Composition and Drivers of Energy Prices and Costs: Case Studies in Selected Energy Intensive Industries – 2018

Final Report Annexes

Annex A – Sectoral analyses

Annex B – Econometric Analysis of Energy and Profitability

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Annex A – Sectoral analyses

1 Bricks and roof tiles

1.1 Introduction

The bricks and tiles sector (NACE Rev.2 23.32) includes manufacturers of products with diverse shapes and properties, divided on the basis of their intended usage. More specifically, bricks and tiles manufacturing entails the production of four different kinds of goods, namely: i) building bricks, including both clay blocks and facing bricks; ii) roof tiles; iii) paving bricks; and iv) chimney bricks and other clay building products.

The bricks and tiles sector is homogeneous, as it includes companies with similar production processes and products – indeed, two main products, bricks and tiles, represent 96% of the sectoral output.

1.2 Overview of the production process

As stated above, the production process is quite homogeneous despite the diversity of the products included in the NACE category. In a nutshell, bricks and tiles are products made from inorganic non-metallic minerals (such as clay), manufactured through a permanent firing process that changes their chemical properties.

The production process consists of five main stages: i) preparation of the raw materials, ii) shaping, iii) drying, iv) firing, and v) finishing (Figure 1).

Preparation of raw materials. Clay constitutes the main raw material employed by the industry, together with a few other argilliferous materials (bentonite, fire clay, etc.) and minerals. Sawdust or residue from the paper industry can be added to increase the porosity of the final product. Due to the low value-to-weight ratio of raw materials, manufacturing plants of bricks and tiles are usually located near extraction sites. In many cases, brick and tile producers are vertically integrated with quarry operations, namely clay extraction. After extraction, raw materials are transported and stored at the production site, where they are prepared, usually through dry or semi-wet processes. During the preparation step, the particle size of raw materials is reduced through pan-mills and double roller crushers, water content is adjusted to the appropriate moisture level, and additives and other raw materials are added.

Shaping. The raw materials are then shaped, through pressing, extrusion or moulding. Extrusion, the most widespread technique, consists of making the raw material sufficiently 'plastic' that it can be forced through the die of the extruder, to acquire the desired form and then be cut into units of the required size. Pressing, which is still used for the manufacture of bricks, consists of loading boxes of the desired shape with a certain volume of clay and then applying pressure from above and below. Moulding, most often a residual technique, consumes less power and energy than pressing or extrusion, but requires a wetter mix of raw materials, thus increasing the energy consumption and time required for drying.

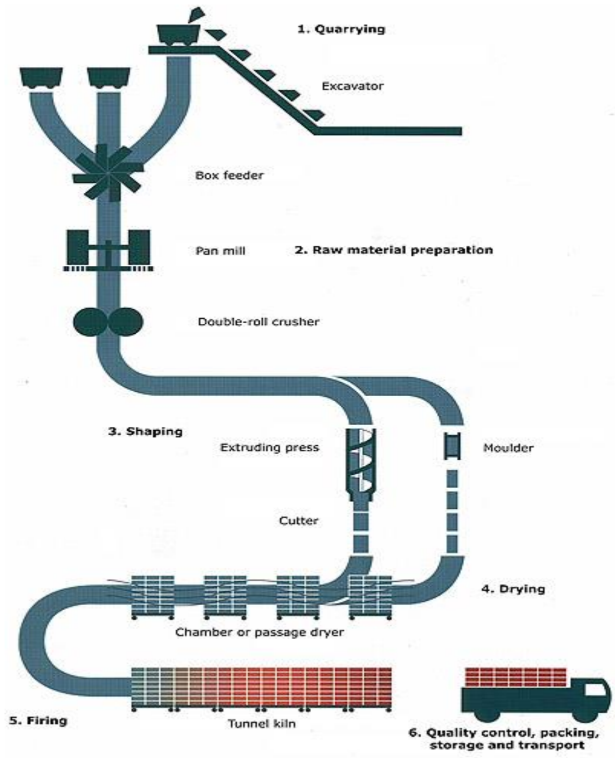
Drying. Drying and firing are the most energy intensive steps of the production process of bricks and tiles. Drying is used to reduce the water content of materials at a relatively low temperature (45°-90°C) and mainly takes place in chamber (intermittent) or tunnel (continuous) dryers. The drying equipment is usually heated through either hot air recovered from the kiln or gas burners. With new and more efficient drying technology, the duration of the process has been significantly reduced and depending on the type of product, drying can last from as few as four hours to over 40 hours.

Firing. Once dried, brick and tiles are fired in kilns. This is the key step to determining the properties of the finished products. Kilns may be either intermittent or continuous, the latter being more suitable for larger plants and more energy-efficient. Most bricks and roof tiles nowadays are fired in continuous tunnel kilns, whose temperature ranges between

800° and 1,300°C, depending on the mineralogical properties of the clay mix, the type of products and the characteristics to be obtained. The firing process lasts from around six hours to over 40 hours, depending on the product. Kilns are usually gas-fired (over 80%), although oil, coal or biomass can also be used. Intermittent kilns can be used to produce smaller batches of specialised roof tiles or bricks.

Finishing. Once fired, products may require subsequent treatment, such as calibration, cutting or surfacing, or be prepared directly for shipping and distribution.

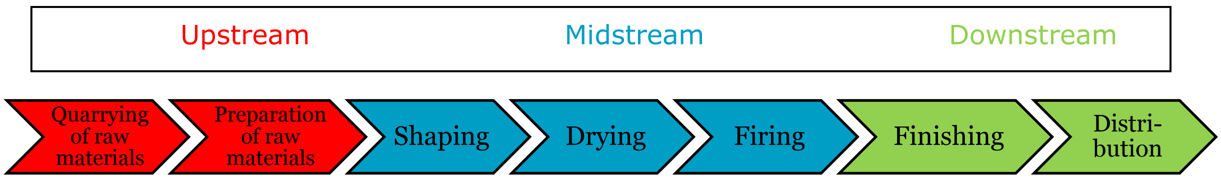
Figure 1 Production process for making bricks and tiles



Source: Tiles and Bricks Europe.

The bricks and tiles value chain is diagrammed in Figure 2. Upstream is defined as the process before the actual manufacturing process, i.e. the mining/quarrying of raw materials and their preparation. The actual manufacturing process – shaping, drying and firing – is defined as midstream. Finally, downstream refers to the post-manufacturing process, meaning finishing and distribution.

Figure 2 Value chain in brick and tile production



Source: Tiles and Bricks Europe.

Given that the construction sector is the main customer for bricks and tiles, demand for these products is volatile due to the sector's seasonality, e.g. lower in winter and higher in spring and autumn. Furthermore, strong dependency on the construction sector has caused a severe downsizing of the production of bricks and tiles due to the economic and financial crisis. (Ecorys et al., 2008).[1]

Based on the input/output table produced by Eurostat,[2] in 2012 the construction industry[3] absorbed more than 61% of the output of non-metallic mineral products,[4] for a value of about €83 billion.[5] As a comparison, the industrial sector buying the next-largest share of non-metallic mineral products is food and beverages, at €4 billion. Private consumption by households' accounts for an additional €13 billion.

As will be discussed below, as a four-digit NACE group, the bricks and tiles sector is homogeneous and includes companies with similar production processes and products. Indeed, two main products, bricks and tiles, represent 96% of the sector's output.

1.3 Industry characteristics

According to the NACE (Rev.2) statistical classification of economic activities in the European Community, bricks and tiles are included in the class 23.32, comprising manufacturers of bricks, tiles and construction products, in baked clay (Table 1).

Table 1 NACE Rev.2 classification of the bricks and tiles sector

SECTION C — MANUFACTURING
23 Manufacture of other non-metallic mineral products
23.3 Manufacture of clay building materials
23.32 **Manufacture of bricks, tiles and construction products, in baked clay**
Building bricks: 23321110 - Non-refractory clay building bricks (excluding siliceous fossil meals or earths)
Flooring blocks: 23321130 - Non-refractory clay flooring blocks, support or filler tiles and the like (excluding siliceous fossil meals or earths)
Roof tiles: 23321250 - Non-refractory clay roofing tiles
Other clay building products: 23321270 - Non-refractory clay constructional products (including chimneypots, cowls, chimney liners and flue-blocks, architectural ornaments, ventilator grills, clay-lathes; excluding pipes, guttering and the like)
Ceramic pipes: 23321300 - Ceramic pipes, conduits, guttering and pipe fittings; drain pipes and guttering with fittings

Source: Authors' elaboration on Eurostat (2017).

<u>Production in the EU</u>

Figure 3 below presents the production value in the bricks and tiles subsector both over time and across all EU Member States (Eurostat SBS, 2017). As for the time trend, the production value of the sector declined by about 25% between 2008 and 2015, from slightly more than €8 billion to €6.2 billion. In general, the sector closely follows the economic trend of the construction sector, which is its main customer, and thus the overall GDP trend. The impact of the crisis has been severe, especially considering that in 2007

[1] Ecorys et al. (2008), 'FWC Sector Competitiveness Studies – Competitiveness of the Ceramics Sector', Final report for DG ENTR.

[2] For further details see: https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/methodology/symmetric-input-output-tables

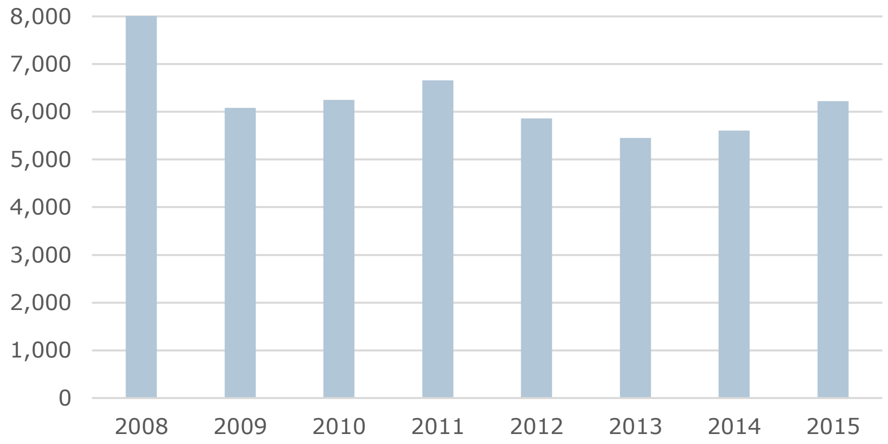
[3] NACE code F.

[4] Including all ceramics and glass products.

[5] Excluding intra-industry trade, which accounted for about €21 billion.

the production value had reached almost €9 billion (CEPS, 2014a).[6] With the financial crisis, from 2008 to 2009, the production value declined by almost 27%.

Figure 3 Production value of bricks and tiles (EU, million €)



Source: Authors' elaboration on Eurostat SBS (2017).

With regard to geographical distribution, the bricks and tiles sector is quite widespread across the EU and significantly correlated with the size of the national economy and the construction sector. As sources of clay are uniformly dispersed across all Member States, and as the low value-to-weight ratio of both the raw materials and the finished products makes transport expensive, local production is required.

For both reasons, the largest producers closely overlap with the largest Member States. In particular, Germany, France, Italy and the UK account for about three-quarters of the market. Together with Belgium, Spain and Poland, these countries account for 90% of the total production value. Belgium is the only exception among the six biggest EU economies: structurally, Belgium has always been the EU Member State with the highest per capita production of bricks and tiles (European Commission, 2007); in addition, Belgium and Germany are among the healthiest construction markets in continental Europe.[7]

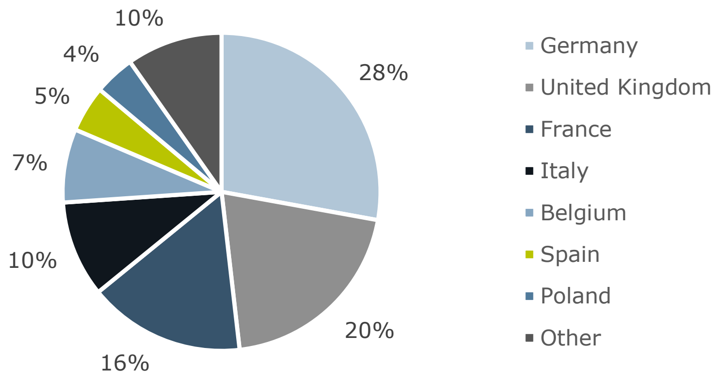
Data on the production output for these four products are measured in different units. As a result, a comprehensive analysis considering the entire output is not possible.[8] Building bricks and roof tiles account for almost all production in terms of value, while flooring blocks and other clay construction products are marginal categories; hence, we focus the analysis below on the former set of products.

[6] Centre for European Policy Studies (2014a), 'Study on Composition and Drivers of Energy Prices and Costs in Energy Intensive Industries: The Case of the Ceramics Industry - Bricks and Roof Tiles', Final Report for DG ENTR.

[7] Based on Euroconstruct data on size (in terms of value) of the construction market.

[8] Building bricks are measured by volume (m^3); roof tiles are measured in number of items; flooring blocks and other clay constructional product are measured by weight (kg).

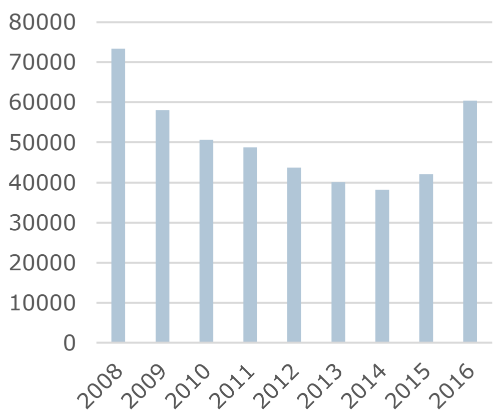
Figure 4 Distribution of production value across largest producers of bricks and tiles in the EU, 2016

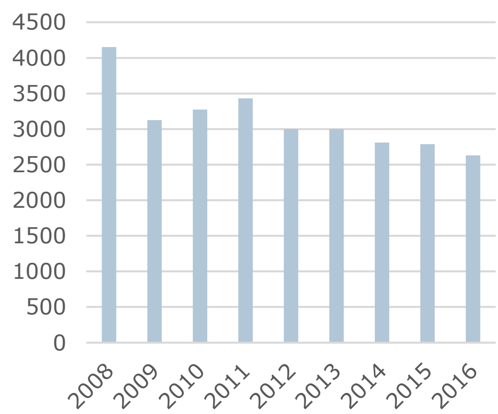


Note: Other includes the remaining EU Member States. However, data for Ireland, Austria, Romania and Slovenia are estimated (trend extrapolation); data are not available for Czech Republic, Denmark, Estonia, Croatia, Latvia, the Netherlands, Finland and Sweden.
Source: Authors' elaboration on Eurostat SBS (2017).

The output of building bricks and roof tiles declined by 18% and 37% respectively between 2008 and 2016, as shown in Figure 5 below.

Figure 5 Output of building bricks (1,000 m^3, left) and roof tiles (million items, right) in the EU, 2008-16

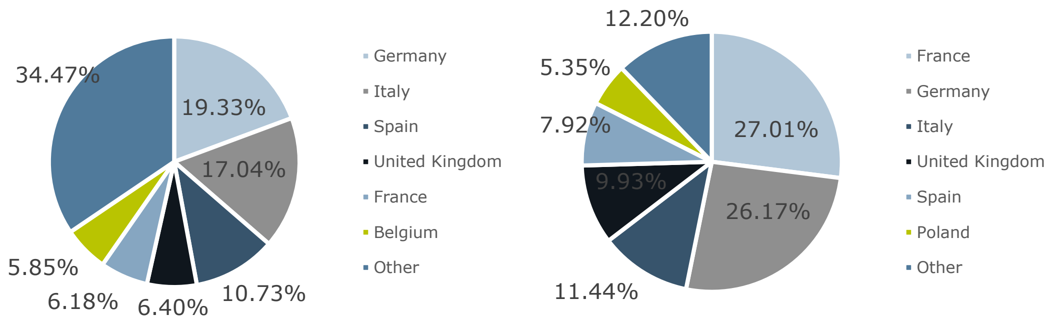




Source: Eurostat Prodcom Database (2017).

With regard to the geographical distribution of the output, the production of roof tiles is more concentrated compared to bricks. In particular, more than 85% of the output is concentrated in six Member States. For building bricks, the six largest producing Member States account for two-thirds of the output.

Figure 6 Distribution of output for building bricks (left) and roof tiles (right) across major producer countries in the EU, 2016



Source: Eurostat Prodcom Database (2017).

Number of companies and plants operating in the EU

Figure 7 below contains similar information with regard to the number of enterprises, which fell by almost 35% between 2008 and 2015. At the same time, enterprises became larger in terms of production value and, as a result, the sector is becoming more consolidated. The bricks and tiles sector is considered more concentrated than other ceramics subsectors (Ecorys et al., 2008).[9]

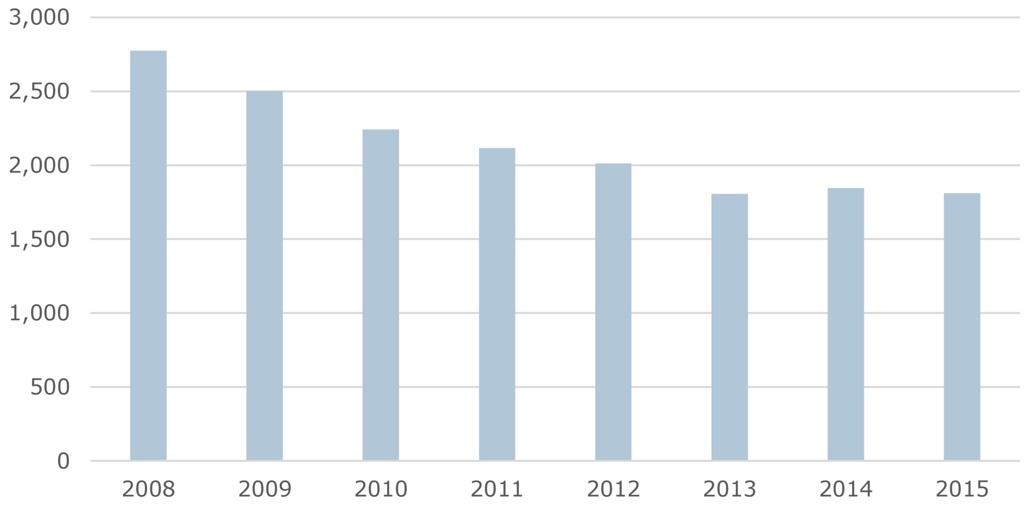
Data on the size class of enterprises in the bricks and tiles sector are not available at a sufficiently granular level of detail.[10] Nevertheless, the stakeholder association estimates that the sector consists of roughly an equal number of large producers and regionally settled SMEs (CEPS, 2014a).[11]

[9] Ecorys et al. (2008), op. cit.

[10] Data on size distribution of enterprises are available at the 3-digit NACE level, which also includes producers of wall and floor tiles. The latter are covered by another sectoral report within this Assignment.

[11] CEPS (2014a) op. cit. The SME definition used corresponds to that adopted by the European Commission: companies with i) fewer than 250 employees and ii) an annual turnover lower than €50 million or an annual balance sheet lower than €43 billion. Small companies are defined as those with: i) fewer than 50 employees and ii) annual turnover or balance sheet less than €10 million. Micro companies are defined as those with: i) fewer than 10 employees and ii) annual turnover or balance sheet less than €2 million. See European Commission (2015), "User guide to the SME definition", 06.05.2015.

Figure 7 Total number of enterprises in the bricks and tile sector, 2008-15 (EU)



Note: Data estimates for Ireland are based on trend extrapolation. No figures are available for Czech Republic.

Source: Authors' elaboration on Eurostat SBS (2017).

Geographical distribution of production and plants over the EU

Comprehensive information on the number and distribution of plants is not available from either public sources or stakeholder associations. The BAT Reference (BREF) document reports the number of plants for selected Member States shown in Table 2 below. Data refer to the early 2000s, and no information on Eastern European countries is available therein.

Another source for estimating the number of plants and their distribution is the European Union Transaction Log (EUTL) Database, which lists all plants registered under the ETS system. Based on this database, manufacturers of bricks and tiles are present in 22 Member States, as reported below in Table 3. However, some Member States excluded smaller plants from the ETS system.[12] Based on the available evidence, these could account for 90% of the installations in Spain[13] and 60% in France.

Another demonstration that the number of plants registered in the EUTL database and the number of installations in the bricks and tiles sector are not coherent is the low number of entries for Italy, which is the country with the largest number of enterprises according to Eurostat and the largest number of plants according to the BREF. Hence, although indications can be extrapolated from both the BREF and the EUTL, no consistent and comprehensive analysis of the number of plants is available for sampling purposes and proxies (such as the production value, the number of enterprises and the production output) will be relied upon.

[12] Installations whose annual emissions are below 25 ktonnes of CO_2 can opt out of the ETS system, provided that the Member State applies 'equivalent measures'. Cf. Art. 27 of the Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC.

[13] For purposes of comparison, the EUTL database included 287 plants for Spain in 2009 and only 64 in 2016; the reduction by more than 75% can be attributed to the reduction in output but also to changes in the application of the opt-out clause (see Fraunhofer ISI, Ecofys and Oeko-Institut e.V. (2009), 'Methodology for the free allocation of emission allowances in the EU ETS post 2012 – Sector report for the ceramics industry', Study for the European Commission., p. 2).

Table 2 Number of plants in the bricks and tile sector as reported in the BREF document

Member State	Number of plants
Italy	238
Germany	183
Portugal	150
France	136
United Kingdom	134
Netherlands	58
Belgium	40
Austria	30
Denmark	26

Source: European Commission (2007).

Table 3 Number of brick and tile plants in selected EU Member States as reported in the EUTL database

Member State	Plants	Member State	Plants
Germany	104	Hungary	15
Spain	54	Denmark	14
France	41	Bulgaria	12
Netherlands	32	Romania	12
Belgium	23	United Kingdom	10
Italy	21	Slovakia	4
Portugal	21	Finland	3
Poland	21	Latvia	2
Austria	21	Sweden	2
Czech Republic	21	Estonia	1
Greece	17	Slovenia	1

Source: EUTL (2017).

Employment

Unfortunately, data on the distribution of companies according to the number of employees in the manufacture of bricks and roof tiles are not publicly available; therefore, the analysis has to focus on the broader manufacture of clay building materials (NACE Rev. 2 code C23.3).

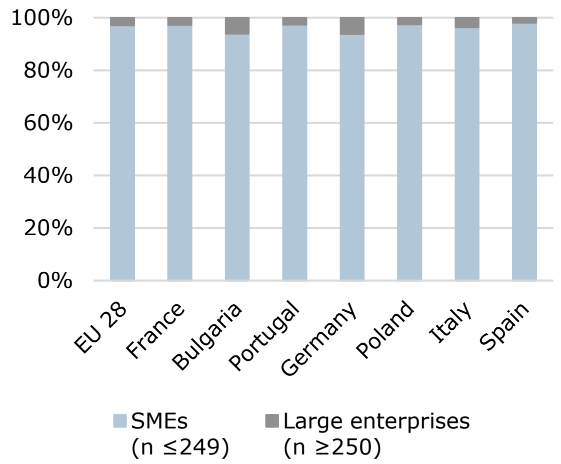
This includes both wall and floor tiles, i.e. the manufacture of ceramic tiles and flags, NACE Rev. 2 code C23.31, and bricks and roof tiles, i.e. the manufacture of bricks, tiles and construction products, in baked clay, NACE Rev. 2 code C23.32. As Figure 8 shows, in 2013,[14] the EU manufacture of clay building materials, in terms of number of firms, was almost entirely dominated by SMEs (97%), while large enterprises played only a marginal role (3%) This pattern was replicated in almost all the major producing countries (see above).

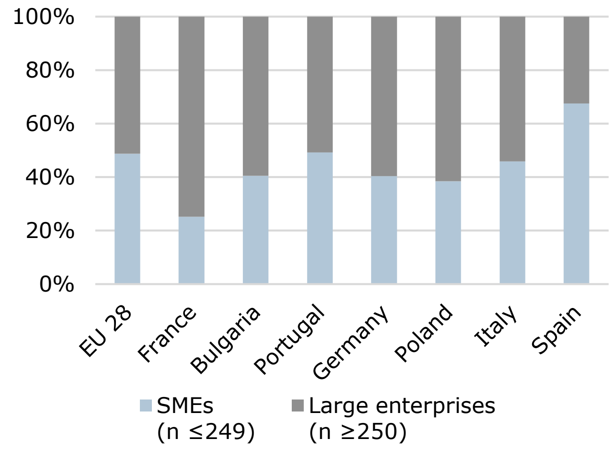
Nevertheless, when it comes to production value, large enterprises were responsible for the main share in the EU (51%) and in all the major countries except Spain. Eurostat data

[14] Ibid.

on employment size for manufacture of clay building materials represent an 'upper bound' for the wall and floor tiles subsector, as it is dominated by companies that are smaller than those operating in the brick and tiles subsector.

Figure 8 Percentage of enterprises (left) and production value (right) by employment size (manufacture of clay building materials, 2013)





Note: Data estimates for Belgium, Bulgaria, Ireland, Greece, France, Croatia, Hungary, the Netherlands, Portugal, Slovenia, Slovakia, Sweden and the UK are based on trend extrapolation. No data are available for Czech Republic or Latvia.
Source: Authors' elaboration on Eurostat SBS (2017).

The sector experienced a strong contraction. Since 2008, the number of employees decreased from 75,000 to just over 44,000 in 2015 (Eurostat, 2017). This decline is comparable to the reduction in the number of enterprises, signalling that firm size remained, on average, constant.

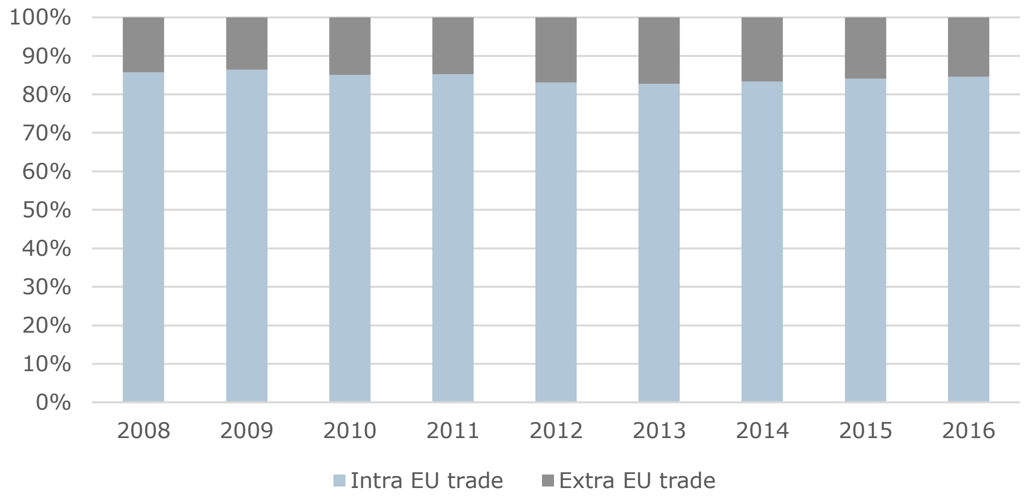
1.4 Trade analysis

The bricks and tiles sector[15] is characterised by a low intra-EU trade intensity, due to the limited intra-EU exchanges. This is due to the low tradability, caused by the limited transportability of both raw materials and finished products. As tradability for bricks and tiles is correlated with distance from the production site, extra-EU trade intensity is even lower, if not marginal.

Figure 9 illustrates the dominance of intra-EU trade over extra-EU trade. In 2016, intra-EU trade accounted for around 84% of total trade, while extra-EU trade only contributed 15%.

[15] For the purpose of trade data analysis, bricks and tiles are defined in this report according to the Harmonized Commodity Description and Coding System (HS). It includes the following: ceramic building bricks, flooring blocks, support or filter tiles, etc. (6904); sub-categories: building bricks (690410) and other (690490); and: roofing tiles, chimney pots, cowls, chimney liners, architectural ornaments and other ceramic constructional goods (6905); sub-categories: roofing tiles (690510) and other (690590).

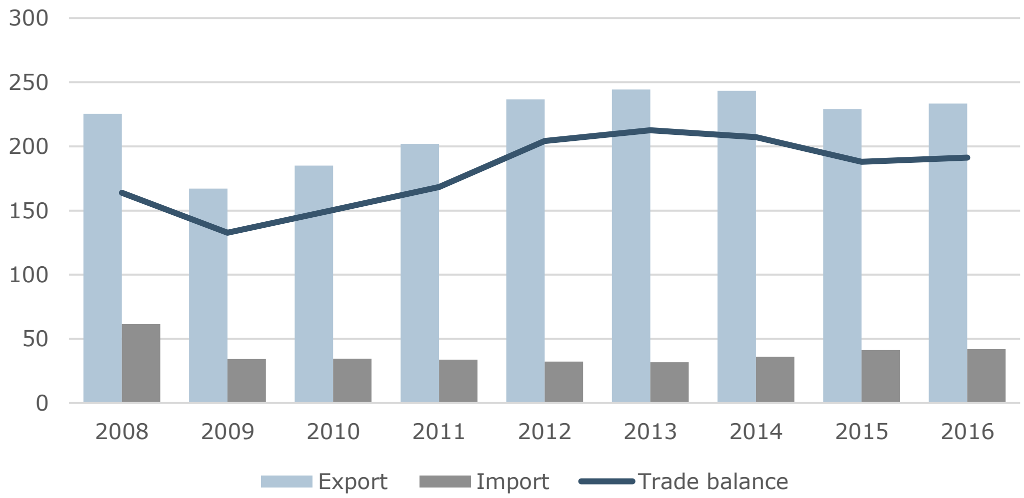
Figure 9 Intra and extra-EU trade in the bricks and tiles sector (EU, %)



Source: Eurostat's COMEXT (2017).

