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Coal Transition in the CZECH REPUBLIC

*An historical case study for the project "Coal Transitions:
Research and Dialogue on the Future of Coal"*

2017



Climate
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*An historical case study for the project "Coal Transitions:
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*This is one of the 6 country case-studies commissioned to collect experience on past coal transitions.
The 6 countries are: Czech Republic, the Netherlands, Poland, Spain, UK, USA. Their role in the Coal Transitions
project was to provide background information for a Synthesis Report for decision makers, and provide general
lessons for national project teams to take into account in developing their coal transitions pathways for the future.*

A project funded by the KR Foundation

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Cite this report as

Dominika Rečková et al. (2017) , Coal Transition in the Czech Republic, IDDRI and Climate Strategies.

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Publishers: IDDRI and Climate Strategies

Editors: Pierre Barthélemy, Andrzej Błachowicz, Germana Canzi, Alexandra Carr, Oliver Sartor, Thomas Spencer

Graphic design: Ivan Pharabod

Abstract

In this report we summarize the development of coal sector in Czech Republic since 1990 with a particular focus on the socio-economic impacts. First we present the key features of the Czech economy and the energy system; second the development of coal mining and lastly the governmental role in the downturn of the coal industry, including its support for renewable energy sources.

History of coal production and coal reserves

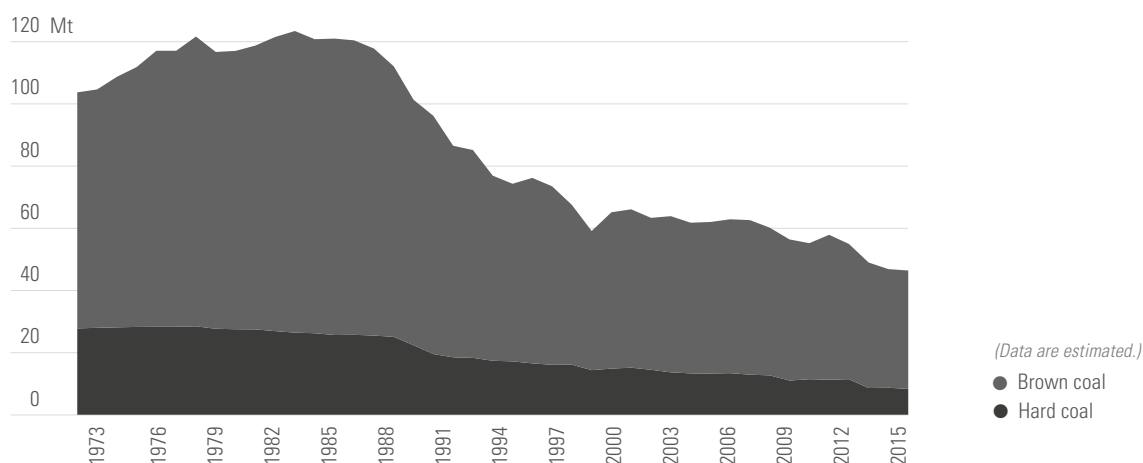
The oldest written mention of mining on the present Czech Republic territory comes from the 15th century, while the expansion of hard coal, brown coal, and lignite mining began with the construction of railways in mid 19th century (Czech News Agency 2016). The main brown coal deposits are located on the border with Germany in the North Bohemian Brown Coal Basin. Hard coal deposits are situated near the Polish border in the Czech part of the Upper Silesian Basin. The mining of coal in the Czech Republic gradually increased from 10 million tonnes in 1876 to over 40 million tonnes in 1950 and then culminated around 1980 at about 120 million tonnes (Maca & Melichar 2016). The slowdown of coal mining was experienced across Western Europe, beginning around the year 1960. The output of the largest producers at the time – Germany, France, England and Belgium – decreased their yearly outputs by anywhere between tens to

hundreds of millions of tonnes. In Middle and Eastern Europe, states continued to mine for economic and mainly political reasons over the next 30 years, starting their downturn after 1990 (Sochor). This was the case in the Czech Republic (see **Figure 1**).

In the Czech Republic coal is the only indigenous energy source. In 2014 the Czech Republic had around 16 million kt of hard coal reserves (1,475,446 kt economic explored, 5,993,812 kt economic prospected and 8,835,351 kt potentially economic reserves); approximately 56 Mt is mineable and about 8 Mt of hard coal per year is presently extracted from 8 deposits.

Brown coal reserves are smaller – in 2014 around 9 million kt (2,273,951 kt economic explored, 2,062,445 kt economic prospected and 4,489,937 kt potentially economic reserves); approximately 796 Mt is exploitable and around 40 Mt of brown coal is mined yearly from 10 deposits (Starý et al. 2015).

Figure 1. Brown and hard coal production, 1973-2015



Source: IEA (2016a), *Coal Information 2016*, www.iea.org/statistics/.

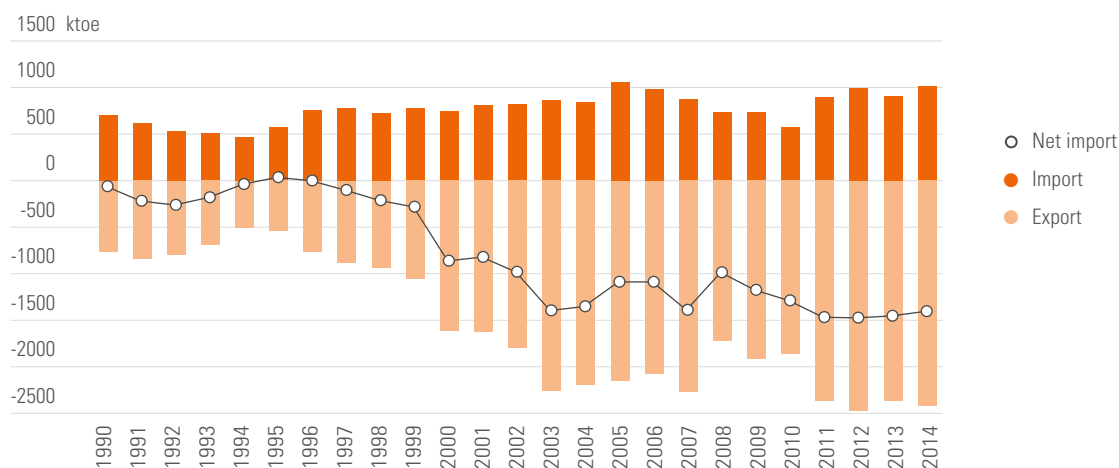
Key features of the Czech economy

The Czech economy underwent significant structural changes between the period 1990 to 2015. The energy intensity decreased significantly between 1995 and 2014, from 398.3 to 256.3 thousand tonnes of oil equivalent (ktoe) per EUR 1,000 of gross domestic product (GDP). It increased slightly in 2010 as a consequence of the economic crisis and decrease of GDP. The increase of GDP per capita and decrease of the unemployment rate were interrupted in 2009 also as a consequence of the economic crisis. After a short recovery in 2011, both GDP per capita and unemployment rate again slightly deteriorated, but the final recovery came in 2013. The proportion of mining and quarrying on Gross Value Added dropped from 3.7% in 1990 to 0.91% in 2015, mainly as a consequence of coal sector decline. (cf. Table A-1 in the Annex).

