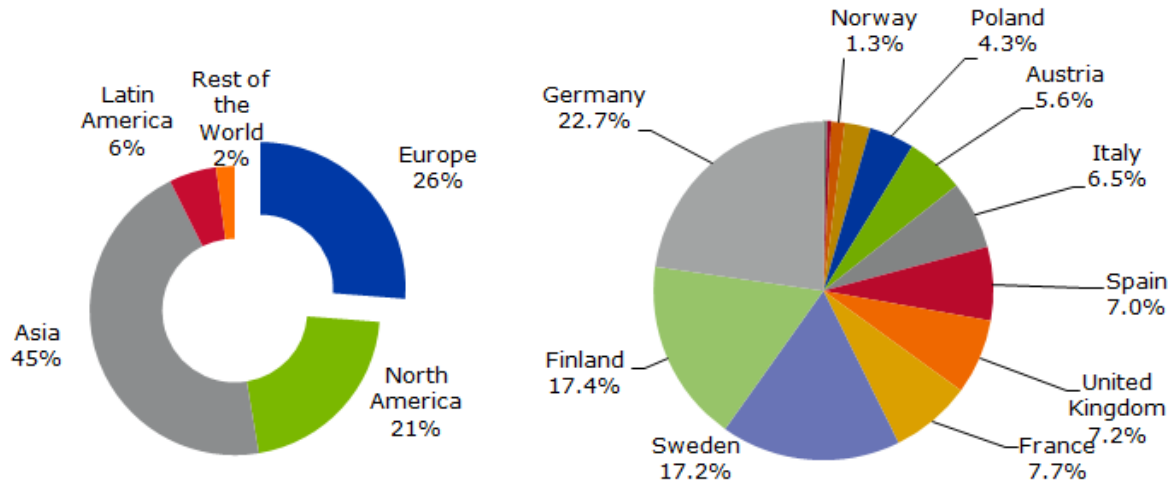


source: own illustration based on EUROSTAT, DESTATIS and www.scb.se

Market situation

Europe produces roughly a quarter of worldwide paper and paperboard. This is only topped by the world's largest producer Asia. North America accounts for 21% (see Figure 14) European production

of paper and paper board (right)



own illustrations based on data from CEPI and VDP

The main producer countries and market situation are different depending on the paper grade. While the market situation for graphic papers is challenging since demand is declining, the outlook for packaging and tissue papers is good.

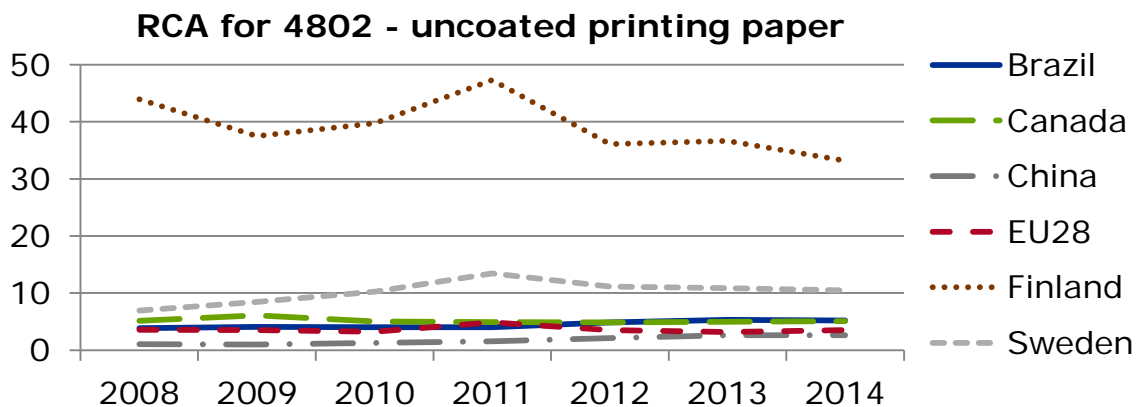
- Graphic papers: Newsprint production has traditionally been concentrated in Finland and Sweden. With the increasing use of recycled fibres, the industry relocated to consumption centres such as Germany, France, the UK and Spain (JRC 2015). Wood-containing printing and writing papers, i.e. papers based mainly on mechanical pulp, are produced mainly in Finland and Germany together supplying roughly 60 % of total production while the production of wood-free printing and writing papers, i.e. papers predominantly based on chemical pulp, is broader distributed. Apart from Germany, Finland, and Sweden also France, Italy and Austria play a leading role, and most other European countries also produce a significant amount of wood-free printing paper (JRC 2015).
- Cartonboard based on recycled fibres is mainly supplied by Germany, Italy, the Netherlands and France while cartonboard from virgin fibres is concentrated in Finland and Sweden (JRC 2015, p.14).
- Tissue production is concentrated in Germany, Italy, the UK, France and Spain and the market is concentrated: Four European producers account for around 40% of total production; two American companies for another 20% (JRC 2015, p.14).

Based on UN comtrade trade data for selected products in the paper industry (HS2007: 4801 newsprint, 4802 Uncoated paper and paperboard, and 4804 uncoated kraft paper (produced from

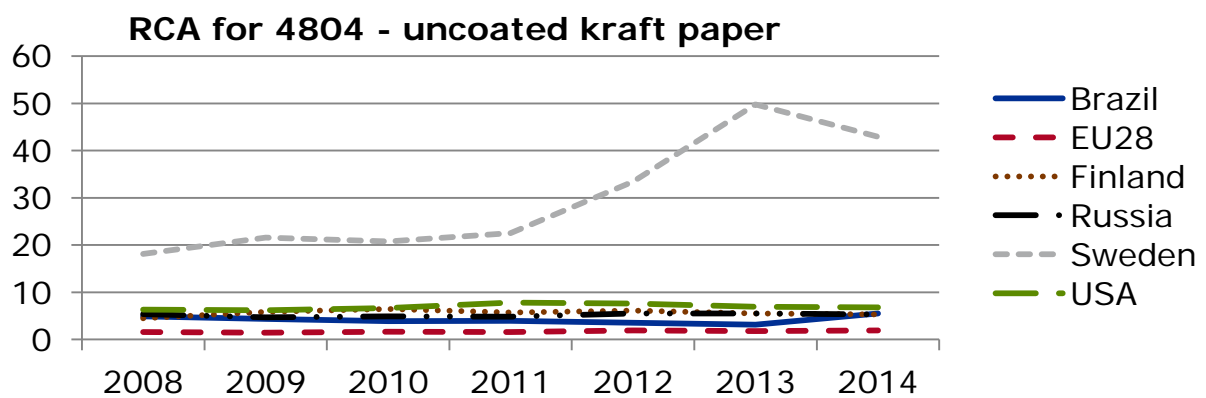
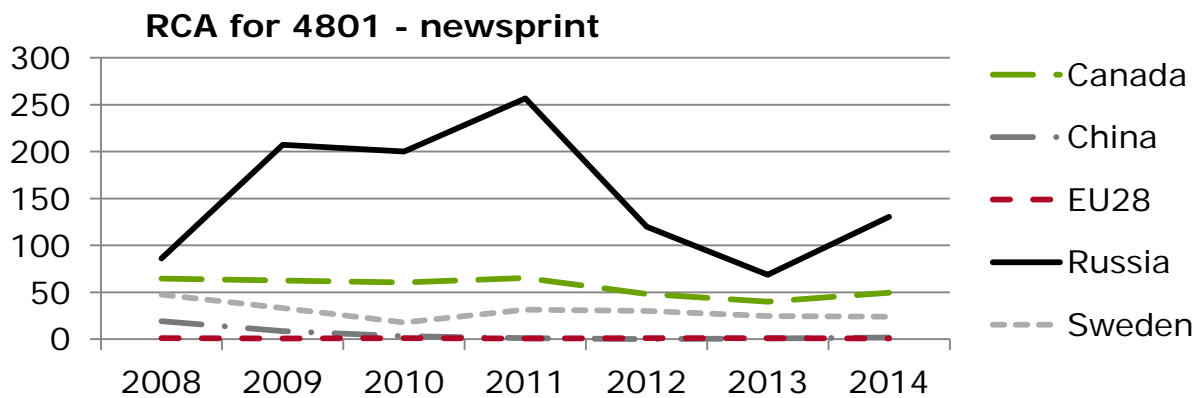
chemical pulp))¹¹ the revealed comparative advantage (RCA) was calculated. It is an indicator for the relative export performance of a certain product compared to the overall export strength of the country.

The analysis reveals that Finland seems to have a comparative advantage in uncoated paper and paperboard for printing and writing purposes that is decreasing over time while the indicator is slightly increasing for Sweden (though at a lower level) (see Figure 14). Concerning Newsprint, Russia had a very high RCA in the years 2009-2011 and the high values indicate a comparative advantage. Canada follows with the second highest values, Sweden is number three. For uncoated kraft paper, the RCA indicates a comparative advantage for Sweden, increasing from 2009-2013, with a minor drop afterwards. The values hint to specialization of the focus countries and existing advantages e.g. from good access to raw materials such as wood. In particular in Finland and Sweden, the values indicate a much stronger export orientation than for the industry on average. But even for the EU-28, typically at the lower end of the graph values are still above one, which implies a more than average export ratio.

Figure 13 Revealed comparative advantage for selected paper products (Code 4802, 4801, 4804) for selected countries 2008-2014

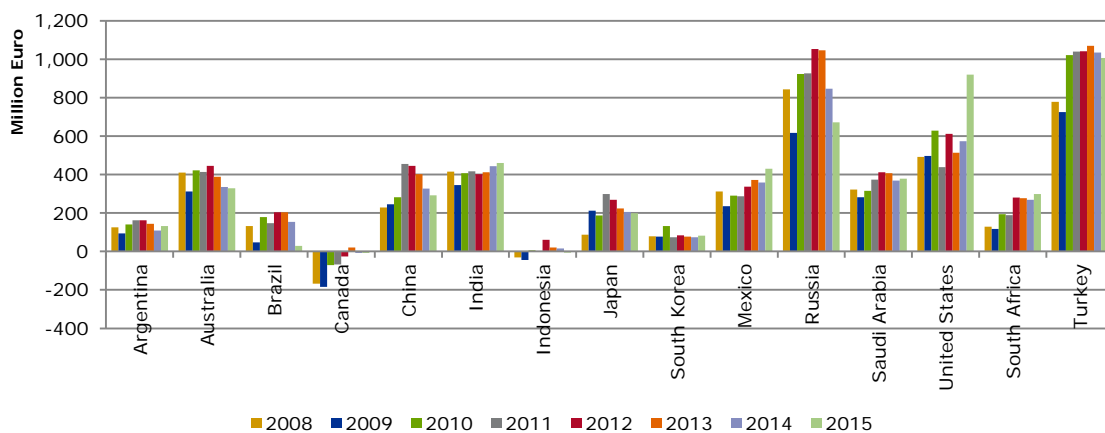


¹¹ 4802 Uncoated paper and paperboard, of a kind used for writing, printing or other graphic purposes, and non perforated punch-cards and punch tape paper, in rolls or rectangular (including square) sheets, of any size, other than paper of heading 48.01 or 48.03. 4804 Uncoated kraft paper and paperboard, in rolls or sheets, other than that of heading 48.02 or 48.03.



Looking at the export-import situation for paper and paperboard in total (i.e. the entire NACE 1712), the major trading partners (based on net exports) are Turkey and Russia followed by the USA. Canada is a net exporter towards the EU (Figure 15).

