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EU coal regions: opportunities and challenges ahead

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EU coal regions: opportunities and challenges ahead
The European coal sector currently employs nearly half million people in direct and indirect activities. By 2030, it is estimated that around 160 000 direct jobs may be lost. Regional development based on a carefully planned restructuring process, to which renewable energy plays central role, will create new employment opportunities.

Contents

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Executive summary

Coal has historically been one of the European economy's main fuels. Today, it accounts for 16% of gross inland energy consumption in the EU, and 24% of the power generation mix. Usage varies across EU Member States, but **six countries still rely on coal to meet at least 20% of their energy demand**. The role of coal is, however, decreasing, as part of the ongoing transformation of the energy system. The need to reduce greenhouse gas emissions has led to an increasing share for renewables; and coal power generation is actively discouraged with stringent post-2020 emission requirements, high CO_2 emission allowance prices, and likely restrictions on coal eligibility for future capacity remuneration mechanisms. Frequently overlooked, however, are the potential **negative impacts** of the ongoing shrinkage of the coal sector **on employment and the economy** in regions hosting **hard coal and lignite mining activities and coal-fired power plants**. Early action therefore needs to be taken to develop alternative business opportunities to maintain or increase regional employment and support economic growth.

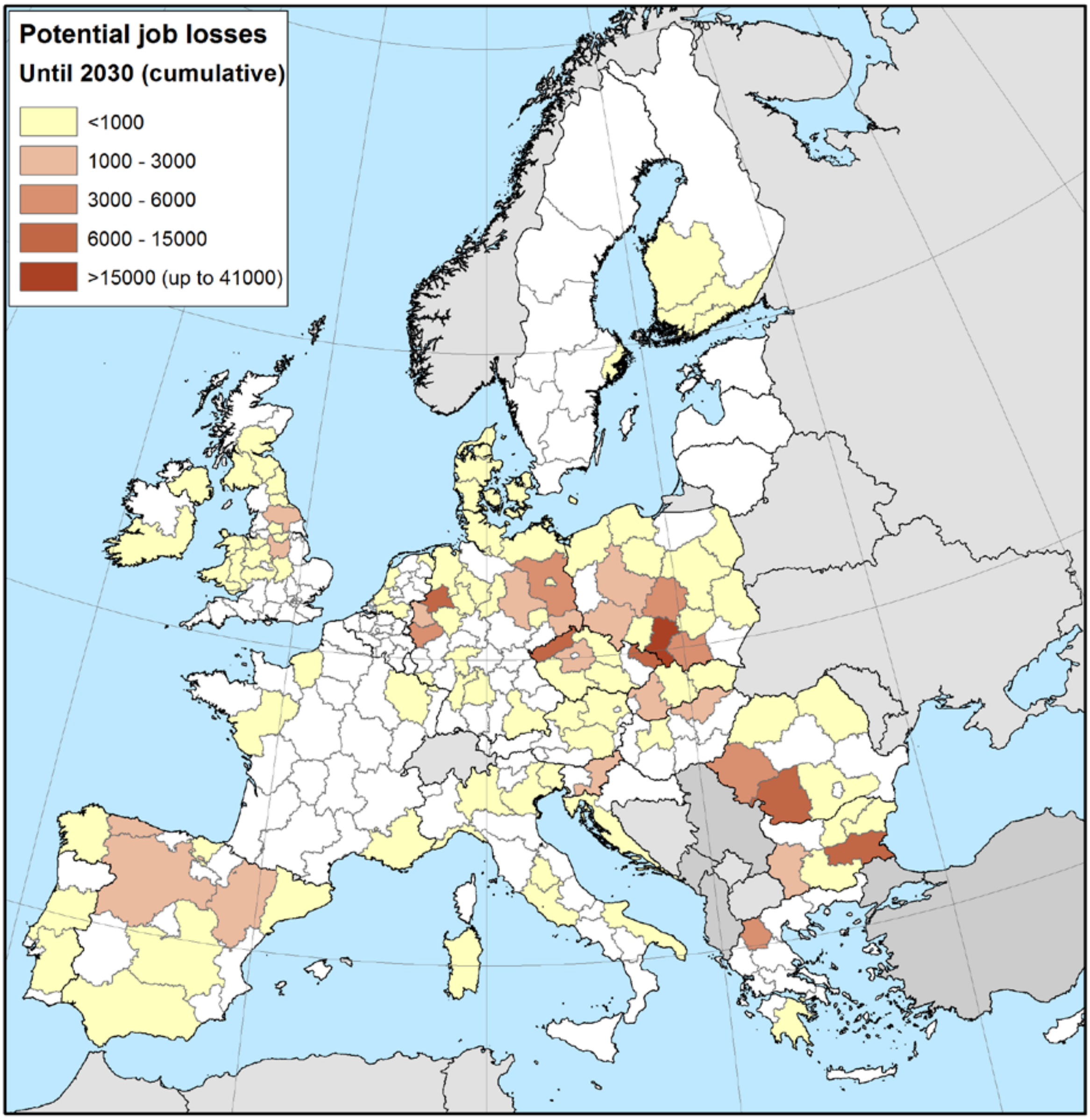
There are currently **207 coal-fired power plants in 21 Member States and 103 NUTS-2 regions** with a total capacity of almost 150 GW (15% of total European power generation capacity); and **128 coal mines in 12 Member States and 41 regions** with a combined annual production of approximately 500 million tonnes (55% of gross EU consumption). Overall, **coal infrastructure is present in 108 European regions**. It is estimated that the coal sector currently **employs about 237 000 people**. The vast majority work in **coal mining (185 000).** Poland employs about half of the coal workforce, followed by Germany, the Czech Republic, Romania, Bulgaria, Greece and Spain. Twenty regions account for nearly 200 000 direct coal-related jobs. Six of these regions are in Poland (including the region of Silesia with an estimated 82 500 jobs in 2015) and another five in Germany. Throughout the coal value chain **the number of indirect jobs dependent on coal activities is up to 215 000**, with four regions in Poland, Bulgaria and Czech Republic presenting above 10 000 jobs each. Many of these jobs will become redundant in the next decade, both in direct and indirect coal activities.

The vast majority of **coal-fired plants in Europe were commissioned more than 30 years ago**. These plants are on average 35 years old, with an estimated efficiency of 35%, well below the current state of the art. **The first wave of power plant retirements will take place in the period 2020-2025**, driven by competition in a carbon-constrained world. **This could lead to the loss of 15,000 direct jobs in power plants**. The countries hit hardest are likely to be the UK, Germany, Poland, the Czech Republic and Spain. A second decommissioning wave between 2025 and 2030 could cause the loss of another 18 000 jobs, mainly in Germany, Poland, UK, Bulgaria and Romania. By then, approximately two thirds of the current coal-fired power generation capacity will have been retired. In two regions, in Poland and in Romania, employment losses may reach or exceed 2 000 jobs; and around 1 000 - 2 000 jobs could be lost in each of a further seven European regions. Carbon capture and storage (CCS) as a mitigation option to reduce CO_2 emissions could facilitate the continuity of operation of retrofitted coal plants in the longer term provided it is economically viable and that legal and regulatory challenges are overcome. Preliminary estimations indicate that **roughly 13% of European capacity can be retrofitted with CCS**.

Coal mines are already closing down due to a lack of competitiveness. In 2014-2017, 27 mines were closed across Germany, Poland, the Czech Republic, Hungary, Romania, Slovakia, Slovenia and the United Kingdom. In 2018, 5 more will close in Germany, Poland Romania and Italy. Further 26 mines are expected to close in Spain. Taking into account criteria, including mine productivity, depth of operation and product quality, it is estimated that coal mines in Romania, Slovakia, Spain, the Czech Republic, Germany, Italy, Poland, Slovenia and the United Kingdom could close in the short to medium term. Overall, it is estimated that about **109 000 mining jobs are exposed to high risk due to a lack of competitiveness**.

The forced closure of many uncompetitive operations between 2015 and 2018, including those currently benefiting from State Aid, might lead to the loss of around 12% of current overall jobs (27 000) by 2020. Thereafter and until 2030, the closure of coal mines will mainly be aligned with the decommissioning rates of coal power plants: by 2025 total cumulative job losses in power plants and mines are likely to increase to 77 000 jobs and by 2030 to around 160 000 jobs.

The map below shows the cumulative coal direct jobs at risk by 2030.



Several regions are expected to be particularly hard hit by the transition: one region in Poland may lose up to 41 000 jobs, and a further three (in the Czech Republic, Romania and Bulgaria) look likely to lose above 10 000 jobs each. The regions with the highest number of jobs at risk are in Poland, Czech Republic, Romania, Bulgaria, Germany and Greece.

In regions with mining infrastructure the dependency on the coal industry resulted in limited development of other economic sectors - **most coal regions have a lower GDP/capita than the national average**. The social impact of an interruption of coal activities seems to be higher in Greece, Bulgaria, Czech Republic, Poland, Romania and Germany where the share of coal jobs amongst the economically active population is higher. On the other hand, this impact is likely to be amplified in regions where the unemployment rate is already high, such as in Greece, where up to 1/3 of the active population is already unemployed.

The decline in coal-related activities will also affect other sectors of the economy. **The European iron and steel sector relies on domestic coking coal - a critical raw material for the European economy - to meet 37% of its needs.** 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. **Mining equipment manufacturers will also be affected**; it has been shown that innovation and manufacturing in mining is directly linked to mining activities in the vicinity. **The number of people involved in the manufacture of mining, quarrying and construction equipment in coal producing countries exceeds 100 000**.

Finally, the **retirement of coal assets should be coupled with a strategically planned and gradual industrial restructuring process**, aiming to support redundant coal workers. New employment and business opportunities can be created by building on the industrial heritage of the affected regions and establishing new, competitive industries and services. **Close cooperation between companies, regulators, investors, land-use planners and local communities is essential** to identify the most sustainable uses and maximize social-economic development. The reclamation of mining sites not only mitigates environmental impacts but can also contribute to the local economy, if new facilities are developed such as recreation centres, museums or science centres. **Although new employment opportunities should come from all sectors of the economy, the energy sector can still remain a driver for regional development.** Conversion into wind or solar parks, for example, could provide re-employment opportunities for coal workers after an adjustment of skills, since electrical and mechanical skills, experience of working under difficult conditions and sophisticated safety experience are highly valued in the wind and solar energy industries. Finally, the re-use of closed mines for geothermal energy or hydropower applications could also provide jobs and socioeconomic benefits to post-mining communities.

1 Introduction

The ongoing transformation of the energy system will have significant impacts on all aspects of the European economy and society at large. The wide-scale deployment of renewable and other low-carbon energy technologies needed to facilitate the energy transition will be a significant source of new jobs. However, it is frequently overlooked that traditional energy sectors, such as those that rely on the production and use of fossil fuels, will shrink, with concomitant negative impacts on employment and thus on the economic conditions of the regions that host these activities. Among fossil fuels, coal activities are likely to be affected most in the short to medium term, by the evolving economic, environmental and electricity market operational requirements.

Coal has historically played a vital role in the European economy:

- Coal has been one of the main fuels of the European economy. In 1990, coal provided for almost 41% of the gross energy consumption in the EU28 Member States, and 39% of power generation. Despite the gradual decrease of its use since the 1990s, coal remains important. In particular for many of the Member States that joined the EU in 2004 and 2007, which rely on indigenous coal for power generation. In 2015, 16% of the gross EU energy consumption was supplied by coal as well as and 24% of electricity generation. Today, 6 Member States rely on coal for at least 20% of their total energy needs (Bulgaria, the Czech Republic, Germany, Greece, Poland and Slovakia), while the reliance of Poland exceeds 50%.
- Coal activities (mining and the operation of power plants) have provided employment in several regions across Europe. In coal mining and related activities, the number of people employed in 2015 is estimated to be between 250 000 and 300 000[1]. This is already 15% lower than in 2008.

The aim of this report is to identify the regions[2] that will be affected by the potential decline of coal mining and coal power-plant activities, and assess the impact on regional jobs. Moreover, the report reviews potential actions that could be undertaken at regional level, which could help re-use retired coal infrastructure and re-deploy personnel to new activities or extend the life of coal power plants with lower impact to the environment, thus maintaining jobs and economic activities within the affected regions.

The report is structured as follows:

Chapter 2 maps the existing coal infrastructure in Europe and identifies those regions that rely on coal activities. In Chapter 3, potential future developments of coal activities including the decommissioning of coal power plants and closure of coal mines are assessed and its impacts are presented over time and at regional level. Chapter 4 reviews possible indirect impacts on other sectors of the economy such as iron and steel, mining equipment manufacturing and coal terminals. These sectors may also require actions to ensure current/optimum levels of operation during the decarbonisation of the energy system. In Chapter 5 mitigation options to extend the life of power plants and to re-use retired coal infra-structure are discussed. These options could be considered for preserving current jobs or enabling the re-employment of a skilled workforce currently active in coal activities, an issue discussed in Chapter 6.

Relevant country factsheets are provided in Annex 21 of this report.

[1] According to EURACOAL, in 2015, the coal mining industry (including direct and indirect activities) provided some 258 000 jobs in the EU28. This figure is comparable with EUROSTAT data for the same year (294 400)

[2] The analysis has been carried-out at NUTS-2 level in line with cohesion policy.

2 The current status of coal[3] mining and power generation in the EU

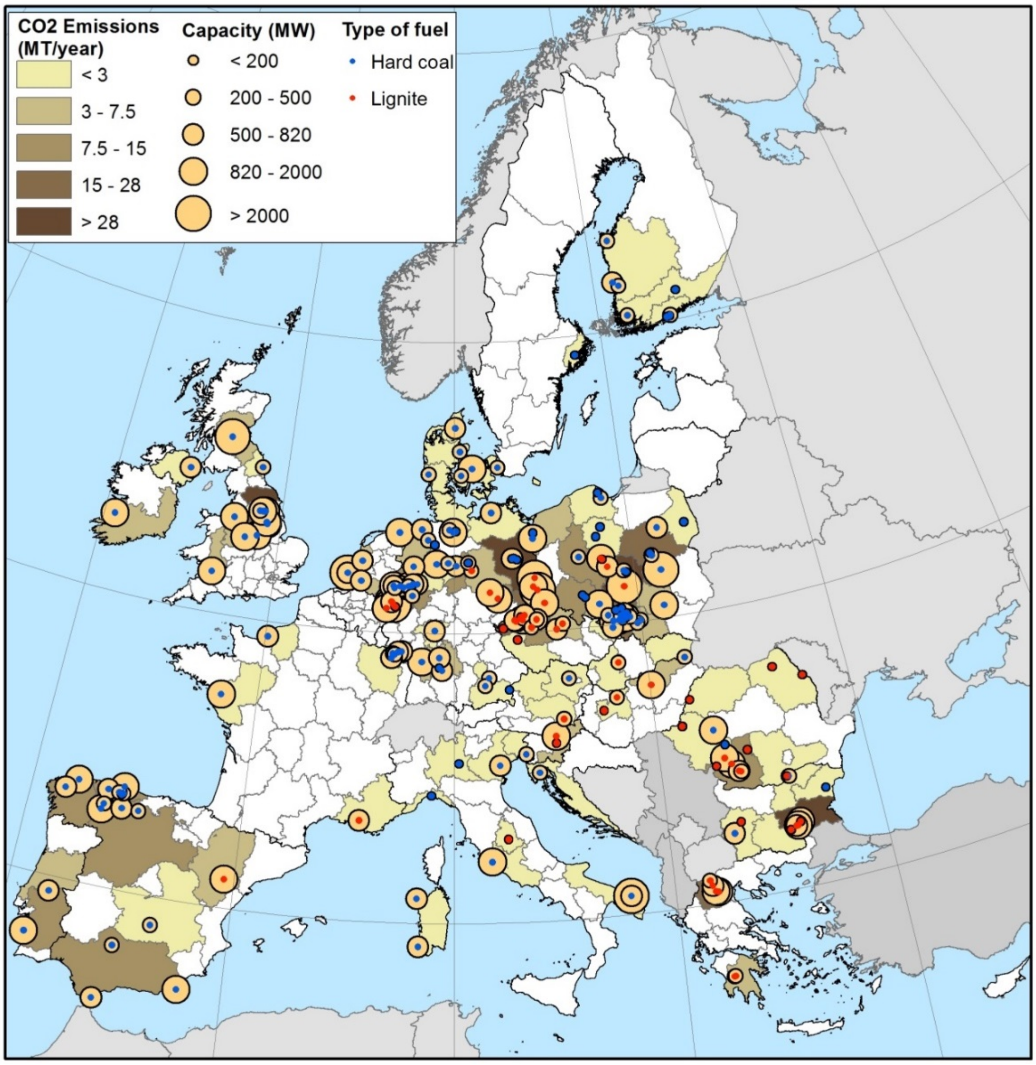
2.1 Coal power plants in the EU

This section provides information on the active coal-fired power plants in the EU. The data source for the analysis is the JRC-PPDB[4] (Kanellopoulos, Hidalgo, Medarac, & Zucker, 2017).

2.1.1 Locations of coal-fired power plants and their efficiencies

In 2016 there were 207 coal power plants operating in 21 Member States, with a total capacity just above 150 GW. Two thirds of these plants use hard coal (with a total capacity of 97 GW) and the remaining use lignite. Their location is shown on the map in Figure 1. The map also provides regional CO_2 emissions at NUTS-2 level.

Figure 1. Location of coal power plants with information on capacity and fuel type; and regional CO_2 emissions at NUTS-2 level.



[3] The term 'Coal' in this report refers to both hard coal and lignite.
[4] The JRC-PPDB is a comprehensive database of power plants in Europe that contains a plethora of information, such as location, capacity, fuel, age, technology type, cooling type, estimated efficiencies and other operational parameters. The database, developed by JRC, draws information from open and confidential sources such as ENTSO-E, Platts and E-PRTR.

The map shows that the highest density of European coal power plants lies in the area stretching from the Netherlands, across Germany and the Czech Republic to Slovakia and Poland. With regards to the type of coal, lignite is used mainly in Germany, eastern Europe and the Balkan peninsula, while hard coal is the primary fuel in Germany, Poland, the United Kingdom, Spain and many coastal areas. Germany, Poland and Spain are the countries that host the largest number of power plants - 53, 37 and 16 respectively. In terms of capacity, Germany hosts 45 GW, followed by Poland (26 GW) and the UK (18 GW), as shown in Figure 2 and Figure 3.

Figure 2. Number of coal power plants by Member State

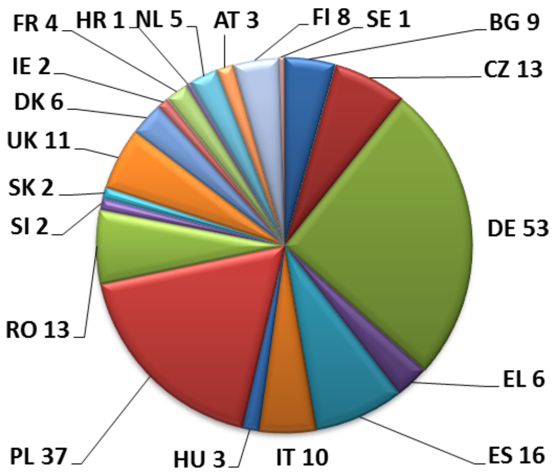
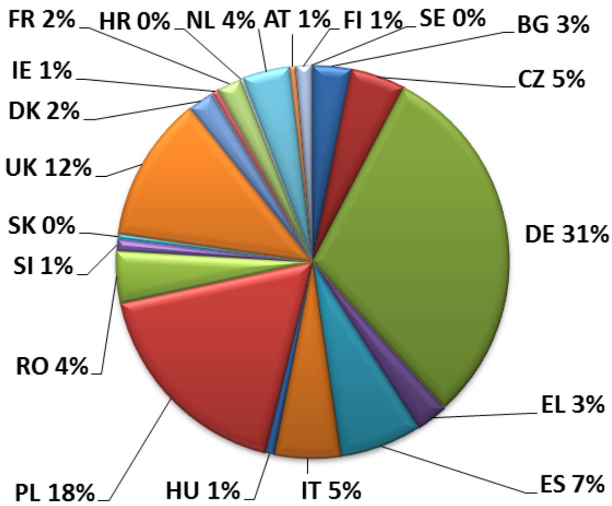


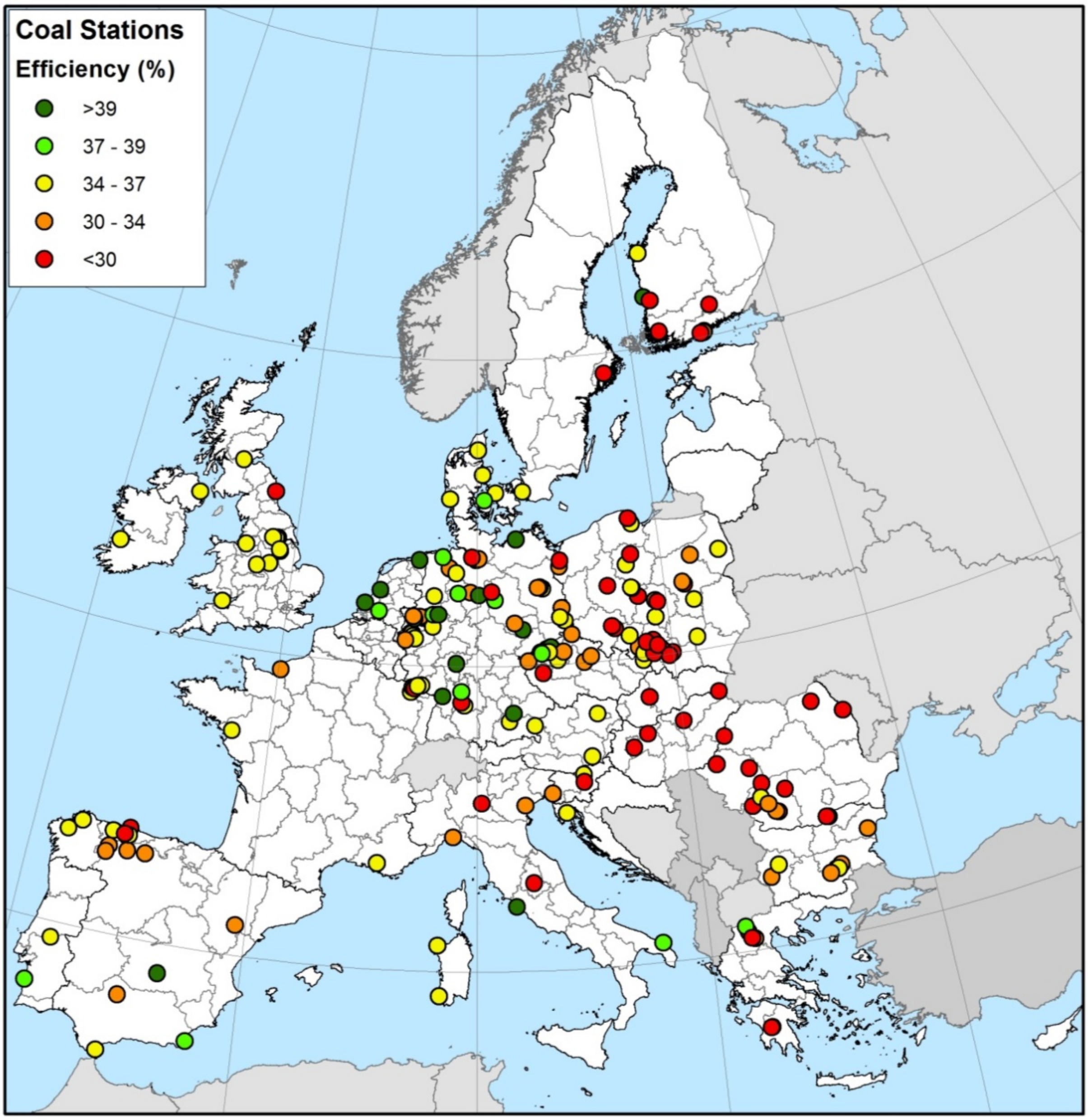
Figure 3. Capacity of coal power plants by Member State



The siting of a coal power plant is related to the location of mining activity discussed in the following section or to points of entry of imported hard coal. Lignite fuelled power plants are usually built close to lignite mines, while hard coal power plants are located either close to the mines, when these are the main fuel source, or close to waterways in cases where hard coal is imported.

One of the most important technical factors for assessing the performance of a power plant is its efficiency, since it is linked to competitiveness. Lower efficiency implies higher fuel consumption which results in higher production costs and CO_2 emissions; such factors affect the income and operating profits of the facility. The estimated efficiencies of coal power plants based on the JRC-PPDB, are shown on the map in Figure 4.

Figure 4. Efficiency ranges of coal power plants.



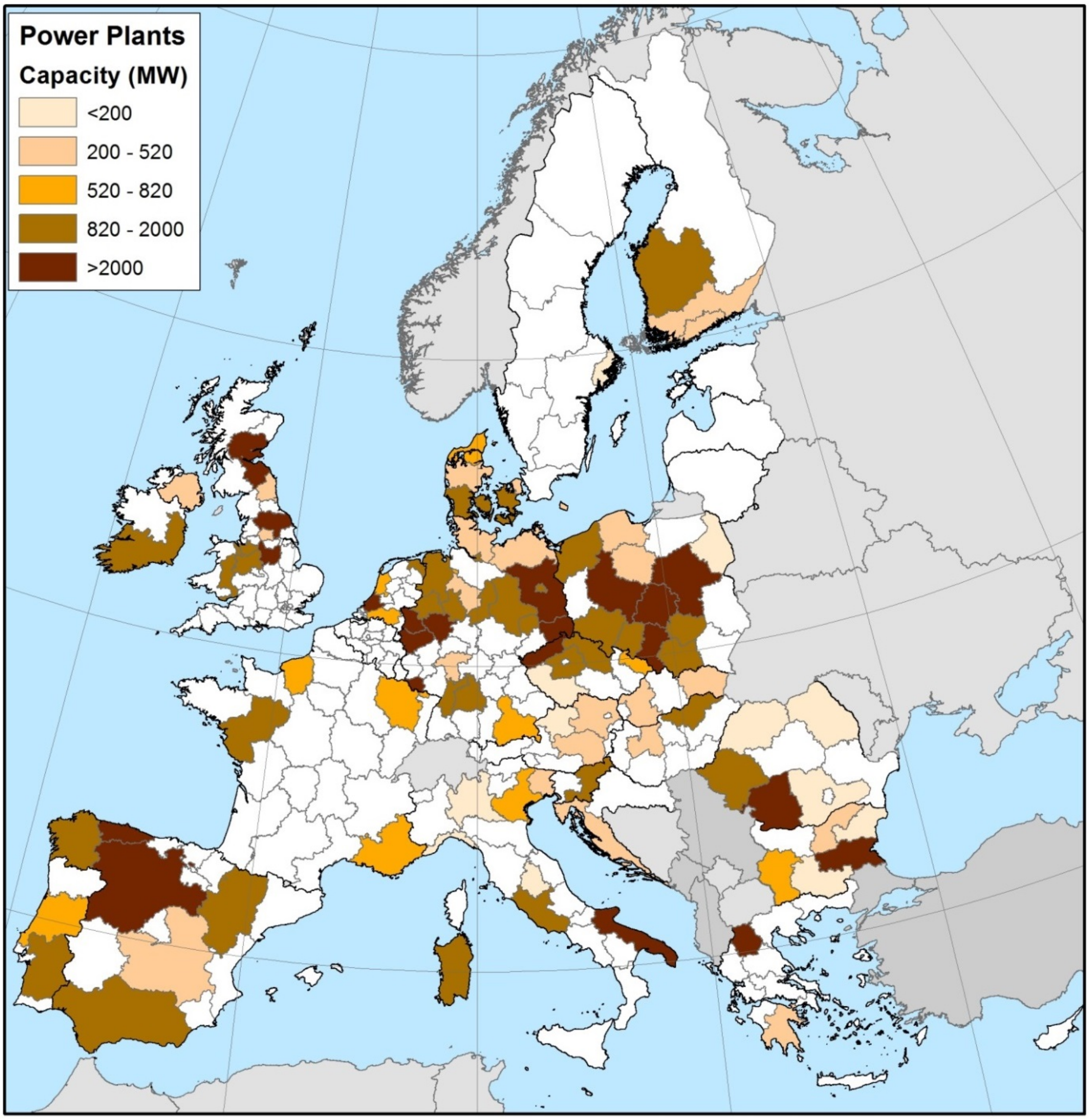
The average coal power plant efficiency in Europe is 35%. The frequency of coal power plants with the lowest efficiency (around or below 30%) is higher in eastern European countries. The most efficient coal fired power plants with energy efficiency above 39% are located mainly in Germany and the Netherlands[5].

[5] It is noted that environmental conditions, beyond technology, affect the efficiency of power plants. The high power plant efficiencies in coastal sites in northern Europe are also due to the availability of cold water for power plant cooling.

2.1.2 Coal-fired power plant capacities and efficiencies at NUTS-2 level

Overall, 103 NUTS 2 regions host coal-fired power plants. The installed capacity of coal-fired power plants, aggregated at NUTS-2 level, is shown in Figure 5.

Figure 5. Installed capacity of coal-fired power plants, aggregated at NUTS-2 level[6]

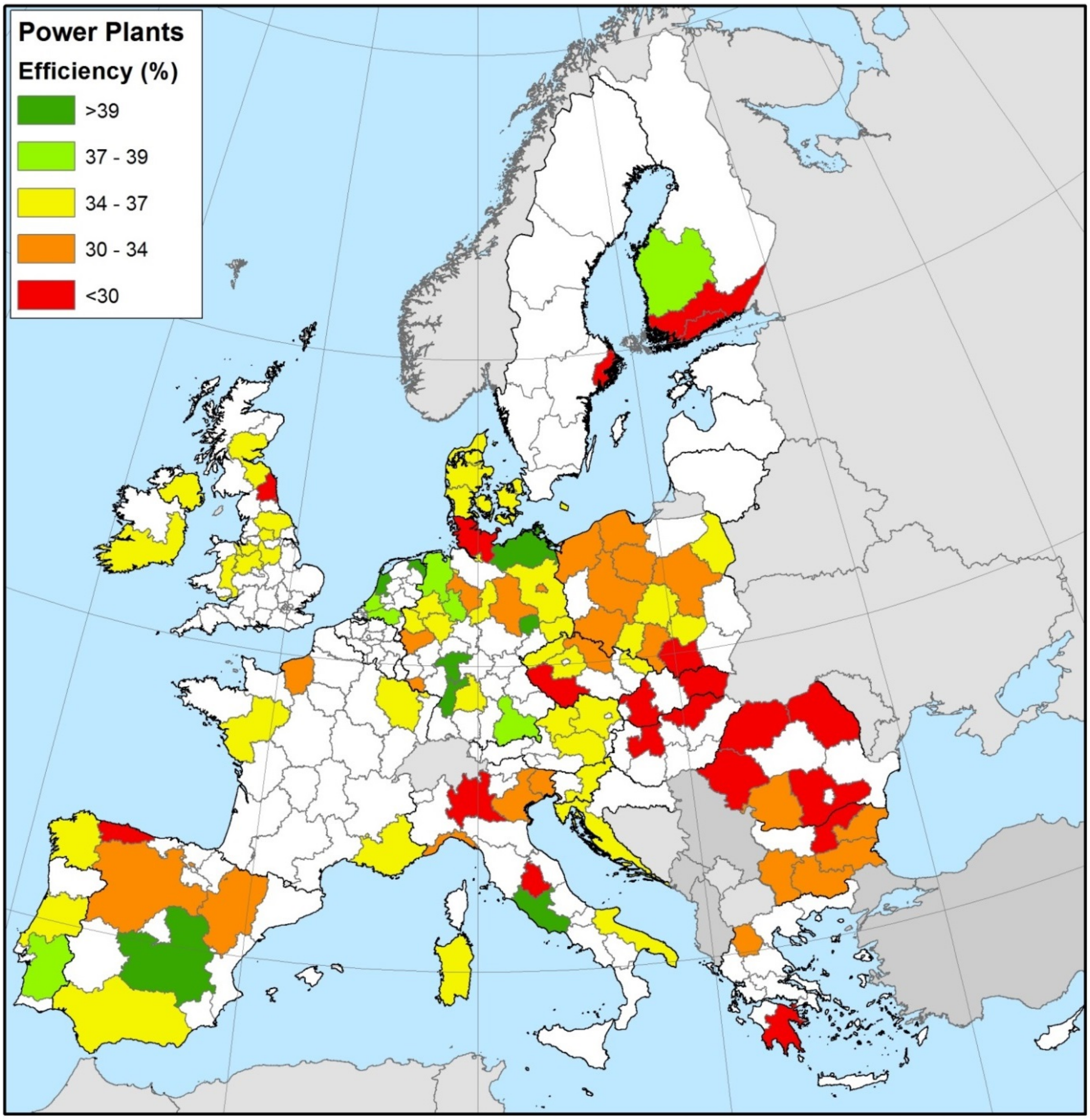


The map shows that besides the area with the highest density of coal-fired power plants stretching from the Netherlands to Poland, there are also some other regions with significant installed capacity, exceeding 2000 MW. These regions are located in Bulgaria, Poland the Czech Republic, Germany, Greece, Spain, Italy, Romania, the Netherlands and the United Kingdom.

The average efficiency of operating coal-fired power plants, at NUTS-2 regional level, is shown in Figure 6.

[6] The map draws information from the JRC-PPDB. The data that underpin this map projection can be found in Annex 2.

Figure 6. Average efficiency of active (2016) coal-fired power plants, at NUTS-2 regions[7]



There are only eight regions with an average efficiency above 39% and an additional seven where this value is above 37%. On the other hand, there are 20 regions in 13 countries (Bulgaria, Czech Republic, Finland, Germany, Greece, Hungary, Italy, Poland, Romania, Slovakia, Spain, Sweden and the United Kingdom) where the average efficiency of coal power plants is estimated below 30% and an additional 25 regions where it is estimated below 34%. This suggests that the continued use of coal as an energy source in many of these regions will require the refurbishment or replacement of old, inefficient power plants due to high costs and CO_2 emissions.

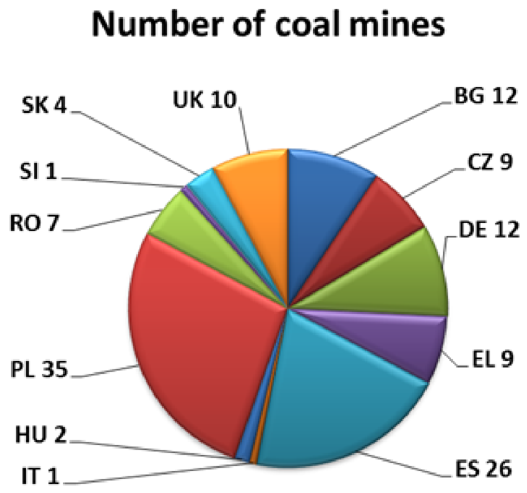
[7] The map draws information from the JRC-PPDB. The data that underpin this map projection can be found in Annex 2.

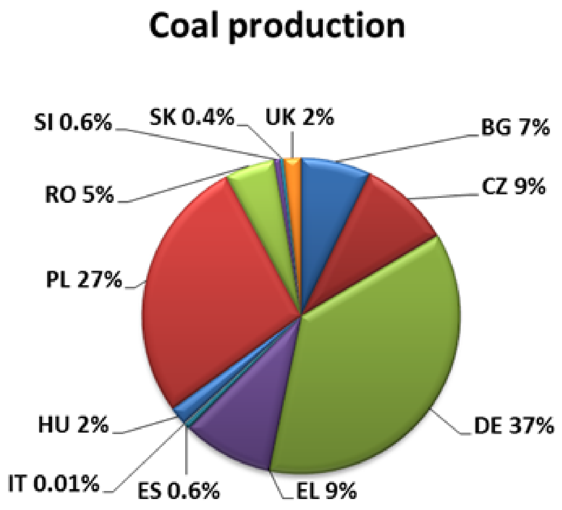
2.2 Coal mines in the EU

This section provides information on operating coal mines in the EU. This information draws from the recently developed Coal Mines Database of the JRC (JRC-CMDB)[8].

In 2015, 128 coal mines appeared to be operating in 12 Member States, with a total annual production capacity of 498 million tonnes. Poland hosts the largest number of coal mines (35), followed by Spain (26), Germany and Bulgaria (12 each). Germany is the largest producer (184 million tonnes annually) followed by Poland (135 million tonnes), Greece and the Czech Republic (46 million tonnes each). The respective shares are shown in Figure 7.

Figure 7. Key figures for European coal mines at national level



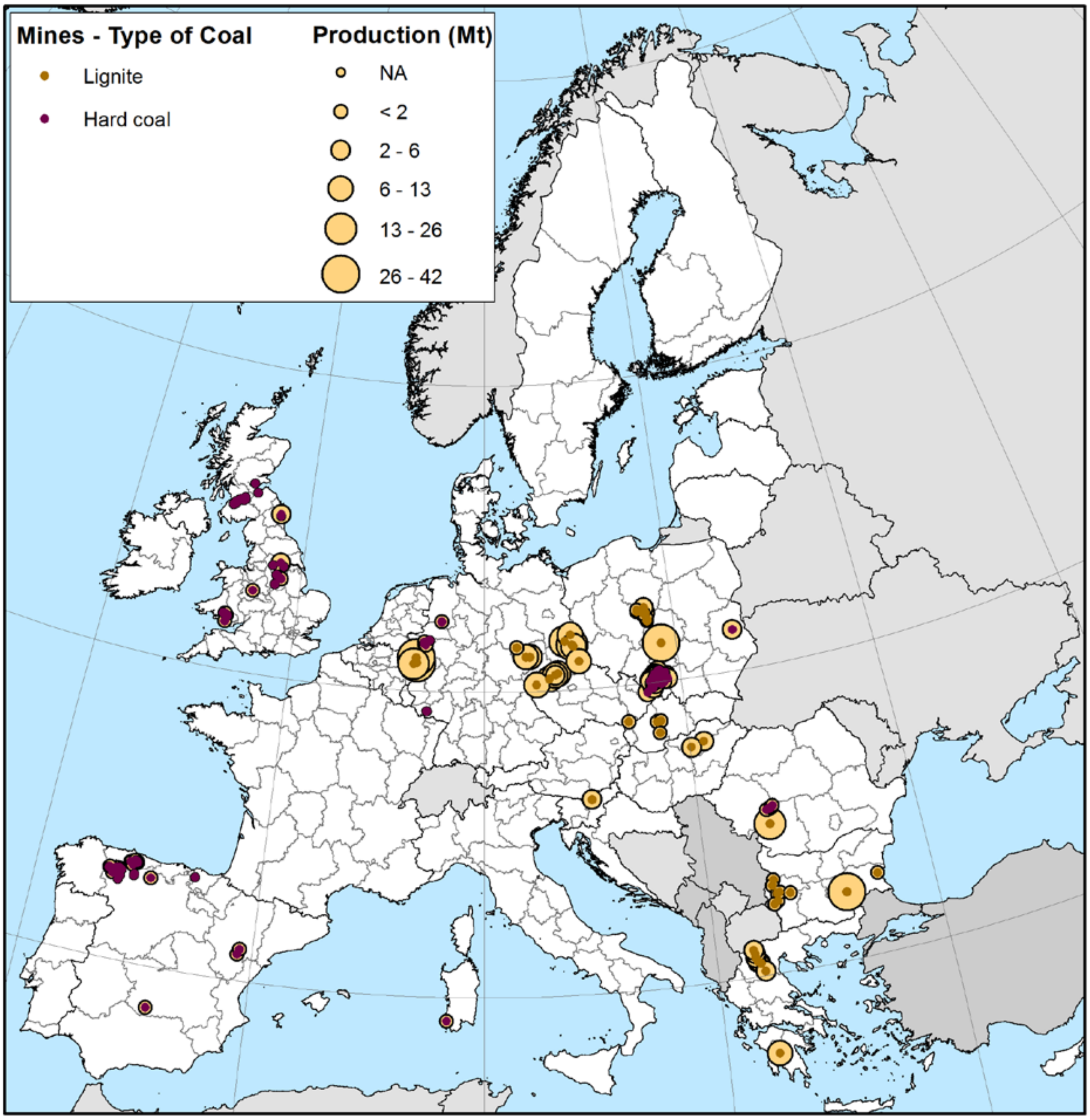


[8] The JRC-CMDB database (Coal Mines Database), produced by DG-JRC is based on information compiled from open and confidential or commercial data providers including: E-PRTR, Euracoal, Mining Atlas, SNL Metals & Mining, CO_2Stop and DG-COMP (State Aid). It includes information on production, employment, types of coal, type of mine operation, mine depth, resources and reserves and announced closures. Data contained refers to 2015.

2.2.1 Location of coal mines

The locations of active coal mines as of 2015 are visualized on the map in Figure 8.

Figure 8. Location of operating coal mines in EU and types of coal produced[9]



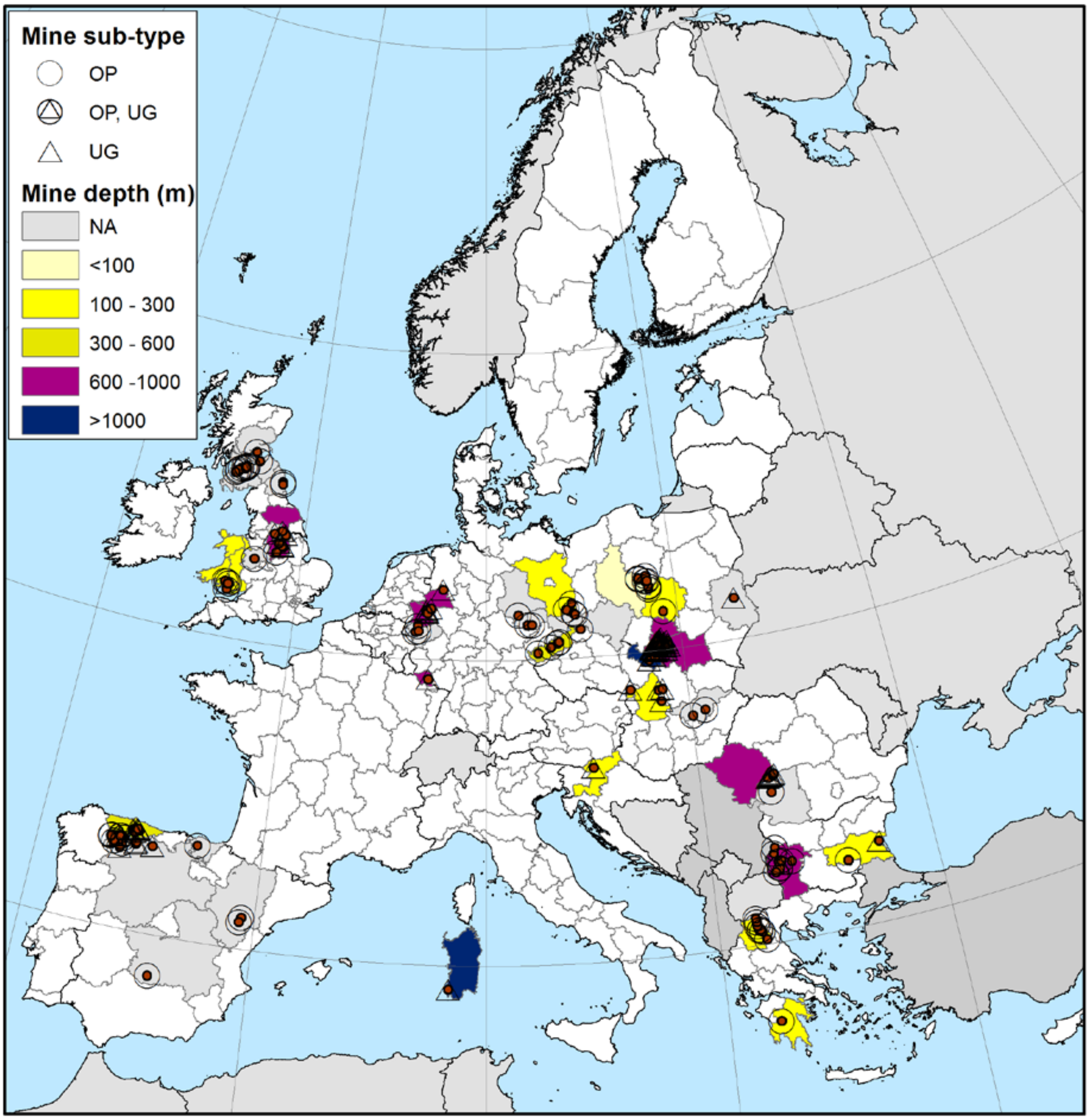
The map shows that two thirds of the coal mines in the European Union are hard coal mines (79 mines)[10]. Of these, around 25% produce metallurgical coal and anthracite, covering mainly the industrial needs of the steel sector. The remaining production centres provide different hard coal qualities, including steam and coking coal. Lignite and brown coal is produced in 49 mines. While Spain and the United Kingdom produce exclusively hard coal, Slovakia, Slovenia, Hungary, Bulgaria and Greece produce only lignite and/or brown coal**.** The largest lignite mines are located in Poland, Germany, Bulgaria and Romania. The largest hard coal mines are located in Poland and the Czech Republic.

[9] Lignite production refers to lignite and brown coal indiscriminately. Hard coal production may include the following coal qualities - thermal coal, coking coal and anthracite.

[10] See Annex 4 for details on the classification of coal and quality parameters in coal-producing countries.

The map in Figure 9 provides information on the type of mine operation and the depth of coal mines. These are factors affecting the competitiveness of a mine.

Figure 9. Information on the mine sub-type and depth of active coal mines in the EU[11]



Nearly half of the mines are surface operations. Lignite is predominantly mined in open-pits while hard coal mines include both surface and underground operations. Deeper mines (beyond 800 m) are located in Poland, Germany, the Czech Republic and Italy[12].

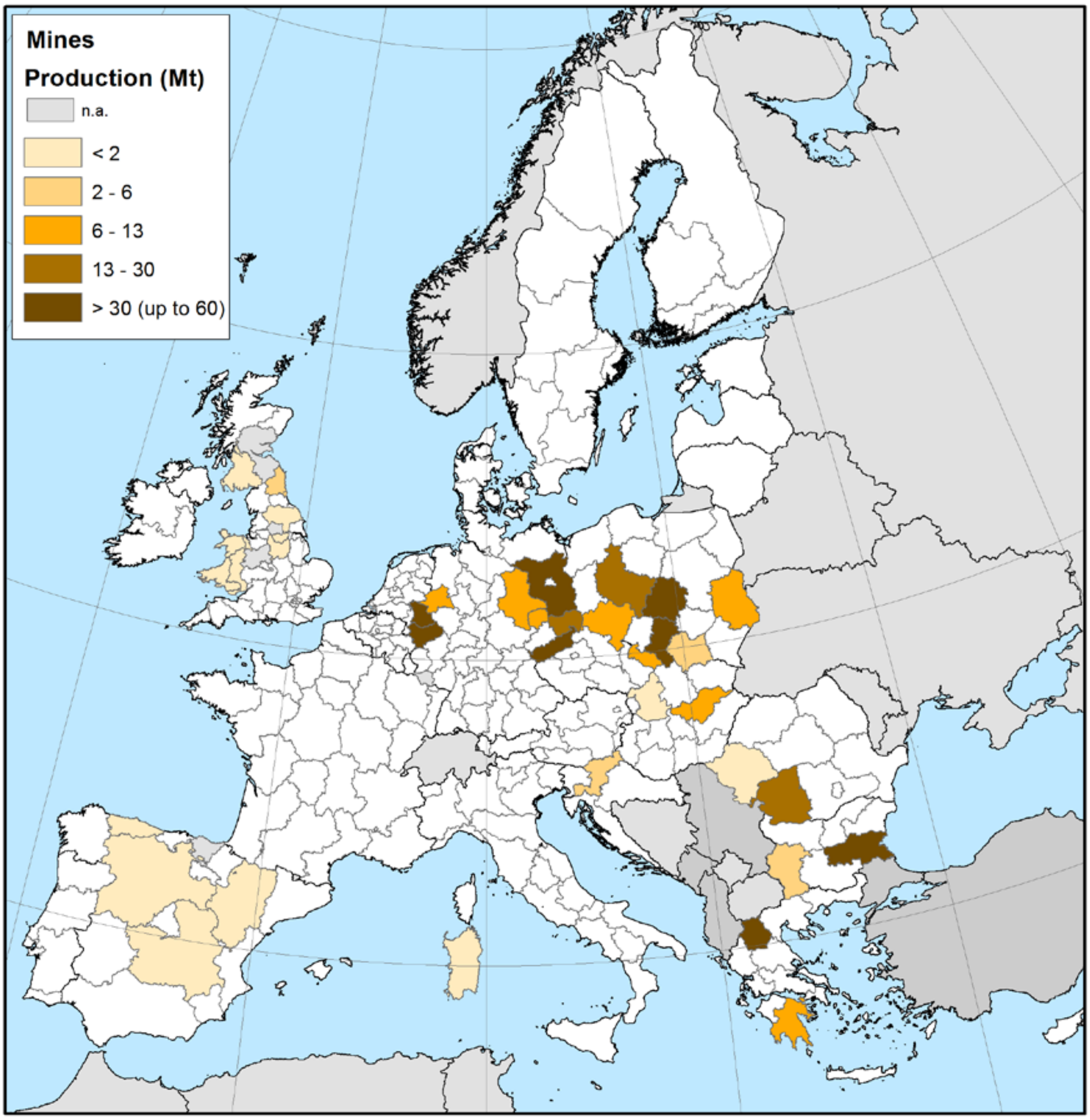
[11] Surface mines are also referred to as open-pit or opencast mines and are denoted as OP; underground operations are denoted by UG. Mine depth data is often not easily available. In some cases an indicative value applicable to the host coalfield as given in (CO2StoP, 2014) was used.

[12] In Germany the deepest coal pits reach depths of up to 1800 m. However, the vast majority of the pits in the Rhur area, are only 500-1000 m deep (Madlener & Specht, 2013). In this coalfield, top coal seams are located at an average depth of 800m (CO2StoP, 2014). In Poland, hard coal mines currently operate at average depths of 770m (official data provided by competent authorities in Poland).

2.2.2 Coal mine production at NUTS-2 level

Overall, 41 NUTS 2 regions host coal mines[13],[14]. The annual production of coal mines, at each NUTS-2 region, is shown in Figure 10 (data refers to 2015).

Figure 10. Annual production of coal mines, aggregated at NUTS-2 level[15]



The map shows that the regions with the highest aggregated production, of more than 30 million tonnes of coal per year, are located in Germany, Poland, the Czech Republic, Greece and Bulgaria. Regions with a yearly production of at least 13 million tonnes can also be found in Romania. PL22 Śląskie (59 million tonnes of hard coal from 28 mines) and DEA2 Köln (60 million tonnes of lignite from 2 mines) are the regions with the highest annual production.

[13] To be noted that production is not available for mines located in 1 region in Spain (ES21), another in Germany (DEC0) and 3 others in the United Kingdom (UKE4, UKM2, UKG2). Taking into account the total production of the mines for which information is available is comparable to published country-level statistics (e.g. Euracoal), one can conclude that negligible amounts can be allocated to them or that the respective production shares were already included in the statistics of neighbouring mines.

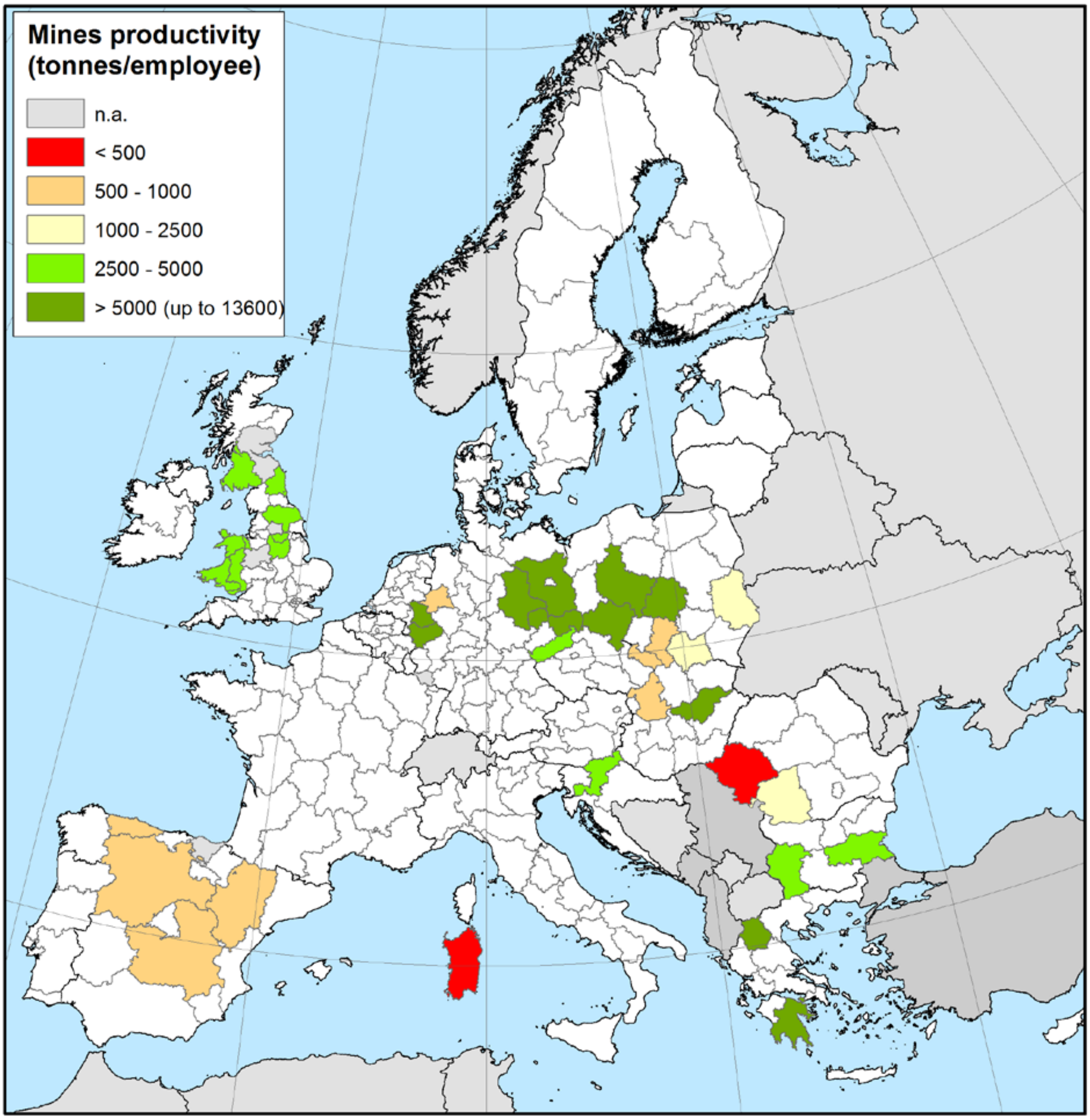
[14] In addition to the 41 regions, another region in Poland (Lubuskie, PL43) is known to host coal mining infra-structure (official data provided by competent authorities in Poland) (see Annex 1).

[15] The table used to support the map projection is given in Annex 3.

2.2.3 Coal mines productivity at NUTS-2 level

One of the key factors that affect the long term viability of a coal mine is its productivity, measured as the annual production of coal per person employed. Estimates on the productivity of coal mines at each NUTS-2 region, are given in Figure 11.