The EU was a net exporter of bricks and tiles for the whole period from 2008 until 2016. In 2016, the EU had a positive trade balance for bricks and tiles of over €191 million.

Figure 10 Extra-EU trade of bricks and tiles (EU, million €)



Source: Eurostat's COMEXT (2017).

The fact that the bricks and tiles sector is not global can also be clearly observed in trade patterns. Not only is trade intensity low, most of the important extra-EU trading partners are located at the European borders (including sea borders with Mediterranean countries). Table 4 shows the 10 most important EU trading partners for bricks and tiles in 2016. Since 2008, Serbia has been the largest exporter to the EU, although the value of its exports decreased by 49% from 2008 until 2016 (from around €36 million to almost €19 million).

In 2016, Switzerland (€25.8 million) was the top destination country for EU exports of bricks and tiles, overtaking Russia, which used to import almost €43 million in 2014, but that figure dropped to €25 million in 2016. The first five partners for EU exports (Switzerland, Russia, Norway, Saudi Arabia and Lebanon) accounted for about 43% of the overall extra-EU trade. Compared to 2008, the top five trading partners remained almost

the same, with the exception of the United States and Bosnia and Herzegovina. In comparison to 2016, trade flows in 2008 were more concentrated and the top five partners accounted for around 51% of exports.

Table 4 Top 10 trading partners in 2016 (% of overall export/import values)

Top 10 destination markets		Top 10 exporters to EU	
Switzerland	11%	Serbia	44%
Russia	11%	Turkey	10%
Norway	9%	China	9%
Saudi Arabia	6%	Macedonia	9%
Lebanon	6%	Pakistan	9%
Bosnia and Herzegovina	5%	Switzerland	4%
United States	5%	United States	3%
Algeria	5%	Egypt	3%
South Korea	5%	Moldova	2%
Ukraine	3%	India	1%

Note: The category "Manufacture of bricks, tiles and construction products, in baked clay" (C2332 NACE Rev.2) corresponds to HS 69.04, 69.05 and 69.06.
Source: Authors' elaboration on COMEXT (2017).

2 Wall and floor tiles

2.1 Introduction

Wall and floor tiles (also known as 'ceramic tiles') are thin slabs made of clay and other inorganic materials (which give them their main physical characteristics). They are usually employed in the construction industry as a finishing material and/or to perform an aesthetic function (European Commission, 2007).[16]

Ceramics tiles are heterogeneous products in terms of physical composition, dimension, weight, shape, surface and colour as well as use. Covering and/or decorating both internal, e.g. kitchen and bathrooms, and external surfaces, swimming pools and public areas are among the most traditional uses for tiles. Moreover, unlike many other ceramic products (such as bricks and roof tiles), wall and floor tiles are high value-added and highly tradable goods; hence, they are more subject to international competition.

2.2 Overview of the production process

The production process includes five main stages: i) preparation of the raw materials, ii) shaping, iii) drying, iv) glazing and v) firing.

Preparation of raw materials. Raw materials preparation consists of selecting, grinding and mixing the necessary inputs. The body composition of the tile is determined by the amount and type of raw materials employed, which ultimately influence factors such as colour, resistance and water absorption. As a consequence, batching, i.e. the selection of the raw material to be employed, has to take into account both physical properties and chemical composition of the inputs.

Once the right combination of materials is determined, they are grinded and mixed together. Inputs are transferred to primary crushers, i.e. jaw or gyratory crushers, which reduce them into large lumps and to hammer mills for a secondary crushing to obtain smaller particles. Sometimes water has to be added (the so-called 'wet milling' process), which, at a later stage, is removed through filtering and spray drying in order to improve the mixing of a multi-component batch.

It is worth noting that, even though 'dry milling' is more energy efficient, wet milling is the most commonly used process in Europe as it allows for finer grinding and, thus, a higher-quality product.

Shaping. Shaping is required to give the desired form to the input mix. This step can take place through two processes, namely dry pressing and extrusion. The former constitutes the most commonly used method and despite the name, the materials still contain 3-10% water. Two types of presses can be employed, i.e. the hydraulic press and friction press. The first is more commonly used in this sector as it gives the manufacturer more control over the process thanks to consistently higher pressure. Unlike dry pressing, extrusion is used when the inputs are still in a more moist and mouldable state.

Drying. Drying consists of the gentle expulsion of residual water through heat. Once shaped, tiles are heated in order to remove the water slowly enough to prevent shrinkage and cracks. This stage might take several days and employ continuous or tunnel driers, which are heated by gas, oil or infrared lamps.

[16] European Commission (2007), 'Reference Document on Best Available Techniques in the Ceramic Manufacturing Industry', August 2007.

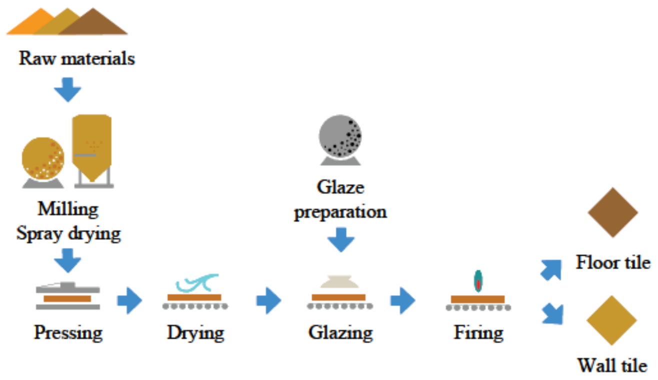
Glazing. Just before firing, tiles are glazed. The glaze is made using methods that are similar to those adopted for the preparation of the body: after a batch formulation is calculated, the raw materials are weighed, mixed and dry- or wet-milled.

Firing. Firing is the core of the production process and allows tiles to acquire their main characteristics, i.e. water-resistance, fire-resistance and hardness. More specifically, ceramic tiles are thermally consolidated into a dense and cohesive body through the use of kilns or ovens. This step can be performed via two different processes depending on whether wet milling or dry milling is used to prepare the raw materials.

Wet-milled tiles require a single firing process through roller kilns, usually taking about 60 minutes at a temperature of at least 1,150°C. For other tiles, a two-step process is employed. First, they go through a preliminary firing before glazing in order to remove the volatile organic chemicals; subsequently, the body and glaze are fired together in a tunnel or batch kiln. In this case, firing can take from two to three days with a temperature of about 1,300°C.

Kilns for firing represent a major capital investment for ceramic tile producers and are characterised by an investment life cycle of more than 40 years. Finally, tiles are ready to be tested before being packed and shipped. Figure 11 gives a schematic illustration of the manufacturing process for a single-fired ceramic tile.

Figure 11 Schematic illustration of a single-fired ceramic tile manufacturing process

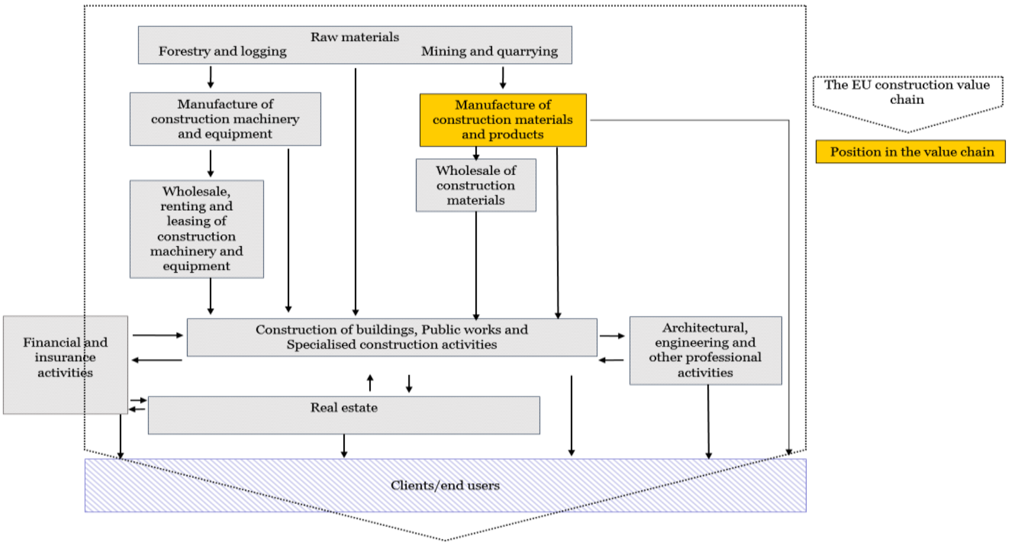


Source: Authors' elaboration on Mezquita et al. (2014)17.

Wall and floor tiles are mainly employed in construction activities; therefore, the subsector is positioned in the upper part of the construction value chain together with the manufacture of other inputs, e.g. cement, concrete, mortars and bricks (Figure 12).

[17] Mezquita et al. (2014), Energy saving in ceramic tile kilns: Cooling gas heat recovery. Applied Thermal Engineering, 65(1), 102-110. p. 102.

Figure 12 Value chain in the wall and floor tiles sector



Source: Authors' elaboration.

2.3 Industry characteristics

According to the NACE (Rev.2) statistical classification of economic activities in the European Community, wall and floor tiles are included in the class 23.31, comprising manufacturers of ceramic tiles and flags (Table 5).

Table 5 NACE Rev.2 classification of the wall and floor tile sector

SECTION C — MANUFACTURING
23 Manufacture of other non-metallic mineral products
23.3 Manufacture of clay building materials
23.31 Manufacture of ceramic tiles and flags
23.31.10.10 Unglazed ceramic mosaic tiles, cubes and similar articles, with a surface area < 49 cm²
23.31.10.20 Glazed ceramic mosaic tiles, cubes and similar articles, with a surface area < 49 cm²
23.31.10.50 Unglazed ceramic and stoneware flags and paving, hearth or wall tiles; unglazed ceramic and stoneware mosaic cubes, etc., whether or not on a backing
23.31.10.71 Glazed ceramic double tiles of the spaltplatten type
23.31.10.73 Glazed stoneware flags and paving, hearth or wall tiles, with a face of > 90 cm²
23.31.10.75 Glazed earthenware or fine pottery ceramic flags and paving, hearth or wall tiles, with a face of > 90 cm²
23.31.10.79 Glazed ceramic flags and paving, hearth or wall tiles excluding double tiles of the spaltplatten type, stoneware, earthenware or fine pottery flags, paving or tiles with a face of not > 90 cm²

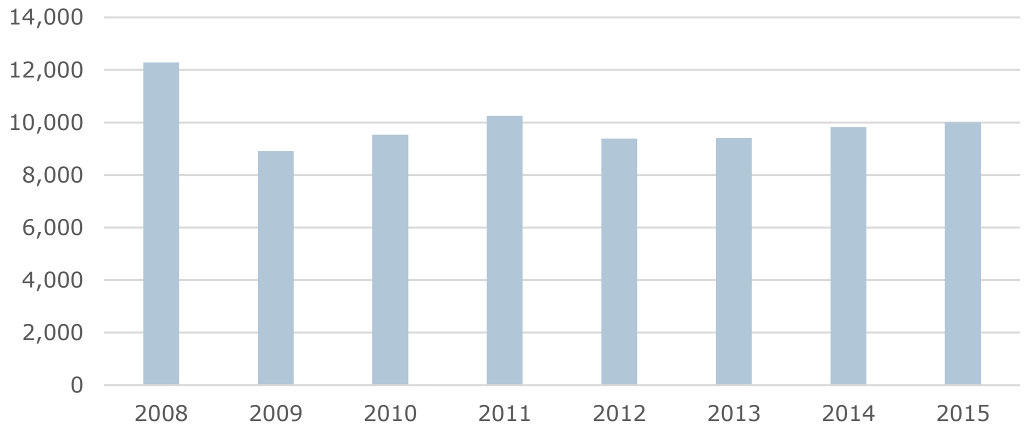
Source: Authors' elaboration on Eurostat (2017).

Production in the EU

Overall, from 2008 to 2015,[18] the value of the EU production of ceramic tiles decreased from €12,281 million in 2008 to €10,005 million in 2015 (-22.7%) (Figure 13). Signs of recovery have been evident since 2012, however, with a slight increment of the values.

[18] 2015 is the last year available on Eurostat.

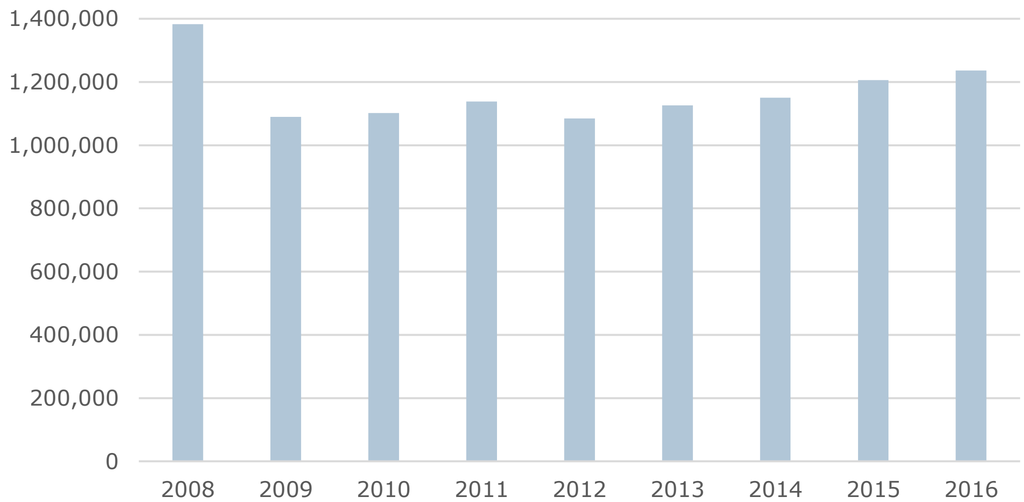
Figure 13 Production value of the wall and floor tiles sector (EU, million €)



Note: Data estimates for France, Estonia, Ireland, Austria, Romania, Slovenia, Slovakia and Sweden are based on trend extrapolation. No data are available for Czech Republic, Denmark, Croatia, Latvia, the Netherlands and Finland.
Source: Authors' elaboration on Eurostat SBS (2017).

Signs of a slow recovery are apparent when taking into account the volumes of production sold by EU firms, which have been growing since 2012. In particular, from 2013 to 2016, on average, the output increased by 3.2% (Figure 14).

Figure 14 Volume of production of ceramic tiles sold (EU-28, thousand m²)

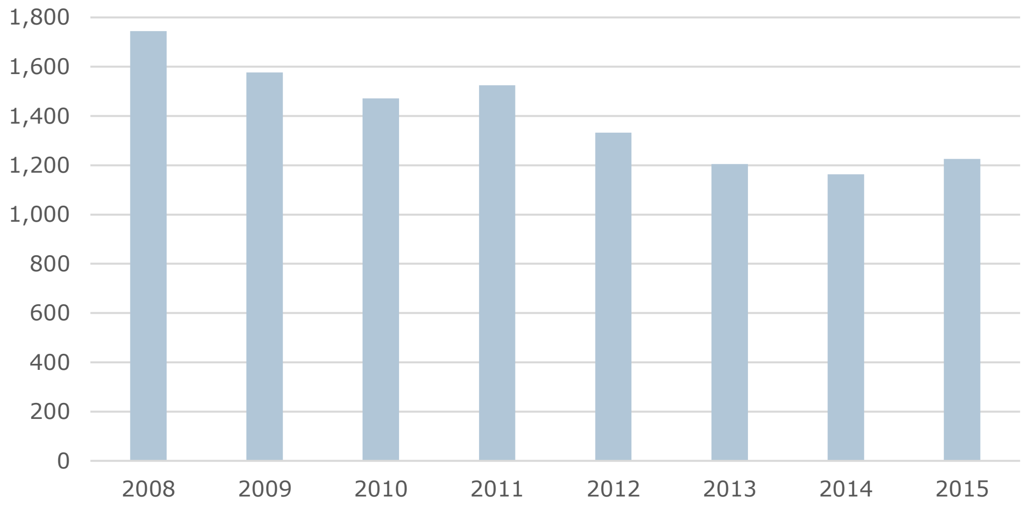


Source: Authors' elaboration on Eurostat Prodcom (2017).

Number of companies and plants operating in the EU

Ceramic tiles are mainly employed in construction activities; hence, this subsector is strongly influenced by the development of the construction industry. As a result of the construction output's contraction due to the financial crisis, in the post-crisis years, the number of enterprises operating in this subsector over the period 2008-15, declined from 1,745 to just 1,225 (-29.8%), as can be seen in Figure 15. Against this background, the last two years assessed in this exercise show a slight recovery mainly linked to the growing production output of the construction sector.

Figure 15 Total number of enterprises producing ceramic tiles in the EU

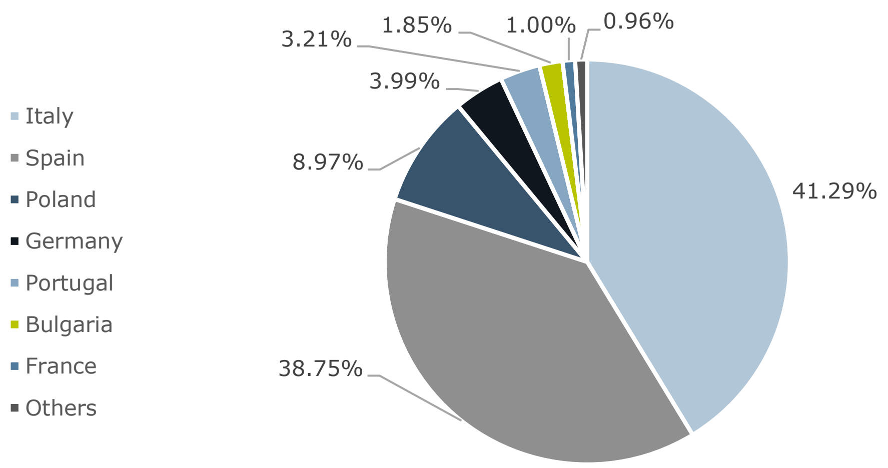


Note: Data estimates for France and Ireland are based on trend extrapolation. No data are available for Czech Republic.
Source: Authors' elaboration on Eurostat SBS (2017).

Geographical distribution of production and plants over EU

The distribution of production volumes sold by each Member State reveals a strong concentration: the top seven countries represented 99% of the 2016 total EU-28 sales, as can be seen in Figure 16.

Figure 16 Share of total volume of ceramic tiles sold, by top producing country (EU, 2016)



Source: Authors' elaboration on Eurostat Prodcom (2017).

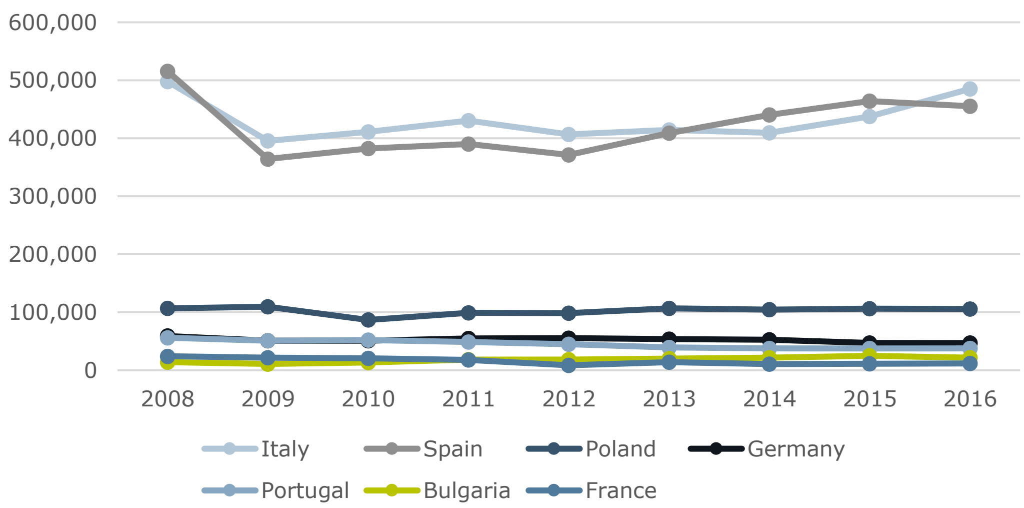
Figure 17 shows that the overall production in these seven Member States decreased by around 8.5% from 2008 to 2016. The trend is quite heterogeneous across countries, however. Whereas the output declined substantially in France (-51.5%) and Portugal (-32.8%), other Member States exhibited a smaller decrease (for instance, the volume of production sold diminished by 2.6% in Italy and by 1.2% in Poland). Bulgaria is the only exception with an increase of 56.8%, even though from 2015 to 2016 its sold production decreased from 24,861,000 m^2 to 21,739,000 m^2.

Italy and Spain have sold the largest share of total production (41.29% and 38.75%, respectively) and have influenced the general EU trend. After the financial crisis decline of 2009, the sold production had two years of consecutive growth in 2010-2011 and dropped again in 2011-2012. After the spillover of 2012, both countries started recovering. Between 2015 and 2016, the Italian production of ceramic tiles overtook the Spanish one, increasing by 3% YoY, whereas the Spanish sold production reduced by almost 2%.

The geographical distribution of production shares is also reflected in the location of plants, which reveals a strong concentration of the major installations in the above-mentioned countries. The largest number of installations were located in Spain (101), Italy (51), Poland (20), Germany (14). Interestingly, Bulgaria, while being one of the main producers in the EU, presented only three major plants.

Nevertheless, it is worth remarking that the accuracy of the analysis based on plant location is limited by the features of the EUTL database, which includes only installations covered by the EU ETS (Table 6).[19] In fact, some small installations might not be recorded in the EUTL database as, according to Article 27 of the ETS Directive (Directive 2003/87/EC), "[f]ollowing consultation with the operator, Member States may exclude from the Community scheme installations which have reported to the competent authority emissions of less than 25,000 tonnes of carbon dioxide equivalent and, where they carry out combustion activities, have a rated thermal input below 35 MW, excluding emissions from biomass, in each of the three years preceding the notification […], and which are subject to measures that will achieve an equivalent contribution to emission reductions, if the Member State concerned complies with the following conditions". In addition, the ETS Directive does not apply to installations manufacturing ceramic products with a production equal to or less than 75 tonnes per day (See Annex I, Directive 2003/87/EC).

Figure 17 Volume of production of ceramic tiles sold by country (thousand m²)



Source: Authors' elaboration on Eurostat Prodcom (2017).

[19] The EUTL database is accessible at: http://ec.europa.eu/environment/ets/napMgt.do;EUROPA_JSESSIONID=gVFZD9JHmhzLIXeD7_3hp_ycJ57siAhFZ-wAHUqn7DBrx6KXtqC2!-198553537.

Table 6 Geographical distribution of plants in major producing EU countries

Member State	Plants
Spain	101
Italy	51
Poland	20
Germany	14
Czech Republic	4
France	3
Bulgaria	3
Portugal	2
Hungary	2
Netherland	2
UK	1
Romania	1

Source: Authors' elaboration on European Commission - EUTL database (2017).

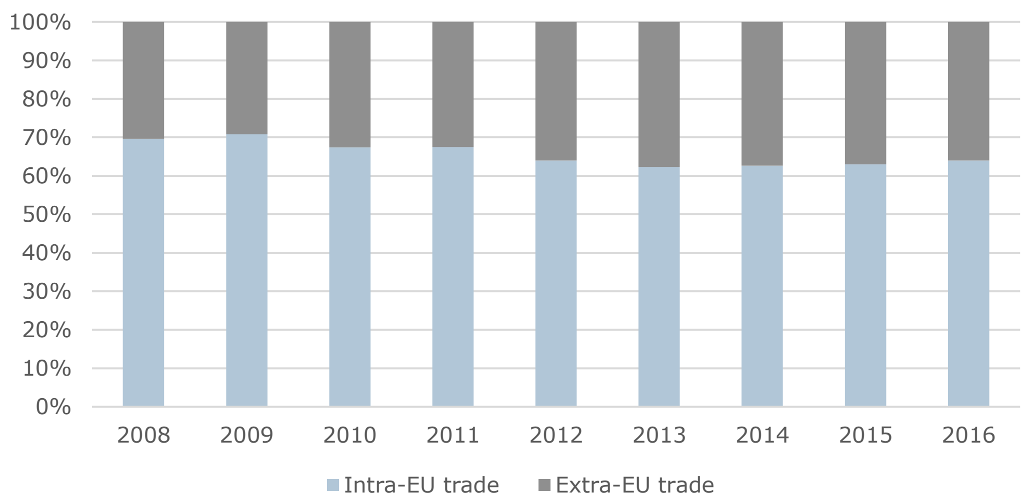
Employment

Employment data for the wall and floor tiles sector is combined with the brick and roof tiles sector, please refer to the employment section in section 1.3.

2.4 Trade analysis

Figure 18 illustrates the relative importance of intra-EU trade over extra-EU trade. In 2016, the intra-EU component accounted for almost 64% of the total trade value.

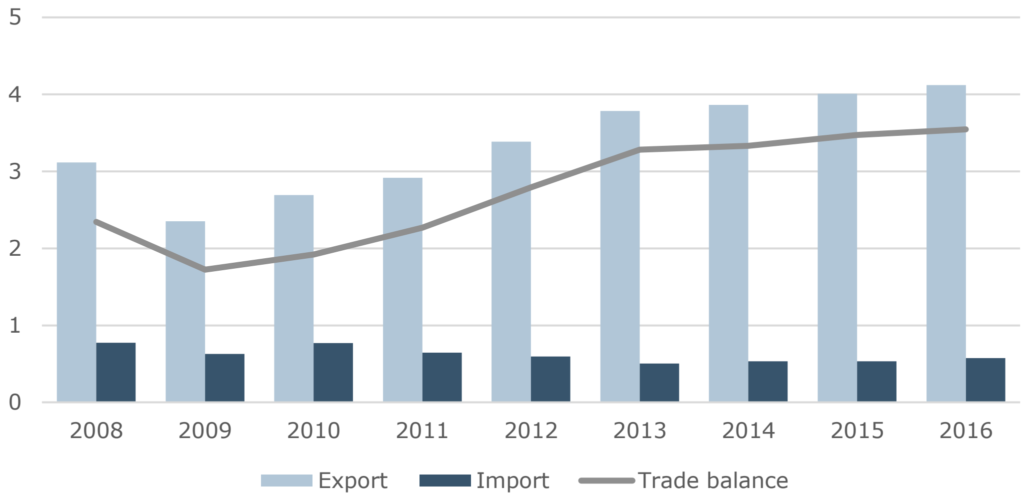
Figure 18 Intra- and extra-EU trade (EU)



Source: Authors' elaboration on Comext (2017).

With regard to international trade, the EU is a net exporter of ceramic tiles (Figure 19). Moreover, the positive trade balance widened after 2009, almost reaching €3.2 billion in 2016. While extra-EU imports decreased over the period 2008-16, extra-EU exports have been steadily growing since 2009. One possible explanation is that the industry tried to overcome the fall in internal demand by following an internationalisation strategy.

Figure 19 Extra-EU trade (EU, billion €)



Source: Authors' elaboration on Eurostat Comext (2017).

Table 7 illustrates the main extra-EU export and import flows of ceramic tiles in 2016.

The United States was the main destination country of ceramic tiles in 2016, accounting for 22% of the EU exports (+1.8% compared to 2015 and +3.8% compared to 2008). Switzerland, Saudi Arabia and Russia followed, accounting for 6%, 5% and 5%, respectively. In 2016, the top exporter to the EU was Turkey with 48% of all EU imports (+2.5% compared to 2015 and +1.9% compared to 2008), followed by China (16%)[20] and United Arab Emirates (11%). In 2008, China was the main exporter to the EU, but since 2008, imports have declined substantially (-30.1% between 2008 and 2016), probably because of an anti-dumping duty imposed by the Council in 2011 on some Chinese companies operating in the subsector (AD 560).[21]

Table 7 Top 10 trading partners of the EU in ceramic tiles, 2016

Top 10 destination markets		Top 10 exporters to EU	
United States	22%	Turkey	48%
Switzerland	6%	China	16%
Saudi Arabia	5%	United Arab Emirates	11%
Russia	5%	India	7%
Israel	4%	Brazil	3%
Canada	4%	Russia	2%
Algeria	3%	Ukraine	2%
Lebanon	3%	Vietnam	2%
United Arab Emirates	3%	Serbia	1%
Morocco	3%	Indonesia	1%

Source: Authors' elaboration on COMEXT (2017).

[20] Reportedly, overcapacity along with an often-subsidised industrial system allow China to place its products in international markets at artificially low prices.

[21] Council Implementing Regulation (EU) No 917/2011 of 12 September 2011 imposing a definitive anti-dumping duty and collecting definitively the provisional duty imposed on imports of ceramic tiles originating in the People's Republic of China.

3 Hollow Glass (glass tableware and packaging glass)

3.1 Introduction

Hollow glass has been used as packaging in many aspects of everyday life since ancient times. The main products of the hollow glass sector are bottles (e.g. for wines, sparkling wines, beers and ciders, soft drinks and mineral water), jars (e.g. for jams, milk products, sauces, oil and vinegar) and other containers (e.g. flacons for perfumery, cosmetics and pharma), which come in different colours and shapes in order to achieve additional features. For instance, brown glass is used to pack light/UV-sensitive contents, such as medicine, juice or beverages containing beer to prolong shelf life. As mentioned, besides packaging, the hollow glass sector also includes tableware, e.g. drinking glasses, pitchers and dishes. The two categories of products are quite different when it comes to production costs, revenues, value-to-weight ratio and international trade, which is considerably higher for glass tableware, thus making these products globally tradable.

3.2 Overview of the production processes

Usually, the production of hollow glass involves five main stages:[22] i) preparation of the raw materials (batching and mixing); ii) melting and refining; iii) forming (blow-and-blow and press-and-blow process); iv) annealing and (online) coating;[23] and v) inspection.