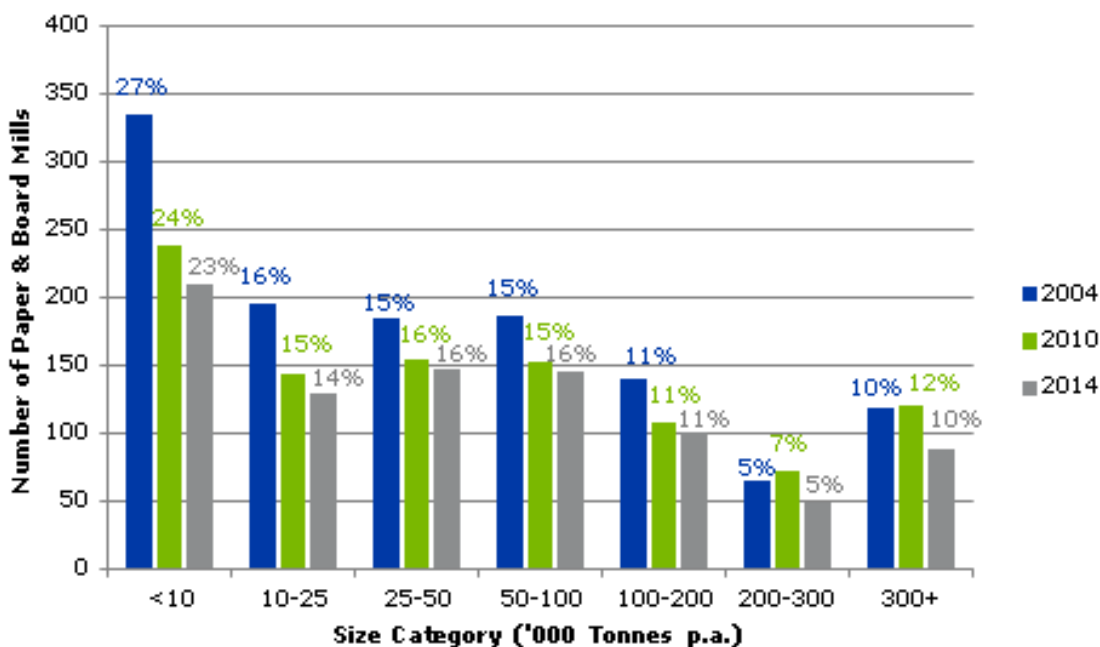
Figure 14 Net exports of paper and board from the EU to G20 countries



own illustration based on data from Eurostat EU Trade Since 1988 By CPA_2008 (DS-057009)

The paper industries are undergoing a process of globalization and consolidation according to JRC (2015) which has not yet come to an end. Over the past years, the number of paper machines decreased (see Figure 16). According to JRC (2015) there is a trend to close smaller production units and build larger facilities. This may be driven by economies of scale and leads to a concentration of production in few large often multinational companies. Importantly, after an initial increase in large mills despite a decrease in the total number of mills, the recent years show that the decline in mills also affects large production units (see Figure 17). There are still many small companies in the market though, that survive through the use of niche strategies on the market (JRC 2015).

Figure 15: Number of paper mills by volume (in CEPI associated countries) 2004, 2010 and 2014



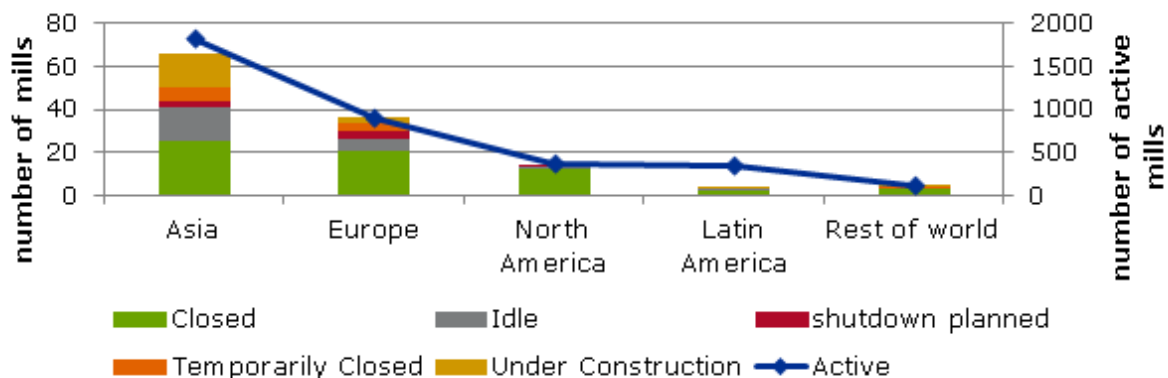
Source: own calculation and illustration based on CEPI data, CEPI 2009, 2011, 2014

New investment is attracted by emerging and growing markets since proximity to demand is an important locational factor for paper making. Concerning tissue paper, within Europe, this implies that the importance of Eastern European countries is growing, in particular since demand in Southern Europe has been affected by the economic crisis while strong growth is expected in Russia, but also in Poland and Romania. Market conditions for packaging are better, but industry is also facing pressure to keep prices down because importers try to gain market share in particular on virgin fibre products (RISI 2015, for white cartonboard). The market for recycled products is so far less targeted by importers and more stable. The recycling rate of 72% reported by CEPI for Europe is likely contributing this, since the availability (and pricing) of raw materials is paper is a locational factor. It adds to this, that certain customers (e.g. in Germany) value graphic papers made from recycling.

Idle capacity is relatively high in Asia. This is in line with reports on overcapacity in China in many sectors “that are considered low-tech or when technology is inexpensive or widely available” (EUCCC 2016). Overcapacity has been driven by number of factors, among other subsidized input prices and local protectionism (EUCCC 2016). China has become a net exporter of paper products, but still, many of its companies are not competitive on international scale (according to EUCCC 2016). This meant declining margins and severe problems for the Chinese industry.

The majority of paper mills under construction is located in Asia, even though mills are also being built in Europe. A more detailed analysis would be needed to interpret the data including closures also in the light of modernization, overcapacity and consolidation.

Figure 16: Number of paper mills by activity status and region of the world



Source: own illustration based on RISI Asset database

International competitiveness

Papermaking is a capital-intensive activity. This can work as an entry barrier for small firms that have difficulty in acquiring the required financial resources. There is a trend of market consolidation in the EU with few multinationals dominating the market. However many smaller companies and family-owned businesses are still also producing in the EU. One reason may be that they follow niche strategies that circumvent (price) competition in commodity paper products.

So far, the European paper industry has succeeded to be among the technological leaders which helped to maintain competitiveness with other regions of the world, despite comparably high production costs (JRC 2015). The industry faces challenges whenever cost of production and raw materials increase. The development of paper industries in Asia and Latin America adds to the problems (JRC 2015). Since many companies are multinationals the competition takes place not only between companies but also within, i.e. at which location new investments will be realized. Furthermore, competition does not only take place directly in the home market but also via shifted import and export balances when global competitors gain market share in European export markets.

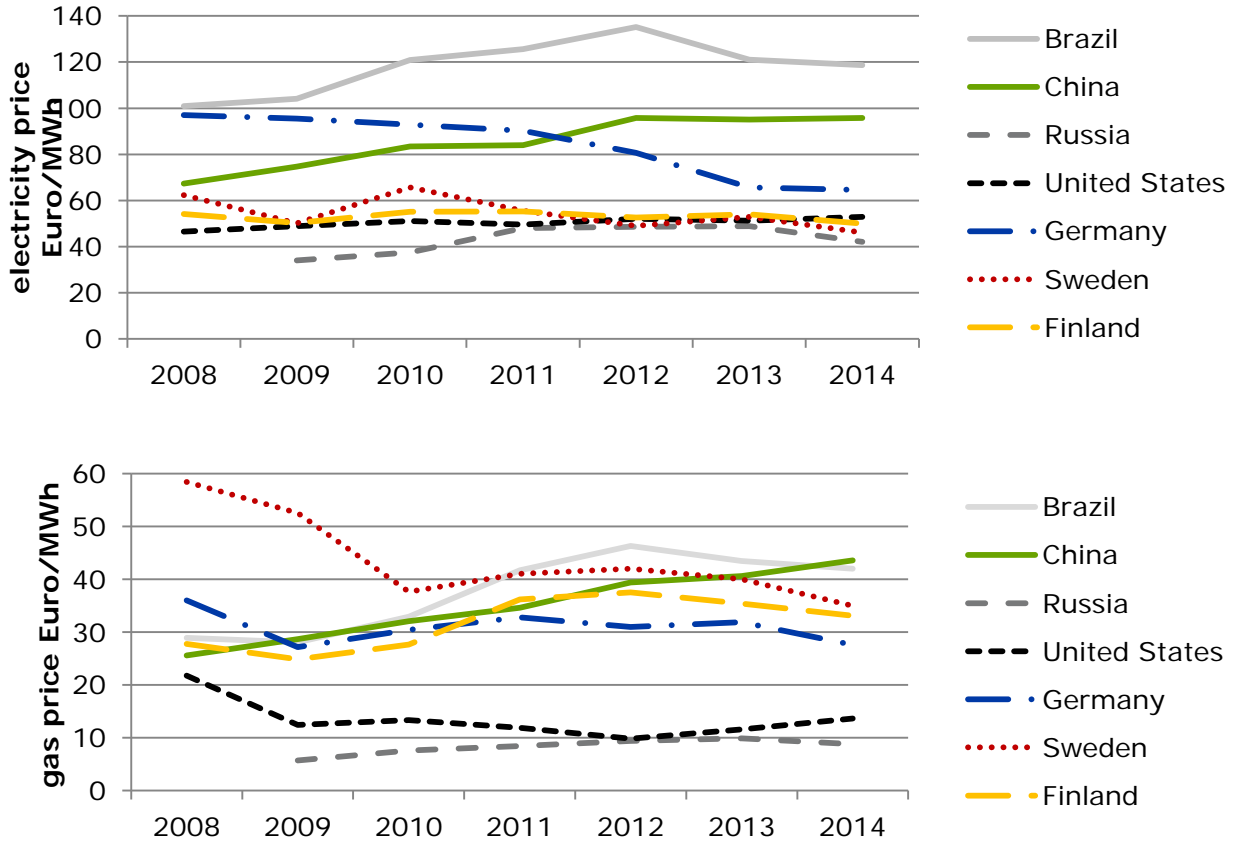
Major actors in global competition come from Russia, China, India and other Asian regions. These have invested substantially in new capacities and are playing an increasing role in reshaping raw material supply and demand. This is particularly true for China, where around 50 % of the total new capacities over the last five years have been built furthered i.a. by state subsidies. This is a severe problem since both the US and the EU have been targets for cheap Chinese imports and are actively pursuing anti-dumping measures. The problem has been recognized by China (EUCC 2016) and it remains to be seen when discussed measures to fight the problem such as progressive electricity pricing take effect. Currency exchange rate and freight rate swings also impact on competitiveness as well as market openness. Market openness might threaten European companies since European markets are fully open, while many emerging markets have tariff and non-tariff barriers (JRC 2015). Apart from China dumped imports may also be a threat from other countries. E.g. in the US also Brazil, Indonesia and Australia (but also Portugal) have been accused of dumping.¹²

Comparing energy costs it can be seen that in particular for Russia and the USA, price data indicates that there may be an advantage at the cost side for natural gas. Even though the annual report from Smurfit Kappa for the year 2015 indicates that realized prices of the European Paper industry may be lower than indicated: they state €22.82 /MWh as peak price and give €17.48 /MWh as the price for natural gas at the end of 2015 (Smurfit Kappa 2016). This is substantially lower than the prices calculated for the paper industry within this project based on task 1 data.