Figure 11. Average productivity of coal mines at NUTS-2 level[16]



It is inferred that the most productive mines in Europe with a production above 10 000 tonnes per employee are located in Germany and Greece where surface lignite mines are operated. The least productive mines with a production below 500 tonnes per employee are located in Italy and Romania. It is stressed that productivity depends on several factors such as local geology or mine depth.

[16] For Bulgaria, Spain and the United Kingdom the calculation of mine productivity is a very rough approximation due to the lack of disaggregated data on employment at each mine site or at regional level. Each region was assigned the average country productivity.

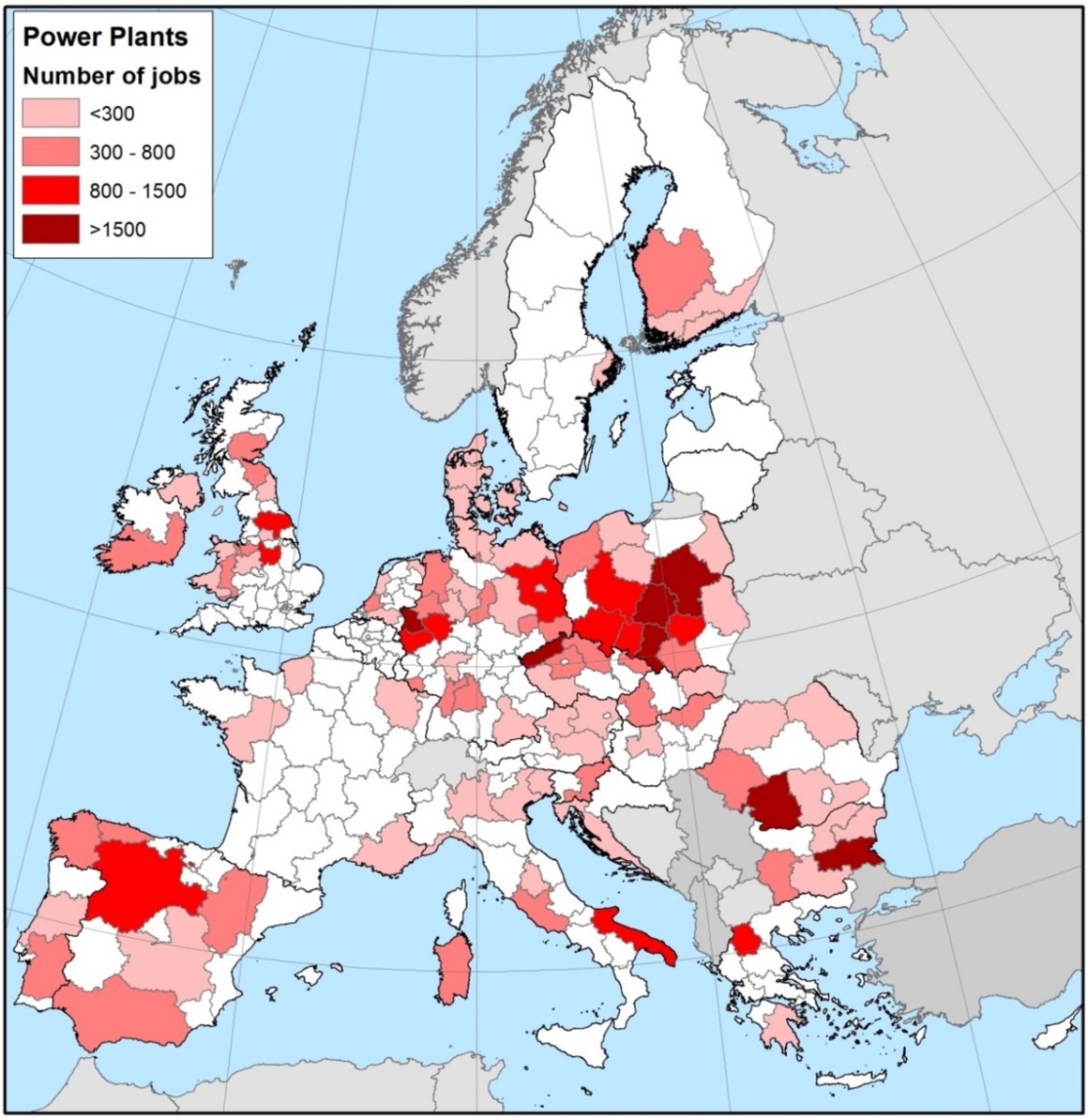
2.3 Direct employment in coal power plants and mines

This section presents a first assessment of the number of direct jobs associated with coal mining and coal-fired power generation, at NUTS-2 level. The detailed results are presented in Annex 5.

2.3.1 Jobs in coal-fired power plants

It is estimated that around 53 000 people work in coal-fired power plants in the EU. The number of jobs per Member State ranges from just above 100 in Sweden to around 13 500 Poland. The map in Figure 12 illustrates the estimated number of direct jobs in active coal-fired power plants at NUTS2 level. The estimates[17] were calculated based on the installed capacity at each Member State and an indicator provided in Annex 6 that links jobs with installed capacity (jobs per MW).

Figure 12. Estimated number of direct jobs in active coal-fired power plants[18]



[17] Specific country indicators (Annex 6) were derived based on the actual number of direct jobs in lignite power plant operation in Germany (Agora Enegiewende, 2017). The basis for deriving the country specific figures was the size of the average power plant in each Member State compared to the size of the average power plant in Germany. The results of this analysis were within the range of 0.14 to 0.84 jobs per MW provided in relevant publications (GreenPeace, Solar Power Europe, & GWEC, 2015; OECD/IEA , 2008).

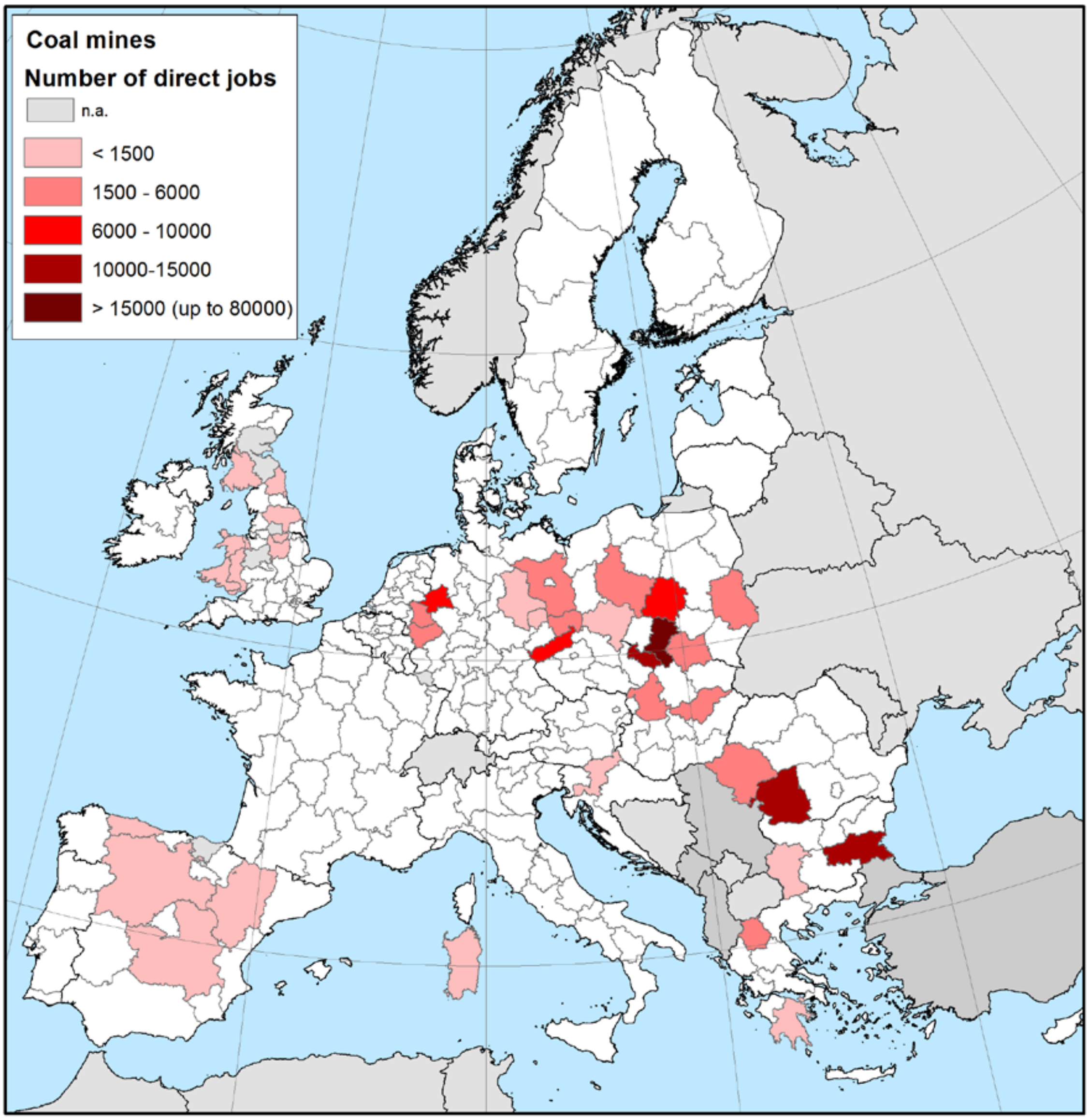
[18] The data supporting the map projection is given in Annex 5.

Poland, Germany, the United Kingdom, Czech Republic, Romania, Spain and Bulgaria are on the top of the list, each hosting more than 2 500 direct jobs in coal fired powerplants. At the regional level Łódzkie (PL11), Śląskie (PL22), Sud-Vest Oltenia (RO41), Mazowieckie (PL12), Düsseldorf (DEA1), Yugoiztochen (BG34) and Severozápad (CZ04) are estimated to host more than 1 500 direct jobs in coal fired power plants.

2.3.2 Jobs and skills in coal mining

This section reports on the number of direct jobs in operating coal mines. It is estimated that coal mining provides for 185 000 jobs across Europe. Employment at national level ranges from around 350 in Italy to just below 100 000 in Poland. The estimates presented in Figure 13 were mainly derived from EURACOAL and/or calculated based on a combination of production levels and an inferred average mine productivity[19].

Figure 13. Number of jobs in coal mines at each NUTS-2 region.

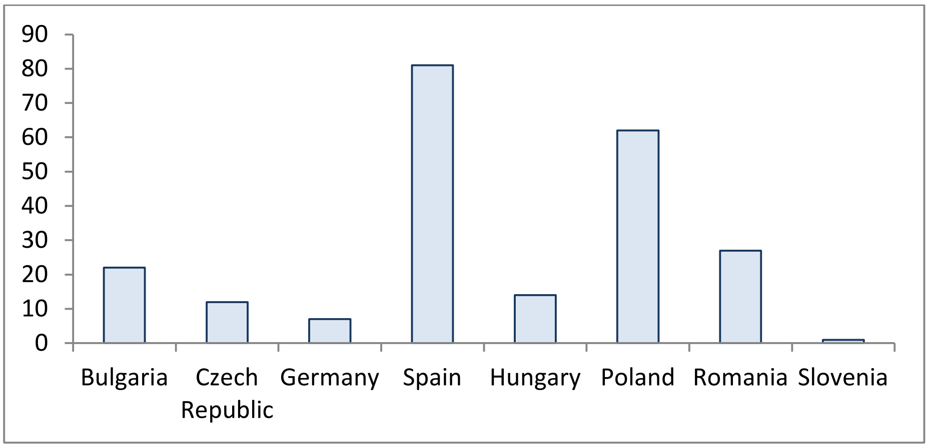


[19] Employment estimates in coal mining are based on country-level information reported by Euracoal made available in the Association's Country profiles (Euracoal, 2017). This information, which is given separately for lignite and hard coal, was further disaggregated based on the production levels of the mines. For some mines or groups of mines in the same region, specific information on jobs also available from the mentioned data source was used instead.

Four NUTS-2 regions in Bulgaria, the Czech Republic, Poland and Romania (BG34, CZ08, PL22 and RO41) account for more than 10 000 employees each in coal mining activities and additional three in the Czech Republic, Germany and Poland (CZ04, DEA3 and PL11) for over 6 000. Another 11 regions host more than 1 500 employees in coal mining.

The Silesia (Śląskie) region in Poland (PL22) provides about 80 000 jobs directly in coal mining. This is also one of the two regions with the highest production in Europe, and one of the largest in terms of number of enterprises active in coal mining (Figure 14).

Figure 14. Number of enterprises within the mining of coal and lignite NACE sector in 2015 – data from Eurostat[20]



Based on EUROSTAT data, Spain hosts the largest number of coal mining enterprises (81 enterprises), despite the fact that it produces only about 3% of total hard coal in EU. This number includes large enterprises and small dependent companies (e.g. SMEs providing indirect services). Alongside Spain and Poland, also Bulgaria and Romania host a high number of enterprises active in coal mining.

The professional groups employed in the mining sector can be grouped into three categories: production employees, auxiliary employees and mine management or support staff. These categories and their specific functions are shown in Table 1.

Table 1. Types of professional groups employed in mining activities - based on (McIntosh, 2010).

Production employees	Auxiliary employees	Mine management and support staff
Continuous miner operator	Scoop operator	General manager
Continuous miner helper	Pocketman	Production foreman
Shuttle car operator	Supplyman	Maintenance foreman
Roof bolter operator	Lampman/warehouse	Mine accountant/purchasing
Scoop operator	Belt maintenance/clean-up	Mine clerk
	Mechanics	Technicians/surveyors
	Electrician	
	Surface utility operator	

[20] Accounts are not available for Greece, Italy, Slovakia and United Kingdom.

The respective shares of employees in each professional group are given in Table 2, for surface and underground operations.

Table 2. Shares of professional groups employed in mining activities[21]

Mine sub-type	Production labour (%)	Auxiliary staff (coal loading and maintenance) (%)	Mine operations staff and supervisors (%)	Management and technical staff (%)
Open-pit (surface)	42.2	39.5	13.3	5.0
Underground	38.0	40.5	17.7	3.8

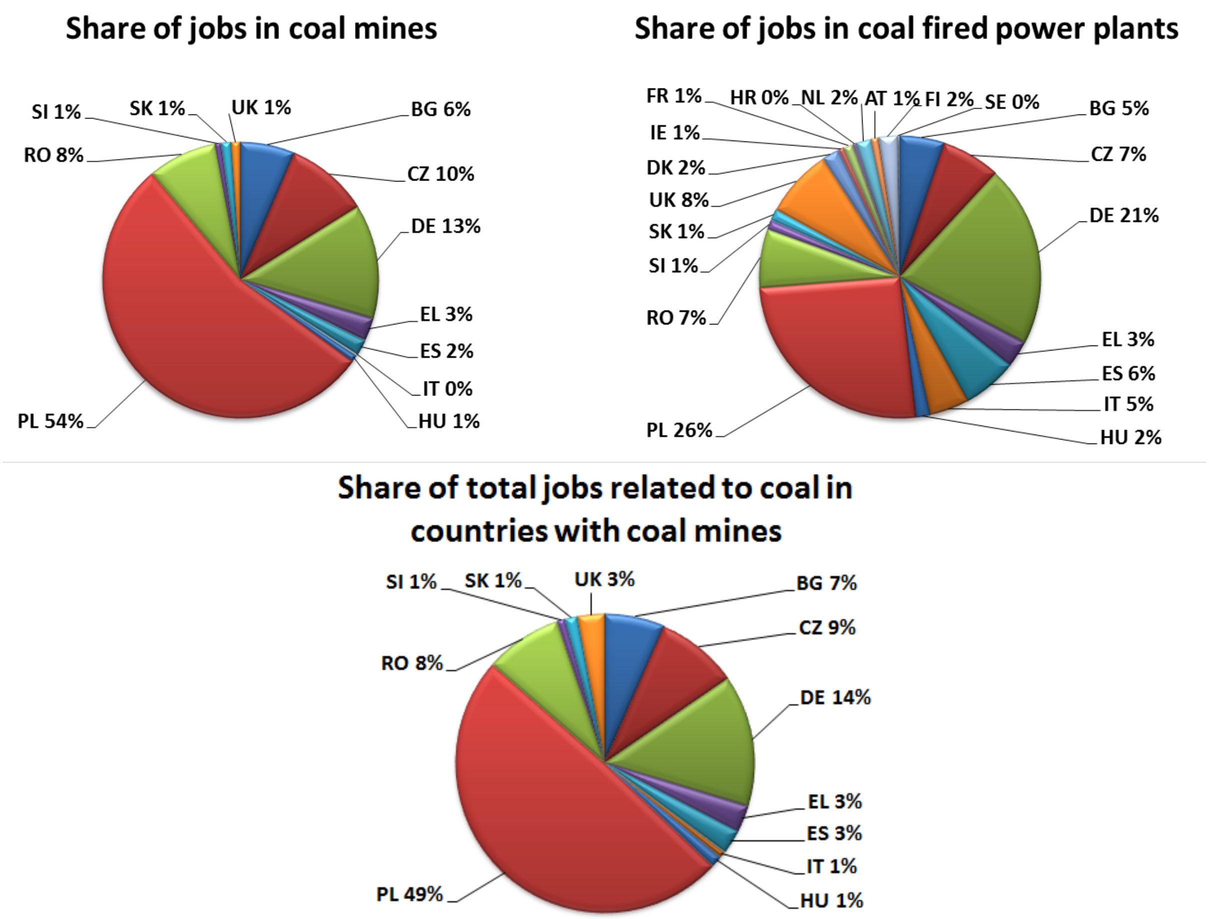
Table 2 demonstrates that management and technical staff account for around 4% of total employment in a mining operation. Production and auxiliary staff are the largest professional groups accounting for 80% of the workforce. Taken together, these occupation groups include equipment operators, electricians and mechanics.

[21] Own calculations based on (McIntosh, 2010). See Annex 7 for further details.

2.3.3 Overall assessment of current direct employment

The overall assessment of direct employment indicates that in the EU28, coal activities provide jobs to about 237 000 people: around 185 000 are employed in coal mining and about 52 000 in coal-fired power plants[22]. Poland holds the largest number of jobs in coal-fired power plants (13 000) followed by Germany (11 000) and the UK (4 100). The number of jobs in coal mines is in some cases an order of magnitude higher. Poland has almost 100 000 people in coal mining, followed by Germany (25 000) and the Czech Republic (18 000). Overall, Poland hosts the largest number of jobs on coal (about 112 600), followed by Germany (35 700), the Czech Republic (21 600) and Romania (18 600), as shown in Figure 15.

Figure 15. Employment in the European coal sector.



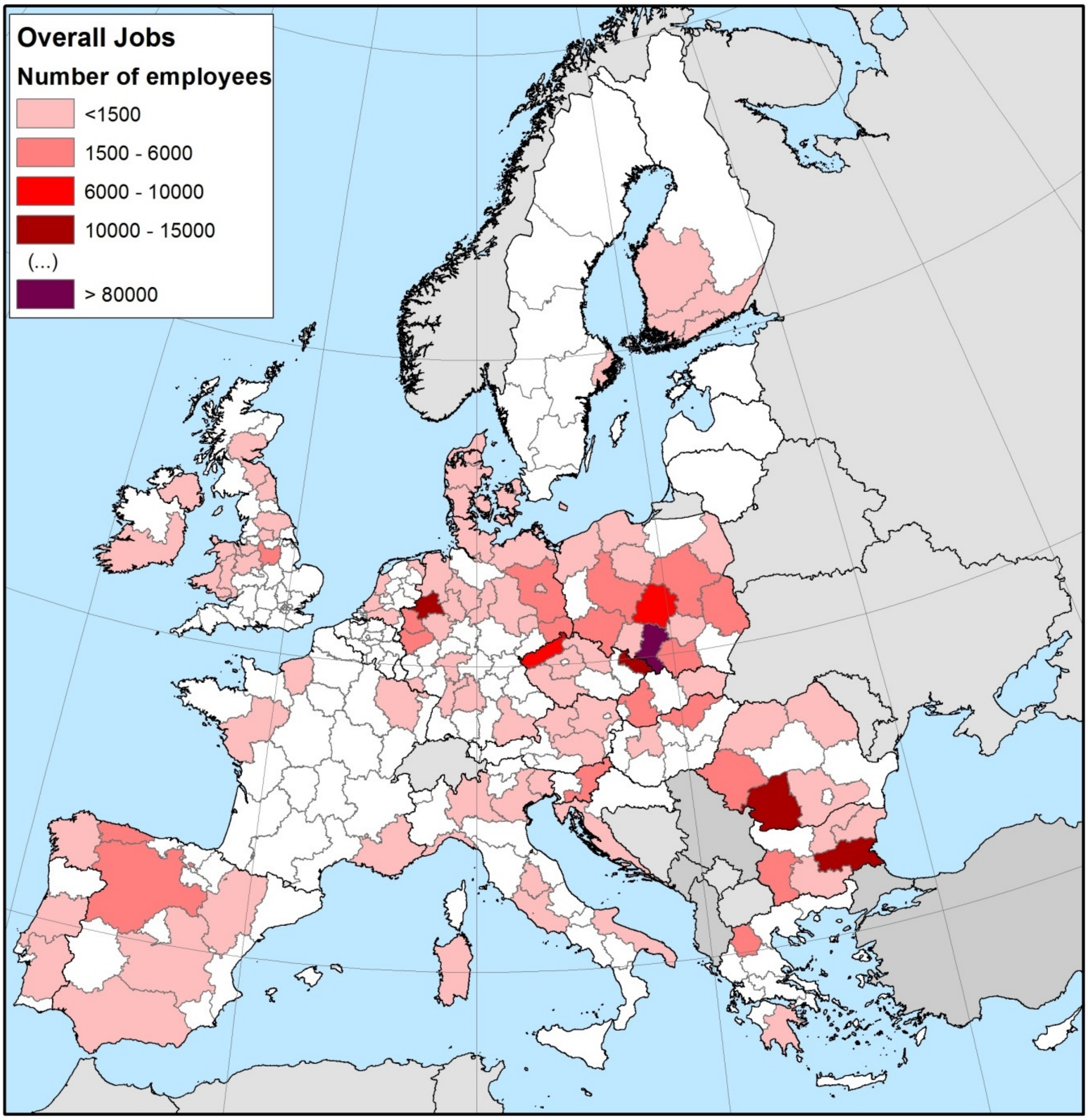
[22] To be noted that according to Eurostat the overall number of jobs in the coal mining sector was 158,945 in 2015 (figures for Germany were not available). In 2014, including Germany, the number of jobs was estimated at 177,143, but employment statistics are not available for Slovenia and Slovakia.

Table 3. Number of jobs in coal power plants and coal mines at country level

Country	Jobs in coal power plants	Jobs in coal mines	Total jobs
Poland	13 000	99 500	112 500
Germany	10 900	24 700	35 700
Czech Republic	3 600	18 000	21 600
Romania	3 600	15 000	18 600
Bulgaria	2 700	11 800	14 500
Spain	3 300	3 400	6 700
Greece	1 600	4 900	6 500
United Kingdom	4 100	2 000	6 100
Slovakia	500	2 200	2 700
Italy	2 400	300	2 700
Hungary	900	1 700	2 500
Slovenia	600	1 300	1 900
Finland	1 100	0	1 100
Denmark	1 000	0	1 000
Netherlands	900	0	900
Portugal	700	0	700
France	600	0	600
Austria	500	0	500
Ireland	400	0	400
Croatia	200	0	200
Sweden	100	0	100

The distribution of the overall number of jobs in the two coal-related sectors - power plants and mining - is given at each NUTS-2 region in Figure 16.

Figure 16. Overall number of jobs in coal power plants and coal mines in NUTS2 regions[23]



The map shows that the regions with the highest overall employment are located in Poland, Romania, Bulgaria and Germany. This distribution follows roughly the distribution of mining jobs, which accounts for the highest number of employees in the same regions. For example the Silesia region in Poland, employs about 82 500 persons, which is more than the total employment in coal power plants in EU28.

[23] The table used to support the map projection is given in Annex 4.

The top 20 regions ranked according to the number of coal-related direct jobs (both power generation and mining) is provided in Table 4.

Table 4. Top 20 regions ranked accordingly to the number of coal-related direct jobs

NUTS-2	Region	Coal related jobs
PL22	Śląskie	82 500
RO41	Sud-Vest Oltenia	13 100
BG34	Yugoiztochen	12 700
CZ08	Moravskoslezsko	10 600
DEA3	Münster	10 000
CZ04	Severozápad	9 700
PL11	Łódzkie	8 900
PL31	Lubelskie	5 800
DEA2	Köln	5 700
EL53	Dytiki Makedonia	5 700
PL21	Małopolskie	5 300
RO42	Vest	5 200
DEA1	Düsseldorf	4 600
DE40	Brandenburg	4 500
DED2	Dresden	3 400
PL41	Wielkopolskie	3 400
SK02	Západné Slovensko	2 500
HU31	Észak-Magyarország	2 300
PL12	Mazowieckie	2 000
ES12	Principado de Asturias	2 000

2.4 Indirect jobs in coal-related activities

Information on indirect jobs related to coal activities is not readily available.

At country-level, EURACOAL provides some estimation of indirect jobs related to coal mining which include power generation, equipment supply, services and R&D. The number of indirect employees and a comparison between direct jobs in coal mining and indirect jobs in the aforementioned areas is provided in the Table 5 for a number of EU countries.

Table 5. Relation between direct and indirect jobs in coal mining activities, according to information made available by EURACOAL for a group of EU Member States

Country	Number of indirect employees	Indirect jobs/Direct jobs[24] (Ratio)
Bulgaria (lignite and brown coal)	46 851	3.9
Germany (hard coal)	15 700	1.6
Germany (lignite)	5 316	0.3
Greece (lignite)	2 438	0.5
Slovenia (lignite)	2 467	1.9
Slovakia (lignite)	430	0.2

In this table a ratio between indirect and direct jobs is given, showing a diversity of relations between the two, with the coefficients ranging noticeably between different Member States. These data show that for every mining job the associated indirect jobs can be in the range of less than 1 up to 3.9. It can also be noted that the proportion of direct jobs is higher in Slovakia, Germany (lignite) and Greece, while indirect jobs account for a higher proportion in Bulgaria, Germany (hard coal) and Slovenia.

Overall, for that group of five countries, indirect activities provide around 73 000 jobs in the EU[25].

With a view to obtaining a more comprehensive outlook of indirect employment related to coal activities across all European countries and NUTS regions, new estimates were developed. These cover more broadly the coal supply chain, including all the linkages with other economic sectors in a region or country.

The estimation of indirect employment in the coal sector relied on the use of input-output tables and multipliers developed by the JRC, originally, for predicting the impacts of a change in the final demand of one sector on other related sectors (Thissen & Mandras, 2017). Indirect employment was estimated by applying the same multipliers to the number of coal direct jobs (see section 2.3.3).

The indices used, besides extending the supply-chain coverage to all sectors that might be impacted by changes in coal mining and coal power plants activities, are assessed at intra-regional level, and also consider spill-over effects at inter-regional level.

Table 6 provides an estimation of indirect jobs at country-level based on the above methodology.

[24] Indirect jobs provided by Euracoal in 2015 include power generation, equipment supply, services and R&D.
[25] This estimation covers a group of five EU countries, excluding six others where coal activities are also considered relevant.

Table 6. Number of indirect jobs in coal-related activities at intra- and inter-regional level[26].

Country	Intra-regional	Inter-regional
Bulgaria	9 452	15 220
Czech Republic	10 018	19 229
Denmark	1 019	2 429
Germany	14 089	34 366
Ireland	280	378
Greece	1 843	4 166
Spain	5 107	9 643
France	525	1 237
Croatia	339	385
Italy	906	3 970
Hungary	2 255	4 735
Netherlands	1 777	3 995
Austria	769	1 943
Poland	48 746	87 760
Portugal	344	1 229
Romania	6 194	10 101
Slovenia	1 270	1 833
Slovakia	1 189	2 058
Finland	1 693	3 240
Sweden	275	573
United Kingdom	2 133	6 276

The table shows that the number of indirect jobs is highest in Poland, with around 49 000 employees in intra-regional supply-chains and around 88 000 when also inter-regional trade is considered[27]. Other countries such as Germany, Czech Republic and Bulgaria also record high levels of indirect employment.

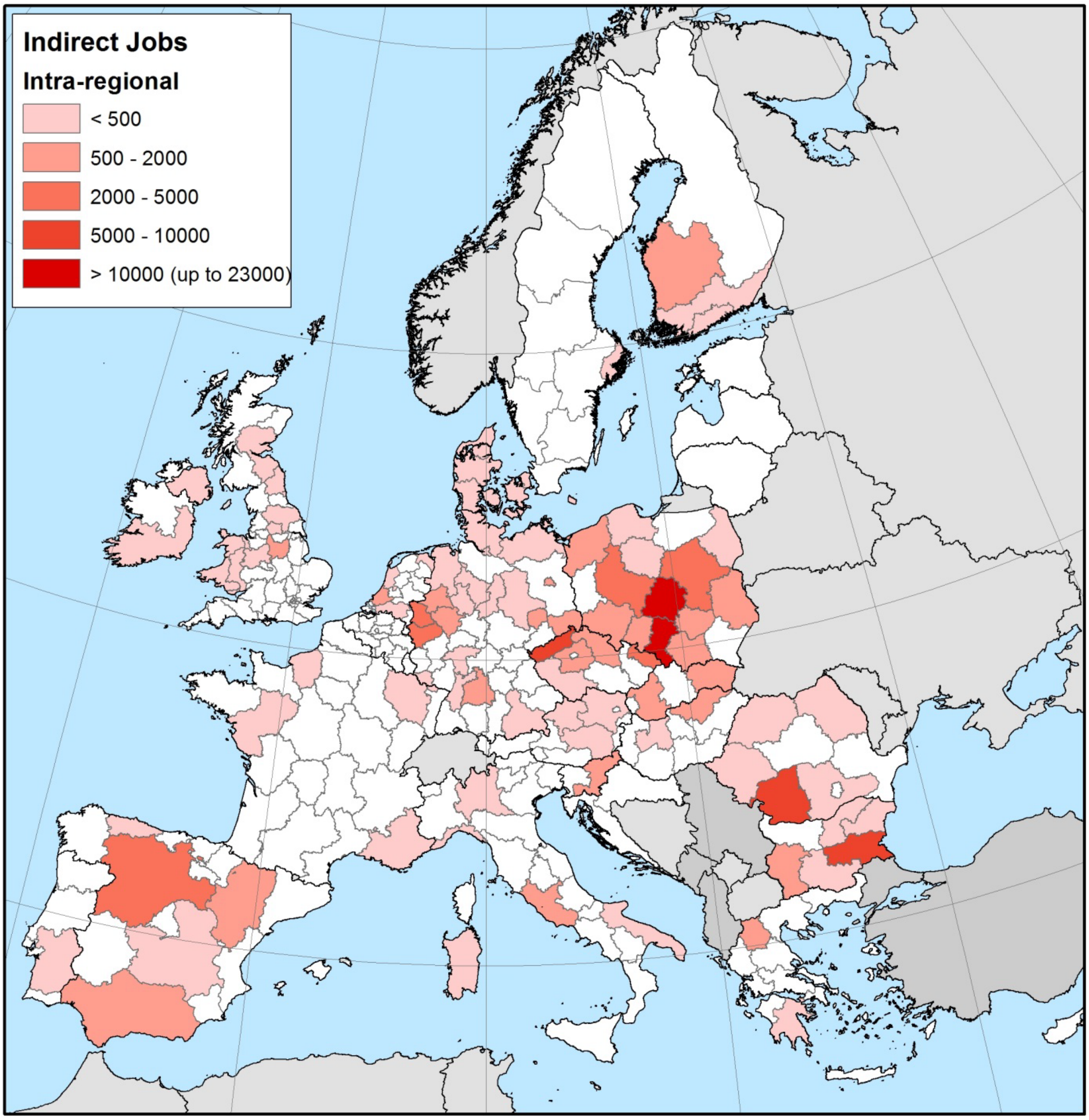
The total number of indirect jobs is up to around 215 000.

[26] The IO methodology is described in Annex 8. For the inter-regional trade estimation see additionally the methodology described in (Thissen & Mandras, 2017).

[27] Note that Inter-regional figures include Intra-regional effect and, therefore, differences are due to the inter-regional trade between NUTS 2 regions.

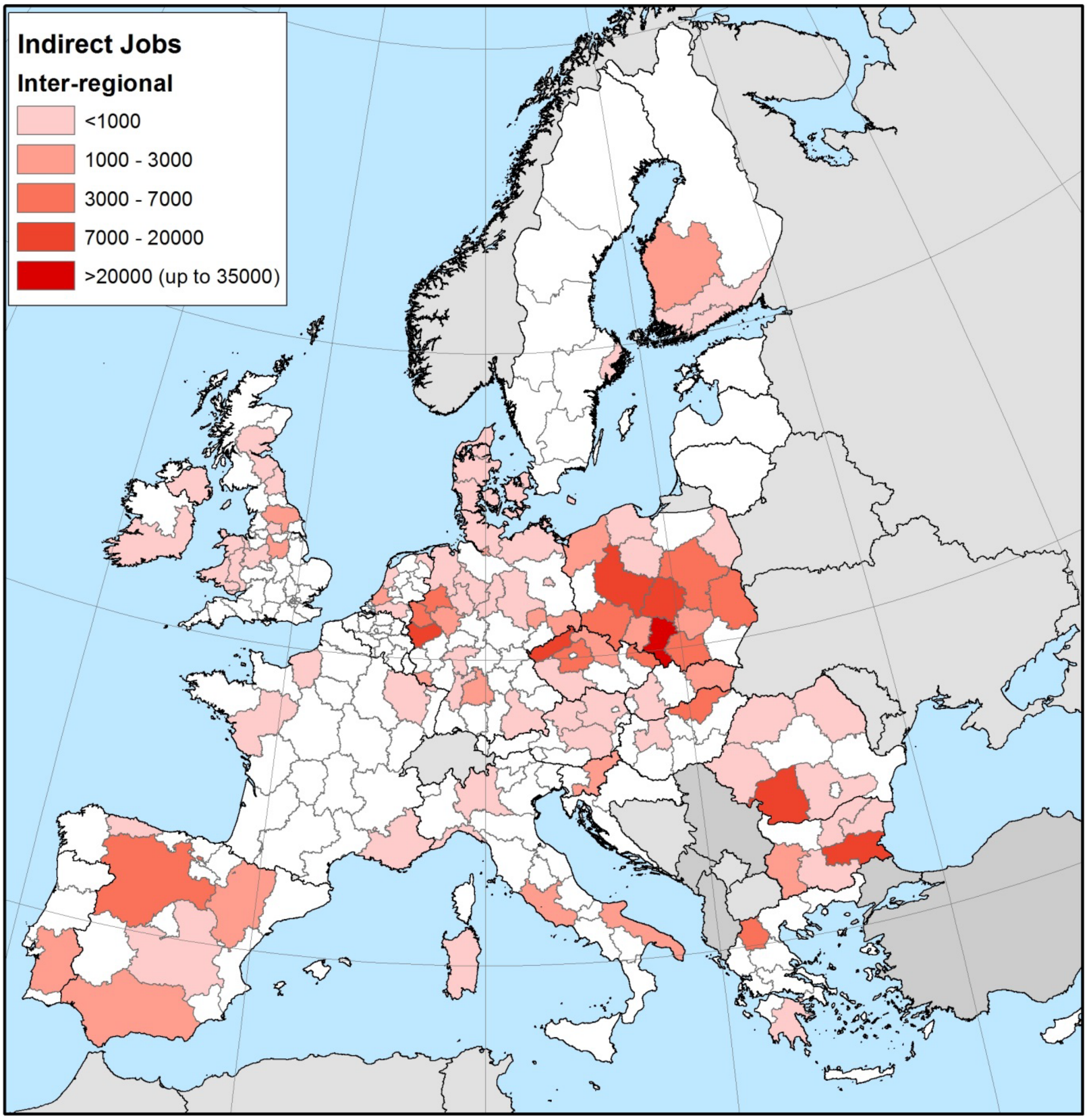
The map in Figure 17 shows the size and distribution of indirect employment amongst European NUTS-2 regions.

Figure 17. Distribution of indirect jobs in intra-regional supply chains



Two regions in Poland (PL22 and PL11) account for the highest number of indirect jobs in intra-regional supply-chains, followed by BG34 in Bulgaria, CZ04 in Czech Republic and RO41 in Romania with over 5000 jobs each.

Figure 18. Distribution of indirect jobs in inter-regional supply chains



The same regions in Poland, Bulgaria and Czech Republic have inter-regional supply chains with a higher number of employees, above 10 000 people. In DEA1, DEA2, PL12, PL31, PL41 and RO41 indirect jobs are also high, influencing between 5 000 and 10 000 workers.

2.5 Emissions of air pollutants

The combustion of hydrocarbons and coal contributes to the emission of air pollutants such as particulate matter (PM10 and PM2.5)[28], sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). The European Environmental agency (EEA) in its 2016 air quality report (European Environment Agency, 2016) reports the following trends regarding air quality:

- Particulate matter: Concentrations of particulate matter (PM) continued to exceed the EU limit and target values in large parts of Europe in 2014. PM10 concentrations above the EU daily limit value were registered in 21 of the 28 EU Member States. Despite decreasing trends, it's expected that in 2020 there will still be high values exceeding this limit, which alerts to the fact that more has to be done to reach acceptable concentrations.
- Nitrogen dioxide: The annual limit value for nitrogen dioxide (NO_2) was widely exceeded across Europe in 2014, and 94% of all values above the annual limit value were observed at traffic stations. In 2000–2014, NO_2 concentrations tended to decrease on average at all types of stations, especially at traffic stations. Nevertheless, if these trends continue until 2020, 7% of stations would still have concentrations above the annual limit value. This calls for additional efforts to reach the EU limit value.
- Sulphur dioxide: The EU‑28 urban population was not exposed to sulphur dioxide (SO_2) concentrations above the EU daily limit value in 2014. However, 38% of the EU‑28 urban population was exposed to SO_2 levels exceeding the World Health Organization (WHO) and Air Quality Guidelines (AQGs) value of 20 $\mu g/m^3$.

A detailed analysis of the impact of coal activities to the air quality across Europe is beyond the scope if this study. The following paragraphs however provide some insight on the contribution of coal activities to the total emissions of these three pollutants across the EU. While these results do have an impact upon, they should not be confused with air quality indicators in regions hosting coal activities.

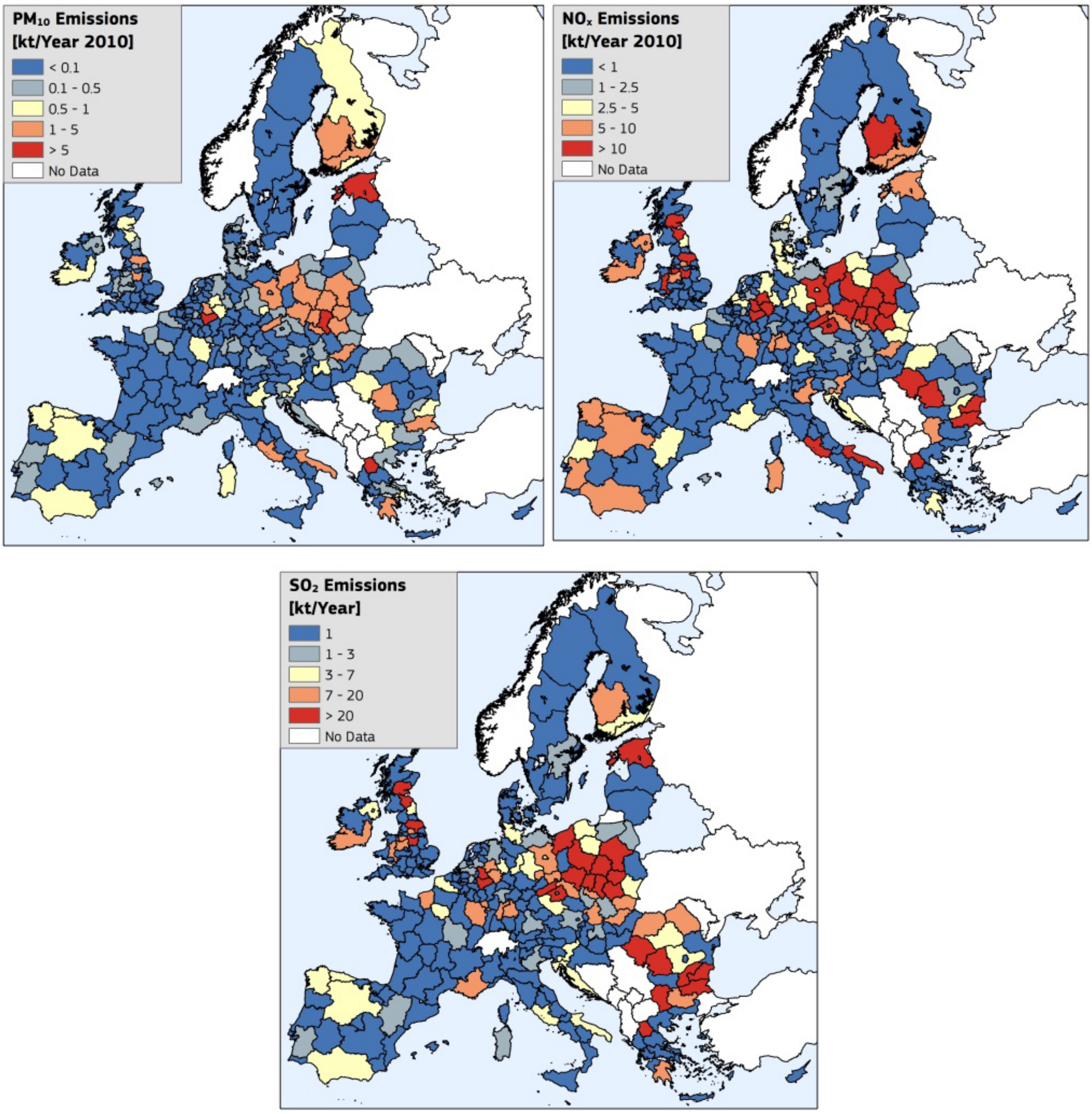
2.5.1 Emissions related to coal activities at NUTS-2 regions

The maps in Figure 19 show the 2010 emissions of air pollutants (PM10, NOx and SO_2[29]) from coal power plants and mines aggregated at NUTS2 level. The maps were generated based on the JRC07 emissions inventory (Trombetti, Pisoni, & Lavalle, 2017) recently developed for use in Integrated Assessment Modelling strategies (IAM) in the fields of regional air-quality and land use and territorial modelling.

[28] PM10 is particulate matter with a diameter of 10 µm or less; PM2.5 is particulate matter with a diameter of 2.5 µm or less.

[29] Nitrogen oxides (NOx) refer specifically to NO and NO_2.

Figure 19. Air Pollutant emissions of coal activities aggregated at NUTS-2



In absolute numbers the emissions vary significantly. In several regions NOx emissions are above 10 Kt/year. The highest PM10 emissions, above 5 kt/year, are located in Silesia (PL22), Western Macedonia (EL53) and Köln (DEA2). As for SO_2 the highest values are significantly above 20 Kt/year in several regions.

Despite not hosting coal activities, Estonia exhibits very high pollutant emissions. These emissions can be attributed to oil shale.

2.5.2 The impact of coal activities on overall emissions

A quantitative overview of the impact of coal activities (power generation and mining) is provided below. We classified the 105 coal regions in the following three classes, denoting the level of coal activity based on the installed coal fired power plant capacity in each region:

LOW : Installed capacity does not exceed 500 MW

MED : Installed capacity between 500 MW and 2 000 MW

HI : Installed capacity exceeds 2 000 MW

The class average total pollutant emissions were calculated for each of the above classes in order to assess the effect of coal activities in total regional emissions[30]. Table 7 provides the ratio of average total emissions in each class to the average total emissions in regions with no coal activity (Class denoted as NONE).

Table 7. Average emissions of pollutants in regions with coal activity compared to regions without

Coal activity	Regions	NOx	PM10	SO_2
HI	31	253%	217%	957%
MED	51	170%	159%	317%
LOW	23	131%	163%	259%
NONE	160	100%	100%	100%

Table 7 tells us that on average regions with significant coal activity exhibit 2 times more emission of PM10, 2.5 times more NOx and almost 10 times more SO_2 emissions compared to regions with no coal activity. Coal is not the only culprit for the above differences. In order to get a feeling of how much coal contributes the class average coal related pollutant emissions were calculated for each of the above classes and subsequently used to derive the class average share of coal emissions with respect to the total regional emitted quantities.

Table 8 provides the calculated contribution of coal activities to the total pollutant emissions averaged for regions belonging in each of the three classes.

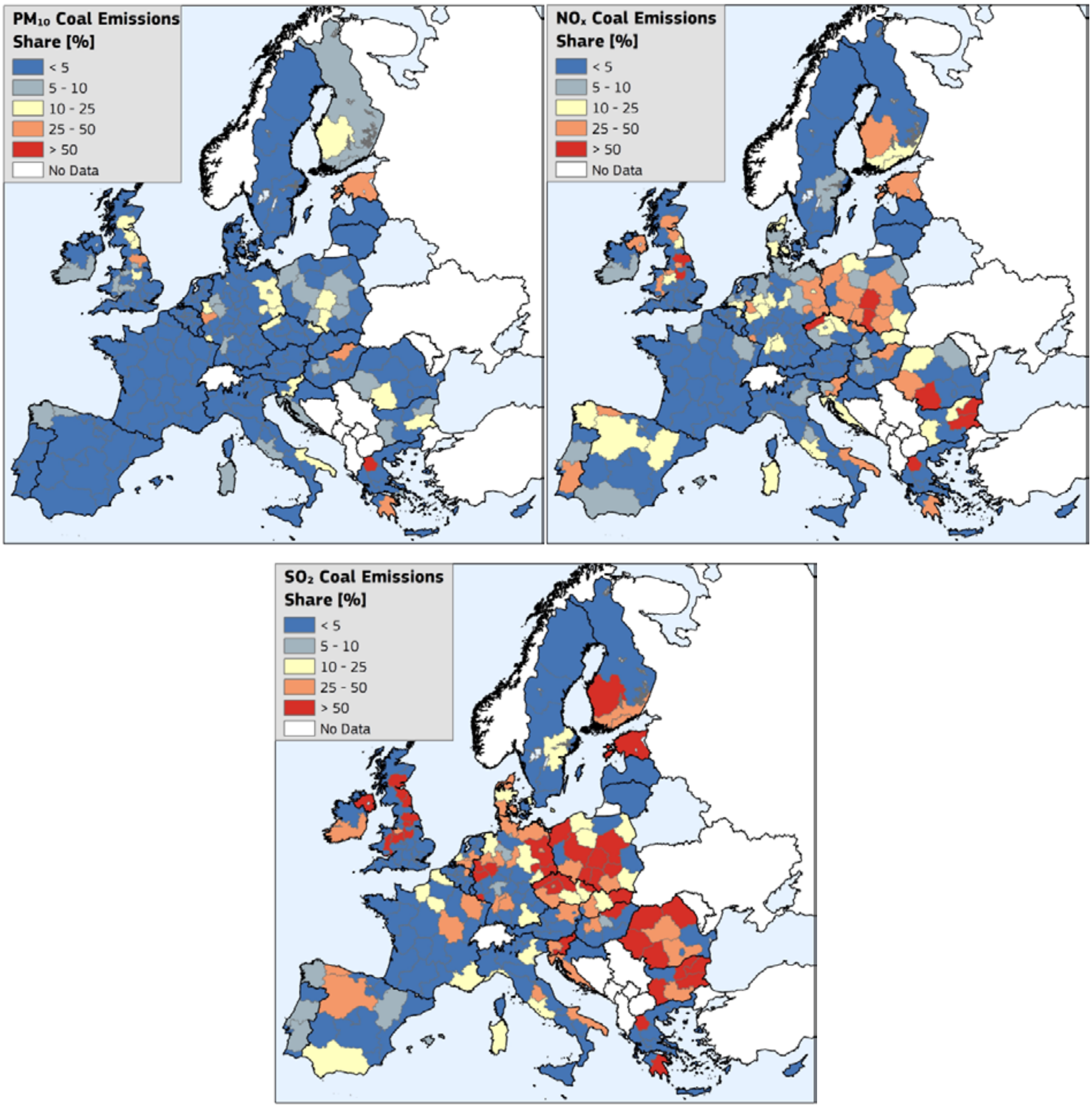
Table 8. Contribution of coal to air pollutant emissions

Coal activity	Regions	NOx	PM10	SO_2
HI	23	41%	18%	63%
MED	51	19%	6%	39%
LOW	31	9%	3%	29%

Table 8 tells us that in regions with high activity coal is responsible on average for 18% of the total particulate (PM10) emissions, for 41% of the total NOx emissions and for 63% of the total SO_2 emissions. Region specific values are provided in the maps in Figure 20.

[30] See Annex 21 for an overview of the activities contributing to the estimation of overall emissions.

Figure 20. Contribution of coal to air pollutant emissions aggregated at NUTS-2



The contribution of coal activities to the total pollutant emissions – particularly SO_2 and NOx appears to be particularly important in regions in central/eastern Europe and the UK.

The analysis presented in this section is intended to provide an overview on the contribution of coal activities to the emission of air pollutants in Europe. Although affected by emission values, air quality is not directly linked to them as it depends on a number of other parameters which are site and source specific.

2.6 Key points

- Coal activities are currently present in 21 Member States and 108 NUTS-2 regions.
- The highest density of European coal-fired power plants lies in the area stretching from the Netherlands, across Germany and the Czech Republic to Poland and from Romania, across Bulgaria down to Greece.
- The most modern power plants exhibiting the highest efficiencies are located in Germany and the Netherlands. The least efficient power plants are located in eastern and south-eastern Europe.
- Regions with the highest aggregated coal production, of more than 30 million tonnes of coal per year, are located in Germany, Czech Republic, Poland, Greece and Bulgaria.
- The most productive mines in Europe with an annual production above 10 000 tonnes per employee are located in Germany and Greece where surface lignite mines are operated. The least productive mines with a production below 500 tonnes per employee are located in Italy and Romania.
- Coal activities offer direct employment to around 237 000 people across Europe. 78% of these jobs are in the mining sector.
- The regions with the highest number of jobs in the coal sector (mines and power plants) are located in Poland, Romania, Bulgaria, Czech Republic, Germany and Greece.
- Key figures for the EU:

  Coal mines

  Number of coal mines: 128

  Coal production: 498 million tonnes

  Coal power plants

  Number of coal power plants: 207

  Capacity: 150 GW

  Employment

  Direct jobs in coal mining: 185 000

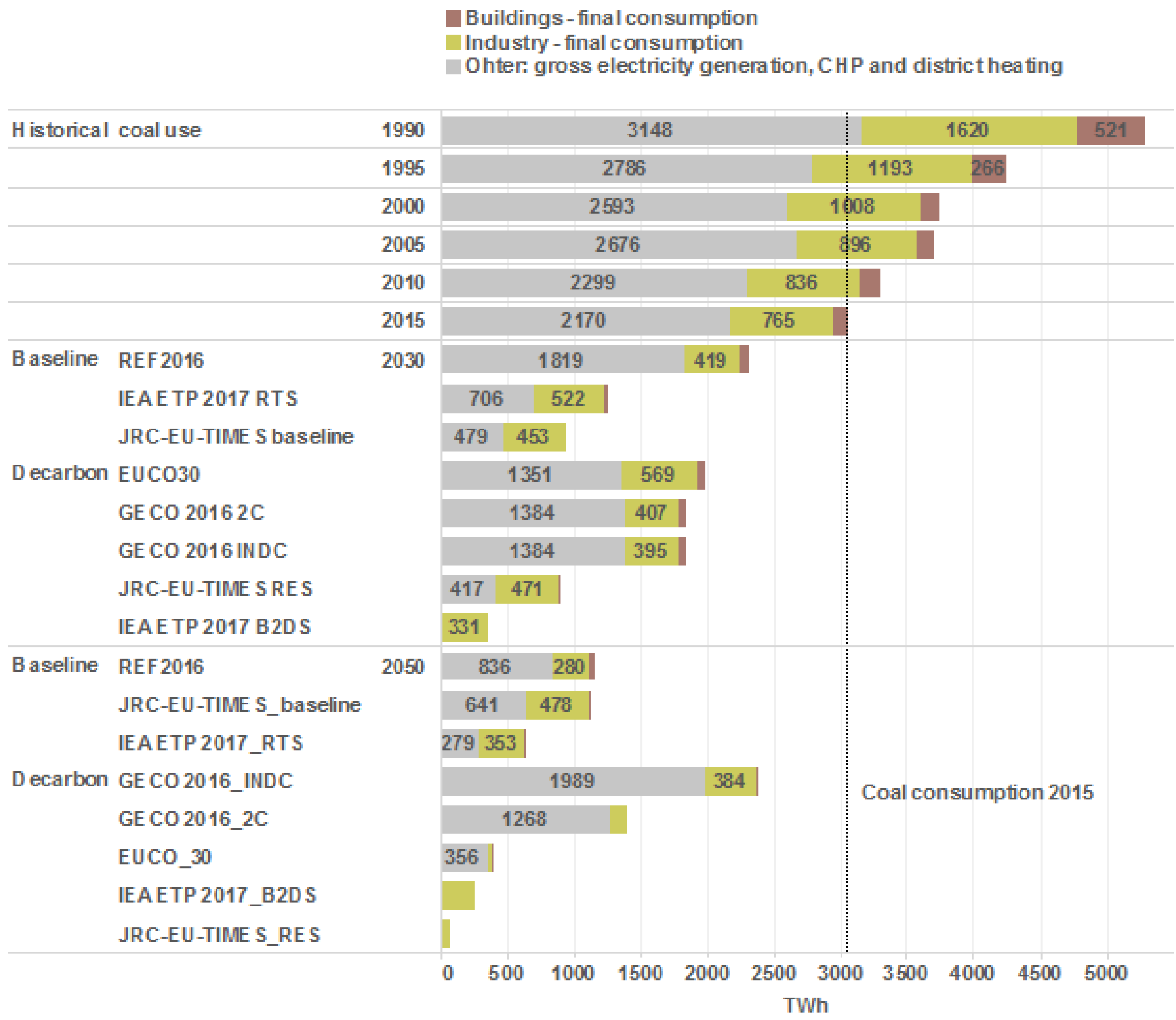
  Direct jobs in power plants: 52 000

  Total direct jobs: 237 000
- The number of indirect jobs in power generation, equipment supply, services and R&D is nearly 73 000 in five European countries. Throughout the coal value chain, considering intra- and inter-regional trade, the number of indirect jobs dependent on coal activities is up to 215 000, with four regions in Poland, Bulgaria and Czech Republic presenting above 10 000 jobs each.
- Coal intensive regions are exposed to significantly higher emissions of pollutants such as particulate matter, nitrogen oxides and sulphur oxides compared to regions with no coal activity. A significant proportion of said emissions is attributed to coal.

3 Possible future developments of coal activities

To put the use of coal into a broader perspective, a summary of its historical and projected consumption up to 2050 is presented herein. Figure 21 shows the use of coal in its three main applications: (1) heating in buildings, (2) energy and material production in industry and (3) power generation, combined production of electricity and heat and/or production of heat for district heating, which combined is the most important application. Power generation is by far the biggest consumer of coal and the almost exclusive user of lignite.