Preparation of raw materials. The raw materials employed depend on the kind of glass produced, e.g. soda-lime glass, lead glass or borosilicate glass. In spite of this potential heterogeneity, hollow glass is primarily of the soda-lime kind[24] whose preparation requires silicon dioxide (sand/silica) (70-74%), sodium oxide (12-16%), calcium oxide (5-11%), magnesium oxide (1-3%) and aluminium oxide (1-3%).[25] These inputs are mixed in a batch plant together with "cullet glass", i.e. recycled glass. As cullet melts at lower temperatures, it reduces natural gas consumption as well as CO_2 emissions.[26] In fact, the loss on ignition or fusion loss can vary, depending on the quantity of cullet used, there being less fusion loss the greater the quantity of cullet.

Melting and refining. The batched raw materials are transported from a mixing silo to a furnace where they are melted down at 1,500°C; operating continuously, furnaces have an investment life between 10 and 15 years. It takes approximately 24 hours to convert a batch of raw materials into molten glass and to refine it to remove any bubbles, after which it is conveyed to the forming area.

Forming. Having been conditioned by careful temperature control in the forehearth, i.e. a channel-like structure fired by a number of small burners, the molten glass enters the feeder and flows through holes in an orifice plate. Streams of glass are cut into gobs of a predetermined weight, which are then guided into individual moulds. In a first stage the gob of glass falls into a blank mould to produce a parison. Depending on the kind of product, hollow glass is formed through two different two-step processes. In the **blow-and-blow process**, used for narrow-neck containers, e.g. bottles, compressed air is blown into the molten gob to create a cavity while this is in the blank mould. The result is a hollow and partly formed container, which is subsequently subjected again to

[22] Consol (2014), "Glass Manufacturing Process" (www.consol.co.za/business/why-glass/glass-manufacturing-process). See also G.L. Robertson (2013), Food Packaging: Principles and Practice, Boca Raton, FL: CRC Press, p. 234.

[23] Coating can be also carried out offline as a downstream activity.

[24] G.L. Robertson (2013), op. cit. pp. 230-231.

[25] Ecorys (2008), "Competitiveness of the Glass Sector", study conducted in the Framework Contract of Sectoral Competitiveness Studies, ENTR/06/054, Final Report, October, p. 48.

[26] See International Energy Agency (2007), "Tracking Industrial Energy Efficiency and CO2 Emissions", study conducted in support of the G8 Plan of Action.

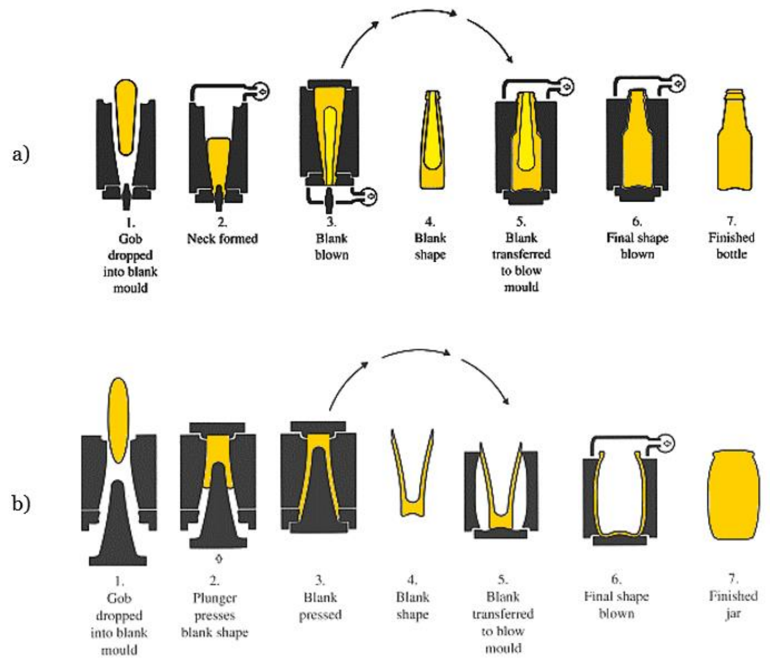
compressed air to blow and mould the final shape. The second process, known as the **press-and-blow method**, is generally used for jars and tapered narrow-neck containers. Here, a metal plunger instead of air is used to press a cavity into the gob in the blank mould before compressed air is used to form the container in the blow mould. Figure 20 provides a schematic illustration of the two above-mentioned shaping processes.

Annealing and (on-line) coating. The formed hollow glassware is removed from the mould and transferred by conveyer to a temperature-controlled tunnel, also called a "lehr", to cool down in a controlled manner. In other words, annealing consists of a heat-treatment meant to relieve internal stresses, prevent uneven cooling and ensure mechanical stability; this process might take up to two hours. While still in the lehr, the external surface is first coated with a thin layer of tin oxide to increase its strength. Eventually, before leaving this phase, the product is also coated with polyethylene wax to protect the surface and prevent scuffing.

Inspection*.* The hollow glassware undergoes visual inspection by high-resolution camera equipment as well as by trained specialists. Rejected containers are sent to the recycling operation to be turned into cullet and re-enter the production process.

Finally, the products are packed and stored, either for direct sale or for secondary processing.

Figure 20 Schematic illustration of the blow-and-blow (a) and press-and-blow (b) processes for forming hollow glass



Source: Authors' elaboration http://cyberglasstrade.com/product.html.

3.3 Industry characteristics

According to the NACE (Rev.2) statistical classification of economic activities in the European Community, both packaging glass and hollow glass are classified under NACE Rev. 2 code 23.13, comprising the manufacturing of hollow glass. Details regarding the specific subsectors within packaging glass and glass tableware are provided in Table 8.

Table 8 NACE Rev. 2 classification of hollow glass sector

SECTION C — MANUFACTURING
23 Manufacture of other non-metallic mineral products
23.1 Manufacture of glass and glass products
23.13 Manufacture of hollow glass
Manufacture of packaging glass
23.13.11.10: Glass preserving jars, stoppers, lids and other closures (including stoppers and closures of any material presented with the containers for which they are intended)
23.13.11.30: Glass containers of a nominal capacity ≥2.5 litres (excluding preserving jars)
23.13.11.40: Bottles of colourless glass of a nominal capacity <2.5 litres, for beverages and foodstuffs (excluding bottles covered with leather or composition leather, infant's feeding bottles)
23.13.11.50: Bottles of coloured glass of a nominal capacity <2.5 litres, for beverages and foodstuffs (excluding bottles covered with leather or composition leather, infant's feeding bottles)
23.13.11.60: Glass containers for beverages and foodstuffs of a nominal capacity <2.5 litres (excluding bottles, flasks covered with leather or composition leather, domestic glassware, vacuum flasks and vessels)
23.13.11.80: Glass containers of a nominal capacity <2.5 litres for the conveyance or packing of goods (excluding for beverages and foodstuffs, for pharmaceutical products, containers made from glass tubing)
Manufacture of glass tableware
23.13.12.20 Drinking glasses (including stemware drinking glasses), other than of glass ceramics, of lead crystal, gathered by hand
23.13.12.40: Drinking glasses (including stemware drinking glasses), other than of glass ceramics, of lead crystal, gathered mechanically
23.13.12.60: Drinking glasses (excluding stemware drinking glasses and products of glass ceramics or lead crystal), of toughened glass
23.13.13.50: Table/kitchen glassware with linear coefficient of expansion ≤5 x 10-6/K, temperature range of 0°C to 300°C excluding glass-ceramics, lead crystal/toughened glass, drinking glasses
23.13.13.90: Table/kitchen glassware (excluding drinking), toughened glass.

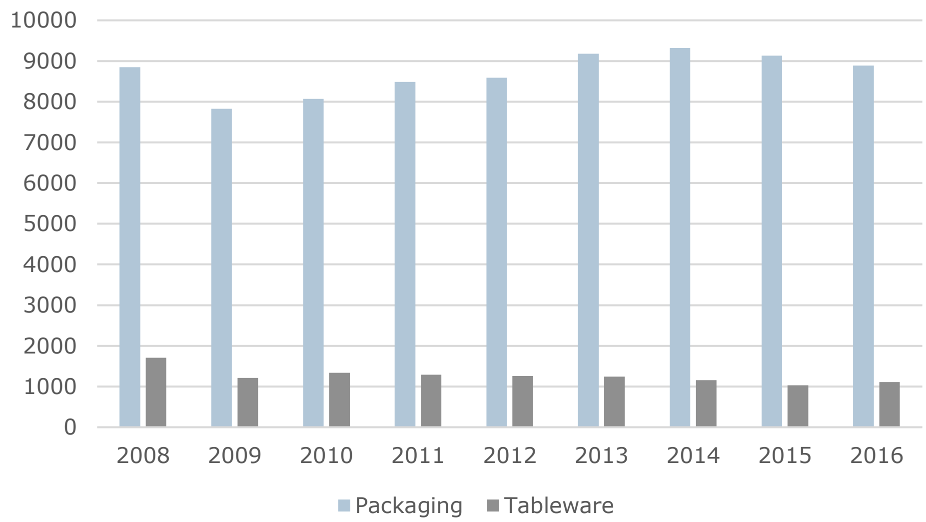
Source: Authors' elaboration on Eurostat (2017).

Production in the EU

After decreasing by about €1 billion between 2008 and 2009, the value of production sold by EU packaging glass producers has constantly increased and has gone beyond the pre-crisis level. In fact, since 2013, the value of production sold for packaging glass has been at around €9 billion.

Conversely, in the EU glass tableware subsector, figures are still far from the pre-crisis level. Moreover, in this subsector, the value of production sold by EU producers has been fluctuating since 2007. More specifically, between 2013 and 2015, the sector registered a contraction and recorded a small improvement between 2015 and 2016.

Figure 21 Value of production sold by EU packaging glass and glass tableware producers (€ millions)

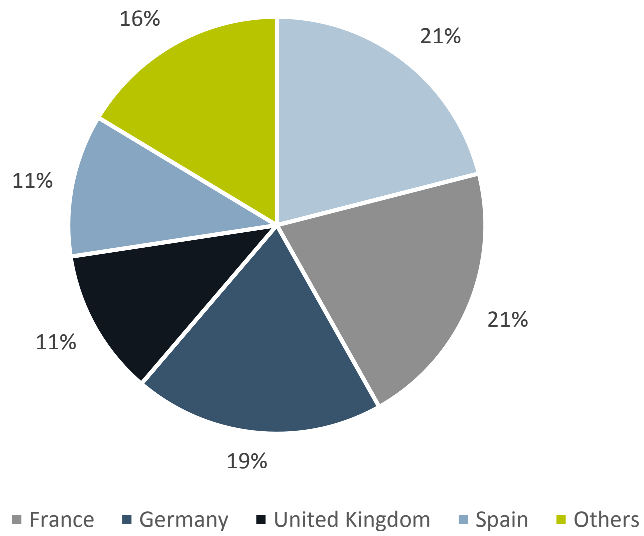


Source: Authors' elaboration based on PRODCOM.

Geographical distribution of production and plants over EU

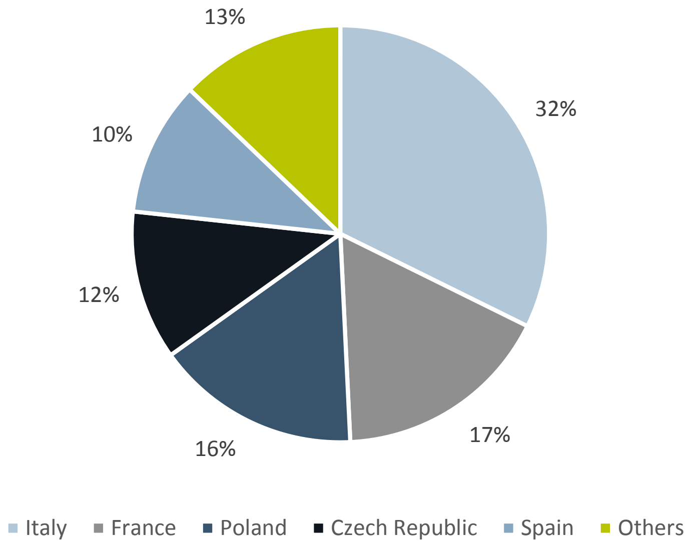
The distribution of production value shows that the hollow glass sector is quite concentrated. Five Member States account for the majority of the EU production. Packaging glass producers are mostly concentrated in France, Italy, Germany, Spain and the UK (Figure 22). For glass tableware, Italy is the largest producer, followed by France, Poland, Czech Republic and Spain (Figure 23).

Figure 22 Production value distribution amongst the top 5 EU packaging glass producers (2016)



Source: Authors' elaboration on Eurostat SBS (2017).

Figure 23 Production value distribution amongst top 5 EU glass tableware producers (2016)



Source: Authors' elaboration on Eurostat SBS (2017).

Another source used to estimate the number of plants and their distribution is the European Union Transaction Log (EUTL) Database, which contains all plants registered under the ETS system. Based on this database, manufacturers of hollow glass are present in 20 Member States, as reported below in Table 9.

Table 9 Number of plants in the EU producing glass tableware, by Member State

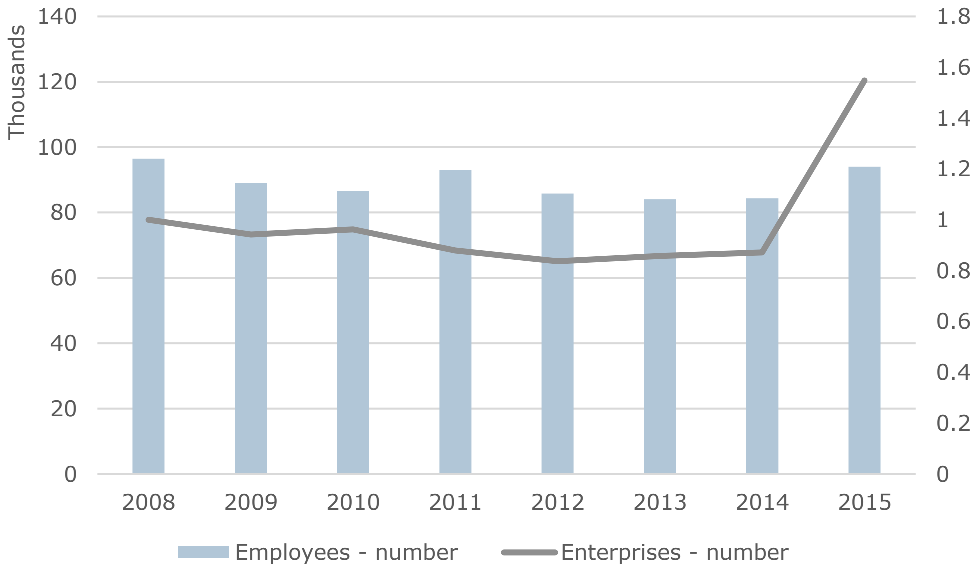
Member State	Number of plants	Member State	Number of plants
DE	36	AT	3
IT	36	BE	3
FR	29	SI	3
PL	17	SK	2
ES	16	DK	1
GB	12	EE	1
CZ	8	GR	1
PT	7	HU	1
NL	5	RO	1
BG	4	SE	1

Source: EUTL (2017).

Employment

The EU hollow glass sector registered a decrease in terms of both employment and enterprise between 2008 and 2014; however, between 2014 and 2015 a major increase was registered (Figure 24).[27]

Figure 24 Number of persons employed (left axis, thousands €) and of enterprises (right axis, index number 2008=100) in the EU hollow glass sector, 2008-15



Source: Authors' elaboration based on Eurostat Structural Business Statistics.

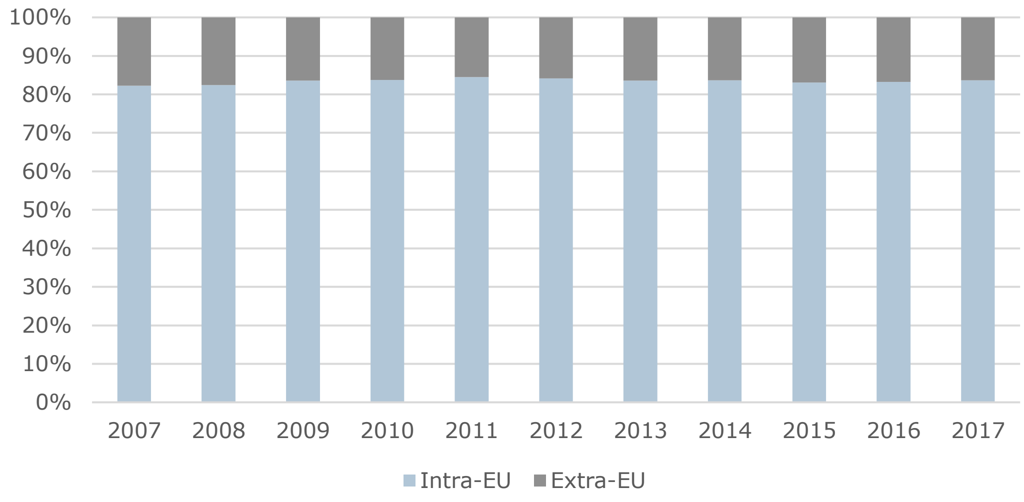
3.4 Trade analysis

Figure 25 and Figure 26 show that intra-EU trade is more relevant than extra-EU trade in the packaging glass and glass tableware sectors. From 2007 to 2017, intra-EU trade of packaging glass accounted for 80% of the total trade, whereas glass tableware recorded an intra-EU trade of around 60% of the total trade.

With regard to international trade, the EU is a net exporter of packaging glass, although imports have slightly increased in recent years. The positive trade balance has been narrowing since 2013. From 2009 onwards, both exports and imports of packaging glass have been increasing. Similarly, the glass tableware subsector sees the EU as a net exporter, with more fluctuations in the last 10 years.

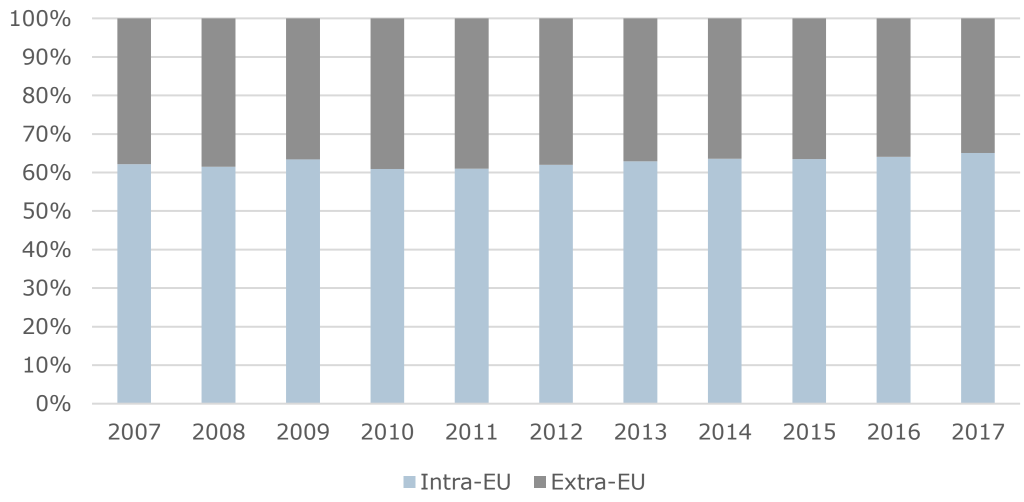
[27] It is worth remarking that the statistics published by the European Container Glass Federation (FEVE) are substantially different from Eurostat data. Direct employment is estimated in the region of 65,000: glass packaging accounts for 44,000 direct employees (FEVE statistics) and glass tableware for 21,000 (EDG/FEVE statistics). In addition, the number of companies has not increased, as Eurostat indicates.

Figure 25 Packaging glass intra and extra-EU trade, 2007-17 (%, EU-28)



Source: Authors' elaboration on COMEXT (2018).

Figure 26 Glass tableware intra and extra-EU trade, 2007-17 (%, EU-28)

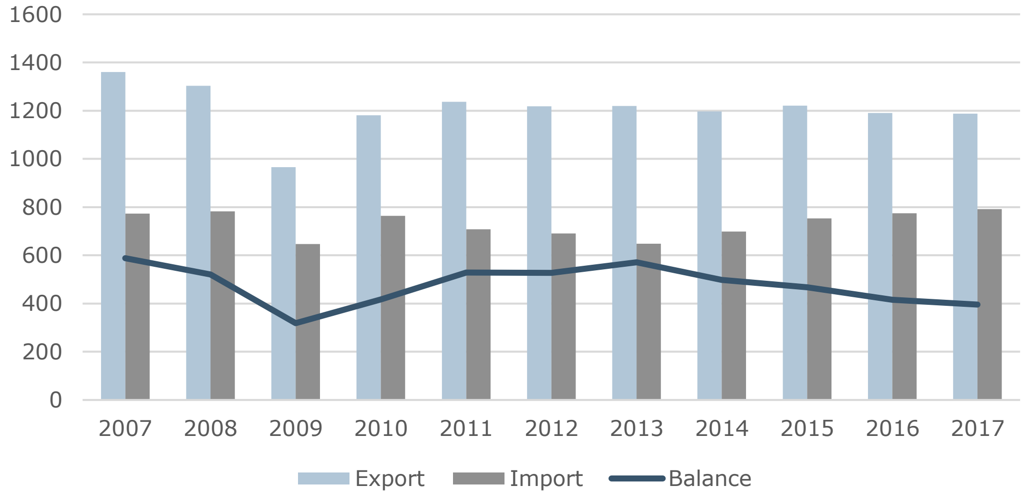


Source: Authors' elaboration on COMEXT (2018).

Figure 27 Packaging glass extra-EU trade flows, 2007-17 (EU, € million)

Source: Authors' elaboration on COMEXT (2018).

Figure 28 Glass tableware extra-EU trade flows, 2007-17 (EU, € million)



Source: Authors' elaboration on COMEXT (2018).

Table 10 identifies the United States as the main destination market for EU exports of packaging glass in 2017, accounting for almost 25% of the exports, followed by Switzerland (14.5%) and Canada (4.3%). Table 11 shows the top 10 countries exporting to the EU in 2017: China holds the highest share of exports to the EU, followed by Ukraine and Switzerland.

Table 10 Top 10 destination markets for packaging glass, 2017 (%)

Top 10 destination markets in 2017	
UNITED STATES	24.7%
SWITZERLAND	14.5%
CANADA	4.3%
RUSSIA	3.9%
SERBIA	3.2%
TURKEY	3.0%
NORWAY	2.7%
ISRAEL	2.7%
AUSTRALIA	2.5%
ALGERIA	2.1%

Source: Authors' elaboration on COMEXT (2018).

Table 11 Top 10 exporters to the EU for packaging glass, 2017 (%)

Top 10 exporters to the EU in 2017	
CHINA	28.2%
UKRAINE	14.4%
SWITZERLAND	10.0%
INDIA	7.2%
UNITED ARAB EMIRATES	7.7%
TURKEY	4.7%
UNITED STATES	4.3%
MOLDOVA	4.3%
RUSSIA	3.7%
TAIWAN	3.0%

Source: Authors' elaboration on COMEXT (2018).

With regard to glass tableware trading partners, Table 12 and Table 13 illustrate the main trade counterparts of the EU in 2017. Considering the exports, the United States is the main destination country also for glass tableware, with a share of 22.1%, followed by Russia and China. On the import side, the EU is mainly importing from China (63.3% of the extra-EU imports come from the country) and Turkey (17.8%). The values are closely aligned with those of previous years.

Table 12 Top 10 destination markets for glass tableware, 2017 (%)

Top 10 destination markets in 2017	
UNITED STATES	22.1%
RUSSIA	7.3%
CHINA	5.5%
SWITZERLAND	5.5%
JAPAN	5.0%
UNITED ARAB EMIRATES	3.4%
NORWAY	3.3%
AUSTRALIA	3.0%
SERBIA	2.6%
CANADA	2.4%

Source: Authors' elaboration on COMEXT (2018).

Table 13 Top 10 exporters to the EU for glass tableware, 2017 (%)

Top 9 exporters to the EU in 2017	
CHINA	63.3%
TURKEY	17.8%
INDIA	3.6%
SERBIA	3.0%
UNITED STATES	1.9%
LIECHTENSTEIN	1.3%
EGYPT	1.0%
SOUTH KOREA	1.0%
RUSSIA	0.9%
SWITZERLAND	0.8%

Source: Authors' elaboration on COMEXT (2018).

4 Aluminium

4.1 Introduction

According to the NACE (Rev.2) statistical classification of economic activities in the European Union, aluminium makers are included in the class 24.42. This includes primary and secondary aluminium production, as well as semi-manufactured aluminium products. This sector description covers three subsectors: i) primary aluminium, ii) secondary aluminium and iii) two downstream activities: rolling mills and extrusion plants.

Aluminium is the most abundant crustal metal on earth and its compounds account roughly for 7% of the earth's crust (Bergsdal et al., 2004).[28] First produced in 1808, the metal has become a central element at the core of industrialised economies.

Aluminium has a number of physical properties that make its usage particularly attractive across different industries:

- Lightweight and excellent electrical conductivity; as a result, aluminium wires are used on a large scale for electricity transmission.
- High workability and strength, often used in the production of vehicles (cars, trains, aircraft) and other industries where the combination of strength and low weight allows for highly efficient fuels properties.
- Good thermal properties and good resistance to corrosion. Aluminium is thus widely used in construction, conditioning, refrigeration and heating exchange industries.
- High malleability, which facilitates the production of thin rolls and sheets that are extensively used by the packaging industry.

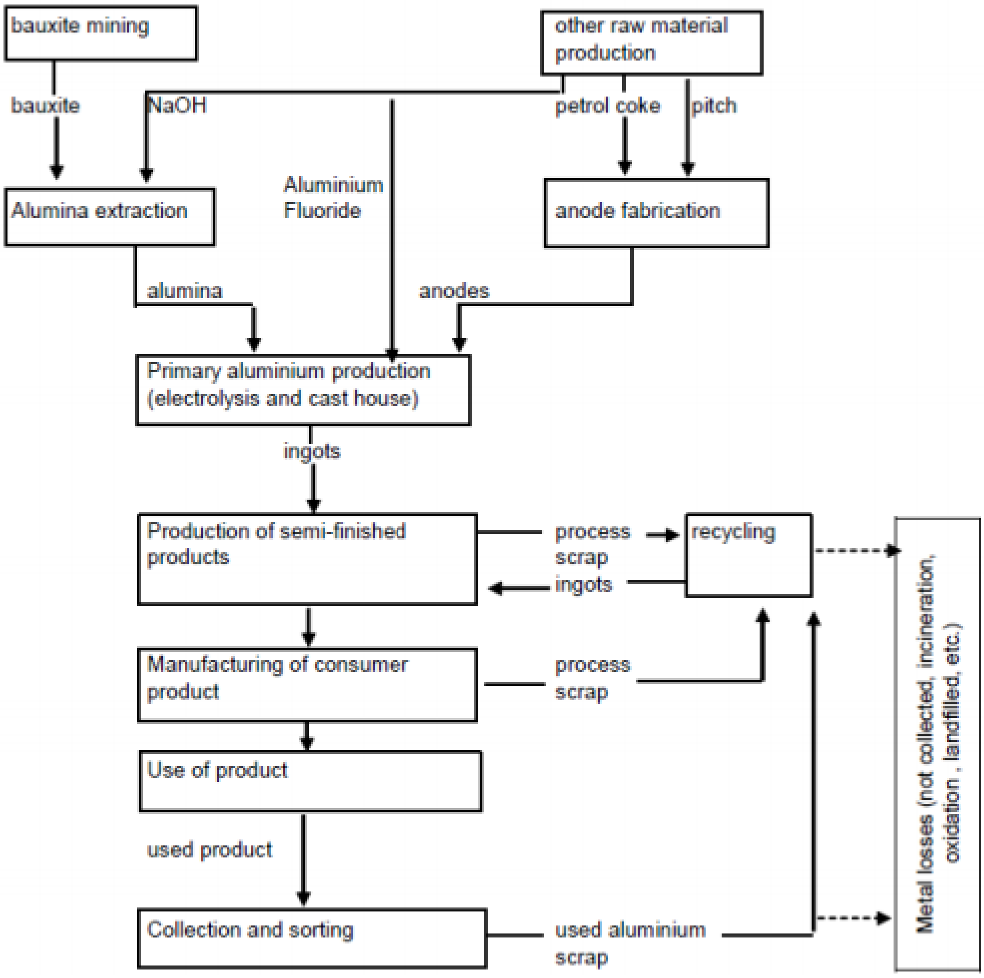
4.2 Overview of the production process

The aluminium production process is elaborate, costly and energy intensive. Once produced, however, aluminium can be recycled indefinitely without losing its major properties.

In order to obtain a final product suitable for industrial usage, three main production phases are generally distinguished: first, the basic raw material bauxite needs to be extracted. Bauxite is then refined into a product called alumina and eventually alumina is smelted into primary aluminium (using carbon-containing anodes as a second raw material). Primary aluminium can be recycled and brought back to the market as secondary aluminium. These different phases are illustrated in Figure 29 below. Both primary and secondary aluminium serve as inputs for downstream users such as rolling mills and extruders.

[28] Bergsdal, H., Strømman, A. H., & Hertwich, E. G. (2004). The aluminium industry-environment, technology and production.

Figure 29 Simplified aluminium life-cycle material flow



Source: JRC (2015) and CEPS & EA (2013).[29]

Production of primary aluminium

The production of primary aluminium is done through the smelting of alumina into primary aluminium, which is then cast into ingots. The casting and smelting processes are integrated in all EU primary aluminium plants. The smelting process (the Hall-Herout process) is very electricity-intensive, and is based on three main inputs: alumina, electricity and carbon (in the form of anodes). The smelting of alumina into aluminium is based on an energy intensive electrolytic process, with temperatures as high as 960°C. During the process, a high current (200 to 350 kA) is passed through the electrolytic bath to produce aluminium metal (IEA, 2012).[30]

Two different technologies have been adopted to increase energy efficiency of the smelting: the Soderberg and Prebake technologies, which differ by the type of anode used (Bergsdal et al., 2004).[31] The Soderberg technology is older and consumes more energy (energy intensity range 15.1-17.5 MWh/t). It is being slowly replaced by the Prebake technology (energy intensity range: 13.6-15.7 MWh/t). New plants and most modernisation programmes for existing plants adopt the new technology, mainly because

[29] JRC (2015) and CEPS & EA (2013) op. cit.

