8 COKING COAL

8.1 Overview

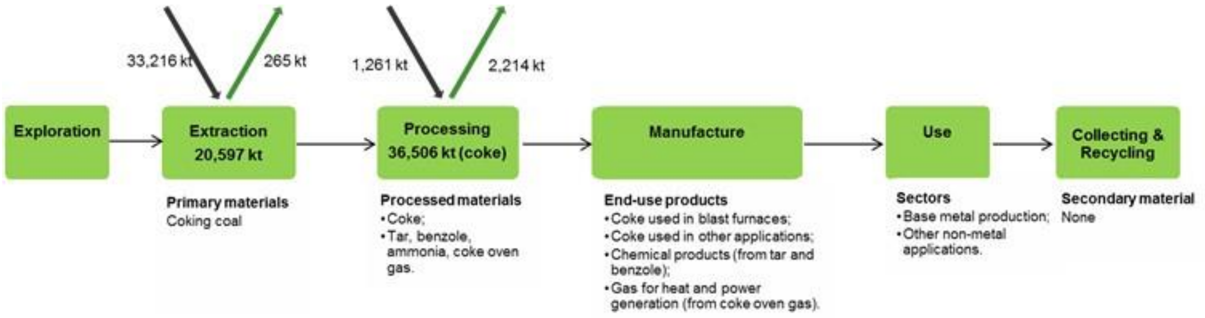

Figure 103: Simplified value chain for coking coal[71]

Coking coal (or metallurgical coal) is a bituminous coal with a suitable quality that allows the production of metallurgical coke, or simply named coke. Coking coal has a higher carbon content than steam coal, as well as a lower level of sulphur, phosphorous and alkalis (World Coal Institute 2009). Coke is the main product of the high-temperature carbonisation of coking coal. Coke is an essential input material in steelmaking as it is used to produce pig iron in blast furnaces acting as the reducing agent of iron ore and as the support of the furnace charge. By-products of coke production such as tar, benzole, ammonia sulphate and sulphur are used for the manufacture of chemicals, as well a coke oven gas used for heat and power generation.

In this assessment, coking coal is analysed in terms of mine production and coke production. The relevant trade code for the extraction stage used is CN code 27011210 "Coking Coal, whether or not pulverised, but not agglomerated".

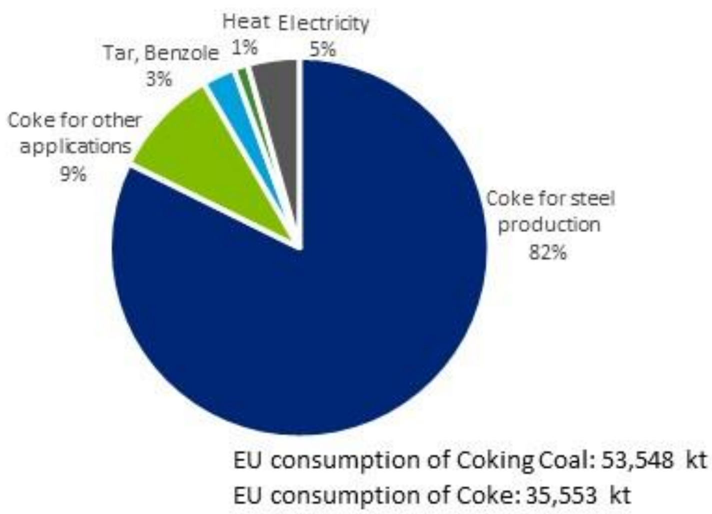

Figure 104: End uses of coking coal (average 2013-2017) (SCRREEN workshop 2019) and EU consumption of coking coal and coke (average 2012-2016) (ESTAT Comext 2019)

[71] JRC elaboration on multiple sources (see next sections)

For the processing stage the trade codes CN 27040010 'Coke and semi-coke of coal, whether or not agglomerated', CN 27040011 'Coke and semi-coke of coal, whether or not agglomerated, for the manufacture of electrodes', and CN 27040019 'Coke and semi-coke of coal, whether or not agglomerated (excl. For the manufacture of electrodes)' were used. Quantities are expressed in tonnes of coking coal and coke and refer to average values for the period 2012-2016 unless otherwise specified.

The world production of coking coal in 2017 was 1,039,005 kt, with an estimated value of EUR 151 billion. Global import demand is expected to rise by an average annual growth rate of 2.3% (7.5 Mt) from 2017 to 2030. China and Australia are the top coking coal producer and exporter, respectively. The coking coal market is directly associated with iron ore and steel demand. There is a sizeable market in terms of volume, with world exports of coking coal at 327,000 kt in 2017, representing 24% of global hard coal trade.

Coking coal price boomed in 2016. The considerable price volatility in the period 2016-2019 reveals that the coking coal market has become extremely susceptible to supply chain disruptions. In the first semester of 2019, the price of Australian premium hard coking coal was relatively stable at around USD 200/tonne.

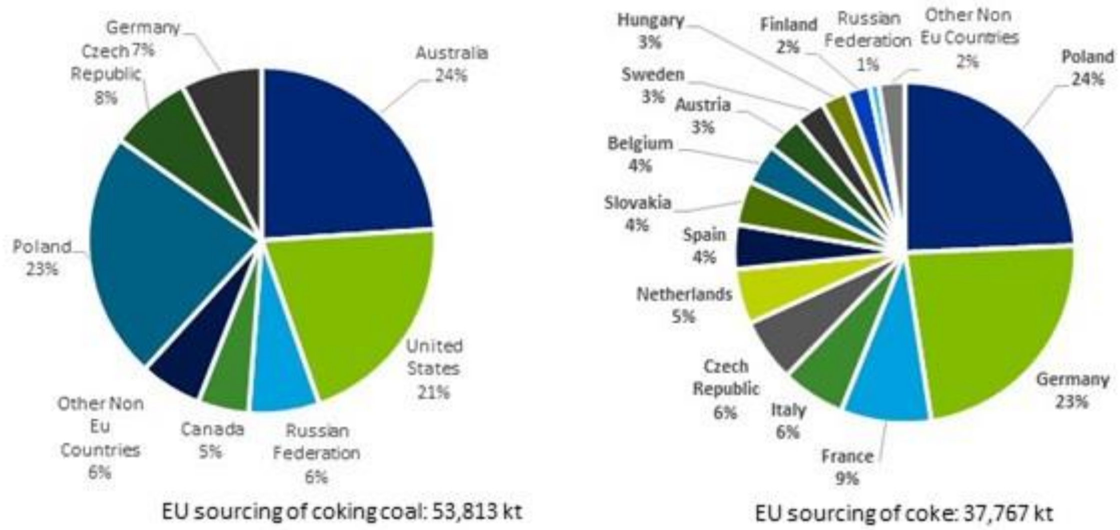

Figure 105: EU sourcing of coking coal and coke.

In the period 2012-2016, the EU consumption of coking coal was around 53,548 kt. Domestic production took place in Poland, Czechia and Germany. The production in Germany ended in 2018. Imports came mostly from Australia (39% of EU imports) and the United States (33% of EU imports). Import reliance for coking coal was 62%. The annual EU production of coke was around 36,506 kt, and Poland and Germany were the leading producers. The EU was a net exporter of coke.

Iron and steel industry is the primary consumer of coking coal. More than 70% ofworld steel production is made in blast furnaces fired with coking coal previously processed in coking plants to form coke. In the EU, 90% of the coking coal demand is converted to coke to be used in blast furnaces of the integrated steel processing route. Several chemical products can be produced from the by-products of coke ovens. There is no other satisfactory material available which can replace completely metallurgical coke in the blast furnace charge. Pulverised coal (PCI) is an alternative material for coking coal (coke) up to a certain level, but the industry has already reached the technical limits of replacement.

No information is available for coking coal's resources and reserves. Figures reported for bituminous coal provide a rough indication of coal suitable for coking coal production. US, China, India, Russia and Australia hold the most extensive reserves worldwide for bituminous coal. Around 22 billion tonnes of bituminous coal reserves are located in the EU, and Poland holds by far the largest amount of reserves (93%) (BP 2018).

More than one billion tonnes of coking coal is produced globally. China dominates the world production of coking coal with more than half of the world output (55%), followed by Australia (16% of the world total). Chinese production is subject to export tax (OECD 2019a). The annual European output of coking coal is around 20,597 kt (WMD 2019) However, since 2019 only Poland and Czechia contribute to European production, as hard coal mining in Germany ended at the end of 2018. Given the type of applications, coking coal is not recyclable (BIO Intelligence Service 2015).

In the context of the EU policy to reduce greenhouse gas emissions[72], the transition to a lower-carbon economy is challenging to coal-related industries. The European steel industry accounted in 2016 for about 7% of the verified greenhouse gas emissions of all stationary installations of the European Union. Process related CO_2 emissions in the steel industry are a natural result of the oxidisation of coke in the iron-making process. Breakthrough innovative technologies are under development to decarbonise steel production; some are aiming to altogether bypass the use of coal for the production of primary steel (European Commission 2018). Steel, the main end-use of coking coal, is present in all industry sectors, including the construction of wind turbines. Some products derived from the by-products of the coking process such as carbon fibres are associated with innovative low-carbon technologies.