Figure 21. Historical and projected use of coal in EU28[31]



[31] Sources: 1) IEA ETP-B2DS and IEA ETP-RTS: Energy Technology Perspectives 2017. International Energy Agency (IEA, 2017), 2) EU Ref: Capros et al., 2016. EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050 (European Commission, 2016), 3) EUCO30: http://charts-move.mostra.eu/en/content/energy-modelling and assuming a linear phase out of the final coal use for buildings (European Commission, 2017), 4) Geco-INDC and Geco-2C: Kitous et al., 2016. GECO 2016. Global Energy and Climate Outlook Road from Paris. Joint Research Centre (Kitous, Keramidas, Vandyck, & Saveyn, 2016), 5) JRC-EU-TIMES baseline: Heatroadmap 4 baseline scenario of the total energy system up to 2050, Joint Research Centre (Nijs, Ruiz Castelló, Hidalgo González, & Stiff, 2017) and 6) JRC-EU-TIMES_Decarb_RES: Joint Research Centre internal calculation (Gago da Camara Simoes , et al., 2013)

Historically, the use of coal has decreased by 42% in the last 25 years, from 5 289 TWh to 3 055 TWh. This is equivalent to an average annual reduction of 2.2%. In the five years period from 2010 to 2015, the coal consumption has decreased by 7% which is equivalent to an average annual reduction of 1.5%, so lower than the full period decrease.

Different scenarios show that the consumption of coal in 2030 and 2050 is in the range from below 500 TWh to almost 2 500 TWh. This wide range can be explained mainly by the different assumptions on climate targets as well as the availability of Carbon Capture and Storage (CCS) and/or Carbon Capture and Utilisation (CCU), discussed later in the report.

In a number of reference or baseline scenarios (REF2016, JRC-EU-TIMES baseline, IEA ETP 2017 Reference Technology Scenario) coal consumption in 2030 will be reduced by at least 24% to 70% compared to today's consumption, depending mainly on the model assumptions for climate and energy targets. In 2050 the reduction of coal consumption could reach 80%.

In the group of scenarios with a decarbonisation target (EUCO30, GECO, JRC-EU-TIMES RES, IEA ETP 2017 Beyond 2 Degrees Scenario) the reduction of coal consumption in 2030 will be of the order of 35% to 54%; and between 54% and 98% in 2050. It is noted that coal is almost phased out in the scenarios by IEA (IEA ETP Beyond 2 Degrees) and the JRC (JRC-EU-TIMES RES). Some decarbonisation scenarios foresee coal consumption levels higher than most baseline scenarios which is only possible when CCS/CCU technologies are deployed.

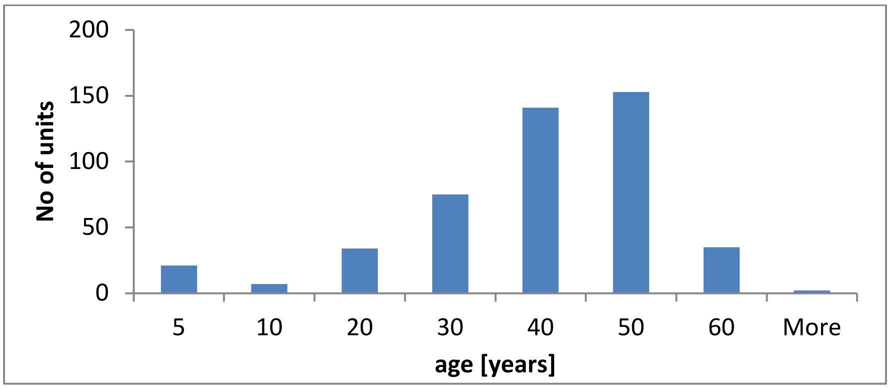
3.1 A snapshot of European coal power plants – Age and new entries

This section presents an analysis of the direct impacts of the decommissioning of coal power plants and the closure of coal mines on employment.

Coal-fired power plants are typically designed for a service life of more than 25 years without significant upgrades. However the service life can be significantly extended beyond that timeframe by replacing or upgrading components.

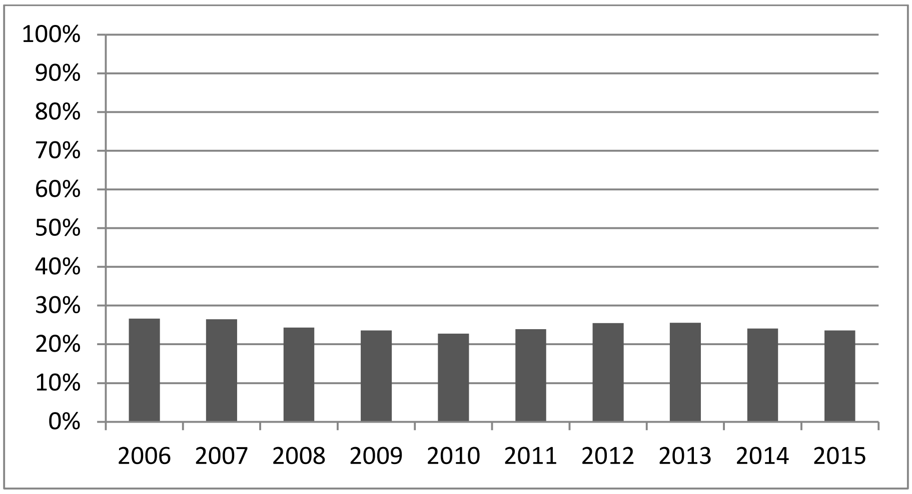
The average age of a coal power plant in the EU is 35 years, with an estimated efficiency of 35%.[32] The graph in Figure 22 shows the age distribution of the European coal power plant fleet. It is perhaps not surprising that the vast majority of coal-fired plants in Europe started their operation more than 30 years ago.

Figure 22. Age distribution of the European coal power plant fleet.



The share of electricity from coal-fuelled power plants in the EU-28 power generation mix changes from year to year, but it remains in the range between 23% and 27%, as shown in graph in Figure 23.[33]

Figure 23. Share of coal and lignite in power generation for EU28



The importance of coal in power generation varies significantly across the EU28. While nine countries make marginal or no use of coal in power generation, Poland generates around 80% of electricity from coal and lignite and four other countries follow with at

[32] JRC-PPDB: weighted average of class-based or real data efficiency

[33] Eurostat: Simplified energy balances - annual data [nrg_100a] and Supply, transformation and consumption of electricity - annual data [nrg_105a]

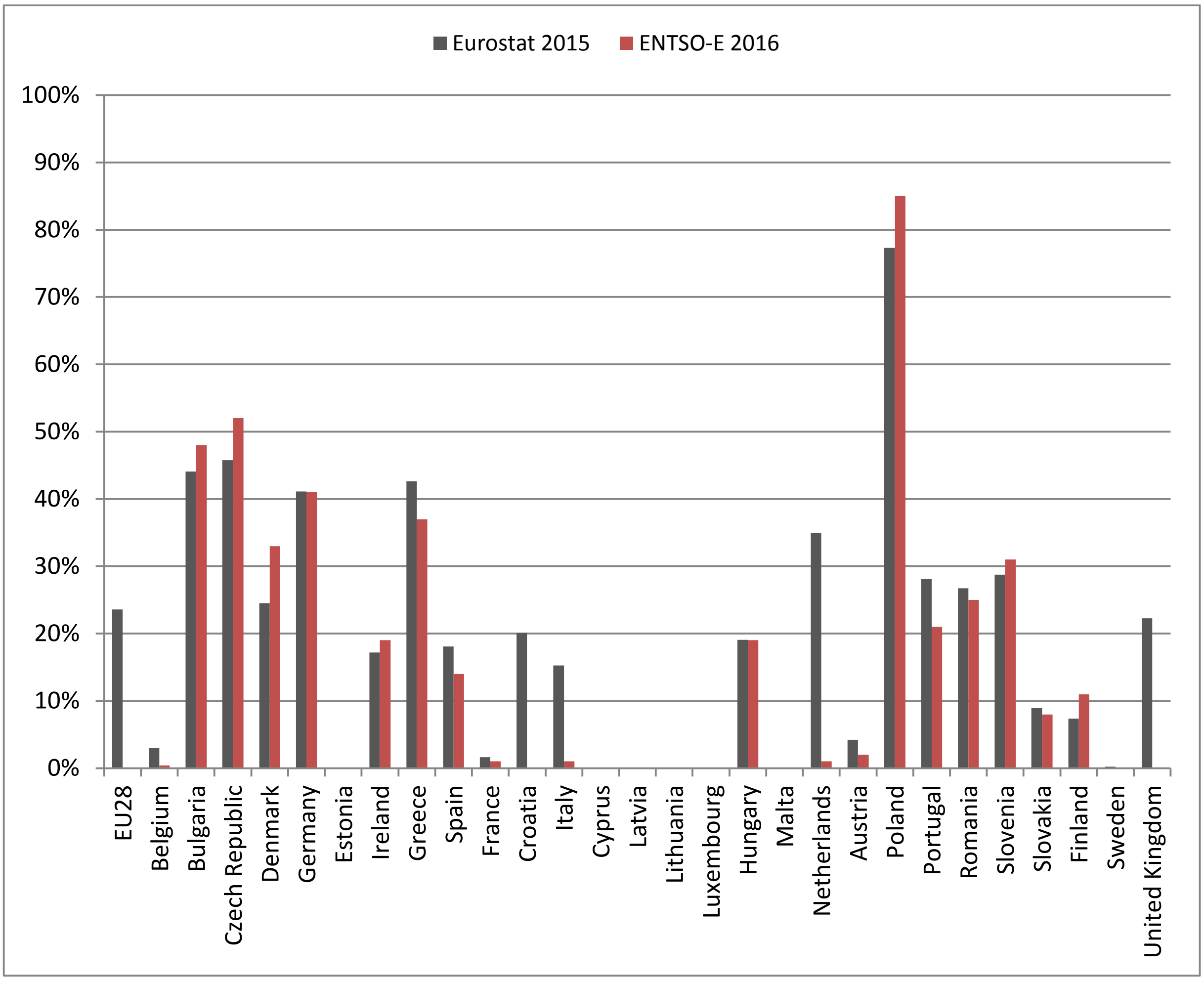
least 40%. The graph in Figure 24 provides the fraction of electricity generated from coal in EU member states. The data from Eurostat relates to 2015[34] while the data from ENTSO-E relates to 2016 and to Member States which reported coal-fuelled power plants in their power generation mix.[35]

The new coal fired capacity under construction or expected to come online until 2025 at country level is shown in Table 9.

Table 9. Coal power plant capacity under construction or expected to come online before 2025[36]

Country	Capacity [MW]
Germany	1 100
Greece	660
Croatia	500
Poland	4 465

Figure 24. Share of electricity generation from coal and lignite in total electricity generation



[34] The data from Eurostat includes four types of fuel (Anthracite, Other Bituminous Coal, Sub-Bituminous Coal and Lignite/Brown Coal)

[35] ENTSO-E transparency platform Aggregated Generation Per Type time series data for 2016

[36] See Annex 11 for details.

3.2 The decommissioning of coal power plants

The increasingly important share of renewables, the anticipated restrictions on coal eligibility to participate in future capacity remuneration mechanisms, the post 2020 emission requirements of the Industrial Emissions Directive (2010/75/EU), as well as uncertainty over prevailing CO_2 prices after 2020 are a few of the factors that the plant operator of a coal plant needs to consider before proceeding with any life-extension investment. A life-extension investment is very likely to introduce co-firing of biomass or lead to a radical fuel switch. The Lynemouth power plant in the UK is quoted as such an example in Box 1.

Box 1. UK: The conversion of Lynemouth coal-fired plant to biomass

The Lynemouth coal-fired 420 MW power plant in Northumberland on the north-eastern coast of England, built in 1972, is about to be retrofitted to operate exclusively on biomass. The main fuel will be wood pellets mostly coming from Southeast United States, West Canada and Russia. With a nominal electric power of 420 MW, an efficiency of 36.9% and a mean load factor of 75.3% the plant will use approximately 1.44-1.56 million dry tonnes of wood pellets a year for the generation of 2.3 TWh of electricity. Within the 12 year lifetime the project will save approximately 17.7 million tons of CO2. The expected fuel cost is 8.18 EUR/GJ and the project levelised cost electricity is €120/MWh. The United Kingdom confirmed support to this project and the European Commission asked for additional information relating to State Aid (European Commission, 2015). Since December 2015, the plant ceased to operate with coal and the conversion project is scheduled for the beginning of 2018.[37]

In the following paragraphs the results of an analysis aiming to identify the power plants most likely to retire in the coming decade are presented. This will allow the estimation of the impact on the hosting regions. In order to assess which plants are most likely to retire first two complementary approaches were followed:

In the first, henceforth called top-down (or TSO[38]-based) approach a ‘survival-of-the-fittest’ analysis on the coal power plant fleet of each Member State was conducted by considering TSO’s reporting on the coal and lignite installed capacity for the years 2025 (ENTSO-E MAF2016[39]) and 2030 (TYNDP scenario 4[40]).

In the second, henceforth called bottom-up approach, the information contained in transitional national plans (TNPs[41]) were used to estimate the possible extent of coal-fired decommissioning capacity that can take place during the first half of the next decade. The base assumption was that all power plants currently addressed by TNPs will be retired by 2025.

[37] http://www.power-technology.com/projects/lynemouth-biomass-power-station-northumberland/

[38] ‘TSO - transmission system operator’ is a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity (Directive 2009/72/EC);

[39] The mid-term adequacy forecast (MAF 2016) presents the first Pan-European probabilistic assessment of adequacy (https://consultations.entsoe.eu/system-development/maf-2016/)

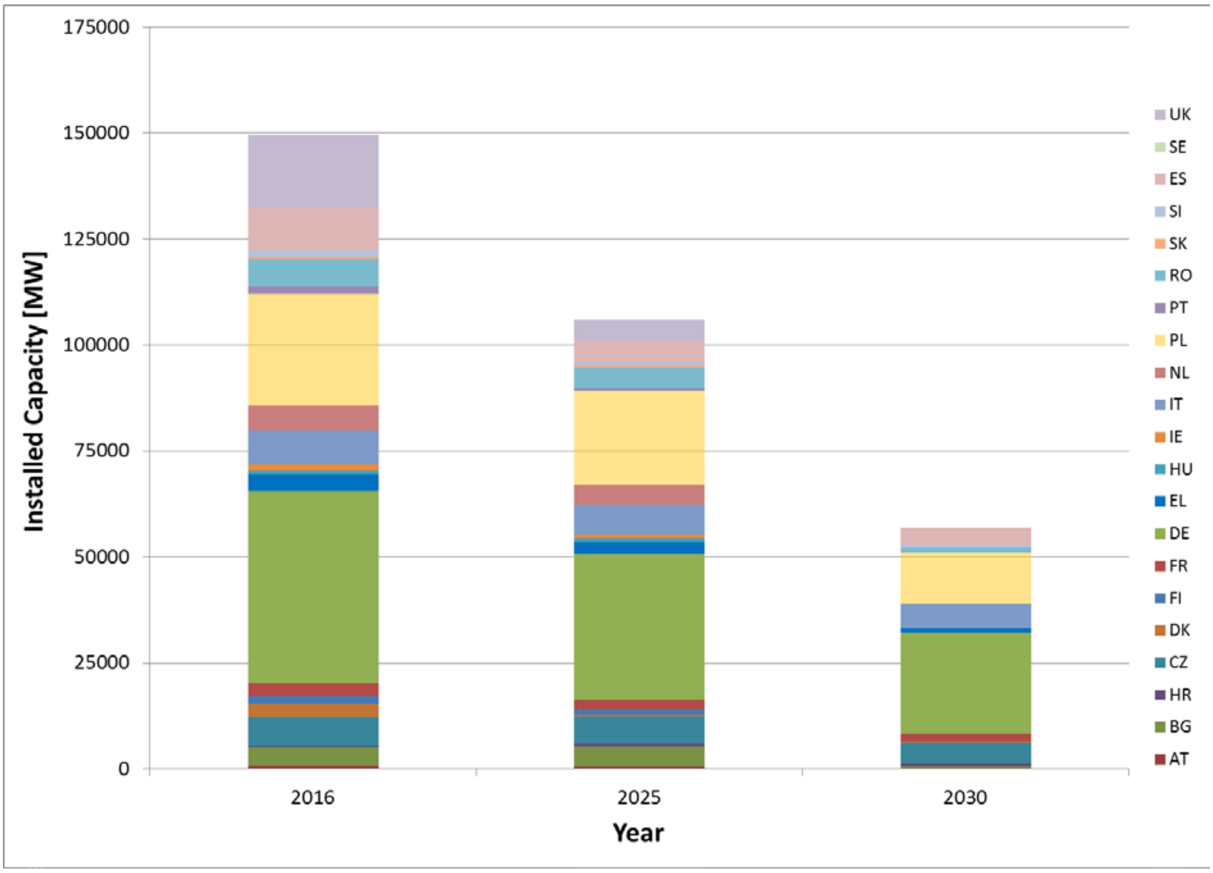
[40] Ten Year Network Development Plan 2016 (http://tyndp.entsoe.eu/)

[41] According to Article 32 of Directive 2010/75/EU on industrial emissions, combustion plants covered by the transitional national plan may be exempted from compliance with the emission limit values by 2020.

3.2.1 The TSO perspective on the installed coal capacity

TSO expectations on future coal-fuelled capacity through 2025 and 2030 were considered in the top down approach. The installed capacity data for 2025 were sourced from ENTSO-E's mid-term adequacy forecast issued in 2016 (MAF 2016), while 2030 installed capacity data were sourced from ENTSO-E's TYNDP - vision 4 scenario. Figure 25 presents the expected coal-fired installed capacity evolution in time, based on the aforementioned studies by ENTSO-E.

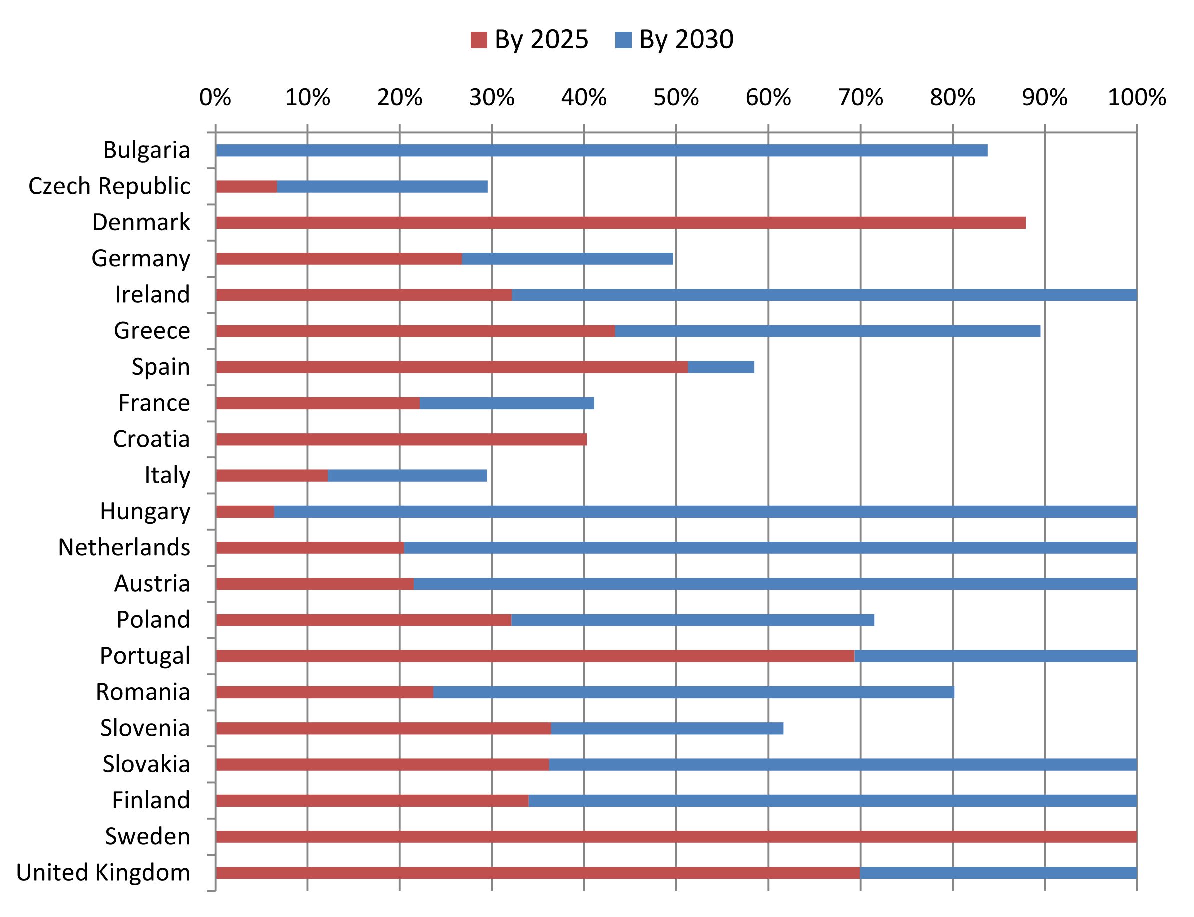
Figure 25 Installed coal capacity in 2025 and 2030 (ENTSO-E)



The JRC analysis includes a calculation for each country of the fraction of the current coal capacity due for retirement by 2025 and 2030. Coal power plants under construction (6.7 GW in total) are considered to be in operation by 2025. As Figure 25 illustrates, the expectation is that the total installed capacity would drop from 150 GW in 2016 to about 105 GW in 2025 and around 55 GW in 2030.

Calculated decommissioning rates of existing coal fired power plants per country are provided in the diagram in Figure 26.

Figure 26. Calculated decommissioning fractions for existing coal power plants



Calculated decommissioning rates are in some cases probably conservative, given the fact that scenarios are based on TSO analysis. This fact is highlighted by the example of the Italian energy strategy document, which addresses the impacts of a considerably faster decarbonisation path compared to what the above figures suggest for Italy, as presented in Box 2 below.

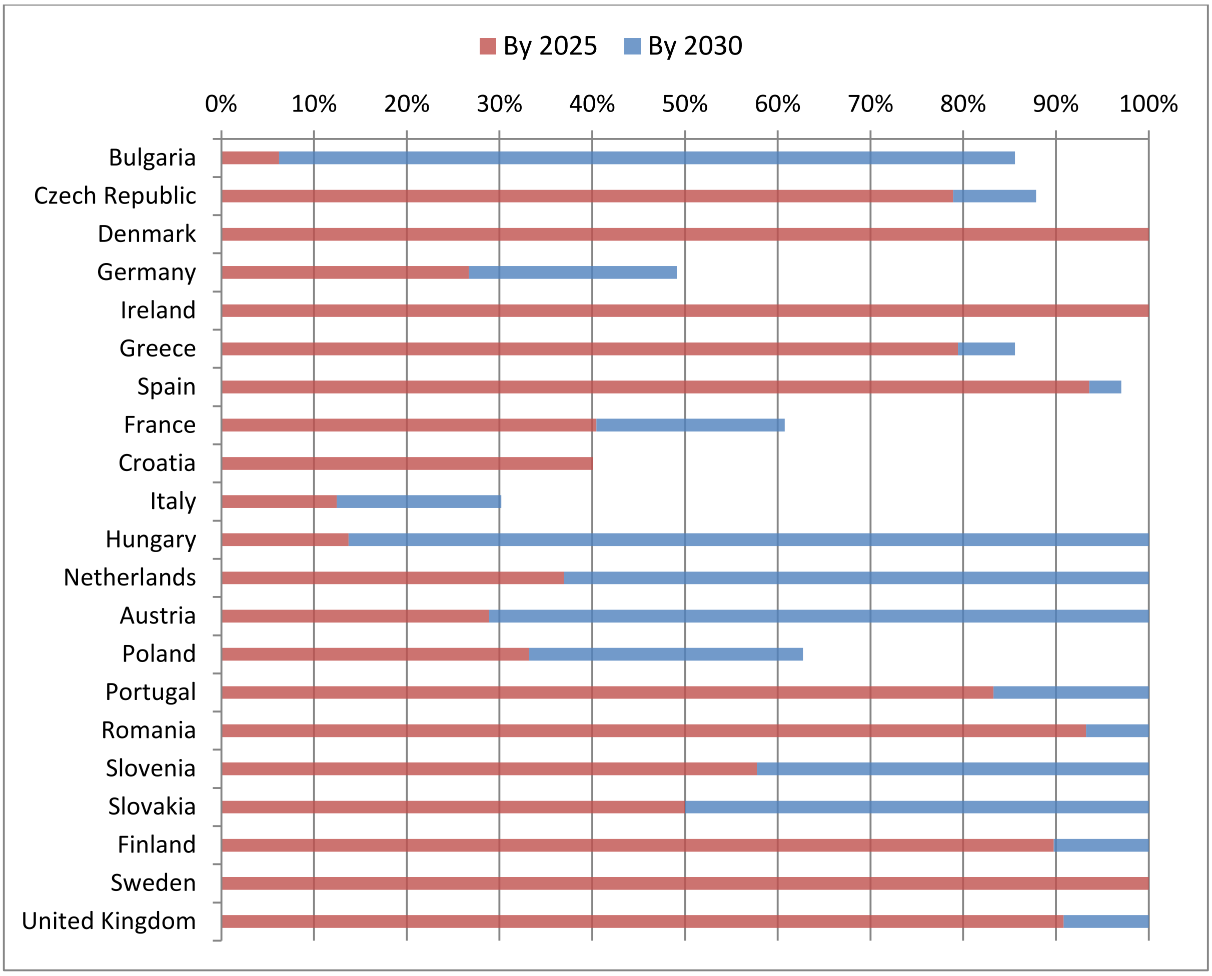
Box 2. The case of Italy

In their recently published Strategia Energetica Nazionale 2017 (Ministri Calenda e Galletti, 2017) the Ministry of Economic Development presented two decarbonisation scenarios beyond the business as usual scenario ("Scenario Inerziale"). In these two scenarios, the decommissioning of 5 GW (60%) and 8 GW (100%) of the country's coal fired installed capacity are presented together with the evaluation of associated investment costs (0.3 billion Euro) and (2.5 billion Euro) respectively. This level of decommissioning is significantly higher than the figure presented in the above figure (30% or 2.4 GW).

3.2.2 The effect of emission requirements

The bottom-up approach presented herein is based on the analysis of the data reported by Member States in their Transitional National Plans (TNP). In July 2017 the European Commission established the best available techniques (BAT) conclusions for large combustion plants[42]. Based on this document it could be assumed that in the case of withdrawal of power plants from TNPs, the closure process for old coal power plants may be faster as shown in Figure 27.

Figure 27. Decommissioning rates due to decommissioning by 2025 of powerplants in the TNPs (% from total installed capacity)



The analysis suggests that in the case of withdrawal of power plants from Transitional National Plans, Denmark and Romania would decommission all their coal power plants by 2030, as opposed to the top-down scenario (87% and 80% respectively). Czech Republic, Spain and Romania could withdraw a larger share of their power plant fleet earlier (2025) as opposed to the top-down approach. Greece and Poland would also face faster closure of coal power plants and the closure in 2030 would exceed estimations of the top down analysis by 2030.

Bulgaria, Ireland, Finland and the United Kingdom would also see faster retirement of plants, but would remain at the same level by 2030, while no effect would be seen in

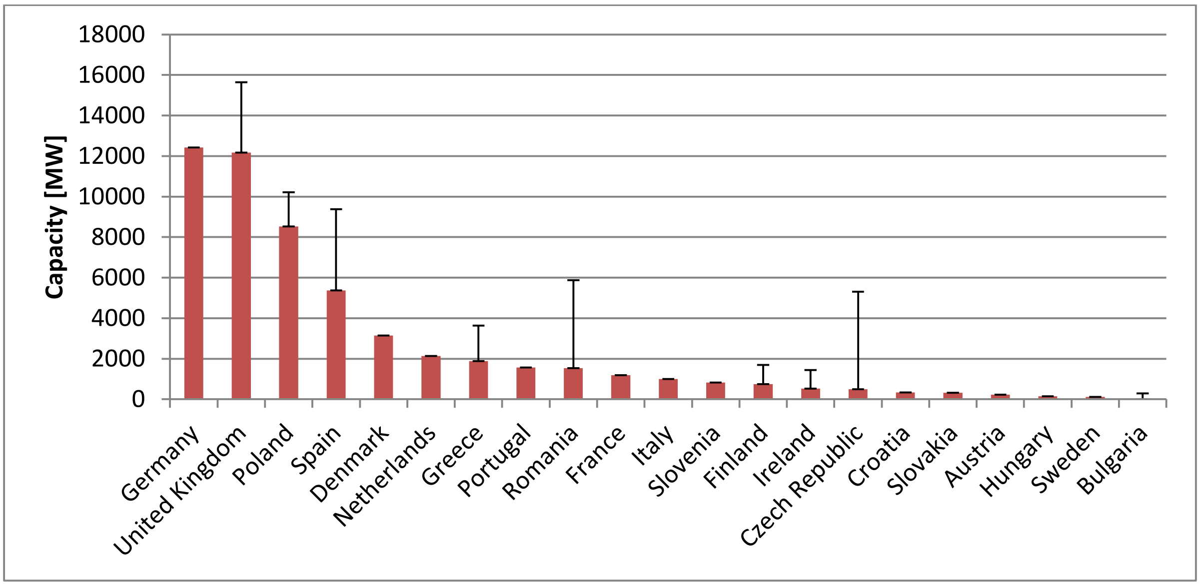
[42] COMMISSION IMPLEMENTING DECISION (EU) 2017/1442 of 31 July 2017 establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for large combustion plants

Denmark, Germany, France, Croatia, Italy, Hungary, The Netherlands, Austria, Portugal, Slovenia, Slovakia and Sweden.

The analysis in the following paragraphs is based on the time horizon introduced by the ENTSO-e studies. Namely it focuses on power plant retirements which may take place in two tranches. The first tranche includes capacity at risk (or likely to retire) by 2025, while the second tranche includes capacity at risk (or likely to retire) by 2030.

The results of decommissioning rates analysis at country level are presented in the following charts. The chart in Figure 28 provides the coal capacity due for retirement at national level by 2025.

Figure 28. Capacity at risk by 2025



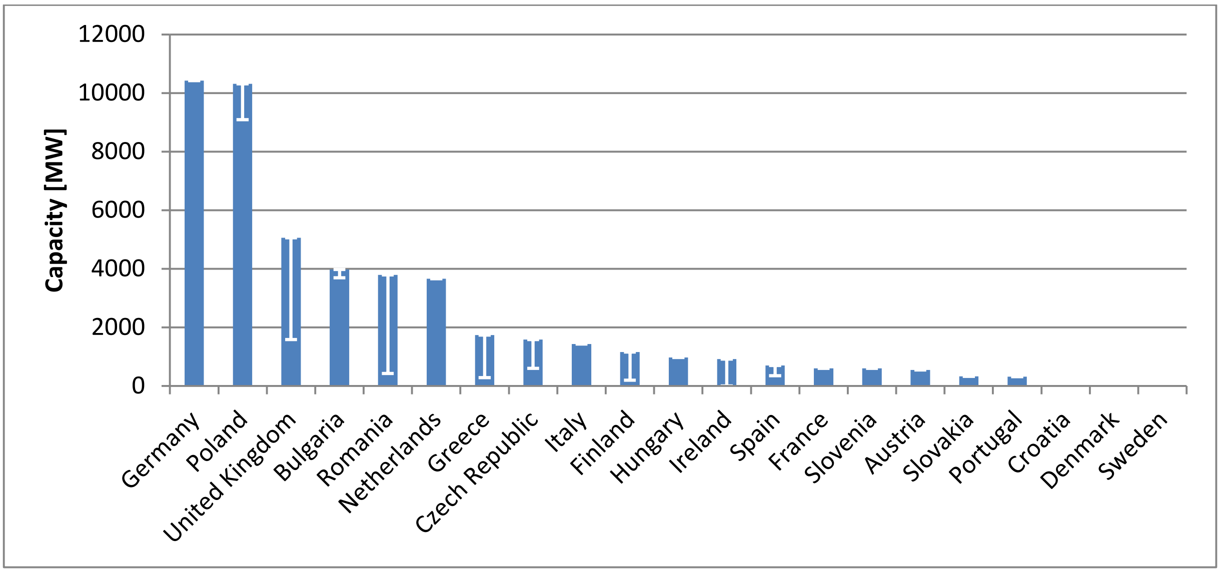
The solid bars provide the expected decommissioning based on the top-down approach, while the error bars on top provide the extent of possible accelerated retirement due to the applicable emission standards for large Combustion plants after 2020 according to Decision 2017/1442[43]

Germany and the United Kingdom rank very high in capacity likely to retire by 2025, followed by Poland, Spain and Denmark. A decommissioning scenario accelerated by emission requirements will mostly affect Spain, Romania, Czech Republic and Greece. The following Figure 29 ranks the countries based on the coal capacity likely to retire by 2030.

This would correspond to capacities which are expected to be decommissioned by 2030. Germany hosts most of these medium risk capacities followed closely by Poland, while the United Kingdom, Bulgaria, Romania and the Netherlands also have significant capacities which would fit in this category.

[43] Commission Implementing Decision (EU) 2017/1442 of 31 July 2017 establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for large combustion plants

Figure 29. Capacity at risk by 2030



As previously, the error bars provide the lower range of capacity likely to retire by 2030. It is basically the capacity that may be decommissioned earlier, due to an eventual decision by power plant operators not to proceed with the appropriate measures in order to comply with the applicable emission standards for large Combustion plants after 2020 according to Decision 2017/1442.

Given the significance of coal in European power systems there may be the impacts on security of supply. It cannot be precluded that some of this capacity will be maintained as strategic reserve.

Box 3. Coal power as stand-by reserve in Germany

With the phase-out of nuclear power by 2022, Germany still strongly relies on large coal-fired power plants. RWE plans the decommisioning of the Inden mine by 2030, currently extracting 15-20 million tonnes per year of lignite, which will lead to the decommissioning of 2 x 300 MW and 2 x 600 MW units at the power plant site Weisweiler.[44] At the same time, some power plants will be used as a stand-by reserve like in the case of 2 x 300 MW Frimmersdorf plant in the period 2017-2021, 2 x 300 MW Niederaußem plant in the period 2018-2022 and 1 x 300 MW Neurath plant in the period 2019-2023 (RWE, 2017). Expected annual costs of this stand-by reserve (klimareserve) at national level are 230 million EUR for the period of seven years (Deutscher Bundestag, 2016).

[44] https://euracoal.eu/info/country-profiles/germany/

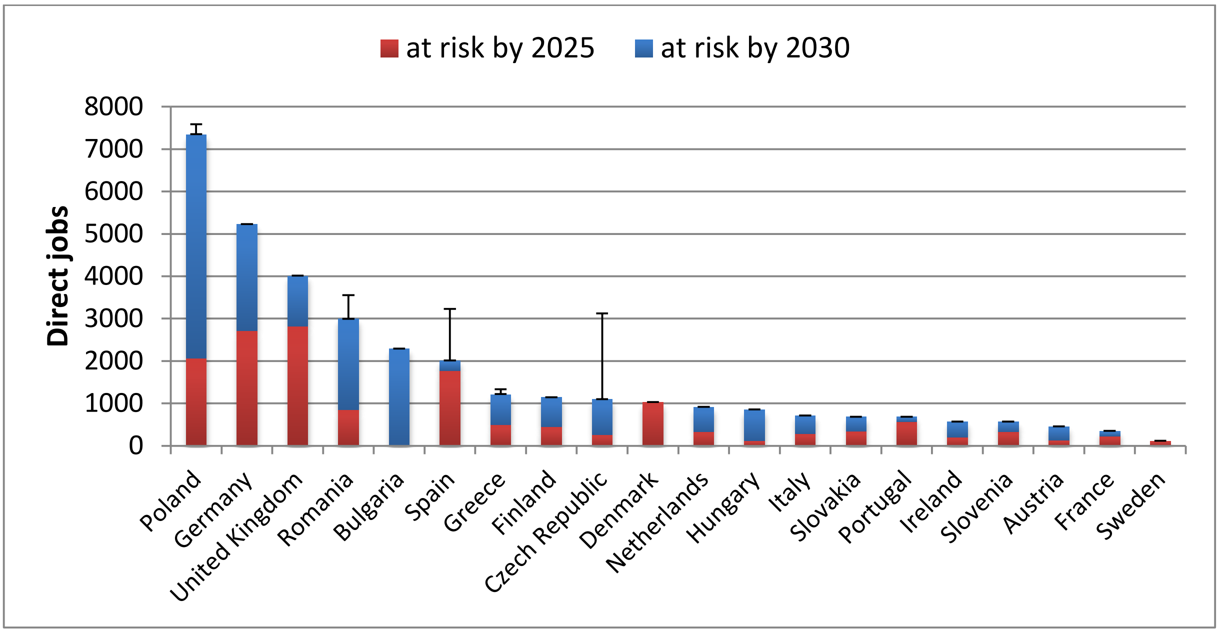
3.3 Impacts of coal power plant retirement on employment

In the previous paragraph the analysis exposed the level of coal capacity in each Member State that is likely to retire within the coming decade. In this section this is translated into direct job losses. Direct job losses are calculated based on country coefficients calculated in paragraph 2.3.1 and provided in Annex 6. These coefficients are directly applied on the capacity expected to be decommissioned and not replaced by new capacity under the assumption that plant personnel from decommissioned units are re-deployed to new power plants to meet the new employment needs (no productivity improvements are considered).

3.3.1 Risk for job losses in power plants at national level

The expected direct job losses in power plant operation due to coal fired power plant decommissioning in the coming decade could reach around 34 000 jobs, that is 64% of the estimated current employment in this activity. Approximately half of those (termed as "high risk") may be lost in the early 20's. The probable impact at country level is presented in the chart in Figure 30. As previously, the error bars provide the corresponding increase in job losses due to accelerated decommissioning caused by operators decisions not to proceed to the appropriate measures in order to comply with the BAT emission requirements.

Figure 30. Probable impact of power plant decommissioning on jobs at country level



The countries which will feel the highest impact from job losses are Poland, Germany, the United Kingdom, Romania, Bulgaria and Spain. It is also important to mention that the first wave of employees being affected is expected to be in the United Kingdom, Germany and Poland.

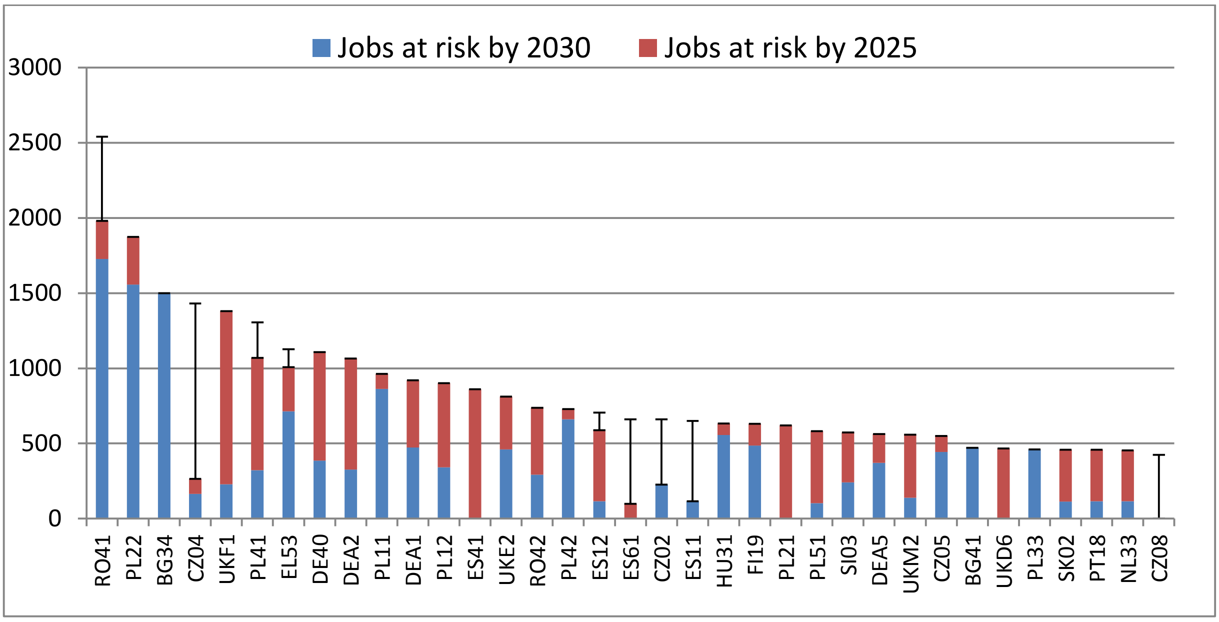
As mentioned previously, the top-down or TSO based approach fails to capture the probable extent of decommissioning which might take place in the Czech Republic and to a lesser extent Spain. Therefore if premature retirements are considered because operators don't retrofit their plants with appropriate exhaust after treatment in order to comply with the BAT emission requirements, Spain and the Czech Republic are expected to compete for the fifth place in the list of most affected countries.

3.3.2 Risk for job losses in power plants at the NUTS-2 regional level

In order to distribute the considered job loss potential to regions, the decommissioning rates calculated at country level are applied to the plant fleet in a "survival-of-the-fittest" assessment based on efficiency and age criteria. This was implemented by the following steps: first the units were ranked according to their estimated efficiency and age. Then the decommissioning rates applicable for each country (for 2025 and 2030) were used to classify the plants in three categories with regard to the possible retirement timing (post 2030, by 2030 and by 2025). The capacity in each category was then aggregated to the regional (NUTS-2) level in order to provide an indication of the number of jobs at risk, directly related to the operation of power plants in each region.

The probable impact at NUTS-2 regions level is shown in the chart in Figure 31 for the regions with the highest impact (loss of more than 350 jobs).

Figure 31. Probable impact of power plant decommissioning on jobs at NUTS-2 regional level



The results of the current analysis for all NUTS-2 regions are provided in Annex 12. The most affected regions, losing more than 1 000 jobs will be in Romania, Poland, Bulgaria, the UK and Germany: RO41 (Sud-Vest Oltenia), PL22 (Śląskie), BG34 (Yugoiztochen), UKF1 (Derbyshire and Nottinghamshire), DE40 (Brandenburg), PL41 (Wielkopolskie) and DEA2 (Köln). It is also worth mentioning that the first regions expected to be mostly effected with job losses are UKF1 (Derbyshire and Nottinghamshire), ES41 (Castilla y León), DEA2 (Köln), PL41 (Wielkopolskie) and DE40 (Brandenburg).

As previously, the error bars provide the impact on jobs if accelerated decommissioning occurs due to coal fired powerplant operators not proceeding with the appropriate measures in order to comply with the BAT emission requirements. The strongest impact difference compared to the top-down (TSO-based) analysis is observed in CZ04 (Severozápad).

3.4 The closure of coal mines

Lignite is used mainly for power and occasionally heat generation in power stations and combined heat and power (CHP) plants, constructed very close to the mine site (also referred to as mine-mouth power stations). Over 95% of lignite is consumed in power generation (Ernst & Young, 2014). The characteristics of this solid fuel make it unsuitable for trade unless the distances involved are very short - it deteriorates rapidly and its high water content makes it excessively expensive to ship (Ernst & Young, 2014).

As a result, the phase-out of coal fired-power plants will render unnecessary most lignite mines, leading eventually in the short-to-medium term to their closure. This can either be aligned with the decommissioning horizons of power plants (see previous section) or can occur due to the depletion of their reserves, or a lack of profitability and competitiveness.

Hard coal, on the other hand, is traded around the world and benefits from a wider range of applications, which includes the steel industry. Hard coal deposits can provide different coal qualities, including steam (also referred to as thermal coal, mainly used in heating and power generation) and coking coal used in the steel making process. At each mine, the extracted coal is processed in preparation plants[45] where it is graded as coking coal or steam coal, based on certain quality parameters. Although most hard coals possess the relevant properties for use in the steel industry, not all produce a coke of desirable quality (American Iron and Steel Institute, 2017). The properties of coals used in the steel-making process are tightly regulated given the effects of coking coal on the quality of the resulting steel (Coking Coal Factsheet, 2017). Information on the shares of steam and coking coal produced at each mine site are not readily available. Some sporadic data, mainly for Polish hard coal mines, are given in Table 10.

Table 10. Distribution of thermal and metallurgical coal shares in coal mines[46]

NUTS-2	Thermal coal (%)	Metallurgical coal (%)	Other types (%)
PL31	100		-
PL22	71.6	27	1.4
CZ08	11	89	-

As the table shows, in the Upper Silesian Basin within the region PL22, previously identified as one of the most impacted regions, 72% of hard coal produced is classified as thermal coal while the remaining 28% is a coking coal product recovered during the processing.

The tight linkage between steam coal and the power sector allows the anticipation of important losses in the asset value of low-quality hard coal mines as a consequence of changes in the EU power sector, under the energy transition. Coking coal usage in the steel sector, on the other hand, can provide new possibilities for extraction and prolonged years of life at least for some mines capable of producing high rank coals, with

[45] Coal preparation, which includes washing, cleaning, processing, and beneficiation, is the method by which mined coal is upgraded in order to satisfy size and purity specifications dictated by a given market (https://www.energy.vt.edu/NCEPStudy/.../Coal_Production_Demands_Chapter4.pdf)

[46] Elaborated based on information available from (Euracoal, 2017), (Prairie Maining Ltd, 2017) and (DG COMP).

consequent employment and distribution advantages, at least in conditions of growing prices.

Additionally to the above-discussed end market situation, developments in coal mining will depend as well on conventional competitiveness factors. Traditional coal basins hosting mines that have been operating for hundreds of years are becoming increasingly technically challenging and costly with many of them facing economic issues.

Box 4. The Murcki mine - one of the oldest Polish mines

The first reference to coal mining in the "Hill Murckowskim" dates back to 1657. At this time coal was mined in opencast operations. The formal establishment of the mine and the start of underground operations dates back to 1769. The mine was initially named "Blessing Emmanuel" ("Emanuelssegen") (Mining Atlas, 2017). Murcki is located in the Silesian region (PL22).

These problems seem to be amplified, by the fact that, under current policies, producers have been reluctant to invest in the modernisation of mining equipment as a strategy to increase productivity or in long-term production capacity through brown field exploration for the replacement of reserves.

As a result of changes in the EU power sector and also because of decreasing hard coal prices in international markets, many EU mines were closed over the past years while others have remained active only through valuable State Aid subsidies allowed under the EC Regulation No 1407/2002[47].

Box 5. Germany: Restructuring of German coal industry

In 2009, Germany notified the European Commission on State Aid to the coal industry related to the implementation of a restructuring plan for the period 2006-2010, approved in 2005. At the time, domestic hard coal production was less competitive than imported coal from countries such as USA, South Africa and Australia, due to high costs of mining at depths of 1 500 metres. The mentioned restructuring plan envisioned a gradual reduction of the financial aid to the mining industry from 2.6 billion EUR in 2006 to 2.1 billion EUR in 2010. The beneficiaries of the state aid were RAG AG, operating eight mines, and Bergwerksgesellschaft Merchweiler mbH with one mine (European Commission, 2009).

Box 6. Poland: Investment aid for hard coal

In 2009, Poland notified the European Commission on investment aid for the hard coal mining sector with the main objective of maintaining a minimum production of coal by guaranteeing access to reserves. The aid was granted for hard coal used to produce electricity, including CHP plants, to produce coke and to fuel blast furnaces in the steel industry. The amount of state aid totalled 100 million EUR. Eligible costs included "opening up deposits in new extraction levels or extension of existing levels, installing or modernising extraction or ventilation pits, purchasing or modernising mining machinery and equipment necessary in the operation process, building or modernising coal mechanical dressing plants and installing centralised or local air conditioning systems" (European Commission, 2010).

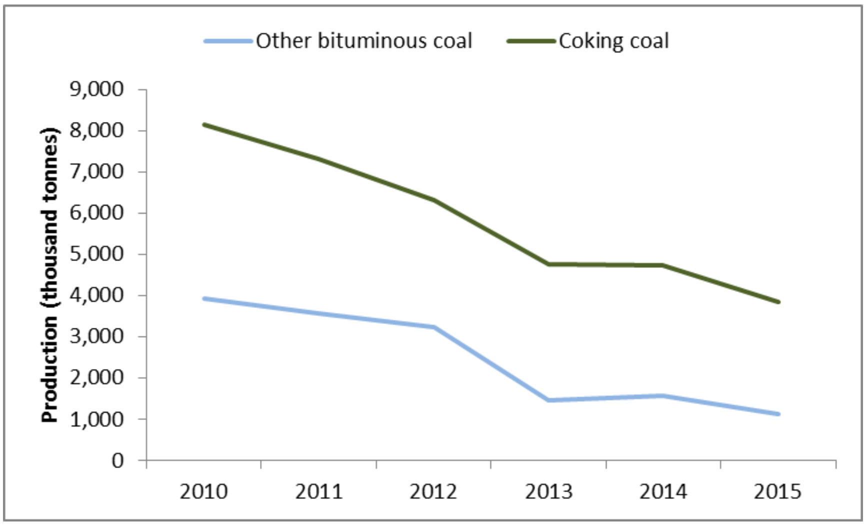
[47] This Decision was adopted with the aim of securing the supply of energy in the EU. It is no longer in force. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32002R1407

3.4.1 Recent and announced closures

Lately the aim of State Aid has switched to the closure of uncompetitive coal mines. Against the backdrop of the EU policy to encourage renewable energy sources and due to the small contribution of subsidised coal to the overall energy mix, subsidies to uncompetitive coal mines are currently being phased-out following the Council Decision 2010/787/EU[48]. Under this Decision, state support to the coal industry is only allowed to facilitate the closure of a mine.

This commitment, adopted at EU level in 2010, was previously assumed by Germany in 2007, which agreed on gradually phasing out long-term subsidies to uncompetitive hard coal mines, prior to their complete retirement by the end of 2018. This has led to declining production over the past years (Figure 32) and will likely result, at the end of the period, in the forced closure of many mines, currently benefiting from aid under the previous Regulation, without which are no longer profitable.

Figure 32. Production of hard coal in Germany in 2010-2015 – data from Eurostat[49]



Recently, also authorities in the Czech Republic (2014), Romania (2016), Poland (2015) and Spain (2012) have requested Aid measures designed to finance the closure of some uncompetitive mines. State Aid is intended to cover operational losses and exceptional environmental and social costs. It is based on an agreed closure plan.

Between 2014 and 2017, 27 mines were closed across Germany, Poland, the Czech Republic, Hungary, Romania, Slovakia, Slovenia and the United Kingdom. In 2018, 5 more will close in Germany, Poland, Romania and Italy (Table 11).

Within this timeframe, also Spain plans to close 26 mines.

[48] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32010D0787

[49] Other bituminous coal mainly refers to steam coal.

Box 7. Czech Republic: The closure of the Paskov mine

In 2014 the Czech authorities notified the European Commission on individual aid to the mining company OSTRAVSKO-KARVINSKÉ DOLY (OKD) for covering exceptional costs of the closure of the Paskov mine. 89% of coal produced at this mine is classified as coking coal, while the remaining 11% is a higher ash thermal coal product recovered during the processing. Due to an increased volatility of coking coal prices in the international markets since 2010 and after several unsuccessful internal restructuring initiatives taken by OKD, the Ministry of Industry and Trade of the Czech Republic and the owner company concluded an agreement in which the State would grant aid to the Paskov mine on the condition of a permanent closure by 31 December 2017. Total costs of paying social welfare benefits at this mine were estimated at about EUR 25 million. The State agreed to cover EUR 23 million and OKD EUR 1.9 million (European Commission, 2015). The production of hard coal at Paskov mine was terminated in 31st March 2017 (OKD, 2017).

Box 8. Spain: The closure of 26 mines

Following a major restructuring of the coal mining sector, in 2012 the Spanish authorities notified the European Commission on the provision of State Aid designed to finance the closure of 26 coal mines until 31st December 2018. In total EUR 2 129 million will be provided to cover both production losses (EUR 674 million) and exceptional costs (EUR 1 455 million). The beneficiaries of the public aid are the companies: Bierzo Alto, Carbones Arlanza, Carbones San Isidro y María, Carbonar, Carbones del Puerto, Cía Gral Minera de Teruel, Cía Astur Leonesa, Encasur, Endesa Generación, Hijos de Baldomero García, La Carbonífera del Ebro, S.A. Hullera Vasco Leonesa, Minera Catalano Aragonesa, Unión Minera del Norte and Hullera del Norte. (European Commission, 2016).

Table 11. Mines per NUTS-2 region that have closed or will close in the timeframe 2014-2018.

Closure plans	2014	2015	2016	2017	2018
CZ04			[Centrum]		
CZ08				[Paskov]	
DE40		[Cottbus-Nord]			
DE91			[Schoningen]		
DEA3					[Prosper-Haniel]
ITG2					[Carbosulcis]
HU21	[Márkusheg]				
PL22		[Kazimierz Juliusz], [Centrum], [Boże Dary], [Mysłowice], [Rozbark V]	[Jas-Mos], [Anna], [Makoszowy]	[Krupiński], [Śląsk], [Wieczorek I], [Pokój I]	[Wieczorek II]
PL21		[Brzeszcze – Wschód]			
RO42		[Petrila]		[Paroseni], [Uricani]	[Lupeni], [Lonea]
Sl03	[Rudnik]				
SK02				[Cigel]	
SK03		[Modry Kamen]			
UKE3		[Hatfield]			
UKE2		[Kellingley]			
UKF1		[Thoresby]			

3.4.2 Performance of operating mines

This section attempts to provide an estimation of the competitiveness of active coal mines, by looking at a group of indicators for which information is more readily available. These can reflect the costs of extraction, incorporate the sensitivities of the end-use sector/s, and reflect the magnitude of the mining resource. This is a necessary step in the assessment of forthcoming mine closures.

Coal production costs are mainly affected by the geological characteristics of the deposits. Therefore, relevant cost effectiveness metrics usually consider the impacts of stripping ratios in the mine performance[50]. Mines with lower stripping ratios usually demonstrate a better performance, as coal production is achieved with fewer excavations as indicated for example by (Ernst & Young, 2014). Additional findings of (Ernst & Young, 2014) demonstrate that in the EU, for a representative sample of lignite mines in Eastern Europe and the Balkans[51], production costs range from 5.1 to 20.3 EUR per tonne, and that mining companies with the lowest performance operate with a higher number of employees.

Lignite quality was also found in the above-mentioned study to be of dominant importance, influencing the mining performance by heavily affecting the cost effectiveness of the mines. It was also found that the mines with an average low calorific value from approximately 4 602 to 17 572 KJ/Kg had a range of production cost of 0.77 to 2.49 EUR/GJ (Ernst & Young, 2014). On the other hand, according to (IEA ETSAP, 2014), in Western Europe, lignite supply costs are estimated at 0.5EUR/GJ.

Some of these criteria influencing the competitiveness of EU coal mines were assessed with the purpose of establishing risk ratings for the coal regions hosting mining activities. The indicators and arguments for the analysis are given below. Their ranking followed a one to three point assessment scale.

- Mine productivity – In order to assess the productivity in mines, the metric of annual production per employee was evaluated across the NUTS-2 regions. The resulting numbers presented in Figure 11 were used to organise the regions into five classes[52]. The highest attribute (3) was given to the least productive while the lowest score (1) was allocated to the more productive mines. Due to its impact in cost-effectiveness metrics, mine productivity ranks were assigned a weight of 2 in the overall risk assessment.

For reference purposes, an average productivity of mines in the US was obtained, using information available at (Administration, U.S. Energy Information, 2016). In the US the average productivity of coal mines is 9 183 tonnes/person employed. From this, one can infer that the US mines are on average more competitive than most EU mines, with exceptions located in Germany and Greece.