[30] IEA (2012), Aluminium Production. Available at: https://iea-etsap.org/E-TechDS/PDF/I10_AlProduction_ER_March2012_Final%20GSOK.pdf

[31] Bergsdal et al., 2004, op. cit.

of the financial savings from the higher electricity efficiency of the Prebake technology (Bergsdal et al., 2004).[32] In 2014, 90% of EU primary aluminium was produced using the Prebake technology. The remaining 10% was produced using the Soderberg technology (Draft BREF, 2014).

Independent of the production technology employed, energy is a major driver of cost. Globally the primary aluminium cost structure generally consists of the following: alumina (34.8% of production costs), electrical power (32.5% of production costs), carbon (13% of production costs) and labour (6.8% of production costs) (CEPS-EA, 2013).[33] The share of production costs accounted for by electricity found in this study for the sampled EU primary smelters is slightly lower (averages across the respondents between 21.1% and 30.1%).

Alumina is priced on the international level, and its cost is therefore roughly the same for all producers. Electricity costs, on the other hand, vary from country to country. Therefore, the smelting process is often located close to supplies of cheap and constant electricity (CEPS-EA, 2013).[34]

Secondary aluminium production

Secondary aluminium is all aluminium produced through the recycling of aluminium scrap, such as wires, cables, casting alloys, used beverage cans, packaging and dross (mixture of metal, alumina and other materials). Aluminium can be recycled indefinitely without losing fundamental properties, such as its light weight and durability. According to the International Aluminium Institute (2013),[35] more than a third of all the aluminium globally produced comes from aluminium scraps. The International Aluminium Institute (2013)[36] estimate that 75% of all aluminium ever produced is still in use.

Since the 1950s, the production of secondary aluminium has been steadily growing, reaching 18 million tonnes of production globally in 2010. The factors contributing to this include: lower energy costs of production compared to primary aluminium (recycling requires only around 5% of the energy consumed during the production of primary aluminium, according to the International Aluminium Institute, 2013)[37] and concerns about sustainable development, environmental legislation and the high market value of aluminium scrap due to the embedded energy from the primary smelting process (CEPS-EA, 2013).[38]

Two different processes are used to recycle aluminium, each tailored to different segments of the downstream market. The refining process produces secondary aluminium using very different types of scraps. This process has a 15% tolerance of impurity (relatively high) and, for this reason, the recycled aluminium can be used by downstream casters (mainly employed in the automotive sector). The remelting process is more complex and needs purer scraps (2-3% maximum impurity tolerance) and therefore recycles mostly industrial

[32] Bergsdal et al., 2004, op. cit.

[33] Centre for European Policy Studies (2013), "Assessment of Cumulative Cost Impact for the Steel and the Aluminium Industry, Final Report Aluminium. October 2013. http://ec.europa.eu/growth/toolsdatabases/newsroom/cf/itemdetail.cfm?item _id=7124&lang=en&title=Final-report--- Assessment-of-Cumulative-CostImpact-for-the-Aluminium-Industry

[34] CEPS (2013) op. cit.

[35] International Aluminium Institute (2013), Global Aluminium Recycling: A Cornerstone of Sustainable Development, Available at: http://www.world-aluminium.org/media/filer_public/2013/01/15/fl0000181.pdf

[36] International Aluminium Institute (2013), op. cit.

[37] International Aluminium Institute (2013), op. cit.

[38] CEPS (2013) op. cit.

scraps. The remelting process generates secondary aluminium that can be used both in rolling mills and extrusion plants.

Recycling plays an important role in the EU. There is, however, a lack of scrap and the export of scrap (mostly to Asia) limits the availability of recycled aluminium. Therefore, primary aluminium production remains necessary for now to cover EU demand for aluminium (JRC, 2015).[39]

Downstream activities

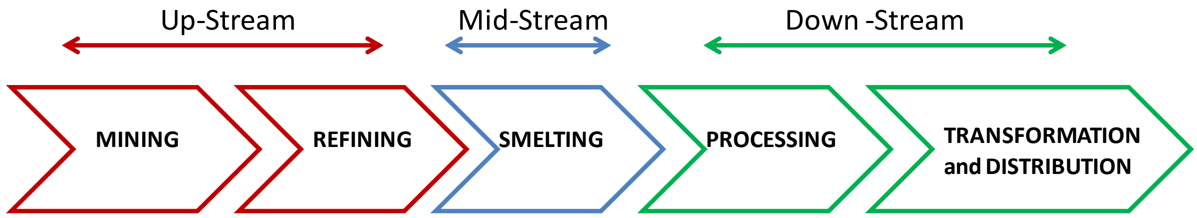
The downstream activities include processing and transformation, which turn aluminium ingots into semi-finished or finished products. The processing required depends on the final user (whether in transportation, packaging, electrical or engineering), who will set specific technical requirements. The automotive and construction sectors have constantly been the two largest aluminium end users, driving demand.

Two major downstream activities that are included in this study are rolling mills and extruders. Rolling mills use hot, cold or foil rolling to produce different types of sheets, plates and foils. The usual production process is rolling thick aluminium between rolls to reduce the thickness and lengthen the rolled product (Aluminium Association, 2007).40 Extruders transform aluminium alloys into objects with a cross-sectional profile. Aluminium is pushed through a die. Aluminium can be hot or cold extruded, which allows it to be shaped according to the specificities of consumers. Construction, transport and aerospace are three sectors that consume extruded aluminium (Spectra aluminium, 2010).[41]

4.3 Industry characteristics

The aluminium value chain is diagrammed in Figure 30, following the definitions from Garen et al. (2009).[42] The upstream and midstream phases are the stages that produce aluminium ingots or liquid aluminium. The downstream phases include the rolling, extruding and casting of aluminium.

Figure 30 Value chain in aluminium production



Source: CEPS and EA (2013).

Energy costs are the key factors in determining where the mid-stream (or smelting) part of the value chain is developed, as it represents on average 30% of the total cost of

[39] JRC, (2015) op. cit.

[40] The Aluminium association, Rolling Aluminum: from the mine through the mill, (2007). Available at: http://www.aluminum.org/sites/default/files/Rolling_Aluminum_From_The_Mine_Through_The_Mill.pdf

[41] Spectra aluminium (2010), "What is aluminium extrusion". Available at: http://www.spectraaluminum.com/what-is-aluminum-extrusion

[42] Garen, J., Jepsen, C., and Scott, F. (2009). Economic Forces Shaping the Aluminum Industry. University of Kentucky, Lexington - report prepared for the Sloan Center for a Sustainable Aluminum Industry.

aluminium production (Garen et al., 2009)[43]. Placing aluminium smelters where they can be supplied with cheap energy is essential to being able to produce at a competitive cost.

Table 14. NACE Rev.2 classification of the aluminium sector

SECTION C — MANUFACTURING
24 Manufacture of other non-metallic mineral products
24.42 Aluminium production
24.42.11 Aluminium, unwrought
24.42.12 Aluminium oxide, excluding artificial corundum
24.42.21 Aluminium powders and flakes
24.42.22 Aluminium bars, rods and profiles
24.42.23 Aluminium wire
24.42.24 Aluminium plates, sheets and strip, of a thickness > 0.2 mm
24.42.25 Aluminium foil, of a thickness ≤ 0.2 mm
24.42.26 Aluminium tubes, pipes and tube or pipe fittings

Source: Authors' elaboration on Eurostat (2018).

<u>Production in the EU</u>

The EU produces approximately 7% of all primary aluminium (European Aluminium, 2016).[44] In 2013, European[45] aluminium production was approximately 8.9 million tonnes (IAI, 2015),[46] of which approximately 4.2 million tonnes were primary aluminium, and 4.7 million tonnes were secondary aluminium (JRC, 2015). However, these statistics include a number of major European countries that are not members of the EU, such as Norway and Iceland. In 2012, 2.1 million tonnes of primary aluminium and 4.1 million tonnes of secondary aluminium were produced in the EU-27 (BAT Reference Document, 2017). In 2017, primary aluminium production was slightly higher at 2.2 million tonnes (European Aluminium, 2018).[47]

The total production value of aluminium dropped in all Member States in 2009 (see Figure 31), with only Poland and Germany showing significant growth between 2010 and 2016. Production values in Member States such as Greece, Italy and Spain have not yet recovered from the crisis, although all grew marginally between 2013 and 2016.

[43] Garen et al. (2009), op. cit.

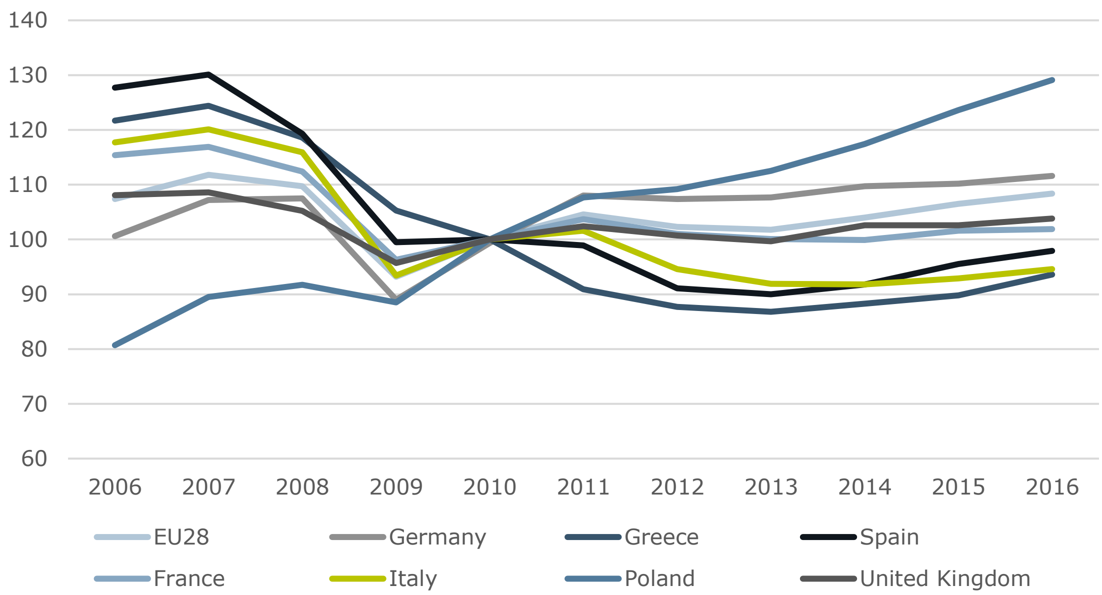
[44] European Aluminium data. Internal data of European Aluminium

[45] The International Aluminium Institute does not make country-level data publicly available. Europe consists of: EU28, Albania, Belarus, Bosnia-Herzegovina, Iceland, Macedonia, Moldova, Norway, Serbia-Montenegro, Turkey and Ukraine.

[46] IAI (2015), The International Aluminium Institute.

[47] European Aluminium Statistics, (2018) https://www.european-aluminium.eu/data/.

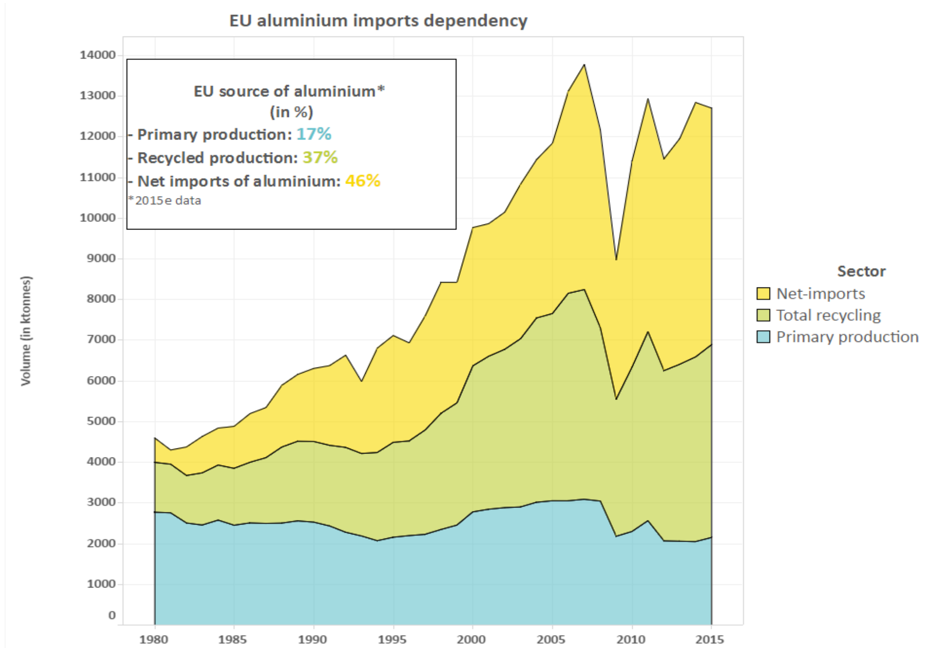
Figure 31 Trends in production values for EU-28 and selected Member States, indexed (2010=100)



Source: Authors' elaboration on Eurostat (2017).

Figure 32 shows that primary aluminium production remained more or less stable between 1980 and 2008, but decreased steadily since the start of the crisis in 2009 and only covered 14% of domestic consumption of aluminium in 2013. Secondary aluminium production increased steadily between 1980 and 2008 before being affected by the crisis. Secondary aluminium production, however, was less affected by the crisis than primary aluminium production. In 2013, it supplied 35% of the domestic consumption of aluminium. Because downstream consumption has continued to grow, and indeed recovered faster than aluminium production after 2009, the domestic demand for aluminium has increasingly outstripped domestic supply.

Figure 32 EU production of primary and secondary aluminium and net imports



Source: European Aluminium (2016).

<u>Number of companies and plants operating in the EU</u>

Table 15 gives an overview of the number of enterprises in the aluminium sector per Member State. These numbers do not match data from the industry association (European Aluminium), as the EUROSTAT data contains a wider scope of downstream activities. Table 15 does however serve to indicate the relative importance of a few Member States in the EU aluminium sector. Germany, Spain, Italy, Poland and the UK each have more than 100 aluminium enterprises. Italy and Germany lead the pack with 313 and 227 enterprises, respectively.

Table 15 Number of enterprises in the EU aluminium sector (NACE Rev.2 24.42) by Member State

	2008	2009	2010	2011	2012	2013	2014	2015
Austria	22	23	24	25	24	23	23	22
Belgium	30	NA	32	NA	50	48	44	22
Bulgaria	13	10	11	11	NA	8	NA	11
Croatia	17	17	15	14	14	13	10	11
Cyprus	NA	NA	NA	NA	NA	NA	NA	NA
Czech Republic	NA	NA	NA	NA	NA	NA	NA	34
Denmark	28	20	16	19	16	9	10	11
Estonia	2	2	2	2	1	1	1	1
Finland	6	6	7	6	6	6	5	5
France	NA	76	93	67	57	62	58	72
Germany	240	231	244	223	225	212	231	227
Greece	40	46	40	36	64	63	64	35
Hungary	19	16	17	16	15	16	15	16
Ireland	NA	NA	NA	NA	NA	NA	NA	36
Italy	318	403	430	415	373	306	289	313
Latvia	7	6	4	5	6	5	7	8
Lithuania	2	1	1	1	1	1	1	0
Luxembourg	3	3	3	3	3	3	3	3
Malta	NA	NA	0	0	0	0	NA	NA
Netherlands	68	71	68	63	61	76	77	70
Poland	53	64	87	107	127	132	131	141
Portugal	57	53	50	53	49	41	39	37
Romania	28	36	33	35	30	30	32	30
Slovakia	NA	NA	13	13	13	12	11	13
Slovenia	8	5	6	7	7	6	6	6
Spain	169	143	137	131	128	104	109	103
Sweden	52	52	48	43	43	48	48	47
United Kingdom	183	166	161	145	138	131	129	128

Source: Eurostat (2017).

a) Primary aluminium

As of 2017, there were 16 primary aluminium smelters active in the EU, run by 10 different companies. The full list of plants appears below in Table 16.

Table 16 Primary aluminium smelters in the EU

Member State	Company	Plant
DE	Trimet	Hamburg
DE	Hydro Aluminium	Neuss
DE	Trimet	AG Essen
DE	Trimet	Limited Voerde
ES	Alcoa	San Ciprian
ES	Alcoa	Aviles
ES	Alcoa	La Coruna
FR	Rio Tinto Alcan	Dunkirk
FR	Trimet	St. Jean
GR	Aluminium de Greece	S.A. Distomon
NL	Aluminium Delfzijl	Delfzijl
RO	ALRO	Slatina
SE	Kubikenborg Aluminium	Sundsvall
SI	Talum	Kidričevo
SK	Slovalco	Ziar nad Hronom
UK	Rio Tinto Alcan	Lochaber

Source: European Aluminium (2017).

b) Secondary aluminium

Data provided by European Aluminium (2018) indicate that there are 214 secondary aluminium plants located in the EU. In both the remelter and refiner industries, there are a limited number of smaller and large players. Large players are often vertically integrated with primary aluminium, rolling and extruder operations; for example, one major recycling player, formerly known as Sapa, was a joint venture between Hydro and Orkla. Since the second half of 2017, Hydro has acquired full ownership of Sapa, which will become a new business area in Hydro, named Extruded Solutions. The 101 refining plants in the EU are operated by 85 companies, and the 109 remelting facilities are operated by 78 companies. In both groups, we find large players such as Hydro Aluminium and Constellium (operating 19 and 6 secondary plants, respectively) and smaller companies that operate just one plant.

c) Downstream activities

Data provided by European Aluminium indicate that there are 59 rolling mills and 309 extruders in Europe. The 59 rolling mills are operated by 43 companies; the 309 extruder installations are operated by 220 companies. These two groups also contain both smaller companies with one or two plants, and large companies such as Constellium and Hydro, which respectively operate 11 and 40 extruders across Europe. Hydro acquired full ownership of Sapa and these extruders in the second half of 2017.

Geographical distribution of production and plants over EU

1) Primary aluminium

At the beginning of 2018, there were 16 primary aluminium plants spread over 10 Member States. The six most important aluminium producing Member States (Germany, Spain, France, Romania, Greece and Slovakia) represented 76% of primary aluminium capacity (EA, 2018)[48].

[48] European Aluminium Statistics, 2018, available at: https://www.european-aluminium.eu/data/.

2) Secondary aluminium

Secondary aluminium plants are both more numerous and more widespread across the EU than primary aluminium plants. The refining industry is operational in 19 Member States, but with the bulk (79%) of EU refining facilities concentrated in seven Member States: France (17 plants), Italy (12), Spain (10), UK (12), Poland (10), Germany (9) and Czech Republic (8) (EA, 2018).[49]

The remelting industry is active in 18 Member States, with 78.9% of all facilities located in six Member States: Italy (30 plants), Germany (24), France (11), Spain (8), UK (7) and Netherlands (6) (EA, 2018).[50]

3) Downstream activities

Rolling mills and extruders can be found in most Member States, and are less concentrated than secondary aluminium production facilities. Out of a total of 18 Member States with rolling facilities, five Member States account for 71% of facilities: Germany (12 plants), Italy (11), Spain (6), France (6) and the UK (4). Extruders can be found in 23 Member States, with 91% in 11 Member States: Italy (72 plants), Spain (61), Germany (40), Greece (27), France (19), Poland (14), the Netherlands (9), Portugal (9), the UK (9), Romania (9) and Belgium (8).

Table 17 gives an overview of the primary, secondary (refiners and remelters), rollers and extruders per Member State (except Malta). Note that a small number of secondary plants are not included in this table, as these plants can switch their production processes between the refiner and remelter processes.

Table 17 Number of plants per production process in each Member State

Member State	Primary aluminium	Secondary aluminium		Rolling Mills	Extrusion
		Remelters	Refiners		
Austria		3	2	1	4
Belgium		2	2	1	8
Bulgaria				1	3
Croatia				1	2
Cyprus					1
Czech Republic		1	7	1	2
Denmark					1
Estonia			1		
Finland		2	1		3
France	2	11	17	6	19
Germany	4	24	9	12	40
Greece	1	3	1	1	27
Hungary		1	5	2	1
Ireland					1
Italy		30	13	11	72
Latvia			1		
Lithuania			1		
Luxembourg		1		1	
Netherlands	1	6	1	1	9
Poland			10	2	14
Portugal		1	1		9
Romania	1	3	1	1	9

[49] European Aluminium Statistics, 2018, op. cit.

[50] European Aluminium Statistics, 2018, op. cit.

Member State	Primary aluminium	Secondary aluminium		Rolling Mills	Extrusion
		Remelters	Refiners		
Slovakia	1	1	2		4
Slovenia	1	1		2	1
Spain	3	8	10	6	61
Sweden	1	4	1	1	3
UK	1	7	12	4	9

Note: The table does not include plants based in Norway (3 extruders, 7 remelters, 2 rollers) and Switzerland (3 extruders, 4 remelters, 2 rollers).
Source: European Aluminium (2018).

Employment

The aluminium industry is the largest of the non-ferrous metal industries in the EU. The EU aluminium industry directly represents a workforce of around 255,000 (BREF, 2014).[51]

4.4 Trade analysis

Aluminium is an internationally traded commodity, and the EU is a net importer. Figure 32 shows that net imports account for 46% of all aluminium processed in the EU. However, both scraps and downstream products are also traded internationally.

The EU trade with third countries in downstream products is dominated by three products: rolled products, extruded products and aluminium wires. The EU is a net exporter of waste and scrap by half a million tonnes, with a value of over €600 million (COMEXT, 2018).

In 2016, the EU had a net export value of half a million tonnes of waste and scrap of aluminium. The EU is a net importer of both extruded products (net imports in 2016: 3,300 tonnes) and aluminium wires (net imports in 2016: 2,000 tonnes). The two largest sources for imported extruded products were Turkey and China in 2016. In the same year, the US was the largest destination for extruded products exported from the EU.

With regard to rolled products, imports have increased significantly since 2008. The EU was a net exporter of rolled products in 2008 with a net export of 43,100 tonnes. Since 2013, the EU has gradually become a net importer and although exports have not increased, imports have doubled since 2008. In 2016, the EU is marginally a net importer of rolled products (net imports reached 18,000 tonnes). The main export markets for EU rollers in 2016 were the US (19,000 tonnes), Switzerland (18,000 tonnes) and Turkey (11,000 tonnes); the majority of imports in 2016 also came from Switzerland (30,000 tonnes), China (26,000 tonnes) and Turkey (24,000 tonnes).

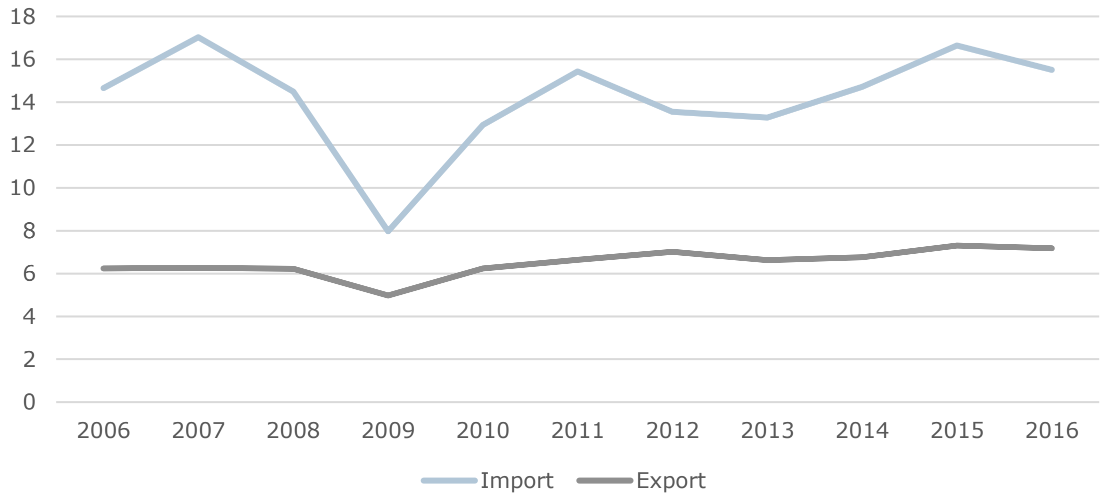
Figure 33 gives an overview of the entire NACE 24.42 sector, and shows the evolution of import and export values for the EU (in € billions). The effects of the crisis that started in 2007 are clear. Export values fell by approximately 20% between 2007 and 2009; at the same time the value of imports more than halved – from over €17 billion in 2007 to just under €8 billion in 2009. Since 2010, export values have remained steady, while import values dropped again in 2011, but recovered by the end of 2015 followed by a small drop in 2016.

Looking at Figure 34, EU imports and exports of aluminium have been increasing since 2006, but imports have increased more significantly. It is clear that the EU is a significant net importer, although the gap between exports and imports narrowed somewhat from 2008 until 2009 and has gradually increased since 2012. In 2006, the EU imported nearly €8.5 billion more in aluminium and aluminium articles than it exported. By 2014, the

[51] Joint research Centre, BAT Reference document for the non-ferrous Metals industries, (2014)

difference was slightly less than €3 billion and, more recently in the 2016, the EU recorded a net import value of €8.3 billion.

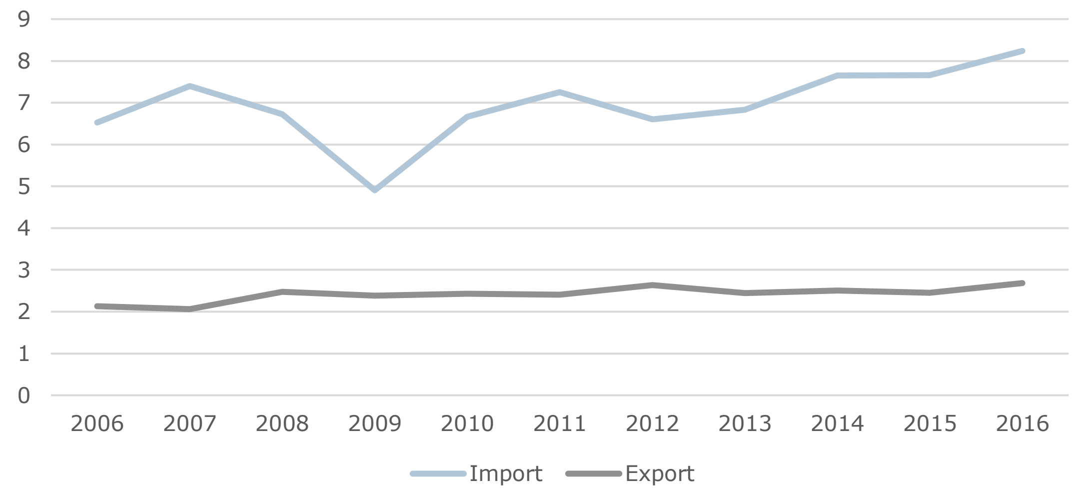
Figure 33 Total EU import and export values, 2006-16 (€ billion)



Source: Authors' elaboration on COMEXT (2018).

If we look at import and export quantities, we see a similar trend. Both import and export quantities dropped significantly between 2007 and 2009, but recovered within a few years. EU export quantities exceeded pre-crisis levels by 2012, and have remained steady since then. Import quantities dropped in 2012, but recovered by the end of 2014 and have continued to increase.

Figure 34 Total EU import and export quantities, 2006-16 (millions of tonnes)



Source: Authors' elaboration on COMEXT (2018).

Table 18 and Table 19 show two snapshots of the trade between the EU and the rest of the world in aluminium products; one for 2008 and one for 2016. Both overall imports and export increased over the period between 2008 and 2016.

The export values in Table 18 show three main export markets that in 2016 accounted for over 41% of total exports: Switzerland, USA and China. While these three countries also figure in the list of main importers to the EU, Norway and the Russian Federation top that list.

Imports from the top three importers to the EU (Norway, Russia and Switzerland) account for nearly €7 billion, or approximately 43% of total imports in 2016. It is apparent that the majority of EU trade in aluminium is concentrated in a limited number of countries. In 2016, just over 80% of all imports came from nine countries, and almost 65% of all EU exports went to nine countries.

Between 2008 and 2016, the relative position of trading partners changed slightly over the 8-year period. While Switzerland and the US were the top two markets to which EU aluminium companies exported in both 2008 and 2016, they have swapped position over the period. Norway fell from fifth place in 2008 to eighth place in 2016. With regard to importers to the EU, the top five have not changed significantly between 2008 and 2016, but the respective values of imports have changed significantly. Norway accounted for nearly a quarter of all imports in 2008 (€3.9 billion), but only a fifth of imports in 2016 (just under €3 billion).

The main EU trading partners, as reported in Table 18 and Table 19, are relevant for the international comparison section of the study, as well as those trading partners that are increasingly competing with European aluminium manufacturers. That section of the study focuses on those countries with significant primary aluminium production capacity that are important trading partners of the EU, most notably China, the Middle East and Russia.

Table 18 Exports of aluminium and aluminium articles between the EU and main trade partners, 2008 and 2016, sorted by export value in 2016 (€)

2008		2016	
Trade Partner	**Exports**	**Trade Partner**	**Exports**
USA	977,094,704	**Switzerland**	1,177,718,213
Switzerland	785,700,456	**USA**	1,100,947,689
China	593,299,709	**China**	696,200,624
Turkey	276,887,380	**Turkey**	436,643,526
Norway	243,105,492	**India**	401,889,805
India	214,639,537	**South Korea**	272,364,090
South Korea	197,575,316	**Mexico**	206,900,226
Saudi Arabia	124,242,249	**Norway**	186,190,339
Mexico	84,868,913	**Saudi Arabia**	180,199,483
TOTAL	**6,220,504,608**	**TOTAL**	**7,172,160,375**

Source: Authors' elaboration on COMEXT (2018).