Concerning electricity prices, for China and Brazil at least the available price data indicates rather high prices similar as for Germany until 2014. However, it is not clear whether paper making firms actually pay these prices. Similar to European countries, privileges may apply that lead to lower prices for paper mills. For example in China, subsidized prices are discussed as one reason for the existing overcapacities (EUCCC 2016).

¹² <http://www.duluthnewtribune.com/business/3919527-us-agency-considers-white-paper-unfair-trade-case>, last accessed 28.3.2016

Figure 17: Electricity and gas prices for paper and board in selected European countries and industrial electricity and gas prices for selected G20 countries



own illustration based on price data task 1 and IEA database on energy prices and CEIC data

Case study 3: Aluminium

Product description

Similar to the steel industry aluminium is an energy intensive bulk product that can be produced via two major production routes:

- Primary production (PA), which uses bauxite and electricity as main inputs.
- Secondary production (SA), which uses aluminium scrap and fuels as major inputs.

Aluminium is one of the main products of the non-ferrous metals industry. The non-ferrous metals industry has been responsible for 3% on the industrial energy demand in 2013 (4% of industrial natural gas demand, 6% of industrial electricity demand) (Eurostat 2016).

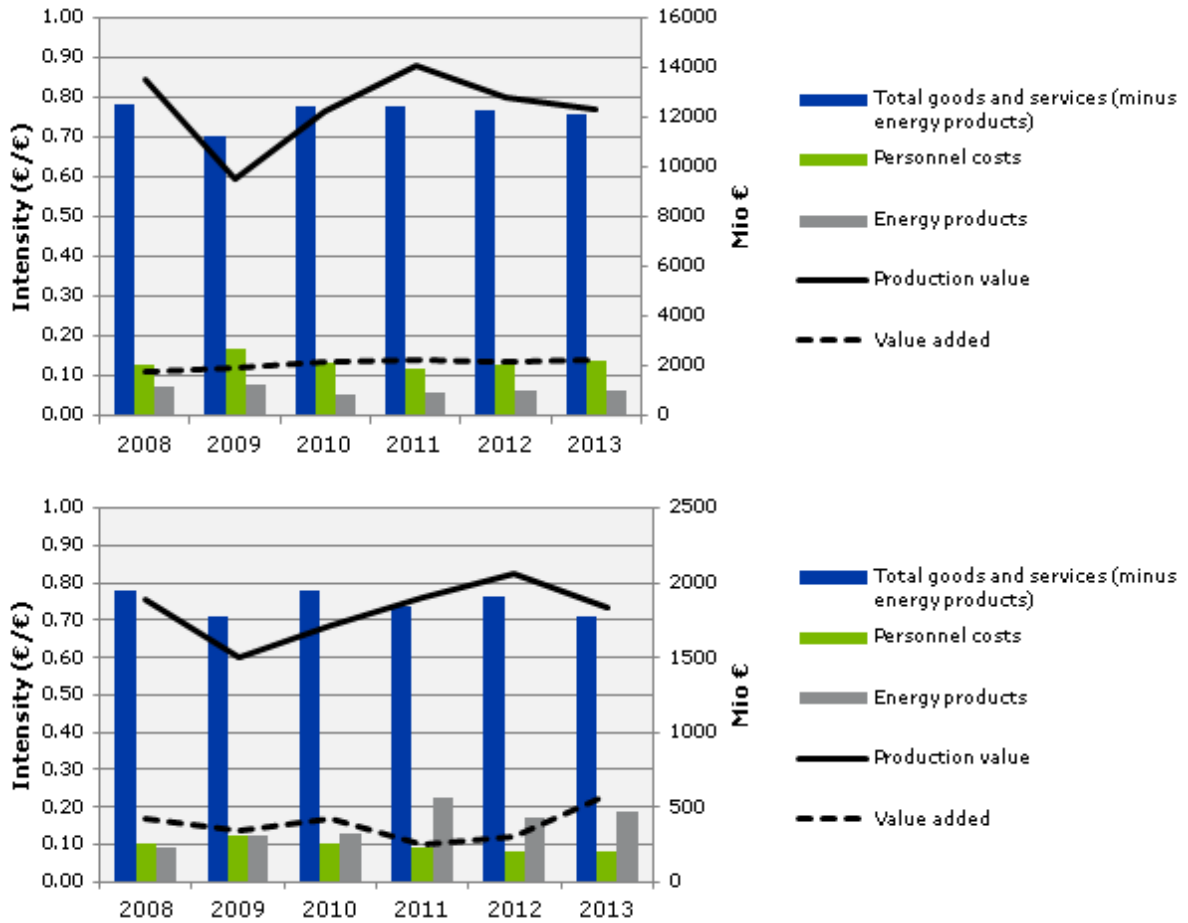
Primary production is much more energy intensive than secondary aluminium production. The most energy-intensive step in this process is the electrolysis where aluminium oxide is turned into pure aluminium. The primary aluminium energy demand is mostly met by electricity. Fleiter et al. 2013 estimated a specific energy consumption level by process as following: PA 58.84. GJ/t (53.64 GJ/t electricity, 5.2 GJ/t fuels), SA 10.67 GJ/t (1.67 GJ/t electricity, 9 GJ/t fuels). As with the steel sector, data are not available to disaggregate primary, secondary and downstream production within the scope of this project.

Product cost structure

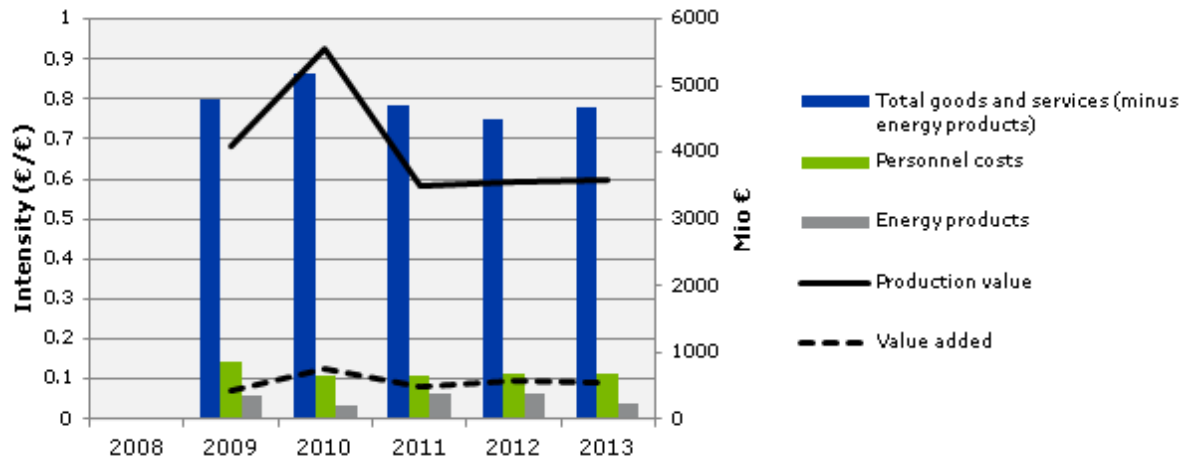
Comparing the German, Greek and French (major value added contributors of the EU28) production cost structure shows, that Greece has a rather high energy product cost intensity to production value. With an average of approximately 0.16 €/€ by product costs to production value between 2008 and 2015 it is significantly higher than in Germany (0.06 €/€) and France (0.05 €/€). Similar to the steel industry these intensities do reflect a country's specialisation.¹³

¹³ The underlying NACE class 2442 for the analysis includes several products among them semi-finished products as well as alloyed aluminum (usually delivered as bulk as well). Alloyed aluminum up to customer requests usually creates a higher value added which may contribute to lower intensities e.g. in Germany and higher cost intensity in Greece with little downstream activity.

Figure 18: Production cost structure (total goods & services¹⁴, personnel costs, energy products), production value, and value added NACE 2442 for Germany (top), Greece (middle), France (bottom)



¹⁴ Total goods and services have been calculated from Eurostat data. Eurostat total purchases of goods and services and contain by definition also energy purchases. To avoid double counting purchases of energy products in value were subtracted from total purchases of goods and services.

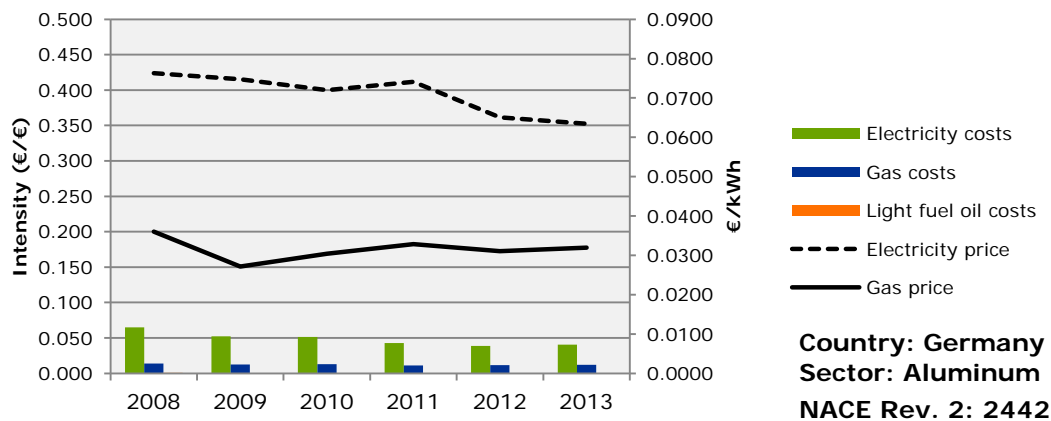


Source: own illustration of Eurostat Structural Business Statistics

As energy consumption data is very limited on NACE 4 level, an analysis on energy carrier level could only be made for Germany. Electricity is the most important energy carrier in Germany for aluminium production (NACE 2442) and has a comparably high intensity to production value (2008 to 2013 average 0.05 €/€ for electricity and 0.01 €/€ for gas; Figure 20). Other energy carriers like petroleum coke and LPG are also relevant for the aluminium production but no detailed time series for these energy carriers have been available.

Similar to the steel industry the available data on energy consumption does include own generation of electricity and fuels. In 2012 in Germany, the sector 2442 supplied approximately 0.3% of its electricity demand from self-generation. In addition, specific companies might have access to lower prices than assumed in this analysis. For this reason the calculated energy costs by energy carrier are higher or lower than the available statistical information on energy product purchases.