8.2 Market analysis, trade and price

8.2.1 Global market

The worldwide production of coking coal in 2017 was 1,079,497 kt accounting for about 17% of the total hard coal production worldwide (WMD, 2019). China is the largest producer of coking coal, with more than half of the global supply (52% in 2017). Chinese production increased by more than three times since 2000 to peak at about 620,000 kt in 2014 but subsequently dropped to 540,000 kt in 2017 (IEA 2018) (WMD, 2019). Other significant producers are Australia (18%), Russia (8%) and the USA (6%). Since 2010, world production of coking coal has been relatively stable at levels of between 900,000 and 1,100,000 kt (WMD, 2019). The rise of hard coal prices on the world market since the summer of 2016 ended the wave of mine closures worldwide with high production costs that had continued over several years (BGR 2017). The value of coking coal production was roughly estimated at EUR 151 billion[73] in 2017.

Coking coal trade reflects the demand for iron ore, pig iron and crude steel (Euracoal 2017). There has been a substantial increase in coking coal consumption during the last 40 years, driven primarily by growing steel production in China as infrastructure has been expanded (IEA 2018).

According to (IEA 2018), in 2017 the global trade (exports) of coking coal was estimated at 327 million tonnes, equal to 24% of total hard coal trade (1,370,000 kt), of which 275 million tonnes represent seaborne trade (Euracoal 2018). Australia is the largest exporter in the global coking coal market, with a share of about 54% (177,000 kt) of total exports in 2017 (IEA 2018). Other important exporting countries are the USA, Canada, Mongolia, and Russia (see Figure 106). China, the world's largest producer, does not export coking coal as it is consumed domestically. Moreover, China imports significant amounts of high-

[72] https://ec.europa.eu/clima/policies/strategies/2050_en

[73] Estimation based on an average price of EUR 145 per tonne in 2017 (Australian hard coking coal) and the reported global production.

quality coking coal. In fact, the selection of coal types depends both on the desired coke quality and the final metal product quality. Also, coking coal produced in India has in some cases undesired quality for use in ironmaking (Sundqvist Ökvist et al. 2018). China does however export metallurgical coke, being the top exporter in the world (data for HS 270400 from (UN Comtrade 2019)). The value of coking coal traded globally was roughly estimated at EUR 47 billion[74] in 2017.

According to 2017 data (Euracoal 2018) (IEA 2018), the seaborne coking coal accounts for around one-quarter of the total world market with the remaining three-quarters consumed within domestic markets, e.g. China and India, and it best represents the international market for coking coal (Eurofer 2019b). The seaborne coking coal market is characterised by the smaller number of supplying countries in comparison to the steam coal market (Euracoal 2019).

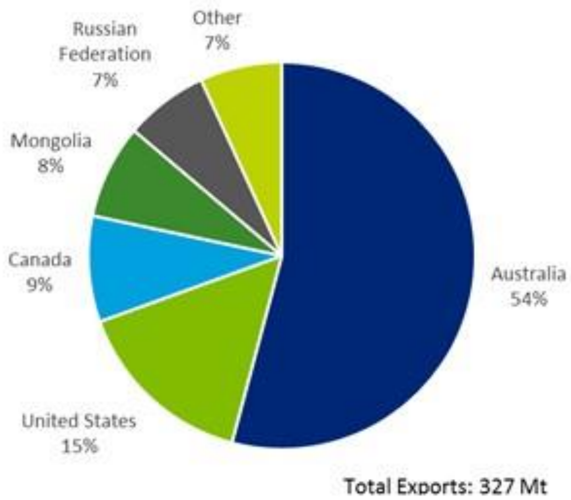

Figure 106: Major coking coal exporters worldwide in 2017. Data from (IEA 2018)

It has to be noted that the coking coal supply chain has high exposure to disruptions such as adverse weather conditions and accidents due to the concentrated supply structure, i.e. number and geographical location of mining areas, capacity and location of ports and railways dedicated to exports (WorldSteel 2019b).

China's production of coking coal was subject to an export tax of 3% (decreased from 10% in 2015) as listed by the OECD Inventory for the year 2017 and the code HS 270112 "Bituminous coal, whether/not pulverised but not agglomerated" (OECD 2019a). A 3% fiscal tax on exports is imposed by Mongolia for coking coal concentrates, and a captive mining restriction by India. The above countries accounted for 60% of the global production of coking coal in 2017. Severe trade-restrictive measures (i.e. export taxes, export quotas, export prohibition) do not apply for coke in 2017 (OECD 2019a).

8.2.2 Outlook for supply and demand

The future worldwide demand for steel drives the market outlook for coking coal demand. A recent report (Commodity Insights 2018) prepared for the Minerals Council of Australia forecasts that the global import demand of metallurgical coal will grow by a rate of 2.3% from 2017 to 2030, representing an annual average growth of 7,5 Mt, mainly driven by strong demand for steel in India (60% increase of import demand) and China (39%

[74] Estimation based on an average price of EUR 145 per tonne in 2017 (Australian hard coking coal).

increase of import demand). The global demand for steel is expected to rise for many years (OECD 2019b), and primary steel production through the BF/BOF route will continue to play an important role in the future (EUROFER 2015).

On the supply side, China is expected to maintain its dominance in the producers' market, with coking coal production increasing from 540,000 kt in 2017 to 551,000 kt by 2028 (IEA 2018). S&P Global estimated an increase of Australian production 182,000 kt in 2018 to 214,000 kt by 2025 due to incoming new supply (S&P Global Market Intelligence 2018). Apart from the significant expansions in the already dominant market players, strong growth potential is reported for Mozambique and Mongolia (Euracoal 2019). Mining supply in the EU will decrease, as hard coal mining in Germany ended at the end of 2018. In 2017, Germany produced 2.3 million tonnes of coking coal (WMD 2019).

Available reserves of coking coal can strongly modify the future supply conditions as increasing quality and cost-benefit aspects may reduce the available volumes of the coking coal (HCC and Premium HCC qualities) necessary for maintaining high environmental performance and market competitiveness. Not all identified and potential deposits of coal can deliver high-quality coking coal. As with all mineral resources, the geographical location of currently active mines and the accessibility of known deposits influences the final cost of the extracted raw material, periodically making the exploitation of marginal deposits unfeasible (Eurofer 2019b).

Table 44: Qualitative forecast of supply and demand of coking coal

Material	Criticality of the material in 2020		Demand forecast			Supply forecast		
	Yes	No	5 years	10 years	20 years	5 years	10 years	20 years
Coking coal	X		+	+	+	+	+	?

8.2.3 EU trade

The EU has historically been a net importer of coking coal because demand from the steel industry exceeds domestic supply (European Commission 2017). Imports have remained relatively steady throughout 2012-2016 at around 33,216 kt per year on average, with a moderate increase to 33,854 kt in 2014, and a modest decrease to 31,121 kt in 2016 (Figure 107). The former can be linked to an increased domestic steel output in the Blast Furnace (BF)/Basic Oxygen Furnace (BOF) route in 2014 by about 3%. The latter is coupled with a decreased domestic production of about 2,100 kt in 2016 in comparison to 2015, as well as with increased coke exports (see Figure 109); The EU crude steel output from the BF/BOF route was stable in 2016 compared to 2015 (Worldsteel 2018). Most of the coking coal imported to the EU originates from Australia and the US (Figure 108). As an average in 2012-2016, the United States and Australia exported into the EU the 72% of all imported coking coal. Therefore, the EU relies on highly concentrated deposits for its imports of coking coal. In the same period, exports of coking coal remained minor at the level of a few hundreds of tonnes, representing around 1% of imports by volume.