In the period 1990-2014 (except for 1995 and 1996), the Czech Republic was a net electricity exporter (see **Figure 2**). Since 2000 it has been one of the three largest net electricity exporters in the European Union (EU) next to France and Germany; it was only in 2012 that excessive exports from Sweden and Norway shifted the Czech Republic into fifth place.¹ Consumption of primary energy sources in the Czech Republic is fast by ½ covered by domestic sources; this energy import dependence of around 50% is among the lowest in the EU. Coal dominates the Czech energy mix and is also used for domestic heating (Ministry of Industry and Trade 2015).

¹ See <http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do> online.

Figure 2. Electricity cross-border trade in the Czech Republic, 1990 - 2014



Source: Eurostat (2016).

Fuel mix in the Czech Republic 1990 - 2014

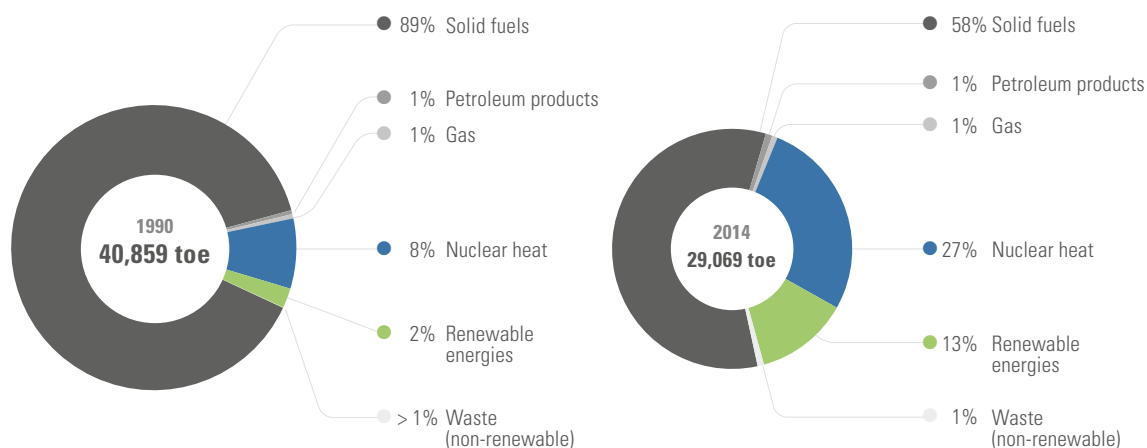
The Czech Republic in 1990 used mainly coal and lignite as the primary energy source (89%), nuclear (8%) was the second most important source (see **Figure 3**). By 2014 coal and lignite had fallen from their dominant position (down to 58%) in favour of all other sources.

Especially nuclear, which more than tripled (27%) and the share of renewables grew from 2% in 1990 to 13% in 2014. The overall primary energy production decreased from 41 ktoe in 1990 to 29 ktoe in 2014. In 2014 brown coal still makes up 39% of energy

production and hard coal 19%. Natural gas is mainly used as a complementary fuel in multi-fired units and for peaking purposes. **Figure 4** depicts the increased production of nuclear power in 2003 (solid line) as a new nuclear plant – Temelin – was completed. After

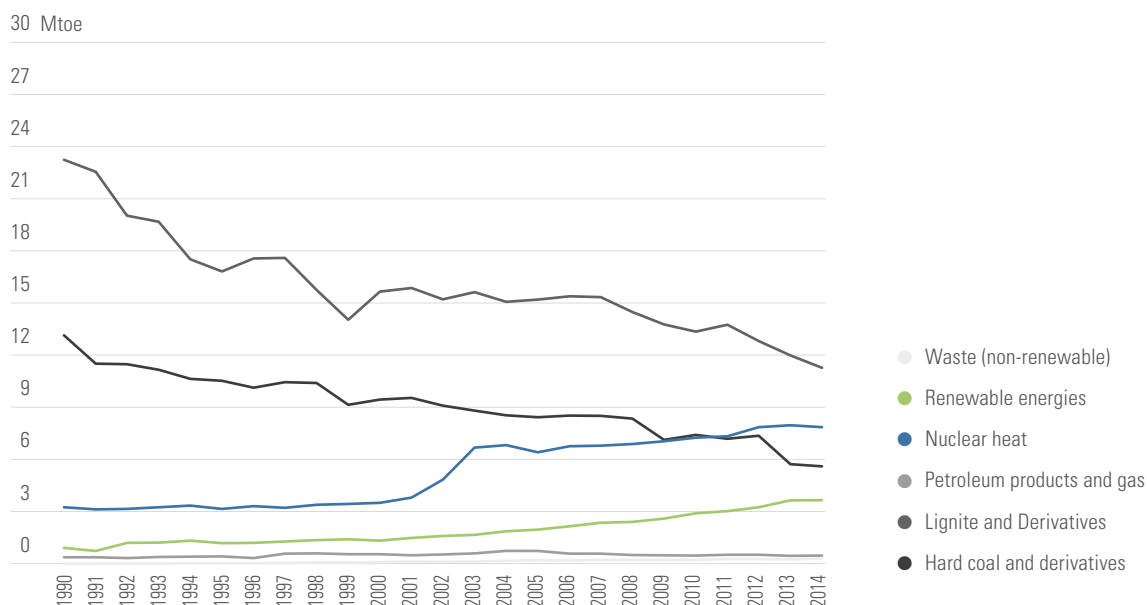
the Czech Republic joined the European Union (EU) in 2004, programmes supporting renewable energy sources started the increasing trend in renewables in the share of energy production.

Figure 3. Comparison of fuel mix production in the Czech Republic 1990 - 2014



Source: Eurostat (2016).

Figure 4. Energy production by source in Mtoe, 1990 –2014



Source: Eurostat (2016).