Figure 19: Energy cost intensity by energy carrier on production value steel NACE 2442 (2008-2013)

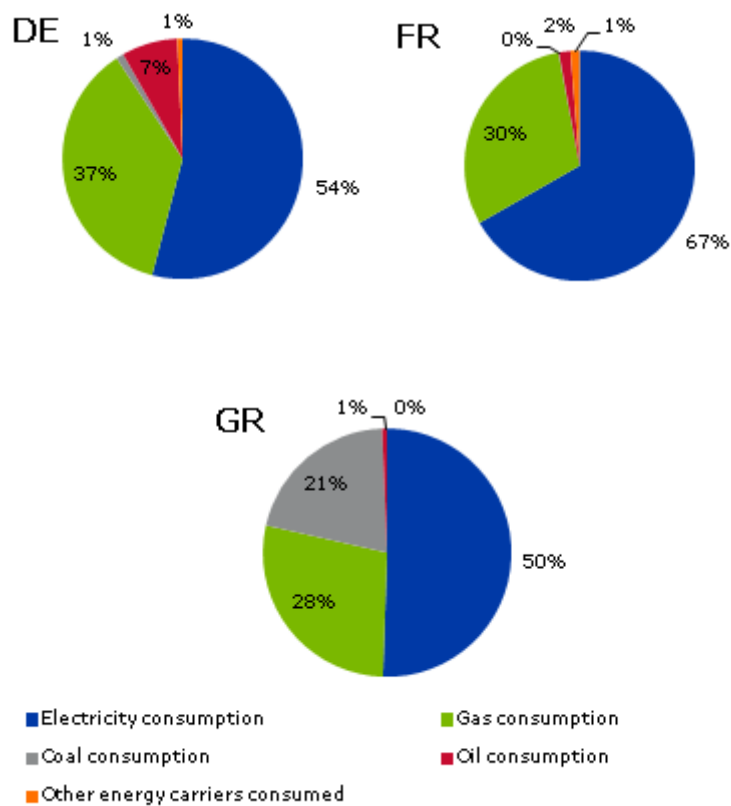


Country: Germany
Sector: Aluminum
NACE Rev. 2: 2442

Source: own illustration of DESTATIS

Analogies for the other two focus countries cannot be drawn as they experience rather different energy consumption by energy carrier for the non-ferrous metals industry (Figure 21). Greece for example has a very high share of coal consumption in its energy carrier mix, while France needs nearly no oil but more electricity than Germany.

Figure 20: Energy consumption by energy carrier non-ferrous metals (2012)



Source: own illustration of Odyssee data

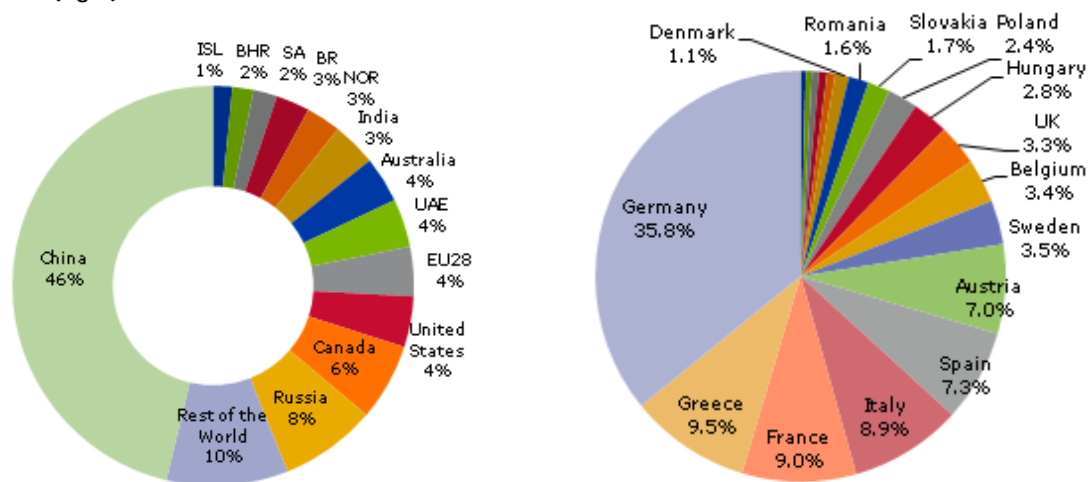
Market situation

Aluminium still faces an increasing demand. It is mainly used in the automotive industry, construction, engineering, and packaging. Aluminium is also used as a substitute for other energy-intensive materials (e.g. light-weight strategies in automotive industry). In comparison to e.g. the steel industry, the primary aluminium industry has a much more heterogeneous market characterized by a variety of small and medium players. Aluminium production can be differentiated in three main groups: unwrought aluminium, aluminium semis, and aluminium products.

The EU28 does not play such a major role in the electricity intensive global primary aluminium market. China, Russia, Canada and the United States account together for more than 60% of the global primary aluminium production (Figure 22). Since 2010 the ranking in the global primary aluminium production shares did not change at all. However absolute shares changed slightly, showing an increase of Chinas share in global production from 39 to 46% while Russia, Canada, the EU28, the UAE, India, Norway, Brazil, Iceland and the rest of the world were losing ~1% each (e.g. EU28 from 5% in 2010 to 4% in 2013).

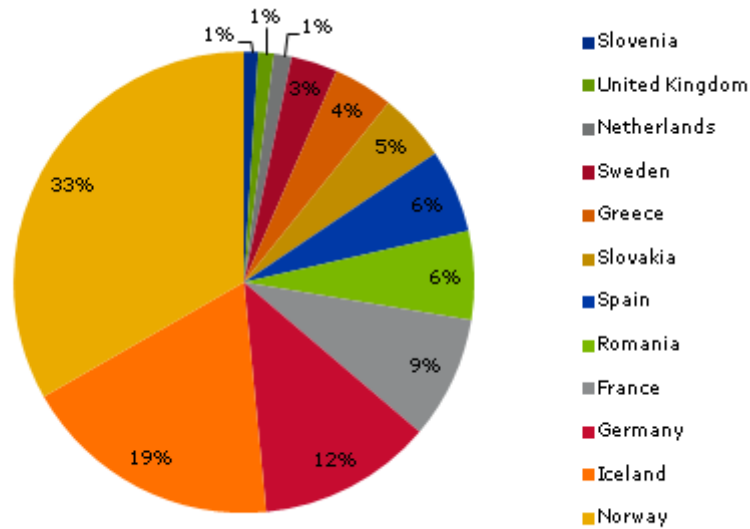
Norway is the largest primary aluminium producer geographically located within Europe and produces nearly as much primary aluminium as India. Primary aluminium production Europe is often located in proximity to hydroelectric and nuclear power plants (Fleiter et al. 2013), explaining the high production shares in Norway and Iceland and France (Figure 23).

Figure 21: Global primary aluminium production shares (left), EU28 aluminium production value added (NACE 2442) distribution (right) 2013



Source: own illustration of USGS 2015 & Eurostat Structural Business Statistics

Figure 22: European primary aluminium production shares 2013



Source: USGS 2015

International competitiveness

Primary aluminium is a globally traded (London Metal Exchange) and consequently highly competitive product. A large share of primary aluminium is imported to Europe, while exports are probably mainly aluminium products. Within the scope of this project it has not been possible to study this in more detail. The following data refer to the class 2442 which covers both aluminium production and aluminium products: Europe's major trading partners are Russia, the United States, Turkey and China (Figure 24). Europe is a net importer especially of Russian and Turkish aluminium products while the United States, Saudi Arabia, Mexico and South Korea are the net importers of European aluminium products (Figure 24). Net imports from Russia, as well as China increased strongly in 2014 respectively 2015. With respect to China, there is a problem of overcapacity which may lead to downwards pressure on prices and also affect international markets. It remains to be seen how China addresses this problem, electricity pricing in the aluminum industry has been reformed and further measures are discussed see e.g. EUCC 2016.

Figure 23: Total trade value (top) and net exports (bottom) of the European Union (EU28) NACE 2442 (2008-2013)



Source: own illustration of Eurostat EU Trade Since 1988 By CPA_2008 (DS-057009)

As shown for the German example its energy costs are strongly driven by electricity prices that can vary regionally. Russia and Norway in particular seem to have cost advantages due to their lower electricity prices (Figure 25). Also two of the main EU28 producers (Greece, France) have comparatively low electricity prices explaining their relatively high share in EU28 primary production.

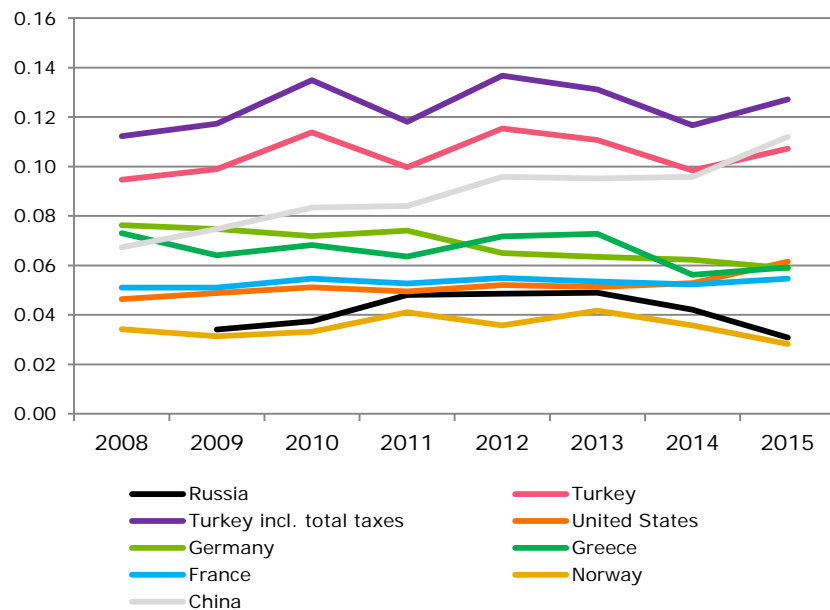
Germany's electricity price is also comparatively low due to certain exemptions and privileges regarding taxes and levies, as in the case of support to renewable energy and the ETS indirect cost.

For the standard product primary aluminium, on product and firm level, after electricity costs, raw materials (anode and alumina) cost are of major importance followed by capital cost and then, labour costs. Grave et al. 2015 have shown that without privileges the electricity costs for one tonne aluminium might have exceeded the market price for aluminium. The analysis has been made for two

companies, which produce both primary and secondary aluminium in different degrees of vertical integration and has shown, that companies react differently on increases of electricity prices – while for one firm the increase has been existence threatening it wasn't for the other firm (Grave et al. 2015).

For primary aluminium, production costs are strongly driven by electricity prices. The ability of some German primary aluminium production sites to work in close cooperation with the downstream industries to satisfy their special needs via customized products can support competitiveness of individual firms. However, the picture can be very different on company level as the competitiveness of individual firms is strongly dependent on their product portfolio. Firms which do not produce premium products might face losses when confronted with high electricity prices (less possibility to transfer price increases to the downstream industries). The competitiveness of European aluminium producers also depends on additional company specific factors including amongst others infrastructure, transport costs, proximity to and networking with customers, and integration with more customized downstream activities. On branch-level, due to intra- and inter- industrial linkages effects on other areas of the industry are possible (Grave et al. 2015).

Figure 24: Electricity prices (€/kWh) for selected countries (2008-2015)



Source: own illustration of price data task 1 and IEA database on energy prices and CEIC data

Case study 4: Hollow glass

Product description

Container glass makes up for roughly two thirds of European glass production. Container glass products encompass bottles and jars used to package and preserve food and drinks but also other products such as perfumes, cosmetics or chemicals. Containers for perfumes, pharmaceuticals and cosmetics are usually a higher value production compared to bottles for beverages such as beer or soft drinks. These products are to a large degree commodity products and the industry is very dependent on the food and beverage industry as a customer of the products. Domestic glass, which is also part of NACE 2313 only accounts for a relatively small fraction of total output: 2% of total glass production or less than 5% of hollow glass production.¹⁵ Hence, the focus of this case study will be on container glass.

Mean energy consumption per ton of produced container glass is 8.7 GJ net calorific value/t net product (JRC 2013). The variance is substantial with a minimum consumption of 3.7 GJ/t and a maximum of 31.5 GJ/t. For bottles and jars, the maximum value is 16.8 GJ/t, i.e. the very high levels occur in the production of flaconnage. The much higher specific consumption is related to the higher quality glass required that needs higher temperatures for melting as well as certain finishing processes but also to the typically smaller furnace size since these are less efficient compared to large smelters. For bottles and jars higher specific consumption is associated with finishing processes, too. The lower end of the range is typically reached in plants with a high share of cullets. Specific energy consumption increases with the age of the furnace because insulation is deteriorating. The increase in energy consumption is in the range of 1.5%-3% per year depending on how well the furnace is maintained (JRC 2013).