- Type of coal produced – types of coal broken down into lignite or brown coal and hard coal were used as benchmark for competiveness. Hard coal has a higher price in comparison to lignite, and this is highest for anthracite. For example average sale prices in 2011 were: 70 EUR/tonne for anthracite, 63 EUR/tonne for hard coal, 13 EUR/tonne for brown coal and 17 EUR/tonne for lignite (IEA ETSAP, 2014). For this reason, lignite and brown coal mines were given the highest possible rank in terms of risk of closure (3); hard coal mines were given the lowest (1). The ranking did not take into account national policy regarding security of energy supply.

- Mine sub-type – surface and underground mining – stemming among other aspects from the fact that surface mining methods recover a higher proportion of the deposit than underground mining - 90% and above according to the (World Coal Association, 2017) - surface-mined coal is normally cheaper than underground-mined coal (IEA ETSAP, 2014). In this way, underground mines pose in general more significant economic challenges and were given a higher risk rating (3).

- Mine depth – although mining costs vary substantially depending on factors such as the seam thickness, stripping ratio and mining techniques[53], deeper mines are in general more costly (IEA ETSAP, 2014). As a result, highest depths (above 1 000 m) were given

[50] In mining, stripping ratio refers to the ratio of the volume of overburden (or waste material) required to be handled in order to extract a certain tonnage of the valuable mineral or ore.

[51] The study covers 201 Mt of lignite production the equivalent of 46% of EU total lignite production. Countries for which information is available include Poland, Greece, Bulgaria, Romania, Slovakia, Hungary.

[52] Annex 13 provides the relevant criteria for the classification.

[53] Relevant cost effectiveness metrics should consider the impacts of stripping ratios. JRC-CMDB offers some information on this parameter which however is insufficient to derive an indicator.

the highest risk rate (3) while surface mines (< 200 m) were given the lowest possible rank (1).

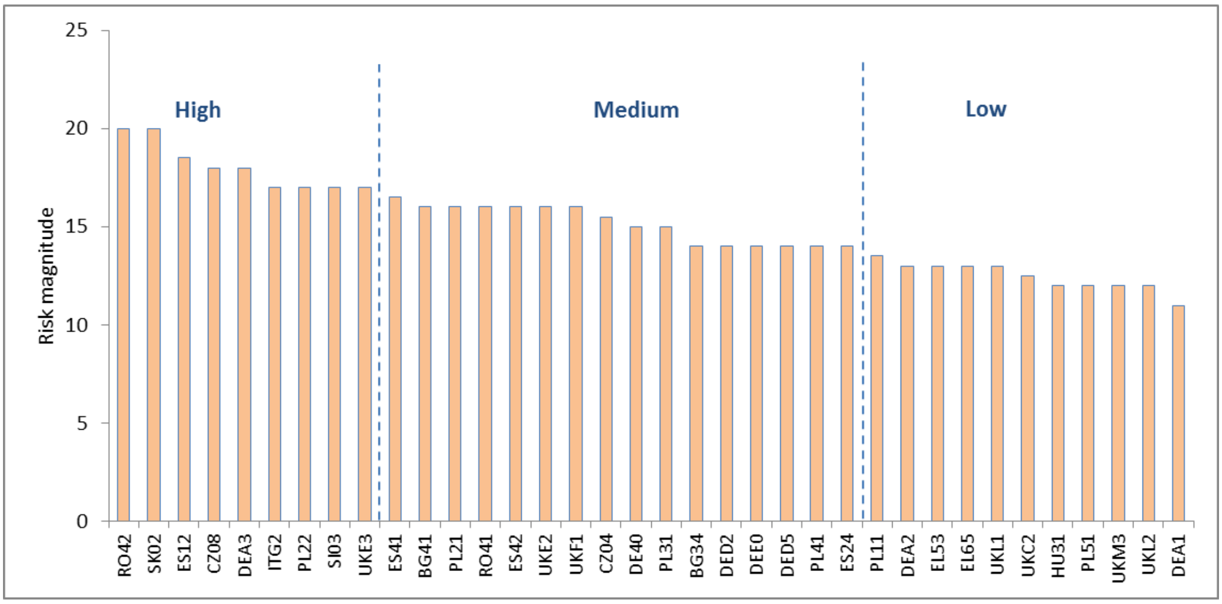
- Resources to production ratio[54] – the remaining amount of the mining resource calculated based on current production levels and expressed in years, was also used as criteria for the performance assessment. Higher ratios representing over 50 years of lasting resources, were given a lower risk rating (1). Besides providing an indication of the size of the deposit, this metric can also expose the magnitude of exploration efforts made to prolong the life of mine.

- Coal quality – the average coal quality measured in terms of calorific value (KJ/Kg) and obtained from Euracoal country-level statistics disaggregated for lignite and hard coal [55], was also used as performance criteria. An average lower calorific value of <15 000 KJ/Kg was given a higher rank (3).

- Closure plans in place – this was qualitatively assessed mainly based on information available from DG-COMP on State Aid allowances to facilitate the closure of uncompetitive coal mines. Regions hosting mines that will be closed until 2018 were rated highly (3).

For each region an overall risk was determined by adding the results of each indicator. The ceiling for the analysis is 24 and the lower limit is 8. Figure 33 presents the results of this analysis.

Figure 33. Risk rating of coal mining regions, obtained from multiple criteria discussed in the text[56].



The graph shows that the following regions in Romania, Slovakia, Spain, Czech Republic, Germany, Italy, Poland, Slovenia and the United Kingdom (RO42, SK02, ES12, CZ08, DEA3, ITG2, PL22, SI03, UKE3) are assigned, in decreasing order, a higher risk rating (equal and above 16.5). Least risky regions include (DEA1, DEA2) in Germany, (PL11 and PL51) in Poland, (EL65, EL53) in Greece, (UKL1, UKC2, UKM3, UKL2) in United Kingdom and (HU31) in Hungary.

[54] The Reserves-to-production ratio (R/P) is the remaining amount of a non-renewable resource, expressed in time. R/P ratios represent the length of time that remaining reserves would last at a given production rate. In the present case, resources estimates at operating mines were used instead. These data was consulted from SNL, representing reported quantities by profiled companies in a given year and includes reserves.

[55] See Annex 4 for details.

[56]. The data that underpin the graph content is given in Annex 14.

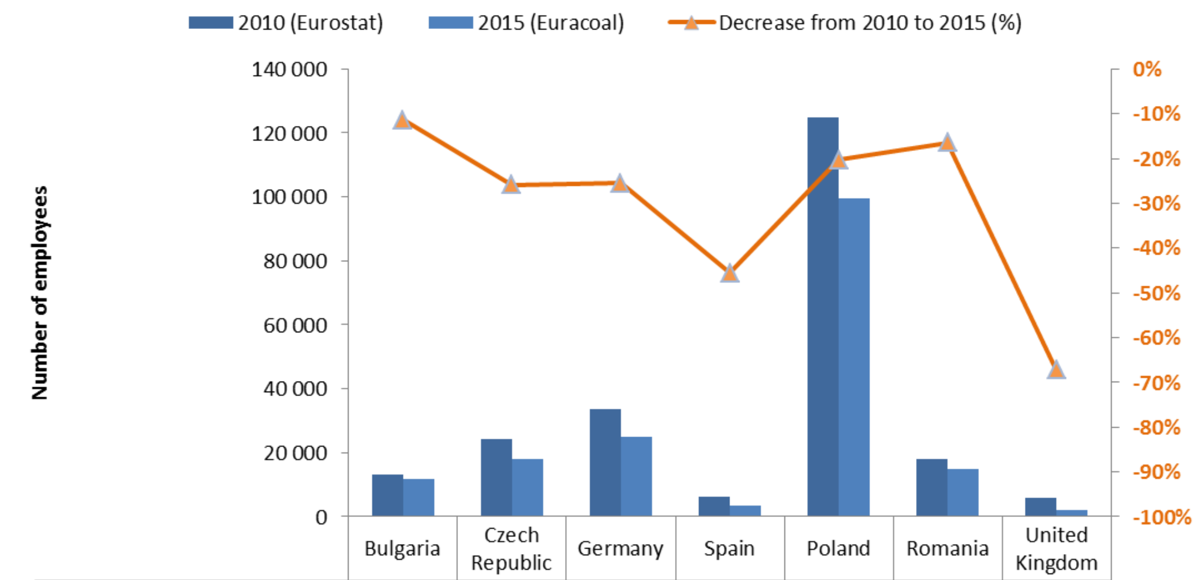
Box 9. Establishing risk ratings for the coal regions hosting mining activities

It is based on the assessment at NUTS-2 level of some criteria influencing the competitiveness of EU coal mines. The indicators and arguments for the analysis are given in the text and include mine productivity, type of coal produced, type of mine operation, mine depth, resources to production ratio, coal quality and the existence of closure plans. The ranking of the regions hosting mining infra-structure followed a one to three point assessment scale. The lowest scores (1) were given to the regions exhibiting better performance in terms of a specific indicator, while higher ranks (3) were allocated to those indicators showing a less competitive position. For each region an overall risk was determined by adding the results of each indicator. The ceiling for the analysis is 24 corresponding to the highest possible rank in terms of risk of mine closure. The lower limit is 8, reflecting a more competitive position of the mines in the region and therefore a decreased risk of closure.

3.5 Impacts on employment of coal mine closures

Changes to the mining sector, namely the closure of coal mines driven by the energy transition, are largely uncertain. It is however evident that the sector already faces significant employment losses at least since 2010, as shown in Figure 34 below.

Figure 34. Evolution of the number of employees within the coal mining sector from 2010 to 2015 and percentage of decrease in the same period – data from Eurostat in 2010 and Euracoal in 2015[57].



	Bulgaria	Czech Republic	Germany	Spain	Poland	Romania	United Kingdom
2010 (Eurostat)	13 300	24 300	33 700	6 100	124 900	18 000	6 000
2015 (Euracoal)	11 800	18 000	25 100	3 300	99 500	15 000	2 000
Decrease from 2010 to 2015 (%)	-11%	-26%	-26%	-46%	-20%	-16%	-67%

The employment trends presented above show that Spain and the UK account for the largest decrease of mining employees in the period from 2010 to 2015 (-46 and -67% respectively). On the other hand, the reduction in the workforce in the same period has been lowest in Bulgaria (-11%) and Romania (-16%).

While the current total number of mining workers is around 185 000, it is estimated that 59% of these positions may face a high risk of redundancy, due to an uncompetitive position of employing mines, which therefore pose a higher risk of closure.

Table 12 summarises the number of jobs exposed to high, medium and low risk with regards to a potential closure of coal mines based on the risk analysis presented above (see Figure 33).

Table 12. Estimated number of mining jobs (rounded) in NUTS-2 regions classified according to risk factor.

High risk	Medium risk	Low risk
109 000	53 300	22 600

Future developments in the coal mining sector may consider as well the perspective of opening new mines, in particular those targeting high rank products. These can represent new production capacities and employment in the short to long-term.

[57] Note: data from Eurostat in 2010 is not available for Greece, Italy, Slovenia and Slovakia.

In the short term, mines currently under construction or in preproduction stages could offer these advantages. However, to our knowledge, the only coal mine in EU in this stage of development (in the United Kingdom) is currently inactive (SNL Metals & Mining, 2017)[58].

Similarly, coal exploration activities are not abundant in the EU. There are some ongoing projects, in various development stages in Czech Republic, Poland and United Kingdom (Table 13) If successful, they can represent new capacities and employment opportunities within the next 10 years, which is the average timeframe to develop a mining project from exploration to construction.

Table 13. Active coal exploration projects in the EU, according to (SNL Metals & Mining, 2017)

Country	Number of projects	Development Stage/s	Reserves & Resources (million tonnes)	Total In-situ Value (M EUR)
Czech Republic	1	Reserves Development	1 600	89 777
Poland	5	Reserves Development; Prefeasibility/Scoping; Feasibility Started	2 315	129 925
United Kingdom	3	Target Outline; Prefeasibility/Scoping	111	6 228

One of the most advanced projects is located in eastern Poland - The Lublin Coal Project. The project is developed by Prairie Mining, which have demonstrated potential for thermal and semi-soft coking with a resource estimate of 1.6 billion tonnes (Mining Atlas, 2017).

[58] Data from SNL was assessed in May, 2017. Resources are presented by SNL as reported by profiled companies in a given year and include reserves. SNL breaks down the mining development phases into three top-level stages, defined as follows: Early-stage (includes grassroots, exploration and target outline) - a project without a defined resource estimate; Late-stage (split into reserves development, prefeasibility/scoping and feasibility either started or completed) - a project with a defined resource that has not yet reached a production decision.

3.6 The influence of power plant decommissioning on mine closures – assessment of impacts on overall direct employment

The previous section presented the total number of mining jobs that could be lost due to mine closure in regions exposed to mine competitiveness risks. In section 3.3.2 a range for the possible impact on power plant employment at NUTS2 level due to the decommissioning of coal -fired power plants, was also given. This section brings together these findings, providing a temporal dimension to potential job losses in coal-related activities, under the main assumption that coal-fired power plant decommissioning will be the main driver for mine closures in the future, independently of their competitiveness.

3.6.1 Methodological details

A methodological procedure was developed to estimate the number of job losses in coal mining within a temporal dimension dictated by the coal power sector between 2020 and 2030.

Since not all types of coal produced in European mines are used in power generation, a factor determining the degree of dependency between mining and power activities was obtained ("dependency factor") which guided subsequently the analysis performed at regional level.

The respective dependency factors for each of the five types of coal attributed to mining activities in the EU are given in Table 14. A dependency factor of one means that mining jobs are directly affected by power plant operation. A value of zero means that mining jobs are not likely to be affected by the decommissioning of power plants in the region.

The coal products considered range from lignite, almost entirely consumed in the power sector, to coking coal and anthracite hardly used in electricity production (see chapter 4). Therefore, for lignite, a dependency factor of 1 was assumed, while on the other hand, coking coal and anthracite were assigned a factor of zero.

Table 14. Factors used to estimate the degree of dependence between coal mining and power generation based on the type of coal extracted at each mine site.

Case	Type of coal	Dependency factor
1	Lignite	1
2	Hard coal (including thermal and coking coal)	1-(coking coal share)
3	Anthracite	0
4	Coking coal	0
5	Thermal coal	1

As for hard coal (case 2, Table 14), which can be graded by quality during processing, into thermal (used in power generation) and coking coal (used in the steel industry), the estimation of the dependency factors demanded that the share of coking coal recovered from hard coal mines, was taken into account.

For data availability reasons, the average country shares provided in section 4 (Table 16) were used instead of mine-specific data. Values between 0 and 1, calculated as 1 minus the national coking coal share were assigned to the regions where hard coal is extracted and used as fuel in power plants.

Until 2020 potential job losses are mainly linked to the coal mining sector, following closures already announced of mines currently benefiting from State Aid (see section 3.4.1).

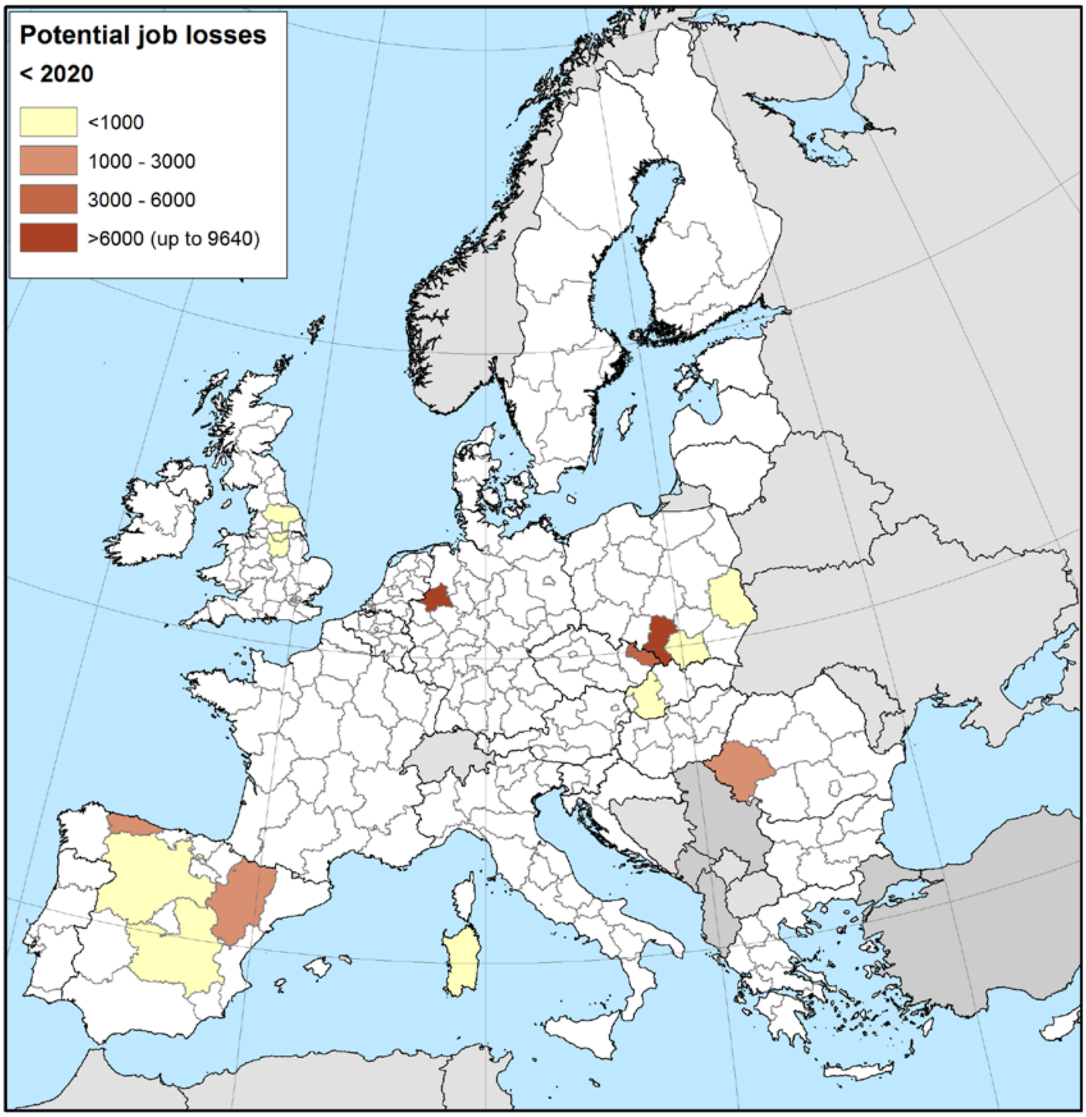
During the next decade impacts will occur on both mining and power plant jobs. Between 2020 and 2030 these losses were estimated based on the decommissioning rates of power plants by 2025 and by 2030 as discussed in the previous section and presented in Figure 26 and Figure 27. For the overall assessment pursued in this section, these rates were also applied to the direct jobs in coal mining to the extent of the dependency found between the mining and the power sector. These were applied to the workforce remaining after 2020.

3.6.2 Potential job losses over time

Potential job losses over time were calculated at NUTS-2 level as the sum of power plant and mining job losses.

Until 2020 the regional distribution and size of these potential losses are given in Figure 35.

Figure 35. Potential job losses until 2020.



The map shows that until 2020 employment losses will be higher in Germany (DEA3, Münster), up to 9 600. It is expected that hard coal mines in DEA3 will face a high risk of closure after the removal of valuable subsidies. Also, in Poland (PL22, Silesia), about at least 6 300 jobs have been lost since 2015.

Two thirds of the estimated current coal mining workforce (128 out of the 185 thousand jobs) could be directly affected by the power sector during the next decade. The amount of potential losses based on the decommissioning of power plants and direct spill-over effects in coal mining between 2020 and 2030, are given in the maps on Figure 36 and Figure 37.

Figure 36. Potential job losses in 2020-2025.

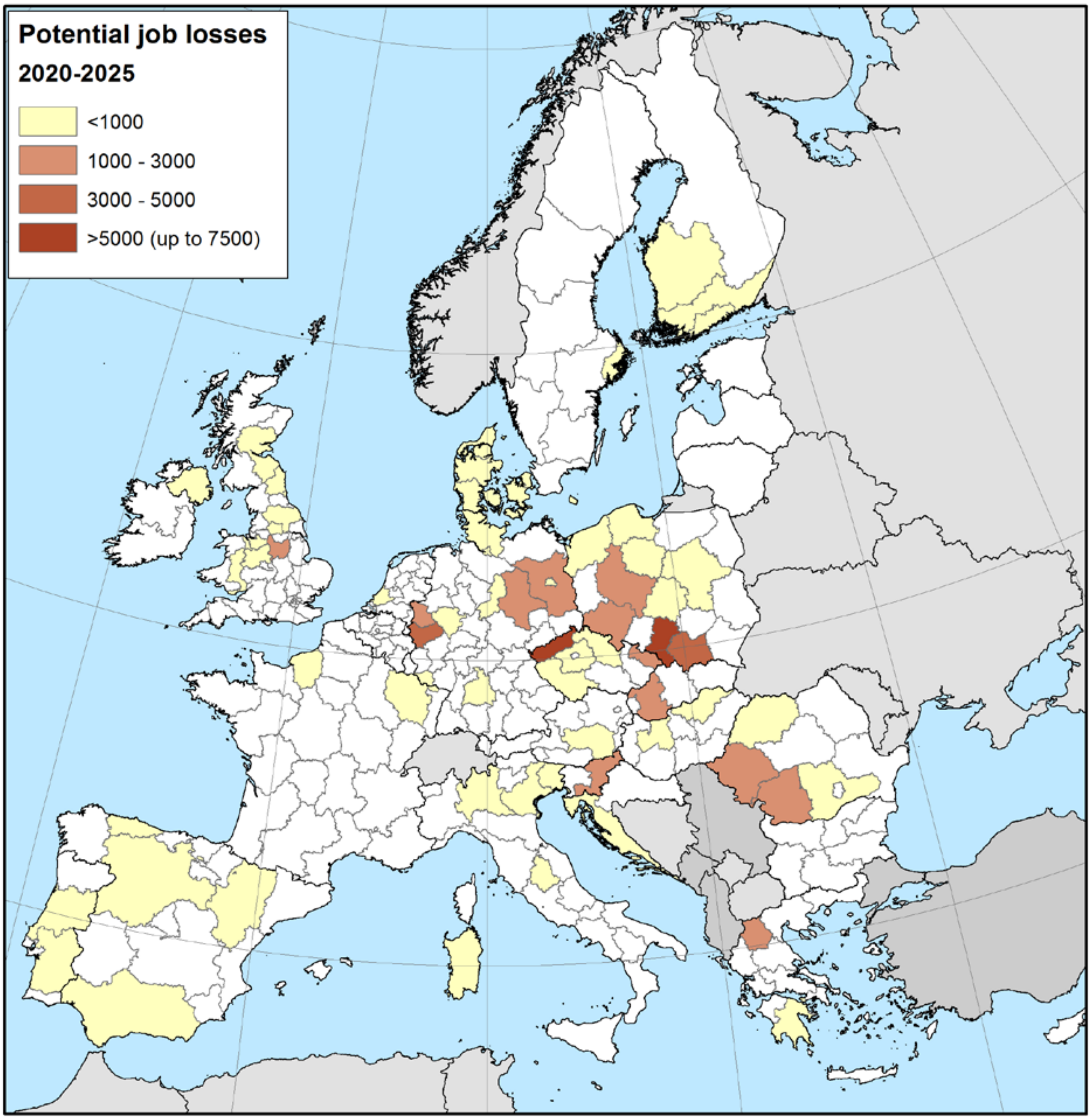
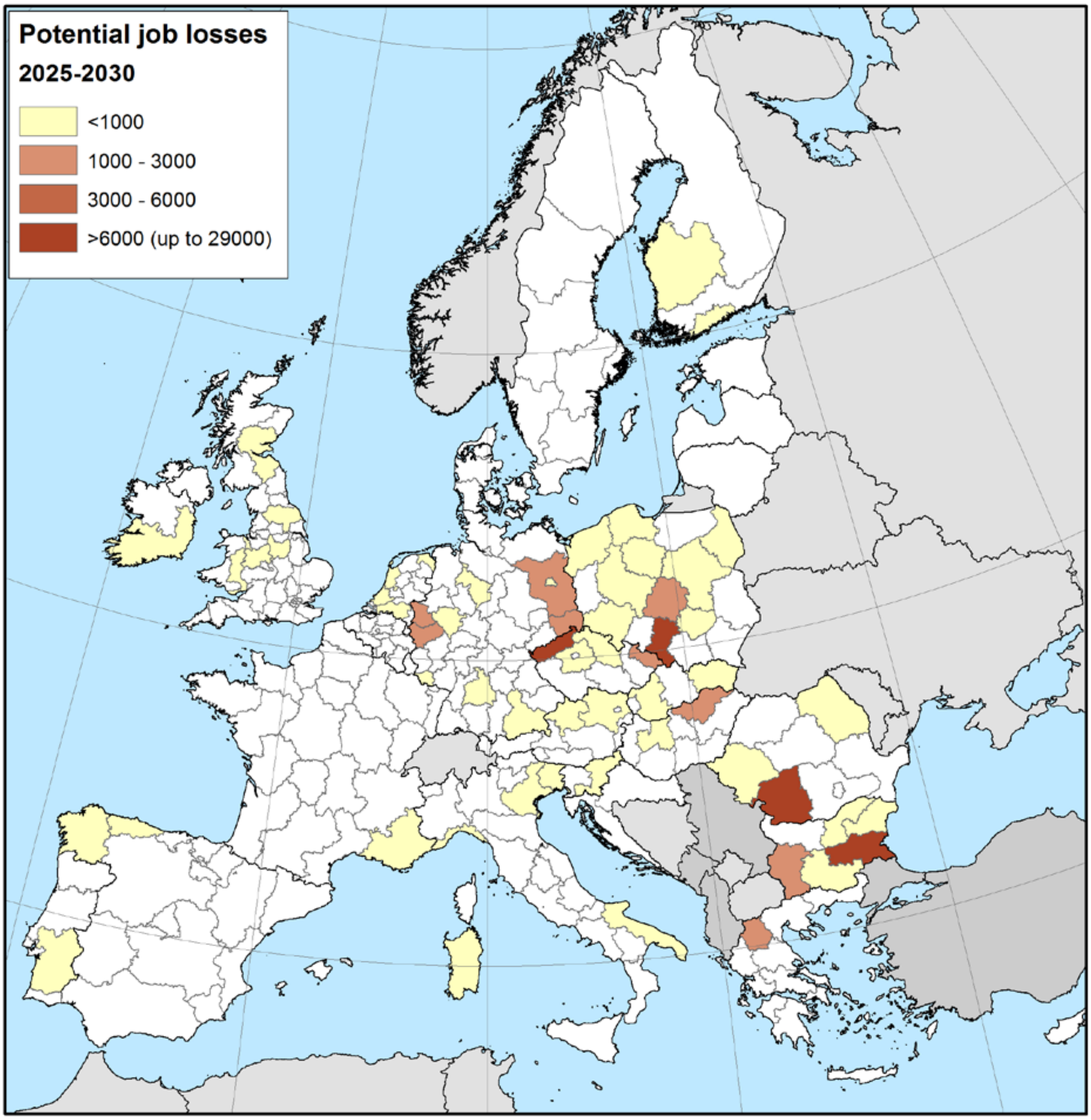


Figure 37. Potential job losses in 2025-2030.



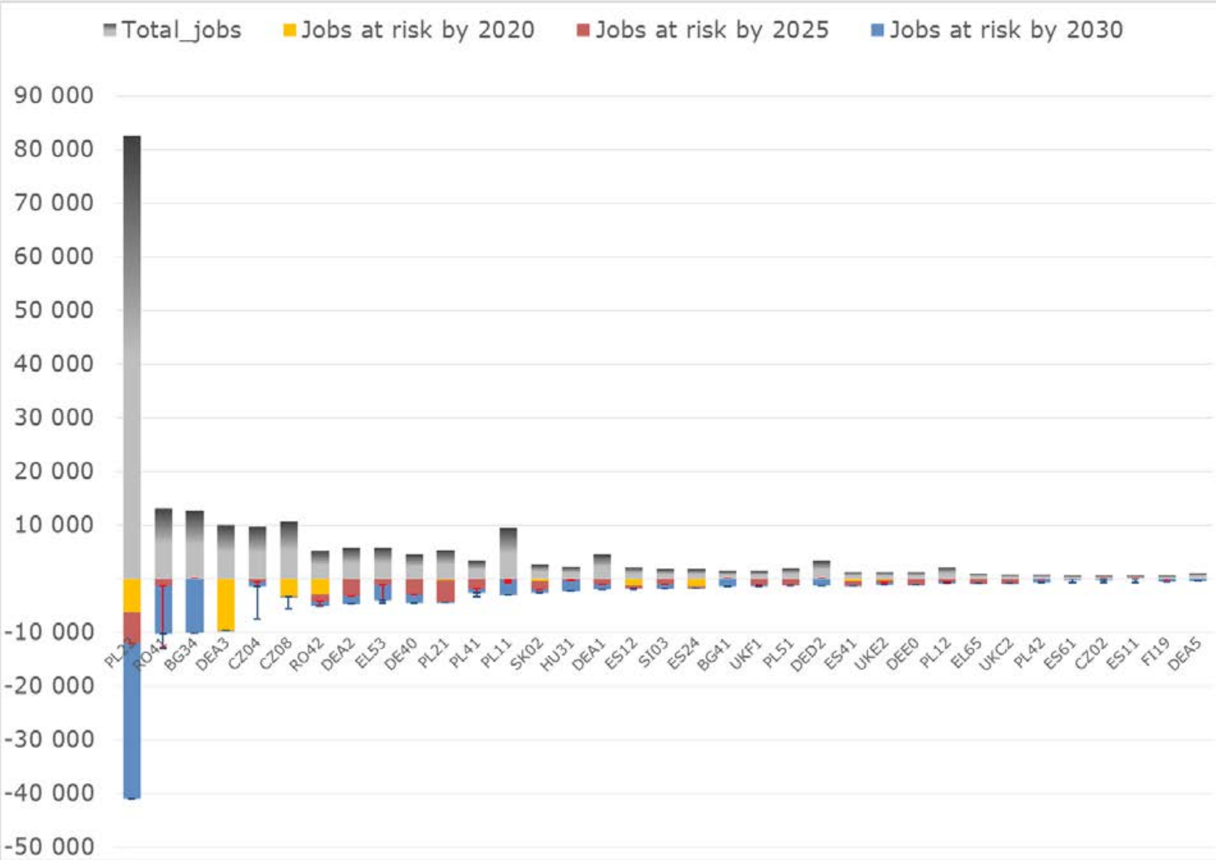
Between 2020 and 2025, most significant job losses are expected in the Czech Republic (CZ04 and CZ08), Poland (PL22 and PL21) and Germany (DEA2 and DE40) with above 2 000 potential losses each. Between 1 000 and 2 000 positions can also become redundant in several other regions located in Poland, Slovakia, Romania, Greece, Germany, the UK and Slovenia.

Between 2025 and 2030, the regions PL22 and BG34 can host the highest number of potential jobs losses in power plants and mines, up to 39 000 in total. In addition several other regions in South-eastern Europe can potentially be highly affected.

3.6.3 Potential job losses against total employment in coal activities over time

Figure 38 presents the potential employment losses against the total current employment in coal activities in each region. Coal jobs at risk by 2025 are portrayed with a red bar and by 2030 with a blue bar. The current total coal related jobs are given in grey.

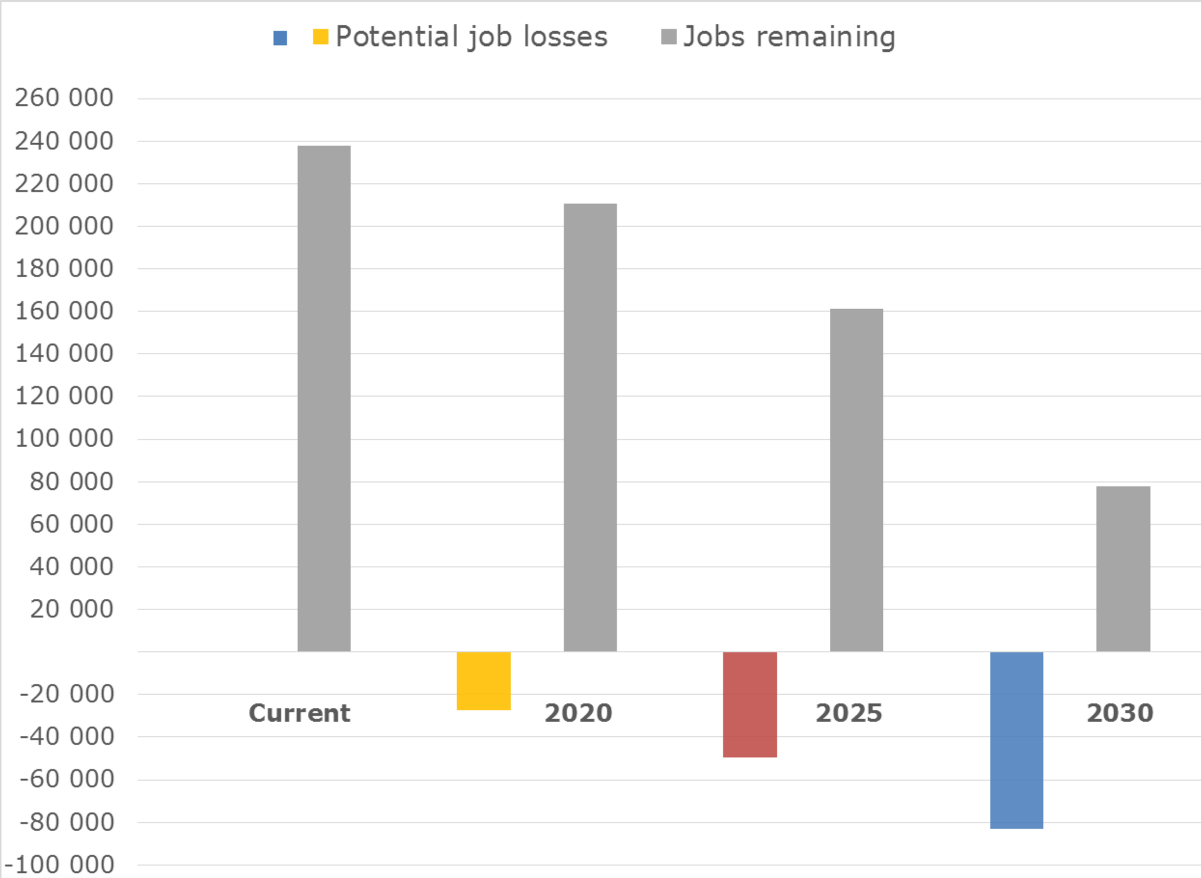
Figure 38. Employment and jobs at risk in the coal sector at regional level



Several regions are expected to be particularly hard hit by the transition: one region in Poland may lose up to 40 000 jobs (approximately 50% of the total in that region), and a further three located in the Czech Republic, Romania and Bulgaria look likely to lose more than 10 000 jobs each. On average the jobs at risk in these regions represent 32% of the total direct coal employment today.

Figure 39 shows the potential evolution of coal employment in the EU. Out of the total estimated current workforce of 238 000, 12% (or 27 000 jobs) are expected to be lost by 2020, another 20% (49 000 jobs) by 2025 and another 35% (83 000 jobs) by 2030.

Figure 39. Possible employment evolution in the coal sector



Assuming the forecasted reduction of coal activities takes place, approximately one third (around 78 000) of the current estimated workforce may still be employed in the coal business after 2030.

3.7 Socio-economic situation of impacted regions

A socio-economic analysis of the regions currently relying on coal activities was performed with the aim of establishing the magnitude of the economic and social impacts emerging from the decommissioning of the coal infrastructure. The criteria used for the analysis includes the gross domestic product (GDP), the unemployment rate and the share of jobs at risk within the economically active population.

3.7.1 GDP in coal regions

Regional GDP represents an economic value which has been produced in the region and is calculated as the sum of consumption, governmental spending, investments and net export of the region. The value GDP/capita is usually used for comparison of economic power of different regions or countries. In this particular analysis, the GDP index defined as $\frac{\text{GDP/cap(NUTS2)}}{\text{GDP/cap(country)}}$ was used for comparing the economic power of the region with the national one. Regions where this GDP index is above 1 are richer than national average and those where the value is below 1 are poorer than national average. Figure 40 presents the GDP index in regions with coal power plants and mines while Table 15 contains a statistical summary of the GDP index in regions with and without coal power plants and/or mines.

Figure 40. GDP index in regions with coal mines

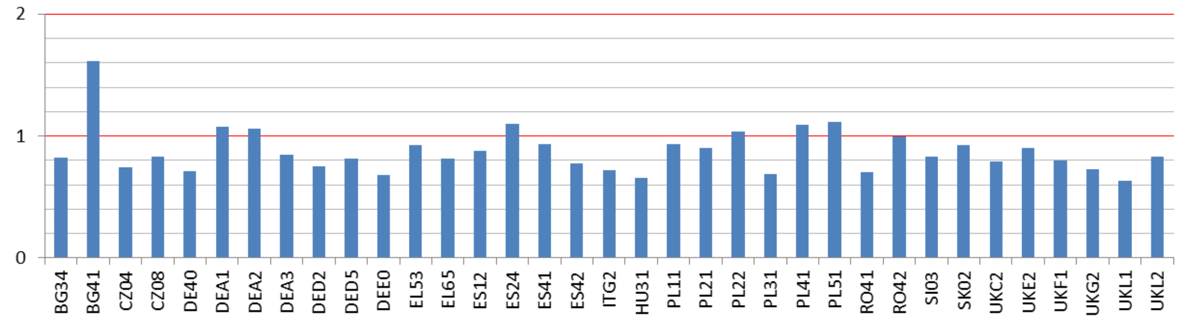


Table 15. GDP index basic statistical analysis

GDP index $\frac{\text{GDP/cap(NUTS2)}}{\text{GDP/cap(country)}}$	Minimum	Average	Maximum
Regions with coal power plants	0.60	0.94	1.66
Regions without coal power plants	0.30	0.96	5.37
Regions with coal mines	0.63	0.88	1.62
Regions without coal mines	0.30	0.96	5.37

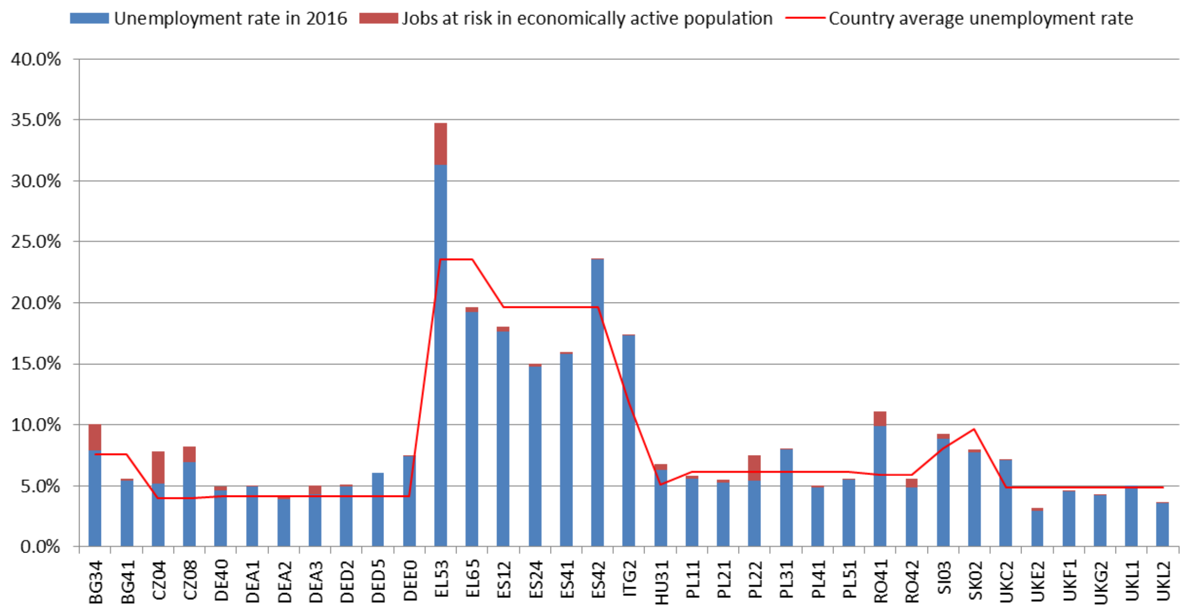
The basic statistical analysis shows that in average, regions with coal power plants and coal mines are the regions with lower economic power than regions without any of these facilities.

A deeper analysis showed that regions with coal power plants or coal mines where the economic power is significantly higher than the country average are BG41, DK01, DE11, DE21, DE50, DE60, DE71, ITC4, NL32, PL12, FI1B and SE11. All of these regions include either capitals like Sofia, Copenhagen, Warsaw, Helsinki or Stockholm or big economic centres like Stuttgart, Munich, Bremen, Hamburg, Frankfurt, Milano or Amsterdam. This brings to conclusion that these regions don't build their economic power on coal related activities, but on other more competitive industries. The economic power of other coal regions is just around or even below the average national economic power.

3.7.2 Unemployment rate in coal regions

The unemployment rate is defined as the share of unemployed people in economically active population. The analysis of unemployment in regions with coal mines is presented in Figure 41.

Figure 41. Unemployment rate in regions with coal mines



Conclusions from the analysis of unemployment rates in regions with coal power plant and regions with coal mines are similar. The unemployment rate is a country specific category, with highest levels (above 15% from active population) found in Greece and Spain and moderate levels (between 10% and 15% from active population) in France, Croatia, Italy and Portugal. Other countries with either coal power plants or coal mines have lower levels of unemployment.

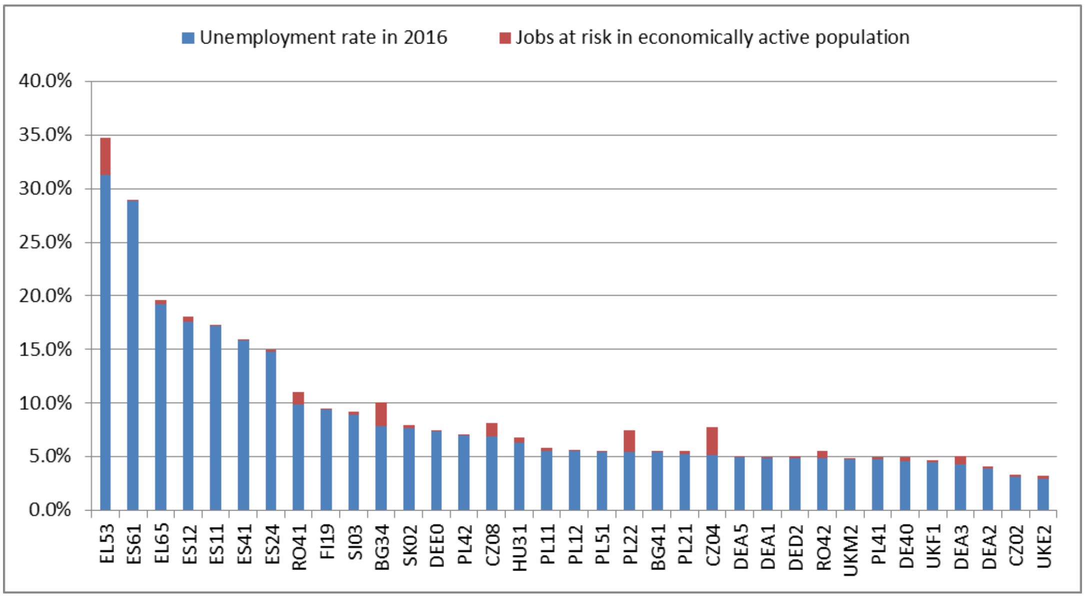
3.7.3 The share of jobs at risk in economically active population in coal regions

The share of jobs at risk in economically active population is analysed in order to understand the social impact of job losses in the region. Although the number of jobs at risk is very high in some of the regions (almost 41 000 in PL22, or between 9 500 and 14 500 in CZ04, RO41, BG34 and DEA3), in order to measure the real social impact in these regions, there is the need to observe current unemployment rate in the region and compare the number of jobs at risk to the economically active population in the region.

Figure 42 shows the analysis of unemployment and jobs at risk in most impacted regions.

Although the number of jobs at risk is very high in some of the regions (almost 41 000 in PL22, or between 9 500 and 14 500 in CZ04, RO41, BG34 and DEA3), in order to measure the real social impact in these regions, there is the need to observe current unemployment rate in the region and compare the number of jobs at risk to the economically active population in the region.

Figure 42. Unemployment rate and jobs at risk in 35 most impacted regions



The region EL53 (Dytiki Makedonia) had almost 31.5% of unemployed population in 2016. Additional 3.5% of active population being at risk of losing jobs due to closure of coal power plants and coal mines will have a significant impact to this region where already now, with coal related activities in place the GDP/capita of the region is more than 25% lower than national average in Greece.

On contrary, the region ES61 (Andalucía), although having a similar level of unemployment in 2016 is not expected to be strongly affected since the number of jobs at risk in this region is relatively low.

Without a proper strategy, the region BG34 (Yugoiztochen) with GDP/capita almost 20% lower than national average and 10 100 jobs at risk might reach unemployment rate at the level of 10%, which is close to maximal value in Bulgaria.

The region PL22 (Śląskie), with by far the highest number of jobs at risk (almost 41 000), is the region with the population of 4.5 million and almost 2 million economically active inhabitants, which means that the unemployment rate from direct job losses could increase from 5.4% to 7.5%, but it is expected that with a proper strategy, this region might have enough power to absorb this strong impact.

With 14 500 jobs at risk, the region CZ04 Severozápad will be the second most affected in absolute numbers, but this is a region with a population above 1.1 million out of which 560 000 are economically active, which means that the impact will be similar to the one in the region PL22, the increase in unemployment rate from 5.2% to 7.8%.

With current unemployment rate at the level of 6.9% and almost 8 000 jobs at risk (1.3% from economically active population), the region CZ08 Moravskoslezsko might find it more difficult to cope with the impact than the region CZ04.

Another region which might be significantly affected is RO41 (Sud-Vest Oltenia) where the unemployment rate could increase from 9.9% to 11.1% due to closure of coal mines and coal power plants.

The region DEA3 (Münster) is also a region with significant number of job losses, but the unemployment rate in this region is already quite low (4.3%) and the share of jobs at risk in economically active population is only 0.7% which means that this region will most probably be able to absorb lost jobs and re-employ these people in other more competitive industries.

Other regions should experience relatively low social impact with the possibility to absorb jobs at risk on medium to long term.

3.8 Key points

- By 2030 approximately two thirds of the current coal-fired power capacity will be decommissioned. The most affected Member States include Germany, the UK, Germany, Poland, the Czech Republic and Spain.
- Nine regions face an estimated job loss potential exceeding 1 000 direct jobs in coal-fired power plants, while for one region more than 2 000 jobs could be at risk.
- The phase-out of coal fired-power plants will likely render unnecessary most lignite mines leading in the short-to-medium term to their closure.
- Changes in the EU power sector can also have an adverse impact on hard coal mines which mainly supply the power market. Some of these mines will face important losses in asset values, during the energy transition.
- Hard coal mines capable of producing coking coal for the steel industry, have a competitive advantage, at least under conditions of growing coal prices.
- Many uncompetitive coal mines have remained active over the past years through valuable State Aid subsidies allowed under the EC Regulation No 1407/2002
- Following the Council Decision 2010/787/EU in place since 2010, State Aid is only allowed to facilitate the closure of a mine. Czech Republic, Romania, Poland and Spain have required State Aid measures designed to finance the closure of some uncompetitive mines
- At least 27 mines have closed in the EU since 2014 and another 5 are slated for closure until the end of 2018. By then, also 26 mines are expected to close in Spain.
- The analysis based on mine competitiveness criteria indicated that around 109 000 coal mining jobs face a high risk of redundancy due to potential closure of uncompetitive mines.
- The forced closure of many uncompetitive operations between 2015 and 2018, including those currently benefiting from State Aid, might lead to the loss of around 12% of current overall jobs (27 000) by 2020. Thereafter and until 2030, the closure of coal mines will mainly be aligned with the decommissioning rates of coal power plants: by 2025 total cumulative job losses in power plants and mines are likely to increase to 77 000 jobs and by 2030 to around 160 000 jobs.
- One region in Poland may lose up to 41 000 jobs and three other regions more than 10 000 jobs.
- The majority of coal regions have a lower regional GDP/capita than the national average.
- Regions with highest unemployment rates (for example in Greece and Spain) are likely to be more sensitive to additional jobs losses. It is expected that the region EL53 (Dytiki Makedonia) with 31.5% of unemployed population in 2016, will face the highest social impact if an additional 3.5% of active population becomes unemployed due to the decommissioning of power plants and mines. In this region, the GDP/capita is already 25% lower than the national average.

4 Possible impacts of a coal phase-out to other economic sectors

A group of other economic sectors related to coal activities, which might be affected by the decommissioning of power plants and closure of coal mines and thus may require actions to ensure current/optimum levels of operation, are discussed below.

4.1 The steel industry

Coking coal is a vital ingredient in the steel-making process (World Coal Association, 2017). On the basis of its economic importance and high supply risks to the EU economy, the European Commission, in 2014, identified coking coal as a critical raw material (EC-CRMs list, 2014). In 2017, coking coal is considered a borderline case, and although it narrowly misses the economic importance threshold, it is kept on the latest list of critical raw materials for the EU[59].

The steel industry, which is found in almost all Member States of the EU, account for 95% of coking coal usage. According to the same source, the industry had a Value Added of around 7 billion EUR between 2010 and 2014 and was a net exporter of over 10 Mt of steel (Coking Coal Factsheet, 2017).

Coking coal is used to make furnace coke which is an intermediate product required to charge, alongside with iron ore, a blast furnace in order to produce pig iron. Coke is produced in coking ovens of the integrated steel production route (Coking Coal Factsheet, 2017). According to the (World Coal Association, 2017), 70% of the steel produced today uses coal.

The requirements of coal for coke-making are much different from those used in other processes (American Iron and Steel Institute, 2017). Certain chemical and physical properties such as low sulphur and phosphorus contents, low ash yield, and a high heating value are essential as discussed for example in the (Coking Coal Factsheet, 2017). As discussed in previous sections, although most hard coals are capable for use in the steelmaking process, not all produce furnace coke of desirable quality (American Iron and Steel Institute, 2017).

Currently, coke-making operations use blends from a variety of coals to compensate for the lack of individual coals with all the necessary properties and to maximize to the extent possible the efficiency of the coke-making process (American Iron and Steel Institute, 2017). These practices make viable some lower quality hard coals for this specific use.

As discussed in the previous section, 79 hard coal production centers provide different coal qualities, in some cases including both steam and coking coal. Of these, around 25% produce metallurgical coal and anthracite. Although information is not available for each mine on the amounts of coking/steam coal recovered, some sporadic data was presented in Table 10. Additional information on this matter can be derived from Comext-Eurostat. This data covering production of coking coal, anthracite and steam coal was used in Table 16.

59 http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en; http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2017:0490:FIN

Table 16. Production (thousand tonnes) of hard coal from EU countries according to Eurostat in 2015 (Comext-Eurostat, 2017) and share of coking coal and anthracite in comparison to steam coal (other bituminous)[60].

	Coking coal	**Anthracite**	**Other bituminous**	**Coking coal (+ anthracite) share (%)**
EU28	20 988	1 558	74 151	23
Czech Republic	4 088	-	4 226	49
Germany	3 843	1 180	1 143	81
Spain	0	378	984	28
Poland	12 985	-	59 191	18
United Kingdom	72	-	8 526	1

The table shows that coking coal and anthracite are produced in the Czech Republic, Germany, Poland and the United Kingdom. Poland and the Czech Republic lead the production of coking coal within the EU. In Czech Republic, coking coal accounts for 49% of hard coal production, in Spain (anthracite) for 28%, in Poland for 18% and 1% in United Kingdom. Germany is the Member State with the highest share of coking coal in the overall hard coal production.

The regions hosting coking coal (or anthracite) mining are the following: CZ08 in the Czech Republic, DEA3 in Germany, PL22 in Poland, ES12 and ES41 in Spain, UKL1 in United Kingdom (JRC-CMDB). With the exception of the UK region and ES41 in Spain, the remaining were identified as high risk in terms of mining performance and competitiveness. Productivity in these regions is low ranging from 695 tonnes/person employed in DEA3 to 900 tonnes/employee in ES12.

Readjustments of the steam coal demand related to anticipated shrinking of the coal power sector can eventually lead to a forced closure of uncompetitive mines supplying both markets in conditions of low prices. This can result in the increase of the EU's dependency on imports for the steel sector.

The EU has historically been a net importer of coking coal, currently relying 63% on imports to cover the demand of the steel industry (Coking Coal Factsheet, 2017).

Relevant Comext-Eurostat data on production and trade in EU-28 is shown in Figure 43.

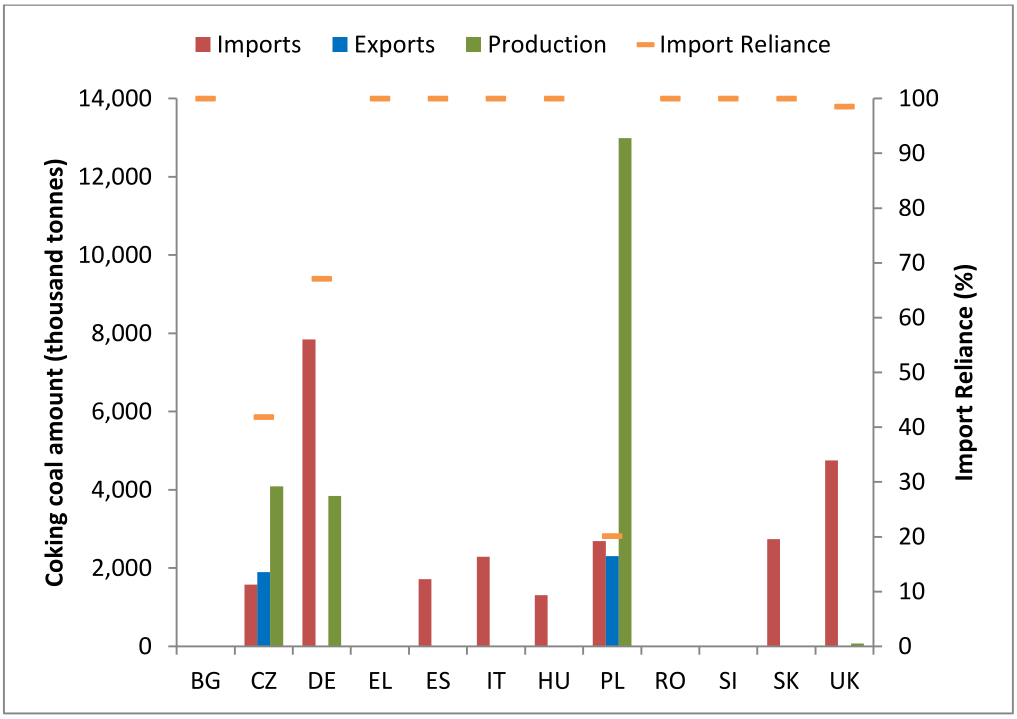
[60] In 2017, hard coal production in Poland included steam coal (80%) and coking coal (20%) (Official data provided by competent authorities in Poland).

Figure 43. EU28 trade flows for coking coal in 2015 (data from Comext - Eurostat, 2016)

The graph shows that imports have remained relatively consistent throughout 2010-2015 at around 45 000 thousand tonnes, with a slight decrease in 2015. In the same period, exports have been consistently low at around 4 500 thousand tonnes.