Key features of coal sector in the Czech Republic after 1990

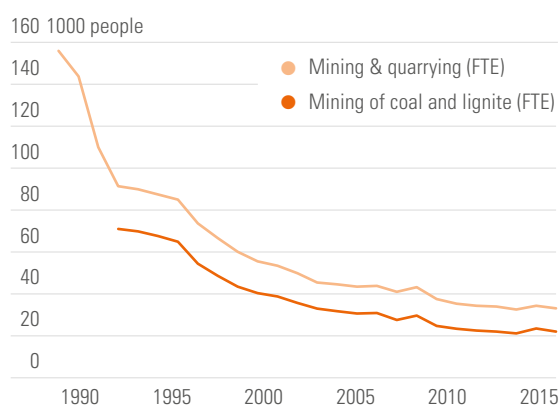
After the political and social change in 1989 in Czechoslovakia, extensive economic transformation began. A strong recession in heavy industry decreased and changed the demand for energy supply which led to production decline. This, together with pressure for environmental improvements, resulted in the coal sector downturn overseen by the government. Many mines were privatized and some closed.² Even in 1993, publically owned companies accounted for 65% of GVA in the whole mining and quarrying sector, while in 2014 it was only 20.5% (see Table A-2 in Annex). Coal output and value added has decreased since 1990 with few exceptions, such as growth in output due to price rises in 1995 or before the crisis in 2009, but production remains constant or decreasing. Compare the increases of output in **Figure 6** (green solid line) and constantly decreasing hard coal production trend in **Figure 7** (green solid line) and brown coal and lignite production trend in **Figure 8** (green solid line). Table A-3 shows the coking hard coal price increase from 86 to 137 Euro between the years 2007 and 2008 and summarizes the increasing brown coal prices trend since 2007.

Since the 1990s, the overall mining and quarrying level has decreased from a point where 156,384 employees

in the mining and quarrying sector produced 36,295 ktoe of coal and lignite (see **Figure 6**). We see a gradual decrease of hard and brown coal derivatives production (solid lines in **Figure 7** and **Figure 8**). The solid line in **Figure 5** shows the number of employees in mining and quarrying in terms of Full Time Equivalents (FTE). Between 1990 and 1993 employment dropped by 41% - i.e. more than 64,000 employees – and this decreasing trend continued until 2015. Table A-1 shows that in 1990 2.9% of all employees worked in the mining and quarrying sector (156,384 in terms of FTE) while in 1993 it was 1.8% (91,906 FTE) and in 2015 it was 0.7% (33,546 FTE). The dashed line in **Figure 5** depicts employment in the mining of coal and lignite, which has a very similar decreasing trend. In 1993, 71,468 (FTE) employees in coal and lignite mining formed 78% of employees in mining and quarrying, while in 2015, 22,509 (FTE) corresponded to 67% of all mining and quarrying employees.

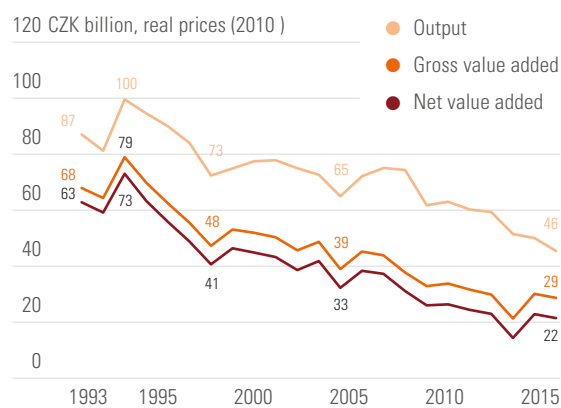
The number of coal reserves is decreasing: in 1990 there were 100 hard coal deposits, by 2014 there were 62; for brown coal the decrease has been from 80 to 52 deposits. The same is true for exploited deposits: 38 hard coal deposits in 1990, and 8 in 2014; 23 brown

Figure 5. Employment of mining and quarrying sector 1990 – 2015, full time equivalents



Source: Czech Statistical Office (2016).

Figure 6. Coal market in Czech Republic, Output, GVA, 1993– 2015



Source: Czech Statistical Office (2016).

² All data from Ministry of the Environment – Yearbook Mineral Commodity summary 2015.

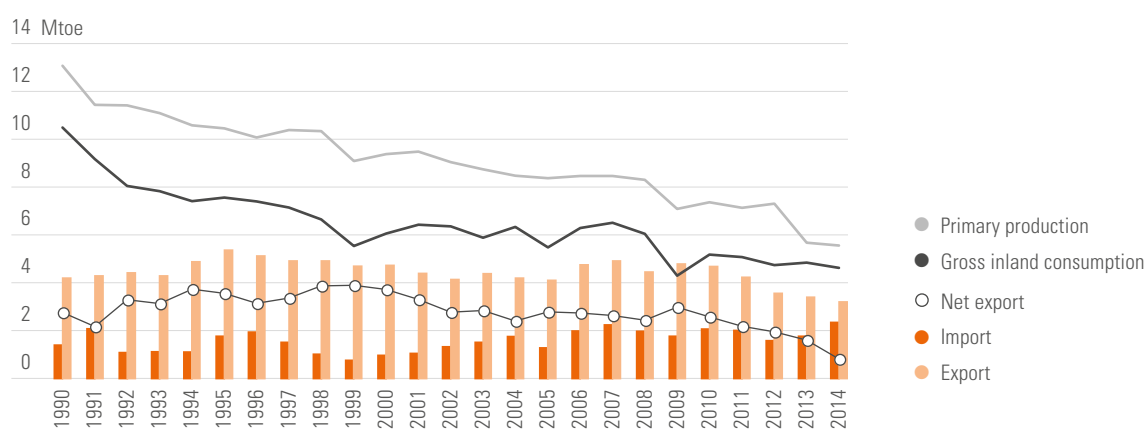
coal deposits in 1990, and 10 in 2014. Table A-4 (see Annex) summarizes actual reserves and production at particular mines.

Production of hard coal was 13,114 ktoe in 1990 and has decreased by more than 55% up to 2014 to 5,597 ktoe. Gross inland hard coal consumption has been a little lower than production since 1990 but the difference is shrinking - in 2014 the gap was 399 ktoe compared to 2,583 ktoe in 1990. The Czech Republic is historically a hard coal net exporter but this volume has significantly decreased since 1990, from 2,802 ktoe to 852 ktoe in 2014; the main part of the exported coal goes to Austria and Slovakia – historically it was Slovakia

and Russia. The main import historically comes from Poland. (Starý et al. 2008a; Starý et al. 2008b; Starý et al. 2009; Starý et al. 2010; Starý et al. 2012; Starý et al. 2015).