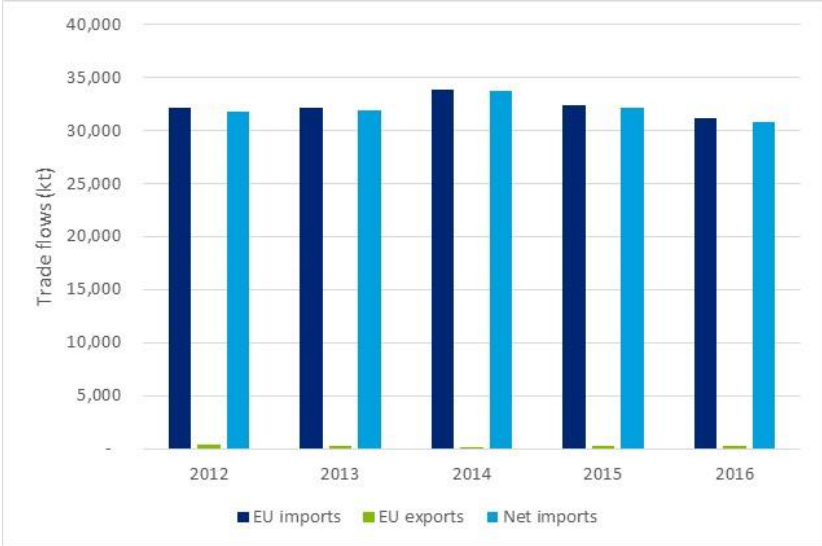

Figure 107: EU trade flows for coking coal (ESTAT Comext 2019)

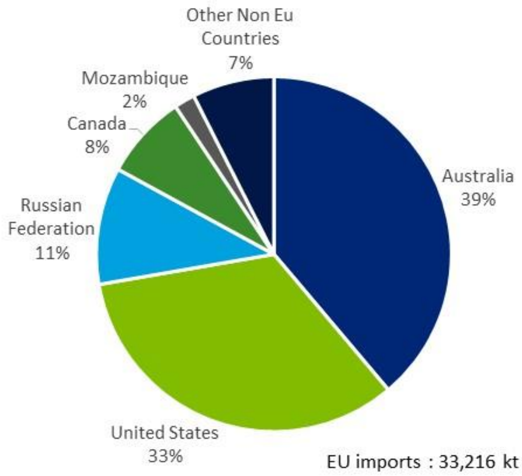

Figure 108: EU imports of coking coal, average 2012-2016 (ESTAT Comext 2019)

The EU is a net exporter of coke (Figure 109), exporting on average over the 2012-2016 period 2,214 kt and importing 1,261 kt annualy (ESTAT Comext 2019). Imports of coke to the EU come mainly from Russia (see Figure 110).

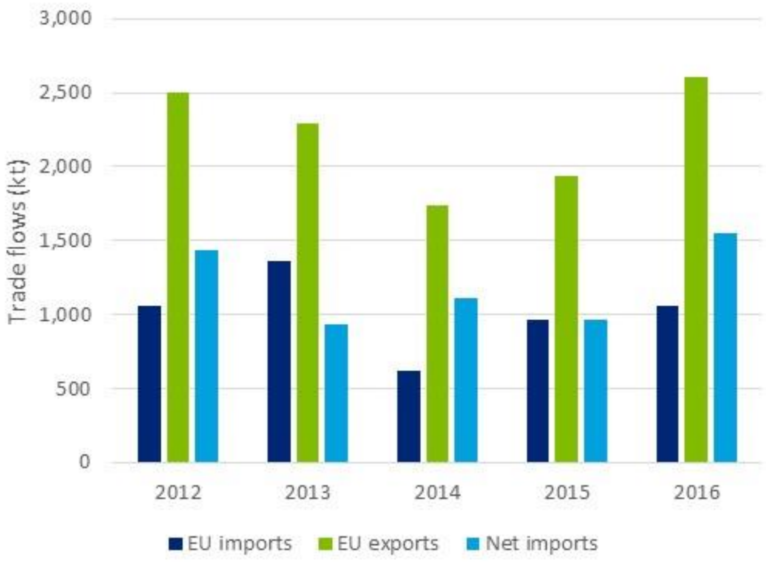

Figure 109: EU trade flows for coke (ESTAT Comext 2019)

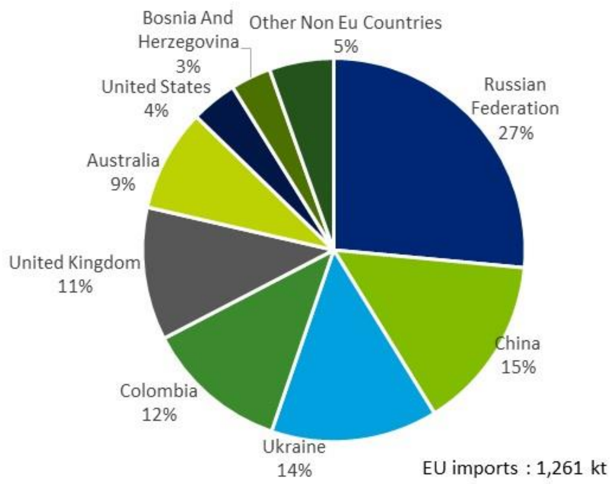

Figure 110: EU imports of coke, average 2012-2016 (ESTAT Comext 2019)

In 2017, countries exporting coking coal or coke to the EU did not apply restrictive export measures, i.e. export taxes, export quotas or export prohibitions (OECD 2019a). Free Trade Agreements exist with Canada, Colombia, Ukraine, United States and Bosnia and Herzegovina (European Commission 2019)

8.2.4 Prices and price volatility

Coking coal is traded both through contracts and in the spot market. Coal spot prices can fluctuate based on-short term market conditions, but contract prices tend to be more stable (US EIA 2019). Coking coal varies in quality, with hard coking coal representing the highest grade, which attracts a premium price. Semi-soft or high-volatile coking coal is of lower quality and as such, is sold at a lower price. Other essential price factors are freight, insurance, and whether the price refers to contracted coal or spot price (CRM Alliance 2018). Coking coal is more expensive than steam coal used in power plants due to the requirement of more thorough cleaning and low impurity level (US EIA 2019). Coke prices are correlated with coking coal prices, though higher at a level estimated roughly of 1.5 to 2 times (data from (JSW 2019b)).

The pricing of coking coal after a long period of substantial stability and low prices ranging from USD 40/tonne to 60/tonne on a yearly basis, started to sharply increase after 2003 due to the growing demand from emerging economies. In particular, the strong demand for steel from China due to large infrastructure projects supported and continues to support high prices for coking coal (Eurofer 2019b). The time series in Figure 111 reveals the sharp rise of the annual coking coal prices from USD 42/tonne in 2003 to USD 230/tonne in 2011, as well as the difference with steam coal prices.

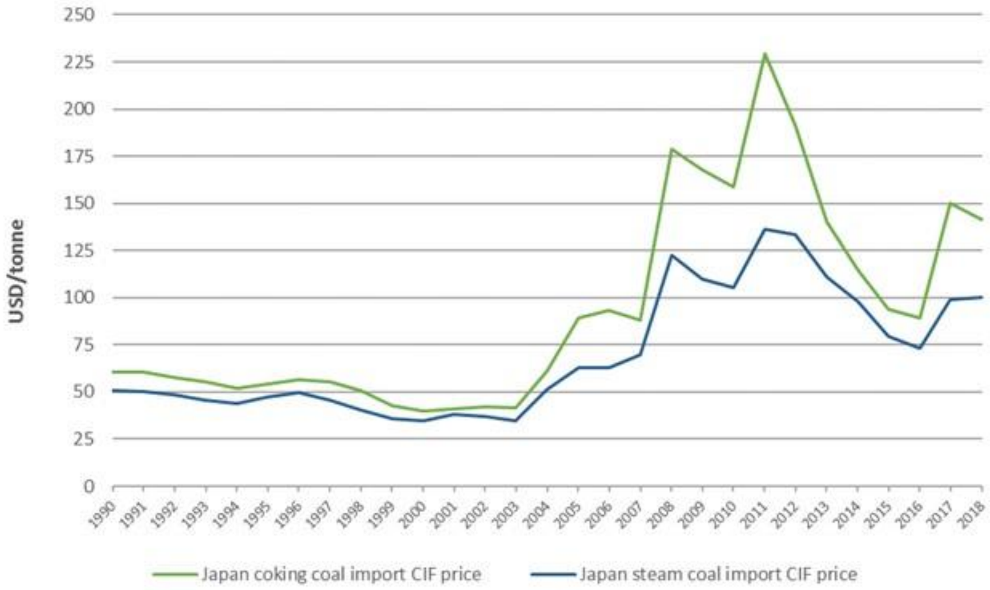

Figure 111: Developments in annual prices of steam coal and coking coal. Data from (BP 2019)

Following the global recession in 2011, coking coal prices had a declining trajectory for many years. In summer of 2016, there has been a sharp rise in prices, which climbed to record highs at the end of 2016. While the monthly average spot price for Australian premium coking coal was still at USD 92/tonne in July 2016, it rose sharply to USD 309/tonne in November 2016 (see Figure 112). In 2017 and 2018, coking coal prices remained very volatile with several drops and spikes but remained at a relatively high average level. On a year-over-year basis, the annual average of the industry benchmark price (high-quality Australian hard coking coal tracked by the Steel Index) increased 65% in 2016, 28% in 2017 and 7% in 2018; in the first semester of 2019 the benchmark spot price is averaging over USD 200/tonne for (S&P Global Market Intelligence, 2019a).