The import reliance situation observed for the EU is also seen in individual countries where coking coal production takes place. Because demand from the steel industry exceeds endogenous supply, countries such as Poland, the Czech Republic and Germany also import coking coal. Amongst them, Poland and the Czech Republic have the lowest import dependencies (20% and 42% respectively). In Germany, on the other hand, where 11 million tonnes were apparently consumed by the steel sector and uncompetitive mines have closed in the past years, the import reliance reaches 67% (Figure 44).

Figure 44. Production, trade and apparent consumption of coking coal in EU coal mining countries, using data from Comext-Eurostat, 2017. Data refers to 2015.



According to (Coking Coal Factsheet, 2017), the majority of coking coal imported to the EU is from the USA and Australia. The same publication also points out the fact that the mix of supplier countries is likely to improve in the short/medium-term due to increases in worldwide mining capacity in Australia and new entrants to the market such as Mozambique and Indonesia. These will be able to cover for the growing EU market deficit expected over the coming years against the backdrop of the closure of uncompetitive mines.

4.2 Mining equipment manufacturers

Equipment manufacturers providing machinery essential for coal mining activities might face some challenges to continue to grow in a sustainable way, by the changes expected ahead in the coal sector.

In recent decades, mining techniques have advanced significantly. As a result, mining practices have moved from labor-intensive to technology-intensive, which led to impressive growth in efficiency and mine productivity (European Commission, 2016). The operation of state-of-the-art complex mining equipment requires highly skilled and well-trained mining personnel (World Coal Association, 2017).

Mining equipment, in general, include machinery used at various mining stages. The type of needs in terms of equipment depends on the type of mine and mining methods applied. For example, large opencast mines can cover an area of many square kilometers and use very large pieces of equipment, such as draglines, power shovels, large trucks, bucket wheel excavators and conveyors (World Coal Association, 2017). In Greece for example, the Public Power Corporation operating lignite mines in Ptolemais and Megalopolis, uses bucket-wheel excavators, spreaders, tripper cars and conveyor belts to mine and transport lignite. Currently, the company operates 48 bucket-wheel excavators and 22 spreaders, together with over 300 kilometers of belt conveyors to accomplish a yearly production of around 40 million tonnes (Euracoal, 2017). In the Lusatian coalfields in Germany, lignite opencast mining employs overburden conveyor bridges of the type F 60, one of the largest systems worldwide, to accommodate the transport of overburden (Figure 45).

Figure 45. F 60 conveyor bridge in the Jänschwalde mine (Brandenburg, Germany)

Source: https://en.wikipedia.org/wiki/Overburden_Conveyor_Bridge_F60

Underground operations, on the other hand, rely for example on continuous miners, shuttle cars and roof bolters.

Table 17 provides an inventory of equipment used in coal underground mining, grouped by activity type.

Table 17. Inventory of mining equipment used in coal underground operations (Datasource: USGS, 2009).

Production Equipment	Auxiliary Equipment	Surface Equipment
Continuous Miners	Utility Scoop	120' Stacker Conveyors
Shuttle Cars	Personnel Carriers	Leased Coal Truck Haulage
Roof Bolters	Rock Duster	
Scoops	Spare Shuttle Cars	
Surf-4cy Loader	Feeder/Breakers	
Grader	Ventilation System	
	Belt System	
	Power Centers	

Equipment costs represent a large share of mining investments. The number of units deployed depends on the size of the mine. For an average underground mine using continuous miner/room & pillar methods, the number of equipment units can be estimated at around 25, with a total cost around 3 million euros (Table 18). According to (IEA ETSAP, 2014) the investment cost required for mobile machinery used in underground room & pillar method is usually below 4 million euros. The costs of long-wall mining machinery[61], on the other hand, can be at more than ten times this amount, as much as 50 million euros (IEA ETSAP, 2014).

[61] For clarification on the mining methods see Annex 4.

Table 18. Number of units and cost of mining equipment for an average size underground mine using continuous miner/room & pillar methods (data source: USGS, 2009).

	No. Units	Unit Cost (€)
Production Equipment		
Continuous Miners	2	498 000
Shuttle Cars	4	109 000
Roof Bolters	2	128 000
Scoops	2	51 000
Surf-4cy Loader	1	171 000
Grader	1	111 000
Auxiliary Equipment		
Utility Scoop	1	51 000
Personnel Carriers	3	38 000
Rock Duster	1	32 000
Spare Shuttle Cars	2	109 000
Feeder/Breakers	2	91 000
Ventilation System	1	80 000
Belt System	1	724 000
Power Centers	2	36 000
Surface Equipment		
120' Stacker Conveyors	1	66 000
Leased Coal Truck Haulage	-	-

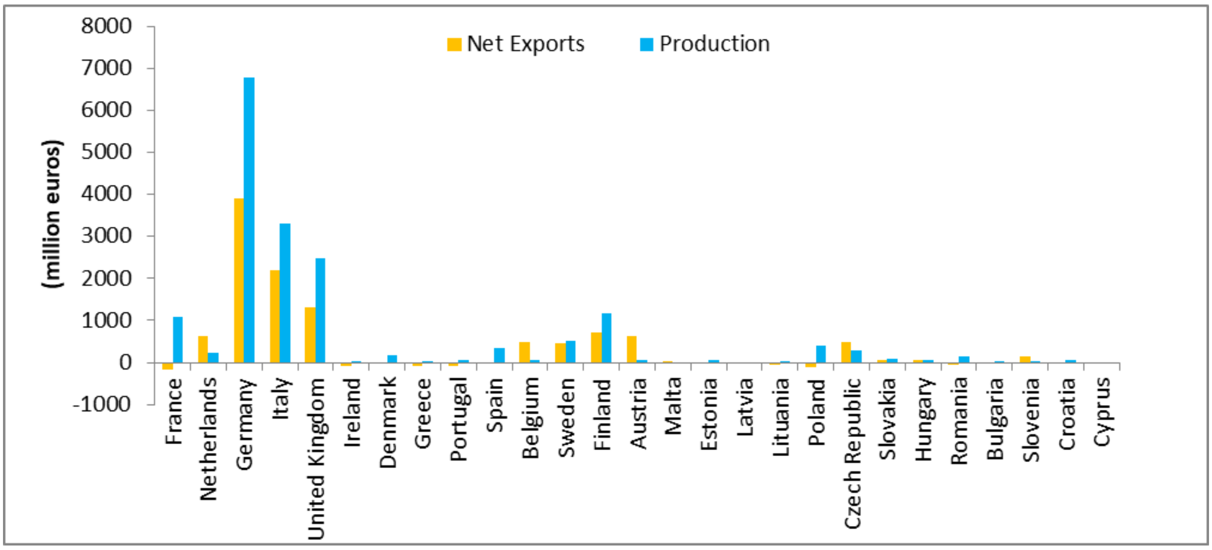
According to the recent Raw Materials Scoreboard (European Commission, 2016), the EU is, together with the USA, the largest producer of mining equipment worldwide, accounting for 25 % of global sales. Another finding of that study is that some of the largest companies are based in countries with a long-standing mining tradition, such as Sweden and Finland. These enterprises are multi-sectorial, with mining equipment accounting for a small proportion of their corporate sales (European Commission, 2016). The Raw Materials Scoreboard also points out the fact that innovation promoted by these companies relies heavily on the existence of mining activities.

The Raw Materials Scoreboard bases its analysis of the mining equipment sector, on a broad spectrum of products for surface and underground mining and for mineral processing, although focusing on data for non-energy raw materials.

For the purposes of the current report, an assessment based on the European database on trade (PRODCOM) was pursued. The group of relevant products for which data was extracted is listed in Annex 16.

Due to data availability reasons, mining equipment manufacturers supplying mainly the coal sector could not be assessed separately. Coal mining methods are in many respects similar to those employed in other mining activities, therefore, the results also reflect the situation of those markets. Figure 46 shows the sold production and net exports of mining equipment in EU.

Figure 46. Sold production and net exports (in million euros) of mining equipment by EU Member States for the overall products in the relevant PRODCOM list[62]. Data refers to 2015.



The graph shows that Germany, Italy and United Kingdom are leading countries for the production and exports of mining equipment. Other exporters include Sweden and Finland. Details on the production, imports and exports value for the EU coal producing countries are given in Table 19 below.

[62] See Annex 15 for details on the typology of mining equipment included through the list of Prodcom classes.

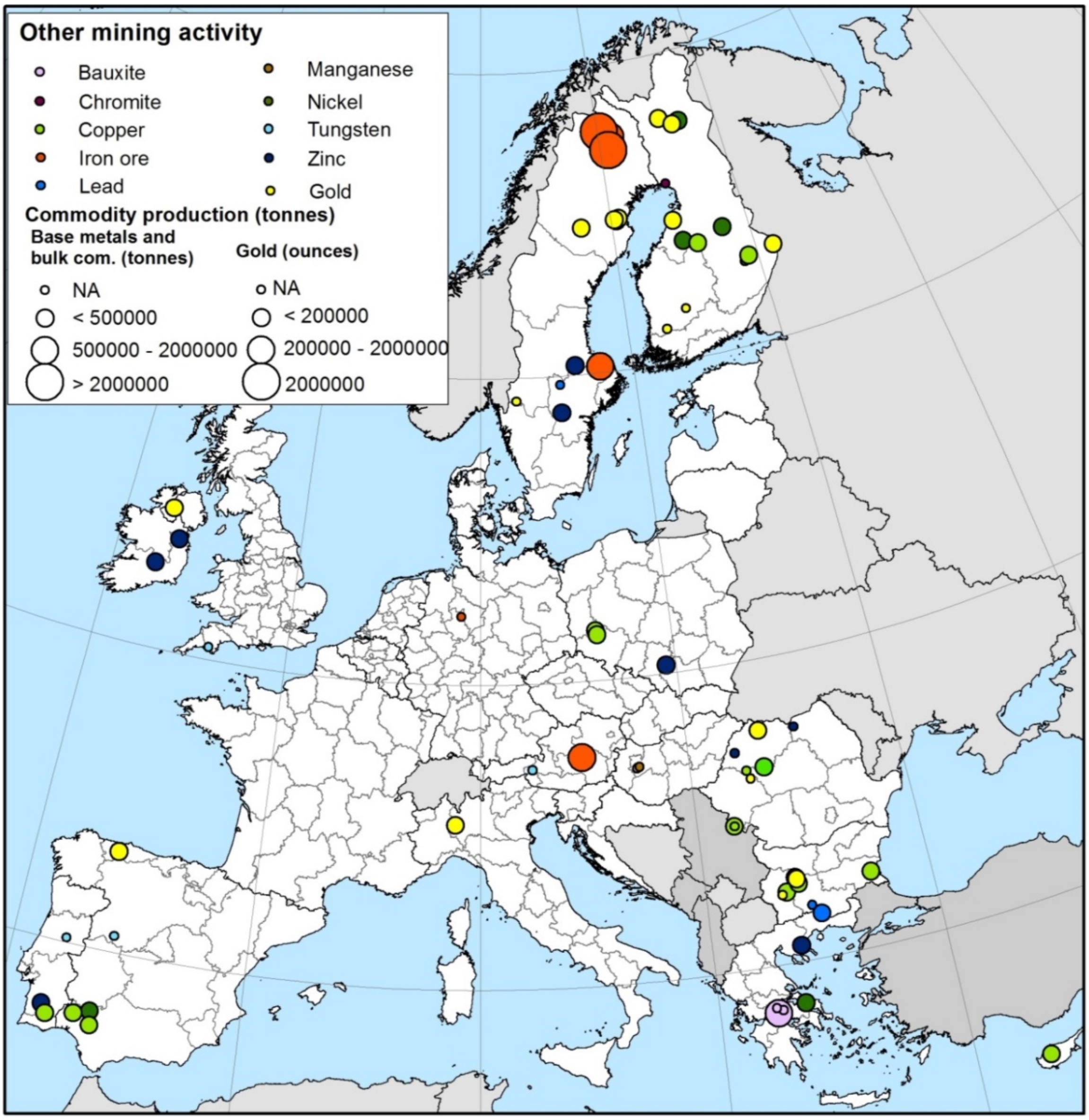
Table 19. Sold production and net exports (in million euros) of mining equipment from EU Member States hosting coal mining activities.

	Exports value	**Imports value**	**Production value**	**Net exports**
Bulgaria	161	185	13	-24
Czech Republic	1 008	535	292	473
Germany	7 939	4 038	6 772	3 901
Greece	41	135	1	-94
Spain	686	714	354	-28
Italy	3 529	1 325	3 300	2 203
Hungary	187	135	49	52
Poland	658	775	390	-117
Romania	172	232	133	-59
Slovenia	269	137	35	131
Slovakia	231	169	83	61
United Kingdom	3 804	2 495	2 469	1 309

The table shows that besides Germany, Italy and United Kingdom, also, the Czech Republic, Slovakia and Slovenia are net exporters of mining equipment. Spain, Poland and Romania although significant players show a slight trade deficit.

As discussed above, these results include also the trade of products which are common to other mining and quarrying. For this reason it is relevant to understand the distribution of other raw materials production in these countries. The location of mining activities focusing on base and precious metals, bulk and specialty commodities are presented in Figure 47.

Figure 47. Location of mining activities focusing on base and precious metals, bulk and specialty commodities[63]



The map shows that other mining activities take place in almost all countries with coal production: bauxite and nickel in Greece; copper, nickel, tungsten and gold in Spain; copper and zinc in Poland; iron ore in Germany; copper, lead and gold in Bulgaria; gold, copper and zinc in Romania; bauxite and manganese in Hungary; tungsten in United Kingdom. Moreover, the map also shows that such activities do not occur in the Czech Republic, Slovakia and Slovenia. In these countries, the activities of the extractive industry are currently restricted to coal mining and quarrying and thereby related developments to the equipment manufacturing sector can be attributed to a large extent to coal.

Additional inputs to this analysis can be obtained from looking at the situation of specific products related to underground mining which is both preponderant in the extraction of metal ores and coal but not employed in quarrying. The market situation of self-propelled front-end shovel loaders specially designed for underground use is provided in Figure 48.

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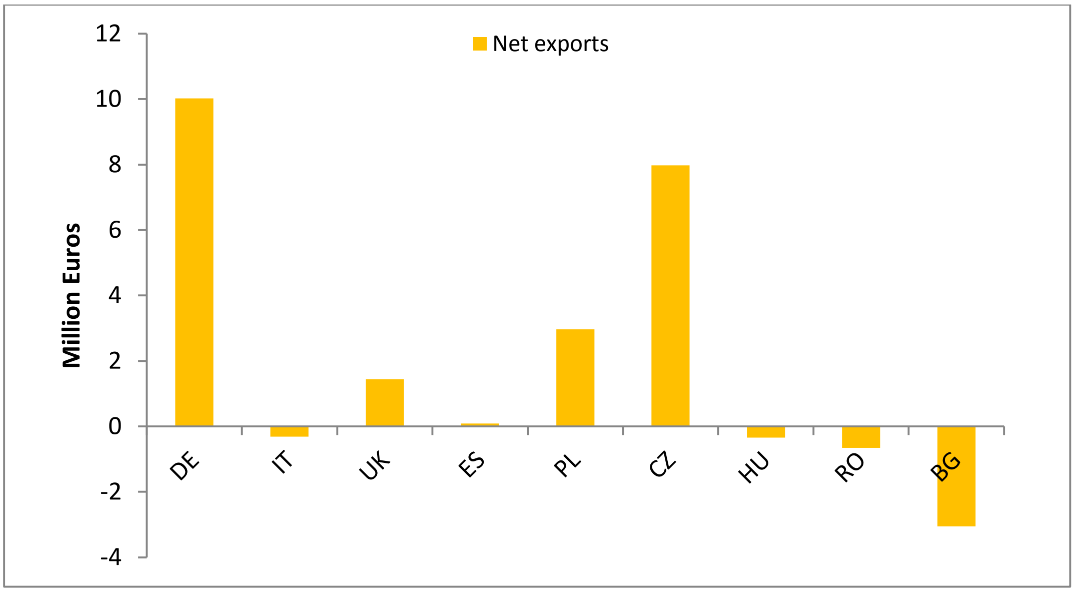
[63] The map draws its information from the SNL Metals&Mining database. This was used to assess mining activities in the EU for the Raw Materials Scoreboard. Data refers to 2015.

Figure 48. Net exports (in million euros) of self-propelled front-end shovel loaders specially designed for underground use in EU Member States hosting coal mining activities (Prodcom code 28922430).



The graph shows that Germany, the Czech Republic, Poland and the United Kingdom are net exporters of equipment in this category. For all the above, at least in the Czech Republic this might result from a sector assisting the coal industry to develop its activities.

In Slovakia the company Banská Mechanizácia a Elektrifikácia Nováky (BME) owned by Hornonitrianske Bane Prievidza (HBP) operating the Nováky, Handlová and Cigel mines, is a modern mining equipment supplier that designs and manufactures high-pressure hydraulic roof supports suitable for longwall mining (specifically longwall top coal caving, LTCC). According to (Euracoal, 2017) the company also produces other mining and construction machinery, as well as equipment for the transport sector.

In Poland (Euracoal, 2017) describes the Polish mining machinery and equipment industry as a well-developed and technically advanced sector benefiting from collaborations with research institutes and technology centres such as KOMAG, EMAG and GIG, to continuously develop and modernise its activities.

In Slovenia the company Premogovnik Velenje, with 135-year tradition in lignite mining developed a patented method for extracting thick coal seams in underground mines (Premogovnik Velenje, 2012). The company benefits from modern mining equipment to implement this effective method.

Box 10. Slovenia: Premogovnik Velenje

The company, exploiting one of the thickest lignite seams in the world, has developed a unique method for extraction in these specific mine conditions. The basic approach at Velenje coal mine is to extend coal extraction above the protected area at the face, allowing natural forces break and crush the seam. Thanks to modern mining equipment, especially hydraulic supports and advanced chain conveyors, the company uses a lower number of wider longwall faces (Euracoal, 2017). At Velenje, specific mine conditions have encouraged the development of innovative mining methods placing the coalmine in the global forefront of underground coalmining (Premogovnik Velenje, 2012). According to (Euracoal, 2017) the knowledge and products of the company offer opportunities for co-operation with countries where there is a need to introduce new technologies.

Manufacturing of machinery for mining, quarrying and construction falls within one of the NACE Rev.2 classes for which Eurostat indicators, such as the number of enterprises and employment, are available. The graphs in Figure 49 and Figure 50 below provide this information for those countries in EU hosting coal mining activities.

Figure 49. Number of enterprises engaged in the manufacture of machinery for mining, quarrying and construction, in coal producing countries (Eurostat, 2016).

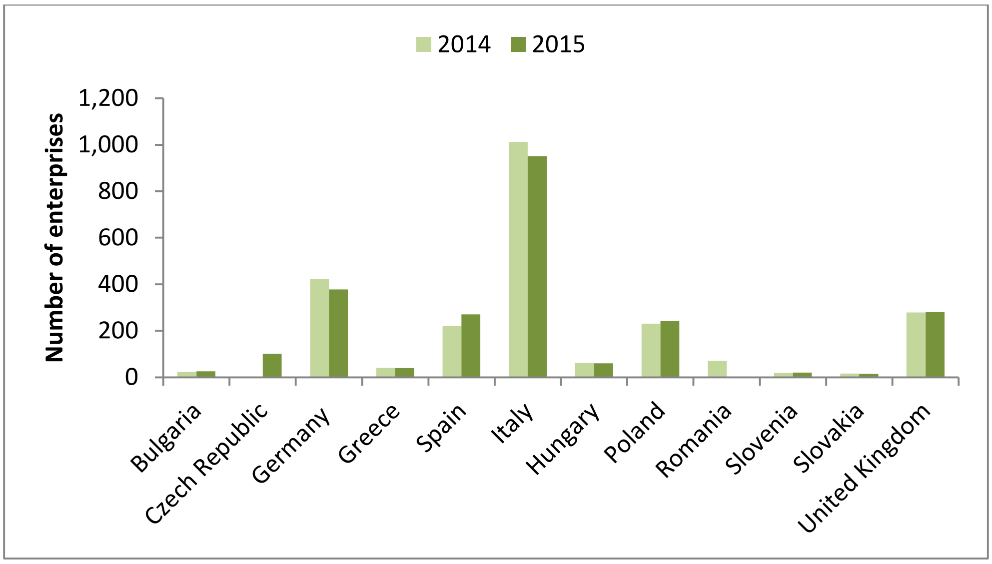
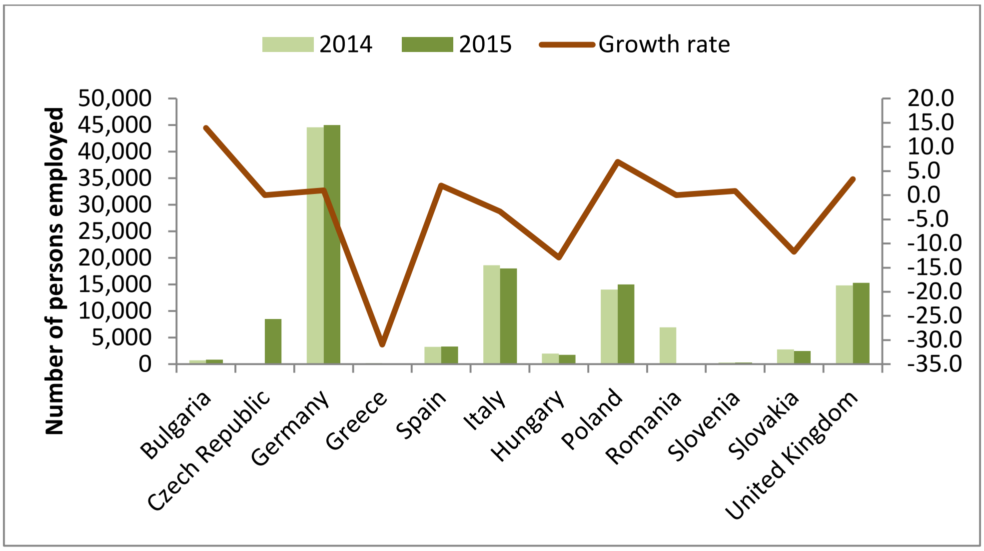


Figure 50. Number of persons employed in the manufacture of machinery for mining, quarrying and construction, in coal producing countries (Eurostat, 2016)



The graphs show that the number of enterprises engaged in the manufacture of machinery for mining, quarrying and construction is highest in Italy, with some 1 000 enterprises, followed by Germany with almost 400 companies. The number of persons employed in the sector is substantial - approximately 45 000 in Germany, 18 000 in Italy and 15 000 in Poland and United Kingdom.

In countries such as the Czech Republic, Slovakia and Slovenia that lack other mining activity but also in Poland, Germany and United Kingdom, market developments and innovation in the mining equipment industry are to a large extent related to coal mining. Keeping the sector internationally competitive under the process of shifting away from coal, might require relevant re-adjustments.

4.3 Coal terminals

The ongoing phase-out and restructuring of the European coal sector can have an impact on terminal operators engaged in the handling, storage and transshipping of coal.

While lignite is unsuitable for long-distance transportation, being mainly consumed at mine-mouth power stations, hard coal is traded world-wide. Hard coal is usually transported on railways, by barges on inland waterways or by large sea vessels such as Panamax or Capesize vessels (IEA ETSAP, 2014). Coal can also be shipped by pipelines as a coal-water mixture (slurry) and, for short distances or small portions of the routes, heavy trucks are also used (IEA ETSAP, 2014). To reduce the burden of coal transportation costs, numerous power plants have been built along the coast, with many located in port facilities.

Europe imports its coal from Russia, Colombia, the USA, South Africa and Australia[64]. A large portion of hard coal is imported through large sea vessels and a smaller portion by inland waterways and railways, namely from Russia, and other CIS countries (Euracoal, 2017) (IEA ETSAP, 2014).

Coal terminals, located in sea ports and inland waterways, play a major role in coal transportation. In the EU, according to (IEA ETSAP, 2014), these include the Amsterdam, Rotterdam and Antwerp ports for the inland Rhine corridor; the Hamburg, Szczecin and Gdansk sea ports for the East-West corridor; Constanta for inland shipment on the Danube and Le Havre and Marseille for the Seine and Rhône. From the port site, coal is delivered by rail to the main recipients, for the most part power stations but also for steelworks and various industries (e.g. cement facilities).

Coal exports from Europe represent a small fraction of transported coal. Poland and the Czech Republic are the only major exporters of hard coal. Poland exports about 13% (9 million tonnes) of its output and the Czech Republic around 44% (3.6 million tonnes). In both countries the amount of exports is equivalent to imports (see Annex 16)[65]. Romania, the United Kingdom and Germany also export limited quantities of hard coal.

Companies operating coal terminals in these ports are generally multipurpose dry bulk operators handling (loading and unloading), storing and transhipping a wide range of bulk freight, such as iron ore, petroleum coke, salt, scrap metal, raw materials for the construction industry, agricultural commodities, etc.

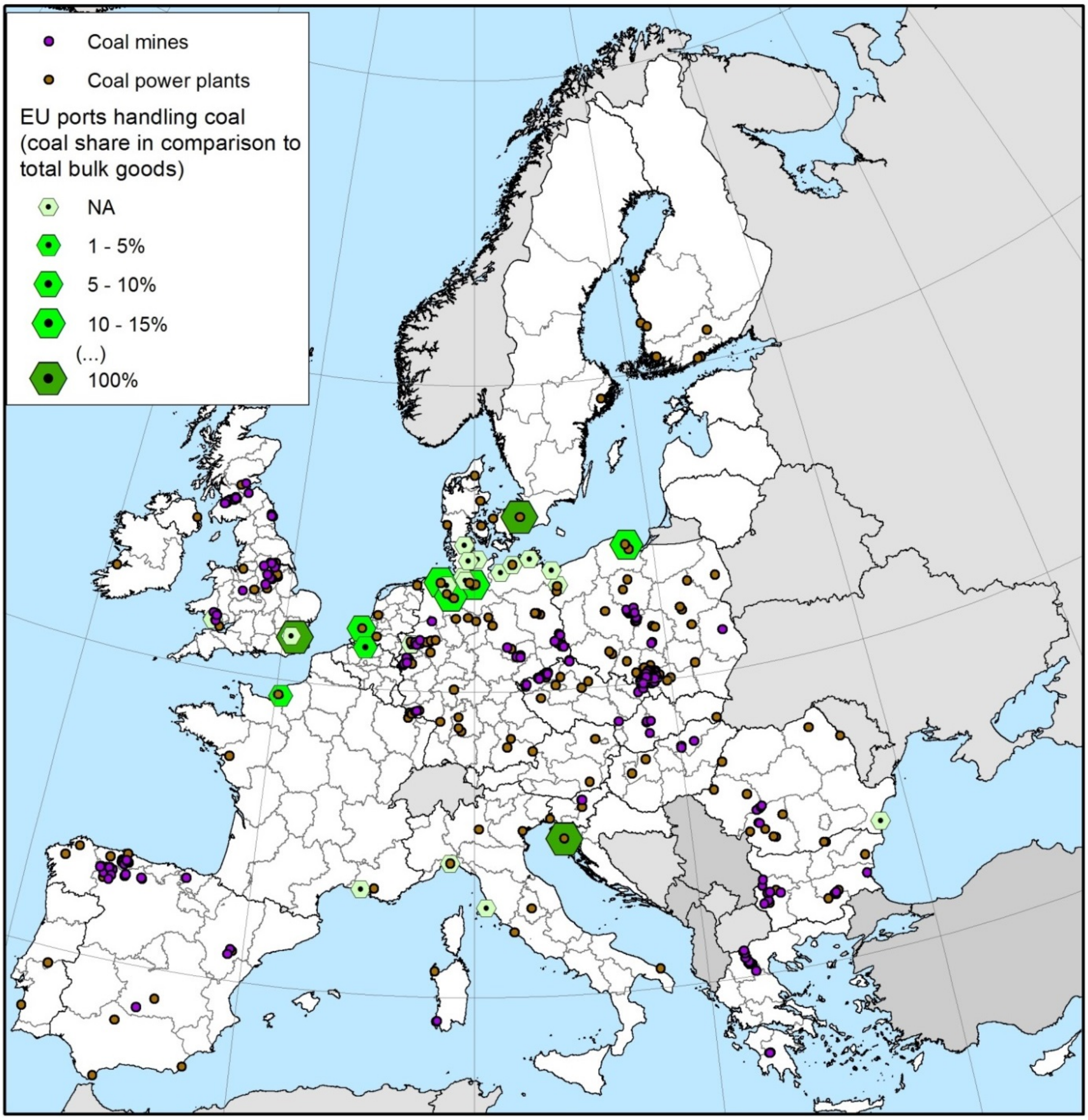
A preliminary analysis of the distribution of coal terminals and the proportion of coal handled by each port is presented next to highlight the importance of coal to the ports sector.

The location of coal terminals in the EU is shown in Figure 51.

[64] Eurostat energy pocketbook, 2016, http://ec.europa.eu/energy/en/data-analysis/energy-statistical-pocketbook, p. 63

[65] See Annex 1 for official data for Poland in 2017.

Figure 51. Location of coal terminals in EU and share of coal transported/handled by the port in comparison to bulk goods – preliminary assessment[66]



The map shows that coal-fired power plants are typically located in the port area or in the vicinity. Although this is not apparent from the map, there are three coal-fired power plants in the port of Rotterdam, two in Bremen, and three in Hamburg.

The map additionally shows that for a group of seven ports for which information is more readily available, the share of coal handled in comparison to bulk goods (incl. solid and liquid) ranges from 1.2% in the port of Le Havre (France) to 17% in Hamburg (Germany). This share is significantly lower when coal is compared with the total throughput of the port, ranging from 1-7% (see Annex 17).

[66]The map draws its data from a preliminary database compiled from the following data providers: (Mining Atlas, 2017), (http://www.sourcewatch.org/index.php/Coal_terminals) and statistics made available by the Port of Rotterdam (https://www.portofrotterdam.com/en/downloads/factsheets-brochures/port-statistics-2015). The dataset is rather incomplete and contain many data gaps in terms of the amounts of coal handled at each port.

Among these, the port of Rotterdam is one of the largest facilities for coal transhipment intended for power plants and the steel industry based in Germany, France, Belgium and the Netherlands (Port of Rotterdam, 2017). The port has a handling capacity of 30.7 million tonnes of coal which represents a share of about 10% of total bulk goods.

EMO is the largest European transshipment terminal for coal and iron ore located in the port of Rotterdam. The EMO terminal was commissioned in 1973 and in addition to loading and unloading operations (from/to ships, rail cars and barges), the terminal provides coal preparation services including screening, blending and washing of coal (EMO, 2017). EMO employs around 350 workers and generates over 200 indirect jobs (EMO, 2017).

At the port of Hamburg, coal accounts for around 17% of the total bulk cargo and 5.6% of the total throughput. The facility has a handling capacity of 7.7 million tonnes of coal. The port of Hamburg handles coal mostly bound for power plants in Lower Saxony and steelworks of Northern and Eastern Germany (Port of Hamburg, 2017). The port area is host to the newly built Hamburg-Moorburg coal-fired power plant.

The map also shows three ports which handle exclusively coal serving adjacent power plants, in Croatia (Plomin), the United Kingdom (Kingsnorth) and Denmark (Amagervaerket). At Plomin, pulverized coal is transported from the terminal by belt conveyors to coal bunkers placed between the power house and the power plant steam generator (Koncar, 2006). In these cases, port activities are in general borne by the power station and are highly mechanized.

The Polish coal exports and imports are handled in the sea ports of Szczecin, Swinoujscie and Gdansk. The port of Szczecin for example is a specialized terminal accounting for nearly 50% of the Polish coal exports (around 4.5 million tonnes). Coal is the main cargo handled in the port (Port of Szczecin, 2017).

4.4 Key points

- Coking coal is a vital ingredient for the steel industry and is identified as a critical raw material by the EC.
- Poland, the Czech Republic and Germany lead the production of coking coal in EU.
- Coking coal (or anthracite) mines in these countries are located in PL22, CZ08 and DEA3, which were previously identified as high risk for competitiveness reasons.
- Coal mine closures will likely affect the European steel industry, increasing the dependence on imports of coking-coal. Currently the EU relies for the supply of coking coal for 63% on its import.
- The diversity of international suppliers shall be able to cover for the growing EU market deficit expected over the coming years and seems to imply that there is no supply risk for the European steel industry.
- Germany, Italy and United Kingdom are leading countries for the production and exports of mining equipment. Also, Czech Republic, Slovenia and Slovakia are net exporters of equipment. Spain, Poland and Romania although significant players show a slight trade deficit.
- In countries such as Czech Republic, Slovenia, Slovakia, but also in Poland, Germany and United Kingdom, market developments and innovation in the mining equipment industry are to a large extent related to coal mining.
- The number of people involved in the manufacture of mining, quarrying and construction equipment in coal producing countries is above 100 000.
- Keeping the sector internationally competitive under the process of shifting away from coal, might require relevant readjustments.
- Coal trade has helped developing the port sector. Specialized coal terminals engaged in the handling, storage and transhipping of coal are located in most European deep-sea ports, dealing mostly with imports of coal from Colombia, United States, Australia and South Africa.
- Companies operating coal terminals are in general multipurpose dry bulk operators handling a wide range of bulk freight.
- In the cases analysed, the share of coal handled in comparison to bulk goods ranges from 1.2% to 17%.
- The size of the companies operating coal terminals can be significant - for example the EMO terminal located in the Port of Rotterdam employs around 350 workers and generates over 200 indirect jobs.
- In Poland, the port of Szczecin accounts for 50% of the Polish coal exports, originating from mines located in high to medium risk regions in terms of performance.
- The potential closure of these mines and the expected decrease in hard coal imports for the European power sector will entail associated structural changes and possibly employment losses in the port sector.

5 Transition Strategies

5.1 CCS/U for coal power plants

Investigating the potential role of innovative technology solutions such as Carbon Capture and Storage (CCS) and/or Carbon Capture and Utilisation (CCU) can be an option during the transition of coal regions, as it offers the possibility to use coal for power generation, while capturing and permanently storing the CO_2 formed during the power generation process. Clean coal technologies have already been identified by European regions as a Smart Specialisation priority in their strategies.[67] A necessary condition for the deployment of CCS is however the commercial viability as well as public and political acceptance of the technology.

5.1.1 "Carbon capture ready" power plants

In 2010, the Global CCS Institute, the International Energy Agency (IEA) and the Carbon Sequestration Leadership Forum (CSLF) together with input from industry and non-government organisations jointly developed the following definition (Global CCS Institute, 2010):

"A CCS Ready (CCSR) facility is a large-scale industrial or power source of CO_2 which could and is intended to be retrofitted with CCS technology when the necessary regulatory and economic drivers are in place. The aim of building new facilities or modifying existing facilities to be CCS Ready is to reduce the risk of carbon emission lock-in or of being unable to fully utilise the facilities in the future without CCS (stranded assets). CCS Ready is not a CO_2 mitigation option, but a way to facilitate CO_2 mitigation in the future. CCSR ceases to be applicable in jurisdictions where the necessary drivers are already in place, or once they come in place".

Under Art. 33 of the CCS Directive, Member States have to ensure that operators of all combustion plants with a rated electrical output of 300 MW or more have assessed whether the conditions of 1) availability of suitable storage sites; 2) economic and technical feasibility of transport facilities and of 3) retrofit for CO_2 capture are met (European Commission, 2009).

Own analysis conducted for this report based on data from the JRC-PPDB[68] indicates that nearly 13% of existing total EU capacity could be "capture ready" in support of the transition to a low carbon future. Introducing the Carbon Capture Readiness (CCR) potential - an indicative metric based on criteria appended in Annex 19 - a preliminary estimation can be conducted for each NUTS-2 region. The CCR potential is determined by the following formula:

$$\boldsymbol{CCR\ potential_a} = \frac{\boldsymbol{CCR\ capacity_a}\ (\boldsymbol{MW})}{\boldsymbol{Maximum\ CCR\ capacity}\ (\boldsymbol{MW})}$$

where ɑ refers to the NUTS-2 region examined.

Using this metric, we estimate how much of the total installed capacity by NUTS-2 region could continue to operate in an environmentally friendly manner when equipped with CO_2 capture equipment, indicating the potential for each NUTS-2 region to adopt this solution. DEA1 (Düsseldorf, Germany) appears to have the highest CCR potential. Amongst the NUTS-2 regions, it has the highest ratio of capacity that can be fitted with carbon capture technology to total installed capacity, becoming the benchmark for CCR potential. Figure 52 shows CCR potential of the rest of the NUTS-2 regions studies, relative to DEA1. Figure 53 shows the relative CCR potential estimations to ITI4 (Lazio, Italy), the region with the second higher CCR potential. We present CCR potential relative to ITI4 too as

[67] DG Energy, July 2017; ANNEX - To the note on Industrial transition in coal, carbon intensive regions
[68] JRC-PPDB is the comprehensive database of power plants in Europe introduced in Chapter 2.

with Germany's potential coal plants phase out, DEA1 might not be the indicative region for CCR potential benchmarking.

Figure 52 CO_2 capture ready potential relative to DEA1 (Düsseldorf) NUTS-2 region

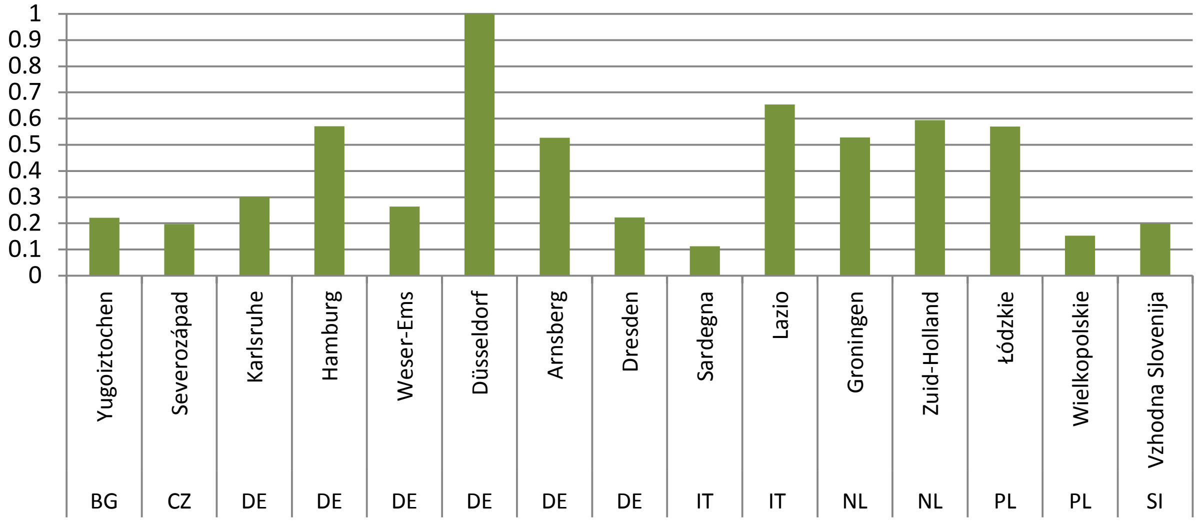
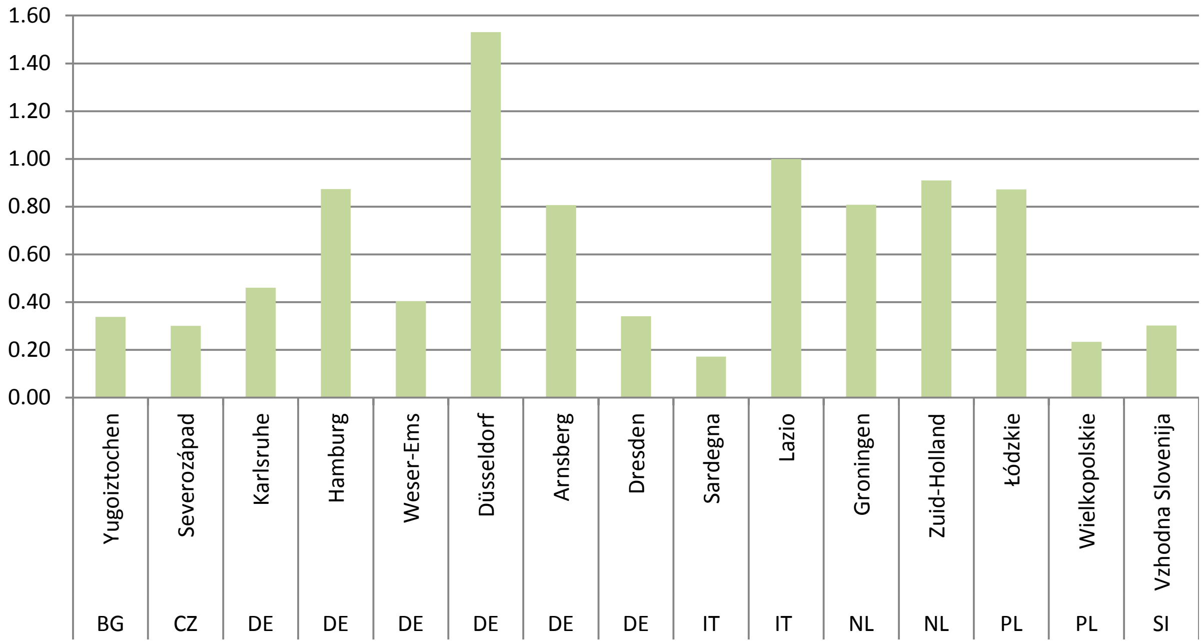


Figure 53. CO_2 capture ready potential relative to ITI4 (Lazio) NUTS-2 region



In countries where CCS could be deployed, the jobs associated with the respective power plants can be preserved and enhanced with the jobs that will be associated with operating the CO_2 capture, transport and storage units. Preliminary analysis shows that additional jobs can be created by implementing CCS in the power plants of the specific regions. As an example, for Łódzkie, Poland (PL11 NUTS-2 region), preliminary estimations indicate a CO_2 capture retrofit potential on more than half of its coal-fired power plant capacity. Thus, for this region alone, the jobs created due to CCS implementation can be in the range of approximately 500 to almost 1 200 jobs. These are based on estimations and depend on the approaches used adopted from literature. Further data confirmation would be necessary to refine these values.

Nevertheless, CCS comes at a cost which, so far, has been difficult to bear. Previous JRC's analysis (European Commission, Joint Research Centre, 2014) showed that, depending on the coal type the plant is using, CCS entails an additional cost of 35% to approximately 70%. These being already existing units, such cost would be additional to that of a conventional installation as well as costs from unforeseen plant modification requirements and essential renovations.[69]

Some gaps and barriers to deploy CCS/CCU have been demonstrated during the Strategic Energy Technology Plan, elaborated by 11 countries (The Czech Republic, France, Germany, Hungary, Italy, Norway, the Netherlands, Turkey, Spain, Sweden and UK). This plan promotes the research, innovation to achieve the ambitious targets for CCS and CCU for 2020 agreed by EU.

5.1.2 Mitigation in construction and industry

Production of construction materials such as cement, results in CO_2 emissions from coal combustion to provide the process heat, and from limestone calcination, which contributes more than half of the total emissions. Over the years the cement industry has substantially reduced CO_2 emissions by, for example, improving energy efficiency among other measures. Yet, an increasing need to reduce emissions further and transition to a low carbon economy is likely to affect this industry more. CO_2 capture and storage is an option to make further reductions and decarbonise this industry permanently.

Iron and steel making processes are energy and carbon intensive as a result of large requirements for fossil fuels, mainly coal, both as feedstock and energy source. This makes it likely that this industry will be affected by the low carbon energy transition.

In the pursuit of a low carbon future, steep cuts would be required in the sector compared to current levels. This is quantified by a requirement of more than 80% reduction in emissions and will require both technical and financial breakthroughs. The European Commission's roadmap indicates that a key technology to achieving larger emission cuts is CCS. CCS is also among the various options that steel companies are evaluating to reduce their carbon footprint (e.g. switching from coal to clean hydrogen). CO_2 capture technologies are mature and can be retrofitted today on existing assets, maintaining the existing equipment (i.e. blast furnaces), without disrupting current production processes and, potentially support the transition of carbon regions.

Regions likely to be hit during the low carbon transition can benefit by considering supporting such activities and diversifying their economies and job markets. This could be especially relevant where CCS has been faced with criticism from the public in the past on a country level (e.g. in Germany and the Netherlands).

[69] Without an existing power generation large-scale installation in Europe, assessing CCS costs bears an inherent uncertainty. Cost data produced are highly case-specific and, consequently, all estimates should be treated very cautiously.

Box 11. CCS/CCU in the construction and in the iron and steel sectors

The feasibility of applying this technique is examined with initiatives for example, in Belgium[70], Hungary[71], Norway[72] and the UK.[73] Proponents of CO_2 utilisation claim it could be a solution to keep the industry innovative towards a low carbon future. Utilising CO_2 capture from point sources to produce aggregates and construction materials could give value to CO_2 and incentivise CO_2 capture. SMEs currently undertaking such activities are aiming to add value to the sector and are providing jobs and support to local communities.

According to the Smart CO_2 Transformation (SCOT) project database:[74]

- ✓ 5 projects are involved in the transformation of CO_2 into minerals in the EEA
- ✓ 13 of these are in the European Union
- ✓ 8 are in former mining regions (Belgium and the Netherlands)
- ✓ Approximately 7 jobs for every 10 kilo tonnes of flue gas treated are expected in the Leeds (UK) region alone[75]
- ✓ 35 people are already employed in a single activity in a former coal region[76]

The European steel sector has been active for more than 10 years in exploring CCS opportunities. The largest effort by the ULCOS[77] programme looked at various CCS concepts but the proposed large scale CCS facility at the steel plant in Florange (FR) was not realized due to early closure of the site.

Steelanol,[78] a Horizon 2020 funded project, explores the transformation of carbon-rich industrial waste gases into advanced bio-ethanol. While trying to decarbonise the industry, job preservation will be crucial. CO_2 utilisation could be an option for continued operation in the transition to a low carbon steel sector.

According to relevant information (Eurofer, 2013):[79]

- ✓ The European iron and steel employs 350 000 highly skilled people.
- ✓ There are over 500 production and processing sites located in 23 EU Member States;
- ✓ The industry suffered a major hit in recent years
- ✓ As a result, several production sites have closed or reduced output
- ✓ Due to these closures 40 000 jobs were lost (European Commission, 2013)

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[70] https://www.project-leilac.eu/
[71] http://solidiatech.com/
[72] http://www.norcem.no/en/carbon_capture
[73] http://c8s.co.uk/
[74] http://database.scotproject.org/projects
[75] http://c8a.co.uk/carbon8-awards-construction-contracts-for-new-leeds-manufacturing-plant/
[76] http://recoval.be/historique/
[77] http://www.ulcos.org/en/index.php
[78] http://www.steelanol.eu/en
[79] http://database.scotproject.org/projects

5.2 CO_2 storage and coal-bed methane production

Carbon capture and storage (CCS) is considered a key mitigation option to avoid CO_2 emissions.

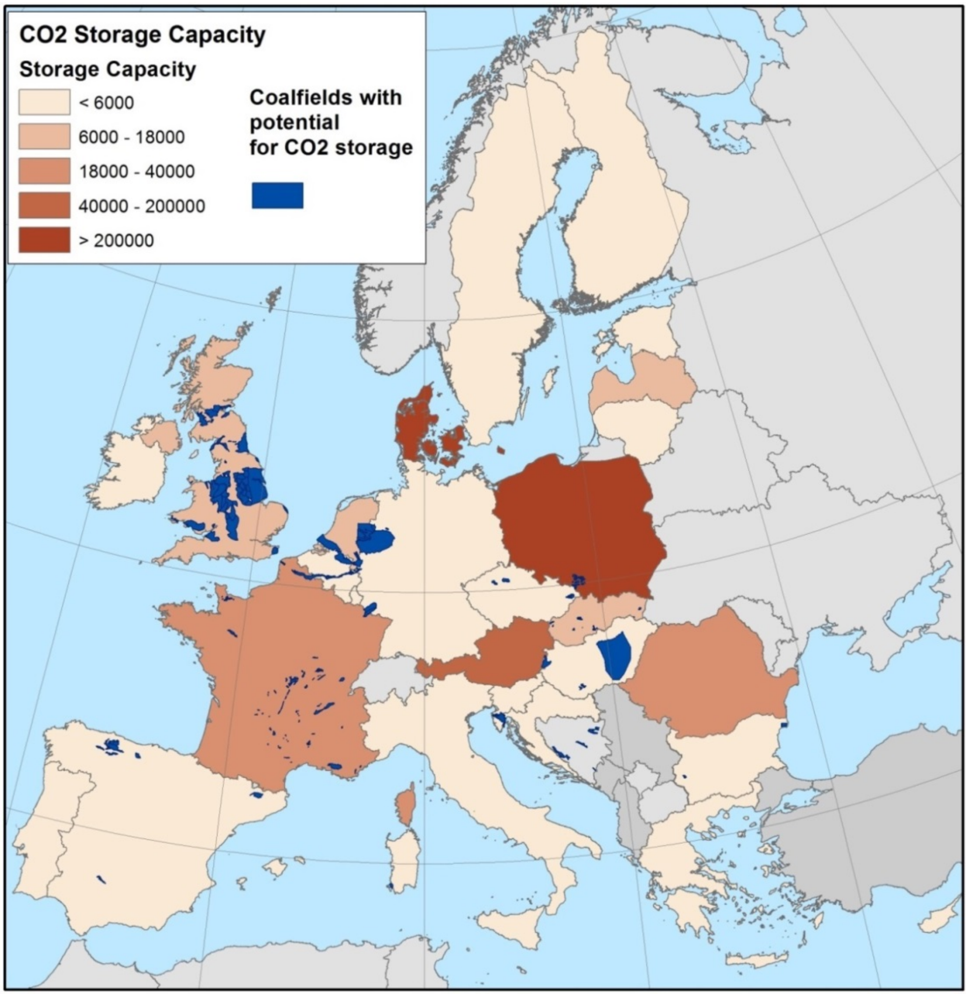
The major application of CCS is to reduce CO_2 emissions from power generation, fossil fuels (coal and gas) and CO_2-intensive industries such as cement or iron and steel[80]. A successful implementation of such technologies could potentially create favourable conditions for a life extension of at least some power plants in Europe.

Under the Paris agreement on climate change, to limit global warming by 2 degrees Celsius, 540 million tonnes of CO_2 would need to be stored each year until 2025 (IEA, 2017). Currently, only 28 million tonnes CO_2 are stored.

Following capture and transport, CO_2 storage can take place in several suitable geological formations such as deep saline aquifers, depleted hydrocarbon fields, basalts (under investigation) and also certain coalfields.

The map in Figure 54 shows the estimated CO_2 storage capacity at each EU Member State. This is an estimation of the overall capacity in offshore and onshore locations, covering the aforementioned group of suitable geological formations.

Figure 54 Estimated CO_2 Storage capacities (in million tonnes) in EU28 and potential coalfields for CO_2 storage



Data sources: EU Geocapacity (2008) and CO2StoP (CO2StoP, 2014)

[80] https://ec.europa.eu/clima/policies/lowcarbon/ccs_en

The map shows that the potential for CO_2 storage is highest in Poland and Denmark. Other countries with a high potential include Austria, France and Romania.

5.2.1 CO_2 storage in coalfields

Taking advantage of the sorption tendency of coal substrates, coal seams offer the potential for CO_2 storage. According to the Global CCS Institute, thickness and depth are the most important parameters to determine how much CO_2 could be absorbed onto coal[81] For example, in-situ pressure and temperature of the coal layers are factors influencing this ability: below 1 500 meters the permeability of coal seams is assumed to be too low for CO_2 injection[82].

The map above shows the location of the main coalfields in Europe with potential for CO_2 storage. The United Kingdom, Belgium, the Netherlands, Germany, Poland and Hungary are countries with large coalfields that could be used for CO_2 storage. Others can be found in France and Spain (EU Geocapacity, 2008).

Some isolated data on the potential for CO_2 storage in coal seams is available from sources such as (GESTCO, 2004) and (EU Geocapacity, 2008). This information is presented in Table 20.

Table 20. CO_2 storage capacity in European coalfields.

Member State	NUTS-2 Region	Coalfield	Estimated storage capacity (Million tonnes of CO_2)
Czech Republic	CZ08	Czech SCB (Silesian coal basin)	118 - 380
Spain	ES12	North West Basin	171
	-	Other basins	22.1
Hungary	HU23	Meczek	68 - 224
	HU31, HU32	Lignite fields	427
Poland	PL22	Polish SCB (Silesian coalbasin)	415 - 1 254
TOTAL			**794 - 2 285**

Data source: EU Geocapacity (2008)

Poland has the highest estimated storage capacity in coalfields, which ascends to 1 254 million tonnes of CO_2.

According to (IEAGHG, 2013), the worldwide potential for CO_2 storage in un-mined and un-mineable coal seams[83] may be as much as 499 Gt CO_2.

At mined areas, on the other hand, the creation of escape pathways for CO_2 via exploration boreholes, mine shafts and roadways, collapsed workings and subsidence are pointed out as factors diminishing the integrity of coal seams for CO_2 storage[84].

[81] https://hub.globalccsinstitute.com/publications/building-cost-curves-co2-storage-european-sector/24-co2-storage-and-coal-bed-methane

[82] https://hub.globalccsinstitute.com/publications/building-cost-curves-co2-storage-european-sector/24-co2-storage-and-coal-bed-methane

[83] In this context an un-mineable coal seam refers to coal deposits located at high depths therefore making extraction uncompetitive.

5.2.2 Coal-bed methane production

Coal deposits can be used as part of an enhanced coal-bed methane (ECBM) project where injected CO_2 displaces the methane that was sorbed onto the coal[85]. Up to 25 m^3 of methane per tonne of coal are contained in coal seams (IEAGHG, 2010) and typically 50% of the methane can be recovered in this process.

Three situations can be considered to recover methane from coal (World Coal Association, 2017):

- Coal Bed Methane (CBM) –methane recovered from un-mined coal seams.

- Coal Mine Methane (CMM) - methane recovered during mining activities, especially underground mining known to produce substantially greater levels of methane. According to (IEA ETSAP, 2014) methane emissions are about 10-25 m^3/tonne for underground coal mining and 0.3 –2.0 m^3/tonne for surface mining.

- Abandoned Mine Methane (AMM) - methane recovered from mines that have been abandoned or closed following the completion of mining operations. According to (IEA ETSAP, 2014), post-mining operations result into methane emissions of 0.4-4.0 m^3/tonne for underground mines and 0-0.2 m^3/tonne for surface mines.

The implementation of CO_2-ECBM solutions has received attention from EU funded projects. Pilot projects and demonstration tests have been developed in Poland - for example RECOPOL, which involved the injection of 760 t CO_2 in 2005[86] and MOVECBM (2011)[87]. Most recently, the ongoing R&D project TOPS[88] developed by a European consortium with international partners, aims at providing technical evidence of the UK potential.

Despite these initiatives, the main CO_2-ECBM projects are being developed outside Europe, in the United States, Canada, Japan and China.

In Europe, (EU Geocapacity, 2008) identified coal basins with high CO_2-ECBM potential in Bulgaria, Slovenia, Poland, Spain, Romania and Italy. The results of this assessment are presented in the table below.

The best potential is located in Slovenia while shallow and small coalfields in Croatia and Slovakia are likely to be less suitable.

Table 21. Coalfields that could be used for CO_2-ECBM in Europe.