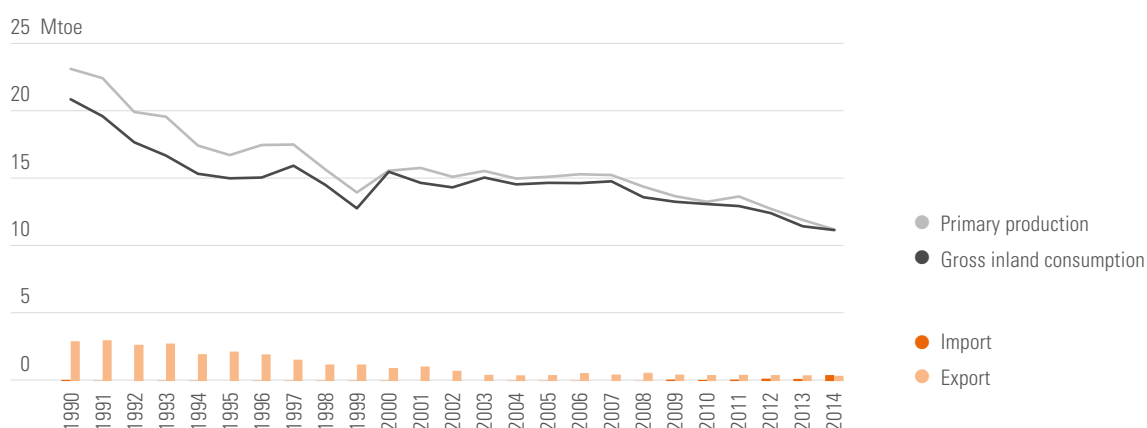
The production of brown coal and derivatives was 23,181 ktoe in 1990 and decreased by more than 50% up to 2014 to 11,249 ktoe. Gross inland consumption has again been a little lower than production since 1990 and the difference is shrinking sharply - in 2014 the gap was 37 ktoe compared to 2,257 ktoe in 1990. The Czech Republic has historically been a brown coal net exporter (in 1990 2,859 ktoe), by 2014 it had become a net importer (58 ktoe).³

Figure 7. Evolution of hard coal market in Czech Republic 1990 – 2014



Source: Eurostat (2016).

Figure 8. Evolution of brown coal market in Czech Republic 1990 – 2014



Source: Eurostat (2016).

³ All data from Eurostat database.

The use of coal in the Czech Republic and its possible replacement

In this section we sum up the use of coal in the Czech Republic during the years 1990 - 2014. We distinguish three categories of use: electricity generation, heat generation, and non-energy use. Brown coal represents 84% of steam coal consumption and hard coal 16% (ASEK 2015). The majority (91.8%) is used for electricity and heat generation and, apart from a small amount used by households, the rest of steam coal is consumed by the industry sector. The overall share of coal combusted in households reaches 20% of the total coal consumption (IEA 2016). The following data also contains production from combined heat and power generation, which is very effective in fuel transformation. This cogeneration now secures almost 50% of all heat generation, in big and medium sources up to 70% and produces around 13% of generated electricity (ASEK 2015).

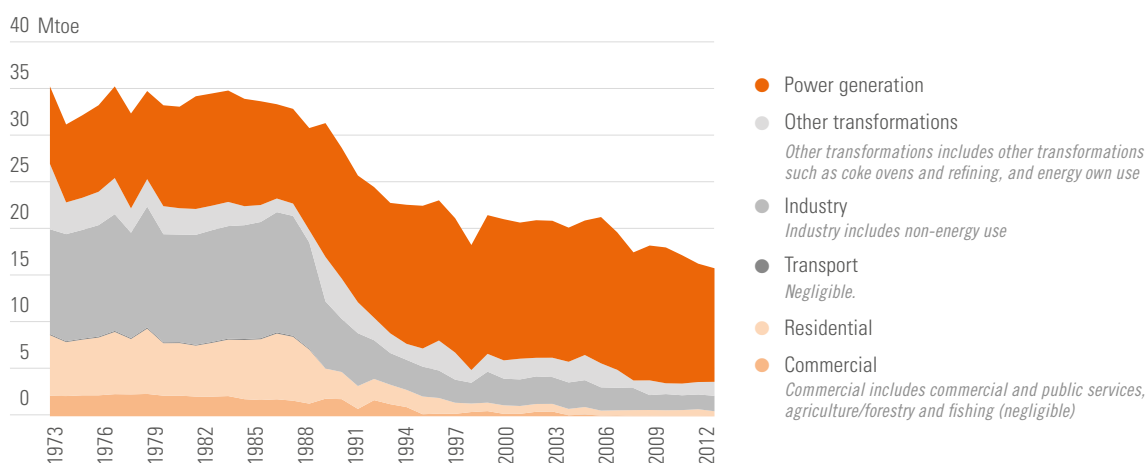
A. Coal as source of Electricity

Lignite and brown coal has been the main source of electricity in the Czech Republic since the beginning of 20th century. In 1990, 66% electricity was generated from brown coal and 9% from hard coal, while nuclear power generated 20% of a total of 5,379,000 toe electricity produced (see Table A-5 in Annex). Electricity production

followed an increasing trend with a steep rise at the beginning of 21st century, and a drop in 2005 and also in the run up to the economic crisis in 2008-9; we see a decreasing tendency from 2013. In 2014, 7,397,000 tonnes of oil equivalent 42% of electricity is generated from brown coal, 35% from nuclear and 6% from hard coal. The importance of other electricity sources also increased from 1990 to 2014: gas from 2% to 5% and renewables from 2% to 11%. The installed capacity of electricity increased during 1990-2014 from 15,279 MW to 23,077 MW due to the new nuclear power plant Temelin in 2003, and combined cycle, hydro and mixed plants in 1996, and wind and solar plants after 2002. **Table 1** summarizes the development of installed electrical capacities by fuels.

State energy policy, conceived in 2015, plans to transform the structure of electricity generation partially by moving away from coal in favour of nuclear power, natural gas and renewables up to 2040. According to its prediction, the share of brown coal in electricity production should fall as a result of energetic modernization up to the year 2025, and then as a result of decreasing brown coal mining. In 2040 the brown coal share should be 15.2% while nuclear should increase to 48.8% and renewables to 22.8% (see **Table 1**) (Ministry of Industry and Trade 2015).

Figure 9. Steam coal supply in the Czech Republic by consuming sector (1973 -- 2014)



Note: TPES by consuming sector. Source: Ralfo 2017; IEA (2016b), Energy Balances of OECD Countries 2016, www.iea.org/statistics/.

B. Coal as Heating source

The dependence on coal is much greater in the heating sector. Lignite and brown coal are responsible for 44% of heat production, followed by 25% from natural gas, and 17% from hard coal. The situation since 1990 (50% brown, 24% hard coal, 14% gas) has not changed much. Oil, which constituted 8% of heat production in 1990, has been practically withdrawn from use and in recent years the importance of other

gases and biofuels has increased; all together they generate 15% of heat (see **Table 2**).

The move away from coal for heating will not be easy. The 2015 National energy conception identified the main challenge as increasing efficiency, together with support for renewables and secondary sources. The transformation should be towards combined heat and power generation plants and to replace coal in households by gas.