Table 19 Imports of aluminium and aluminium articles between the EU and main trade partners, 2008 and 2016, sorted by import value in 2016 (€)

2008		2016	
Trade Partner	**Imports**	**Trade Partner**	**Imports**
Norway	3,905,882,835	**Norway**	2,845,925,246
Russia	1,731,843,115	**Russia**	2,548,495,753
Iceland	1,282,344,294	**Switzerland**	1,371,006,759
Switzerland	894,160,495	**Iceland**	1,239,302,822
Mozambique	669,526,337	**United Arab Emirates**	1,036,964,099
Turkey	642,533,948	**China**	1,001,835,751
China	577,102,237	**Turkey**	985,871,251
USA	505,813,943	**Mozambique**	807,167,776
United Arab Emirates	420,724,587	**USA**	632,552,743
TOTAL	**14,486,008,011**	**TOTAL**	**15,500,275,339**

Source: Authors' elaboration on COMEXT (2018).

5 Steel

5.1 Introduction

According to the NACE (Rev.2) statistical classification of economic activities in the European Union, steel-makers are included in the division 24 Manufacture of basic metals. Steel plants covered by this analysis report under at least four groups: 24.1: Manufacture of basic iron and steel and ferro-alloys; 24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel; 24.3 Manufacture of other products of first processing of steel; and 24.5 Casting of metals. Groups 24.3 and 24.5 are further split into separate classes, e.g. 24.31 Cold drawing of bars, 24.32 Cold rolling of narrow strip, 24.51 Casting of iron and 24.52 Casting of steel.

The steel industry value chain includes all the processes required to transform raw materials (mainly coal, iron ore, electricity and scrap) into finished steel products. Generally, one must have the following infrastructures in place to produce steel:

- Coke ovens
- Sinter and pellet plants
- Blast furnaces
- Steel furnaces
- Rolling and finishing mills

Since the 1980s, the EU steel industry has developed from a process- and product-oriented industry to a market-oriented industry. This evolution is the result of a restructuring effort involving consolidation and closure of inefficient and obsolete plants as well as selective investment in new technologies. During this transformation process – often accompanied by privatisation of state-owned plants – the industry has become more capital-intensive and labour productivity has increased considerably.

Today, the EU steel sector is a modern customer-oriented industry with its main customer base found within the EU home markets, particularly in high-end segments. It focuses on high-quality products, product innovation and value creation supported by technological development, efficiency and skilled manpower. The EU steel industry is dominated by large multinational companies.

The steel sector overall is confronted with major challenges, notably in terms of costs and access to raw materials and energy, which are having a serious impact on its performance. Moreover, the increasing capacity, production and international engagement outside the EU constitutes a threat, as market shares are being lost to non-European countries such as China. The Chinese steel market has an excess in supply due to a lower growth in demand and considerable new production capacity. As a result, China is exporting more steel, including to the EU, and thereby affecting the market price. Furthermore, the EU steel industry is affected by the new and expected tightening of European environmental and climate legislation.

The competitiveness of the EU steel industry depends, among other things, on access to and prices of inputs, such as energy and raw materials. Moreover, labour-related input factors are important in this regard, notably in terms of skill levels and competency development strategies. The following factors comprise the most relevant inputs to the steel industry: iron ore and scrap metal, coking coal, energy, transport and labour (Ecorys, 2008).[52]

[52] Ecorys, Study on the Competitiveness of the European Steel Sector, 2008, Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwidhsePzJvbAhVNb5oKHcZKCJcQFggnMAA&url=http%3A%2F%2Fec.europa.eu%2FDocsRoo

Today, in terms of geographical regions, the EU is still the world's second-largest producer of crude steel, after Asia, accounting for around 10% of world output. However, there has not been any growth in EU steel production in recent years. While the EU steel industry is structured to produce all types and qualities of steel products, its competitiveness remains mainly linked to high-quality and often tailor-made products in demanding end-user segments.

5.2 Overview of the production process

Based on the degree of vertical integration, steel-making plants are generally classified into two different groups:

a) **Integrated plants**: These comprise fully integrated plants, where all the production stages are performed (from coke-making to product-finishing), and partially integrated plants, where coke ovens are not installed, and coke-making is outsourced. Integrated plants use blast furnaces (BFs) and basic oxygen furnaces (BOFs) to transform iron ore and coke into steel, also referred to as primary steel-making. Steel scrap is often also added.
b) **Minimills**: These plants comprise only steel furnaces and rolling and finishing facilities. Minimills mostly utilise electric arc furnaces (EAFs) to produce steel, and mainly rely on scrap, and only sometimes for a smaller part on raw iron, which is usually purchased as processed input, also referred to as secondary steel-making. In general, EAFs have much lower production capacities than BOFs.

According to the World Steel Association (2017a),[53] BOFs account for 60.3% of EU crude steel production whereas EAFs only account for 39.7%.

The steel-making industry's value chain can be separated into four major production stages: coke-making, iron-making, steel-making and rolling and finishing (Egenhofer et al., 2013).[54] Figure 33 shows these major production stages.

Coke-making is the first production stage in fully integrated plants. Coke is the fuel for iron-making and is produced by processing low-ash, low-sulphur bituminous coal. Pulverised coal is added in the coke oven through an opening located in the top of the oven. When the ports are sealed, the coal is heated, in the absence of oxygen, at high temperatures (1200°-1300°C). The necessary heat is provided by external combustion of fuels and recovered waste gases. Coke is the solid material remaining in the oven. Coke-making is an energy intensive process. New technologies therefore aim at reducing the quantity of coke required.

In partially integrated plants, coke is purchased as a processed input and steel-making starts with the **iron-making** in BFs. These furnaces are vertical cylindrical vessels (up to 35 meters high and up to 15 meters wide) where iron ore, coke (the fuel) and limestone (the flux) are loaded at the top and are subject to a smelting reduction process mainly aiming at reducing iron ore and removing impurities. Hot air, usually heated through recovered exhaust gases, is blown into the base of the vessel, supplying heat and oxygen for combustion. At the bottom of the furnace, molten iron and slag are collected as

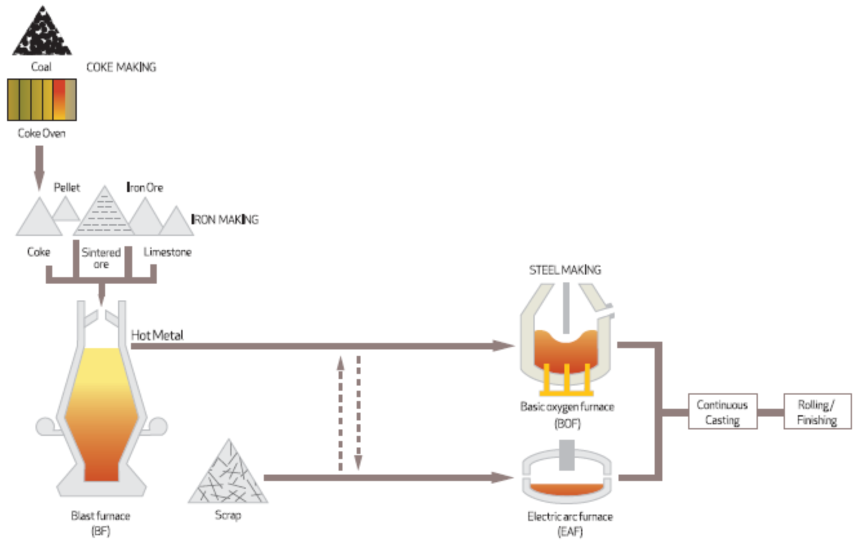
m%2Fdocuments%2F1988%2Fattachments%2F1%2Ftranslations%2Fen%2Frenditions%2Fpdf&usg=AOvVaw0vpeFTlzqhRN8ccrq8wTG9

[53] World Steel Association (2017a), World Steel in Figures 2017, Available at: https://www.worldsteel.org/en/dam/jcr:0474d208-9108-4927-ace8-ac5445c5df8/World+Steel+in+Figures+2017.pdf

[54] Egenhofer et al. (2013), The Steel Industry in the European Union: Composition and drivers of energy prices and costs (CEPS study).

outputs. Molten iron may either be cast into ingots (the so-called 'pigs') or transferred directly to a connected steel furnace.

Figure 35 Main production routes in making steel



Source: World Coal Institute (2007).

The production of iron accounts for approximately 55% of the total cost per tonne of steel and constitutes the largest cost category in integrated steel plants (Madar, 2009).[55] Also new technologies are being adopted for iron-making. Direct reduction ironmaking (DRI) is a new process using gas, rather than coke, as fuel, being particularly cheap in countries with access to low-cost natural gas. In any case, BFs are still deemed the best solution for integrated facilities, considering both their improved efficiency and their significant economies of scale. In integrated mills, sinter and pellet plants may also be installed, and this equipment is relatively common in Europe. Sinter plants enable recycling of iron-rich material, which is otherwise disposed of as production waste. Pellets are hard spheres, which are preferred to lump ore in BFs because hot air can circulate more freely, thus improving the efficiency of the iron-making process.

Steel-making consists of a process of transforming raw iron into steel by removing impurities (mainly carbon, phosphorus and sulphur). The remaining quantity of carbon is crucial to determining the hardness of the steel. During the steel-making process, other metals (manganese, nickel, chromium and vanadium) may be added to create alloys, thus obtaining specific qualities of steel. In steel-making, the more production stages are integrated, the more production costs per tonne are reduced; therefore, the industry is moving towards full automation and continuous production flow.

Molten iron from BFs is traditionally refined in BOFs, which are cylindrical vessels lined with refractories where high-purity oxygen is blown under pressure. To eliminate impurities, limestone and other flux are added in the BOF process, thus producing slag that is removed from molten steel. As heat is produced in this exothermic process, scrap is usually added as a coolant. In BOFs, up to 30% of scrap iron and steel can be combined with molten iron (Ecorys, 2008).[56]

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[55] Madar, D. (2010). Big Steel: technology, trade, and survival in a global market. UBC Press.

[56] Ecorys, (2008), op. cit.

The EAF is a completely different technology for steel-making, usually adopted in mini-mills. The main inputs for the EAF are scrap and electricity. Electrodes installed within the furnace melt scrap through the heat created by an electric arc. Limestone and other flux are added in the EAF to remove impurities from molten steel. EAFs are economic and efficient at relatively small volumes of production compared to BOFs, in particular because they can be easily shut down and restarted.

In the last production stage – rolling and finishing – blooms, billets and slabs are transformed into finished steel products in rolling facilities. A traditional distinction is made between 'flat' and 'long' products. Long products are rolled from blooms and billets. Blooms (characterised by a rectangular cross-section of 16 cm or more) are rolled into structural beams. Billets (characterised by a square cross-section of 4 to 14 cm) are rolled into bars, rods and wire.

Long products for the construction market represent the bulk of the production. They have relatively limited production costs and are intended to comply with lower standards; hence, they are considered low added-value products. Slabs (flat cross-section) are rolled into steel plates and coiled sheets, the latter being produced in rolls. Coiled sheets are the most-used steel product, with automotive and appliance producers being the bigger customers. Rolling facilities form these products in a succession of stages where the steel passes through rollers with progressively narrower clearances.

Flat products have relatively higher production costs and comply with higher required standards, thus being high added-value products. One of the most crucial aspects of a finished product is the quality of the surface. In particular, to avoid corrosion, a protective coating has to be applied. Finished products also include tubes and pipes, which comprise two main production processes: seamless and welded pipes. The former is made in vertically integrated plants (BOF or EAF), whereas the latter is usually made by companies buying steel on the market.

A broader definition of the industry value chain would include upstream suppliers of raw materials (iron, ore, coking coal or coke, scrap) and, downstream, intermediaries (service centres, stockholding companies, etc.) and final customers (producers of steel end products comprising mainly automotive, construction, packaging, durable consumer goods and mechanical engineering industries) (Ecorys, 2008).[57]

5.3 Industry characteristics

Fundamental for steel business conditions is the supply of raw materials, thereby making localisation decisions a key business strategy. Iron ore and (coking) coal are the most important commodities for steel production. Owing to cheaper iron ore and coal from abroad, new steel plants have been located along the coast near ports. Traditionally steel plants were located within or close to resource-rich European regions.

The steel industry is one of the most transport-intensive industries, as it produces heavy and often bulky goods, and almost 30% of the world's finished steel products pass from one country to another. Therefore, transport costs amount to 5-15% of the selling price of the products. Freight transport within Europe makes use of three basic modes of transport, i.e. rail, road and water. The price of transportation from Central Europe (Poland, Hungary, Slovakia, etc.) often rules out deliveries to markets outside Europe.

High capital requirements constitute one of the main business conditions in steel production, and steel-making is characterised by high levels of fixed costs, especially in integrated steel mills. Large facilities are only profitable if annual production capacity equals or exceeds 2 million tonnes. Steel mills run for several years and it is difficult to adjust production to demand because of the cost and structural stress associated with

[57] Ecorys, (2008), op. cit.

heating and cooling of the furnaces. EAF technology has lower capital requirements, because electric arc furnaces are more flexible and adjust easily to demand.

The steel industry is an energy intensive industry, consuming three main energy carriers, ranked in the following order: coal, natural gas and electricity.

The steel sector is characterised by economies of scale and scope, and achieving economies of scale for new producers requires mass production of steel. Therefore, along with new technologies and the privatisation of major European steel industries in the 1990s, a wave of takeovers and mergers occurred.

As a result of the consolidation in the European steel industry, relatively few companies account for a large share of steel production. High capital investments, high economies of scale and excess capacities of existing plants are high entry and exit barriers (Ecorys, 2008).[58]

The European steel industry is increasingly driven by customer requirements, and therefore close relationships with customers are important for steel producers. The steel industry feeds parts and materials to other industries, such as the automotive, construction and consumer appliances sectors, and is fundamentally dependent on and very sensitive to developments in the general economy.

Because of international trade, the competitiveness of the EU steel industry is highly affected by exchange rates. When the euro appreciates significantly (such as it did in 2006-07), exchange rates put a lot of pressure on the EU steel industry.

The following data analysis focuses on the manufacturing of basic iron and steel and ferro-alloys (NACE 24.1), which cover the production of crude steel from BF/BOF and EAF production. NACE 24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel, 24.3 Manufacture of other products of first processing of steel and 24.5 Casting of metals, in contrast, are not analysed, as the latter bottom-up analysis of energy costs focuses on BF/BOF and EAF production sites only.

Production in the EU

According to Eurofer (2017),[59] total crude steel production in the EU-28 amounted to more than 168 million tonnes in 2017 (see Figure 36). During the economic and financial crisis (2007–09), EU production declined by roughly 24%. Between 2009 and 2016, production peaked in 2011 with nearly 178 million tonnes, still being far from the peaks reached during the middle of the first decade of this century. From 2012 to 2015, the industry's production output remained fairly stable, at around 168 million tonnes. The year 2016 showed the lowest production value since 2010 with 161 million tonnes, while in 2017 a production increase was again observed.

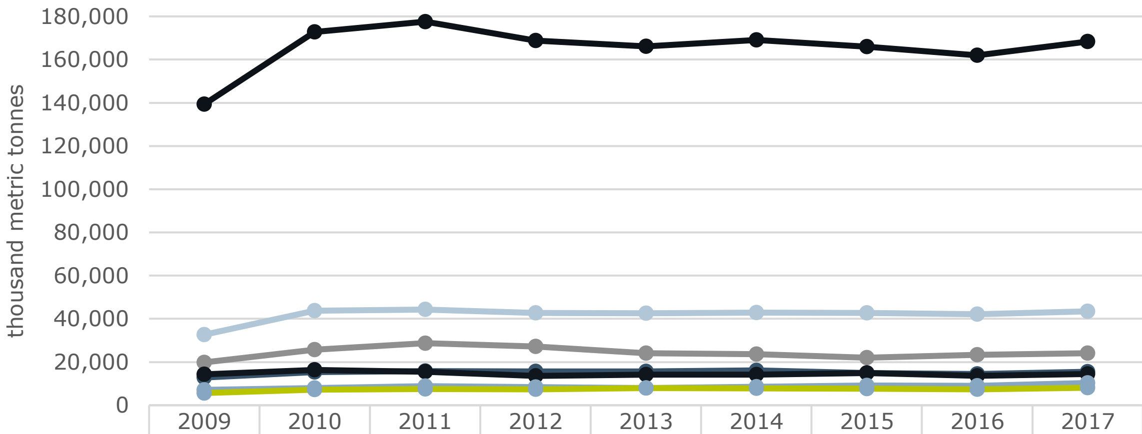
Crude steel production is concentrated in a relatively limited number of EU countries. In 2016,[60] six countries – Germany, Italy, France, Spain, Poland and Austria – accounted for more than two-thirds of total EU crude steel production. With a market share of nearly 26%, Germany represented the largest producer.

[58] Ecorys, (2008), op. cit.

[59] http://www.eurofer.org/Facts%26Figures/Crude%20Steel%20Production/All%20Qualities.fhtml

[60] Note that final 2017 crude steel production values had not been published at the time of completing this study (27.06. 2017).

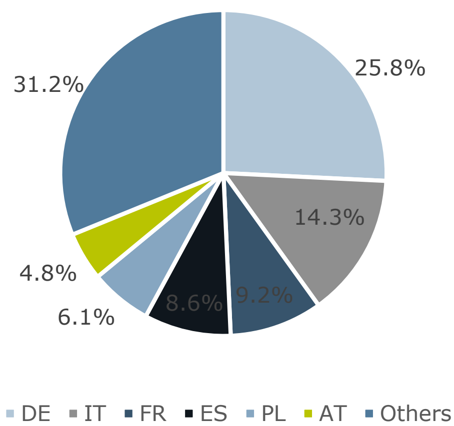
Figure 36 Total crude steel production in the EU and selected Member States, 2009-2017



	2009	2010	2011	2012	2013	2014	2015	2016	2017
DE	32,670	43,830	44,284	42,661	42,645	42,943	42,676	42,080	43,400
IT	19,848	25,750	28,735	27,252	24,093	23,714	22,018	23,373	24,100
FR	12,840	15,414	15,780	15,607	15,685	16,143	14,984	14,413	15,500
ES	14,358	16,343	15,504	13,639	14,130	14,187	14,846	13,631	14,500
PL	7,129	7,993	8,779	8,366	7,950	8,541	9,198	8,940	10,300
AT	5,662	7,206	7,474	7,421	7,953	7,876	7,687	7,438	8,100
EU 28	139,349	172,782	177,576	168,756	166,191	169,126	166,042	161,982	168,400

Source: Authors' elaboration based on Eurofer (2017a).

Figure 37 Share of crude steel production by major producing EU Member States, 2016



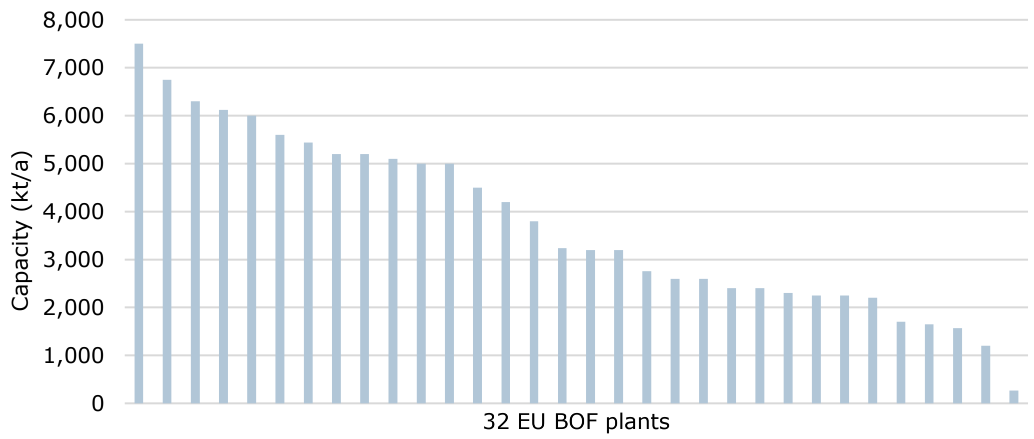
Source: Authors' elaboration based on Eurofer (2017a).

Number and capacity of plants operating in the EU

Figure 38 and Figure 39 illustrate the plant-specific crude steel nominal capacities of BOF and EAF plants within the EU, sorted from large to small in terms of capacity (based on data from the German Steel Institute VDEh). In total, there are 32 BOF plants and 170 EAF plants in the EU.

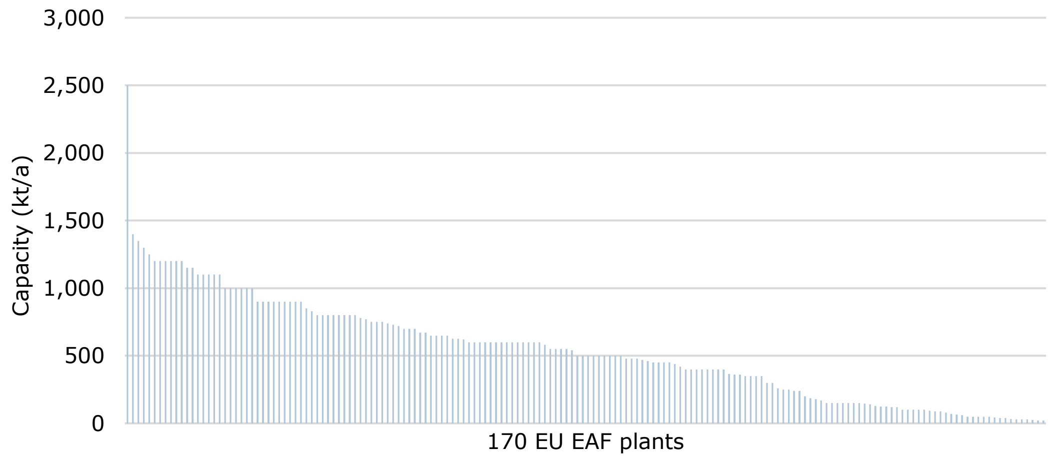
The largest BOF plant operated by Tata Steel has an annual production capacity of 7.5 million tonnes, whereas the smallest has an annual capacity of roughly 0.27 million tonnes. EAFs, in contrast, are generally much smaller. The largest EAF plant operated by the Arvedi Group has an annual production capacity of 2.5 million tonnes, whereas the smallest has an annual capacity of only 0.02 million tonnes. The average annual BOF capacity in the EU is around 3.75 million tonnes with a standard deviation of 1.8 million tonnes. The average annual EAF capacity in the EU is 0.54 million tonnes with a standard deviation of 0.38 million tonnes. The total BOF and EAF crude steel production capacity in the EU adds up to respectively 119 million tonnes and 92 million tonnes, resulting in a total European crude steel production capacity of 211 million tonnes. Given that the European total crude steel production in 2016 was 162 million tonnes, while the total crude steel production capacity was 211 million tonnes, the utilisation rate in the steel sector was around 77% in 2016.

Figure 38 Total and plant-specific crude steel nominal capacities of total and BOF and EAF plants within the EU



Note: The number of BOF plants included in the VDEh data (32) slightly deviates from the number of BOF plants provided by Eurofer (37).
Source: Authors' elaboration based on VDEh

Figure 39 Total and plant-specific crude steel nominal capacities of total EAF plants within the EU27



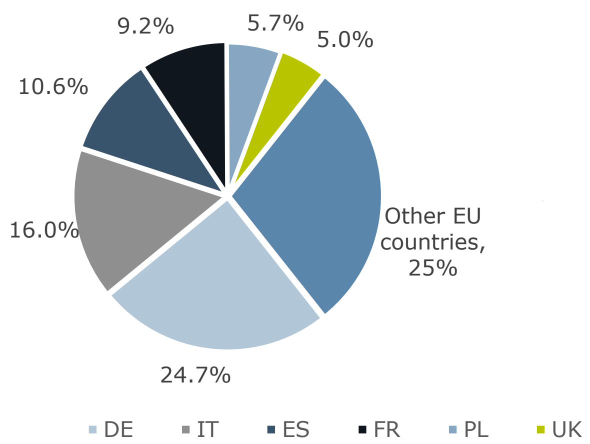
Source: Authors' elaboration based on 2018 data from steel plant database provided by VDEh.

It is important to note that small- and medium-sized companies (SMEs) are not relevant among steel-making facilities.

According to Eurofer, there are more than 500 steel production sites across 24 EU Member States, which can be distinguished between primary (BFs and/or BOFs) and secondary steel-making plants (EAFs) and steel-processing plants, e.g. rolling facilities, product mills and coating facilities. The number of facilities is subject to continuous changes due to ongoing consolidation processes. Only primary and secondary steel-making plants are considered relevant in the scope of this study, as processing plants are too heterogeneous, small in size as well as relatively less energy intensive in general.

As presented in Figure 40, in 2017 Germany accounted for the highest share of EU crude steel capacity (24.7%), followed by Italy with a share of 16%. Spain (10.6%) and France (9.2%) have very similar production capacities, while Poland accounts for 5.7% and the United Kingdom for 5.0%.

Figure 40 Share of crude steel capacity by major producing EU Member States, 2017



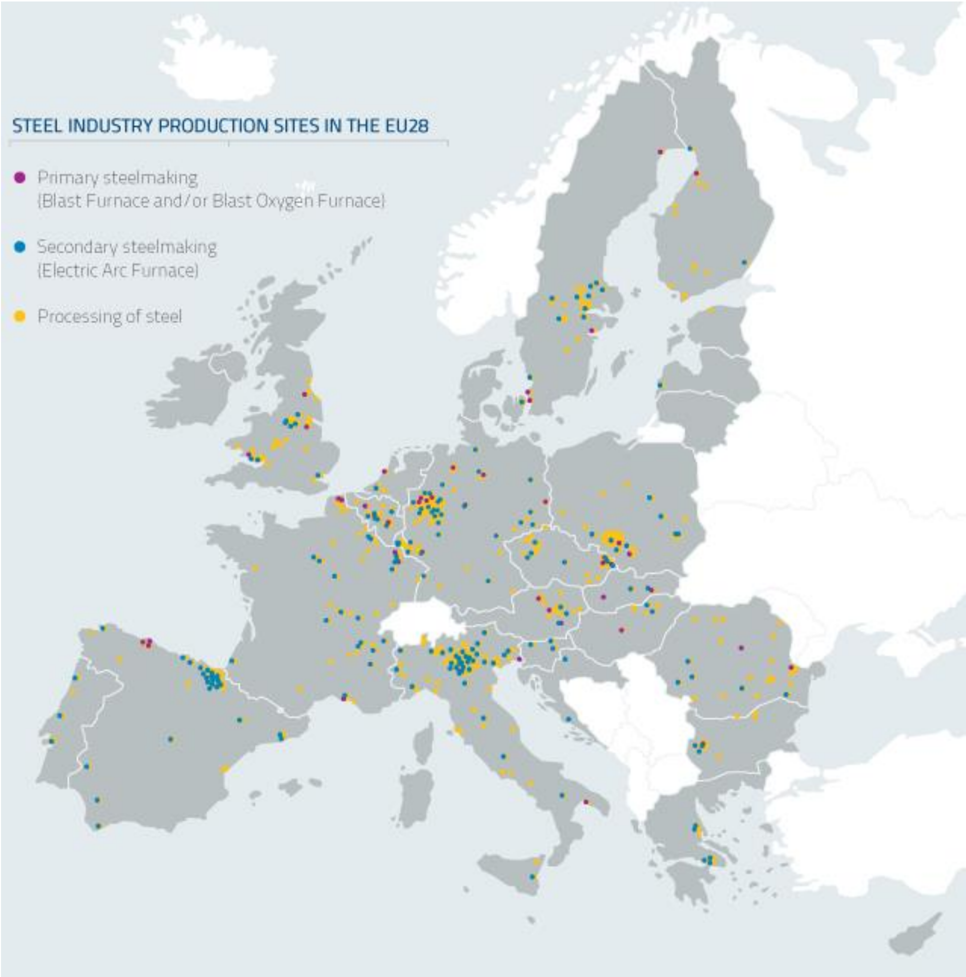
Source: Authors' elaboration based on VDEh (2018).

Geographical distribution of plants across the EU

The map in Figure 41 shows the geographical distribution of primary, secondary steel-making plants as well as steel-processing plants across the EU. Focusing on primary and secondary steel-making, one can see that there are several major regional steel-making clusters. Primary steel-making was traditionally clustered near resource-rich regions such as the Saar, Ruhr, Lorraine, the Midlands, Wallonia and Silesia. As a result of cheaper iron ore and coal from abroad, new plants have been located along the coast near ports to handle imported materials and energy. With secondary steel-making, northern Italy and the Basque region in Spain can also be identified as major European steel-making clusters.

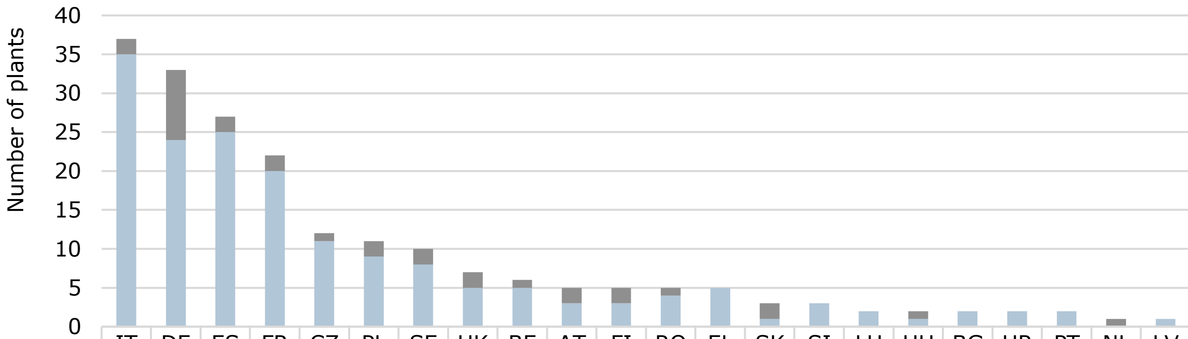
Figure 42 shows the share of BOF and EAF plant sites in the EU as well as the number of primary (BOF) and secondary (EAF) plants, by country: Italy (37) and Germany (33) operate the largest number of steel plants, followed by Spain (27) and France (22). The remaining plants are distributed across other countries. The figure shows that Italy, Spain and France have a high concentration of EAF, their share lying at above 90%. Germany, in contrast, has a much lower share of EAF (73%), highlighting its concentration in BOF steel production.