The glass sector is capital-intensive and investment cycles are relatively long. Furnaces once built have a lifetime of approximately 20 years. Rebuilds of existing furnaces are likely to be used to upgrade capacity to match potential growth in the sector instead of building new plants (JRC 2013). A "rebuild of a medium sized furnace (around 250 tonnes per day) will cost in the region of EUR 3 to 5 million"¹⁶ while a green field investment for a new plant of a comparable size would be around 40 to 50 million Euro (incl. infrastructure) (JRC 2013).

Product cost structure

The sector NACE Rev 2. 2313 Manufacture of hollow glass accounted for roughly 1% of industrial electricity consumption and 2% of industrial natural gas consumption. Even though this seems low, it is still over proportional, since the share in total industrial value added of the hollow glass sector is

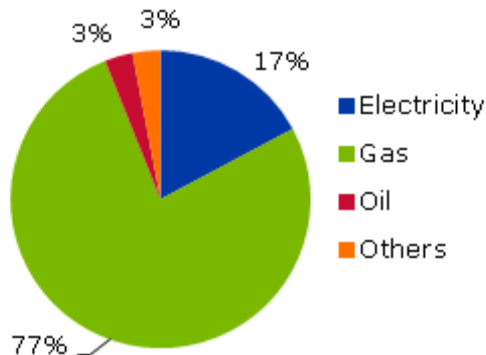
¹⁵ <http://www.glassallianceeurope.eu/en/main-glass-sectors>, last access 29.3.2016

¹⁶ Actual expenditure may be much higher, if the rebuild is used to implement any upgrades to the process.

only 0.3%. Please note, that these values are based on Germany where data has been available (year 2013) and are not representative for entire Europe. Germany is the biggest producer of hollow glass in Europe. Together with Italy and France it accounts for more than 50% of value added of the sector at European level. The following analysis focuses on these three countries, but statistical energy consumption information has not been available for all and hence is only presented for Germany. Again, this does not imply that the results are representative for Europe.

The biggest share of energy used in glass making is used to melt the glass with 75% (JRC 2013). The three main energy carriers used are fuel oils, natural gas and electricity. According to JRC (2013) fuel oil has been most commonly used in the past, but natural gas is by now predominant in several European countries. For lack of data availability only German data is presented.¹⁷ In Germany, gas accounts for 77% of the energy used in the sector manufacture of hollow glass followed by electricity with 17%. Oil and other energy carriers only account for 3% each (see Figure 26).

Figure 25: Energy mix in manufacture of hollow glass in Germany 2013 (NACE Rev 2 2313)



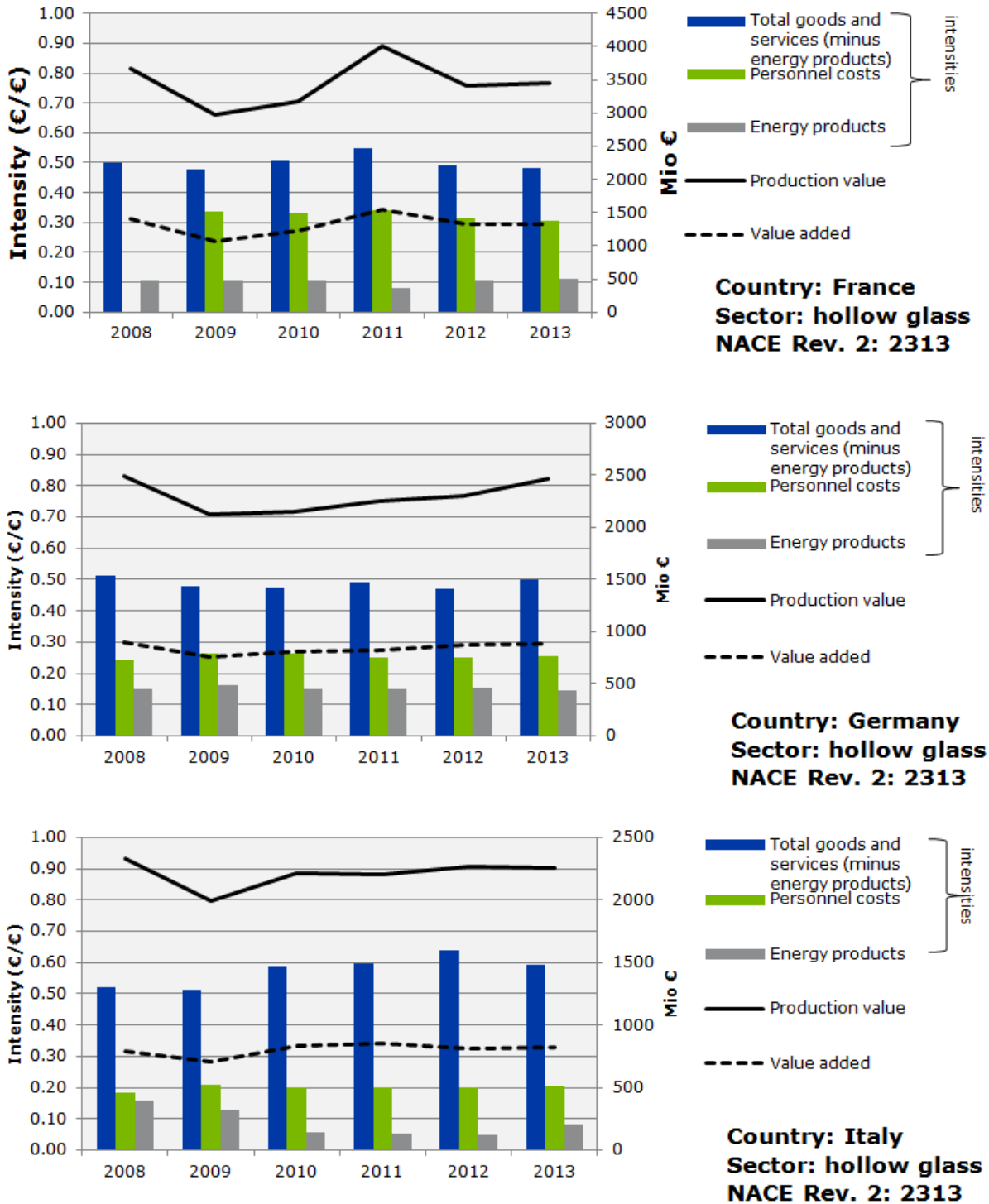
own illustration based on DESTATIS

The cost structure in France, Germany and Italy of the hollow glass sector is broadly similar: the dominating part is purchases of goods and services (excluding energy) with 50%-60% followed by personnel cost that make up 20%-30% of the production value and energy purchases with 5%-15%. The components together add up to roughly 90% of production value in all three countries. This can be interpreted as potential margins being similar in the countries under the condition that product prices that can be realized in sales are comparable. However, the structure of the different cost components is slightly different (see Figure 27). In relation to the production value, purchases of energy products are around 0.1€/€ in France, and slightly higher with around 0.12€/€ in Germany. In Italy, energy purchases were only roughly 0.5€/€ from 2010 to 2012 and are still below 0.10€/€ after an increase in 2013. In 2008 and 2009 energy purchases have been similarly high as in France and Germany with 0.15€/€ and 0.12€/€. In Italy, also relative personnel cost (in relation to production value) are lowest with 0.20€/€. In Germany, personnel cost intensity (to production value) is around

¹⁷ For France, data is only available for the sector manufacture of glass and glass products (231) that includes flat glass and glass fibres. For Italy no data is available on energy consumption in glass making.

0.25€/€ and in France even 0.30€/€. This could be due to product differences, but within this study we did not have sufficient data to check this hypothesis.

Figure 26: Production cost structure of the sector covered by NACE Rev. 2 2313 - Manufacture of hollow glass (as production cost intensity of purchases of total goods & services, personnel costs, energy products), production value, value added for France (top), Germany (middle), Italy (bottom)

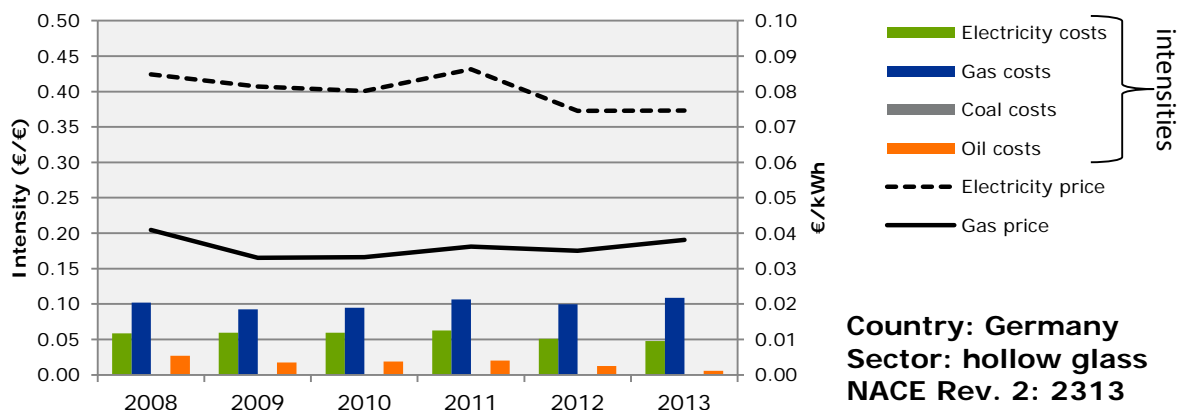


own illustration based on EUROSTAT

As energy consumption data is very limited on NACE 4 level, only for the case of Germany an analysis on energy carrier level could be made (see Figure 28). Natural gas as the fuel predominantly used also has the highest cost with an intensity to production value of roughly 0.1€/€. Electricity intensity has been around 0.5€/€ with a very light decrease attributed to a decrease in the electricity price since consumption has been more or less stable. Oil costs play a minor role and show a decreasing trend over the period. The decrease is caused by a significant decrease in oil use. Other energy carriers do not play a major role for hollow glass production.

The cost by energy carrier are overestimating the real cost, since the sum of the calculated cost by energy carrier is higher than the energy purchases published for hollow glass in Eurostat. The difference varies over the years from 5% to nearly 30%. One potential reason is self-generation of electricity which is not included in the data. No detailed data over the considered time period is available. In 2011 and 2012 self-generation of electricity in the German hollow glass sector has been 2.4% and 1.4% of demand (based on DESTATIS). This electricity does not need to be bought in the market, but part of the fuel used goes into electricity generation. However, this effect is not sufficient to explain the deviation. Another reason can be that specific companies might have access to lower prices than assumed in this analysis.