Table 1. Prediction of gross electricity generation by fuel 2010 - 2040

	2010	2015	2020	2025	2030	2035	2040
Hard coal	7.0%	6.2%	4.7%	4.9%	3.4%	3.0%	2.2%
Brown coal	50.0%	43.2%	41.0%	34.8%	33.3%	25.5%	15.2%
Natural gas	1.3%	3.9%	4.3%	4.7%	4.8%	4.5%	8.0%
Other gas	1.3%	1.2%	1.3%	1.3%	1.3%	1.2%	1.3%
Nuclear	32.6%	33.7%	34.9%	36.2%	37.5%	44.9%	48.8%
Other fuels	0.9%	0.9%	1.0%	1.5%	1.7%	1.6%	1.6%
Renewables	6.9%	10.8%	12.8%	16.4%	18.0%	19.2%	22.8%
Total	85 910	93 443	90 156	83 826	84 013	91 631	88 542

Source: National energy conception 2015 - (Ministry of Industry and Trade 2015).

Table 2. Delivered heat by fuel 1990 - 2015

	Nuclear	Bitumial coal	Lignite/ Brown coal	Oil	Natural Gas	Coke oven gas	Blast Furnance gas	Biofuels	Other	Total gross production (ktoe)
1990	0%	24%	50%	8%	14%	2%	2%	0%	0%	3702
1991	0%	24%	49%	8%	15%	2%	2%	0%	0%	3826
1992	0%	24%	48%	8%	15%	2%	2%	0%	0%	3911
1993	0%	24%	47%	9%	15%	1%	2%	1%	0%	3996
1994	0%	27%	43%	9%	16%	2%	2%	1%	0%	3854
1995	0%	22%	46%	9%	18%	2%	1%	1%	0%	4202
1996	0%	21%	46%	8%	21%	2%	1%	1%	0%	4564
1997	0%	14%	55%	6%	20%	2%	1%	2%	0%	4308
1998	0%	17%	49%	6%	22%	2%	2%	3%	0%	3775
1999	0%	19%	45%	6%	22%	1%	1%	4%	1%	3518
2000	0%	19%	43%	5%	25%	2%	2%	4%	1%	3325
2001	0%	19%	44%	5%	25%	2%	2%	3%	1%	3565
2002	0%	18%	41%	5%	26%	2%	1%	4%	3%	3402
2003	0%	19%	40%	5%	26%	2%	1%	5%	2%	3518
2004	1%	19%	39%	4%	27%	2%	1%	5%	2%	3449
2005	1%	18%	42%	4%	27%	2%	1%	3%	2%	3326
2006	1%	21%	42%	3%	25%	2%	1%	2%	2%	3136
2007	1%	21%	42%	2%	25%	2%	1%	3%	2%	3078
2008	1%	21%	46%	2%	22%	2%	1%	3%	2%	3097
2009	1%	24%	41%	2%	24%	2%	1%	3%	2%	2904
2010	1%	23%	41%	1%	24%	2%	3%	3%	2%	3113
2011	1%	19%	43%	1%	24%	3%	3%	4%	3%	2945
2012	1%	18%	43%	1%	25%	3%	3%	4%	3%	3061
2013	1%	17%	43%	0%	25%	3%	3%	6%	3%	2995
2014	1%	17%	44%	0%	25%	2%	3%	7%	3%	2919

Source: Eurostat (2016).

C. Non - energy coal use

The use of coal in the Czech Republic for non-energy purposes, such as coke in metallurgy or in human or veterinary medicine, oscillates around 300 000 tones of oil equivalent, although there was a large drop in 2005

and 2009 during the economic crisis (see **Table 3**). Brown coal is also used in paper and the production of printing products. For these purposes, coal is irreplaceable.

Table 3. Non-energy use of solid fuels in the Czech Republic 1990 - 2015

Solid fuels Final non-energy consumption (ktoe)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	314	338	389	299	376	339	343	242	303	279	288	321	365

Source: Eurostat (2016) (Consumption from 1990 to 2001 was 0).

The state role in the coal sector after 1990 – mining limits

Until 1993, mines were organized into big coalfields and the profits and losses were redistributed within the coalfield. After this date, the redistribution process was cancelled and non-profitable mines were closed. The state provided support for social and health benefits, the technical liquidation of the mines, and for landscape recovery – which is discussed in the next section in detail. The government divided state-owned coal mining companies into units of profitable and unprofitable mines on one deposit to make them capable of paying part of the costs of the mining phase out.⁴ The current mine situation, including operating organization, is summarized in **Table 4** and **Table 5**.

In 1991 the government imposed so-called ecological territorial limits in six mining locations in the North Bohemian Brown Coal Basin. The affected area covers 591 km² with 34 villages (including 8 cities) around the cities of Bilina, Most and Litvinov. The area includes so-called economically troubled regions, as defined in the regional development strategy of the Czech Republic for 2014 – 2020. This means above-average unemployment, low living standards, low degree of economic performance, low average income, and adverse demographic trends (Ministry of Regional Development 2013). The mineral commodity summary 2015 points reserves of about 0.9 billion tonnes be-

yond the limits represent about 18-year mining. There is currently a hot debate around the possible easing of the limitations imposed on two mines – Czechoslovak Army (henceforth “CSA”) and Bilina – which would bring about 400 million tonnes of brown coal (see **Figure 10**). As noted by (Maca & Melichar 2016) without revoking the limits, only one mine (Vrsany) would remain in operation by 2038 and its reserves would diminish by around 2060. The Czech Republic currently imports brown coal to meet its demand, a situation that will not improve in future unless the limits are revoked (see **Figure 11**).

The government has already extended the limits in 2008 and in 2015 (100 – 120 mil. t of brown coal in the period 2020 - 2055) in the Bilina mine to secure the heating industry in the Czech Republic and to preserve jobs for miners. The excavation works are likely to expand to a distance of less than 500 m from the nearest village. The limits in the CSA mine were not broken because doing so would destroy entire villages: Horní Jiretin and Cernice. In the current circumstances, mining in the CSA mine should end in 2024. The Minister of Industry and Trade – Mr. Mladek – added that the potential need for coal from the CSA mine depends on the development of nuclear energy, renewable sources and the fulfillment of the National energy conception (Odbor 10500 2015).

⁴ Source: http://slon.diamo.cz/hpyt/2003/sekce_V/L06.htm.