Country	NUTS-2 Region	Coalfield / Suitability for CO_2-ECBM	Number of operating Mines	Depth (m)
Bulgaria	BG32, BG41	Dobrudja, Bobov Dol (both not sufficient explored)	8	830
Croatia	HR03	Shallow and small coalfields	0	NA
Italy	ITG2	Sulcis, Sardinia	1	1 000
Poland	PL22, PL31	Lower Silesian & Lublin basins	30	770

[84] https://hub.globalccsinstitute.com/publications/building-cost-curves-co2-storage-european-sector/24-co2-storage-and-coal-bed-methane

[85] https://hub.globalccsinstitute.com/publications/building-cost-curves-co2-storage-european-sector/24-co2-storage-and-coal-bed-methane/ In this context methane is also referred to as coal bed or coal mine gas.

[86] http://cordis.europa.eu/project/rcn/58615_en.html

[87] http://cordis.europa.eu/project/rcn/81409_en.html

[88] http://cordis.europa.eu/result/rcn/175917_en.html

Romania	RO42	Resita (bad geological conditions for CO_2-ECBM)	6	NA
Slovenia	SI03	Mura (good CO_2-ECBM potential)	1	
Slovakia	SK02, SK03	Shallow and small coalfields	4	200

Source:EU Geocapacity (2008)

These concepts, besides having climate relevance (e.g. if not collected, coal mine gas is released into the atmosphere), could also minimise potential risks resulting from methane uncontrolled emission, accumulation and explosiveness (Backhaus, Mroz, & Willenbrink, 2002). Moreover, the utilisation and trade of recovered methane can help address the high costs of CO_2 storage.

For example, the calorific value of coal mine gas from abandoned mines is high. It is estimated at 14 to 30 MJ/m^3 which, according to (Backhaus, Mroz, & Willenbrink, 2002), would allow an economic exploitation. According to the same publication, the potential for coal mine gas in North-Rhine Westphalia (Poland) is significant - as much as 110 million tonnes of methane are released per year, most of it is usable.

In Europe, recent estimates indicate that up to 15 billion tonnes of CO_2 can be stored via CO_2-ECBM. Poland has the highest storage capacity of 6.63 billion tonnes of CO_2 (Godec, Koperna, & Gale, 2014). Further assessments are however necessary to reveal supplementary details on the potential and technical feasibility for CO_2 storage and methane extraction in coalfields.

5.2.3 CCS implementation and jobs

In respect of the relevant EC legislation, the CCS directive entered into force in April 2009 (Directive 2009/31/EC)[89] with the aim to establish a legal framework to safely store CO_2, based upon the availability of suitable geological formations, the lifetime of the storage sites, and the conception of a monitoring plan, which shall be updated every five years, regarding risks of leakage, any assessments changes, new scientific knowledge and/or improvements on the available technology. The operator remains responsible for the monitoring post-closure period.

Currently, 16 Member States have legislation confirming the CCS directive but only Poland has determined a storage area. Germany has limited in 4 Million tonnes CO_2 the amount that can be stored at national level and in 1.3 million tonnes the amount at storage site. Other Member States with CO_2 storage assessments are United Kingdom, Sweden and the Netherlands. On the other hand, Greece, Hungary, Denmark, Italy and Bulgaria also expressed interest to allow CO_2 storage in their territory and are developing their assessments (EU internal report on implementation of directive 2009/31/EC. 2016).

With respect to jobs, across Europe, it is estimated that around 330 000 jobs can be created in the supply chain, namely in the provision of CCS equipment, plant operation and CO_2 storage facility operation (ZEP, 2013).

[89] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0031

5.3 Mine reclamation – potential uses of mine sites following closure

Coal extraction from surface and underground mines changes the natural landscape. In view of the large areas typically affected, especially in the case of surface mines, large scale intervention is needed upon mine closure to bring the landscape close to its original natural form.

Land reclamation is therefore an integral part of any mining project. Reclamation of a mine site involves a number of activities aimed at returning the land and watercourses to an acceptable environmental state and productive use (Mining Facts, 2017). These activities typically begin with clean-up/remediation actions to remove or isolate contaminants in pre-existing tailings storage facilities, the collection and treatment of any contaminated mine effluents (including acid mine drainage in cases where sulphides are abundant in coal seams) preventing negative effects on streams and groundwater, the physical stabilization of landforms and structures (mine shafts,, tailings, etc) and the restoration of topsoil. In the case of underground coal mines, additional works might be required to control land subsidence and also the risks related to methane release (RECORE, 2006), (World Coal Association, 2017).

In the post-closure phase monitoring programs are implemented to assess the effectiveness of the reclamation measures and to identify any corrective action that may be needed (Mining Facts, 2017).

Today, these remediation actions, which are specific to each mine, are part of closure plans required by regulatory agencies at national level. They are a component of the environmental impact assessment process and are submitted for approval previous to the award of mining rights.

In EU, the mining industry is subject to the Environmental Liability Directive which is based on the "polluter pays" principle[90]. The Directive is in force since 2004 and was progressively incorporated into national laws until 2007. In the past, under less stringent regulations, mines were often abandoned without being adequately reclaimed.

Although mine owners have a legal obligation to manage the risks and environmental consequences of stopping mining activities (RECORE, 2006), many European coal mining companies have been unable to handle alone the social and environmental costs of closing a mine. Since 2010, national authorities in many EU countries have reported to the European Commission on state aid measures awarded to coal companies for covering exceptional costs (incl. those related to the rehabilitation) resulting from the closure of uncompetitive mines (see for example boxes 7 and 8).

Box 12. Germany - coal mine rehabilitation to be financed by the proceeds of a private RAG Foundation (Euracoal, 2017)

In Germany continuing liabilities after the final phase-out of hard coal mining (i.e. mine water management) will be financed by the proceeds of a private RAG Foundation, created in July 2007. Using its assets, the Foundation will also promote education, science and culture in the mining regions.

Following rehabilitation, mine sites have been typically restored to their pre-mine uses (e.g. re-cultivation, forestry, agriculture). The establishment of a functional/sustainable ecosystem (using for example native forest species), not necessarily the one that existed before mining began, is now one of the priorities (Mining Facts, 2017).

Many reclamation projects have valued the creation of recreational areas and leisure parks as a means to revitalize the social-economic structures of a mining region. The

[90] http://www.europarl.europa.eu/RegData/bibliotheque/briefing/2012/120376/LDM_BRI(2012)120376_REV1_EN.pdf; http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:l28120&from=EN

Lusatian region in Germany, for example, where the extraction of coal at surface lignite mines once shaped the landscape, has witnessed an impressive transformation of the natural landscape. Today 23 artificial lakes offer various possibilities for leisure activities (Tourismusverband Spreewald, 2011) (see Figure 55). Coal mining is still active at the Nochten and Reichwalde open-pits, demonstrating that recreational and mining activities can co-exist.

Figure 55 Artificial lakes at the Lusatian region in Germany created by flooding various old coal pits.

In Spain, trout and salmon fishing are good examples of a new leisure activity that attracts tourists to former coal opencast mines in Asturias (RECORE, 2006). Other creative re-uses of coal mines are found in the Czech Republic and Poland. In the Czech Republic, the mining companies Vršanska Uhelna and Severni Energeticka built the Most Hippodrome, which also includes a racecourse, an in-line skating track measuring 3 Km, a golf course and a recreational park (Hipodrom Most, 2017). The hippodrome receives 100 000 visitors every year (Euracoal, 2013). In Poland, the Kamieńsk Mountain, built of overburden from the lignite mine Bełchatow (still operating), is the highest peak in Central Poland. A comprehensive rehabilitation plan transformed this industrial location into an attractive summer and winter tourist resort. The main attraction is a 760 m long ski slope and the site also offers a modern toboggan run and several bike trails (Euracoal, 2013).

Some other mine sites have been reconverted into museums or destined for other cultural activities. The development of mining heritage is a driver for local development, having tourism as main catalyst. Some examples include The Ruhr Museum at Zollverein (Ruhr Museum, 2017)[91] in Germany or The Big Pit National Coal Museum, in South Wales[92] , both including visits to the underground galleries and recognized UNESCO World Heritage sites in 2001 and 2000, respectively; the Landek Park and Museum, in the Czech Republic[93] which received the Henry Ford prize, in recognition of the revitalization of deteriorated areas, respect for the environment and cultural heritage[94];

[91] https://www.ruhrmuseum.de/startseite/
[92] https://museum.wales/bigpit/
[93] http://www.landekpark.cz/
[94] (RECORE, 2006)

the Escucha mine Museum in Spain[95], and the mining History Centre located at Lewarde, France[96].

Mining heritage has an important role in enhancing leisure and tourism for mining regions (RECORE, 2006). The Ruhr Museum for example attracts over 250 000 visitors and The Big Pit National Museum around 110 000 visitors every year.

Also some equipment/machinery used in former coal mines constitute unique pieces of industrial heritage. For example, the overburden conveyor bridge used until 1992 (Mining Atlas, 2017) at the Klettwitz-Nord lignite mine (Lichterfeld-Schacksdorf in the Lusatian region, Germany), is today open for visitors and is one of the anchor points of the European Route of Industrial Heritage[97] (see Figure 45 for an example of this type of equipment).

Thus, reclaimed mine sites constitute an asset with high added value for the social-economic development of the concerned regions. Planning is required to anticipate and identify the most appropriate solution to drive local development. At each mine site, a long-term vision is essential to take full advantage of the mining legacy and ensure that one solution does not hinder another more beneficial use.

Close cooperation between mining companies, regulators, land-use planners, investors, the regional/local government and citizens is essential to identify the most sustainable uses and maximize social-economic development (RECORE, 2006). In line with this, the experience in Central and Eastern Europe shows that cooperation among many scientific disciplines and areas of expertise, the involvement of local communities and the presence of an adequate legal framework are essential for the rehabilitation and utilization of post-mining areas (Wirth, Černič Mali, & Fischer, 2012).

Reshaping of mining areas should aim as well to develop new activities by attracting investments that can actively contribute to the economic growth of the region. In many coal mining regions, the dependency on the mining industry resulted in limited development of other economic sectors (RECORE, 2006). The road and also the housing infrastructure which is generally unsuitable, obsolete or deteriorated is pointed out as one of the main problems faced by the local authorities (RECORE, 2006). While the renovation of this infrastructure is fundamental to convert and prepare the area for national and international investors, the high cost of bringing them up to date creates barriers to a successful transition.

An example of a successful reconversion project of a former mine site into an industrial area is given in the box below.

Box 13. Czech Republic - The reconversion of the old Frantisek mine into an industrial area

After the closure of the Frantisek mine in 1999, the Horní Suchá municipality, facing high unemployment and a potentially devastated facility, committed to transform the old mine into a modern industrial park. The re-cultivation of the site was followed by investments into a new technical infrastructure and communication systems - roads, various networks and the grounds themselves have been improved (RECORE, 2006). The main focus of the project was to update the mining infrastructure which included 43 000 m^2 of buildings (RECORE, 2006). The municipality utilized the subsidy program for regeneration of land to successfully develop the project. The revitalized area with a size of 14 ha was awarded the “Brownfield of the Year 2009” in a competition held annually by the Ministry of Industry and Trade and the CzechInvest agency. Currently, the industrial park has 25 companies employing around 300 people (Asental, 2015).

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95 http://www.museomineroescucha.es/
96 http://www.chm-lewarde.com/en/the-mining-history-centre/presentation-and-missions/
97 http://www.erih.net/

5.4 The reconversion of coal mines for renewable energy generation

Mine site reconversion to renewable energy generation can provide economic value and contribute to energy security after the closure of a mine. Many renewable energy projects are already in place or have been proposed at coal mining sites, as discussed in the following sections. Solutions need to be addressed on a case-by-case basis to ensure suitability to the local conditions.

5.4.1 Opportunities in solar power

Former mine sites with favourable sun exposure can make good locations for solar power generation. Mine sites often cover extensive areas with flat landforms reshaped by the mining activity, and also include artificial slopes and ridges at higher elevation formed by the accumulation of tailings and other mine waste.

The development of such projects benefits from the existence of infrastructures in place which would avoid additional capital costs (Whitbread-Abrutat & Coppin, 2012). These include electricity transmission lines from coal mining operations but also those provided from mine-mouth coal power plants, if present.

Additional aspects in favour of the development of a solar power project include the generally lower land transaction costs in former mining areas, which tend to have relatively few owners in comparison to “greenfield” sites (Whitbread-Abrutat & Coppin, 2012).

Examples of the redevelopment of former mine sites for solar energy generation are many, particularly in Germany. In 2004, the former Goettelborn lignite mine in Saarland (southwest Germany) was converted into a solar energy park, becoming at the time, the largest of its kind. The Geosol solar plant at Espenhain (Leipzig) was constructed in 2004 on a former lignite mine site. The facility consists of some 33 500 solar modules and generates 5 MW (New Europe, 2004). These and other examples of this use in Germany are given in Figure 56.

Box 14. The former Goettelborn coal mine in Saarland (see aerial view below)

The site of the former Goettelborn coal mine in Saarland, southwest Germany, converted into a solar energy park in 2004, generates 8.4 MW from 49 000 modules, covering an area of 165 000 m2 (German Coal Association, 2012).

Other countries have adopted similar solutions, taking advantage of the potential of solar power at some former mine sites. In the United Kingdom a large-scale solar PV farm was developed on the south-facing site of the former Wheal Jane tin mine near Truro in Cornwall. The project developed by Lightsource Renewable Energy houses 5 680 solar panels with a generating capacity of 1 437 MWh of electricity a year (Hughes, 2011)

Besides PV plants located on-ground, opportunities for floating solar farms in flooded open-pit mines might also exist[98].

At mine sites where other more valuable socio-economic uses may be ruled out, energy production from solar power is a strategic possibility. On the one hand the positive social perception towards renewables means that this reconversion option is likely to be met without opposition. In addition, this alternative besides benefiting energy security can also help create new jobs and enable reemployment particularly during the construction phase.

[98] In Portugal a pilot project of floating solar panels at an existing hydro-electric power station was initiated by EDP back in 2015 and has been operating since the end of November, 2016. https://www.pv-tech.org/news/first-ever-hydro-electric-and-floating-solar-project-operating-in-portugal

Figure 56. Aerial views of solar farms on the sites of former coal mines in Germany (Source: Google Earth).

5.4.2 Opportunities in wind power

Some former coal mines are located in areas with very suitable characteristics for the installation of large-scale wind farms as (US EPA, 2012):

- They are placed in high-latitude areas with high wind resource.
- They cover extensive and open areas so that large-scale wind projects can be installed in only one location.
- Some infrastructure of the former coal mines can be reused for the wind farms including power transmission lines and other infrastructure (e.g. roads). This reduces both the decommissioning costs of the mine and the capital costs of the new wind farm.

Currently there is an increasing potential as more coal mining activities are declining. As an example, a 2009 study of former coal mining land across the UK examined the potential for wind power generation and identified 106 sites, with the potential for nearly 4 GW of generating capacity, some 10 TWh/year (Whitbread-Abrutat & Coppin, 2012). Wind energy projects can additionally have significant positive environmental, economic and social impacts on the coal-mining area as has been already shown by a number of successful projects.

The installation of wind energy projects in former coal mining areas also has a positive impact on local economy. New local employment opportunities are created during construction and operation phases. For instance, the Black Law wind farm located in Scotland has recently been extended from 54 to 88 wind turbines reaching 187 MW. (ScottishPower Renewables, 2017) has noted that jobs for almost 2 000 construction workers and technical support staff have been created. Another example is the Windpark Klettwitz in Germany repowered in 2015 reaching 93 MW nominal power. During the construction process more than 120 people were involved (GICON, 2015). In the United States, the Glenrock wind farm in Wyoming has a combined wind energy power capacity of 237 MW with 158 wind turbines in the three projects (Glenrock, Rolling Hills, and Glenrock III). It is located on the former Dave Johnston Mine occupying a length of almost 5 km. This project has been fully operational since 2009 and it can generate sufficient energy to meet the electricity needs of about 66 000 homes annually (Cnet, 2009). During construction, more than 300 people were employed in temporary construction jobs and it currently has about 15 permanent jobs. Moreover, Rocky Mountain Power, the mine's operator, is working with local institutions in order to create some degree programs in wind turbine technology (US EPA, 2012).

On the other hand, wind energy projects can also enable re-employment of a skilled labour from the mining sector (Whitbread-Abrutat & Coppin, 2012). As an example, in the coal mining area of East Ayrshire (UK), a wind farm developer has proposed a training programme for 60 new paid traineeships at the proposed Lethans Wind Farm, depending on approval of the wind farm. "As a former mining community, this area has been hit hard by unemployment in recent years with a real lack of opportunities for young people to access employment (BanksGroup, 2017)." A similar offer has been put forward in Wyoming (USA) by a turbine manufacturer (Cardwell, Wind project in Wyoming envisions coal miners as trainees, 2017).

In addition to creating new jobs, additional revenues at local, regional and/or national level can be generated as a result of occupying the land as well as local spending during the construction and operation phases of a wind farm. For instance, the Oakdale Colliery wind project is located in the former Oakdale Colliery coal mine that covers approximately 162 hectares in Wales. It has 4 MW (2 Senvion MM100 wind turbines of 2MW rated power each) and it will generate approximately 10 GWh/year (The Guardian, 2014). This project has been developed via a public-private partnership between Partnerships for Renewables and a Welsh local authority. In addition to providing local benefits in terms of job creation, the project will provide additional revenues to the local community. Thus, Partnerships for Renewables will pay rent to the council for use of the area as well as a community benefit package of about EUR 11 000 per year during the lifetime of the project that will be invested on projects that create some social, economic or environmental benefit (Partnerships for Renewables , 2017).

Building wind farms on a former coal mine can also have some other positive social impacts. They will likely achieve a higher social acceptance compared to wind farms placed on greenfield sites as they may be considered as a valuable asset for the local community (US EPA, 2012). One of the biggest technical challenges of constructing a wind farm on locations where mining activities were performed is related with the variable ground conditions. The additional analysis and remediation required in the foundations to ensure that the surface is structurally strong enough can lead to higher costs compared to a greenfield site (Whitbread-Abrutat & Coppin, 2012). Some projects have implemented some solutions to overcome this technical challenge. The Windpark Klettwitz in Germany and the Maesgwyn Wind Farm in the United Kingdom used the dynamic compaction method to increase the density of the ground and solve its instability (GICON, 2015), (Pennant Walters Limited, 2013). Additionally, specially-developed combined pile-raft foundations were installed in the Windpark Klettwitz (GICON, 2015).

The Somerset wind farm in Pennsylvania (USA) implemented several innovative construction approaches. Namely, the structural instability of the ground was overcome by installing weights under each turbine. Besides, to ensure the stability of a wind turbine placed over the main corridor of the mine, concrete was poured into the shaft to stabilize the structure before pouring the turbine’s foundation. In addition, a tilt sensor was installed on the turbine to detect any land subsidence (US EPA, 2012). Similarly, the Casselman wind power project which is also located in Somerset County, Pennsylvania uses an innovative approach to prevent structural instability. Eight of the project's 23 wind turbines are located atop of a rehabilitated surface mine. Mine spoils (loose rocks and soil excavated during coal mining) were discovered during the geotechnical survey at the location of the planned turbines. A first of its kind engineering solution was developed using a micropile foundation. Each foundation comprises twenty-four micropiles extending through the spoils and anchors the turbine into the bedrock at about 33 meters under the ground. The Pennsylvania Energy Development Authority supported the Casselman project with a grant of about EUR 420 000 to offset the increased development costs (Avangridrenewables, 2017) (Barr Engineering, 2017).

Another technical challenge for the construction of a wind farm on a former coal mine may be the removal of existing infrastructure such as buildings, underground gas pipes and overhead wiring (US EPA, 2012). Other examples of wind farms planned or installed on a former coal mine are:

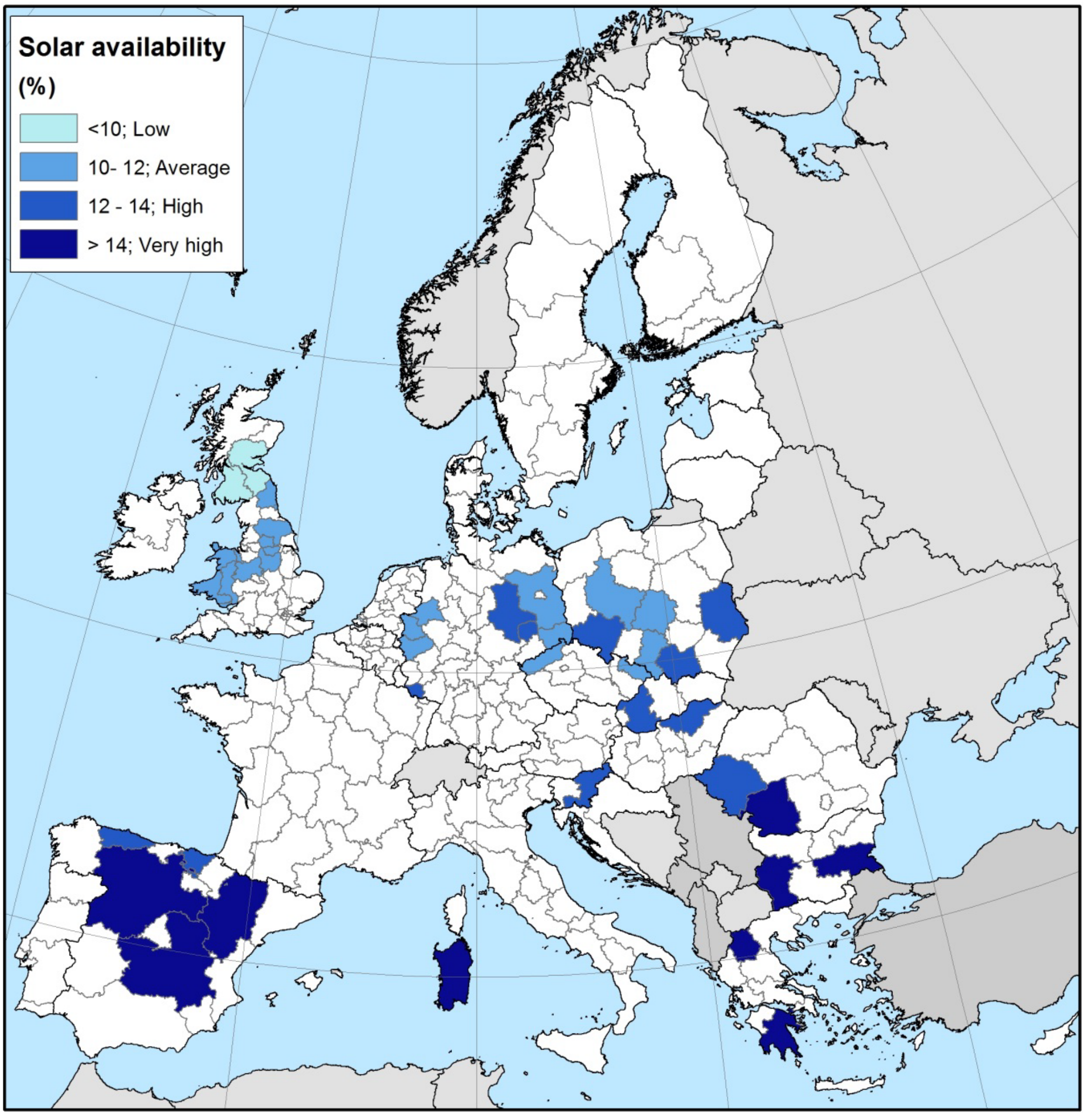
- The NedPower Mount Storm Wind project located in Virginia (USA) is planned to have 132 wind turbines with a total capacity of 264 MW (US EPA, 2012).
- The Stony Creek wind farm in Pennsylvania (USA) with an expected capacity of 53 MW (UPI, 2009).
- The Buffalo Mountain project in Tennessee (USA) with 29 MW after its expansion (US EPA, 2012) (Choi & Song , 2017).

5.4.3 Wind and solar resource potentials

In this section the availability of wind and solar resources as determined by (Gonzalez-Aparicio, et al., 2017) and (Gonzalez-Aparicio, Huld, Careri, Monforti, & Zucker, 2017) are presented. For the purposes of the present analysis, these values were averaged in each of the 41 regions hosting coal mine infra-structure, in order to obtain a first glance into the feasibility of converting these sites to host renewable energy facilities, with benefits discussed in sections 5.4.1 and 5.4.2.

Wind and solar resources exhibit significant variability across Europe, with average solar and wind availability/capacity factors[99] ranging between 12-14% and 15-25%, respectively. Figure 57 illustrates the distribution of the mentioned solar and shows that mine sites located in southern countries, namely in Spain, Italy, Greece, Slovenia, Romania and Bulgaria, can benefit from a highly available solar resource, making the conversion of former mine sites for the production of solar energy more attractive.

Figure 57. Solar availability factors (%) at NUTS 2 regions hosting coal mining infra-structure.

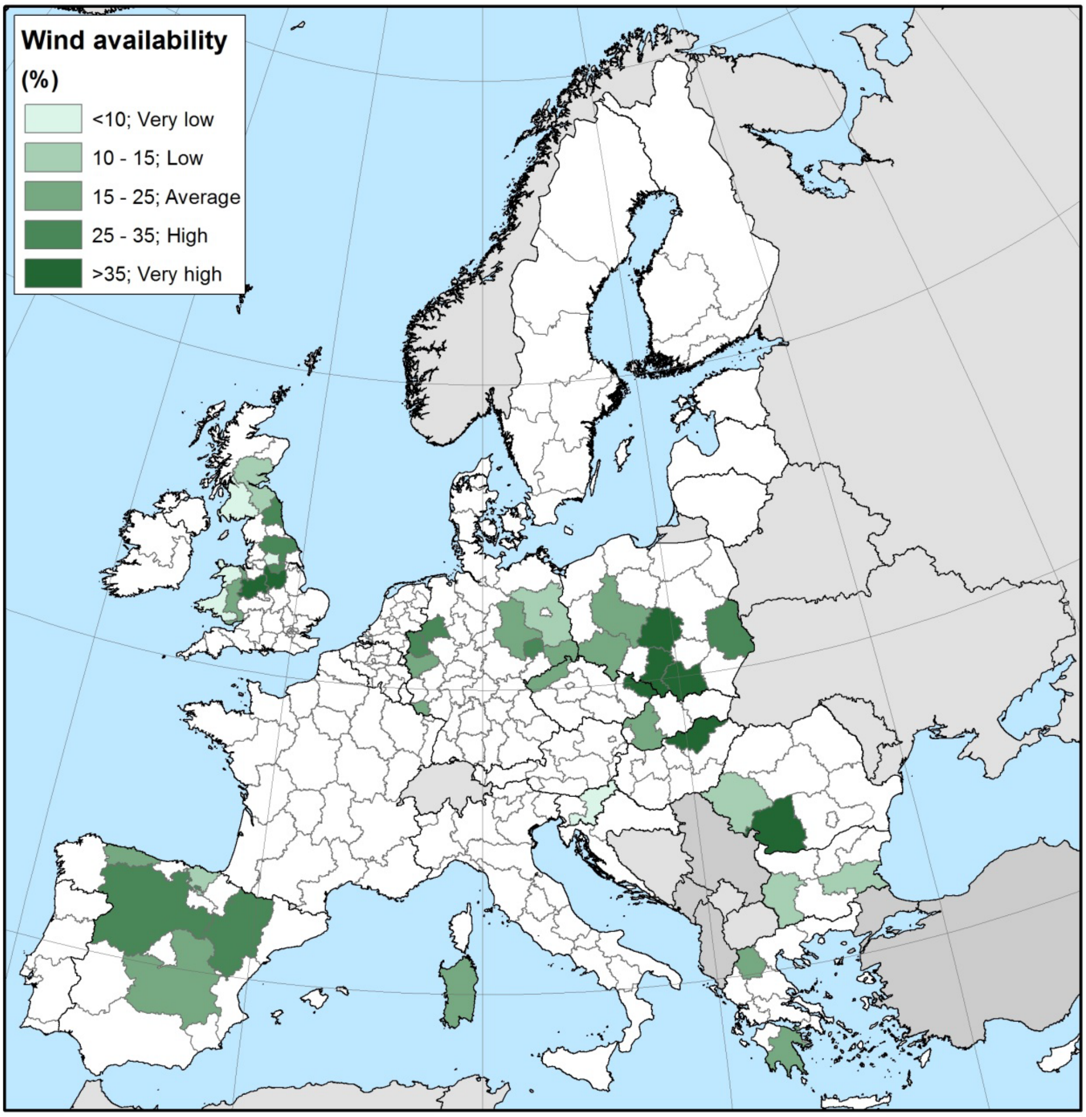


[99] Wind and solar capacity factors are defined as the average power generated, divided by the installed capacity (that is, the maximum power that is possible to generate).

The solar resource in central and northern European regions is lower, but depending on the specific local conditions, the conversion can still be considered feasible. Mine sites located in northern regions of the United Kingdom, mainly Scotland, have however a significantly lower solar resource which would render uneconomic this form of energy production.

The availability of wind resources is very site-specific and it typically depends on the landscape and the distance from the sea, which means that each site requires a detailed examination for an assessment of suitability. It is expected that mines located at high-altitudes will have a generally higher wind resource. A first impression of the suitability of different coal mining regions can be obtained by observing Figure 58. For example, central and eastern regions in the United Kingdom have high or very high wind resource availability but the country’s western regions offer low or very low potentials because of unfavourable wind patterns.

Figure 58. Wind availability factors (%) at NUTS 2 coal mine regions.



On the other hand, mine sites located in central and eastern European regions present higher suitability for wind power generation. In these regions, the wind resource potential range from average to very high.

Finally, despite the diversity of the wind potential situation in southern European regions, some degree of suitability for wind power generation can potentially be expected.

Annex 19 provides the wind and solar availability/capacity factors in the 41 coal mining regions.

5.4.4 Geothermal energy production in closed coal mines

Closed and flooded mines have good potential as low-enthalpy geothermal resources, which may be used for small to medium scale power generation and for heating and cooling purposes. This efficient, cost-effective solution has been implemented in many countries around the world (Ramos, Breede, & Falcone, 2015) and has significant potential in Europe, in particular for district heating and the creation of sustainable post-mining communities.

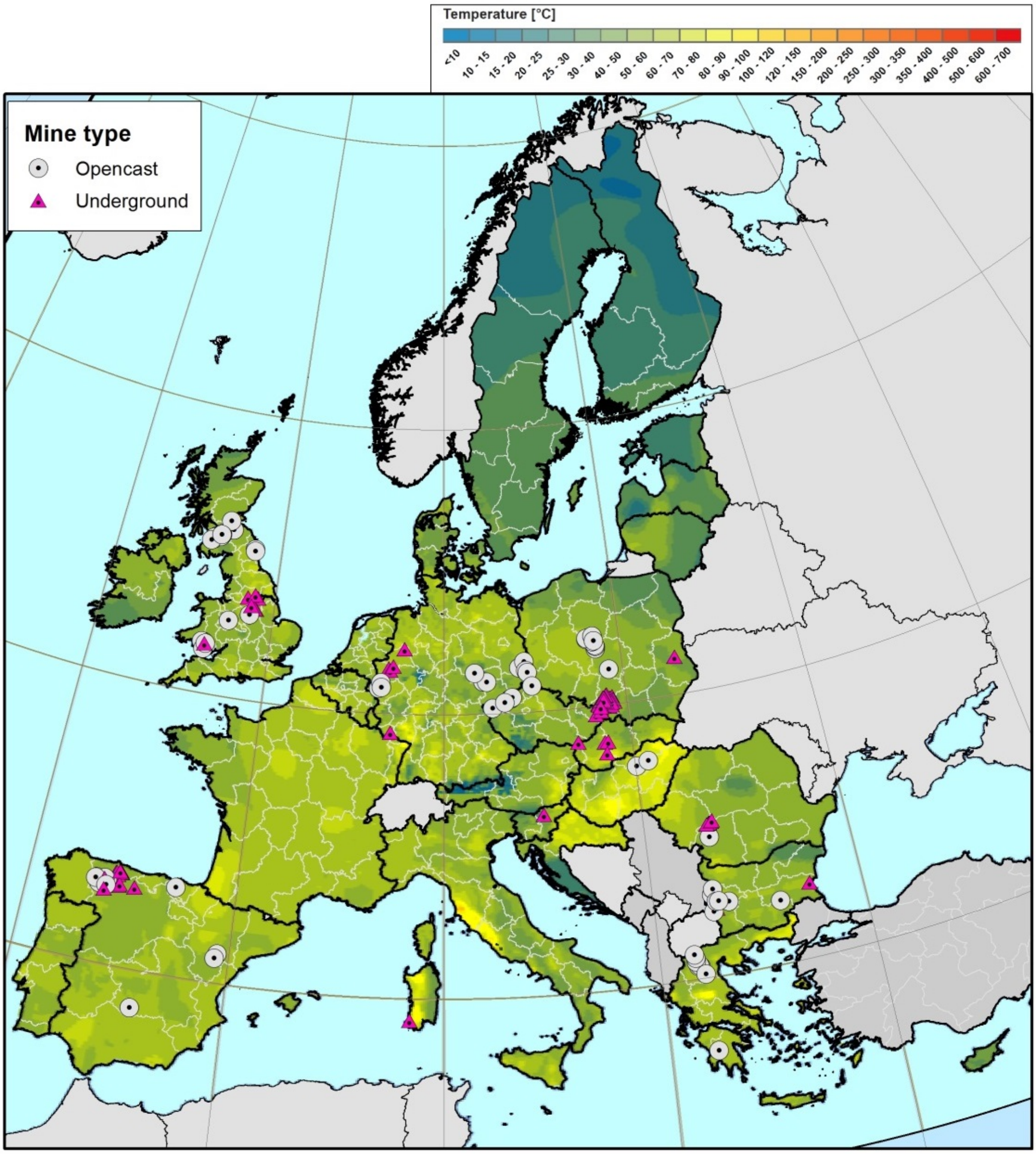
Heating and cooling makes up half of the EU-28 total final energy demand and relies mainly on fossil fuels (Heat Roadmap Europe, 2017). In Europe, the market share of district heating technology is only about 10% of the heating market. Of some 5 000 district heating systems, 180 are geothermal district heating systems, with a total installed capacity of around 1.1 GWth, producing about 4 250 GWh of thermal power. Many EU countries have NREAP targets to increase geothermal district heating in the energy supply but are falling short of these due to difficulties with implementation (Dumas & Bartosik, 2014). The geothermal potential of closed underground coal mines in Europe has been estimated in the order of several thousand megawatts thermal (3GWth is proposed as an initial estimate) with an estimated reduction in CO_2 emissions associated with using the mines instead of conventional heating and cooling technologies at around 5 000 tonnes/year (Díez & Díaz-Aguado, 2014). This could provide an opportunity to quickly expand the geothermal share of the district heating market whilst reducing emissions and reliance on energy imports.

For example, as can be seen from the map in Figure 59, Slovakian coal mines exist in areas with relatively high temperatures at depth. The potential of mine waters here has already been noted by (Bajtos, 2001) in Nováky (20°C), Handlová (11.6°C), Cígel (14°C), Modrý Kameò (closed, 17°C) and Gbely (16°C). Whilst most are still in operation, these mines could provide between 0.69MW and 5.79MW respectively.

The mining techniques used for exploration and evaluation of potential mineral resources are applicable for the exploration and assessment work for geothermal project development and the equipment and services originating from the mining sector will need to be used in order to speed up the growth of the geothermal sector. Since the geothermal industry currently lacks skilled workers, scientists and researchers, the sector is likely to try to absorb workers from declining industries (Schütz, Huenges, Spalek, Bruhn, Pérez, & de Gregorio, 2013) such as coal mining. The most important professions for geothermal organisations include geologists and engineers, geophysicists, geochemists, technicians, maintainers and drilling consultants and such workers could transfer from the mining sector with varying degrees of retraining. Typically more jobs are created during the exploration / construction phases than the operation of the plant itself, hence the mining professions would most probably have transferable skills in particular for these phases of geothermal projects.

Despite the positive socio-economic impacts that may be achieved by using mines for the recovery of low carbon geothermal energy and the large number of closed mines, relatively few mines have been used in this way in Europe. The REMINING-LOWEX project funded under FP6 (SUSTDEV) was aimed at the redevelopment of European mining areas into sustainable communities by integrating supply and demand side, based on low exergy principles. In this project, four local communities (Heerlen in the Netherlands, Zagorje in Slovenia, Czeladz in Poland and Cherno More in Bulgaria) aimed to demonstrate the use of local but low-valued renewable energy sources from water in closed mines for heating and cooling of buildings through integrated building and energy system. They aimed to create two sustainable mining communities (Heerlen and Zagorje) with 50% to 100% CO_2 reduction and 60% renewable energy sources. The Heerlen project, located in the province of Limburg, the Netherlands was considered the most successful.

Figure 59. Temperature at the depth of 1000m at locations of coal mines in Europe



Data source for the base map: (Limberger , et al., 2014)

Other European projects are identified by Ramos et al. (2015) in a comprehensive review and are located in Germany, Norway, Spain and the United Kingdom (Ramos, Breede, & Falcone, 2015). In almost all cases the heat is used for space heating in buildings but other uses such as heating pools are also mentioned. The majority of the described projects were found in Germany. The “GrEEn-Projekt”, in the Alsdorf municipality in North Rhine Westphalia, a geothermal system for several buildings, is owned by Energeticon Company. In the old mining town of Ehrenfriedersdorf, two different geothermal projects have been implemented which utilize the mine water from different sections of the closed mine. In Freiberg, Saxony, two geothermal heating systems exist. One is used for heating a castle and museum and one for heating buildings in Freiberg University of Mining and Technology. In the city of Marienberg, a geothermal low-enthalpy project uses mine water temperature to supply heat to the adventure pool, Aqua Marien, a tennis hall, and some supermarkets. In Wettelrode, Saxony-Anhalt, a geothermal pilot system was installed to provide heat and hot water to the for the Wettelrode Rohrigschacht mining museum.

Box 15. The Netherlands: 'Minewater' district heating project, Heerlen

The region of Parkstad Limburg, once reliant on coal mining, is now a hub for new energy research, where educational and research institutions, entrepreneurs and government collaborate to gain valuable experience through practical experiments in new technologies and production facilities such as the Heerlen Minewater project. The project aims to promote local employment, involve local educational and research institutions and to achieve a high social involvement and sustainability awareness of the inhabitants.

Now one of the world's largest geothermal district heating systems using mine water, the Minewater project began as a pilot system, completed in 2008 (Verhoeven R. e., 2013) and was upgraded to a full-scale hybrid sustainable energy structure called Minewater 2.0 (Verhoeven, et al., 2014). The project is a part of the Heerlen Sustainable Energy Structure Plan and includes energy exchange rather than energy supply, making use of cluster grids to exchange energy between buildings and the existing mine water grid to exchange energy between cluster grids. Energy is stored and regenerated in the mine waters, rather than depleting it through the addition of a poly-generation system using bio-CHP, solar energy and waste heat from data centres and industry. Cooling towers are used for peak cold demand. The hydraulic and thermal capacity of the mine was increased by improving the well pumps and pressure system and by reusing the existing mine water return pipe to supply and dispose of mine water. The supply of hot and cold mine water is fully automated and demand-driven by using a pressurized buffer system at extraction wells and special injection valves at injections wells. Mine water installations at the various buildings, clusters and wells are controlled via internet-connected process control units that communicate to a central monitoring system (Verhoeven, et al., 2014). In 2015, the objective was to service 500 000 m^2 by the end of 2016 (Verhoeven R. e., 2013) with an eventual total of 800 000 m^2 resulting in a CO_2 emission reduction of 65% on heating and cooling for these connections (Verhoeven R. e., 2013).

In a more recent development, the Glasgow Geothermal Energy Research Field will be launched in 2017, on a 10 million EUR site near Glasgow city, as part of the UK Geoenergy Observatories Project led by The Natural Environment Research Council (NERC) and the British Geological Survey (BGS). Glasgow's research field aims to become a world-class research site attracting globally leading scientists and engineers, to investigate the use of coal mine waters for producing geothermal energy.

Worldwide reviews of other cases of using mines to harness geothermal energy are also available (Banks, Athresh, Al-Habaibeh, & Burnside, 2017) and (Ramos, Breede, & Falcone, 2015). The feasibility of using mines to recover geothermal energy depends on factors such as the mine history, water and air flow, hydrology, geology and of course the political and regulatory environment (Malolepszy, Demollin-Schneiders, & Bowers, 2005), (Díez & Díaz-Aguado, 2014).

5.4.5 Opportunities in hydro power plants and Pumped Hydroelectric Storage (PHS)

Hydropower is one of the most widely used renewable power sources in Europe covering 10.4% of gross final electricity consumption (EC - JRC, 2017). Generally for hydropower utilisation there is the need of water source and the height difference. The potential for using this energy is proportional to the height difference, which can be achieved and to the water flow which is available. In some cases, open pit coal mines were built close to rivers and sometimes at higher altitudes. This may provide an opportunity to use these locations as locations for a hydro power plant if the open pit was used as an artificial lake.

Box 16. Spain: Hydropower project at As Pontes

The Spanish energy company Endesa operated the open pit 'As Pontes' hard coal mine for the purpose of power generation. From 1976 to 2008 the mine produced 261 million tonnes of brown coal (Mining Atlas, 2017). After closure, the open-pit of almost 18 km of perimeter and 205 m of depth was filled with water from rivers Eume[100] and Meidelo. The resulting lake is located 20 km from the Atlantic ocean and at the altitude of 330 m. This was recognized by Endesa as an opportunity for a hydro power plant project with the capacity between 300 and 600 MW. [101]

Source: Google Earth

Pumped hydropower storage (PHS) was originally deployed in the course of the 20th century to meet peak demand with base-load generation. The basic principle of a PHS system is to store energy by means of two reservoirs located at different elevations. In times of low demand, electricity from the grid is used to pump water to the higher reservoir, while in times of peak demand the water is released to generate electricity, hence operating a reversible cycle of grid electricity (EC - JRC, 2014). According to JRC's report "Assessment of the European potential for pumped hydropower energy storage", a theoretical potential of 123 TWh, and a realisable potential of around 80 TWh, exists in Europe, considering only topologies based on one already existing reservoir (Gimeno-

[100] http://www.farodevigo.es/sociedad-cultura/2012/05/17/mina-as-pontes-mayor-lago-espana/649252.html
[101] http://www.energynews.es/english/endesa-proyecta-una-central-de-bombeo-en-el-embalse-de-as-pontes/

Gutiérrez & Lacal-Arántegui, 2013). It is recognised that further potential exists in newly to be developed green fields, out-of-use mines and quarries, or sea-based pumped hydro.

There are at least two elements of mines that could fit in innovative PHS systems: an open pit could be used as surface reservoir (or reservoirs) and deep-underground cavities could be used as lower reservoirs. Both options can be used in different ways. In combination with other non-mine reservoirs, an open pit could serve as either upper or lower reservoir, depending on the configuration of the surrounding terrain while deep-underground cavities could be used as lower reservoirs. In exceptional cases, where both open pit and underground mine are in close proximity, they could be used in combination to form a single PHS system where the open pit is the upper reservoir and the underground cavities the lower reservoir. For example, the open pit could be used along with a nearby existing reservoir to form a PHS system. In some cases as in the example of Genex, Kidston, Australia, two nearby open pits could constitute both reservoirs. There are examples in Australia[102] and in the EU of old mines developed or being developed as part of new hydropower schemes. In Ireland, the Silvermines Hydro Electric Power Station was announced in 2016 by the Irish Minister for the Environment, Mr Alan Kelly[103]. The 360 MW plant will consider the decontamination of water in a pit that time and rain have already transformed in a reservoir. A second reservoir will be built in order to constitute a closed PHS system.

Both pits and underground cavities risk being flooded with rain, surface and/or groundwater, and in order to avoid this, mines have systems to avoid it. However, after a mine is abandoned, those systems stop being maintained and it is a matter of time that water fills up the mines. Water can become acidic which is a complication in using the mines as part of a PHS.

Thus the use of the deep-underground cavities as water reservoir requires careful engineering and environmental considerations regarding e.g. acidification and groundwater. Cavities remaining from coal mining might not be used and new cavities would have to be built. In this context, prospectively the main advantage of using existing mines (as opposed to a new underground cavity) is the use of mine shafts to reduce the cost of excavation (Euanmearns, 2017[104]). In any case, research is needed as well on the hydrogeological consequences produced by the cyclic solicitations (continuous pumping and injection)[105].

The network of tunnels in the Central Coal Basin in Asturias, northern Spain, has also been suggested as a possible lower storage for the development of an underground pumped-storage project. Parts of this infrastructure will soon become available for alternative uses since most of the underground coal mining facilities in Spain are currently being phased out, with an expected closure date at the end of 2018 (Menéndez et al., 2017). According to the authors this infrastructure can hold approximately 200 000 m^3 at depths ranging between 300 and 600 m. Nine projects have been studied in mines that are not currently flooded.

There is not a single former mine developed as underground PHS, although there are proposals in the US (Virginia and California)[106]. In Germany, the conversion of the Prosper-Haniel hard coal underground mine in North-Rhine Westphalia, expected to close in 2018, has been proposed (PEi, 2017).

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102 https://arena.gov.au/projects/kidston-pumped-storage-project/

103 https://www.irishtimes.com/business/energy-and-resources/hydro-electric-power-station-to-be-developed-in-co-tipperary-1.2492364

104 http://euanmearns.com/a-brief-review-of-underground-coal-mine-energy-storage/

105 Bodeux et al., 2016: Interactions between groundwater and the cavity of an old slate mine used as lower reservoir of an UPSH (Underground Pumped Storage Hydroelectricity): A modelling approach. Available at http://www.sciencedirect.com/science/article/pii/S0013795216308171

106 http://southeastenergynews.com/2017/03/13/in-virginia-push-for-pumped-hydro-storage-questions-arise-about-viability/

Based on preliminary reviews, Euanmearns (2017) estimates likely that mine hydropower will be just as problematic and no more economic than underground pumped hydro storage, and not much cheaper than battery storage.

The option of using pits of abandoned mines as part of new PHS schemes constitutes a more realisable proposal.

5.5 Key points

- Transition strategies for the coal sector range from extending the life of current power plants through CCS/U solutions to finding new uses for closed coal mines.
- Retrofitting coal plants with carbon capture technologies could enable mitigation of carbon emissions while preserving or creating additional jobs in coal power plants, however costs can be prohibitive.
- Coal dependent industries, such as cement, iron or steel produce carbon emissions that must be cut by up to 80%; these industries can benefit from using CCS technologies to reduce their carbon footprint and resultant costs.
- The CO_2 storage capacity in several suitable geological formations can be up to 200 billion tonnes of CO_2 in Poland.
- Coalfields in the Czech Republic, Hungary, Poland and Spain, in particular, show potential for carbon storage presenting an estimated capacity of 0.8-2.3 billion tonnes of CO_2.
- The use of coal deposits for enhanced coal-bed methane extraction can provide 15 billion tonnes of CO_2 storage capacity in Europe. Alone, Poland has the potential to store around 6.6 billion tonnes.
- The full deployment of CCS in Europe has the potential to create up to 330 000 jobs in equipment supply and manufacturing, plant and facility operation.
- The reclamation of a mine site involves a number of activities aimed at the remediation of environmental impacts and returning the land to a productive use. Building on the industrial heritage of mine sites, new facilities such as recreation centres, museums and science centres can be developed thereby contributing to the local economy.
- The reconversion of former mine sites to renewable energy generation can reduce decommissioning costs, contribute to energy security and provide economic value and jobs to post-mining communities. The development of such projects benefits from the existence of infra-structure and extensive land availability; solutions need to be addressed on a case-by-case basis to ensure suitability to the local conditions.
- Many renewable energy projects are already in place or have been proposed at coal mining sites. Examples of mine site redevelopment for solar and wind energy generation are many, particularly in Germany.
- The implementation of geothermal heating systems utilizing mine water from different sections of a closed coal mine has been successfully tested with positive socio-economic impacts for example in the Netherlands.
- Hydro power plants and pumped hydroelectric storage are seen as opportunities for example in Spain and Germany.
- Close cooperation between companies, regulators, investors, land-use planners and local communities is essential to identify the most sustainable uses and maximize social-economic development.

6 Re-employment and skills

Transition away from coal transforms the economy of a region parallel to challenging coal workers to adjust to these changes.

6.1 Re-employment opportunities and skills needs

The successful economic restructuring of a coal region does not necessarily mean full employment among former coal workers.

Sector, skill and location (region) are three dimensions along which coal workers have to make decisions to adjust to new economic conditions. Staying in the same sector or seeking employment in other sectors, potential availability of retraining schemes and willingness to move to other regions are the opportunities and choices they face (see Table 22 for examples). In addition, some employees may normally retire or policies may make early retirement possible, removing these people from the active population. In coal regions in transition that successfully undergo economic restructuring and establish other (e.g. clean energy) industries, inward migration from other regions is also possible.

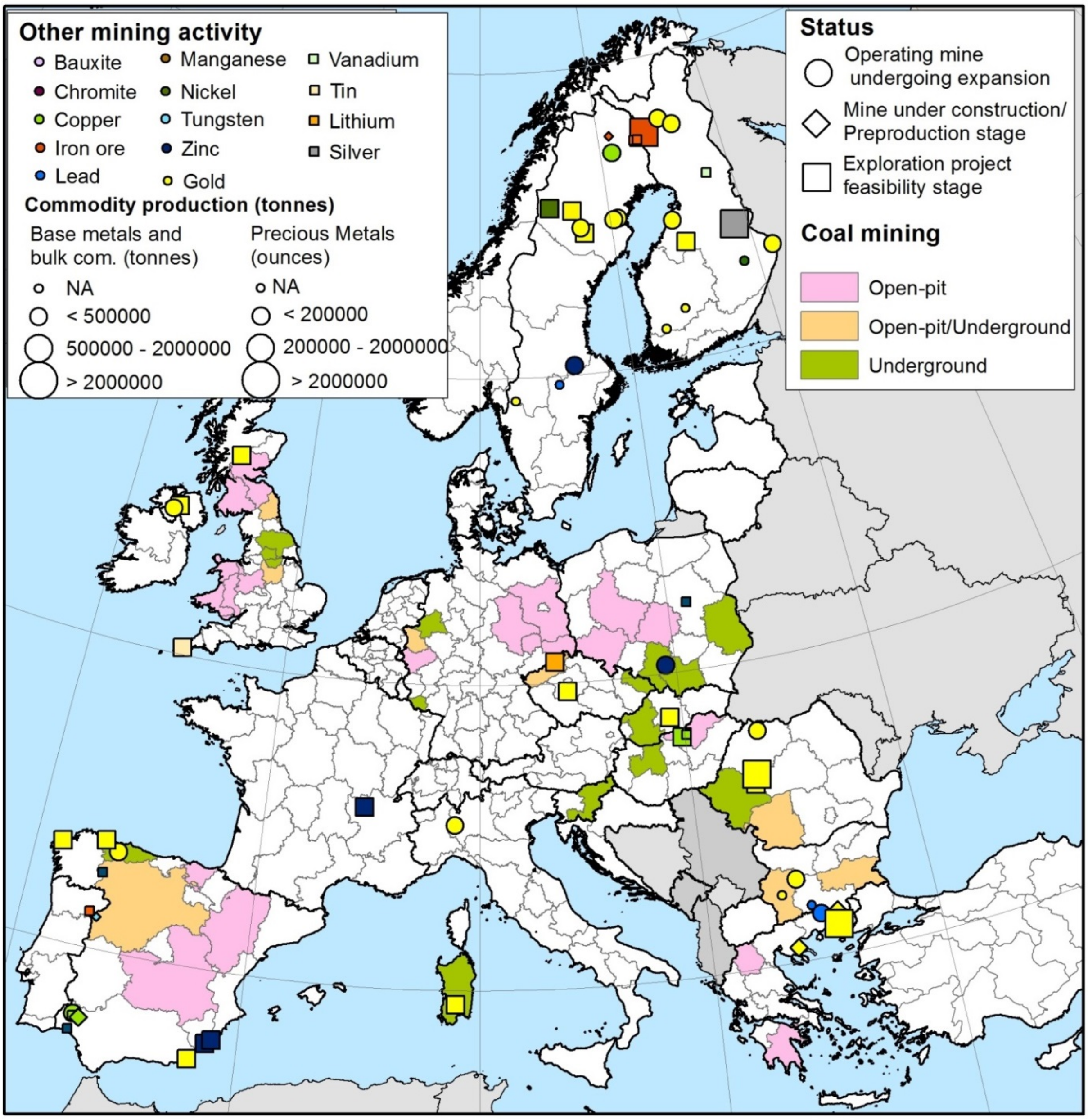
Table 22. Reemployment examples

Sector	Skill	Region	Example
Same	Same	Same	Power plant operator working in biomass power plant after plant conversion
			Former coal miner working in an underground copper mine in the same region
Other	Same	Same	Geologist working in research centre in same region
Other	Other	Same	Industrial electrician retrained as wind farm technician working on wind farm located on the site of the former coal mine
Same	Same	Other	Coal miner working in competitive coal mine in other region
			Power plant operator working in coal power plant in other region
			Mining engineer in a similar role in a gold mine in other region
Same	Other	Other	Former janitor at coal power plant retrained as welder working in coal mine in other region
Other	Other	Other	Industrial electrician retrained as wind farm technician working on wind farm located in other region
Other	Same	Other	Shuttle car operator working in same role in mine in different region
Same	Other	Same	Geologist working as specialist tour guide after mine reclamation with museum

Other types of mines can potentially provide employment to coal miners losing their jobs. The map in Figure 60 provides an overview of the location of new and expanding mines in Europe focusing on precious metals, base metals and bulk commodities, that within the next two years (possibly longer for late-stage exploration projects) will be in demand of labour force with the same or similar skill sets as coal mines. Additionally, jobs might also be available in operating mines (see Figure 47) that although not undergoing expansion, might have to replace retiring staff. Although there are cases where both coal and other mines are located in the same regions (e.g. gold mines in Asturias or in

Bulgaria), most of them are located outside the coal regions which implies a need to relocate for former coal workers.

Figure 60. Other mining activity in EU - Operating mines undergoing expansion, mines under construction and at preproduction stage, and late-stage exploration projects at feasibility stage[107]



[107] The map draws from the (European Commission, 2016). It is expected that some of these mine-stage projects have been further developed.

In case coal workers seek reemployment in the same region, this can take place in the same or other sectors, with the same skillset or a modified skillset. New work opportunities might arise on the decommissioned sites themselves[108], or within the region as a whole. The experience of Central Europe shows (in various mining sectors) that the number of jobs created in some types of post-mining sectors (e.g. in tourism and recreation, catering, education, and construction) is, while not negligible, usually smaller than the number of jobs lost. Furthermore, SMEs were found to play an important role in sports, cultural and tourism type post-mining activities (Wirth, Černič Mali, & Fischer, 2012).

The ability of a region to attract new industries depends on framework conditions (e.g. geographical location, interregional cooperation, administrative barriers at the national level such as grid quotas for RES) as well as the presence of long-term regional planning. The transition of coal regions to sustainable energy can be facilitated by carrying out social and vulnerability assessments at existing coal mines and conventional power plants; preliminary and comprehensive strategic planning; the integration of climate friendly and climate resilient technologies as part of governments' capacity building strategies; the starting of inclusive processes at community level for envisioning a future beyond coal; the inclusion of transition away from coal in state level energy and climate policies; and securing financial support (e.g. through considering how to best use EU funds to support the transformation of mining communities) (CEE Bankwatch Network, 2016) (Wirth, Černič Mali, & Fischer, 2012). In the immediate aftermath of mine and power plant closures the opening of temporary community resource centres offering advice on job opportunities and training, as well as counselling services can be very positively received, e.g. in Wyoming, USA (Zaffos, 2016).