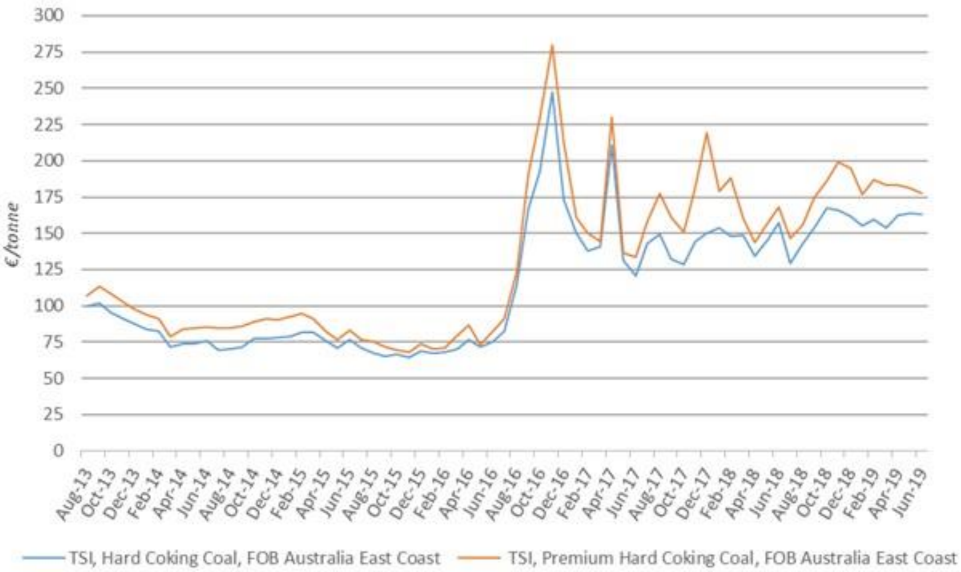

Figure 112: Coking coal spot prices (The Steel Index), FOB Australia East Coast, monthly average (EUR/tonne). Data from (S&P Global Market Intelligence 2019a)

The significant volatility in the 2017-2018 period can be attributed to higher demand from China and India, as well as by short-term increase of demand in other markets, but mostly to supply-side factors, e.g. severe supply bottlenecks in Australia caused by floods and cyclones which restricted shipments due to low train availability (Euracoal 2018) (Deloitte 2018) (CRU 2018)(S&P Global Market Intelligence 2019b). Similar weather-related supply disruption events influencing the pricing of coking coal occurred in the Australian mining region of Queensland in 2009 and 2011 (Eurofer 2019b).
The higher coal prices since 2016 mark the end of the previous period of oversupply (BGR 2017). A large degree of volatility is expected to be maintained in the short term, due to the rise in global demand and the relatively low amount of investment in exploration and the development of new coal projects (BGR 2019a).

Figure 113 presents the evolution of unit value for imports of coking coal and coke in the EU. After a five-year decline, in 2016 the annual average unit value for imports of coking coal was EUR 96/tonne, and EUR 117/tonne for imports of coke and semi-coke of coal. In 2017, the annual average unit value for imported coking coal rose by around 80% at EUR 171/tonne, and remained at high levels in 2018. The annual average unit value for imported coke and semi-coke of coal increased by about 60% in 2017 to EUR 186/tonne, and in 2018 by 15% on a year-on-year basis at EUR 213/tonne.

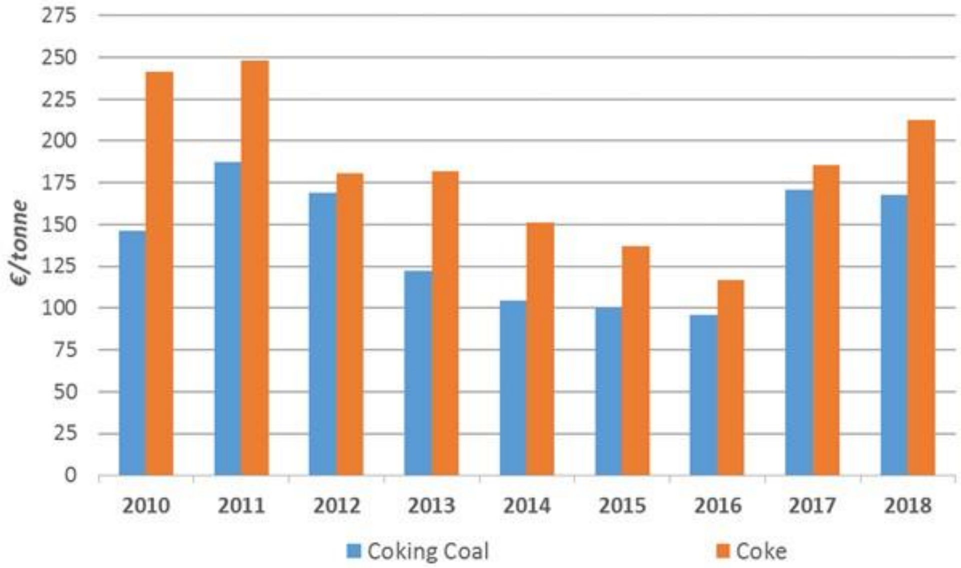

Figure 113: Unit value[75] of EU imports of coking coal and coke/semi-coke of coal, yearly average (EUR/tonne). Data from (ESTAT Comext 2019)

8.3 EU demand

8.3.1 EU consumption

The EU apparent consumption of coking coal is calculated at approximately 53,548 kt in volume as an average for the period 2012-2016. Of this, about 20,332 kt per year came from within the EU (calculated as EU production – exports to non-EU countries) and 33,216 kt were imported. Based on these figures, the net import reliance is 62%. The annual EU apparent consumption of coke is calculated at 35,553 kt for the same period. The EU is not import reliant as it is a net exporter of coke.

The EU apparent consumption of coking coal declined by 10% from 2012 to 2016, from 54,152 kt in 2012 to 48,915 kt in 2016, mainly due to declining domestic production from 22,393 kt in 2012 to 18,102 kt in 2016 (ESTAT Comext 2019)(WMD 2019). In the same period, the EU coke consumption was relatively stable, ranging from 35,800 to 34,800 kt.

It has to be noted that the aforementioned consumption levels of coking coal and coke include the use of PCI in the blast furnace (see Section 8.3.3), and PCI injection has already reached its technical limits in the EU industry (Eurofer 2019a).

8.3.2 Uses and end-uses of coking coal in the EU

The use of coking coal in the steel making process is the most significant application. 90% of coke is used in the iron making process (blast furnace) for generating the necessary

[75] For coking coal, the imports unit value is calculated for the trade code CN 27011210 "Coking Coal, whether or not pulverised, but not agglomerated". For coke/semi-coke of coal, the imports unit value is considered for the combined quantity and value for trade codes: CN 27040010 'Coke and semi-coke of coal, whether or not agglomerated', CN 27040011 'Coke and semi-coke of coal, whether or not agglomerated, for the manufacture of electrodes', and CN 27040019 'Coke and semi-coke of coal, whether or not agglomerated (excl. For the manufacture of electrodes). Semi-coke is a different product from coke formed by incomplete carbonisation of coke. However, trade data for coke and semi-coke are aggregated

process heat, as a reduction medium of iron ores, carburisation of the hot metal, supporting the furnace charge, and providing permeability inside the furnace. More than 70% of world steel production is made by the integrated steelmaking route which is based on the blast furnace (BF) and basic oxygen furnace (BOF) processes, and therefore, relies on coking coal (World Coal Association 2019)(World Coal Institute 2009). In the EU, 60% of steel production, which requires coking coal, is produced via the blast furnace route (European Commission 2018). The average production of one tonne of steel in the integrated steelmaking process requires the use of 630 kilograms of coke, and therefore 780 kilograms of coking coal (WorldSteel 2019a) (World Coal Institute 2009).

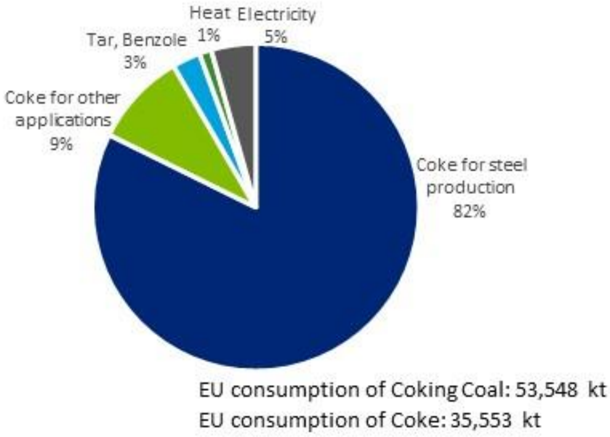

Figure 114: EU end uses of coking coal (average 2013-2017) (IChPW 2019) and EU consumption of coking coal and coke (average 2012-2016) (Eurostat Comext 2019)(WMD 2019)

According to data from (BIO Intelligence Service 2015) 1% of coking coal is used in the manufacture of electrodes generally intended for the metallurgical industry, and tar is an essential source material. Coking coal is also used in the production of foundry coke employed in foundry melting furnaces by some producers of base metals and ferroalloys (FeMn and FeCr). Other minor users of metallurgical coke are producers of non-metallic minerals such as phosphates, calcium carbide, soda ash and stone wool, or as a household heating fuel.