Table 4. Brown coal and lignite mining territories with status to November 15, 2016

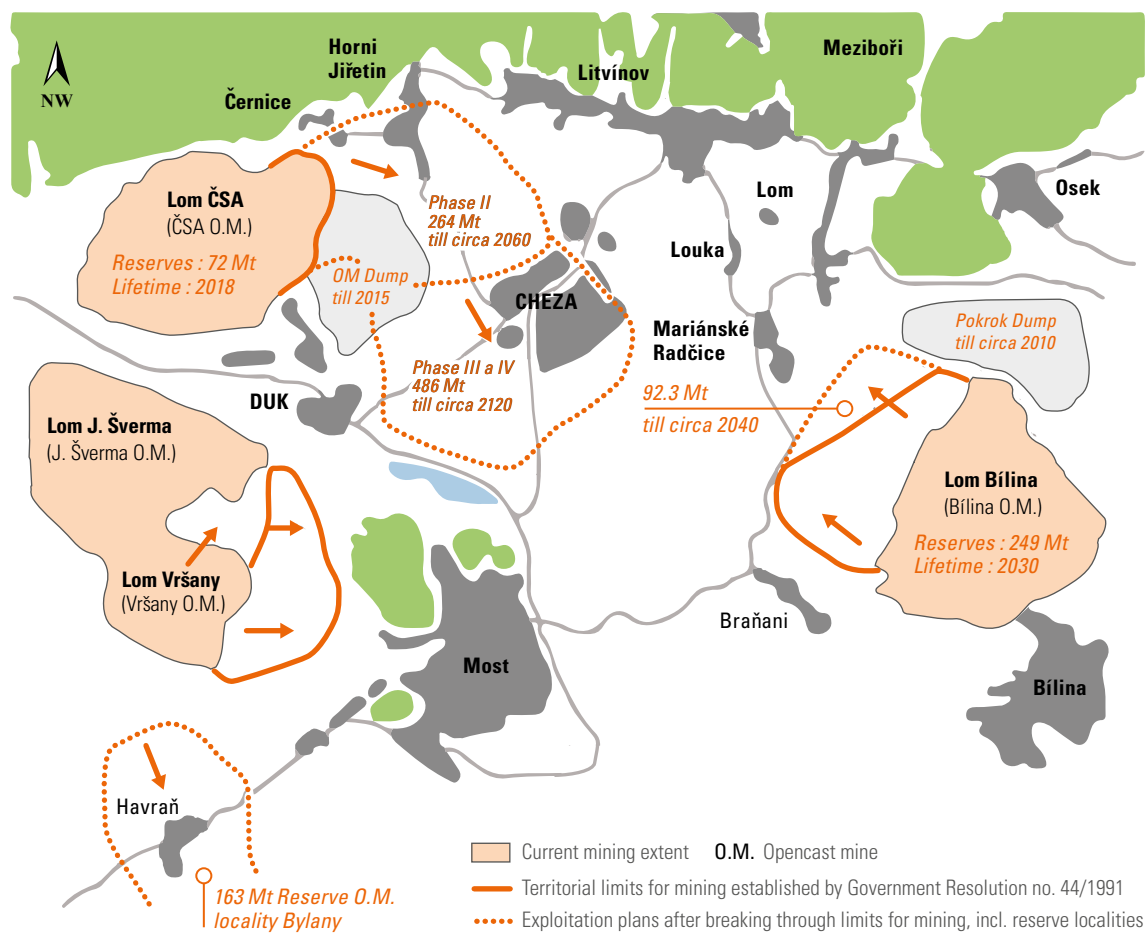
Name	Organization	Open date	District
Exploration			
Lom II	Palivový kombinát Ústí, státní podnik	24.2.1970	Most
Mined deposits			
Alberov	Sokolovská uhelná, právní nástupce, a.s.	27.7.1962	Sokolov
Bílina	Severočeské doly a.s.	10.11.1976	Teplice
Dolní Jiřetín	Severní energetická a.s.	24.12.1969	Most
Duchcov I	Humatex, a.s.	11.5.2002	Teplice
Ervěnice	Severní energetická a.s.	29.11.1985	Most
Holešice	Vršanská uhelná a.s.	18.12.1985	Most
Královské Poříčí	Sokolovská uhelná, právní nástupce, a.s.	27.7.1962	Sokolov
Nové Sedlo	Sokolovská uhelná, právní nástupce, a.s.	14.11.1962	Sokolov
Tušimice	Severočeské doly a.s.	25.10.1977	Chomutov
Vršany	Vršanská uhelná a.s.	13.2.1976	Most
Zabrušany	Humatex, a.s.	11.5.2002	Teplice
Closing deposits			
Hodonín	UVR Mníšek pod Brdy a.s.	12.6.1981	Hodonín
Most	Palivový kombinát Ústí, státní podnik	21.3.1986	Most
Stopped mining, security regime			
Slatinice	Vršanská uhelná a.s.	17.12.1979	Most
Reserve deposit			
Komořany u Mostu	Severní energetická a.s.	29.6.1970	Most
Closed deposits, 0 reserves			
Bukovany	Sokolovská uhelná, právní nástupce, a.s.	22.1.1962	Sokolov
Duchcov	Severočeské doly a.s.	25.5.1992	Teplice
Habartov	Sokolovská uhelná, právní nástupce, a.s.	9.11.1989	Sokolov
Hrdlovka	Severočeské doly a.s.	1.6.1964	Teplice
Svatava	Sokolovská uhelná, právní nástupce, a.s.	14.10.1964	Sokolov
Liquidation terminated, but unresolved conflicts			
Dolní Litvínov	Severní energetická a.s.	21.2.1970	Most
Kopisty I	Severní energetická a.s.	27.3.1986	Most
Kopisty II	Severní energetická a.s.	5.4.1986	Most
Lomnice	Sokolovská uhelná, právní nástupce, a.s.	16.5.1966	Sokolov
Okořín	Vršanská uhelná a.s.	3.12.1969	Chomutov
Souš II	Severní energetická a.s.	22.12.1969	Most
Souš III	Severní energetická a.s.	25.8.1970	Most
Záluží u Litvínova	Severní energetická a.s.	21.2.1970	Most

Source: The State Mining Administration n.d.