Figure 41 Steel industry production sites in the EU



Source: Eurofer (2017b)
http://www.eurofer.org/About%20Steel/EuropeanSteelMap.fhtml.

Figure 42 Steel industry plants in the EU (202 in total)



	IT	DE	ES	FR	CZ	PL	SE	UK	BE	AT	FI	RO	EL	SK	SI	LU	HU	BG	HR	PT	NL	LV
BOFs	2	9	2	2	1	2	2	2	1	2	2	1	0	2	0	0	1	0	0	0	1	0
EAFs	35	24	25	20	11	9	8	5	5	3	3	4	5	1	3	2	1	2	2	2	0	1

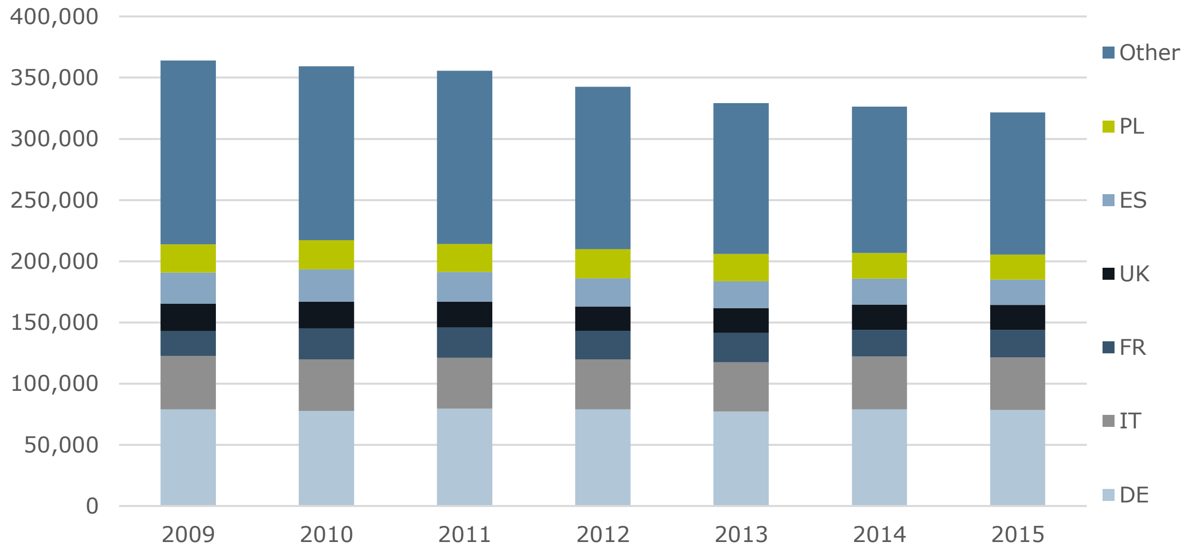
EAFs BOFs

Source: Authors' elaboration based on Eurofer, 2018.

Employment

According to Eurofer (2016), the European steel industry directly employs 330,000 people. Figure 43 illustrates the number of people working in the manufacture of basic iron and steel and of ferro-alloys (NACE 24.1) in the EU-28 in 2015 (Eurostat, 2017a).[61] Germany, which is the European Union's largest steel producer, employs a greater number of people in its steel industry than any other EU-28 nation (78,000), followed by Italy with 43,000. It is worth noting that from 2009 to 2015, the total number of jobs in the EU continuously decreased from 364,000 in 2009 to 322,000 in 2015.

Figure 43 Employment in NACE 24.1 Manufacture of basic iron and steel and of ferro-alloys



Source: Authors' elaboration based on annual detailed enterprise statistics for industry (sbs_na_ind_r2) in Eurostat.

5.4 Trade analysis

While steel production in the EU decreased by roughly 23% between 2007 and 2016, Asian countries, especially China, increased their production by more than 76% over the same period (see Figure 44). Between 2008 and 2009, steel production dropped by roughly 30% in the EU and North America, and underwent a weak recovery in the three following years. Asia is the global leader with a share of 69% global production in 2016, the EU ranks second (10%), followed by North America (7%) and CIS (6%). The EU, North America, CIS and Asian countries account for more than 92% of the world's steel production.

According to Eurostat (2017b), the trade balance of basic iron, steel and ferro-alloy products according to NACE (24.1) is negative, as extra-EU imports are higher than extra-EU exports. In 2016, 25 million tonnes were exported while 43 million tonnes were imported.

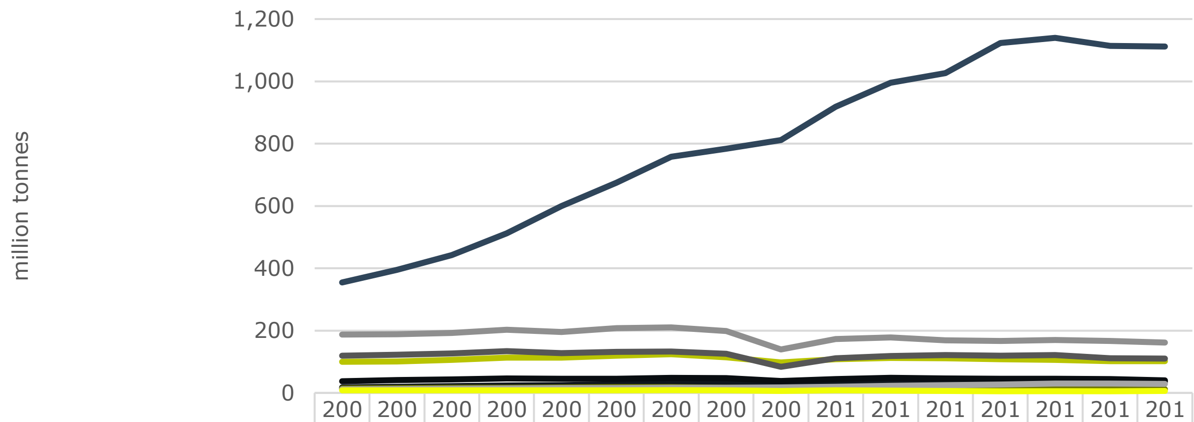
EU trade in iron and steel is dominated by intra-EU flows. According to Eurostat (2017b),[62] in 2016, intra-EU exports accounted for nearly 80% of total exports of EU economies,

[61] Eurostat (2017a), Eurostat Website (http://appsso.eurostat.ec.europa.eu/nui/show.do).

[62] Eurostat (2017b), International Trade (http://epp.eurostat.ec.europa.eu/newxtweb/submitlayoutselect.do).

while only 20% of trade was directed towards extra-EU economies. In 2012, in contrast, intra-EU exports accounted for only 74% of total exports of EU economies, while 26% of trade was directed towards extra-EU economies. This means that extra-EU exports seem to be decreasing. The same trend is observed with regard to imports: in 2016, 69% of imports came from the EU and 31% from outside EU borders. In 2012, 75% of imports came from the EU and 25% from outside EU borders.

Figure 44 Global crude steel production, 2001-15 (million tonnes)



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
European Union (28)	187	188	193	202	196	207	210	199	139	173	178	169	166	169	166	162
Other Europe	18	19	21	24	25	28	31	32	29	34	39	40	39	38	36	36
C.I.S.	100	101	106	113	113	120	124	114	98	108	113	111	108	106	102	102
North America	120	123	126	134	128	131	133	125	84	112	119	122	119	121	111	111
Sout America	37	41	43	46	45	45	48	47	38	44	48	46	46	45	44	40
Africa	15	16	16	17	18	19	19	17	15	17	16	15	16	15	15	12
Middle East	12	12	13	14	15	15	16	17	18	20	23	25	27	30	30	29
Asia	355	395	442	513	599	675	758	784	812	918	995	1,02	1,12	1,14	1,11	1,11
Oceania	8	8	8	8	9	9	9	8	6	8	7	6	6	5	6	6

Source: Authors' elaboration based on World Steel Association.[63]

Figure 45 shows the export and import trade volumes of EU basic iron, steel and ferro-alloys products with the 10 most relevant G20 countries (in terms of volume) from 2008 to 2014. In 2016, the EU exported the largest volume (roughly 4.5 million tonnes) of iron and steel to Turkey, closely followed by the United States with 3.4 million tonnes. The exports to the United States are now back to a similar level as they were before 2014. China imported roughly 1 million tonnes in 2016, accounting for around 8% of EU exports.

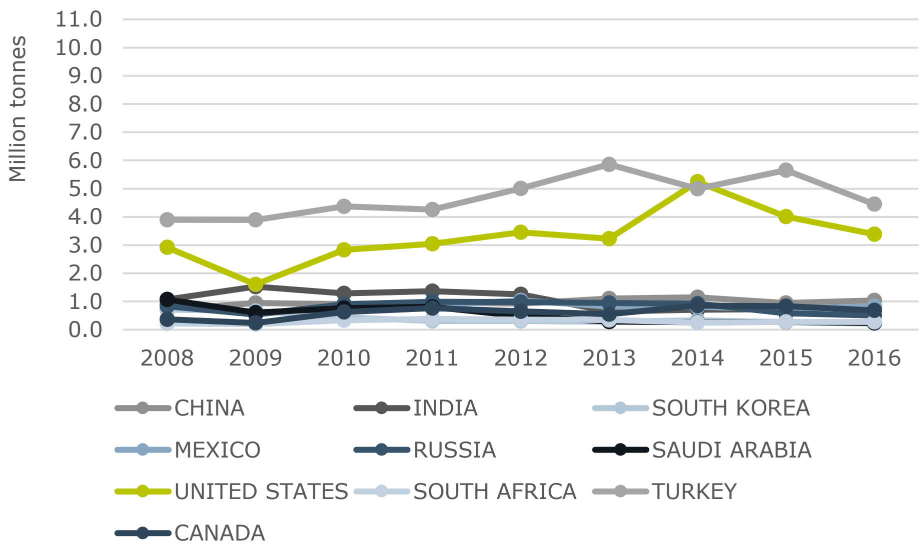
The largest importer into the EU was Russia, whose import volumes increased substantially over the last two years. The country's import volume is now back to 2008 values with more than 10 million tonnes. Between 2010 and 2014, this value was fairly stable, at 7.5 to 8 million tonnes. Imports from China were the second highest in terms of volume, also with a significant increase in volume since 2013-14. After the crisis years 2008 and 2009, import levels increased to 4.3 million tonnes in 2011, decreased to 2.8 million tonnes in 2012 and increased again to roughly 4.7 million tonnes in 2014. The 2016 volumes are around twice as high as the volumes in 2010, 2012 and 2013.

Overall, EU28 is a net exporter of steel products to the United States and Turkey and a net importer of Chinese and Russian steel products. Steel imports have become increasingly significant, mainly due to large overcapacities in and subsidised exports from

[63] Monthly production 2017-2018 (https://www.worldsteel.org/steel-by-topic/statistics/monthly-crude-steel-and-iron-production.html).

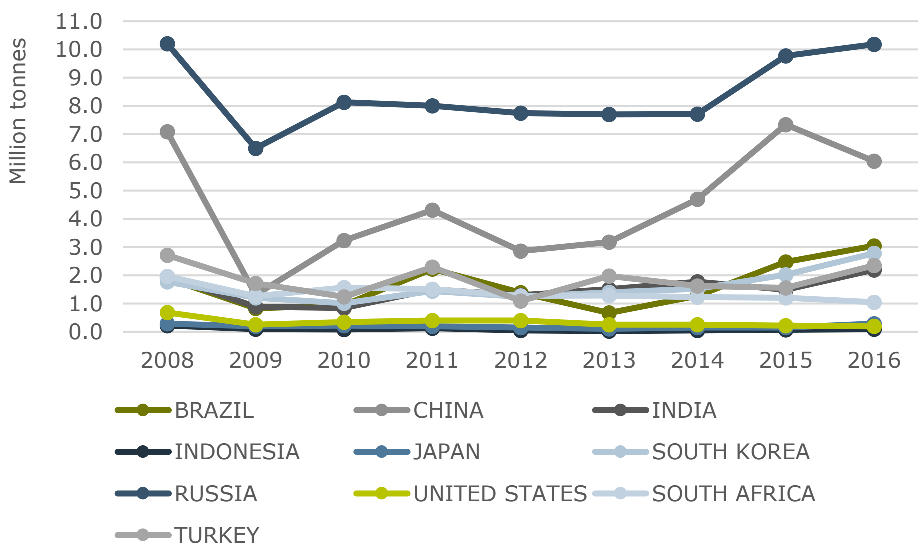
China. The weakening of the Russian ruble has made steel imports much cheaper for European economies, leading to increasing import volumes from Russia.

Figure 45 EU export volumes of basic iron, steel and ferro-alloys with the 10 most relevant G20 countries (in terms of volume), 2008-14



Source: Eurostat (2017b) (NACE 4, 24.10).

Figure 46 EU import volumes of basic iron, steel and ferro-alloys with the 10 most relevant G20 countries (in terms of volume), 2008-14



Source: Eurostat (2017b) (NACE 4, 24.10).

6 Nitrogen fertilisers

6.1 Introduction

According to the NACE (Rev.2) statistical classification of economic activities in the European Union, fertilisers are included in division C20.15.

The European fertiliser industry is an energy and greenhouse gas-intensive industry. The production of the key building block – ammonia – requires by far the most energy compared with the entire production process of fertilisers, and European ammonia plants are the most energy-efficient in the world (Ecofys, 2015)[64].

The production of fertilisers is based on the transformation of raw materials, such as air, water, natural gas, phosphate and potash ores, into ammonium nitrate, urea, urea nitrate, and other phosphate- and potash-based products. Although natural gas, phosphate and potash are generally abundant on a global scale, Europe has limited sources within its geographical scope. Therefore, the European fertiliser industry depends mostly on imported raw materials, which makes it vulnerable to the supply and prices of countries outside Europe. It is important to note that as natural gas prices rise in Europe, the industry is even more challenged to stay competitive in the global market (Fertilisers Europe, 2015)[65].

In the European market, nitrogen-based fertilisers are the most frequently used, accounting for 67% of total consumption. Based on European farmers' experience, the most effective sources of crop nitrogen are ammonium nitrate (AN) and calcium ammonium nitrate (CAN). Other nitrogen-based fertilisers (e.g. urea, urea ammonium nitrate solution or UAN) are also used. The consumption of phosphate and potash-based fertilisers in the EU is about 16% and 17%, respectively, usually in combination with nitrogen fertiliser.

6.2 Overview of the production process

Nitrogen-based fertilisers

The first step in the process is the production of ammonia (NH3) via the Haber-Bosch process, which is done by mixing nitrogen from the air with hydrogen from natural gas at a high temperature and high pressure. In this first stage, already 60% of the natural gas is used as raw material; the remaining 40% is used in the synthesis process of ammonia (the second step).

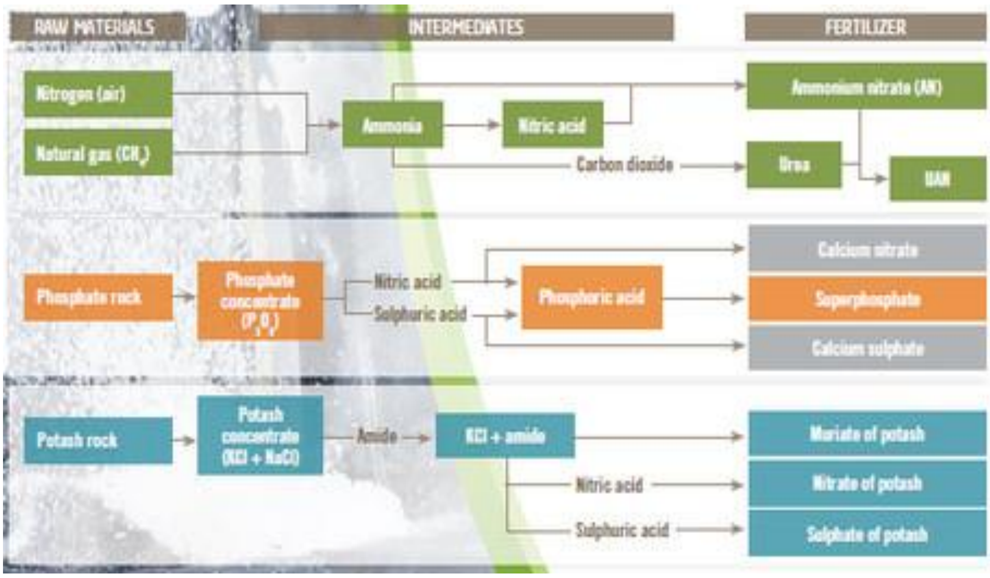
As a second step in the process, part of the ammonia is transformed into nitric acid, which is then mixed with the rest of the ammonia to produce ammonium nitrate (AN). The ammonia could also be mixed with liquid carbon dioxide to produce urea. Both urea and AN can be mixed with water to form urea ammonium nitrate solution (UAN).

Figure 47 diagrams the steps followed in the production of fertilisers.

[64] Ecofys (2015), Fertilisers and Climate Change: Looking to the 2050.

[65] Fertilizers Europe (2015), Annual Overview, Ensuring quality fertilization, available at: http://www.fertilizerseurope.com/fileadmin/user_upload/publications/all_publications/Annual_Overview_2015_HD.pdf

Figure 47 Steps in the production of fertilisers



Source: Fertilizer Europe, 2017.[66]

6.3 Industry characteristics

Over the last decade, the European fertiliser industry has experienced a relatively solid growth, but the market has been slowing down in the last few years due to less demand caused by a combination of lower commodity prices worldwide and the Russian market embargo. As European farmers sense the pressure on their businesses, they are now more cautious in their spending on farming materials, including fertilisers.

In parallel, global production of fertilisers is increasing (mostly outside Europe), driven by lower energy prices in certain markets. This has led to an increase in fertiliser imports, which tend to push out the European producers.[67]

The year 2016 has been particularly challenging for the European fertiliser industry. Farmers' expenditure continued its decline and coincided with an increase in fertiliser production in North Africa, due to low energy prices in that region. In turn, fertiliser prices dropped substantially. In the second half of the year, the prices slightly recovered due to an extensive closure of coal and urea plants in China. Nevertheless, prices remain lower than the historical market prices.[68]

Number and capacity of plants operating in the EU

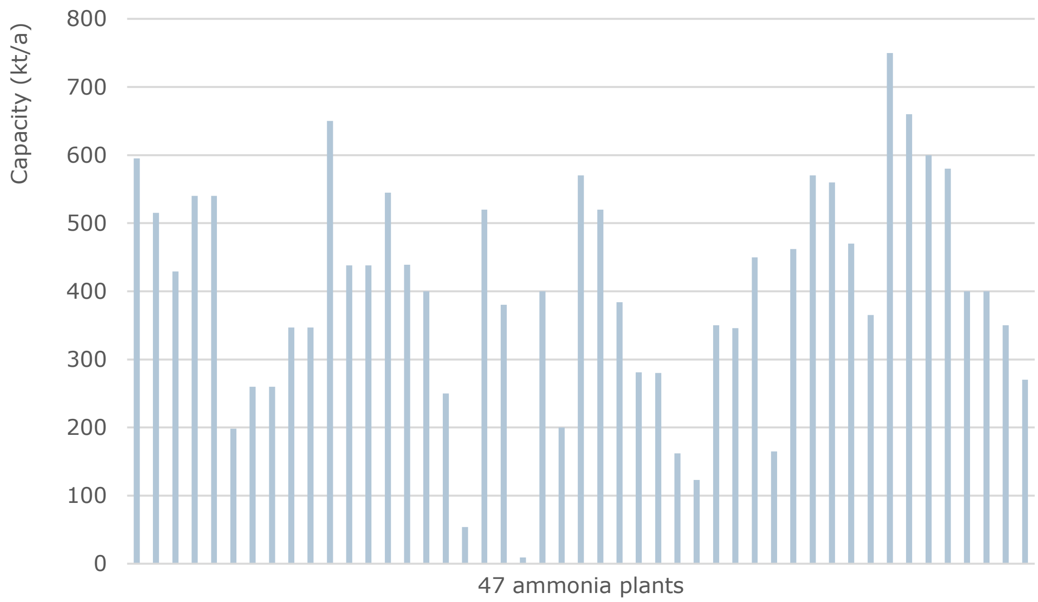
The total production capacity of ammonia in the EU is 18,822 kt/a. Figure 48 illustrates the plant capacities sorted from large to small capacity levels in the EU. The largest ammonia plant has an annual capacity of 750 kt/a, whereas the smallest has an annual capacity of only 54 kt/a.

[66] Fertilisers Europe, Website. Available at: https://www.fertilizerseurope.com/get-to-know-us/the-story-of-fertilizers/

[67] Fertilisers Europe (2015), op. cit.

[68] Michigan State University Extension, available at: http://msue.anr.msu.edu/news/year_end_fertilizer_prices_in_2016

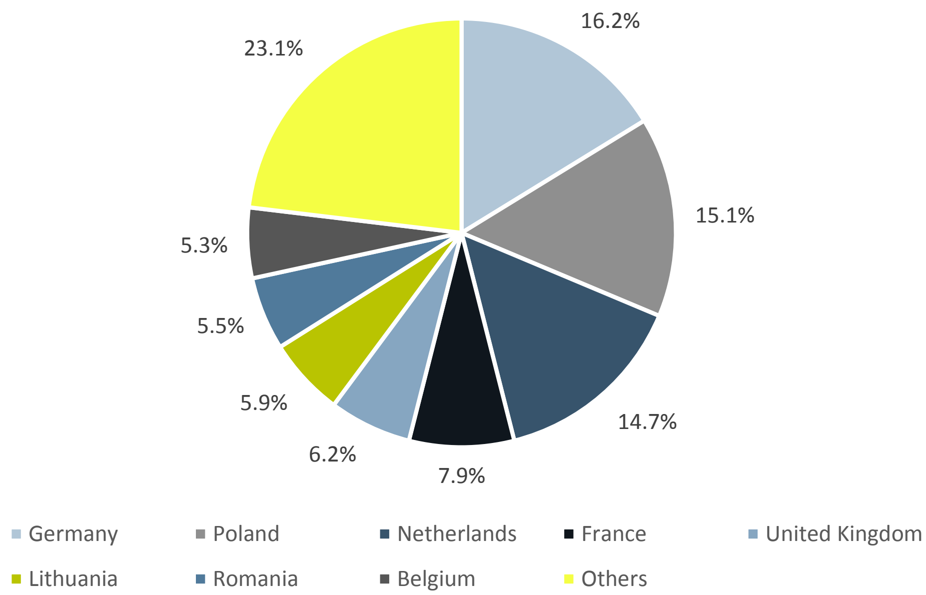
Figure 48 Capacities of all 47 ammonia plants in the EU, 2017



Source: Unpublished data from Fertilisers Europe (year 2017).

The largest share of ammonia capacity is found within three countries: Germany (16%), Poland (15%) and the Netherlands (15%). Countries like France, the United Kingdom, Lithuania, Romania and Belgium have individual capacities ranging from 5% to 8%. Figure 49 provides a snapshot of the capacity distribution among EU countries in 2017.

Figure 49 Share of ammonia capacity within the EU, 2017

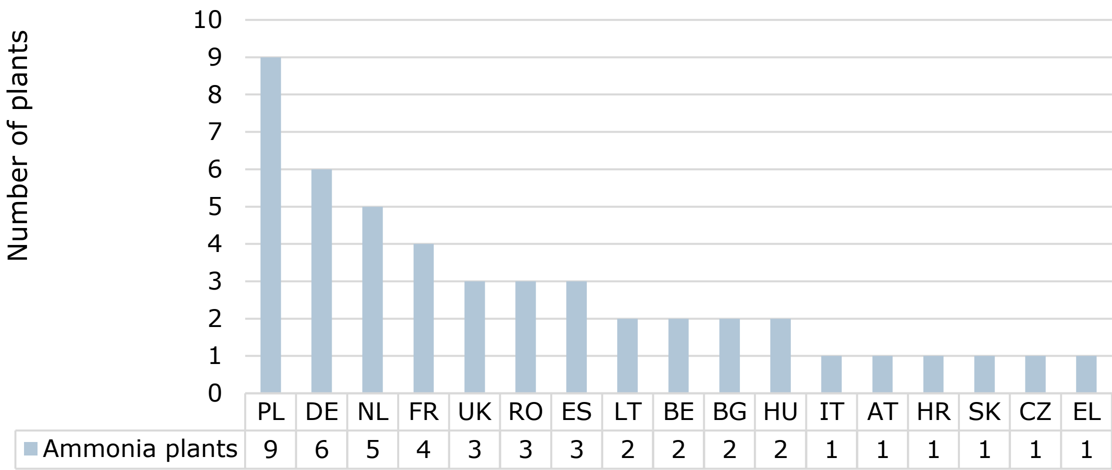


Source: Unpublished data from Fertilisers Europe (year 2017).

Geographical distribution of plants over the EU

There are 47 ammonia plants in the European Union. Figure 50 shows the distribution of ammonia plants by country, with the top five countries including Poland (9), Germany (6), Netherlands (5), France (4) and United Kingdom (3).

Figure 50 Ammonia plants in the EU (47 in total), 2017



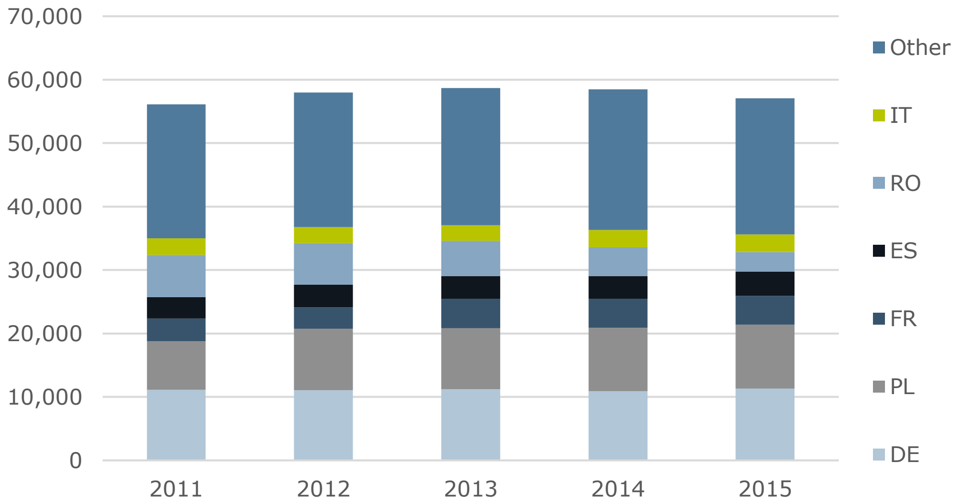
Source: Unpublished data from Fertilisers Europe (year 2017).

Employment

The European fertiliser industry generated close to 60,000 jobs.

Figure 51 illustrates the number of people working in the manufacture of fertilisers and nitrogen compounds in the EU 28 in 2015.[69] Germany and Poland, which are the European Union's largest fertiliser producers, employ a greater number of people in this industry, followed by Spain, Romania and Italy.

Figure 51 Employment in NACE 20.15 Manufacture of fertilisers and nitrogen compounds, 2011-15



Source: Authors' elaboration based on annual detailed enterprise statistics for industry (sbs_na_ind_r2) in Eurostat.

[69] Eurostat, 2017.

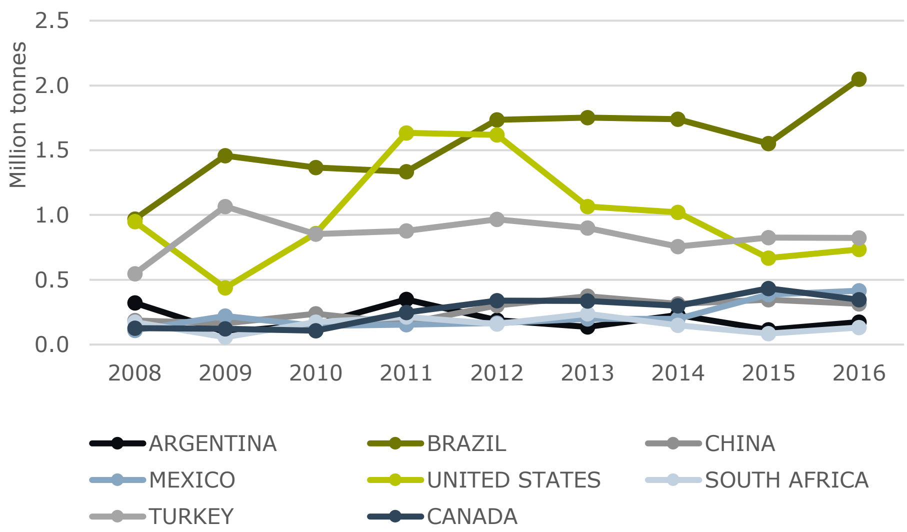
6.4 *Trade analysis*

According to Eurostat (2017b), the trade balance of fertilisers and nitrogen compounds according to NACE (20.15) is negative, as extra-EU imports are higher than extra-EU exports. In 2016, 19.7 million tonnes were exported, while only 9.5 million tonnes were imported. This trade deficit has been constantly increasing from 2011 to 2016.