Several products can be produced from by-products (coke oven gas, benzole, coal tar, ammonia sulphate and sulphur) of coke ovens. Ammonia gas recovered from coke ovens is used to manufacture ammonia salts, nitric acid and agricultural fertilisers, while refined coal tar is employed in the manufacture of chemicals (e.g. creosote oil, naphthalene, phenol, and benzene) as well as in carbon fibres (World Coal Association 2019) (Remus et al. 2013) (Ozon 2018) (Dıez, Alvarez, and Barriocanal 2002) (JSW 2019a). Benzole (benzene, toluene, xylene) is also used in the chemical industry, whereas coke oven gas can be used for heat and power generation as it contains almost 55% of hydrogen (IChPW 2019).

Relevant industry sectors are described using the NACE sector codes (Eurostat 2019). The calculation of economic importance is based on the use of the NACE 2-digit codes and the value added at factor cost for the identified sectors (Table 45). The value-added data correspond to average 2012-2016 figures.

Table 45: Coking coal applications, 2-digit and examples of associated 4-digit NACE sectors, and value-added per sector (IChPW 2019)(SCRREEN workshops 2019)(Eurostat 2019)

Applications	2-digit NACE sector	Value-added of the sector (millions EUR)	Examples of 4-digit NACE sector(s)
Coke for steel production	C24 – Manufacture of basic metals	55,426	C24.10 - Manufacture of basic iron and steel and of ferro-alloys
Coke for other applications	C23 - Manufacture of other non-metallic mineral products	57,255	C2399 – Manufacture of other non-metallic mineral products n.e.c
Other uses (tar, benzole, electricity and heat)	C20 - Manufacture of chemicals and chemical products	105,514	C20.14 – Manufacture of other organic basic chemicals –Distillation of coal tar C20.15 – Manufacture of fertilizers and nitrogen compoundsammonia

8.3.3 Substitution

Currently, there are no technologically feasible and economically reasonable alternatives to completely replace coking coal in the production of steel from iron ore (Eurofer 2019b). The main reason is that metallurgical coke in the blast furnace charge supports the iron ore burden and provides a permeable matrix necessary for slag and metal to pass down into the hearth and hot gases to move upwards into the stack (European Commission 2017)(SCRREEN workshops 2019).

Coking coal (coke) can be replaced by pulverised coal (PCI) up to a certain level, which then requires the remaining hard coking coal to be of higher quality, mainly premium hard coking coal, otherwise the performance of steel production process can be strongly lowered (Eurofer 2019b). About 30% of coal can be saved by injecting fine coal particles into the blast furnace as one tonne of PCI coal used for steel production can replace about 1.4 tonnes of coking coal by reducing the amount of coke required. Coals used for pulverised coal injection into blast furnaces have more narrowly defined qualities than steam coal (WorldSteel 2019a). PCI coal is mainly used to achieve cost benefits by replacing coke, thus skipping the costly coke-making stage. Pulverised coal injection is a technique widely applied in the EU (Addendum in Pardo, Moya and Vatopoulos, 2015), and the industry has already reached the technical limits for coke substitution (Eurofer 2019a). For this reason, PCI does not affect the substitution index of coking coal in the criticality assesment. A 30% substitution of coking coal with PCI was assumed in the EU MSA study of coking coal (background data from (BIO Intelligence Service 2015)).

In addition, for some production processes, natural gas may substitute for as much as 10% of coking coal (Eurofer 2019b). Natural gas is a reducing agent in the production of Direct Reduced Iron (DRI) from iron ore, an alternative production route for crude steel.Hhowever, this technology is not common in Europe (Pardo, Moya, and Vatopoulos 2015). In the EU, only 700 kt of DRI was produced in 2017 (Worldsteel 2018), corresponding to less than 1% of the EU total iron production, as the technology is not commercially viable due to the high cost of gas (Eurofer 2019a).

Different methods have been explored to enable the use of coals with lower quality in the coking process without undermining coke quality. These are for example: the stamp charging technology with oil additives, the "Scope 21" coke-making process in Japan using high blending ratio (over 50%) of non- or slightly-coking coal, the use of hypercoal as additive to coking coal blend (Tercero et al. 2018) (Sundqvist Ökvist et al. 2018). The cost for hypercoal is higher, but it enables the use of some thermal coals (CRM experts 2019). Waste plastics in coking coal blend is also an alternative that can replace the use of 1-2% of coking coal (Tercero et al. 2018). However, as less suitable coking materials significantly influence coke quality, it is possible to use only low amounts of secondary materials in the coking process (Sundqvist Ökvist et al. 2018). It is estimated that economically favourable alternatives (such as hypercoal and waste plastics) can be used to substitute 5-10% of coking coal for metallurgical applications (Tercero et al. 2018).

Other materials, such as hydrogen and natural gas potentially used in the blast furnace are not substitutes of coking coal *per se* as they do not provide mechanical support to the charge of the blast furnace nor the necessary carbon monoxide (CO) for reducing the iron ore, but perform only the function of delivering heat (CRM experts 2019). However, in the future, specific processes may substitute coking coal with natural gas, hydrogen and biomass, e.g. Hisarna process (Pardo, Moya, and Vatopoulos 2015).

Fines of coke (coke breezes), which are used in the sintering of iron fines, can be substituted by ultra-grade anthracite. Also, part of the coke can be replaced in the blast furnace by anthracite as a heat source (CRM experts 2019).

For the production of electrodes, natural graphite and synthetic graphite can replace effectively coking coal (Tercero et al. 2018)(Sundqvist Ökvist et al. 2018).

8.4 Supply

8.4.1 EU supply chain

Figure 115 shows the coking coal flows (in C content) through the EU economy.

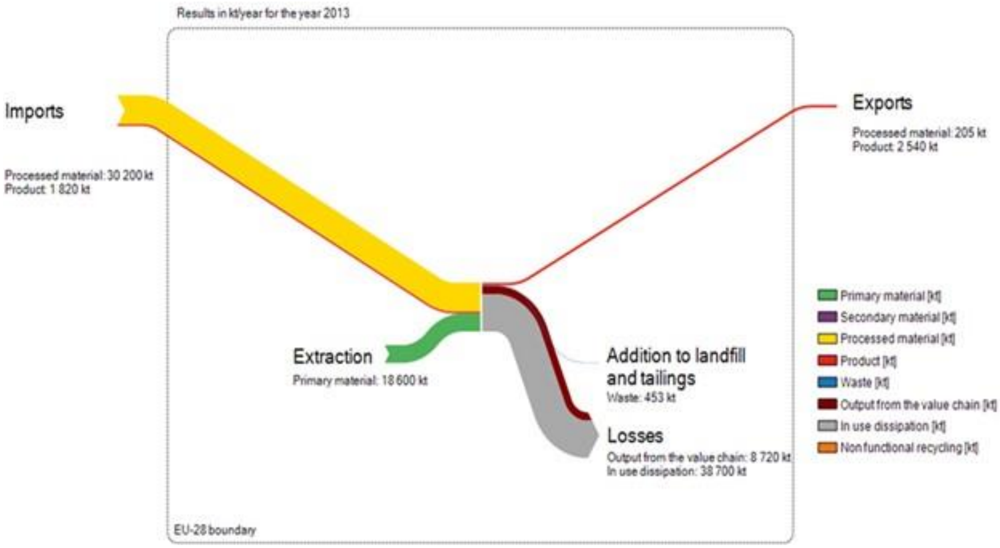

Figure 115: Simplified MSA of coking coal flows in the EU. 2013. (BIO Intelligence Service 2015)

8.4.1.1 EU sourcing of coking coal

EU sourcing of coking coal amounts to 53,813 kt (domestic production + imports). The annual average EU production of coking coal over 2012-2016 was 20,597 kt. Over the same period, coking coal was produced in Poland, Czechia and Germany. The EU production declined by 20% from 2012 to 2016, mainly due to decreased production from Czechia and Germany;(WMD 2019); in Germany, production ended in 2018. EU domestic production covered 38% of its needs.

In 2017, around 25% of the active hard coal mines in the EU produced metallurgical coal (and anthracite). In particular:

- In *Poland*, 18 hard coal mines were active in the Silesia (Śląskie) region, with 27% of coal produced in this region classified as coking coal;
- In *Czechia*, hard coal is mined at two underground mines located in the Moravskoslezsko region (Karviná and Darkov, ČSM), in which the extracted coal is graded as coking coal or steam coal based on its quality parameters. In the same region, the Paskov mine, with 89% of coal produced classified as coking coal, terminated its production in 2017;
- In *Germany*, two remaining underground hard coal mines produced steam coal and coking coal in 2016, the Prosper-Haniel mine, and the Ibbenbüren mine located in the Münster region (P. Alves Dias et al. 2018)(Euracoal 2017). Those mines were active only till the end of 2018. Therefore, Germany does not any longer contribute to the EU coking coal supply side.

In total, the share of coking coal in the overall EU hard coal production was on average 21% for the period 2012–2016. In Poland, coking coal accounted for 17% of hard coal production, while the share of coking coal in the overall hard coal production in Czechia and Germany 2017 was 50% and 56% respectively (WMD 2019).