Figure 27: German energy cost intensities by energy carrier NACE 2313 (2008-2013)



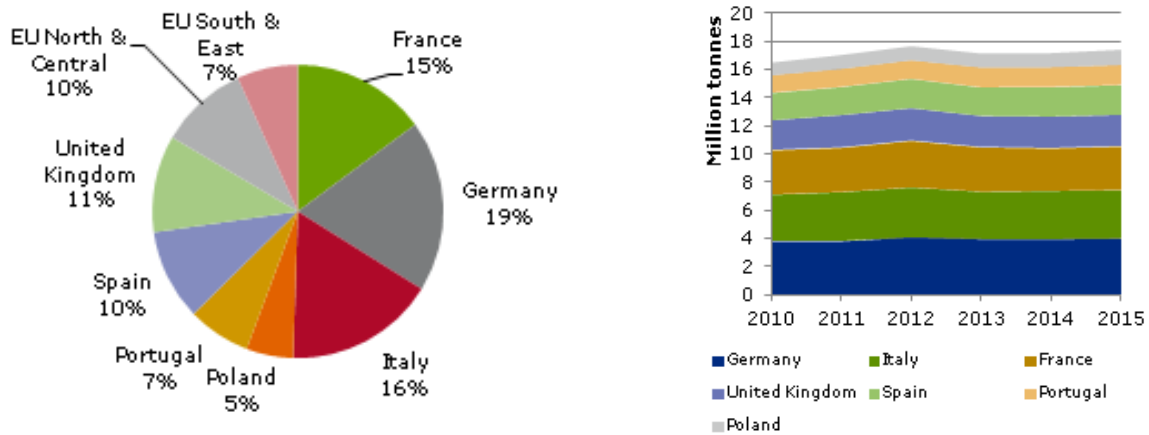
source: own illustration based on EUROSTAT and DESTATIS

Market situation

Concerning container glass, most of the production is sold to downstream industries such as beverages and food that use the containers for packaging and then sell the packed products into the European and international market. The relative importance of different customer industries varies between member states. In broad terms, the production volume (by weight) distributes among the three main customer industries as follows: 75% for beverages, 20% for food (mostly jars) and 5% for perfumes, pharmaceuticals and technical product containers.

Worldwide, Europe is the largest glass producer with roughly one-third of the total global market (Glass Alliance 2015). Within Europe, the three top producers of hollow glass are Germany, France, and Italy based on 2014 data (production volume in tons) (see Figure 29). Exports of European glass producers towards G20 countries had a value of roughly 8% of production value. This indicates that a major share of production is traded within Europe. Within the domestic glass sector, the situation is likely different: in lead crystal the EU is said to be a “major global player with 80-90% of all lead crystal glassware being produced in the European Union” and the market is described as mature featuring a long-term modest growth (Ecorys et al. 2008).

Figure 28: European container glass production distribution (2014) and development 2010-2015



EU North & central: Austria, Belgium, Denmark, Estonia, Finland, Netherlands, Sweden
 EU South & East: Bulgaria, Croatia, Czech Republic, Greece Hungary, Romania, Slovakia
 own calculations and illustrations based on data from FEVE¹⁸

The recent development of production levels has been relatively stable, even moderately increasing (see Figure 29) after previous declines that may be attributed to the financial crisis. The associated reduction in consumer demand caused reductions in production capacity in 2008 both by temporary and permanent closures of furnaces and “more importantly [...] seriously reduced the industry’s ability to access capital and investment” (JRC 2013). According to Glass Alliance Europe, with 10 new furnaces significant new investments have been realized close to Europe in Russia, Ukraine, Moldova, Macedonia, Serbia as well as Egypt and Saudi Arabia while several closures took place in the EU.

However, last year FEVE (2015), the industry association for container glass reported “a solid growth” for the European container glass industry confirming the stable growth of the last years. FEVE underlines that “all EU countries recorded positive growth although at different paces”. The highest

¹⁸ http://www.feve.org/index.php?option=com_content&view=article&id=10&Itemid=11 , last access 29.3.2016

increase was reported for Poland with 7.4% and also the increase in the South-East area (2.9%), North-Central area (2.1%) and France (2.2%) were higher than the growth on EU average (1.6%).

Growth happens even though container glass is challenged by alternative packaging solutions in particular plastic bottles and laminated cartons (JRC 2013). A potential reason for the positive market situation may be an interest of consumers in pure, green, and sustainable food and beverage packaging as well as the high quality image of glass in comparison to plastic and metal containers.¹⁹

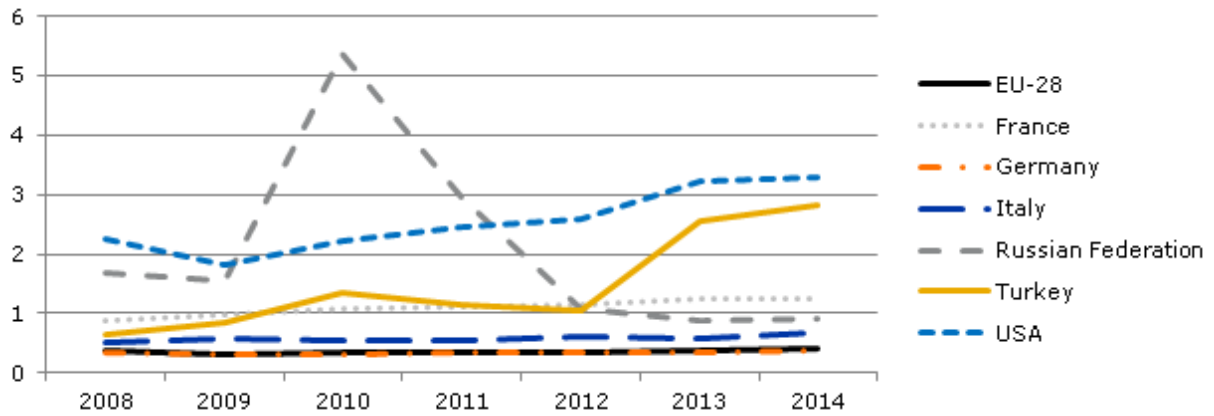
But significant growth has also taken place outside the EU with Turkey reporting an increase of 14.8%. This may increase competitive pressure for European producers. Based on UN comtrade trade data for the glass industry (HS2007: 710 Glass and glassware)²⁰ the revealed comparative advantage (RCA) was calculated. It is an indicator for the relative export performance of a certain product compared to the overall export strength of the country. The analysis reveals that in particular the USA seem to have a comparative advantage in the glass industry that is increasing over time. Russia had a peak in 2010 but otherwise shows a decreasing RCA (Figure 30, high RCA in comparison with the other focus countries). Notably the RCA for glass in Turkey strongly increased over the past years. This may be an impact of capacity expansion (see above) and hint to increasing competitive pressure since already today, Turkey is one of the top import origins after China. China (not included in the graph) has an RCA substantially below 1 and decreasing.

Within the EU member states considered, France has a RCA for glass slightly above one indicating that glass is slightly more export oriented than French industry on average. Italy and Germany both have RCAs significantly below 1. One reason for rather low RCAs may be that glass is to a large degree traded rather locally while export takes place of the packaged products for which the glass containers are used.

¹⁹ <http://www.glassonline.com/site/news/channelname/Containers/channel/136/id/24460>

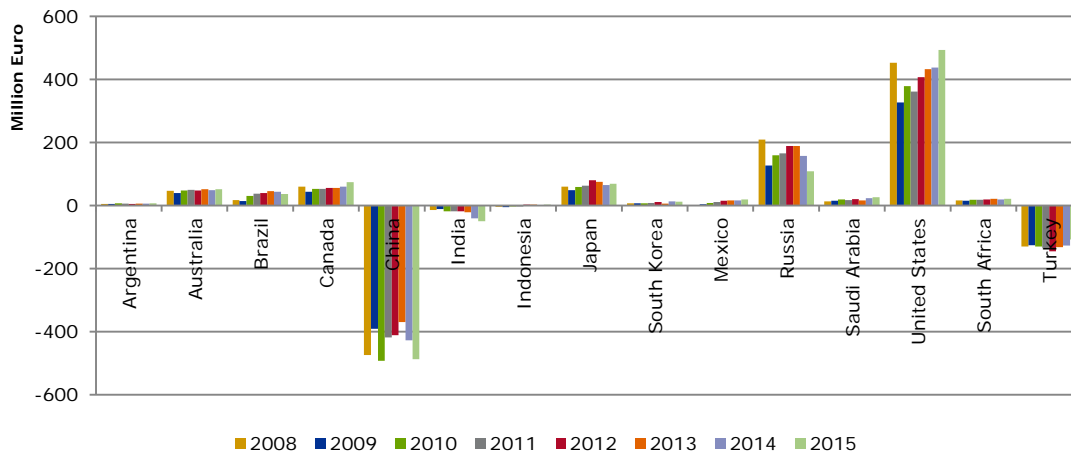
²⁰ Glass and glassware // Carboys, bottles, flasks, jars, pots, phials, ampoules and other containers, of glass, of a kind used for the conveyance or packing of goods; preserving jars of glass; stoppers, lids and other closures, of glass.

Figure 29: RCA for glass and glassware (Code 710) for selected countries 2008-2014



The largest export destinations among the non-EU G20 for hollow glass i.e. the sector NACE Rev 2313 (based on Eurostat, in monetary terms) are the United States followed by Russia. Figure 31 shows the net exports. The imports and exports vary over time, but the general picture remains relatively stable. Net exports to the US and at a much lower starting level in Brazil and Saudi Arabia have been increasing over the past few years.

Figure 30: Net exports of container glass from the EU to G20 countries



own illustration based on data from Eurostat EU Trade Since 1988 By CPA_2008 (DS-057009)

International competitiveness

Because of the relatively high weight of glass containers, the transport distance of the packaged products is typically limited to a few hundred kilometres, since transport cost are high in relation to the sales price (JRC 2013). This implies that markets are rather regional. Flaconnage is generally more exposed to international competition (JRC 2013). Some regions have their own characteristic

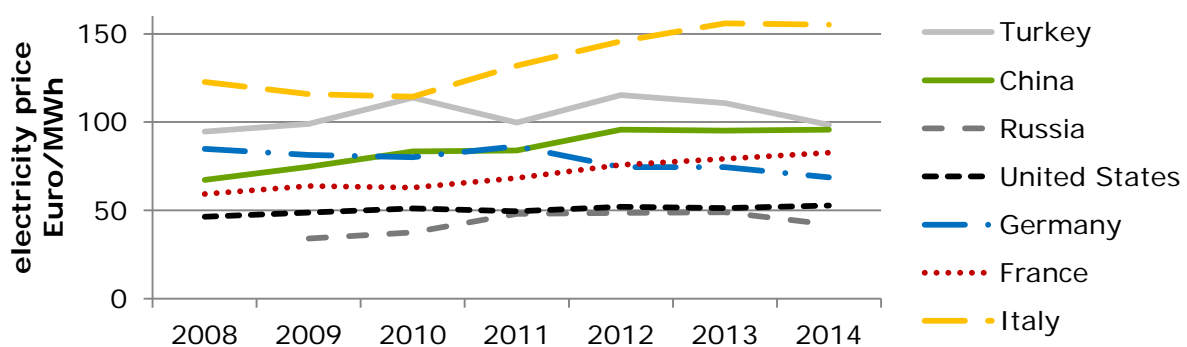
glass containers e.g. in wine regions or for local beers. This creates room for specialization strategies and hinders market concentration. Still, glass making is capital-intensive. This implies that only large firms with financial resources can enter the market. Smaller actors do exist but are rather uncommon (CE Delft & Oeko-Institut 2015). Even though actors are rather large they are said to have little bargaining power towards their client industries (beverage firms etc) and suppliers of raw materials (CE Delft & Oeko-Institut 2015).