Before this decision the ministry of industry and trade prepared studies of social and economic impacts for individual variants. For the approved variant it predicts that the biggest loss of primary mining jobs (720) will take place up to 2019, and then decrease by a further 107 jobs up to 2049. At the same time, many of the 3,275 retired positions will have to be replaced by new employees. Together 4,129 employees will be dismissed

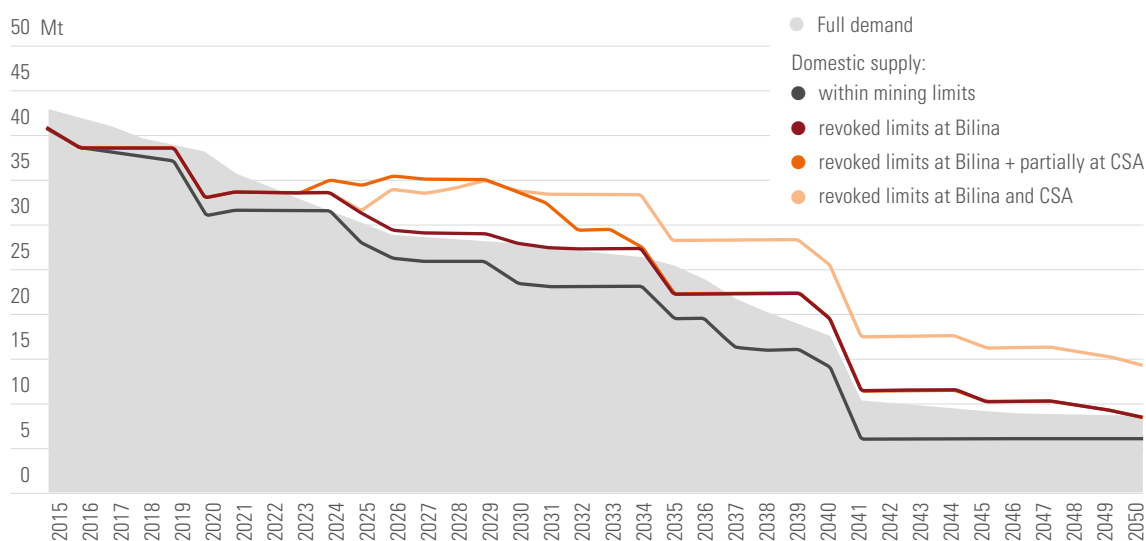
or retired between the years 2015 and 2049. A similar scenario affects the follow-up jobs. The study predicts an overall drop in employees of between 1,108 and 2,217 until 2019, and then between 1,989 and 6,629 to the year 2049, based on the multiplier (0.75 or 1.5) used. According to the estimate of labour market flexibility over the whole period (35 years) potentially only 603 persons will become long term unemployed (PWC 2015).

Figure 10. Ecological territorial limits in the North Bohemian Basin



Source: Mineral Commodity summary of the Czech Republic 2015, © VÚHU Most 2003 (modified).

Figure 11. Domestic brown coal supply and demand for heat and electricity production under the revised mining limits



Source: Maca and Melichar 2016.

Table 5. Hard coal mining territories with status to November 15, 2016

Name	Organization	Open date	District
Exploration			
Staříč	OKD, a.s.	18.12.1962	Frýdek-Místek
Trojanovice	OKD, a.s.	30.6.1989	Nový Jičín
Mined deposits			
Darkov	OKD, a.s.	11.3.1977	Karviná
Dolní Suchá	OKD, a.s.	6.4.1961	Karviná
Doubrava u Orlové	OKD, a.s.	4.10.1961	Karviná
Karviná - Doly I	OKD, a.s.	1.10.1979	Karviná
Karviná Doly II	OKD, a.s.	12.2.1964	Karviná
Lazy	OKD, a.s.	28.4.1961	Karviná
Louky	OKD, a.s.	15.10.1984	Karviná
Petřvald I	OKD, a.s.	10.4.1987	Karviná
Rynholec	České lupkové závody, a.s.	16.3.1965	Rakovník
Stonava	OKD, a.s.	12.12.1960	Karviná
Closing deposits			
Žacléř	GEMEC - UNION a.s.	12.7.1976	Trutnov
Closed deposits, 0 reserves			
Poruba	DIAMO, státní podnik odštěpný závod ODRA	29.6.1963	Karviná
Vitkovice	DIAMO, státní podnik odštěpný závod ODRA	17.2.1983	Ostrava

Source: The State Mining Administration n.d.

Measures to ease transition

Table 6 summarizes the measures the Czech government have implemented to ease the transition away from coal production and consumption. It is a collection of individual measures that do not create an official state strategy. As the transition from coal to other energy sources has been a gradual process since 1990, we have to distinguish two types of state support. First, there is support that deals with debts from the past regime, that embraces environmental remediation, and the costs of closing mines as well as the provision of benefits for miners that became unemployed in the 1990s. The second type of support is financial compensation to support more effective coal technologies and renewable energy sources and to help regions affected by mining decline. These regions are often economically troubled and in socially excluded localities and as such they are more supported by regional programmes in many areas (infrastructure, environment, entrepreneurship, unemployment, research & development, etc.) (Ministry of Regional Development 2013).

Table 7 quantifies the support directly connected with the phasing out of mining activities and the restoration of land damaged by mining. Table A-7 then quantifies the total support provided to the fossil fuel sector and Table A-8 the support for renewable energy sources.

During the period of the greatest number of redundancies, some miners were reallocated to mines that were still working, instead of retired miners or to other companies in the same sector, while the older generation of miners took early retirement and the others were retrained.

Last year the biggest hard coal company OKD employing about 9,500 people declared insolvency due to high indebtedness and decreasing world prices of hard coal. The Czech government reacted by providing an exceptional state loan of CZK 700 million (from state company PRISCO) to continue mining and facilitate a gradual phasing out (10510 2016). Furthermore, the state carried out many development activities in the region including the establishment of a new industrial

Table 6. Transition strategies — Typology (the Czech Republic)

	Compensation or grandfathering (backward-looking)	Structural adjustment assistance (forward-looking, narrow)	Adaptive support (forward-looking, broad)
Consumers/ households	Energy tax repayments if mineral oil used for heating Exemption of real estate tax for 5 years when switching to RES.	Reduced VAT on energy-efficient heating, Green Saving program (e.g. the replacement of coal boilers with gas boilers or thermal insulation).	Advice on energy efficiency for example via program Green for savings.
Workers	Social allowances of CZK 5 280 for miners in the first 3 – 30 months following redundancy depending on the length of employment; early retirement; Health and social benefits for miners released before 1993 (including compensations for lost earnings).	Retraining programmes for ex-miners; help with finding new job; regional transport allowances of CZK 1000 – 3 500	--
Communities	Compensation of Municipalities Affected by Mining Funded from Royalties on Mining Leases	Support of manufacturing companies; new industrial zones	Support under the regional strategies for economically troubled regions.
Corporations	Financial resources for elimination of environmental damages, reclamation of areas affected by mining and social costs of phasing out mining such as health benefits for miners.	No barriers in the market economy for business adaptation (e.g. new technology and sources like gas can replace coal)	Guaranteed Feed-in-Tariffs and Premiums for electricity of RES; Biofuel obligation

Source: Table content by the author(s). Table concept by Fergus Green.