The cases of Saarland and the Ruhr Region in Germany provide examples of a strategic approach towards a gradual industrial restructuring process, which already started in the 1950-60s. Parallel to supporting and restructuring the steel and metal industry, other industries (automotive and tourism) were established. Strong investment in R&D, the creation of universities and research centres (in IT, biotechnology and medicine), establishment of technology parks, support of technology transfer, and targeted support for SMEs have been key elements of the transition. Trade unions were important in facilitating negotiated phase outs from the coal industry. Structural regional policy and the use of European Structural Funds and Cohesion Fund played a crucial role. The regions also benefited from positive location factors: being situated in the heart of Europe, potential for cooperation with surrounding regions in neighbouring countries, as well the availability of large areas (a combination ideal for logistics, trade chains and transport companies). A social compensation plan was set up to support the transition to new jobs. Generous early retirement (from 45/49 years) schemes were introduced. Supportive framework policies, such as the flexibility of labour contracts and simple permitting procedures for new businesses enabled employment in non-coal industries. Reflecting the difficulty of transition away from coal, despite the gradual and comprehensive approach to industrial restructuring, unemployment remains higher in Saarland and the Ruhr Region than in surrounding regions in Germany. (Caspari, 2012) (Staatskanzlei Saarland) (Schulte, 2009) (Rampeltshammer & Kurtz, 2011) (Schultz & Lautsch, 2010)

Coal heritage is a source of pride for many former coal communities, and heritage and history can be used as an asset. The Ruhr Region is an example of cultural rebranding and of a coal region reinventing itself. In Essen the Zollverein industrial complex, formerly the largest and most modern colliery in the world was converted to a museum and reopened as a UNESCO World Heritage Site. The museum and gallery at Zollverein receives 250 000 visitors a year (Bryce, 2017). It is home to several businesses,

[108] Chapter 5 of this report outlined site specific solutions of mitigating the impacts of plant retirement and mine closures (including mine site reclamation for touristic, cultural, and sport use; mine site conversion for renewable energy generation; and clean coal technologies).

including artists, jewellery designers, choreographers, design firms and tourism companies. Other former mines in the region also function as business parks and event spaces, hosting music concerts as well as food and cultural festivals. In 2010 Essen represented the whole of the Ruhr Region as European Capital of Culture. Other Ruhr region cities offer further modes of reinvention: in Dortmund a former steel plant site was converted to a nanotechnology hub and recreation area. In Gelsenkirchen a Science Park was opened on the site of the former coal-powered steel plant, hosting 51 businesses, with 900 solar panels installed. A former mine site in Dinslaken was converted into a forest plantation, offering biomass processing jobs for skilled workers. In Bochum (now the site of the German Mining Museum), serving as an example of adjustment in the private sector, a family-owned company went from producing gear boxes for mines to producing gear boxes for wind turbines. (Winland, 2017) (Bryce, 2017) (Worldwatch Institute, 2017) These examples also demonstrate how transition away from coal results in a more diverse economic structure and associated skills needs.

The GA Drilling company in Slovakia represents an example for technical innovation, which may potentially absorb (partially) the technically skilled work force in former coal regions. The company developed a unique plasma-based drilling technology enabling geothermal energy utilisation at competitive costs almost anywhere, including former coal mining sites (GA Drilling, 2017). In the geothermal sector the most sought after occupations in the O&M phase of the value chain include plant managers, engineers, plant technicians, site operators and service repairmen (Xu, 2016). Through the provision of job-specific training, former coal workers, including operators, as well as electrical and mechanical engineers can be requalified to work with the innovative plasma-based drilling technology in the geothermal sector.

Coal workers may need to adjust their skills to find employment in another sector. Adjustment of skills can take place in different intensity re-education activities, ranging from comprehensive re-training programmes and apprenticeships, to short-term on the job training. In terms of the type of occupations needed in receiving industries, all renewable energy sub-sectors report skill shortages for engineers and technicians (ILO, 2011). More highly qualified employees are more in demand in renewable energy sectors than people with lower qualification levels, e.g. with profiles from vocational training (Hockenos, 2017). The sought after occupations are also present in the coal sectors, potentially providing reemployment opportunities for coal workers (Table 23 has an overview of coal sector occupations and principal occupations difficult to fill in some clean energy sub-sectors). The wind and solar PV industries have been identified as particularly suitable for reemploying coal workers after adjustment of skills.

Table 23. Coal sector occupations and principal occupations difficult to fill in some clean energy sub-sectors [based on (Coal Association of Canada) and (ILO, 2011) Table 3]

Coal sector professions (highly skilled)	Mining engineers, geological engineers, civil engineers, operations engineers, geologists, information systems analysts, transportation managers, human resources specialists, managers, executives
Coal sector trades (medium skilled)	Pipefitters, heavy duty equipment mechanics, industrial electricians, welders, heavy equipment operators, millwrights, explosive workers, blasters
Coal sector (low skilled)	Janitors, continuous miner operators
Clean energy sub-sector	**Occupations difficult to fill**
Wind energy	Project developers; service technicians; data analysts; electrical, computer and construction engineers.
Solar energy	PV and solar thermal system installers and maintainers; building installers
Geothermal energy	Trainers; geo-thermal engineers

Germany's well-established vocational education and training system (VET) is an example of a successful public initiative, combining practical and theoretical training. The VET, undergoing regular adjustments since 2000 to reflect the needs of new sectors, has been reported to cope remarkably well with the demands of the Energiewende. An advanced vocational degree (specialist technician) has also been introduced (representing a level of expertise above that of the skilled worker), requiring professional experience and additional two years of study at a vocational college. Furthermore, technical collages created new professional categories reflecting the Energiewende, including environmental technician, solar technician, technician in wind energy technology, as well as technician for renewable energies. The private sector also participates actively in the VET: Enercon, a major player in the German wind power industry tutors apprentices in 20 professions, including commerce, product design, and diverse industrial trades ranging from metalwork to industrial engineering (Hockenos, 2017). Reemployment of coal workers at the Dortmund airport is an example of successful cooperation between public services and private companies, supported by financing of adequate training. The airport developed a qualifying training course, hiring 76 retrained former miners (RECORE, 2006). In Silesia, Poland a theoretical and technical training course, including workshops and on-the-job training has been set up targeting 70 different professions. The inclusion of executive officers of companies in the development of the courses' content ensured their relevance (RECORE, 2006).

Box 17. Spain: Mobilization of the European Globalisation and Adjustment Fund (EGF) in the area of coal and lignite mining

The Castile and Leon region in Spain provides an example of the mobilization of the European Globalisation and Adjustment Fund (EGF) in the area of coal and lignite mining[109]. This is especially interesting as the mining of coal and lignite has not been among the typically preferred content areas in the overall 168 projects supported by the EGF since 2007 (European Commission, 2017). In early 2017 Spain requested EUR 1 million EGF co-financing following the dismissal of 339 coal miners from five coal mines in Castile and Leon. The specific mining area faces challenges due to its remote location, small, isolated towns, limited mobility and infrastructural connectivity. The request for support also had a youth unemployment mitigating dimension: 125 local persons under the age of 30 and not in employment, education and training, are also targeted by the action. Supported activities include welcome and information sessions; occupational guidance and counselling; intensive job-search assistance; training in cross-sector skills and competences and vocational training; promotion of entrepreneurship; and support for business start-ups as well as a programme of incentives (European Parliament, 2017). The Castile and Leon region tops Spanish regions in terms of installed wind capacity (Asociación Eolica Española, 2017) with 24% of all installations in the country located here. Furthermore, recent renewable energy auctions in Spain resulted in the award of 4 GW of wind quotas (Ministerio de Energía, Turismo y Agenda Digital, 2017a) (Ministerio de Energía, Turismo y Agenda Digital, 2017b). Under these circumstances the retraining and skills adjustment activities co-financed by the European Union through the EGF are expected to contribute to the local reemployment in the clean energy sector of formal coal workers and young job seekers. Other coal regions would benefit from detailed analysis of successful proposals and guidance on how to best use EGF and other streams of EU funding in the transition period.

Some retraining programmes have been initiated directly by the private sector. For example in Wyoming (USA), a wind-turbine manufacturer announced a retraining programme for coal workers in order to supply labour force for installation, operation and maintenance of new wind farms on former coal mine sites (Cardwell, 2017). The two-week training programme includes lectures and field trainings with a special emphasis on technical and safety issues e.g. rescue training, tower climb. Mainly electrical and mechanical skills, as well as experience in working under difficult conditions were those highlighted by the company as making coal workers attractive for the wind industry (GoldWind, 2017). Similar re-training has been announced in the EU, for example at East Ayrshire in the UK, for 60 traineeships at the proposed Lethans Wind Farm (Banks Group, 2017).

The sophisticated safety experience characterizing some occupations in the coal industry (e.g. explosive workers, ordinance handlers and blasters) was found to be useful for the role of commercial solar technicians, after engaging in additional training (Pearce, 2016). In Kentucky, USA, businesses are innovating to use former coal workers in new ways: relying on their technology and robotics related skills, some coal workers have been hired as IT developers after a short six-week retraining (Peterson, 2016).

In terms of wages, in the solar industry in the USA it was found that the annual pay is attractive at all levels of education. Furthermore, technical workers would make more in the solar industry than previously in coal, while coal sector managers and particularly executives would make less (Pearce, 2016).

[109] The EGF provides support to people losing their jobs as a result of major structural changes in world trade patterns due to globalisation. In contrast to the long-term perspective of the EU Structural and Investment Funds, the EGF provides workers with one-off individual support that is limited in time. (European Commission, 2017).

6.2 Key points

- A strategically planned and a gradual industrial restructuring process can support the adjustment of coal workers in coal regions undergoing transition.
- Building on the industrial heritage of coal regions in combination with efforts to establish new, competitive industries and services contributes to a gradual post-coal transition.
- Other mining activities in the same or other regions can possibly offer reemployment opportunities at least for the workforce engaged in coal mining.
- The wind and solar PV industries have been identified as particularly suitable for reemploying coal workers after adjustment of skills. Electrical and mechanical skills, experience in working under difficult conditions and sophisticated safety experience have been valued highly by the wind and solar PV sectors.

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List of abbreviations and definitions

CCR – Carbon Capture Readiness

CCSR – Carbon Capture and Storage Ready

CCS/U – Carbon Capture, Storage and Utilisation

CCU – Carbon capture and utilisation

CMDB - Coal Mines Database

CO_2StoP - Assessment of CO2 storage potential in Europe

CSLF – Carbon Sequestration Leadership Forum

DG COMP –Directorate General for Competition

DG ENER - Directorate General for Energy

JRC – Directorate General Joint Research Centre

ECBM – Enhanced coal bed methane

EU – European Union

EU Geocapacity – Assessing European Capacity for geological storage of carbon dioxide

EURACOAL – European Association for coal and lignite

EEA – European Economic Area

ENTSO-E - European network of transmission system operators for electricity

E-PRTR – European pollutant release and transfer register

GESTCO – European potential for geological storage of CO2 from fossil fuel combustion

IEA – International energy Agency

IEAGHG – International energy Agency, greenhouse gas R & D Programme

IPR - intellectual property rights

JRC-CMDB - JRC Coal Mines Database

JRC-PPDB - JRC Power Plant Database

MOVECBM – Monitoring and verification of CO2 storage and ECBM in Poland

Mt – Million tonnes

MW – megawatt, unity of power.

NUTS – Nomenclature of territorial units for statistics

- NUTS-1 – Major socio-economic regions
- NUTS-2 – Basic regions for the application of regional policies
- NUTS-3 – Small regions for specific analysis

OECD – Organisation for Economic Co-operation and Development

OP- Open-pit or opencast mine

PHS, PSHP – Pumped hydropower storage plant

PRODCOM - *PRODuction COMmunautaire (French)*, European database of production of manufactured goods

RECOPOL – Reduction of CO2 emission by means of CO2 storage in coal seams in the silesian coal basin of Poland.

SMEs – Small Medium Enterprises

TOPS - Technology options for coupled underground coal gasification and CO_2 capture and storage.

TSO- Transmission System Operator

UG- Underground mine

UPSHP – Underground Pumped Hydrological Storage

USGS – United States Geological Survey

ZEP - Zero Emissions Platform

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Annex 1. Coal mining sector in Poland – official data provided by competent authorities in Poland

A. Number of coal mines

Coal type	Region	2015	2016	2017
Hard coal	Total hard coal	30	23	21
	PL21 Małopolskie			2
	PL22 Śląskie			18
	PL31 Lubelskie			1
Lignite	Total lignite	5	5	5
	PL11 Łódzkie			1
	PL41 Wielkopolskie			2
	PL43 Lubuskie			1
	PL51 Dolnośląskie			1

B. Coal production (million tonnes)

Coal type	Region	2015	2016	2017
Hard coal	Total hard coal	72.2	70.4	65.5
	PL21 Małopolskie			5.0
	PL22 Śląskie			51.4
	PL31 Lubelskie			9.1
Lignite	Total lignite	63.1	60.2	61.2
	PL11 Łódzkie			42.6
	PL41 Wielkopolskie			11.5
	PL43 Lubuskie			0.1
	PL51 Dolnośląskie			6.9

C. Employment (thousand employees)

Coal type	Region	2015	2016	2017
Total	Poland			> 91.6
Hard coal	Total hard coal	97.7	88.2	82.7
	PL21 Małopolskie			4.9
	PL22 Śląskie			73.3
	PL31 Lubelskie			4.5
Lignite	Total lignite			> 8.9
	PL11 Łódzkie			4.9
	PL41 Wielkopolskie			1.5
	PL43 Lubuskie			N/A
	PL51 Dolnośląskie			2.5

D. Hard coal balance (million tonnes)

Balance element	2015	2016	2017	2017 thermal coal	2017 coking coal
Hard coal production	72.2	70.4	65.5	53.0	12.5
Import	10.3	8.3	13.4	9.7	3.7
Import from Russia (%)	59%	63%	65.1%	83.3%	16.3%
Import from Australia (%)	19%	20%	13.0%		47.7%
Export	7.7	8.3	6.4	3.8	2.6
Consumption for energy	71.7	78.5	74.3	61.2	13.1
Consumption in power sector			38.8	38.8	
Consumption in metal industry			1.3		1.3

Annex 2 Coal-fired power plant capacity in EU Member States, aggregated at NUTS-2 level

NUTS 2	NUTS name	Country	Average age (yrs)	Capacity (MW)	Efficiency[110]
AT12	Niederösterreich	Austria	30	392	35%
AT22	Steiermark	Austria	30	220	35%
AT31	Oberösterreich	Austria	30	150	36%
BG32	Severen tsentralen	Bulgaria	37	290	29%
BG33	Severoiztochen	Bulgaria	51	152	34%
BG34	Yugoiztochen	Bulgaria	30	3 271	34%
BG41	Yugozapaden	Bulgaria	44	816	34%
BG42	Yuzhen tsentralen	Bulgaria	45	120	34%
HR03	Jadranska Hrvatska	Croatia	27	335	35%
CZ02	Střední Čechy	Czech Republic	33	1 248	36%
CZ03	Jihozápad	Czech Republic	56	111	29%
CZ04	Severozápad	Czech Republic	41	3 518	37%
CZ05	Severovýchod	Czech Republic	43	1 040	33%
CZ08	Moravskoslezsko	Czech Republic	40	800	35%
DK01	Hovedstaden	Denmark	22	343	34%
DK02	Sjælland	Denmark	39	827	35%
DK03	Syddanmark	Denmark	25	860	37%
DK04	Midtjylland	Denmark	32	375	35%
DK05	Nordjylland	Denmark	27	740	36%
FI19	Länsi-Suomi	Finland	29	1 043	38%
FI1B	Helsinki-Uusimaa	Finland	37	463	30%
FI1C	Etelä-Suomi	Finland	46	388	25%
FR23	Haute-Normandie	France	33	600	31%
FR41	Lorraine	France	35	595	36%
FR51	Pays de la Loire	France	32	1 160	37%
FR82	Provence-Alpes-Côte d'Azur	France	32	600	36%
DE11	Stuttgart	Germany	27	1 686	36%
DE12	Karlsruhe	Germany	13	1 462	42%
DE21	Oberbayern	Germany	28	805	38%
DE30	Berlin	Germany	33	998	32%
DE40	Brandenburg	Germany	27	4 600	34%
DE50	Bremen	Germany	40	805	36%
DE60	Hamburg	Germany	4	1 910	36%
DE71	Darmstadt	Germany	24	510	40%
DE80	Mecklenburg-Vorpommern	Germany	22	514	42%
DE91	Braunschweig	Germany	33	1 520	36%
DE92	Hannover	Germany	27	300	34%

[110] The efficiency is calculated by JRC based on known plant parameters (age, type, fuel).

NUTS 2	NUTS name	Country	Average age (yrs)	Capacity (MW)	Efficiency[111]
DE94	Weser-Ems	Germany	21	1 570	39%
DEA1	Düsseldorf	Germany	26	8 374	36%
DEA2	Köln	Germany	38	5 435	34%
DEA3	Münster	Germany	39	1 532	35%
DEA4	Detmold	Germany	29	875	39%
DEA5	Arnsberg	Germany	25	4 610	37%
DEC0	Saarland	Germany	37	2 216	34%
DED2	Dresden	Germany	21	2 582	37%
DED5	Leipzig	Germany	16	1 866	42%
DEE0	Sachsen-Anhalt	Germany	20	960	31%
DEF0	Schleswig-Holstein	Germany	24	290	29%
EL53	Dytiki Makedonia	Greece	31	3 401	30%
EL65	Peloponnisos	Greece	33	511	25%
HU21	Közép-Dunántúl	Hungary	43	294	29%
HU31	Észak-Magyarország	Hungary	45	836	29%
IE02	Southern and Eastern	Ireland	30	915	35%
ITC3	Liguria	Italy	56	136	34%
ITC4	Lombardia	Italy	28	139	29%
ITF4	Puglia	Italy	27	3 280	37%
ITG2	Sardegna	Italy	21	1 230	34%
ITH3	Veneto	Italy	43	805	34%
ITH4	Friuli-Venezia Giulia	Italy	48	336	34%
ITI2	Umbria	Italy	49	130	29%
ITI4	Lazio	Italy	7	1 980	42%
NL11	Groningen	Netherlands	1	1 600	40%
NL32	Noord-Holland	Netherlands	22	680	41%
NL33	Zuid-Holland	Netherlands	17	2 871	38%
NL41	Noord-Brabant	Netherlands	23	643	39%
PL11	Łódzkie	Poland	23	4960	36%
PL12	Mazowieckie	Poland	49	3 954	34%
PL21	Małopolskie	Poland	38	1 214	29%
PL22	Śląskie	Poland	35	5 690	34%
PL33	Świętokrzyskie	Poland	35	1 575	35%
PL34	Podlaskie	Poland	25	157	35%
PL41	Wielkopolskie	Poland	39	2 553	33%
PL42	Zachodniopomorskie	Poland	42	1 424	33%
PL51	Dolnośląskie	Poland	35	1 599	33%
PL52	Opolskie	Poland	25	1 710	35%
PL61	Kujawsko-pomorskie	Poland	24	283	33%
PL63	Pomorskie	Poland	39	322	33%
PT16	Centro	Portugal	22	628	36%
PT18	Alentejo	Portugal	29	1 250	37%

[111] The efficiency is calculated by JRC based on known plant parameters (age, type, fuel).

NUTS 2	NUTS name	Country	Average age (yrs)	Capacity (MW)	Efficiency[112]
RO11	Nord-Vest	Romania	47	145	29%
RO21	Nord-Est	Romania	28	200	29%
RO31	Sud - Muntenia	Romania	30	150	29%
RO41	Sud-Vest Oltenia	Romania	37	4 505	33%
RO42	Vest	Romania	42	1 308	29%
SK02	Západné Slovensko	Slovakia	52	266	14%
SK04	Východné Slovensko	Slovakia	49	220	29%
SI03	Vzhodna Slovenija	Slovenia	26	1 420	36%
ES11	Galicia	Spain	38	1 960	35%
ES12	Principado de Asturias	Spain	35	2 123	29%
ES24	Aragón	Spain	37	1 055	33%
ES41	Castilla y León	Spain	38	2 594	33%
ES42	Castilla-La Mancha	Spain	19	296	42%
ES61	Andalucía	Spain	28	1 990	36%
SE11	Stockholm	Sweden	26	114	29%
UKC2	Northumberland and Tyne and Wear	United Kingdom	44	420	29%
UKD6	Cheshire	United Kingdom	44	2 000	36%
UKE2	North Yorkshire	United Kingdom	38	3 480	37%
UKE4	West Yorkshire	United Kingdom	49	500	36%
UKF1	Derbyshire and Nottinghamshire	United Kingdom	47	5 924	36%
UKG2	Shropshire and Staffordshire	United Kingdom	46	1 000	36%
UKL2	East Wales	United Kingdom	40	1 500	36%
UKM2	Eastern Scotland	United Kingdom	46	2 400	36%
UKN0	Northern Ireland	United Kingdom	34	520	35%

[112] The efficiency is calculated by JRC based on known plant parameters (age, type, fuel).

Annex 3 Coal mines in EU Member States by NUTS-2 region

NUTS 2	NUTS name	Country	Type of coal	Mine type	Production (Mt)	Productivity (tonnes/ employee)	Depth (m)	No. mi-nes
BG34	Yugoiztochen	Bulgaria	Lignite	OP, UG	32.6	3 026	182	4
BG41	Yugozapaden	Bulgaria	Brown coal	OP, UG	3	3 026	830	8
CZ08	Moravskoslezsko	Czech Republic	Hard coal	UG	8.3	819	1300	3
CZ04	Severozápad	Czech Republic	Lignite	OP	38.1	4 842	400	6
DEA3	Münster	Germany	Hard coal	UG	6.7	695	800	2
DEA2	Köln	Germany	Lignite	OP	60	13 575	NA	2
DEA1	Düsseldorf	Germany	Lignite	OP	35	13 576	NA	1
DEC0	Saarland	Germany	Hard coal	UG	na	na	600	na
DE40	Brandenburg	Germany	Lignite	OP	34	9 994	110	2
DED2	Dresden	Germany	Lignite	OP	28	10 061	NA	2
DEE0	Sachsen-Anhalt	Germany	Lignite	OP	9.3	10 288	NA	2
DED5	Leipzig	Germany	Lignite	OP	10	9 960	NA	1
EL53	Dytiki Makedonia	Greece	Lignite	OP	37.9	8 849	175	8
EL65	Peloponnisos	Greece	Lignite	OP	8.1	12 736	175	1
HU31	Észak-Magyarország	Hungary	Lignite	OP	9.3	5 619	NA	2
ITG2	Sardegna	Italy	Hard coal	UG	0.073	210	1000	1
PL22	Śląskie	Poland	Hard coal	UG	59	742	770	28
PL21	Małopolskie	Poland	Hard coal	UG	4.7	1 012	770	2
PL31	Lubelskie	Poland	Hard coal	UG	8.5	1 473	770	1
PL11	Łódzkie	Poland	Lignite	OP	42.1	6 590	300	1
PL51	Dolnośląskie	Poland	Lignite	OP	7.3	6 588	NA	1
PL41	Wielkopolskie	Poland	Lignite	OP	13.7	6 590	54	2
RO41	Sud-Vest Oltenia	Romania	Lignite	OP	24	2 264	NA	1
RO42	Vest	Romania	Hard coal	UG	1.3	293	NA	6
SK02	Západné Slovensko	Slovakia	Lignite	UG	1.8	822	225	4
SI03	Vzhodna Slovenija	Slovenia	Lignite	UG	3.2	2 512	160	1
ES24	Aragón	Spain	Hard coal	OP	1.3	914	NA	2
ES12	Principado de Asturias	Spain	Hard coal	UG	1.2	914	450	11
ES41	Castilla y León	Spain	Hard coal	OP, UG	0.36	914	NA	11
ES42	Castilla-La Mancha	Spain	Hard coal	OP	0.2	914	NA	1
ES21	País Vasco	Spain	Hard coal	OP	na	na	na	na
UKC2	Northumberland and Tyne and Wear	United Kingdom	Hard coal	OP, UG	3.15	4 354	NA	2
UKE3	South Yorkshire	United Kingdom	Hard coal	UG	0.15	4 354	NA	2
UKE4	West Yorkshire	United Kingdom	Hard coal	UG	na	na	NA	na
UKE2	North Yorkshire	United	Hard	UG	1.45	4 354	800	1

		Kingdom	coal					
UKF1	Derbyshire and Nottinghamshire	United Kingdom	Hard coal	OP, UG	0.35	4 354	800	1
UKM3	South Western Scotland	United Kingdom	Hard coal	OP	1.05	4 354	NA	1
UKM2	Eastern Scotland	United Kingdom	Hard coal	OP	na	na	NA	na
UKG2	Shropshire and Staffordshire	United Kingdom	Hard coal	OP	na	na	NA	na
UKL2	East Wales	United Kingdom	Hard coal	OP	0.8	4 354	NA	1
UKL1	West Wales and The Valleys	United Kingdom	Hard coal	OP, UG	1.6	4 354	150	2

Annex 4 Types of coal and mining methods – Overview

Coal can be classified into four main types, based on its carbon and energy content:

- Anthracite: 86-97% carbon and a heating value slightly higher than bituminous coal.
- Bituminous coal: further divided into coking and steam coal - 45-86% carbon; is used for power generation and as raw material in the iron & steel industry.
- Sub-bituminous coal: 35-45% carbon and a lower heating value than bituminous coal.
- Lignite: 25%-35% carbon; it is used largely for power generation. It has the lowest heating value from all types.

Anthracite and bituminous coal are hard coals while sub-bituminous coal and lignite are soft or brown coals. Coal properties are rather specific for each deposit. As a consequence, the moisture content and heating value vary widely depending on the coal type and location. Typical heating values are given in the table below. Coking coals, used to manufacture coke in the steel industry are at the highest quality (IEA - Coal Mining and Logistics, 2014).

Types of coal and typical parameters

Type of coal	Quality	Moisture content	Carbon / energy content	Typical high / low heating values (TJ / kt) (1)	Uses (2)
Anthracite	Hard coal	Low	High	27.70 - 32.56	Domestic/industrial including smokeless fuel
Bituminous – Metallurgical (coking coal)	Hard coal	Low	High	24.42 - 32.56	Production of iron and steel
Bituminous – Thermal (steam coal)	Hard coal	Low	High		Power generation, cement production, industrial uses
Sub-bituminous	Low rank coal	High	Low	19.31 - 26.75	Power generation, cement manufacture, Industrial uses
Lignite	Low rank coal	High	Low	14.65 - 19.31	Largely power generation

(1) (IEA ETSAP, 2014)
(2) (World Coal Association, 2017)

Coal rank and grade at EU coal producing countries (based on EURACOAL country statistics)

Country	Type of coal	Calorific value kJ/kg	Ash content % a.r.	Moisture content % a.r.	Sulphur content % a.r.
Bulgaria	Brown coal	12 140-13 400	<26	<16	<2.7
Bulgaria	Lignite	5 652-7 746	17-45	51-60	2.2-2.8
Czech Republic	Hard coal	25 490-32 070	4.3-18.9	3.5-9.9	0.42-0.43
Czech Republic	Lignite	11 600-20 560	6.0-37.8	26.5-38.3	0.78-1.44
Germany	Hard coal	30 264	3.3-21.0	2.5-13.0	0.45-1.8
Germany	Lignite	7 800-11 500	2.5-20.0	40.0-61.5	0.12-2.5
Greece	Lignite	3 770-9 630	15.1-19.0	41.0-57.9	0.4-1.0
Spain	Hard coal	18 231	34.6	13.2	2.5
Hungary	Hard coal	18 333	NA	NA	NA
Hungary	Lignite	7 186	20.5	47.4	1.3
Poland	Hard coal	21 000-28 000	8.0-30.0	6.5-11.0	0.4-1.2
Poland	Lignite	7 400-10 300	6.0-12.0	50.0-60.0	0.2-1.1
Romania	Hard coal	14 200-15 900	37-44	5.0-7.4	0.5-1.8
Romania	Lignite	7 200-8 200	30-36	40-43	1.0-1.5
Slovenia	Lignite	11 300	14	36	1.4
Slovakia	Lignite	10 450	<25	<35	<2.5
United Kingdom	Hard coal	22 000-27 000	14.0-18.0	10.0-12.0	0.8-2.5

Coal is mined by two main methods depending on the geology and economics of the deposit: surface or ‘opencast’ mining and underground or ‘deep’ mining (World Coal Association).

For underground mining, the two main methods are:

1) Room-and-pillar, where deposits are mined by cutting a network of ‘rooms’ and leaving behind ‘pillars’ for roof support (IEA ETSAP, 2014) . "These pillars can be up to 40% of the total coal in the seam - although this coal can sometimes be recovered at a later stage." (World Coal Association, 2017).

2) Long-wall, mining by full extraction from a section of the seam or ‘face’ using mechanical shearers. (IEA ETSAP, 2014). "The coal 'face' can vary in length from 100-350m. Self-advancing, hydraulically-powered supports temporarily hold up the roof while coal is extracted. When coal has been extracted from the area, the roof is allowed to collapse. Over 75% of the coal in the deposit can be extracted from panels of coal that can extend 3km through the coal seam" (World Coal Association, 2017).

Annex 5 Distribution of direct jobs in coal activities in the NUTS-2 regions

Nuts-2	Name	Country	Plant O&M jobs (direct)	Mining jobs (direct)	Total jobs
AT12	Niederösterreich	Austria	236	0	236
AT22	Steiermark	Austria	132	0	132
AT31	Oberösterreich	Austria	90	0	90
BG32	Severen tsentralen	Bulgaria	167	0	167
BG33	Severoiztochen	Bulgaria	88	0	88
BG34	Yugoiztochen	Bulgaria	1 885	10 773	12 658
BG41	Yugozapaden	Bulgaria	470	991	1 461
BG42	Yuzhen tsentralen	Bulgaria	69	0	69
CZ02	Střední Čechy	Czech Republic	661	0	661
CZ03	Jihozápad	Czech Republic	59	0	59
CZ04	Severozápad	Czech Republic	1 862	7 869	9 731
CZ05	Severovýchod	Czech Republic	550	0	550
CZ08	Moravskoslezsko	Czech Republic	423	10 131	10 554
DE11	Stuttgart	Germany	406	0	406
DE12	Karlsruhe	Germany	352	0	352
DE21	Oberbayern	Germany	194	0	194
DE30	Berlin	Germany	240	0	240
DE40	Brandenburg	Germany	1 107	3 402	4 509
DE50	Bremen	Germany	194	0	194
DE60	Hamburg	Germany	460	0	460
DE71	Darmstadt	Germany	123	0	123
DE80	Mecklenburg-Vorpommern	Germany	124	0	124
DE91	Braunschweig	Germany	366	0	366
DE92	Hannover	Germany	72	0	72
DE94	Weser-Ems	Germany	378	0	378
DEA1	Düsseldorf	Germany	2 016	2 578	4 594
DEA2	Köln	Germany	1 308	4 420	5 728
DEA3	Münster	Germany	369	9 640	10 009
DEA4	Detmold	Germany	211	0	211
DEA5	Arnsberg	Germany	1 110	0	1 110
DEC0	Saarland	Germany	533	NA	533
DED2	Dresden	Germany	621	2 783	3 404
DED5	Leipzig	Germany	449	1 004	1 453
DEE0	Sachsen-Anhalt	Germany	231	904	1 135
DEF0	Schleswig-Holstein	Germany	70	0	70
DK01	Hovedstaden	Denmark	113	0	113
DK02	Sjælland	Denmark	271	0	271
DK03	Syddanmark	Denmark	282	0	282
DK04	Midtjylland	Denmark	123	0	123
DK05	Nordjylland	Denmark	243	0	243
EL53	Dytiki Makedonia	Greece	1 398	4 283	5 681

Nuts-2	Name	Country	Plant O&M jobs (direct)	Mining jobs (direct)	Total jobs
EL65	Peloponnisos	Greece	210	636	846
ES11	Galicia	Spain	651	0	651
ES12	Principado de Asturias	Spain	705	1 313	2 018
ES21	País Vasco	Spain	0	NA	NA
ES24	Aragón	Spain	350	1 422	1 772
ES41	Castilla y León	Spain	861	394	1 255
ES42	Castilla-La Mancha	Spain	98	219	317
ES61	Andalucía	Spain	661	0	661
FI19	Länsi-Suomi	Finland	632	0	632
FI1B	Helsinki-Uusimaa	Finland	280	0	280
FI1C	Etelä-Suomi	Finland	235	0	235
FR23	Haute-Normandie	France	116	0	116
FR41	Lorraine	France	115	0	115
FR51	Pays de la Loire	France	225	0	225
FR82	Provence-Alpes-Côte d'Azur	France	116	0	116
HR03	Jadranska Hrvatska	Croatia	229	0	229
HU21	Közép-Dunántúl	Hungary	222	0	222
HU31	Észak-Magyarország	Hungary	632	1 655	2 287
IE02	Southern and Eastern	Ireland	366	0	366
ITC3	Liguria	Italy	40	0	40
ITC4	Lombardia	Italy	41	0	41
ITF4	Puglia	Italy	966	0	966
ITG2	Sardegna	Italy	362	348	710
ITH3	Veneto	Italy	237	0	237
ITH4	Friuli-Venezia Giulia	Italy	99	0	99
ITI2	Umbria	Italy	38	0	38
ITI4	Lazio	Italy	583	0	583
NL11	Groningen	Netherlands	253	0	253
NL32	Noord-Holland	Netherlands	108	0	108
NL33	Zuid-Holland	Netherlands	455	0	455
NL41	Noord-Brabant	Netherlands	102	0	102
PL11	Łódzkie	Poland	2538	6 388	8 926
PL12	Mazowieckie	Poland	2 023	0	2 023
PL21	Małopolskie	Poland	621	4 644	5 265
PL22	Śląskie	Poland	2 911	79 548	82 459
PL31	Lubelskie	Poland	0	5 769	5 769
PL33	Świętokrzyskie	Poland	806	0	806
PL34	Podlaskie	Poland	80	0	80
PL41	Wielkopolskie	Poland	1 306	2 079	3 385
PL42	Zachodniopomorskie	Poland	729	0	729
PL51	Dolnośląskie	Poland	818	1 108	1 926
PL52	Opolskie	Poland	875	0	875

Nuts-2	Name	Country	Plant O&M jobs (direct)	Mining jobs (direct)	Total jobs
PL61	Kujawsko-pomorskie	Poland	145	0	145
PL63	Pomorskie	Poland	165	0	165
PT16	Centro	Portugal	230	0	230
PT18	Alentejo	Portugal	458	0	458
RO11	Nord-Vest	Romania	82	0	82
RO21	Nord-Est	Romania	113	0	113
RO31	Sud - Muntenia	Romania	85	0	85
RO41	Sud-Vest Oltenia	Romania	2 539	10 600	13 139
RO42	Vest	Romania	737	4 442	5 179
SE11	Stockholm	Sweden	115	0	115
SI03	Vzhodna Slovenija	Slovenia	573	1 274	1 847
SK02	Západné Slovensko	Slovakia	277	2 190	2 467
SK04	Východné Slovensko	Slovakia	229	0	229
UKC2	Northumberland and Tyne and Wear	United Kingdom	98	723	821
UKD6	Cheshire	United Kingdom	466	0	466
UKE2	North Yorkshire	United Kingdom	811	333	1 144
UKE3	South Yorkshire	United Kingdom	0	34	34
UKE4	West Yorkshire	United Kingdom	117	NA	117
UKF1	Derbyshire and Nottinghamshire	United Kingdom	1 381	80	1 461
UKG2	Shropshire and Staffordshire	United Kingdom	233	NA	233
UKL1	West Wales and The Valleys	United Kingdom	0	376	376
UKL2	East Wales	United Kingdom	350	184	534
UKM2	Eastern Scotland	United Kingdom	559	NA	559
UKM3	South Western Scotland	United Kingdom	0	241	241
UKN0	Northern Ireland	United Kingdom	121	0	121
Total	**EU-28 (rounded)**		**52 600**	**184 800**	**237 400**

Annex 6 Coefficient used in determining direct jobs in power plants

Country	Average unit size (MW)	Country coefficient (Jobs/MW)
Bulgaria	199	**0.58**
Czech Republic	217	**0.53**
Denmark	349	**0.33**
Germany	476	**0.24**
Ireland	287	**0.40**
Greece	279	**0.41**
Spain	345	**0.33**
France	591	**0.19**
Croatia	168	**0.68**
Italy	389	**0.29**
Hungary	152	**0.76**
Netherlands	724	**0.16**
Austria	191	**0.60**
Poland	224	**0.51**
Portugal	313	**0.37**
Romania	203	**0.56**
Slovenia	284	**0.40**
Slovakia	110	**1.04**
Finland	189	**0.61**
Sweden	114	**1.01**
United Kingdom	492	**0.23**

Annex 7 Shares of professional groups employed in mining activities

Mine type	U.S. Mine / mining method used as reference	Production labour (%)	Auxiliary labour (%)	Mine operations staff and supervisors (%)	Management and technical staff (%)
OP	Area Mining or Mountain Top Mining	28.57	50.0	15.71	5.71
OP	Truck-Shovel Stripping in the Gillette Coalfield, Wyoming (2:1 Ratio)	41.04	41.98	10.85	6.13
OP	Truck-Shovel Stripping in the Gillette Coalfield, Wyoming (3:1 Ratio)	43.68	37.55	13.41	5.36
OP	Dragline and Truck-Shovel Stripping in the Gillette Coalfield, Wyoming (3:1 Ratio)	43.28	37.01	15.22	4.48
OP	Dragline and Truck-Shovel Stripping in the Gillette Coalfield, Wyoming (6:1 Ratio)	54.23	31.10	11.32	3.35
UG	Room and Pillar Mining Assumptions (Mine Model for the Appalachian Basin for Moderate Seam Thickness	38.87	43.72	13.77	3.64
UG	Longwall Mining Assumptions (Mine Model for the Appalachian Basin in Moderate Seam Thickness	37.20	37.20	21.73	3.87

(own calculation based on (McIntosh, 2010)

OP stands for open-pit mine; UG stands for underground mine.

Annex 8 Methodology behind the estimation of indirect employment

The IO tables can be defined as a set of sectorally disaggregated regional or national economic accounts. It is a snapshot of flows of products and services in the economy for a single year. The Basic principle of IO table is to identify and disaggregate all of the monetary flows between industries (inter-industry expenditure flows), consumers and industries and industries and supplies of factors in the economy ((Miller & Blair, 2009)).

The Input-Output modelling approach is commonly used to assess the economic benefits/losses induced by a given project or investment and it can be very useful whenever the objective is to evaluate the impacts generated by linkages along supply chains. Thus, under a number of assumptions, IO accounts can be used as the basis for economic modelling where exogenous final demands drives total output. The transmissions mechanism linking changes in exogenous demands to changes in aggregate and sectoral activity are called multipliers.

The two key assumptions in IO modelling are: (a) the supply-side of the economy is entirely passive to the level of demand and, (b) the production technology for all sectors is represented by fixed coefficients (i.e. an increase/decrease in the production of any one sector's output means a proportional increase (or decrease) in that sector's input requirements.

A key output from IO analysis is the calculation of the industry linkages (defined as multipliers) used to study the knock-on effects throughout the economy of a change in final demand. IO multipliers allow us to measure how an increase/decrease in final demand of one sector entails expansionary (or the opposite) effects on the output of intermediate sectors which, correspondingly, increase their demand for their own intermediates inputs and so on. The activity generated by the sum of these demands for intermediate inputs is known as the indirect effect. In this analysis, with some transformations, multipliers are related to changes in employment instead of in the final demand. In other words indirect job loss/increase can be calculated using direct jobs (without needs to convert jobs in monetary values).

Notice that IO multipliers, describing average effects, do not take account of economies of scale, unused capacity or technological change. Thus, IO multipliers could be used to quantify the economic impact derived from a demand-shock assuming that the average relationships in the IO table apply at the margin. Moreover, we enrich this analysis providing not only Intra-regional multipliers but also Inter-regional multipliers in order to take into account also the trade connections between regions.

Annex 9 Number of coal indirect jobs at NUTS-2

Nuts-2	NUTS-2 Name	Country	Intra-regional	Inter-regional (total)
AT12	Niederösterreich	Austria	309	825
AT22	Steiermark	Austria	260	623
AT31	Oberösterreich	Austria	200	495
BG32	Severen tsentralen	Bulgaria	132	399
BG33	Severoiztochen	Bulgaria	75	189
BG34	Yugoiztochen	Bulgaria	7 495	12 063
BG41	Yugozapaden	Bulgaria	1 676	2 415
BG42	Yuzhen tsentralen	Bulgaria	74	154
CZ02	Střední Čechy	Czech Republic	1 213	3 069
CZ03	Jihozápad	Czech Republic	85	163
CZ04	Severozápad	Czech Republic	5 843	10 310
CZ05	Severovýchod	Czech Republic	759	1 847
CZ08	Moravskoslezsko	Czech Republic	2 118	3 840
DE11	Stuttgart	Germany	776	1 643
DE12	Karlsruhe	Germany	352	816
DE21	Oberbayern	Germany	398	762
DE30	Berlin	Germany	510	831
DE50	Bremen	Germany	47	270
DE60	Hamburg	Germany	353	1 080
DE71	Darmstadt	Germany	164	341
DE80	Mecklenburg-Vorpommern	Germany	23	100
DE91	Braunschweig	Germany	236	728
DE92	Hannover	Germany	48	125
DE94	Weser-Ems	Germany	156	408
DEA1	Düsseldorf	Germany	3 227	6 754
DEA2	Köln	Germany	3 726	8 275
DEA3	Münster	Germany	1 025	3 365
DEA4	Detmold	Germany	125	376
DEA5	Arnsberg	Germany	1 101	2 715
DEC0	Saarland	Germany	482	1 234
DED2	Dresden	Germany	534	2 156
DED5	Leipzig	Germany	593	1 648
DEE0	Sachsen-Anhalt	Germany	170	625
DEF0	Schleswig-Holstein	Germany	43	114
DK01	Hovedstaden	Denmark	77	201
DK02	Sjælland	Denmark	241	743
DK03	Syddanmark	Denmark	264	533
DK04	Midtjylland	Denmark	121	247
DK05	Nordjylland	Denmark	316	705
EL53	Dytiki Makedonia	Greece	1 640	3 603
EL65	Peloponnisos	Greece	203	563
ES12	Principado de Asturias	Spain	243	453

ES24	Aragón	Spain	1 261	2 524
ES41	Castilla y León	Spain	2 074	3 651
ES42	Castilla-La Mancha	Spain	428	793
ES61	Andalucía	Spain	1 101	2 222
FI19	Länsi-Suomi	Finland	1 635	2 674
FI1B	Helsinki-Uusimaa	Finland	15	237
FI1C	Etelä-Suomi	Finland	43	329
FR23	Haute-Normandie	France	65	195
FR41	Lorraine	France	84	190
FR51	Pays de la Loire	France	268	607
FR82	Provence-Alpes-Côte d'Azur	France	108	245
HRV	Jadranska Hrvatska	Croatia	339	385
HU21	Közép-Dunántúl	Hungary	421	872
HU31	Észak-Magyarország	Hungary	1 834	3 863
IE02	Southern and Eastern	Ireland	280	378
ITC3	Liguria	Italy	1	33
ITC4	Lombardia	Italy	4	67
ITF4	Puglia	Italy	53	1 714
ITG2	Sardegna	Italy	36	708
ITI4	Lazio	Italy	812	1 448
NL11	Groningen	Netherlands	349	806
NL32	Noord-Holland	Netherlands	235	590
NL33	Zuid-Holland	Netherlands	928	2 091
NL41	Noord-Brabant	Netherlands	265	508
PL11	Łódzkie	Poland	10 846	19 459
PL12	Mazowieckie	Poland	3 347	5 733
PL21	Małopolskie	Poland	1 848	3 703
PL22	Śląskie	Poland	22 106	34 536
PL31	Lubelskie	Poland	1 510	4 709
PL33	Świętokrzyskie	Poland	1 207	2 495
PL34	Podlaskie	Poland	126	255
PL41	Wielkopolskie	Poland	3 447	8 090
PL42	Zachodniopomorskie	Poland	959	2 081
PL51	Dolnośląskie	Poland	1 698	3 045
PL52	Opolskie	Poland	1 113	2 556
PL61	Kujawsko-pomorskie	Poland	237	508
PL63	Pomorskie	Poland	302	590
PT18	Alentejo	Portugal	344	1 229
RO11	Nord-Vest	Romania	169	324
RO21	Nord-Est	Romania	175	350
RO31	Sud - Muntenia	Romania	240	394
RO41	Sud-Vest Oltenia	Romania	5 115	8 214
RO42	Vest	Romania	495	819
SE11	Stockholm	Sweden	275	573

SI03	Vzhodna Slovenija	Slovenia	1 270	1 833
SK02	Západné Slovensko	Slovakia	584	998
SK04	Východné Slovensko	Slovakia	605	1 060
UKC2	Northumberland and Tyne and Wear	United Kingdom	160	326
UKE2	North Yorkshire	United Kingdom	427	1 590
UKE4	West Yorkshire	United Kingdom	79	293
UKF1	Derbyshire and Nottinghamshire	United Kingdom	705	1 822
UKG2	Shropshire and Staffordshire	United Kingdom	31	124
UKL1	West Wales and The Valleys	United Kingdom	173	325
UKL2	East Wales	United Kingdom	264	887
UKM2	Eastern Scotland	United Kingdom	219	732
UKN0	Northern Ireland	United Kingdom	75	177

Annex 10 Number of employees in lignite and hard coal mining in EU.

Country	Number of employees direct in coal mining
Bulgaria (lignite and brown coal)	11 765
Czech Republic (hard coal)	10 131
Czech Republic (lignite)	7 869
Germany (hard coal)	9 640
Germany (lignite)	15 428
Greece (lignite)	4 919
Spain (hard coal)	3 324
Hungary (lignite)	1 655
Poland (hard coal)	89 924
Poland (lignite)	9 574
Romania (hard coal)	4 442
Romania (lignite)	10 600
Slovenia (lignite)	1 274
Slovakia (lignite)	2 190
United Kingdom (hard coal)	1 975

Values provided in thousands; data source: EURACOAL; data refers to 2015

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
EU 28						222.4	215.1	194.9	177.1	158.9
Bulgaria	15.7	14.3	13.9	13.8	13.3	13.3	12.9	12.5	12.1	12.0
Czech Republic					24.3	23.0	22.5	21.6	20.0	18.7
Germany	45.2	42.4	38.4	35.1	33.7	28.9	27.0	22.5	20.2	
Greece			0.2	0.2						0.1
Spain	9.2	8.5	7.3	6.7	6.1	5.4	4.8	4.0	3.7	1.9
Hungary	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1
Poland	142.4	135.9	138.3	142.3	124.9	122.1	121.9	116.8	:	96.0
Romania	22.0	20.9	20.8	20.0	18.0	17.0	11.5	5.8	2.2	1.8
Slovenia										
Slovakia										
United Kingdom	6.8		5.9		6.0	6.5	8.0	5.4	3.8	2.8

Values provided in thousands; data source: Eurostat

Annex 11 Coal power plants under construction

Unit	Company	Capacity (MW)	Country	Region	Commissioning
Datteln 4	Uniper Kraftwerke GmbH	1 100	Germany	North Rhine-Westphalia	2018
Ptolemaida-V	PPC	660	Greece	West Macedonia	2020
Plomin C	HEP	500	Croatia	Istra	Unknown
Jaworzno III unit 7	Tauron	910	Poland	Śląskie	2019
Kozienice Unit 11	Elektrownia Wytwarzanie S.A.	1 075	Poland	Mazowieckie	2017
Opole Unit 5	PGE	900	Poland	Opolskie	2018
Opole Unit 6	PGE	900	Poland	Opolskie	2019
Turów Unit 11	PGE	460	Poland	Dolnośląskie	2019
Zabrze	Fortum	220	Poland	Śląskie	2018

Data source: http://endcoal.org/

Annex 12 Potential impact of power plants decommissioning on jobs at NUTS-2 level

NUTS-2	NUTS-2 name	Country	Capacity likely to retire by [MW]			Direct power plant jobs impacted		
			post 2030	2030	2025	2030	2025	TOTAL
BG32	Severen tsentralen	Bulgaria	0	290	0	167	0	167
BG33	Severoiztochen	Bulgaria	0	152	0	88	0	88
BG34	Yugoiztochen	Bulgaria	670	2 601	0	1 499	0	1 499
BG41	Yugozapaden	Bulgaria	0	816	0	470	0	470
BG42	Yuzhen tsentralen	Bulgaria	0	120	0	69	0	69
CZ02	Střední Čechy	Czech Republic	820	428	0	227	0	227
CZ03	Jihozápad	Czech Republic	0	0	111	0	59	59
CZ04	Severozápad	Czech Republic	3 016	310	192	164	102	266
CZ05	Severovýchod	Czech Republic	0	840	200	445	106	550
CZ08	Moravskoslezsko	Czech Republic	800	0	0	0	0	0
DK01	Hovedstaden	Denmark	0	0	343	0	113	113
DK02	Sjælland	Denmark	0	0	827	0	271	271
DK03	Syddanmark	Denmark	0	0	860	0	282	282
DK04	Midtjylland	Denmark	0	0	375	0	123	123
DK05	Nordjylland	Denmark	0	0	740	0	243	243
DE11	Stuttgart	Germany	1 238	348	100	84	24	108
DE12	Karlsruhe	Germany	1 462	0	0	0	0	0
DE21	Oberbayern	Germany	472	333	0	80	0	80
DE30	Berlin	Germany	0	164	834	39	201	240
DE40	Brandenburg	Germany	0	1 600	3 000	385	722	1 107
DE50	Bremen	Germany	330	475	0	114	0	114
DE60	Hamburg	Germany	1 730	0	180	0	43	43
DE71	Darmstadt	Germany	510	0	0	0	0	0
DE80	Mecklenburg-Vorpommern	Germany	514	0	0	0	0	0
DE91	Braunschweig	Germany	1 080	0	440	0	106	106
DE92	Hannover	Germany	0	300	0	72	0	72
DE94	Weser-Ems	Germany	1 570	0	0	0	0	0
DEA1	Düsseldorf	Germany	4 552	1 966	1 856	473	447	920
DEA2	Köln	Germany	1 012	1 353	3 070	326	739	1 065
DEA3	Münster	Germany	792	370	370	89	-176	-87
DEA4	Detmold	Germany	875	0	0	0	0	0
DEA5	Arnsberg	Germany	2 268	1 542	800	371	193	564
DEC0	Saarland	Germany	726	966	524	233	126	359
DED2	Dresden	Germany	1 582	1 000	0	241	0	241
DED5	Leipzig	Germany	1 866	0	0	0	0	0
DEE0	Sachsen-Anhalt	Germany	0	0	960	0	231	231
DEF0	Schleswig-Holstein	Germany	0	0	290	0	70	70

NUTS-2	NUTS-2 name	Country	Capacity likely to retire by [MW]			Direct power plant jobs impacted		
			post 2030	2030	2025	2030	2025	TOTAL
IE02	Southern and Eastern	Ireland	0	915	0	366	0	366
EL53	Dytiki Makedonia	Greece	289	1 736	1 376	713	294	1 008
EL65	Peloponnisos	Greece	0	0	511	0	210	210
ES11	Galicia	Spain	1 609	351	0	117	0	117
ES12	Principado de Asturias	Spain	348	347	1 428	115	474	589
ES24	Aragón3	Spain	0	0	1 055	0	350	350
ES41	Castilla y León	Spain	0	0	2 594	0	861	861
ES42	Castilla-La Mancha	Spain	296	0	0	0	0	0
ES61	Andalucía	Spain	1 690	0	300	0	100	100
FR23	Haute-Normandie	France	0	0	600	0	116	116
FR41	Lorraine	France	0	0	595	0	115	115
FR51	Pays de la Loire	France	1 160	0	0	0	0	0
FR82	Provence-Alpes-Côte d'Azur	France	0	600	0	116	0	116
HR03	Jadranska Hrvatska	Croatia	0	0	335	0	0	0
ITC3	Liguria	Italy	0	136	0	40	0	40
ITC4	Lombardia	Italy	0	0	139	0	41	41
ITF4	Puglia	Italy	2 960	320	0	94	0	94
ITG2	Sardegna	Italy	670	320	240	94	71	165
ITH3	Veneto	Italy	0	485	320	143	94	237
ITH4	Friuli-Venezia Giulia	Italy	0	165	171	49	50	99
ITI2	Umbria	Italy	0	0	130	0	38	38
ITI4	Lazio	Italy	1 980	0	0	0	0	0
HU21	Közép-Dunántúl	Hungary	0	239	55	181	42	222
HU31	Észak-Magyarország	Hungary	0	736	100	557	76	632
NL11	Groningen	Netherlands	0	1 600	0	253	0	253
NL32	Noord-Holland	Netherlands	0	680	0	108	0	108
NL33	Zuid-Holland	Netherlands	0	731	2 140	116	339	455
NL41	Noord-Brabant	Netherlands	0	643	0	102	0	102
AT12	Niederösterreich	Austria	0	392	0	236	0	236
AT22	Steiermark	Austria	0	0	220	0	132	132
AT31	Oberösterreich	Austria	0	150	0	90	0	90

NUTS-2	NUTS-2 name	Country	Capacity likely to retire by [MW]			Direct power plant jobs impacted		
			post 2030	2030	2025	2030	2025	TOTAL
PL11	Łódzkie	Poland	3 936	1 685	198	862	101	964
PL12	Mazowieckie	Poland	1 120	666	2 168	341	559	900
PL21	Małopolskie	Poland	0	0	1 214	0	621	621
PL22	Śląskie	Poland	900	3 044	1 746	1 558	315	1 873
PL33	Świętokrzyskie	Poland	675	900	0	461	0	461
PL34	Podlaskie	Poland	0	157	0	80	0	80
PL41	Wielkopolskie	Poland	464	628	1 461	321	748	1 069
PL42	Zachodniopomorskie	Poland	0	1 290	134	660	69	729
PL51	Dolnośląskie	Poland	0	200	1 399	102	480	583
PL52	Opolskie	Poland	370	1 340	0	686	-921	-235
PL61	Kujawsko-pomorskie	Poland	0	183	100	94	51	145
PL63	Pomorskie	Poland	0	217	105	111	54	165
PT16	Centro	Portugal	0	0	628	0	230	230
PT18	Alentejo	Portugal	0	314	936	115	343	458
RO11	Nord-Vest	Romania	0	0	145	0	82	82
RO21	Nord-Est	Romania	0	200	0	113	0	113
RO31	Sud - Muntenia	Romania	0	0	150	0	85	85
RO41	Sud-Vest Oltenia	Romania	990	3 065	450	1 727	254	1 981
RO42	Vest	Romania	0	520	788	293	444	737
SI03	Vzhodna Slovenija	Slovenia	0	600	820	242	331	573
SK02	Západné Slovensko	Slovakia	0	133	133	138	139	277
SK04	Východné Slovensko	Slovakia	0	220	0	229	0	229
FI19	Länsi-Suomi	Finland	0	803	240	486	145	632
FI1B	Helsinki-Uusimaa	Finland	0	349	114	211	69	280
FI1C	Etelä-Suomi	Finland	0	0	388	0	235	235
SE11	Stockholm	Sweden	0	0	114	0	115	115
UKC2	Northumberland and Tyne and Wear	United Kingdom	0	0	420	0	98	98
UKD6	Cheshire	United Kingdom	0	0	2 000	0	466	466
UKE2	North Yorkshire	United Kingdom	0	1 980	1 500	461	350	811
UKE4	West Yorkshire	United Kingdom	0	0	500	0	117	117
UKF1	Derbyshire and Nottinghamshire	United Kingdom	0	981	4 943	229	1 152	1 381
UKG2	Shropshire and Staffordshire	United Kingdom	0	500	500	117	117	233
UKL2	East Wales	United Kingdom	0	1 000	500	233	117	350
UKM2	Eastern Scotland	United Kingdom	0	600	1 800	140	419	559
UKN0	Northern Ireland	United Kingdom	0	0	520	0	121	121

Annex 13 Assessment of the performance of mining regions – ranking criteria.