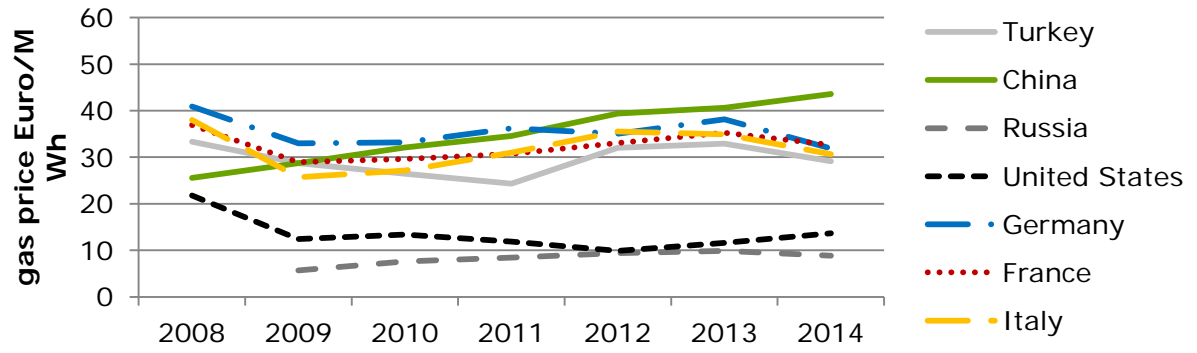
Suppliers of raw material are typically large international firms against which glass producers have little bargaining power (CE Delft & Oeko-Institut 2015). This implies that they have to take prices for material input such as soda ash. On the other hand, since those materials are traded on an international market, they impact all producers similarly and hence do not convey major competitive advantages or disadvantages. This increases the importance of variable cost-factors in determining cost-competitiveness amongst which are energy cost.

The global positioning of food and beverage as well as pharmaceuticals and cosmetics firms contributes to an internationalization of the glass industry. The glass industry grows or shrinks in tandem with the demand for the packaged products that are sold both domestically and internationally.

Concerning energy cost, prices in particular Russia and the USA indicate that there may be an advantage at the cost side for natural gas as well as electricity. Electricity prices indicate an increasing cost disadvantage for Italy. Prices have also increased in France, while electricity prices for Germany and Turkey went down (see Figure 32).

Figure 31: Electricity and gas prices for hollow glass in selected European countries and industrial electricity and gas prices for selected G20 countries





Case study 5: Chlorine

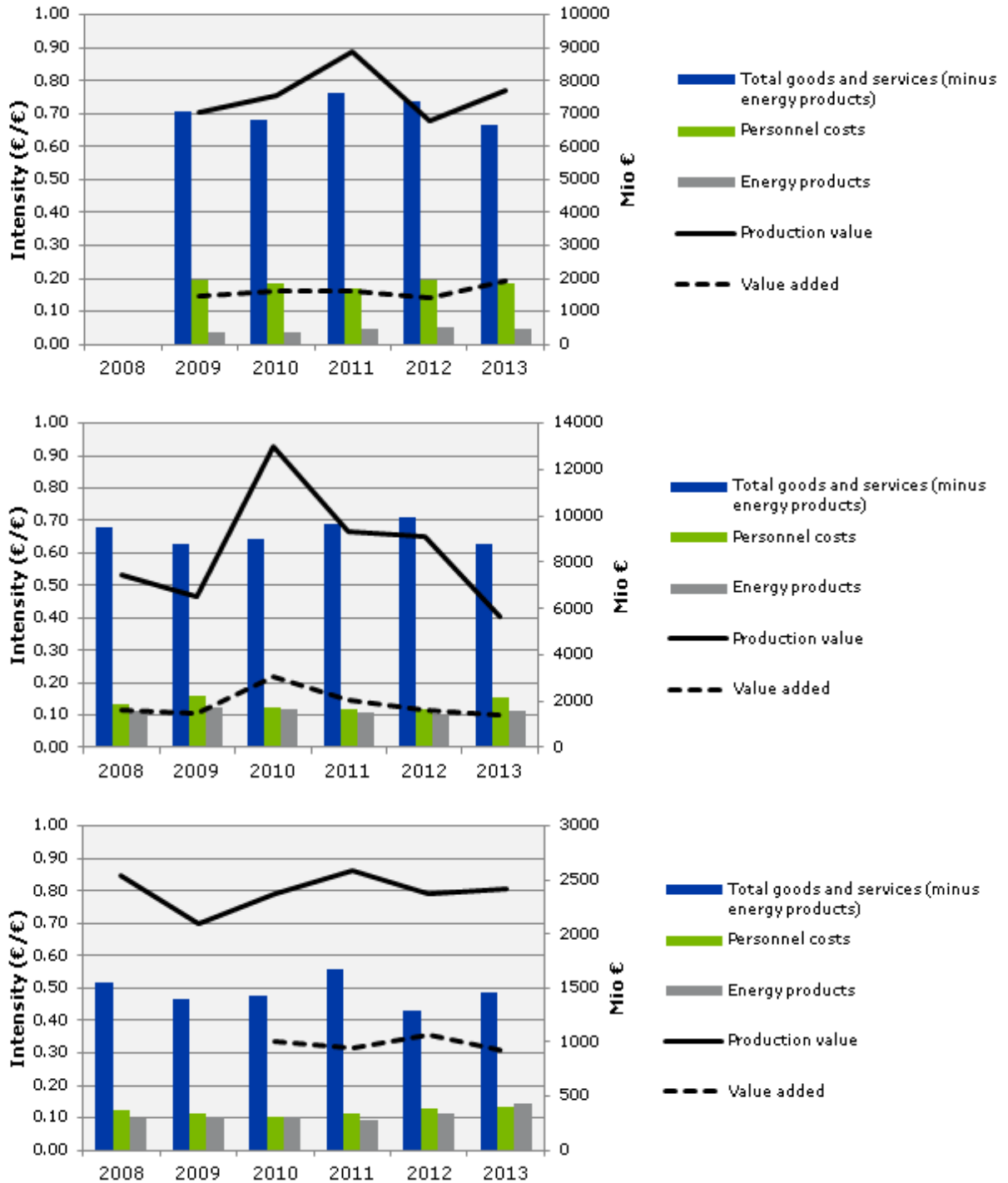
Product description

In chlorine production there exist four major production technologies: the mercury (will be banned in 2017), diaphragm, membrane and molten salt electrolysis. Every technology has different energy inputs and delivers different concentrations of end products (e.g. the mercury process delivers NaOH of 50% concentration, the membrane process 25-30% concentration). The fifth production technology depolarized cathode has been developed by Bayer a few years ago. It does not produce hydrogen as a co-product and also has a 25-30 % lower electricity consumption (Clotman 2016).

Product cost structure

Comparing the French, German and UK (major value added contributors of the EU28) production cost structure shows, that while Germany and UK have a higher magnitude of intensity of energy product costs to production value between 2008 and 2015 (0.11 €/€ German average and 0.11 €/€ United Kingdom average), the average French energy product costs intensities are significantly lower at 0.04 €/€ (Figure 33). One reason for these lower intensities might be the cheaper nuclear electricity in France, however as discussed below there might be several other reasons (e.g. production process, integration with other chemical plants, etc.) for the lower energy product intensity in France compared to Germany and the UK.

Figure 32: Production cost structure (total goods & services, personnel costs, energy products), production value, and value added NACE 2013 for France (top), Germany (middle), United Kingdom (bottom)



Source: own illustration of Eurostat Structural Business Statistics

According to Euro Chlor, estimating the cost structure for chlor-alkali production is rather difficult as there are different production technologies for chlorine. Depending on the production process, they have different energy inputs and deliver different concentrations of end products, which makes them difficult to compare (e.g. the mercury process delivers NaOH of 50% concentration, the membrane process only 25-30% concentration – further concentration would need extra energy). Furthermore, the processes have different energy consumptions as shown in the product description above. (Clotman 2016)

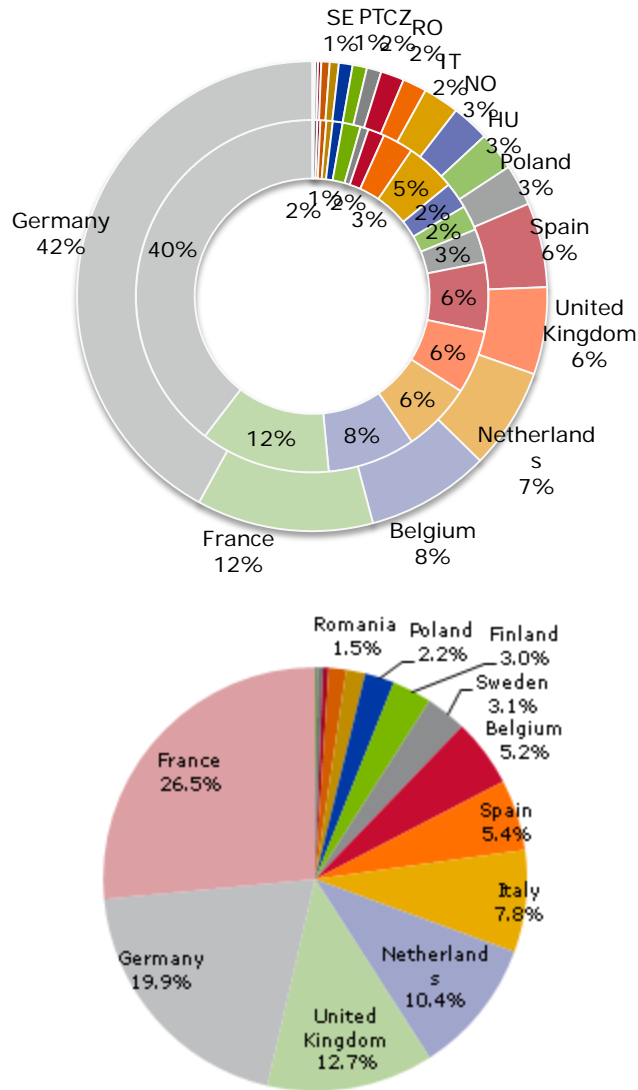
Another reason is the quickly changing process landscape in Europe (e.g. European ban of mercury process by December 2017 has led to a conversion of mercury based plants to membrane technology as well as plants closures and/or replacement by larger membrane plants). As a consequence the European chlorine production energy mix is constantly changing in contrast to other regions like the US or China. In addition, the integration of chlorine production sites in other large chemical plants (obtaining cooling water, steam, electricity, etc.) or vinyl and PVC plants makes them difficult to compare among each other and with other isolated plants. (Clotman 2016)

Egenhofer et al. (2014), using 9 sample plants who answered questionnaires, estimated the share of electricity costs in chlorine production in total energy costs of 91% percent and 43-45 percent of total production costs.

Market situation

In 2015 Germany had, with 42%, the largest chlorine production capacities in Europe, followed by France (12%), Belgium (8%), the Netherlands (7%) and UK (6%) (Figure 30). In comparison to other industry, like e.g. steel, the European production structure did not change significantly since 2009. Only Italy and Germany lost a share $\geq 2\%$. Germany is ranked in fourth place globally behind China, the US and Japan (Grave et al. 2015).