EU trade in fertilisers and nitrogen compounds is dominated by intra-EU flows. According to Eurostat (2017b),[70] in 2016, intra-EU exports accounted for nearly 75% of total EU economies' exports, while only 25% of trade was directed towards extra-EU economies. In terms of imports, in 2016, 61.5% of imports came from the EU and 38.5% from outside EU borders.

Figure 52 and Figure 53 shows the export and import trade volumes of EU basic iron, steel and ferro-alloys products with the 10 most-relevant G20 countries (in terms of volume) from 2008 and 2014. In the last few years, the EU exports of fertilisers and nitrogen compounds have been mostly to Brazil. In 2016 alone, the EU exported more than 2 million tonnes to Brazil, followed by 0.8 million tonnes of exports to Turkey and 0.7 million tonnes to the USA. On the other hand, the EU imported volumes of fertilisers and nitrogen compounds predominantly from Russia. The imported fertiliser from the latter country has been steadily increasing since 2012, reaching more than 7 million tonnes in 2016. The rest of the countries from which the EU imports fertilisers and nitrogen compounds accounted individually for less than 0.6 million tonnes in 2016. Overall, the EU is a net importer of fertilisers and nitrogen compounds.

Figure 52 EU export volumes of fertilisers and nitrogen compounds (NACE 20.15) with the 10 most-relevant G20 countries (in terms of volume), 2008-16

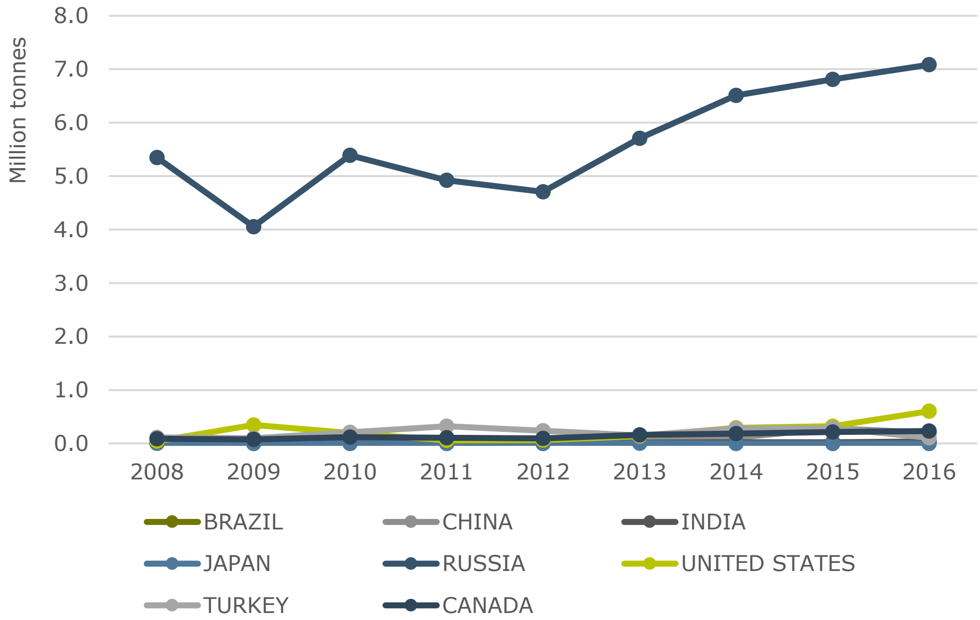


Source: Eurostat (2017b)[71] (NACE, 20.15).

[70] Eurostat (2017b), International Trade (http://epp.eurostat.ec.europa.eu/newxtweb/submitlayoutselect.do)

[71] Eurostat (2017b), International Trade (http://epp.eurostat.ec.europa.eu/newxtweb/submitlayoutselect.do).

Figure 53 EU import volumes of fertilisers and nitrogen compounds (NACE 20.15) with the 10 most-relevant G20 countries (in terms of volume), 2008-16



Source: Eurostat (2017b), International Trade http://epp.eurostat.ec.europa.eu/newxtweb/submitlayoutselect.do (NACE, 20.15).

7 Refineries

7.1 Introduction

According to the NACE (Rev.2) statistical classification of economic activities in the European Union, refineries are included in division 19, which is composed of the manufacture of coke oven products (19.10) and the manufacture of refined petroleum products (19.20).

A modern refinery is a highly integrated facility, separating and transforming crude oil into a wide variety of products, including transportation fuels, residual fuel oils and lubricants. The simplest refinery type is a facility in which crude oil is separated into lighter and heavier fractions through the process of distillation. Modern refineries have developed more complex and integrated systems, in which hydrocarbon compounds are not only distilled, but also converted and blended into a wider array of products.

The European refining sector has been going through a restructuring process, necessitated both by changes in the global economy, as well as the necessity of addressing climate and environmental externalities.

Several international oil companies are divesting from refining capacity in Europe and are expanding in non-OECD countries, while non-European international companies are emerging as the more important investors. The latter, however, currently remain relatively minor players. Furthermore, refineries are more reluctant to make medium- to long-term investments in Europe. According to Mc Kinsey (2015),[72] the announced additions to European capacity and investments to 2020 are lower than in any other region of the world (except Africa).

Since 2008, the EU's crude processing capacity has been on a decreasing trend. In early 2012, for example, Petroplus, Europe's largest independent refiner, filed for insolvency. Eni, an Italian company, transformed its Venice refinery into a so-called 'Green Refinery' by converting their conventional refinery into a bio refinery, producing high-grade biofuels (Eni, 2016).[73] Total halved its oil processing operations at its Lindsey refinery in Britain in 2016, and converted the La Mede refinery in France to biofuels (Reuters, 2016)[74].

The key dynamics underlying these developments are the changing local market conditions and uncertain future prospects, especially as a result of reduced demand, overcapacity and shifting product demand to low-carbon fuels such as (bio-)diesel and also electro-mobility.

7.2 Overview of the production process

In all refineries, the first production process is the distillation of crude oil. The most important distillation processes are crude or atmospheric distillation, and vacuum distillation. Hydro-skimming refineries and topping refineries only use these rather simple processes, while 'complex refineries' add more advanced conversion technologies after distillation.

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[72] Mc Kinsey (2015), "Profitability in a world of overcapacity", May 2015, available at: https://www.mckinsey.com/industries/oil-and-gas/our-insights/profitability-in-a-world-of-overcapacity

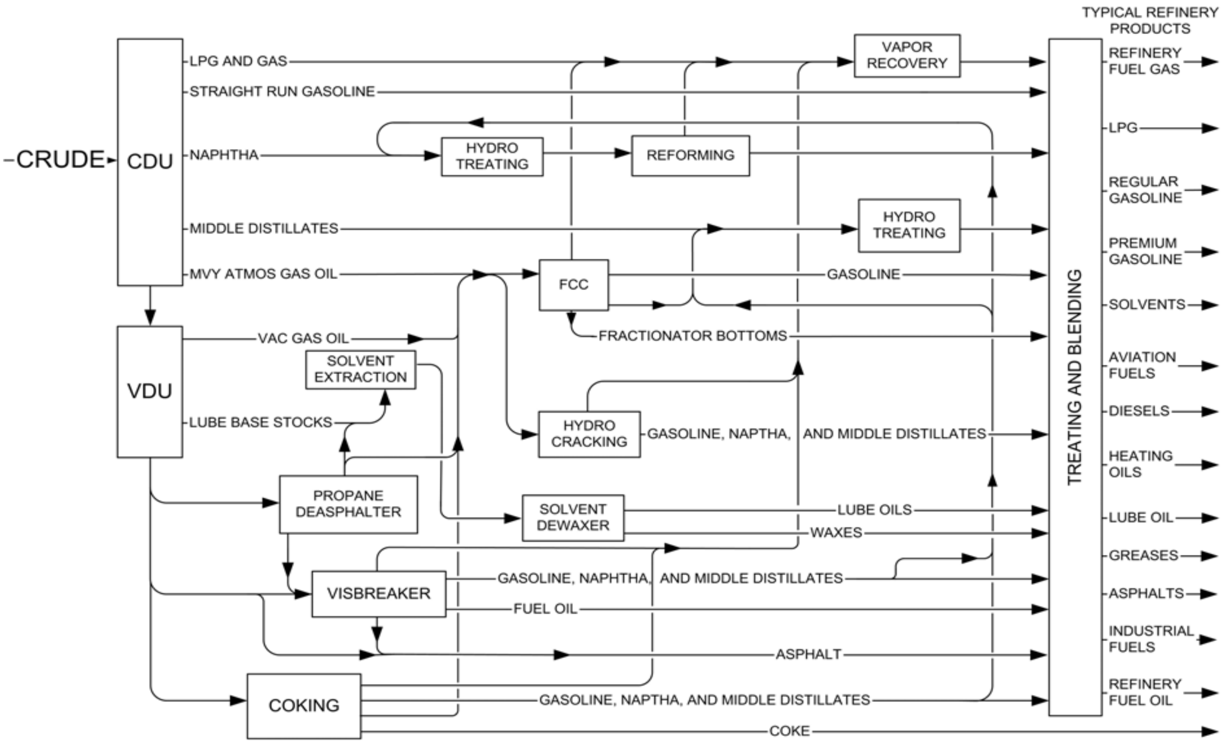
[73] ENI (2016), "Eni Refinery, Venice". Available at : https://www.eni.com/docs/en_IT/enicom/operations/stories-people/green-refinery/ENI-Raffineria-Eni-Venezia-07.12.16.pdf

[74] Reuters (2016), "Fight for survival returns to Europe's battle-hardened refineries", 29 July 2016, available at: https://www.reuters.com/article/us-refineries-europe-idUSKCN1091O1

Common conversion technologies are based on thermal or catalytic processes. Newer processes, such as hydrocrackers, are used to produce lighter products from the heavy bottom products. Finally, all products can be treated further to upgrade their quality, e.g. sulphur removal using a hydro-treater. Side-processes that are used to condition inputs or to produce hydrogen and other by-products include crude conditioning, e.g. desalting, hydrogen production, power and steam production and asphalt production. Lubricants and other specialised products may be produced at separate locations. Most refineries are connected to a larger petrochemical complex, in which case they supply feedstock to chemical commodity producers. According to the Joint Research Centre (2015),[75] refineries that are part of a petrochemical complex have more flexibility in optimising their intermediate product streams, as well as benefit from shared operating costs. Such integration may thus significantly improve refining profitability.

Figure 54 provides a simplified flow diagram of a refinery, displaying the main production steps. The descriptions follow the flow diagram, starting with the intake of the crude through to the production of the final products. The flow of intermediates between the processes will vary by refinery, and depends on the structure of the refinery, the type of crude processes and the product mix.

Figure 54. Simplified flow chart of refining processes and product flows



Source: EPA (2010) [76]

Fluid Catalytic Cracker (FCC): The fuel oil from the crude oil distillation unit (CDU) is converted into lighter products over a hot catalyst bed in the fluid catalytic cracker (FCC). This produces high octane gasoline, diesel and fuel oil. The FCC is mostly used to convert heavy fuel oils into gasoline and lighter products and has virtually replaced all thermal

[75] Lukach, R., Marschinski, R., Bakhtieva, D., Mraz, M., Temurshoev, U., Eder, P., & Sancho, L. D. (2015). EU Petroleum Refining Fitness Check: Impact of EU Legislation on Sectoral Economic Performance (No. JRC96206). Joint Research Centre (Seville site).

[76] EPA, AVAILABLE AND EMERGING TECHNOLOGIES FOR REDUCING GREENHOUSE GAS EMISSIONS FROM THE PETROLEUM REFINING INDUSTRY (2010) (https://www.epa.gov/sites/production/files/2015-12/documents/refineries.pdf).

crackers. Fluid catalytic crackers are net energy users, due to the energy needed to preheat the feed stream. However, modern FCC designs also produce steam and power.

Hydrocracker (HCU): The HCU has become an important process in the modern refinery, and allows for flexibility in product mix. It provides a better balance of gasoline and distillates, improves gasoline yield and octane quality, and can supplement the FCC to upgrade heavy feedstocks. In the HCU, light fuel oil is converted into lighter products under a high hydrogen pressure and over a hot catalyst bed. The main products are naphtha, jet fuel and diesel oil. It consumes energy in the form of fuel, steam and electricity (for compressors and pumps). The hydrocracker also consumes energy indirectly in the form of hydrogen.

Coking: A new generation of coking processes has added additional flexibility to the refinery by converting the heavy bottom feed into lighter feedstocks and coke. Modern coking processes can also be used to prepare a feed for the hydrocracker.

Visbreaker: Visbreaking is a relatively mild thermal cracking operation, used to reduce the viscosity of the bottom products to produce fuel oil. This reduces the production of heavy fuel oils, while the products can be used to increase FCC feedstock and increase gasoline yields. There are two main processes: coil (or furnace) cracking and soak cracking. Coil cracking uses higher reactor temperatures and shorter residence times, while soak cracking has slightly lower temperatures and longer residence times.

Alkylation and Polymerization: Alkylation (the reverse of cracking) is used to produce alkylates (used in higher-octane motor fuels), as well as butane liquids, LPG and a tar-like by-product. Alkylation processes use steam and power. There are no large differences in energy intensity between both processes.

Hydrogen Manufacturing Unit or Steam reforming (HMU) are supporting processes that do not produce the main refinery products but intermediates used in the various refining processes. Hydrogen is generated from natural gas and steam over a hot catalyst bed. Energy is used in the form of fuel (to heat the reformer), steam (in the steam reforming) and power (for compression).

Gas Processing Unit: Refinery gas processing units are used to recover C_3, C_4, C_5 and C_6 components from the different processes, and to produce a desulfurised gas which can be used as fuel, or for hydrogen production in steam reforming.

Acid Gas Removal: Acid gases, such as H_2S, are produced as a by-product of higher quality refinery products and need to be removed to reduce air pollution (before 1970, they were simply burned off).

Bitumen Blower (BBU): Hot air is blown onto heavy fuel oil to produce bitumen or asphalt.

Other processes may be used in refineries to produce lubricants (lube oil), petrochemical feedstocks and other specialty products. These processes consist mainly of blending, stripping and separation processes. These processes are not discussed in detail here, as they are not found in a large number of refineries.

7.3 Industry characteristics

The European refinery sector is mature, consolidated and characterised by highly capital-intensive assets, high economies of scale and low margins in comparison to non-EU regions. Market rivalry is strong, as a result of historical refining overcapacity and the mature nature of the European oil product market.

Buyers of European oil products have consolidated and are now concentrated in the highly competitive marketing and retail market. The presence of supermarkets in the oil product

retail market has increased these competitive pressures. International suppliers, on the other hand, are building up competitive pressure against European refiners. Despite significant entry barriers, European refiners are increasingly challenged by the entry of new competitors, as many emerging economies are ramping up complex, partially export-driven, domestic refining capacity, such as the Middle East and India. Consequently, both the supply and demand sides are challenging the European refinery sector (CIEP, 2017).[77]

With the increased penetration of substitutes in the oil product markets, such as ethanol-based gasoline/diesel and electric vehicles, demand for oil products in the EU and export markets is rather declining. At the same time, EU legislation supports these alternatives and also requires compliance with various emissions standards by the industry, aimed at addressing the externalities of this industry with regard to climate change. According to the Joint Research Centre (2015)[78], the EU-quantified average regulatory cost impact corresponds to, at most, 25% of EU refineries' observed net margin decline relative to competitor regions during 2000-12.

From the perspective of vertical integration and financial capabilities, there is a diverse pattern of refineries within the EU. On the one hand, vertically integrated and financially strong owners of European refineries are divesting from their European refineries. On the other hand, moderately vertically integrated and financially capable companies, such as national champions from emerging markets, are increasing their presence in the European refining sector (CIEP, 2017).[79]

Although it has shifted over the years, ownership of European refineries can broadly be divided into four categories: International Oil Companies (IOCs), National Oil Companies (NOCs) and Merchants and Joint Ventures (JVs). A concentration of IOCs can be seen in Northwest Europe, Italy and Spain, although the refining capacity of oil majors has recently decreased as divestment campaigns have gained traction. The presence of NOCs in the EU refining sector is shifting as Rosneft is consolidating its stake, while Tamoil and Kuwait Petroleum Corporation are exiting the European market (CIEP, 2017).[80]

Production and production capacity in the EU

Figure 55 highlights the general downward trend in total European refinery capacity as well as refinery throughput (i.e. an indicator for the production level of the refinery sector). From 2007 to 2015, the capacity declined by more than 10%. Since 2007, the utilisation rate of EU refineries has continuously dropped from 87% to a lowest of 78% in 2014. In 2015, a reverse of this trend has been observed, with the utilisation of European refineries oscillating around 85%. This rate is commonly accepted as a requirement for efficient economic operations of a refinery (FuelsEurope, 2017a).[81] Low utilisation rates and the related increasing competition to supply the remaining EU demand, will likely force the industry to further reduce its capacities (Oil and Energy Trends, 2014).[82]

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[77] CIEP (2017), The European Refining sector: a diversity of markets? Available at: http://www.clingendaelenergy.com/files.cfm?event=files.download&ui=3125E7A1-5254-00CF-FD03037B4A0D3062

[78] Joint Research Centre (JRC), 2015. EU Petroleum Refining Fitness Check: Impact of EU Legislation on Sectoral Economic Performance. EUR 27262. Luxembourg (Luxembourg): Publications Office of the European Union

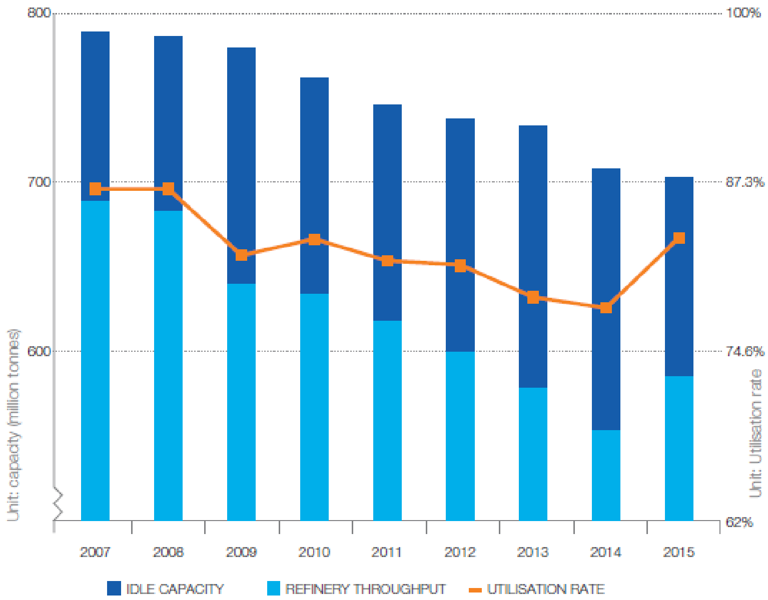
[79] CIEP (2017), op. cit.

[80] CIEP (2017), op. cit.

[81] FuelsEurope (2015a), Statistical Report 2015.

[82] *Oil and Energy Trends* (2014), "FOCUS: European refinery closures continue as foreign competition increases", Vol. 39, No. 3, pp. 3-6.

Figure 55. Capacity and production levels of European refineries, 2007-15

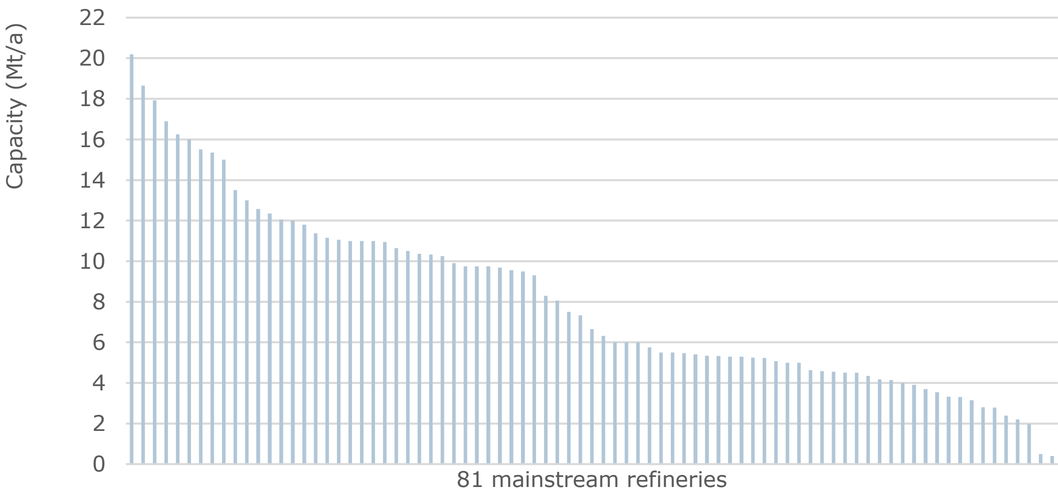


Source: FuelsEurope (2017).

Number and capacity of plants operating in the EU

Based on recent (unpublished) data from FuelsEurope, there are 81 mainstream refineries in the EU.[83] Figure 56 illustrates the capacities sorted from the largest to the smallest. The largest refinery has an annual capacity of 20.2 million tonnes, whereas the smallest has an annual capacity of only 0.4 million tonnes. The average annual capacity for refineries in the EU is 8.1 million tonnes, with a standard deviation of roughly 4.5 million tonnes. The total mainstream refinery capacity in Europe adds up to 656 million tonnes.

Figure 56. Capacities of all 81 mainstream refineries in the EU, 2017



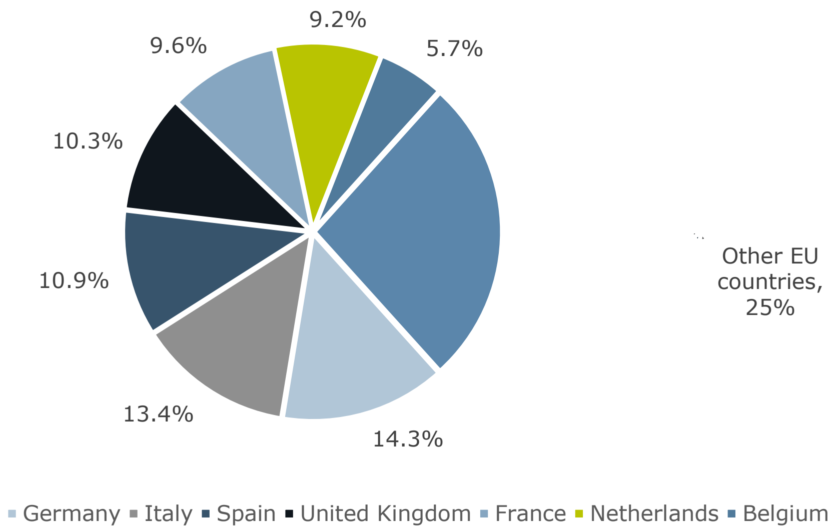
Source: Unpublished data from FuelsEurope.

[83] It is important to note that so-called mainstream refineries exclude any small petroleum oil sites performing specialised functions (such as bitumen and lube oil manufacture), as they are atypical for the refinery sector (Concawe (2012), EU refinery energy systems and efficiency).

None of the refineries falls under the EC definition of small- and medium-sized companies (SMEs).

As presented in Figure 57, in 2016 Germany accounted for the highest share of EU refining capacity (14.3%), followed closely by Italy with a share of 13.4%. Spain (10.9%) and United Kingdom (10.3%) have very similar production capacities, while France accounts for 9.6% and the Netherlands 9.2%. Due to its proximity to the sea, Belgium also has a relatively high share of refining capacity (5.7%) despite its relatively small economic size. According to FuelsEurope (2017)[84], the region Europe/Eurasia still remains the third-largest refining region in the world, with a share of 17.3% in 2017 (following Asia Pacific with 33.7% and North America with 22.7%). That share, however, has been decreasing steadily since 2006: Europe's share in global refining capacity in 2013 was 19%, while it 17.7% in 2015.

Figure 57 Share of refining capacity within the EU, 2017



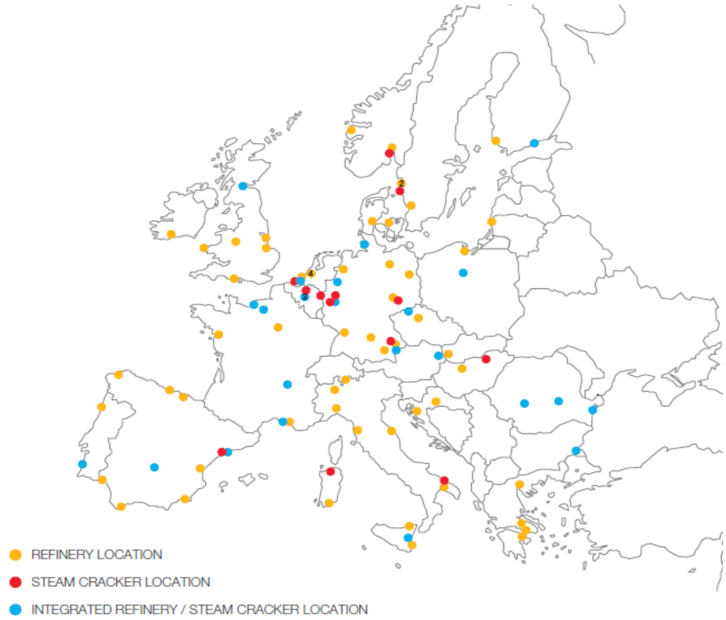
Source: Unpublished data from FuelsEurope.

Geographical distribution of plants over the EU

The map in Figure 58 shows the geographical distribution of the refinery, steam cracker and integrated refinery/steam cracker locations across the EU. It is important to note that many refineries are integrated with or located very close to steam crackers that produce products for the petrochemical industry. Such interconnections show that refining is an intrinsic part of the industrial value chain and provides the basis for many products derived from crude oil. Most of the industry is situated close to the coast, or, as is the case of Germany, near the Rhine River, since shipping is an important means of transport for the sector.

[84] FuelsEurope (2017), Website.

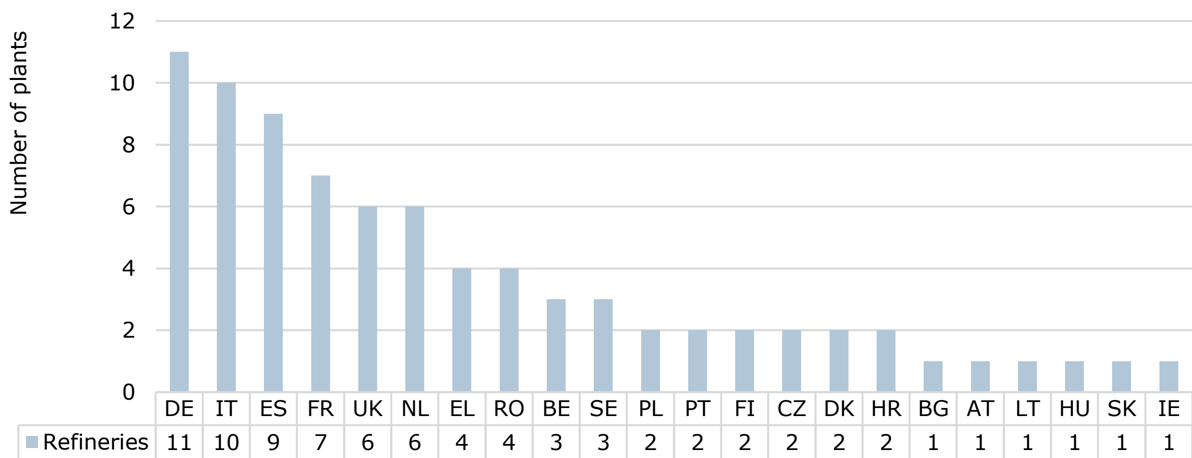
Figure 58 Refinery and steam cracker sites in the EU



Source: FuelsEurope (2017).

Figure 59 shows the distribution of refinery plants by country: Germany (11) and Italy (10) and Spain (9) operate the largest number of plants, followed by France (7), the United Kingdom (7) and the Netherlands (6). The remaining plants are distributed across other countries.

Figure 59. Refinery plants in the EU (81 in total), 2017



	DE	IT	ES	FR	UK	NL	EL	RO	BE	SE	PL	PT	FI	CZ	DK	HR	BG	AT	LT	HU	SK	IE
Refineries	11	10	9	7	6	6	4	4	3	3	2	2	2	2	2	2	1	1	1	1	1	1

Source: Unpublished data from FuelsEurope.

Employment

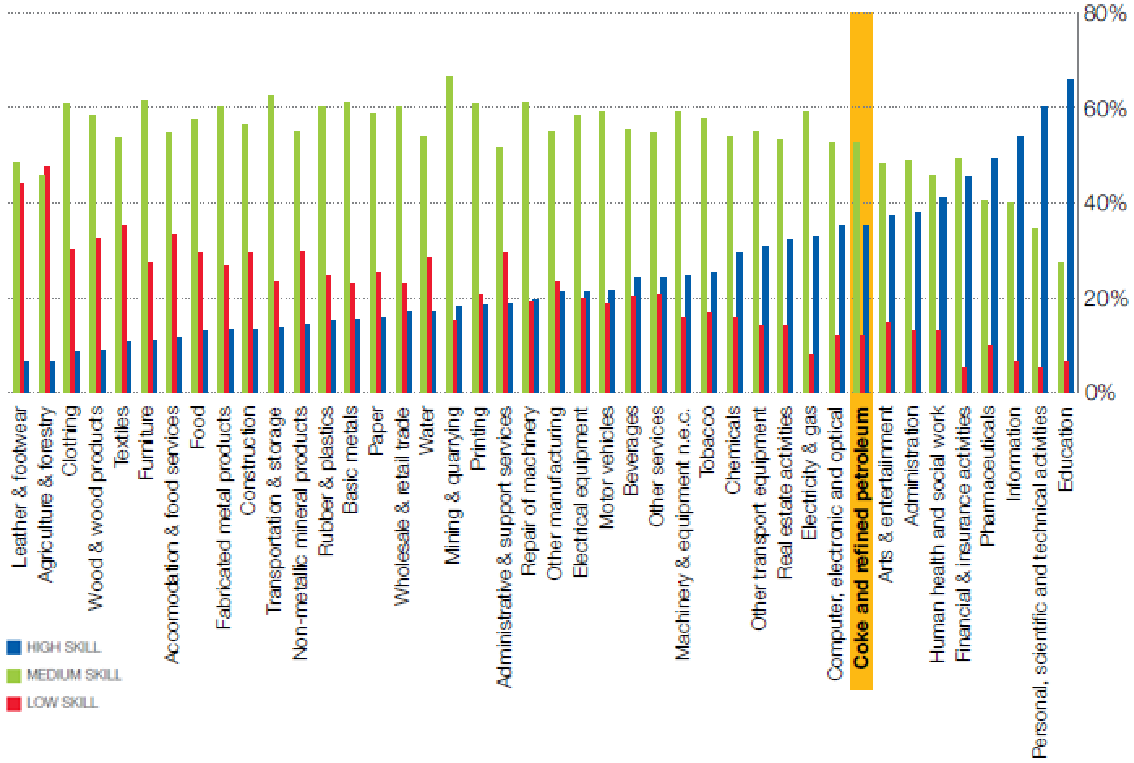
According to FuelsEurope (2016b),[85] refineries provide work for approximately 120,000 employees and contractors. Indirect employment accounts for an additional 1.2 million jobs, many of which are in highly skilled technical positions, logistics or marketing.