Despite domestic production, the EU remains dependent on imports of coking coal, with net import reliance of 62%. The majority of coking coal imported to the EU comes from the USA and Australia, which cover 24% and 21% of the total EU supply respectively (see Figure 116). Due to the closure of mines in Germany, the EU import reliance will increase from 2019 onwards. In case the annual average production of 4,060 kt from Germany in the reference period 2012-2016 is replaced entirely by imports, and assuming that the apparent consumption remains constant, then the EU net import reliance would increase to 69%.

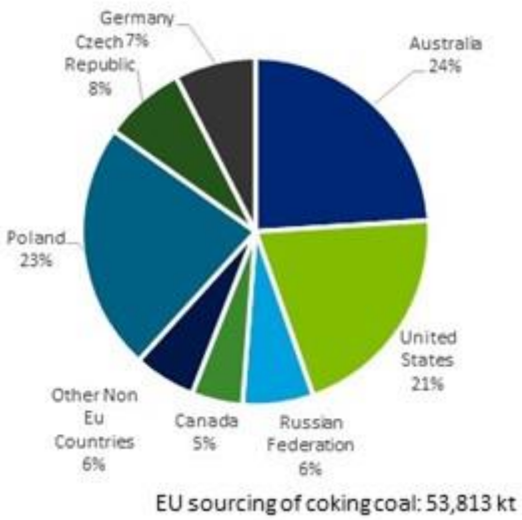

Figure 116: EU sourcing of coking coal. Average 2012-2016 (WMD 2019) (ESTAT Comext 2019)

8.4.1.2 EU sourcing of coke

EU sourcing (domestic production + imports) of coke amounts to 37,660 kt. The annual average EU production of coke over 2012-2016 was 36,506 kt (VDKI 2017). Coke is produced in 13 Member States. EU production covers 100% of domestic consumption.

In 2017, around 60 % of the EU crude steel production took place in integrated steelmaking plants (Blast furnace/Basic Oxygen furnace process), in which coke oven plants are typically an operational unit. Coking coal can also be converted into coke in individual coking plants before marketing to the iron industry. For example in Poland, the major producer of coking coal in the EU, coke is produced at the Przyjaźń and Zabrze coking plants operated by the mining company JSW (JSW 2019a).

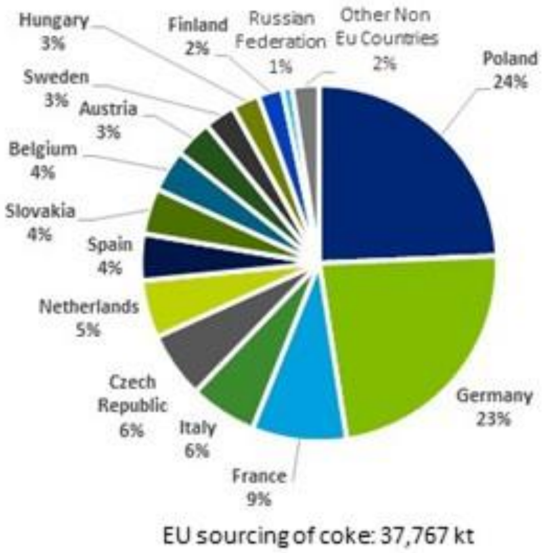

Figure 117: EU sourcing of coke. Average 2012-2016 (VDKI 2017) (ESTAT Comext 2019)

8.4.2 Supply from primary materials

8.4.2.1 Geology, resources and reserves of coking coal

Geological occurrence: Coal is a combustible, carbonaceous sedimentary rock, which is composed of fossilised plant remains, minerals and water. Coal is formed as accumulated dead plant materials in swamp ecosystems are buried beneath layers of younger sediments and altered by the combined effects of pressure and heat over millions of years to form individual carbon-rich coal layers, known as seams. The characteristics of coals are determined by the coalification process (e.g. varying types of buried vegetation, depths of burial, temperature and pressure at those depths, time of coal deposit formation). The composition and the amount of impurities (e.g. sulphur and phosphorous), the content of volatile matter and ash strongly condition the possible uses of the coal. For that reason, different groups and sub-groups of coal are identified, and each of them is used for specific purposes only. The most common classification of coals is based on rank, which represents the degree of coalification that has occurred. Classification of coals by rank ranges progressively from brown coals, which include lignite and sub-bituminous coal, to black or hard coals that comprise bituminous coal, semi-anthracite and anthracite. Anthracite (most carbonaceous) is classified as high-rank while lignite (least carbonaceous) is classified as low-rank. Coal types can be differentiated in the ranking sequence by several properties, e.g. elemental composition, volatile matter content, fixed carbon content, calorific value, water content, etc.; many different classification systems have been developed on a national and international level. Coking coal is classified as medium-rank bituminous coal which contains more carbon, less moisture and ash than low-rank coals. Coking coals usually have a volatile matter yield between 20% and 30% (dry, ash-free basis) (BGS 2010)(World Coal Association 2019)(World Coal Institute 2009)(Eurofer 2019b) (European Commission 2012).

The properties of coking coal have to be more tightly controlled than steam coal used in power stations and other uses, given the major impact of coke on blast furnace operation and pig iron composition. The required properties for coking coal to be suitable for steelmaking are low ash, sulphur and phosphorus content, as well as the ability to soften, swell and then solidify into a porous material of high strength when heated to a sufficiently high temperature in the absence of air (caking ability). A coal's caking properties are the primary determinant of its suitability for coke production (BGS 2010)(World Coal Association 2019)(World Coal Institute 2009).

Global resources and reserves*:* Many different national and international definitions and classifications exist to subdivide coal resources into different classes, e.g. hard coal, brown coal, steam coal, coking coal, etc. These subdivisions are either based on scientific (physical, chemical, petrographic), technical (heating value, plasticity, swelling index), commercial, or combined parameters. As different definitions and cut-off values are used to subdivide the volumes of coal resources and reserves, e.g. into brown coal and hard coal, the resulting figures are not comparable (European Commission 2012). There are no resource and reserve data on coking coal at the national/regional level reported using the United Nations Framework Classification (UNFC)(European Commission 2017).

However, bituminous coal reserves can be a rough indication of raw materials suitable for extracting coking coal. The known reserves of anthracite and bituminous coal were approximately 718 billion tonnes at the end of 2017 (BP 2018), sufficient to meet the demand for centuries. The United States has the world's largest reserves, followed by China and India (Table 46).

Table 46: Global proved reserves[76] of anthracite and bituminous coal at the end of 2017 (Data from (BP 2018))

Country	Bituminous coal and anthracite reserves (billion tonnes)	Percentage of the total (%)
US	220.8	30.7%
China	130.8	18.2%
India	92.8	12.9%
Russian Federation	69.6	9.7%
Australia	68.3	9.5%
Ukraine	32.0	4.5%
Kazakhstan	25.6	3.6%
Poland	19.8	2.8%
Indonesia	15.1	2.1%
South Africa	9.9	1.4%
Others	33.5	4.7%
Total world	**718.3**	100%

EU resources and reserves[77]: There are no published data on coking coal resources and reserves using the United Nations Framework Classification (UNFC). Reserves of 22 billion tonnes of anthracite and bituminous coal are reported in the EU, the majority of them is located in Poland (see Table 47) mostly in the Upper Silesian basin (79% of the total hard coal reserves in Poland) where 27% of the hard coal reserves consists of coking coal (Eurocoal 2017). Other than the resource estimation reported in Minerals4EU website, deposit of antimony was reported in Rockliden, Sweden at 10 Mt with 0.18% Sb, (also contains 4.03% Zn, 1.82% Cu, 52 ppm Ag, 0.06 ppm Au) (Depaux, G., 2019).

[76] Generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions. The data series for total proved coal reserves does not necessarily meet the definitions, guidelines and practices used for determining proved reserves at the company level.

[77] The Minerals4EU project is the only repository of some mineral resource and reserve data. However, there are no data for coking coal in the Mineral4EU website, for both resources and reserves in Europe.

Table 47: EU total proved reserves[78] of anthracite and bituminous coal at the end of 2018 (Data from (BP 2019))

Country	Bituminous coal and anthracite reserves (billion tonnes)
Poland	20,542
Spain	868
Hungary	276
Bulgaria	192
Czechia	110
Romania	11
Germany	3
Total EU	**22,002**

Exploration and new mine development projects in the EU: In Poland, there are two ongoing new mine development projects in progress (Prairie Mining 2019):

- The *Jan Karski* project in the Lublin coal basin. The project has a potential to produce thermal and semi-soft coking coal. JORC-compliant total resources amount to 728 Mt of in-situ coal and probable ore reserves are estimated at 139.1 Mt of marketable coal, and the annual production can yield 6.3 Mt of marketable coal. The results of a pre-feasibility study were announced in March 2016.
- The *Debiensko* project in Upper Silesian coal basin. The project aims to produce premium hard coking coal (mid-vol and low-vol HCC). Resources reported under the JORC code comprise a total resource of 301 Mt of in-situ coal, and annual production is projected at 68 Mt of saleable coal over a 26 year period. A scoping study was published in March 2017.