Indicator	Scores
Productivity (production per person employed, tonnes)	
<500	3
500-1000	2.5
1000-2500	2
2500-5000	1.5
>5000	1
Type of coal	
Lignite and brown coal	3
Hard coal (including steam, coking, anthracite)	1
Mine sub-type	
OP	1
OP,UG	2
UG	3
Mine depth (m)	
<200	1
200-599	1.5
600-999	2
>1000	3
Closures (recent and announced, between 2015 and 2018)	
Yes	3
No	1
Resources/reserves to production ratio (years)	
<10; NA	3
10-50	2
>50	1
Coal quality (calorific value, KJ/Kg)	
<15000	3
15000-25000	2
>250000	1

Annex 14 Risk ratings for the coal regions hosting mining activities and associated jobs at NUTS-2 level

NUTS-2	NUTS-2 name	Type of coal	Jobs	Risk rate	Risk zone
RO42	Vest	Hard coal	4 442	20	High
SK02	Západné Slovensko	Lignite	2 190	20	High
ES12	Principado de Asturias	Hard coal	1 313	18.5	High
CZ08	Moravskoslezsko	Hard coal	10 131	18	High
DEA3	Münster	Hard coal	9 640	18	High
ITG2	Sardegna	Hard coal	348	17	High
PL22	Śląskie	Hard coal	79 548	17	High
SI03	Vzhodna Slovenija	Lignite	1 274	17	High
UKE3	South Yorkshire	Hard coal	34	17	High
ES41	Castilla y León	Hard coal	394	16.5	Medium
BG41	Yugozapaden	Brown coal	991	16	Medium
PL21	Małopolskie	Hard coal	4 644	16	Medium
RO41	Sud-Vest Oltenia	Lignite	10 600	16	Medium
ES42	Castilla-La Mancha	Hard coal	219	16	Medium
UKE2	North Yorkshire	Hard coal	333	16	Medium
UKF1	Derbyshire and Nottinghamshire	Hard coal	80	16	Medium
CZ04	Severozápad	Lignite	7 869	15.5	Medium
DE40	Brandenburg	Lignite	3 402	15	Medium
PL31	Lubelskie	Hard coal	5 769	15	Medium
BG34	Yugoiztochen	Lignite	10 773	14	Medium
DED2	Dresden	Lignite	2 783	14	Medium
DEE0	Sachsen-Anhalt	Lignite	904	14	Medium
DED5	Leipzig	Lignite	1 004	14	Medium
PL41	Wielkopolskie	Lignite	2 079	14	Medium
ES24	Aragón	Hard coal	1 422	14	Medium
PL11	Łódzkie	Lignite	6 388	13.5	Low
DEA2	Köln	Lignite	4 420	13	Low
EL53	Dytiki Makedonia	Lignite	4 283	13	Low
EL65	Peloponnisos	Lignite	636	13	Low
UKL1	West Wales and The Valleys	Hard coal	367	13	Low
UKC2	Northumberland and Tyne and Wear	Hard coal	723	12.5	Low
HU31	Észak-Magyarország	Lignite	1 655	12	Low
PL51	Dolnośląskie	Lignite	1 108	12	Low
UKM3	South Western Scotland	Hard coal	241	12	Low
UKL2	East Wales	Hard coal	184	12	Low
DEA1	Düsseldorf	Lignite	2 578	11	Low

Annex 15 Relevant PRODCOM codes within the NACE class 28.92 – manufacture of machinery for mining, quarrying and construction -for the calculation of mining equipment exports

PRODCOM	Description	HS code
CPA: 28.92.11	Continuous-action elevators and conveyors, for underground use	8428 31
28.92.11.00	Continuous-action elevators and conveyors, for underground use p/st S	
CPA: 28.92.12	Coal or rock cutters and tunnelling machinery; other boring and sinking machinery	
28.92.12.33	Self-propelled coal or rock cutters and tunnelling machinery p/st S	8430 31
28.92.12.35	Coal or rock cutters and tunnelling machinery (excluding self-propelled)	8430 39
28.92.12.53	Self-propelled boring or sinking machinery p/st S	8430 41
28.92.12.55	Boring or sinking machinery (including fixed platforms used for oil or natural gas exploration) (excluding self-propelled)	8430 49
CPA: 28.92.21	Self propelled bulldozers and angledozers	
28.92.21.30	Crawler dozers (excluding wheeled)	8429 11
28.92.21.50	Wheeled dozers (excluding track-laying) p/st S	8429 19
CPA: 28.92.22	Self-propelled graders and levellers; motor scrapers	
28.92.22.10	Motor graders, levellers and scrapers p/st S	8429 20
CPA: 28.92.23	Self-propelled tamping machines and road-rollers	
28.92.23.10	Ride-on compaction equipment and the like p/st S	8429[.40(.10 + .30 + .90)]
CPA: 28.92.24	Self-propelled front-end shovel loaders	
28.92.24.30	Loaders specially designed for underground use p/st S	8429 51 10
28.92.24.50	Wheeled or crawler front-end shovel loaders (excl. specially designed for underground use)	8429[.51(.91 + .99)]
CPA: 28.92.25	Self-propelled mechanical shovels, excavators and shovel loaders, with a 360 degree revolving superstructure, except front-end shovel loaders	
28.92.25.00	Self-propelled mechanical shovels, excavators and shovel loaders, with a 360 degree revolving superstructure, except front-end shovel loaders	8429[.52(.10 + .90)]
CPA: 28.92.26	Other self-propelled mechanical shovels, excavators and shovel loaders; other self-propelled machinery for mining	
28.92.26.30	Self-propelled mechanical shovels, excavators and shovel loaders (excl. self-propelled mechanical shovels with a 360° revolving superstructure and front-end shovel loaders)	8429 59
28.92.26.50	Self-propelled earth moving, excavating... machinery, n.e.c. p/st S	8430 50
CPA: 28.92.27	Bulldozer or angledozer blades	
28.92.27.00	Bulldozer or angledozer blades kg S S2	8431 42
CPA: 28.92.28	Dumpers for off-highway use	
28.92.28.10	Dumpers for off-highway use p/st S	8704[.10(.10 + .90)]
CPA: 28.92.30	Other excavating machinery	
28.92.30.10	Pile-drivers and pile-extractors p/st S	8430 10
28.92.30.30	Snow-ploughs and snow-blowers	8430 20
28.92.30.50	Tamping or compacting machinery (excluding self-propelled) p/st S	8430 61
28.92.30.70	Scrapers earth moving, excavating, extracting... machinery, not self-propelled	8430 69
28.92.30.90	Machinery for public works, building or the like, n.e.s. p/st S	8479 10

CPA: 28.92.40	Machinery for sorting, grinding, mixing and similar treatment of earth, stone, ores and other mineral substances	
28.92.40.30	Sorting, screening, separating, washing machines; crushing, grinding, mixing, kneading machines excluding concrete/mortar mixers, machines for mixing mineral substances with bitumen p/st S	8474[.10 + .20 + .39]
28.92.40.50	Concrete or mortar mixers	8474 31
28.92.40.70	Machines for mixing mineral substances with bitumen p/st S	8474 32
CPA: 28.92.50	Track-laying tractors	
28.92.50.00	Track-laying tractors p/st S	8701 30
CPA: 28.92.61	Parts for boring or sinking or excavating machinery; parts of cranes	
28.92.61.30	Parts for boring or sinking machinery S S2	8431 43
28.92.61.50	Parts for earthmoving equipment, ships' derricks, cranes, mobile lifting frames excluding buckets, shovels, grabs, grips, blades (all types of construction equipment), for boring/sinking machinery	8431[.49(.20 + .80)]
CPA: 28.92.62	Parts of machinery for sorting, grinding or other treatment of earth, stone and the like	
28.92.62.00	Parts of machinery of HS 8474	8474[.90(.10 + .90)]

Annex 16 Production,trade and usage of hard coal in 2015

Country	Production (Mt)	Imports (Mt)	Exports (Mt)	Hard coal usage (2015)	Sourcing country for imports (2015)
Belgium	0	4.2	0	Power industry	Russia, Australia and the USA
Bulgaria	0.035	1.1	0	NA	NA
Czech Republic	8.2	2.9	3.6	Power generation and steel industries	NA
Denmark	0	2.8	0	Power and heat generation, including district heating	Russia, Colombia and South Africa
Germany	6.7	55.5	0.1	Power and heat generation; steel industries; small quantities used in the residential heating market	Russia and other CIS countries with a market share of 29.0%, followed by Colombia, the United States, Australia, Poland and South Africa.
Estonia	0	<0,1	0	NA	NA
Ireland	0	2.4	0	NA	Colombia
Greece	0	0.3	0	Power generation	NA
Spain	3	19	0	Power generation; steel industries	NA
France	0	14.3	0	Power and steel industries	NA
Croatia	0	1	0	Power industry	NA
Italy	0	19.6	0		South Africa, Russia, Indonesia, the USA, Colombia and Australia
Cyprus	0	NA	0	Cement industry	NA
Latvia	0	<0,1	0	NA	Russia
Lithuania	0	0.3	0	NA	NA
Luxembourg	0	0.073	0	Cement industry	NA
Hungary	0	1.3	0	NA	NA
Malta	0	0	0	Reports no coal consumption	Reports no coal consumption
The Netherlands	0	12.4	0	Power and steel industries	Colombia, South Africa, the USA and Russia
Austria	0	3	0	Power and steel industries	Poland, the Czech Republic, the United States and Russia
Poland	70.4	8.2	9	Power generation and steel industries	Russia (60.3%). Smaller quantities from Australia (coking coal), the Czech Republic, the United States and Colombia.
Portugal	0	5.6	0	Power industry	Colombia
Romania	1.3	1.2	0.4	Heat and power generation	NA
Slovakia	0	3.7	0	NA	NA
Slovenia	0	0.4	0	Heat and power generation	NA
Finland	0	3.5	0	Power and steel industries; small quantities used in the cement industry	Steam coal from Russia and coking coal from North America

Country	Production (Mt)	Imports (Mt)	Exports (Mt)	Hard coal usage (2015)	Sourcing country for imports (2015)
Sweden	0	2.7	0	Steel industry; limited quantities used in combined heat and power plants; small quantities used in the pulp and paper industry	Australia and the USA
United Kingdom	8.5	25.5	0.4	Power generation and steel industries; small quantities used in the residential heating market	Russia, Colombia and the United States are the main sources, accounting for almost 90% of all imports

Data refers to 2015; data source EURACOAL.

Annex 17 Coal terminals in EU

Coal terminal / Port	Owner	Country	Coal share (in comparison to bulk goods) %	Coal share (in comparison to total throughput) %
Antwerp	Mercuria	Belgium	2	0.8
Amagervaerket	Not known	Denmark	100	100
Port of Bremen	Bremenports GmbH & Co. KG	Germany	12.6	1.8
Port of Wilhelmshaven	Niedersachsen Ports GmbH & Co. KG	Germany	15	
Port of Nordenham	Rhenus Midgard	Germany	NA	NA
Port of Hamburg	Hamburg Port Authority	Germany	16.9	5.6
Gluckstadt Port	Schramm Group	Germany	NA	NA
Port of Flensburg	Not known	Germany	NA	NA
Rendsburg Port	Brunsbüttel Ports GmbH	Germany	NA	NA
Port of Kiel	Seehafen Kiel GmbH Co.	Germany	NA	NA
Port of Wismar	Seehafen Wismar GmbH	Germany	NA	NA
Rostock Port	Not known	Germany	NA	3.4
Port of Stralsund	Stralsund GmbH	Germany	NA	NA
Port of Stade	Not known	Germany	NA	NA
Rendsburg Port	Brunsbüttel Ports GmbH	Germany	NA	NA
Schwelgern	ThyssenKrupp	Germany	NA	NA
Orsoy	NIAG	Germany	0	NA
Le Havre Main	Le Havre Port	France	1.2	0.7
Fos Sur Mer (Marseille)	APM terminals	France	NA	NA
Plomin	Not known	Croatia	100	100
Genoa	Not known	Italy	NA	NA
Piombino	Not known	Italy	NA	NA
Port of Rotterdam	Port of Rotterdam Authority	Netherlands	9.8	6.6
EMO terminal	Port of Rotterdam Authority	Netherlands	NA	NA
Szczecin	Szczecin and Swinoujscie Seaports Authority	Poland	NA	NA
Swinoujscie	Szczecin and Swinoujscie Seaports Authority	Poland	NA	NA
Port of Gdynia	Port of Gdynia Authority SA	Poland	12.5	NA
Constanta	Not known	Romania	NA	0
Port Talbot	Associated British Ports	United Kingdom	NA	NA
Kingsnorth	Not known	United Kingdom	100	100
Tilbury	Not known	United Kingdom	NA	NA

Annex 18 Wind and solar resource potential (availability factors)

NUTS 2	Solar availability (%)	Wind availability (%)
BG34	15.39	14.05
BG41	15.16	14.05
CZ04	11.75	15.37
CZ08	11.91	38.19
DE40	11.80	14.41
DEA1	11.65	30.90
DEA2	11.69	20.28
DEA3	11.49	25.88
DEC0	12.23	15.25
DED2	11.76	17.08
DED5	12.08	28.46
DEE0	12.06	18.47
EL53	16.26	24.87
EL65	17.89	17.20
ES12	13.87	15.12
ES21	13.93	13.07
ES24	18.45	27.35
ES41	17.63	25.54
ES42	18.98	20.15
HU31	13.85	39.94
ITG2	17.80	16.30
PL11	12.00	41.85
PL21	12.01	55.08
PL22	11.95	67.41
PL31	12.10	28.15
PL41	11.99	22.84
PL51	12.03	16.16
RO41	14.87	60.01
RO42	13.96	11.58
SI03	13.97	8.88
SK02	13.56	16.79
UKC2	10.26	29.16
UKE2	10.42	25.08
UKE3	10.66	26.00
UKE4	10.32	4.73
UKF1	10.78	47.78

NUTS 2	Solar availability (%)	Wind availability (%)
UKG2	10.82	63.84
UKL1	10.74	9.55
UKL2	10.70	17.12
UKM2	9.68	12.37
UKM3	9.80	9.60

Annex 19 Criteria to determine carbon capture readiness

Criteria to determine a CCSR facility and assumptions include but are not limited to:

- The facility is technically capable of being fully retrofitted for CO_2 capture and related units, and adequate space is available;
- Combustion plants with a rated electrical output of 300 MW or more are CO_2 capture ready;
- Power plants in the medium age band (~10 years old) are CO_2 capture ready, even if this may be a fairly conservative assumption;[113]
- One or more choices of capture technology which are proven or whose performance can be reliably estimated as being suitable are available;
- Retrofitted capture equipment can be connected to the existing facilities effectively and without an excessive outage period;
- Pipeline or other route(s) such as shipping, to storage of CO_2 can be available;
- One or more potential storage areas which have been appropriately assessed and found likely to be suitable for safe geological storage of projected full lifetime volumes and rates of captured CO_2 are available;
- Additional water requirements have been identified and credible ways exist, in which these requirements could be overcome;
- The costs of retrofitting capture, transport and storage can be incurred;
- The public and local communities are engaged and consent;
- Consideration of health, safety and environmental issues has been taken and relevant approvals are in place, including a CO_2 monitoring plan.

[113] In the literature, "recently" built fossil fuel-fired power plants have been considered these commissioned after 1997 (Graus, Roglieri, Jaworski, Worrell, & Alberio, 2011; Ecofys, 2008). This does not imply that older power plants cannot be retrofitted with carbon capture – see Boundary Dam CCS project where CCS was retrofitted to a renovated unit, commissioned originally in the 1970s.

Annex 20 Methodology on the regional downscaling of pollutant emissions

The JRC07 emissions inventory is based on country total emission data from the Greenhouse Gas and Air Pollution Interactions and Synergies Model ((Amann, et al., 2011)). The disaggregation of national emission data is based on the usage of 63 spatial surrogates for each GAINS sector/activity combination.

The total emissions maps are produced summing up the maps of national values downscaled at NUTS2 level for each of the considered sector/activity combinations. These single sectors can be grouped in SNAP97 (Selected Nomenclature for Air Pollution - CORe INventory AIR emissions, CORINAIR) Level 1 Macro sectors (see Table below).

SNAP	Sector Name
1	Combustion in energy and transformation industries
2	Non-industrial combustion plants
3	Combustion in manufacturing industry
4	Production processes
5	Extraction and distribution of fossil fuels
6	Solvent and other product use
7	Road transport
8	Other mobile sources and machinery
9	Waste treatment and disposal
10	Agriculture

The disaggregation of national emissions to the powerplants was implemented by using the plant-specific operating net capacity (MW) sourced from the S&P Global Platts Geodatabase (2015). Wherever plant-specific data were not available average country-specific data were used.

Emissions from coal mining activities are extracted from the European Pollutant Release and Transfer Register database (E-PRTR v8, http://prtr.ec.europa.eu/). The national modelled emission value for each pollutant was disaggregated to all facilities in EU28 which reported emissions from coal mining activities (NACE sector 5.1 and 5.2).

The downscaling of road transport emissions (SNAP7) is based on road network data, population density estimates highway traffic data and a transport model output.

The road networks are derived from Open Street Map (OSM contributors, 2015), distinguishing the following categories: motorways, national roads and regional/local roads. Land-use information is then used to classify national and regional/local roads in terms of urban and not-urban types.

The Residential (Non-industrial) combustion emissions are part of the Economic Macro Sector SNAP2 which includes small combustion processes from residential and commercial plants as well as plants in agriculture. The emissions from this macro sector are mainly due to fuelwood and coal burning and are of crucial importance for certain pollutants (e.g.: PM2.5, NOx). The emissions from fuelwood have been distributed based on population weighted according to the assumption that in urban centres usage of firewood in the domestic sector is remarkably lower than in rural areas and towns/suburbs. The usage of natural gas and coal burning was instead considered to be directly proportional to the population density.

Annex 21 Country factsheets

Country factsheets are provided in the following pages.

Bulgaria

Coal mines	Coal power plants	Estimated jobs
Number of mines **12**	Number of power plants **7**	Mining jobs **11 800**
Production **36 Mt**	Capacity **4 377 MW**	Power plant jobs **2 700**
		Total jobs **14 500**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
BG34	Lignite & brown coal (hard coal insignificant)	OP, UG	32.6	3 026	182	4	Maritsa lignite field
BG41	Lignite & brown coal	OP, UG	3		830	8	Bobov Dol, Pernik, Black Sea and Oranovo

*OP - Open pit; UG - underground mine; Mt (million tonnes); Resources & reserves represent the sum of resources including reserves at operating mines (the same applies to the other factsheets).

Coal power plants (NUTS-2 level)

NUTS-2	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age (years)
BG32	Severen tsentralen	290	29	37
BG33	Severoiztochen	152	34	51
BG34	Yugoiztochen	3 271	34	30
BG41	Yugozapaden	816	34	44
BG42	Yuzhen tsentralen	120	34	45

Estimates of employment in coal related activities

NUTS-2	Location	Jobs in Coal mines	Jobs in power plants	Total Jobs
BG32	Severen tsentralen	**0**	167	167
BG33	Severoiztochen	**0**	88	88
BG34	Yugoiztochen	10 773	1 885	12 658
BG41	Yugozapaden	991	470	1 461
BG42	Yuzhen tsentralen	**0**	69	69


Legend
Coal power plants
Coal mines
Bulgaria
NUTS-2 region
RO12
RO22
RO31
RO32
RO41
BG32
BG33
BG31
BG34
BG41
BG42
TR21
MK00
EL51
EL52
EL53
TR22
TR22

Czech Republic

Coal mines	Coal power plants	Estimated jobs
Number of mines **9**	Number of power plants **13**	Coal mine jobs **18 000**
Production **46 Mt**	Capacity **6 717 MW**	Power plant jobs **3 600**
		Total jobs **21 600**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Average productivity	Coal depth (m)	No. mines	Coalfield (or company)
CZ08	Hard coal	UG	8.3	819	1 300	3	Ostrava-Karviná basin (USCB)
CZ04	Lignite & Brown coal	OP, (UG minor)	38.1	4 842	400	6	Northern Bohemian and Sokolov basins

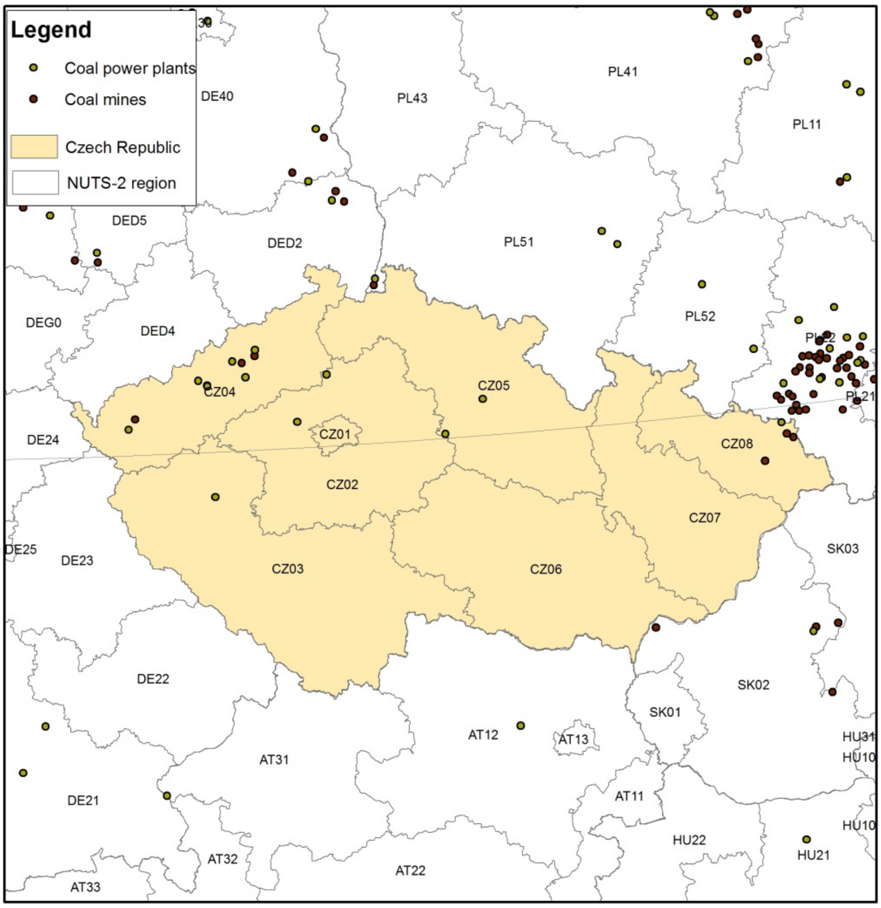
* OP Open pit mine; UG Underground mine; Mt (million tonnes); USCB - Upper Silesian Coal Basin.

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age (years)
CZ02	Střední Čechy	1 248	36	33
CZ03	Jihozápad	111	29	56
CZ04	Severozápad	3 518	37	41
CZ05	Severovýchod	1 040	33	43
CZ08	Moravskoslezsko	800	35	40

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of Jobs in Coal mines (operating)	Number Jobs in coal power plants	Total number of Jobs
CZ02	Střední Čechy	0	661	661
CZ03	Jihozápad	0	59	59
CZ04	Severozápad	7 869	1 862	9 731
CZ05	Severovýchod	0	550	550
CZ08	Moravskoslezsko	10 131	423	10 554


Legend
Coal power plants
Coal mines
Czech Republic
NUTS-2 region
DE40
PL43
PL41
PL11
DED5
DED2
PL51
DEG0
DED4
PL52
CZ04
CZ05
CZ01
DE24
CZ08
CZ02
CZ07
DE25
DE23
CZ03
CZ06
SK03
DE22
SK02
SK01
AT12
AT13
AT31
DE21
AT11
HU22
HU21
AT32
AT22
AT33

Germany

Coal mines	Coal power plants	Employment
Number of mines **12**	Number of power plants **53**	Coal mine jobs **25 000**
Production **184 Mt**	Capacity **45 420 MW**	Power plant jobs **11 000**
		Total jobs **35 700**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
DEA3	Hard coal incl. Anthracite	UG	6.7	695	800	2	Ibbenbüren, Ruhr
DEA2	Lignite	OP	60.0	13 575	NA	2	Rhineland Area
DEA1	Lignite	OP	35.0	13 576	800	1	Rhineland Area
DEC0	Hard coal	UG	NA	NA	600	NA	Saar
DE40	Lignite	OP	34	10 000	110	2	Lusatian Area
DED2	Lignite	OP	28	10 000	NA	2	Lusatian Area
DEE0	Lignite	OP	9.3	10 000	NA	2	Central German Area
DED5	Lignite	OP	10	10 000	NA	1	Central German Area

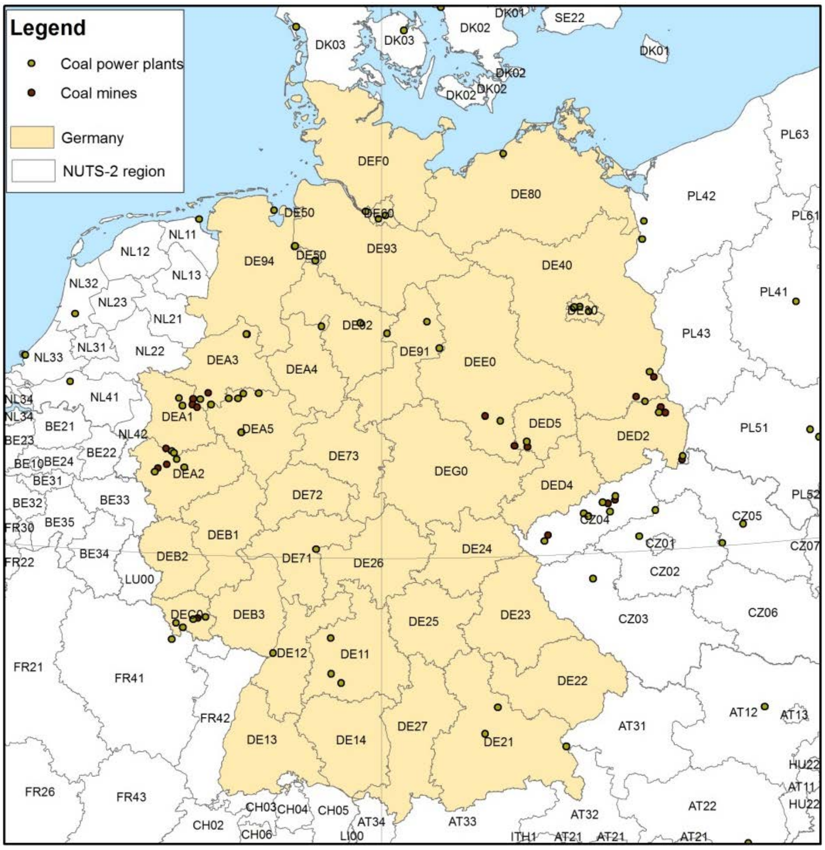
* OP Open pit mine; UG Underground mine; Mt (million tonnes)

Coal power plants (NUTS-2 level)

NUTS-2 Region	NUTS-2 name	Capacity (MW)	Average efficiency (%)	Age (years)
DE11	Stuttgart	1 686	36%	27
DE12	Karlsruhe	1 462	42%	13
DE21	Oberbayern	805	38%	28
DE30	Berlin	998	32%	33
DE40	Brandenburg	4 600	34%	27
DE50	Bremen	805	36%	40
DE60	Hamburg	1 910	36%	4
DE71	Darmstadt	510	40%	24
DE80	Mecklenburg-Vorpommern	514	42%	22
DE91	Braunschweig	1 520	36%	33
DE92	Hannover	300	34%	27
DE94	Weser-Ems	1 570	39%	21
DEA1	Düsseldorf	8 374	36%	26
DEA2	Köln	5 435	34%	38
DEA3	Münster	1 532	35%	39
DEA4	Detmold	875	39%	29
DEA5	Arnsberg	4 610	37%	25
DEC0	Saarland	2 216	34%	37
DED2	Dresden	2 582	37%	21
DED5	Leipzig	1 866	42%	16
DEE0	Sachsen-Anhalt	960	31%	20
DEF0	Schleswig-Holstein	290	29%	24

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of Jobs in coal mines	Number of jobs in coal power plants	Total number of Jobs
DE11	Stuttgart	0	406	406
DE12	Karlsruhe	0	352	352
DE21	Oberbayern	0	194	194
DE30	Berlin	0	240	240
DE40	Brandenburg	3 402	1 107	4 509
DE50	Bremen	0	194	194
DE60	Hamburg	0	460	460
DE71	Darmstadt	0	123	123
DE80	Mecklenburg-Vorpommern	0	124	124
DE91	Braunschweig	0	366	366
DE92	Hannover	0	72	72
DE94	Weser-Ems	0	378	378
DEA1	Düsseldorf	2 578	2 016	4 594
DEA2	Köln	4 420	1 308	5 728
DEA3	Münster	9 640	369	10 009
DEA4	Detmold	0	211	211
DEA5	Arnsberg	0	1 110	1 110
DEC0	Saarland	0	533	533
DED2	Dresden	2 783	621	3 405
DED5	Leipzig	1 004	449	1 453
DEE0	Sachsen-Anhalt	904	231	1 135
DEF0	Schleswig-Holstein	0	70	70



Greece

Coal mines	Coal power plants	Employment
Number of mines **9**	Number of power plants **7**	Coal mine jobs **4 900**
Production: **46 Mt**	Capacity **4 186 MW**	Power plant jobs **1 600**
		Total jobs **6 500**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
EL53	Lignite	OP	37.9	9 000	175	8	Western Macedonian Field; Elassona
EL65	Lignite	OP	8.1	12 736	175	1	Megalopolis

* OP Open-pit mine; Mt (million tonnes)

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age (Years)
EL53	Dytiki Makedonia	3 401	30	31
EL65	Peloponnisos	511	25	33

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of jobs in coal mines	Number jobs in coal power plants	Total number of Jobs
EL53	Dytiki Makedonia	4 283	1 398	5 681
EL65	Peloponnisos	636	210	846


Legend
Coal power plants
Coal mines
Greece
NUTS-2 region
BG41
BG42
MK00
TR10
TR21
TR41
TR22
TR33
TR31
TR32
EL51
EL52
EL53
EL54
EL61
EL62
EL63
EL64
EL30
EL65
EL41
EL42
EL43

Hungary

Coal mines	Coal power plants	Employment
Number of mines **2**	Number of power plants **2**	Coal mine jobs **1 600**
Production **9.3 Mt**	Capacity **1 130 MW**	Power plant jobs **900**
		Total jobs **2 500**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
HU31	Lignite	OP	9.3	5 600	NA	2	Matra

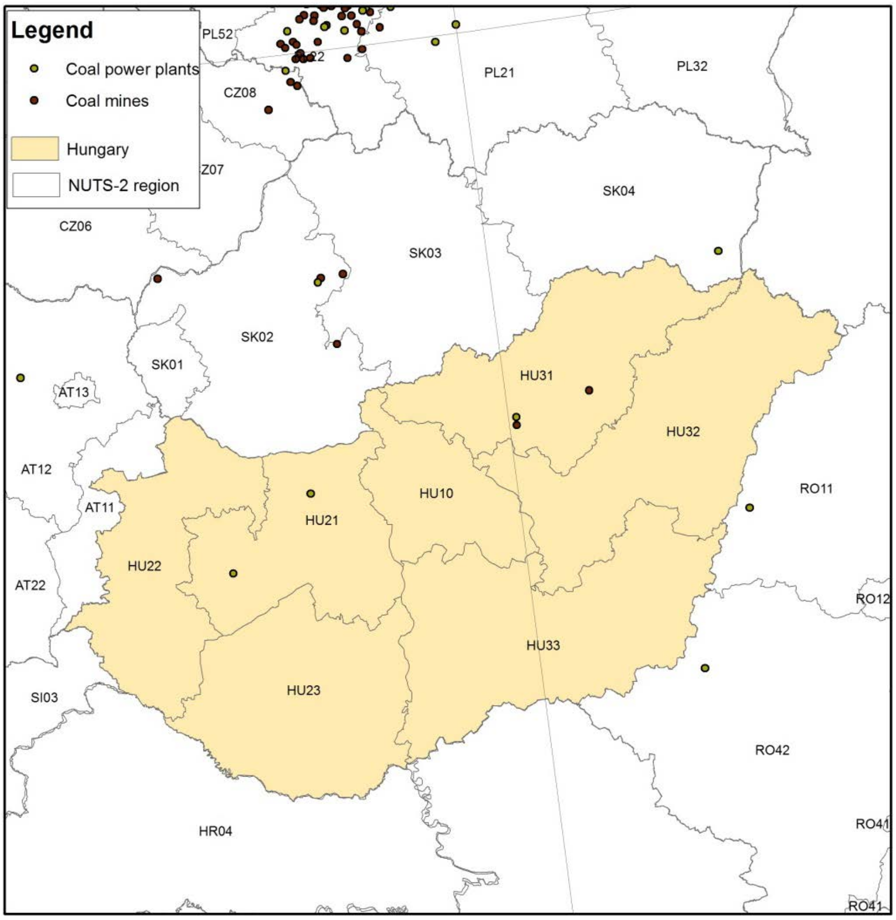
*OP - Open pit mine; Mt (million tonnes)

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency	Age
HU21	Közép-Dunántúl	1 130	29%	44
HU31	Észak-Magyarország			

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of Jobs in Coal mines (operating)	Number Jobs in coal power plants	Total number of Jobs
HU21	Közép-Dunántúl	0	222	222
HU31	Észak-Magyarország	1 655	632	2 287


Legend
Coal power plants
Coal mines
Hungary
NUTS-2 region
PL52
PL21
PL32
CZ08
CZ07
CZ06
SK04
SK03
SK02
SK01
AT13
AT12
AT11
AT22
HU31
HU32
HU10
HU21
HU22
HU23
HU33
RO11
RO12
RO42
RO41
SI03
HR04

Italy

Coal mines	Coal power plants	Employment
Number of mines **1**	Number of power plants **10**	Coal mining jobs **350**
Production **0.1 Mt**	Capacity **8 036 MW**	Power plant jobs **2 400**
		Total jobs **2 750**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
ITG2	Hard coal	UG	0.073	210	1 000	1	Sulcis

UG"* underground mine; Mt (million tonnes)

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age (Years)
ITC3	Liguria	136	34	56
ITC4	Lombardia	139	29	28
ITF4	Puglia	3 280	37	27
ITG2	Sardegna	1 230	34	21
ITH3	Veneto	805	34	43
ITH4	Friuli-Venezia Giulia	336	34	48
ITI2	Umbria	130	29	49
ITI4	Lazio	1 980	42	7

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of Jobs in coal mines	Number jobs in coal power plants	Total number of Jobs
ITC3	Liguria	0	40	40
ITC4	Lombardia	0	41	41
ITF4	Puglia	0	966	966
ITG2	Sardegna	348	362	710
ITH3	Veneto	0	237	237
ITH4	Friuli-Venezia Giulia	0	99	99
ITI2	Umbria	0	38	38
ITI4	Lazio	0	583	583


Legend
Coal power plants
Coal mines
Italy
NUTS-2 region
FR43
CH02
CH06
AT34
AT33
CH05
ITH1
AT32
AT22
AT21
AT11
CH07
CH01
ITH2
ITH4
SI04
SI03
FR71
ITC2
ITC4
ITH3
ITC1
HR03
ITH5
FR82
ITC3
ITI1
ITI3
ITI2
FR83
ITF1
ITI4
ITF2
ITF3
ITF4
ITF5
ITG2
ITF6
ITG1

Poland

Coal mines	Coal power plants	Employment
Number of mines **35**	Number of power plants **37**	Coal mine jobs **99 500**
Production **135 Mt**	Capacity **25 400 MW**	Power plant jobs **13 000**
		Total jobs **112 500**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
PL22	Hard coal	UG	59	742		28	Upper Silesian Basin
PL21	Hard coal	UG	4.7	1 012	770	2	Upper Silesian Basin
PL31	Hard coal	UG	8.5	1 473		1	Lublin Basin
PL11	Lignite	OP	42.1	6 590	300	1	Belchatów
PL51	Lignite	OP	7.3	6 588	NA	1	Bogatynia
PL41	Lignite	OP	13.7	6 590	54	2	Konin-Adamov

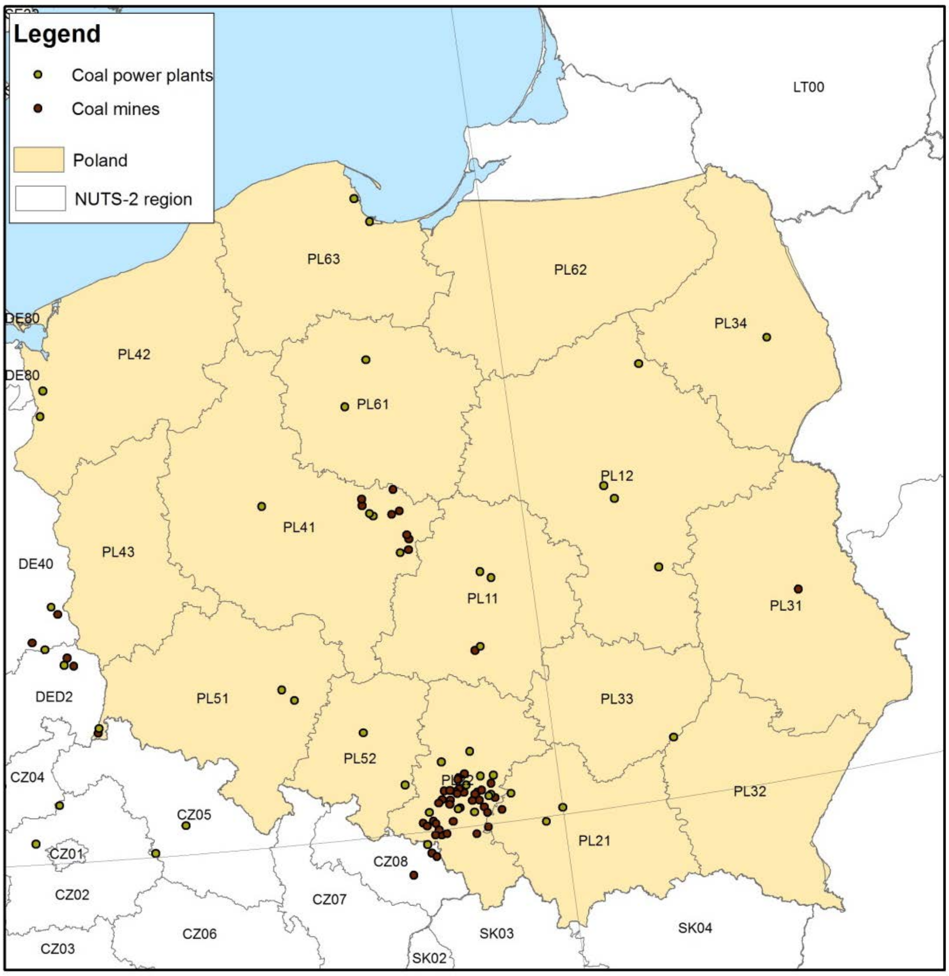
* OP - Open pit mine; UG - underground mine; Mt (million tonnes); n.a.* (not available data)

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age (years)
PL11	Łódzkie	4 960	36	23
PL12	Mazowieckie	3 954	34	49
PL21	Małopolskie	1 214	29	38
PL22	Śląskie	5 690	34	35
PL33	Świętokrzyskie	1 575	35	35
PL34	Podlaskie	157	35	25
PL41	Wielkopolskie	2 553	33	39
PL42	Zachodniopomorskie	1 424	33	42
PL51	Dolnośląskie	1 599	33	35
PL52	Opolskie	1 710	35	25
PL61	Kujawsko-pomorskie	283	33	24
PL63	Pomorskie	322	33	39

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of jobs in coal mines	Number jobs in coal power plants	Total number of Jobs
PL11	Łódzkie	6 388	2 538	8 926
PL12	Mazowieckie	0	2 023	2 023
PL21	Małopolskie	4 644	621	5 265
PL22	Śląskie	79 548	2 911	82 459
PL31	Lubelskie	5 769	0	5 769
PL33	Świętokrzyskie	0	806	806
PL34	Podlaskie	0	80	80
PL41	Wielkopolskie	2 079	1 306	3 385
PL42	Zachodniopomorskie	0	729	729
PL51	Dolnośląskie	1 108	818	1 926
PL52	Opolskie	0	875	875
PL61	Kujawsko-pomorskie	0	145	145
PL63	Pomorskie	0	165	165



Romania

Coal mines	Coal power plants	Employment
Number of mines **7**	Number of power plants **13**	Coal mine jobs **15 000**
Production **25 Mt**	Capacity **6 308 MW**	Power plant jobs **3 600**
		Total jobs **18 600**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
RO41	Lignite	OP	24.0	2 264	NA	1	Oltenia Basin
RO42	Hard coal	UG	1.3	293	NA	6	Jiu Valley

*OP Open pit mine; UG underground mine; Mt (million tonnes); NA not available/not analysed.

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age
RO11	Nord-Vest	145	29	47
RO21	Nord-Est	200	29	28
RO31	Sud -Muntenia	150	29	30
RO41	Sud-Vest Oltenia	4 505	33	37
RO42	Vest	1 308	29	42

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of Jobs in Coal mines (operating)	Number Jobs in coal power plants	Total number of Jobs
RO11	Nord-Vest	0	82	82
RO21	Nord-Est	0	113	113
RO31	Sud - Muntenia	0	85	85
RO41	Sud-Vest Oltenia	10 600	2 539	13 139
RO42	Vest	4 442	800	5 242


Legend
Coal power plants
Coal mines
Romania
NUTS-2 region
PL21
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SK04
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HU32
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RO11
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RO12
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RO42
RO41
RO32
RO31
BG32
BG33
BG31
BG34
BG41
BG42

Slovakia

Coal mines	Coal power plants	Employment
Number of mines **4**	Number of power plants **2**	Coal mine jobs **2 200**
Production **1.8 Mt**	Capacity **486 MW**	Power plant jobs **500**
		Total jobs **2 700**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
SK02	Lignite	UG	1.8[114]	822	225	4	Hornonitrianske Bane Prievidza, Bana Cáry[115]

*UG underground mine; Mt (million tonnes).

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age (years)
SK02	Západné Slovensko	486	29	50
SK04	Východné Slovensko			

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of Jobs in coal mines	Number Jobs in coal power plants	Total number of Jobs
SK02	Západné Slovensko	2 190[116]	459[117]	2
SK04	Východné Slovensko	0	229[118]	

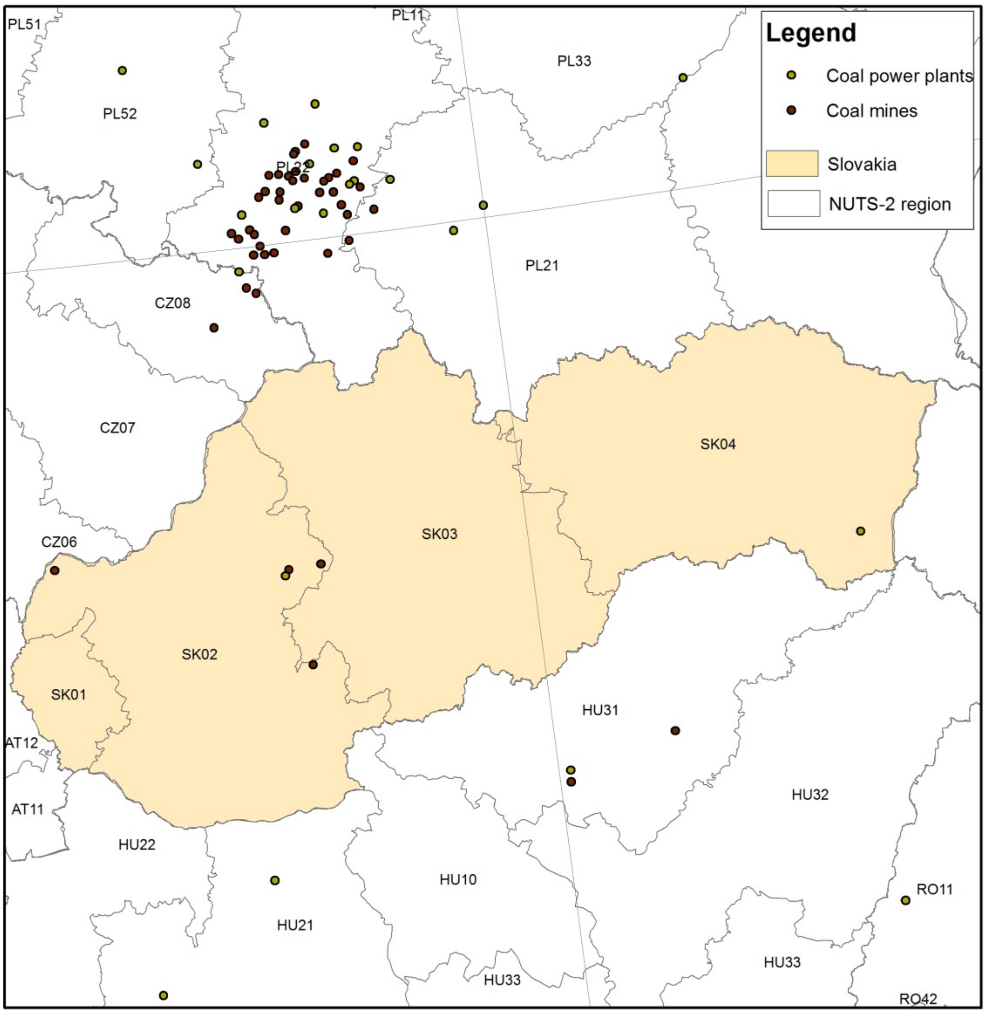
[114] In 2016, lignite sales reached 1.9 million tonnes (Communication of the Ministry of Economy of the Slovak Republic, 19 March 2018).

[115] Bana Cary was acquired by HBP (Hornonitrianske bane Prievidza) in November 2015 (HBP presentation, 2018).

[116] In 2016, the number of jobs in core mining activities was 2 270 (Discussion of the European Commission's expert team with representatives of the public administration and the private sector at the Government Office of the Slovak Republic in 6 July 2017). In 2016, HBP mines group had an average 3 948 employees (Communication of the Ministry of Economy of the Slovak Republic, 19 March 2018).

[117] In 2016, the Nováky Power Station employed 200 workers (Communication of the Ministry of Economy of the Slovak Republic, 19 March 2018).

[118] In 2016 the Vojany Power Plant employed 132 people (Výročná správa, Annual Report 2016).



Legend
Coal power plants
Coal mines
Slovakia
NUTS-2 region
PL51
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PL33
PL52
PL22
PL21
CZ08
CZ07
CZ06
SK04
SK03
SK02
SK01
AT12
AT11
HU31
HU32
HU22
HU21
HU10
HU33
RO11
RO42

Slovenia

Coal mines	Coal power plants	Employment
Number of mines **1**	Number of power plants **2**	Coal mine jobs **1 300**
Production **3.2 Mt**	Capacity **1 420 MW**	Power plant jobs **600**
		Total jobs **1 900**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
SI03	Lignite	UG	3.2	2 512	160	1	Premogovnik Velenje

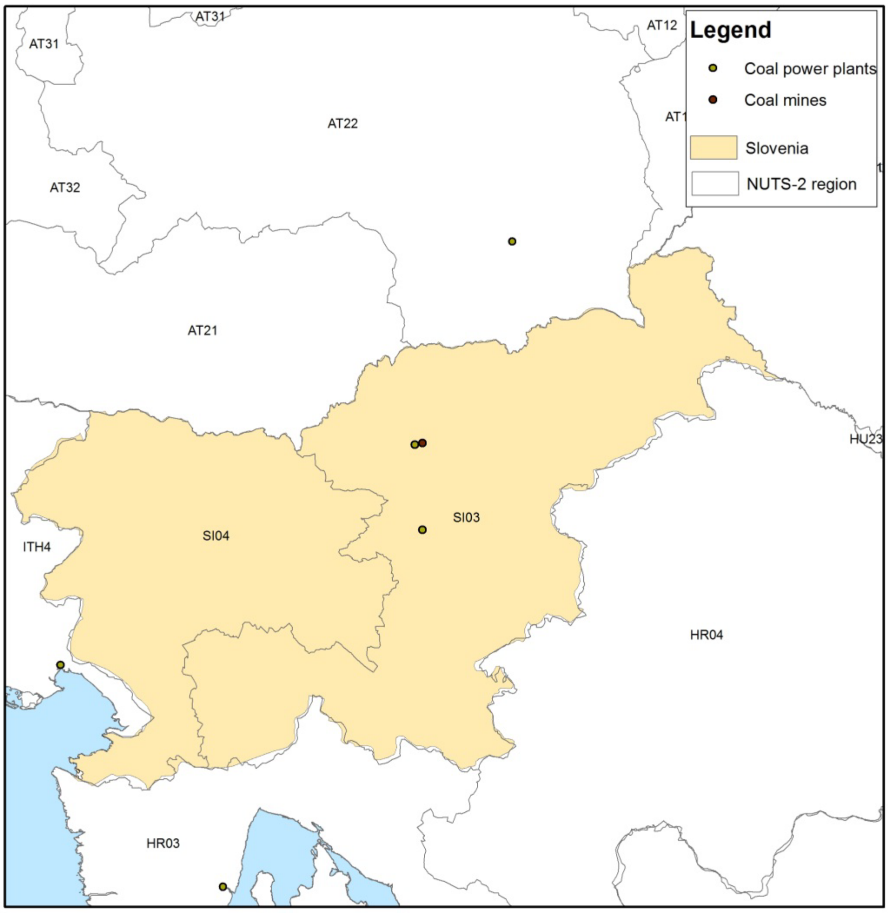
* UG underground mine; Mt (million tonnes); n.a. not available/not analysed.

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age (Years)
SI03	Vzhodna Slovenija	1 420	36	26

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of Jobs in Coal mines (operating)	Number Jobs in coal power plants	Total number of Jobs
SI03	Vzhodna Slovenija	1 274	573	1 847


Legend
Coal power plants
Coal mines
Slovenia
NUTS-2 region
AT31
AT31
AT12
AT22
AT32
AT21
SI04
SI03
ITH4
HU23
HR04
HR03

Spain

Coal mines	Coal power plants	Employment
Number of mines **26**	Number of power plants **16**	Coal mine jobs **3 300**
Production **3.0 Mt**	Capacity **10 018 MW**	Power plant jobs **3 300**
		Total jobs **6 700**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
ES24	Hard coal	OP	1.3	914	NA	2	Teruel
ES12	Hard coal (Metallurgical, others)	UG	1.2		450	11	Leon-Palencia
ES41	Hard coal (Metallurgical, others)	OP, UG	0.36		NA	11	Leon-Palencia, Nalon
ES42	Hard coal (Thermal)	OP	0.2		NA	1	Puertollano
ES21	Hard coal (Metallurgical)	OP	NA		NA	1	Nafarrondo

*OP Open pit mine; UG underground mine; Mt (million tonnes); NA *(not available/not analysed)

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age (years)
ES11	Galicia	1 960	35	38
ES12	Principado de Asturias	2 123	29	35
ES24	Aragón	1 055	33	37
ES41	Castilla y León	2 594	33	38
ES42	Castilla-La Mancha	296	42	19
ES61	Andalucía	1 990	36	28

Estimates of employment in coal related activities

NUTS 2 Region	Location	Number of jobs in coal mines	Number jobs in coal power plants	Total number of Jobs
ES11	Galicia	NA	651	651
ES12	Principado de Asturias	1 313	705	2 018
ES24	Aragón	1 422	350	1 772
ES41	Castilla y León	394	861	1 255
ES42	Castilla-La Mancha	219	98	317
ES61	Andalucía	0	661	661
ES21	País Vasco	n.a.	0	n.a.


Legend
Coal power plants
Coal mines
Spain
NUTS-2 region
ES11
ES13
ES21
ES22
ES23
ES24
ES30
ES41
ES42
ES43
ES51
ES52
ES53
ES61
ES62
ES63
PT11
PT15
PT16
PT17
PT18
FR62
FR81

United Kingdom

Coal mines	Coal power plants	Employment
Number of mines **10**	Number of power plants **11**	Coal mine jobs **2 000**
Production **8.5 Mt**	Capacity **17 224 MW**	Power plant jobs **4 100**
		Total jobs **6 100**

Coal mines

NUTS-2	Type of coal	Mine type*	Production (Mt)	Producti-vity	Coal depth (m)	No. mines	Coalfield (or company)
UKC2	Hard coal (thermal, others)	OP, UG	3.15		NA	2	Northumberland Coalfield
UKE3	Hard coal (thermal, others)	UG	0.15		NA	2	East Pennine Coalfield
UKE4	Hard coal	UG	na		NA	na	East Pennine Coalfield
UKE2	Hard coal (Thermal)	UG	1.45		800	1	East Pennine Coalfield
UKF1	Hard coal (thermal, others)	OP, UG	0.35	4 354	800	1	East Pennine Coalfield
UKM3	Hard coal	OP	1.05		NA	1	Ayrshire Coalfield
UKM2	Hard coal	OP	na		NA	na	Fife Coalfield
UKG2	Hard coal (Thermal)	OP	na		NA	na	South Lancashire Coalfield
UKL2	Hard coal (anthracite)	OP	0.8		150	1	South Wales Coalfield
UKL1	Hard coal (Metallurgical)	OP, UG	1.6		150	2	South Wales Coalfield

*OP Open pit mine; UG underground mine; Mt (million tonnes); NA (not available/not analysed)

Coal power plants (NUTS-2 level)

NUTS 2 Region	NUTS2 name	Capacity (MW)	Average efficiency (%)	Age (years)
UKC2	Northumberland and Tyne and Wear	420	29	44
UKD6	Cheshire	2 000	36	44
UKE2	North Yorkshire	3 480	37	38
UKE4	West Yorkshire	500	36	49
UKF1	Derbyshire and Nottinghamshire	5 924	36	47
UKG2	Shropshire and Staffordshire	1 000	36	46
UKL2	East Wales	1 500	36	40
UKM2	Eastern Scotland	2 400	36	46
UKN0	Northern Ireland	520	35	34

Estimates of employment in coal related activities

NUTS 2 Region	NUTS-2 Name	Number of jobs in coal mines	Number jobs in coal power plants	Total number of Jobs
UKC2	Northumberland and Tyne and Wear	723	98	821
UKD6	Cheshire	0	466	466
UKE2	North Yorkshire	333	811	1 144
UKE4	West Yorkshire	n.a.	117	117
UKF1	Derbyshire and Nottinghamshire	80	1 381	1 461
UKG2	Shropshire and Staffordshire	n.a.	233	233
UKL1	West Wales and The Valleys	367	0	367
UKL2	East Wales	184	350	534
UKM2	Eastern Scotland	n.a.	559	559
UKM3	South Western Scotland	241	0	241
UKE3	South Yorkshire	34	0	34
UKN0	Northern Ireland	0	121	121

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