[85] FuelsEurope (2016b), Unpublished database of EU refining capacities

Eurostat (2017d)[86] estimates that the refinery sector (NACE 19.20 Manufacture of refined petroleum products sector) employed nearly 117,000 people in 2015 in the EU-28. While employment seemed to be on a continuously decreasing trend from 2009 to 2014, in 2015 the number of people employed increased again.

According to data presented by the EU's annual competitiveness report in 2013, the European refining industry employs one of the largest percentages of highly skilled workers out of all manufacturing industries, just after the pharmaceutical industry (see Figure 60).

Figure 60 Skill and knowledge intensities (% of total employment) in the European refining industry



Source: FuelsEurope (2015a).

According to Eurostat (2017e),[87] it is important to note that small- and medium-sized companies (SMEs) within NACE 19.2 Manufacture of refined petroleum products are less relevant, as more than 96% of turnover is made by companies with more than 250 persons.

7.4 Trade analysis

Major trade flows to and from the EU are a result of the imbalance in demand for gasoline vs diesel in Europe. Figure 61 shows net trade flows for refined products. Due to the significant excess gasoline production capacity, in 2015 nearly 70% of the EU refineries' net exports is gasoline. Some 38% of these exports go to North America, a traditional market for exports of surplus gasoline, but North America is reducing its imports due to

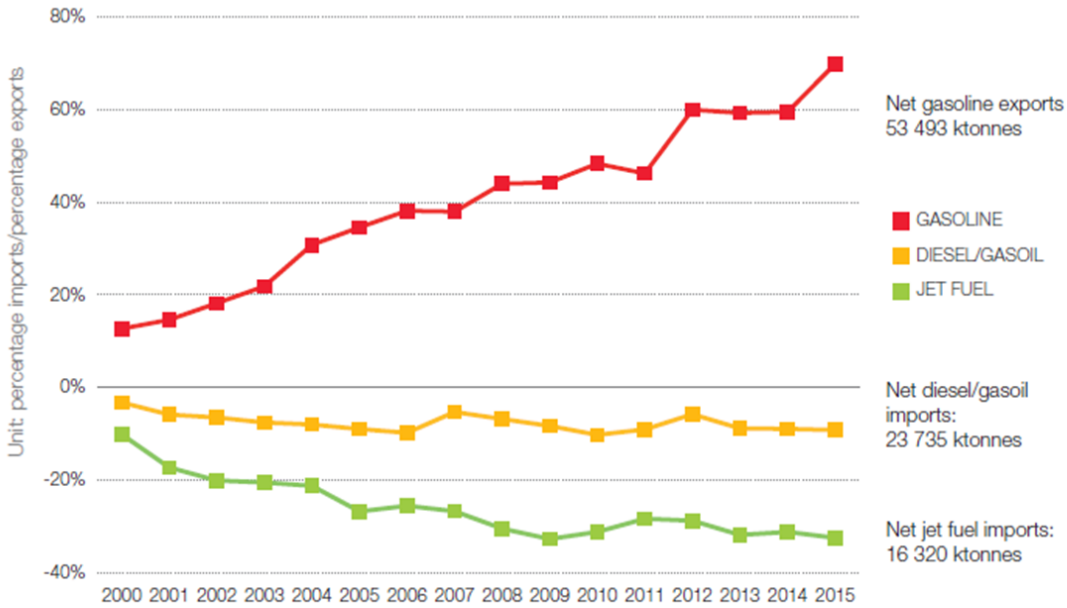
[86] Eurostat (2017d), Annual detailed enterprise statistics for industry http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en

[87] Eurostat (2017e), Industry by employment size class

shale gas/oil production. Another 38% is exported to Asia, while 24% is going to Africa (FuelsEurope, 2017a).

For gasoline, EU refineries have to find new export opportunities and compete in other markets. At the same time, EU refineries do not cover the EU's demand for diesel and jet fuel, resulting in an import dependency on other countries, especially Russia, the Middle East and the US (FuelsEurope, 2017a).

Figure 61 Net trade flows for refined products



Source: FuelsEurope (2017a).

According to Eurostat (2017b), trade in refined petroleum products (NACE 24.1) was fairly balanced from 2008 to 2016, as extra-EU imports were always at a similar level than extra-EU exports. In 2016, 160 million tonnes were exported while 161 million tonnes were imported. In 2016, intra-EU exports of refined petroleum products accounted for around 57% of total EU economies' exports, while the remaining 43% was directed towards extra-EU economies. Both percentage values remained stable from 2008 to 2016. The same is observed for import volumes: in 2016, 57% of total traded imports came from EU economies, i.e. intra-EU trade, and 43% from outside EU borders. As for exports, this was similar over the entire period from 2008 to 2016.

The total EU trade volume of refined petroleum products with G20 countries has been growing steadily since 2008, largely caused by strongly growing import quantities. In 2008, total imports were at around 77 million tonnes, while in 2016 this value reached 112 million tonnes. Export volumes, in contrast, remained stable, except for the crisis years 2009 and 2010 when it dropped sharply. In 2008, exports reached a volume of 48 million tonnes, while in 2016 this value is similar at around 49 million tonnes.

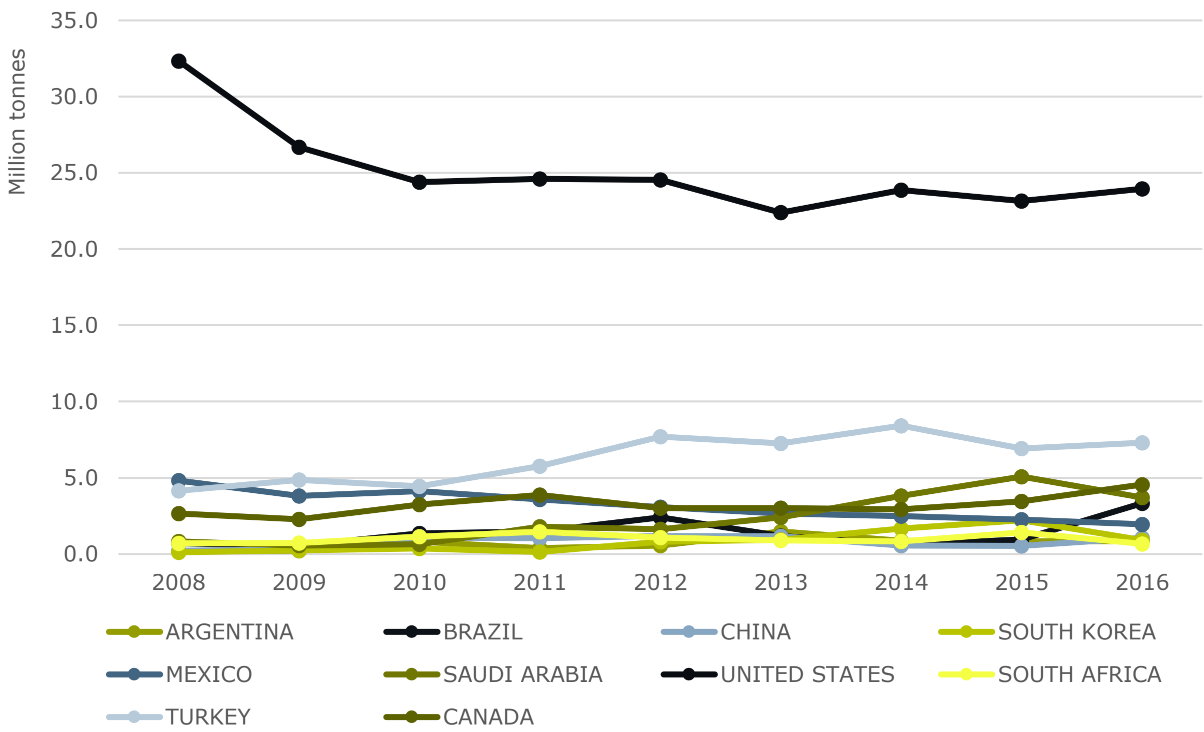
Figure 62 shows the EU export and import trade volumes of manufactured refined petroleum products with the 10 most-relevant (in terms of volume) G20 countries from 2008 to 2016. It illustrates that, from 2008 to 2016, the EU exported the largest share of its refined petroleum products to the United States. These volumes, however, have been decreasing from 32 million tonnes in 2008 to 24 million tonnes in 2012 and have since then been stable.

With significantly smaller volumes, Turkey and Canada followed the United States as the second and third largest importers of EU products throughout nearly the entire period from

2008 to 2016. Exports from the EU to Saudi Arabia also became quite substantial during 2013, reaching a similar volume as Canada in 2016. Exports to Turkey accounted for around 7.3 million tonnes in 2016, being nearly double the size as the exports to Canada or Saudi Arabia in the same year. China, in contrast, played an insignificant role regarding EU exports from the refining industry.

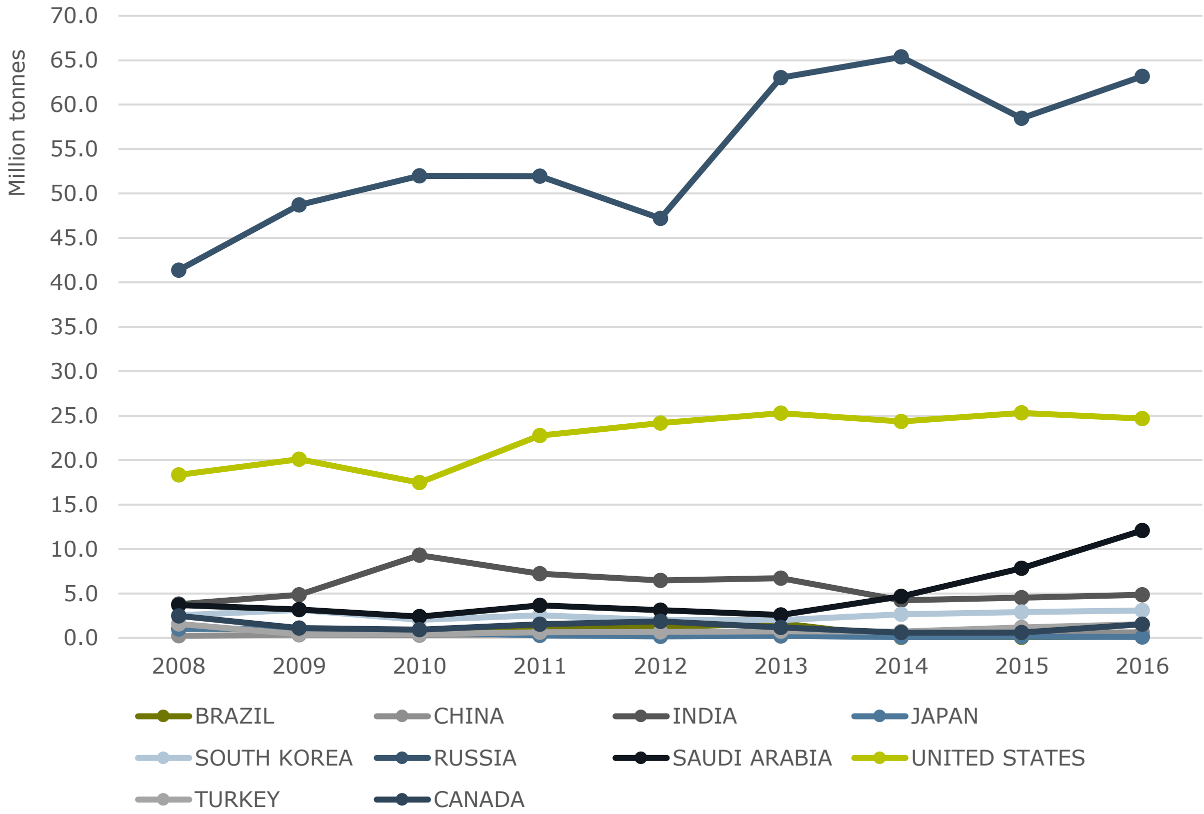
The highest imports to the EU by far, with a volume of nearly 65 million tonnes in 2016, came from Russia. Since 2008, these imports from Russia have steadily increased. The United States represents the second largest exporter to the EU. Since 2012, its export volume to the EU has remained stable at a volume of around 25 million tonnes. Note that this is equal to the United States' imports from the EU, meaning that the EU and the United States have a neutral trade balance. Between 2008 and 2013, India represented the third-largest exporter to the EU. Its volumes, however, continuously decreased from 2010 to 2014, and then remained stable. China's exports to the EU, in comparison, are again less significant.

Figure 62 EU export volumes of refined petroleum products with the 10 most-relevant G20 countries (in terms of volume), 2008-16



Source: Eurostat (2017b), International Trade (http://epp.eurostat.ec.europa.eu/newxtweb/submitlayoutselect.do) (NACE, 19.2).

Figure 63 EU import volumes of refined petroleum products with the 10 most-relevant G20 countries (in terms of volume), 2008-16



Source: Eurostat (2017b), International Trade (http://epp.eurostat.ec.europa.eu/newxtweb/submitlayoutselect.do) (NACE, 19.2).

Annex B – Econometric Analysis of Energy and Profitability

8 Econometric Analysis of Energy and Profitability

This Annex presents the results of:

- An econometric analysis aimed at assessing the impact of electricity and gas prices on the profitability of EU energy intensive companies.
- An energy decomposition analysis aimed at assessing the impact of changes in energy prices and energy efficiency on energy costs borne by EU energy intensive producers.

8.1 Introduction

This section discusses the results of an econometric analysis of the panel data collected from the 211 plants that participated in the 2018 EPC study (and previous editions, upon authorisation). The analysis aims to gain insight into the impact of the relevant energy characteristics of plants on their profitability. More specifically, it aims to assess whether the prices of electricity and natural gas have an impact on the profitability of plants operating in energy intensive sectors, and if so, to what degree.

8.2 The data

The data assessed are panel data collected from 211 plants operating in eight energy intensive sectors (and 11 subsectors) in 25 Member States over the period 2008-2017. The variables used in the models are detailed in Table 20. Log transformations are performed on the numeric variables to ensure interpretability of results in the final models. In addition to the variables below, the country, year and industrial subsector are all used in the model, although they are included as fixed-effect controls.

Table 20 Variable description and type

Variable	Description	Type
Independent variables		
n_profit_ebit	Profitability assessed as the EBIT divided by the turnover	Percentage
n_profit_ebitda	Profitability assessed as the EBITDA divided by the turnover	Percentage
Dependent variables		
ln_n_e_price_mwh	The price a plant paid per MWh of electricity in a specific year	Log transformation
ln_n_g_price_mwh	The price a plant paid per MWh of natural gas in a specific year	Log transformation
Control variables		
Vertical_Integration	Indicator of the level of vertical integration in a given plant. This is based on the total number of production process activities the plant partakes in.	Integer scale 1-9
SME	Indicator if the plant is part of a SME or not	Dummy 0-1
ln_n_production_capacity	The maximum production capacity of a plant	Log transformation
n_production_saturation	Percentage of the maximum production capacity of a plant utilised in a given year	Percentage

Source: Authors' elaboration.

Statistics pertaining to each variable included in the models are shown in Table 21.

Table 21 Variable characteristics

Variable	Observations	Mean	Standard deviation	Min	Max
SME	1,920	0.302083	0.459281	0	1
Vertical_Integration	1,830	5.169399	2.200637	1	9
Production_Capacity	1,430	178,873.5	144,260.2	9,855	7.00E+05
Production_Saturation	1,186	0.690431	0.231156	0.112211	1
E_Price_MWh	1,385	76.05166	24.45956	23.35106	143.2564935
G_price_mwh	1,326	26.88803	5.380287	11.98716	42.34705875
Profit_EBIT	998	0.059012	0.089193	-0.18274	0.330818619
Profit_EBITDA	1,045	0.130874	0.101985	-0.16449	0.458915555

Source: Authors' calculations.

8.3 Methodology

As the data are in a panel format, with plant-level observations across 10 years, we use a fixed-effect model to assess the determinants of profitability. This allows for control over sector, year and country variables in order to account for differences between these groups. The analysis relies on four model specifications (with and without control variables, and including different fixed-effect controls) which are run for two outcomes, namely EBITDA/turnover and EBIT/turnover (profitability indicators). This allows for any assessment of whether the plant depreciation and amortisation plays a significant role in changing the coefficients. The four models can be found below:

1. $Profitability_{fict} = c + Electricity\ Price_{fict} + Natural\ Gas\ Price_{fict} + e_{it} + \varepsilon_{fict}$
2. $Profitability_{fict} = c + Electricity\ Price_{fict} + Natural\ Gas\ Price_{fict} + e_{it} + \varphi_c + \varepsilon_{fict}$
3. $Profitability_{fict} = c + Electricity\ Price_{fict} + Natural\ Gas\ Price_{fict} + Vertical\ Integration_{fict} + SME_{fict} + Production\ Capacity_{fict} + Production\ Saturation_{fict} + e_{it} + \varphi_c + \varepsilon_{fict}$
4. $Profitability_{fict} = c + Electricity\ Price_{fict} + Natural\ Gas\ Price_{fict} + Production\ Capacity_{fict} + Production\ Saturation_{fict} + e_{it} + \varphi_c + \epsilon_f + \varepsilon_{fict}$

Where '*fict*' denotes a plant *f* in industry *i*, in country *c*, observed in a year *t*. ϵ_f is the individual plant effect, e_{it} is the industrial sector time-specific effect, φ_c is the country effect. The two main independent variables of interest are $Electricity\ Price_{fict}$ and $Natural\ Gas\ Price_{fict}$. Thus, there is a natural progression in model testing, where first we only control for the industrial sector time-specific effects. The second model then introduces an additional control for the country fixed effects. Third, we add plant-level control variables: vertical integration, SME, production capacity and production saturation. The final model then adds a plant level control for model comparison with model 3, to see how unobserved individual plant characteristics change the coefficients of the independent variables.[88]

8.4 Results

The results for the models can be found in Table 22. It is clear that an assessment across the four different models in each group provides different results, although the coefficients

[88] Vertical integration and SME are constant across all 10 years of the panel data; thus, when considering plant level fixed effects, these variables can no longer be estimated in the model.

do not change drastically across the four models. All but one of the models provide a statistically significant negative association between the natural gas price and plant profitability, while the electricity price is only significant among the sampled plants in model 1. This section will compare each model (1,2,3 and 4) between the two groups (EBIT/turnover and EBITDA/turnover).

- **Model 1.** Here the EBITDA/turnover shows a stronger negative correlation with electricity price than in the model for EBIT/turnover, with a decrease of about 0.035 percentage points vs. 0.015 percentage points following an increase of 1% in the electricity price. This is logical, as the EBITDA/turnover is a better representation of profitability in terms of plant operating costs. However, the correlation between natural gas prices and margins is statistically insignificant with regard to EBITDA/turnover, and marginally significant when it comes to EBIT/turnover. However, results stemming from this model should be interpreted with caution, as the model does not account for differences across countries, which are very important when it comes to the electricity prices.
- **Model 2.** When controlling for the country fixed effects, the results are very different. When regressed on EBITDA/turnover, natural gas prices are now marginally significant with an increase in 1% representing a decrease of 0.019 percentage points of profitability. The coefficient in the model with EBIT is quantitatively similar. By contrast, changes in electricity prices are not correlated with changes in profitability.
- **Model 3.** When adding plant control variables, the negative correlations found in model 2 are increased slightly for natural gas, while electricity prices are still statistically insignificant. When considering EBIT/turnover as the dependent variable, vertical integration, production capacity and production saturation are significant, while only vertical integration and production saturation are significant when considering EBITDA/turnover. In all cases, there was a positive correlation, which is logical. Plants that take better advantage of economies of scale, opt for more vertical integration and have greater capacity utilisation are more profitable in both models.
- **Model 4.** Here the vertical integration and SME variables are dropped as these plant-level characteristics are captured by the inclusion of the plant-level effect as a control in the model. Interestingly, including plant effects reduced the negative correlation and statistical significance in the EBIT model, but increased it in the EBITDA model. In both models, the only other statistically significant variable is the production saturation, which, as in model 3, indicates a positive relationship with profitability.

With regard to overall model fit and explained variance, the number of observations and R^2 are examined. The 4th models in both cases provide the highest explained variance with 76.3% for EBIT and 82.4% for EBITDA. This is logical as EBIT could be partially explained by company-level rather than plant-level features. Interestingly, the R^2 grows when moving from model 1 to model 4: this is equivalent to say that profitability is better explained when accounting for country-level features, control variables and plant-level features. When including control variables, the amount of observation decreased, but it is still large enough to provide statistically significant results in all models.

8.5 Summary

From this analysis it is possible to conclude that there is a negative relationship between the prices of natural gas and a plant's profitability within the energy intensive sectors covered by the EPC Study. However, aside from model 1, the electricity prices were not statistically significant in determining the plant's profitability. This may be partially explained by the fact that most of the observations comes from gas-intensive, rather than electricity-intensive plants.[89]

[89] In models 1 and 2, observations from electricity-intensive sectors (primary aluminium and steel EAF) represent about 12% of the total observations retained; in models 3 and 4, they represent about 6% of the total observations retained.

Table 22 Fixed effect model results

	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
VARIABLES	n_profit_ebit	n_profit_ebit	n_profit_ebit	n_profit_ebit	n_profit_ebitda	n_profit_ebitda	n_profit_ebitda	n_profit_ebitda
ln_n_e_price_mwh	-0.0150**	0.000900	0.0130	0.0101	-0.0350***	-0.00174	0.00522	-0.00191
	(0.00691)	(0.00774)	(0.0104)	(0.00935)	(0.00866)	(0.00833)	(0.00966)	(0.00779)
ln_n_g_price_mwh	-0.0171*	-0.0239**	-0.0284**	-0.0232*	-0.0164	-0.0190*	-0.0226*	-0.0321***
	(0.00896)	(0.0106)	(0.0129)	(0.0130)	(0.0108)	(0.0114)	(0.0121)	(0.0109)
Vertical_Integration			0.0117***				0.0128***	
			(0.00437)				(0.00448)	
SME			0.00137				-0.0166	
			(0.0103)				(0.0136)	
ln_n_production_capacity			0.0202***	0.0643			0.00388	0.0520
			(0.00699)	(0.0514)			(0.00895)	(0.0603)
n_production_saturation			0.0910***	0.125***			0.0651***	0.149***
			(0.0240)	(0.0371)			(0.0244)	(0.0340)
Observations	796	796	612	612	834	834	636	636
R-squared	0.344	0.448	0.498	0.763	0.315	0.481	0.555	0.824
Sector*Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Controls	No	No	Yes	Yes	No	No	Yes	Yes
Plant FE	No	No	No	Yes	No	No	No	Yes
Clusters	201	201	177	177	205	205	178	178

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' calculations.

9 Energy Decomposition Analysis

9.1 Introduction

This section highlights the results of an energy decomposition analysis aiming to assess the specific contributions of different energy components to the change in energy costs in the sectors covered by the EPC Study, over a given time series.

9.2 The data

The data used in this analysis are taken from the plants participating the 2018 EPC study. However, because the calculation of the index has strict requirements on data gaps, the analysis is based on data from 99 of the total 211 plants that participated in the Study. The data are measured across five years (from 2012 to 2016), as this period had the greatest amount of data available for the largest number of plants. Only data from the EPC study are used in the decomposition analysis, as the application is at the micro level and thus (for accurate representativeness of the indexes) the use of macro level data is not advised. The number of plants per sector is shown in Table 23**.**

Table 23 Number of plants included in decomposition analysis

Sector	Number of plants
Aluminium	10
Bricks and Roof Tiles	25
Glass Tableware	12
Fertilisers	7
Packaging Glass	24
Steel (EAF & BOF)	10
Wall and Floor Tiles	11

Source: Authors' elaboration.

The variables that are used are the energy costs, production activity (output), energy intensity and energy prices. Energy variables are calculated based on the data pertaining to purchased electricity, purchased natural gas and self-production of electricity among the included plants.

9.3 Methodology

Energy decomposition analysis breaks down components contributing to, in this case, the change in the cost of energy and creating an index for each individual component, as well as the total change. The method used in this analysis is the multiplicative Logarithmic Mean Divisia Index (LDMI). This approach is used, as the analysis relies on both quantity and intensity indicators and this method provides interpretability of both of the indexes in terms of percentage change in the components.[90] The equation that is used in the case of this analysis assessing the change in energy costs is:

$$C = \sum_i C_i = \sum_i Q \frac{E_i}{Q_i} P_i$$

Where *C* is the cost of energy (in €, constant prices[91]) and *i* is a specific sector. Q is the production output or activity (in tonnes), E_i/Q_i is the energy intensity (in MWh/tonne) and *P* is the energy price (in €, constant prices[92]).

[90] For further details, see B.W. Ang (2015), "LMDI decomposition approach: A guide for implementation", *Energy Policy*, Vol. 86, issue C, pp 233-238.

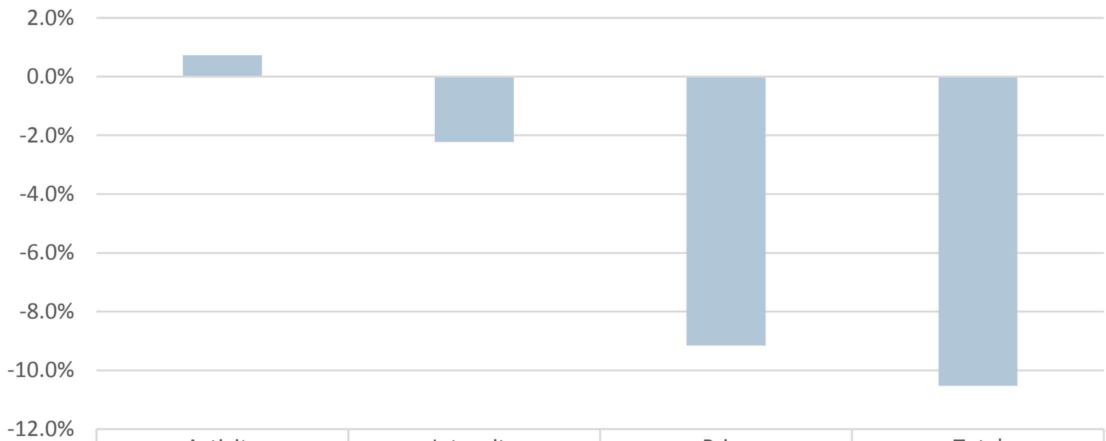
[91] Base period: 2012.

[92] *Idem*.

9.4 Results

The results indicate a downward energy cost trend among the sampled plants (average annual growth rate -10.5%; Figure 64). This is caused by relatively stable production activity within the sampled plants (average annual growth rate +0.7%), combined with a large decrease in price (average annual growth rate -9.2%) and a relatively smaller decrease in the energy intensity (average annual growth rate -2.2%). Changes year-over-year are shown in Figure 65.

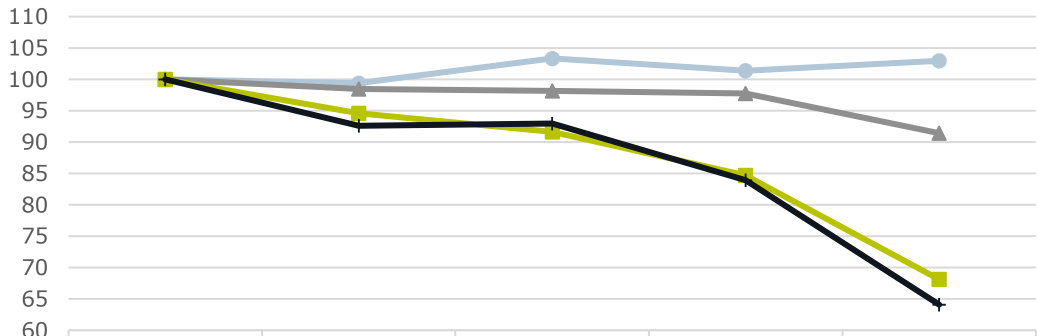
Figure 64 Average annual growth rate in energy costs and components, 2012-2016



	Activity	Intensity	Price	Total
% change	0.7%	-2.2%	-9.2%	-10.5%

Source: Authors' elaboration.

Figure 65 LDMI (index number, 2012=100), 2012-2016



	2012	2013	2014	2015	2016
Activity	100	99.41	103.34	101.38	102.93
Intensity	100	98.48	98.15	97.75	91.41
Price	100	94.57	91.65	84.69	68.10
Total	100	92.58	92.96	83.92	64.08

Source: Authors' elaboration.

It is important to note that this methodology is commonly applied at the macro level; therefore, results based on this small sample of plants may or may not reflect results from similar studies conducted using macroeconomic data.

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