Figure 33: European chlorine production capacity (top), EU28 NACE 2013 value added distribution (bottom) 2013

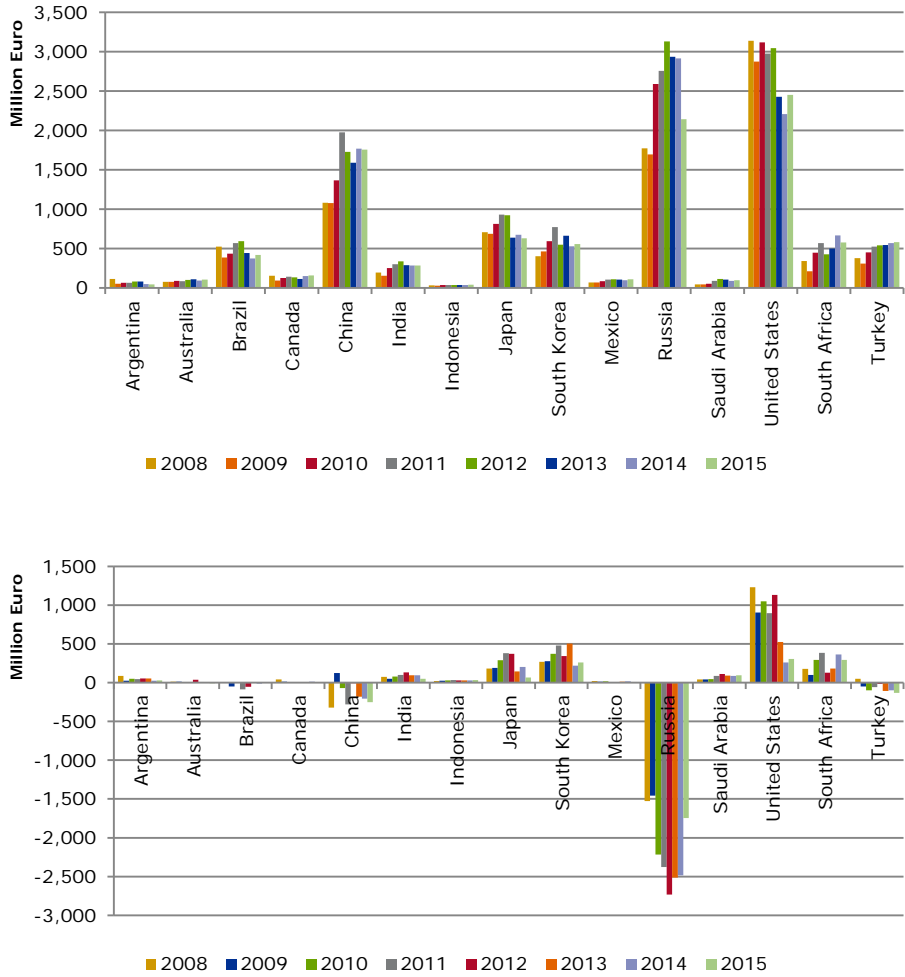


Source: own illustration of Eurochlor & Eurostat Structural Business Statistics

International competitiveness

Europe's major trading partners are Russia, the United States, and China (Figure 35). Europe is a net importer especially of Russian chlor-alkali products while the United States are the major net importers of European chlor-alkali products (Figure 31).

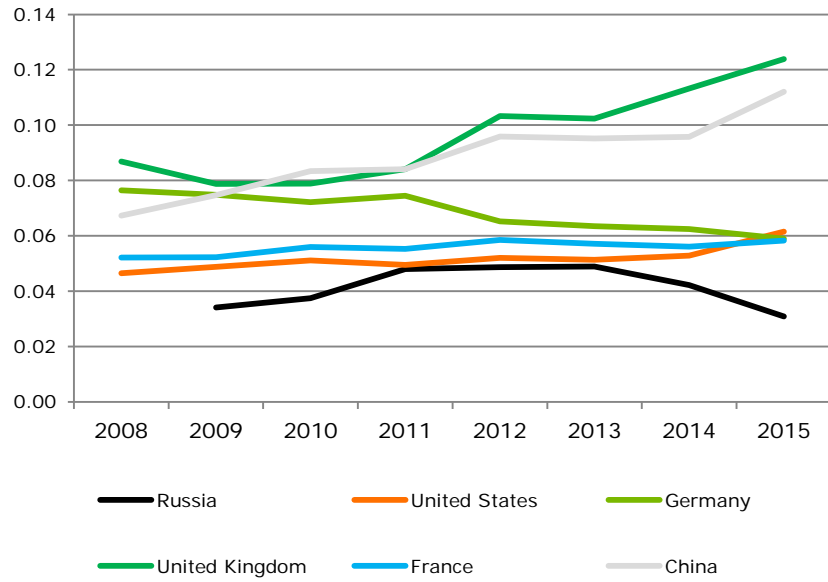
Figure 34: Total trade value (top) and net exports (bottom) of the European Union (EU28) NACE 2013 (2008-2013)



Source: own illustration of Eurostat EU Trade Since 2008 By CPA_2008 (DS-057009)

Comparison of electricity prices shows, that especially Russia who is a major chlorine exporter into the EU28 has significantly lower electricity prices in comparison to France and the United Kingdom. This creates an advantage on the cost side for Russia or in other words disadvantage for the European countries compared to Russia. US electricity prices are also rather low however net exports of the EU28 into the US are positive. They declined strongly in 2013/14 as did total trade value, but stabilized in 2015.

Figure 35: Electricity prices (€/kWh) for selected countries (2008-2015)



Source: own illustration of price data task 1 and IEA database on energy prices and CEIC data

References Cost structure case studies

Arens Marlene, Worrell Ernst, Schleich Joachim 2012: Energy intensity development of the German iron and steel industry between 1991 and 2007. Energy Volume 45 Issue 1 pages 786-797. The 24th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy, ECOS 2011.

CE Delft & Oeko-Institut 2015: Ex-post investigation of cost pass-through in the EU ETS - An analysis for six sectors. ISBN: 978-92-79-53403-4
http://ec.europa.eu/clima/policies/ets/cap/allocation/docs/ex-post_investigation_of_cost_en.pdf

CEPI 2010: Annual Statistics 2009. European Pulp and Paper Industry.

CEPI 2011: Key Statistics 2010. European Pulp and Paper Industry.

CEPI 2012: Key Statistics 2011. European Pulp and Paper Industry.

CEPI 2013: Key Statistics 2012. European Pulp and Paper Industry.

CEPI 2014: Key Statistics 2013. European Pulp and Paper Industry.

CEPI 2015: Key Statistics 2014. European Pulp and Paper Industry.

DESTATIS: Erhebung über die Energieverwendung Tabelle 1: Strombilanz und Tabelle 2: Energieverbrauch nach Energieträgern.

Dirk Clotman 2016: Communications Manager Euro Chlor. Email from 2016-02-04.

Ecorys et al. 2008. FWC Sector Competitiveness Studies - Competitiveness of the Glass Sector Within the Framework Contract of Sectoral Competitiveness Studies – ENTR/06/054 - Final report, 14 October 2008. Ref. Ares(2014)75605 - 15/01/2014. Ecorys, Teknologisk Institut, Cambridge Econometrics, CESifo, Idea Consult commissioned by Directorate-General Enterprise & Industry.

Egenhofer Christian, Schrefler Lorna, Rizos Vasileios, Infelise Frederico, Luchetta Giacomo, Simonelli Felice, Stoefs Wijnand, Timini Jacopo, Colantoni Lorenze (2014): Final Report for a study on composition and drivers of energy prices and costs in energy intensive industries: the cas of the chemical industry – chlorine. Centre for European Policy Studies. FOR THE PROCUREMENT OF STUDIES AND OTHER SUPPORTING SERVICES ON COMMISSION IMPACT ASSESSMENTS AND EVALUATION. Brussels

EUCCC 2016: Overcapacity in China - An Impediment to the Party's Reform Agenda. Roland Berger commissioned by the European Union Chamber of Commerce in China.

Eurostat Structural Business Statistics o.J. *Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2]*. URL:

http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

Eurostat International Trade Statistics, EU Trade Since 1988 By CPA_2008 (DS-057009).

FEVE 2015: Press Release – EU Container Glass Production Growth shows industry resilience.

Brussels, 2nd April 2015. URL: <http://www.feve.org/images/stories/2015/pr-prod-year2014final.pdf> [29.02.2016]

Fleiter, Tobias, Schломann, Barbara & Eichhammer, Wolfgang (Hg.) 2013: *Energieverbrauch und CO2-Emissionen industrieller Prozesstechnologien – Einsparpotenziale, Hemmnisse und Instrumente*. Stuttgart: Fraunhofer Verlag.

Gerspacher, A., Arens, M., Eichhammer, W., 2011: Zukunftsmarkt Energieeffiziente Stahlherstellung - Fallstudie im Rahmen des Vorhabens „Wissenschaftliche Begleitforschung zu übergreifenden technischen, ökologischen, ökonomischen und strategischen Aspekten des nationalen Teils der Klimaschutzinitiative“, Fraunhofer Institut für System- und Innovationsforschung (ISI), Karlsruhe.

Glass Alliance 2015: Industry report: Glass Alliance. The EU glass industry in 2014-2015. www.glass-international.com

ISI & Ecofys 2015: Stromkosten der energieintensiven Industrie. Ein internationaler Vergleich - Zusammenfassung der Ergebnisse – http://www.isi.fraunhofer.de/isi-wAssets/docs/x/de/projekte/Strompreiswirkung_330639/Industriestrompreise_Abschlussbericht.pdf

JRC 2013: Best Available Techniques (BAT) Reference Document for the Manufacture of Glass, JRC Reference Report, Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control). ISBN 978-92-79-28284-3 (pdf)

JRC 2015: Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board, JRC science and Policy Reports, Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control). ISBN 978-92-79-48167-3 (PDF)

Katharina Grave, Mandana Hazrat, Sil Boeve, Felix von Blücher, Charles Bourgault, Barbara Breitschopf, Nele Friedrichsen, Marlene Arens, Ali Aydemir, Martin Pudlik, Vicki Duscha, Jose Ordonez, Christian Lutz, Anett Großmann, Markus Flaute 2015: Electricity Costs of Energy Intensive Industries: An International Comparison. Report for the German Ministry of Economic Affairs and Energy. <http://www.ecofys.com/files/files/ecofys-fraunhoferisi-2015-electricity-costs-of-energy-intensive-industries.pdf>

OECD (2012), *OECD Economic Surveys: Luxembourg 2012*, OECD Publishing. ISBN 978-92-64-18887-7 (PDF)

Pauliuk, Stefan, Wang, Tao & Müller, Daniel B. 2013. Steel all over the world: Estimating in-use stocks of iron for 200 countries. *Resources, Conservation and Recycling* 71, 22–30.

Renda, Andrea; Pelkmans, Jaques; Egenhofer, Christian; Marcu, Andrei; Schrefler, Lorna; Luchetta, Giacomo; Simonelli, Felice; Valiante, Diego; Mustilli, Frederica; Infelise, Federico; Stoefs, Wijnand (2013): Assessment of cumulative cost impact for the steel industry, Centre for European Policy Studies; Economisti Associati. http://ec.europa.eu/enterprise/sectors/metals-minerals/files/steel-cum-cost-imp_en.pdf. [Stand 2013-10-11]

RISI 2015: Paper Packaging Monitor Europe - A Monthly Monitor of the European Paper Packaging Markets. January 2015.

Smurfit Kappa 2016: Annual Report 2015. URL: http://resources-acc.smurfitkappa.com/Resources/Documents/SKG_plc_Annual_Report_2015.pdf [29.03.2016]

United Nations UN comtrade o.J. *UN comtrade: United Nations Commodity Trade Statistics Database*. New York. URL: <http://comtrade.un.org/db/>

VDP 2014: Papier 2013 - Ein Leistungsbericht.

World Steel Association 2014/2015. *Steel Statistical Yearbook*. Brussels. URL: <http://www.worldsteel.org/statistics/statistics-archive/yearbook-archive.html> [Stand 2015-03-14].



ECOFYS

sustainable energy for everyone

 **Fraunhofer**
ISI



ECOFYS Netherlands B.V.

Kanaalweg 15G
3526 KL Utrecht

T: +31 (0) 30 662-3300

F: +31 (0) 30 662-3301

E: info@ecofys.com

I: www.ecofys.com