8.4.2.2 Production of coking coal

Coal is mined by open-pit or underground methods, depending on the morphology of the coal deposit. Surface mining is applied when the coal seam is near the land surface (BGS 2010). Before marketing, Run-of-mine coal is upgraded in preparation plants where the extracted hard coal is graded as coking coal or steam coal, based on certain quality parameters. Preparation may include washing, crushing, sieving, and gravity concentration to satisfy size and purity specifications of the intended use.

The use of coking coal for metallurgical applications, i.e. steel production, require that certain physical and chemical properties are tested in advance in order to check the complete compatibility of the raw material with the production process (i.e. CSR index – coke strength after reaction). Moreover, also the content on impurities like sulphur and phosphorus, and not only, impose in which industrial processes the coking coal can be used. For this reason the coking coal is subdivided in different products: Premium Hard Coking Coal (PHCC), Hard Coking Coal (HCC), High-Volatile HCC (Semi-HCC), Semi-soft coking coal (SSCC), Low Vol PCI, each of them identified by different properties and performance when employed in the industrial processes. In general, the EU steel production should be fed using Premium HCC and HCC for maintaining the high environmental performance of the installations (i.e. higher quality HCC means the use of less raw materials and lower emissions). In particular, the European integrated steel process routes uses the most advanced technologies using PHCC and HCC only, in

[78] Generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions. The data series for total proved coal reserves does not necessarily meet the definitions, guidelines and practices used for determining proved reserves at the company level.

compliance with European environmental laws. Any substantial substitution of these high-quality coking coals will surely increase the whole environmental impact (Eurofer 2019b).

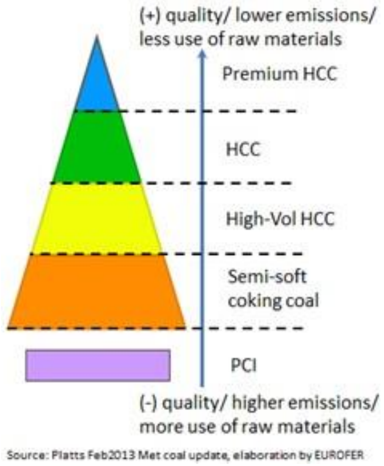

Figure 118: Coking coal products (European Commission 2014)

8.4.2.3 World and EU mine production of coking coal

The annual world supply of coking coal was about 1,079,497 kt as an average between 2012 and 2016. As can be seen in Figure 119, China was by far the biggest producer of coking coal globally, producing 55% of the world's total. Other significant producers are Australia (16%), Russia (7%) and the United States (6%). The overall EU production of coking coal accounted for 2% of world production. The European production of coal was about 20.597 kt. 60% of the EU output was mined in Poland, whereas Germany and the Czech Republic contributed to 20% each over the years 2012-2016.

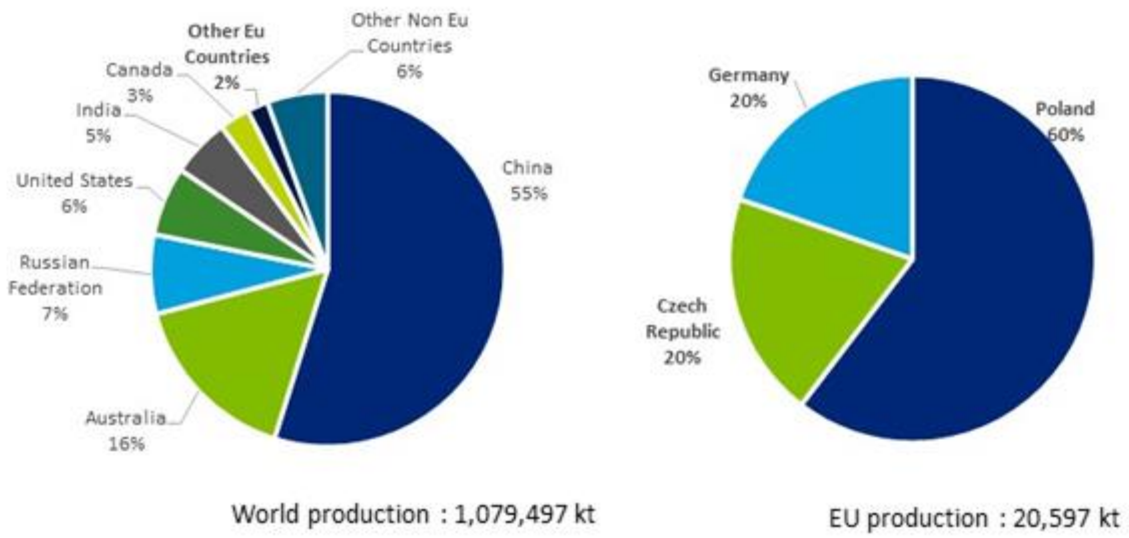

Figure 119: Global and EU mine production of coking coal. Average for the years 2012-2016. (WMD 2019)

8.4.3 Processing of coking coal

Coking coal is converted into coke, semi-coke and coke by-products in coke ovens. Coke making, or carbonisation, entails heating the coal to high temperatures (1,150 to 1,350

°C) in the absence of oxygen to drive off gases and impurities and concentrate the carbon content (Remus et al. 2013). Semi-coke is formed by incomplete carbonisation of coal, with a reduced air supply, at a temperature of between 450 and 700 °C.

Before coke making, selected bituminous coal grades are usually blended and pulverised to control the size and quality of the feed. During heating, the physical properties of coking coal allow the coal particles to pass through softening, fusing, and solidification into hard and porous coke lumps. They are are then quenched with either water or air before storage or direct transfer to the blast furnace. Exhaust gases are collected and processed to recover combustible gases for heat production and other by-products (Remus et al. 2013)(Dıez, Alvarez, and Barriocanal 2002). The coke yield varies from 700 kg to 800 kg of dry coke per tonne dry coal (approximately 1250-1400 kg coking coal is needed for the production of 1 tonne of coke depending on the volatile content), and the coke oven gas production ranges from 140 kg to 200 kg per tonne dry coal. The yield of tar and benzole (benzene, toluene, xylene) is reported to be 50 kg per tonne dry coal (IChPW 2019).

8.4.3.1 World and EU production of coke

The annual EU production of coke was around 36,506 kt as an average from 2012 to 2016. 13 Member States are listed as coke producers (VDKI 2017). Poland and Germany, with 25% and 24% respectively, have the highest share of EU production.

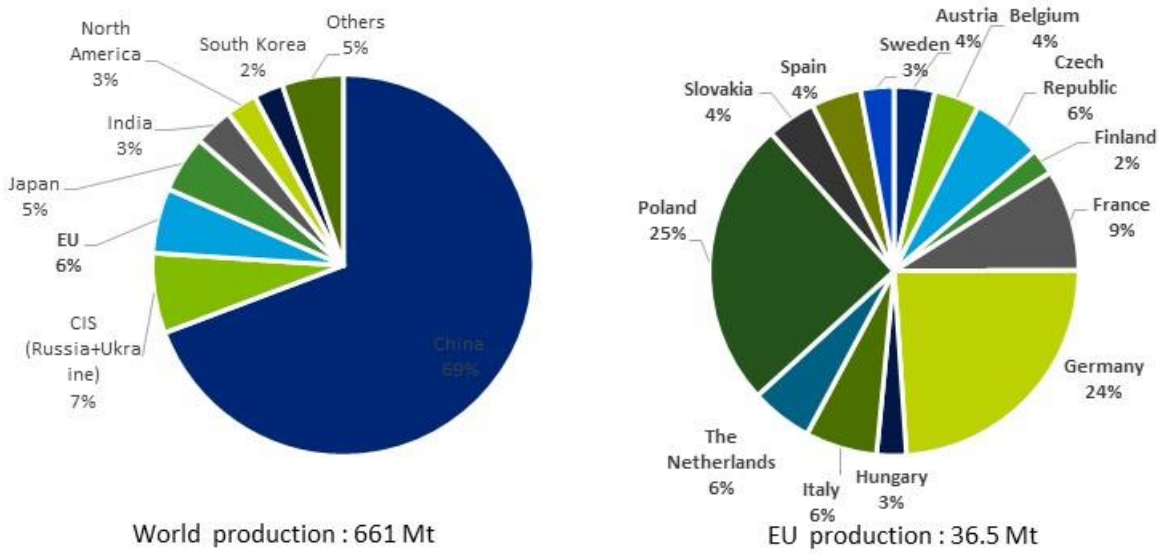

Figure 120: World and EU coke production. Average for the years 2012-2016. Data from (VDKI 2017)

8.4.4 Supply from secondary materials/recycling

Recycling is not applicable as coke is entirely dissipated after its use as it is oxidised to CO_2 (BIO Intelligence Service 2015). Therefore, the EOL-RIR is 0%.

Table 48: Material flows relevant to the EOL-RIR of coking coal in 2013[79]. Data from (BIO Intelligence Service 2015a)

MSA Flow	Value (tonnes)
B.1.1 Production of primary material as the main product in EU sent to processing in EU	18,117

[79] EOL-RIR=(G.1.1+G.1.2)/(B.1.1+B.1.2+C.1.3+D.1.3+C.1.4+G.1.1+G.1.2)

B.1.2 Production of primary material as by-product in EU sent to processing in EU	0
C.1.3 Imports to EU of primary material	0
C.1.4 Imports to EU of secondary material	0
D.1.3 Imports to EU of processed material	30,181
E.1.6 Products at end of life in EU collected for treatment	0
F.1.1 Exports from EU of manufactured products at end-of-life	0
F.1.2 Imports to EU of manufactured products at end-of-life	0
G.1.1 Production of secondary material from post-consumer functional recycling in EU sent to processing in EU	0
G.1.2 Production of secondary material from post-consumer functional recycling in EU sent to manufacture in EU	0

8.5 Other considerations

8.5.1 Environmental and health and safety issues

As an energy-intensive industry, the European steel industry accounted in 2016 for about 7% of the verified greenhouse gas emissions of all stationary installations of the European Union and around 22% of industrial emissions excluding combustion. Most of the emissions come from the iron ore reduction process, in which the carbon provided by the coke acts as the reductant. Reducing the carbon intensity of the blast furnace steelmaking route is, therefore, one of the two methods - the other is the increased share of the electric furnace steelmaking route- to decarbonise the steel industry. Among the novel technologies to achieve emissions reduction are carbon capture and storage, carbon capture and utilisation, hydrogen-based steelmaking, iron ore electrolysis. Currently, there are several innovative low carbon projects under development in the European iron and steel industry, with market entry forecasted within the next decade. Such breakthrough innovations will constitute an entirely new production system that would replace production processes that have been used and optimised for many decades. As an example, the hydrogen-based direct reduction process aims using hydrogen to completely bypass the use of coal for the production of primary steel (European Commission 2018). However, they are not going to be available in the next decade (IChPW 2019).

Imported coking coal to the EU has a higher carbon footprint. It is reported that EU-based production has lower carbon emissions by 1.5-3 times compared to coking coal imported from Australia due to maritime emissions (JSW 2019b) (IChPW 2019).

EU OSH requirements exist to protect workers' health and safety, employers need to identify which hazardous substances they use at the workplace, carry out a risk assessment and introduce appropriate, proportionate and effective risk management measures to eliminate or control exposure, to consult with the workers who should receive training and, as appropriate, health surveillance[80].

8.5.2 Contribution to low-carbon technologies

By definition, the contribution of coking coal to low-carbon technologies is not applicable. Nevertheless, coking coal is an essential ingredient in steel production, and the importance of steel in all industrial sectors is beyond doubt. Steel is necessary for low-carbon technologies in the broad areas of transport (e.g. tower structures and associated concrete infrastructure, generators), wind power (e.g. for specific magnetic properties, and essential structural elements within wind turbines), solar power etc. (Euromines 2019). More information is available in the Iron Ore factsheet.

[80] https://ec.europa.eu/social/main.jsp?catId=148

Also, noteworthy is the use of products derived from the by-products of coke production in some innovative technologies. For example, carbon fibres produced from coal tar are used in aviation and automotive industry where they offer a great lightweight potential with benefits in fuel consumption but also for hydrogen storage tanks, where they provide the container to be hermetic, tight and meet all safety standards for hydrogen storage. While tanks are produced in Europe, carbon fibers are mostly imported from Asia. Moreover, in the case that hydrogen separation from coke oven gas is achieved, it can be used in fuel cells for zero-emission power generation and transport. JSW reports that the amount of hydrogen circulating in its coking plants is almost 75 kt annually which could fuel about 600 hydrogen-fuelled buses or over 4,000 hydrogen-fuelled cars. Another technology is carbon materials used in aviation, defence and electronics for their lightweight and durability, as well as in small amounts (1-3%) in graphite anodes of Li-ion batteries which are produced from needle coke (JSW 2019b).

Compared to the conventional oil-based needle coke, the coal-based needle coke has certain distinguishing characteristics, such as high heat durability and world's lowest thermal expansion rate (Mitsubishi Chemical Corporation 2019). Currently there are only four companies globally that produce this product of a high technology, mostly Japanese[81]. JSW estimates that its own capacity production of needle coke (own coal tar processing) would provide 10% of European demand for this processed material (JSW). Taking into account the proximity of other coal tar suppliers it would be possible for JSW to produce up to 60.000 tonnes of needle coke annually. Electrode applications are projected to grow at a high CAGR of 7.3% by 2025 and therefore global demand for needle coke is also estimated to grow over 5% annually in next 5 years (Grand View research, 2019). Meanwhile local production of coal tar is decreasing together with a decrease of coke production. This will cause not only a total dependence from import of coke for steel industry but also of those processed materials used for carbon fibers and in battery value chain.

8.5.3 Socio-economic issues

Coking coal faces political, technical and financial challenges in the transition to a lower-carbon economy (CRM Alliance 2018). The decline in coal-related activities might also affect the iron and steel sector. Hard coal mines capable of producing this type of coal could continue to operate purely by serving this sector, as long as coking coal prices are sufficient enough to sustain mining operations (P. Alves Dias et al. 2018).

The level of governance of countries supplying coking coal to the EU is medium to high, except the Russian Federation providing 6% if the total EU sourcing. At the global level, more than half of the supply (55%) derives from a country with low governance, i.e. China. In this country, governance is deficient in the area of "Voice and accountability" (World Bank 2018).

The importance of coking coal mining in Europe is analysed in the report of the European Commission *EU coal regions: opportunities and challenges ahead* (2018) by the Joint Research Centre (JRC)(P. Alves Dias et al. 2018).

8.6 Comparison with previous EU assessments

The assessment has been conducted using the same methodology as for the 2017 list. The calculations of the Supply Risk (SR) for 2014 and 2017 lists have been performed for the

[81] https://www.televisory.com/blogs/-/blogs/can-lithium-ion-anode-demand-for-needle-coke-reduce-availability-for-electrode-players-

mine stage (coking coal). In the current assessment, the supply risk has been analysed at both the mine and the processing stage (coke). The results of the current and earlier assessments are shown in Table 49.

Table 49: Economic importance and supply risk results for coking coal in the assessments of 2011, 2014, 2017, 2020. (European Commission 2011);(European Commission 2014); (European Commission 2017)

Assessment	2011			2014			2017			2020	
Indicator	EI	SR		EI	SR		EI	SR		EI	SR
Coking coal	not assesed	not assesed		8.9	1.2		2.3	1.0		3.0	1.2

Coking coal was not assessed in 2011, and it was identified as critical in the 2014 assessment. The sharp decline of the economic importance results in the 2017 assessment is the result by the change in methodology, i.e. base metal was isolated from metal products on NACE 2-digit level, and the mega sector approach was discarded. This resulted in a lower overall value-added and thereby impacted the Economic Importance score for coking coal. In the 2017 assessment, although coking coal missed the economic importance threshold, for the sake of caution, it was kept on the list of critical raw materials for the EU[82].

In the current assessment, the Supply Risk (SR) was calculated using both the HHI for global supply and EU supply as prescribed in the revised methodology. The results show that the supply risk is higher at the extraction stage (SR=1.19) than the processing stage (SR=0.34). The stage with the highest score has been considered as representing the overall supply risk for coking coal, i.e. SR=1.19 (rounded to 1.2). The SR appears increased in comparison to the 2017 assessment due to two reasons. Firstly, different substitute materials were considered for the substitution index in the current assessment in relation to the 2017 exercise. In particular, the use of PCI does not contribute to the substitutability of coking coal, as it is a widely applied technique by the EU steel industry which has already reached its technical limits. In the previous assessment the factor for PCI introduced in the calculation of the substitution index was 30%. Secondly, in the 2017 assessment, an erroneous allocation of EU production in the calculation formulas of the EU supply risk component resulted in lower supply risk by 0.1 (i.e. SR=1.0 instead of SR=1.1).

The Economic Importance (EI) indicator has increased due to the introduction in the calculation of the NACE 2-digit sector "C20 - Manufacture of chemicals and chemical products" of high value-added, and a lower share allocated to the NACE 2-digit sector "C24 – Manufacture of basic metals" of lower value-added.

8.7 Data sources

Production data of coking coal were sourced from 'World Mining Data' published by the Austrian Ministry for Sustainability and Tourism and the International Organising Committee for the World Mining Congress Austrian Ministry of Science, Technology and Commerce. The source of data for the production of coke was the German Coal Importers Association (VDKi). Eurostat (Comext) provided the data for EU trade flows for coking coal and coke. The end-uses of refined products of coking coal were provided by the Institute of Chemical Processing of Coal (IChPW).

[82] Commission's Communication 'on the 2017 list of Critical Raw Materials for the EU' (COM(2017) 490 final)

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