Table 7. Transfer of risk to governance, Czech Republic, in million CZK (only those quantified)

	2006	2007	2008	2009	2010	2011
Financing of the technical work related to closing mines and rectifying the consequences of past mining activity	1,840	1,746	1,719	1,563	1,564	1,564
Elimination of past environmental damages by coal mines			2,687			
Compensation of municipalities affected by mining	16	16	15	15	15	15
Programmes Financing Remediation of Ecological Damage attributable to coal mining, petroleum, and gas extraction	x	x	x	x	x	1,800
Remediation of Environmental Damages Caused by Mining	153	165	169	161	161	161

Note: x - support spent only in the year 2011 is reported; see text above for the cumulative amount.

zone Nad Barborou and provided support for the manufacturing company Hyundai Mobis, along with social benefits for released miners (Odbor 10500 2016). The situation of the release of OKD miners eased also a new processing line of extractive waste launched in the summer of 2016 (10500 2016b). Initially, OKD has planned to close the Paskov mine, with approximately 1,800 employees, in May 2017. Some of the employees have already left and found new positions in many other sectors (transport, IT, engineering, etc.). It was not only the Ministry of Labour and Social Affairs that helped to find new positions for the miners, private

companies (such as LMC) were also supportive, including through the provision of training courses. The Ministry, in cooperation with OKD, the Employment Department and The Confederation of Industry and Traffic, created supportive web pages, called A New Shift, and also offered business advice at consultation centers in the mines (Nová šichta, 2014).

Phasing-out of mining activities

The Czech government committed to the state financing of the technical work related to closing mines and

rectifying the consequences of past mining activity, and covering the social costs of the phasing out of mining activity, such as covering health benefits for miners. Overall, since the initiation of the mining phase out in 1992, a total of CZK 72 billion (≈€3 billion) was released from the state budget up to 2009. CZK 43 billion (€1.7 billion) was spent on technical work related to the phase out of mining and on restoring the consequences of mining operations, and a remaining CZK 29 billion (€1.2 billion) was spent on social health benefits for miners (MoE 2010). About 43% of support was allocated to coal mining; CZK 16.6 billion to technical work and CZK 14.5 billion to social health expenses. As reported by The Ministry of the Environment, the total amount of money reserved is up to €1,500 million. Every year during 2005-2011, between 1,563 and 1.890 million CZK was spent (that is €59 to €69 million). During the period 1992-2009, total support for uranium amounted to CZK 13 billion, which was spent on technical work, while CZK 4.6 billion was spent on social health.

Rehabilitation of environmentally damaged land

In 2006, the Ministry of Finance of the Czech Republic decided to use revenues from privatisation for financing the rehabilitation of land that had been environmentally damaged due to mining activity that had taken place before privatisation of the Czech mines. By the end of 2009, three coal mining entities had received financial resources from the National Property Fund of the Czech Republic in order to address environmental damage. By December 2009, about 2,687 million CZK (€102 million) were allocated from the National Property Fund of the Czech Republic to coal mines in order to deal with past environmental damages, with an additional CZK 25.5 billion (€1.0 billion) available for next drawing. An additional CZK 8.0 billion (€3.2 billion) was guaranteed to DIAMO, a uranium mining company, which had claimed CZK 3.1 billion by December 2009.

Programmes financing the remediation of ecological damage

Only since 1994 have mining companies in the Czech Republic been obliged to generate financial reserves for the remediation and reclamation of areas affected

by mining. Therefore, the state has taken on responsibility for the financial remediation of ecological damage that arose prior to 1994, which has particularly involved: support for coal mining companies in the Ústí nad Labem, Karlovy Vary and Kladno Region; ecological revitalisation following termination of coal mining in the Moravian-Silesian Region; and restoration work in areas affected by crude oil and natural gas extraction in the South Moravian Region. The total spent on the ecological remediation of land affected by coal mining was estimated to be around 36 billion CZK (€1,361 million), while around 712 million CZK (€27 million) and 465 million CZK (€18 million) has been spent on land affected by petroleum and gas extraction, respectively. About 1,800 million CZK (€73 million) was allocated in the year 2011. As of December 2009, the funds spent amounted to CZK 4.4 billion (€0.18 billion), while CZK 5.7 billion (€0.23 billion) were allocated to progress projects, and CZK 4.1 billion (€0.16 billion) is the remaining financial amount required to secure additional money for the projects in progress.

Remediation of environmental damage caused by mining

Environmental damage caused by mining is mitigated in the Czech Republic through clean-up measures that are funded by revenues from royalties on coal extraction. Mining companies are obliged to pay royalties on the minerals they extract; however, these levies are capped to a maximum of 10% of the market price of the extracted minerals. Before 1999, the Regional Mining Authority transferred the collected revenue equally between the state budget and the budget of those municipalities on which the mining leases were located. Half of the revenues transferred to the state budget (i.e. 25% of the total collected royalties on extracted minerals) are earmarked for the remediation of environmental damage caused by the mining of reserved deposits. Since 2000, the proportion of revenues transferred to the state budget has been reduced at 25 %, and all of which must be spent on the remediation of environmental damage caused by mining activity. Remediation of environmental damage caused by mining amounted annually to between 153 and 170 million CZK (about € 5-7 million) during 2005-2011.

Future outlook

It is possible that the new supercritical power plant Ledvice and two refurbished power plants Tusimice II (4 x 200 MW) and Prunerov II (3 x 250 MW) were the last major coal units built between 2009-2016 in the Czech Republic (Ralfo 2017). State energy policy plans to further lower the share of coal in energy and heat production for environmental reasons, but it still sees coal as strategic from security and economic perspectives. The use of coal should be however as efficient and ecological as possible (Ministry of Industry and Trade 2015). The substitute for coal should be nuclear energy. The State energy conception 2015 plans for the construction of additional nuclear capacity, aiming for a production of around 20 TWh till 2035 and lifespan extension of the second nuclear power plant

Dučovany (up to 60 years). The main advantages of nuclear power are low fuel prices and the possibility of its use as a strategic reserve.

As mentioned in Section 5, the replacement of coal in heating is a more difficult task than for electricity generation. Furthermore, when moving away from coal one has to take into account the economical aspect: coal is a very cheap energy source. The State energy conception 2015 plans for the use of brown coal in heating and for highly effective combined generation. It sees potential in the energetic use of waste and therefore penalties for landfill waste.

Lessons learned

Finding the solution of past environmental damages caused by mining last a long time period with unclear opinion of the government on state participation. Some government resolutions have not been respected (supporting the switching process from coal as an energy source) (Sochor n.d.). This has led to the necessary abandonment of brown coal mining limitations at Biličina mine to secure sources for heating and to avoid the rapid dismissal of employees. There is also a question regarding whether the abandonment of mining limits was necessary or appropriate when taking into account the emissions targets that the Czech Republic has committed to fulfill up to 2040.

The privatization of mines was not ideal and as a consequence some new mining companies were plundered and many closed mines deals till today with unresolved property conflicts. A glaring example of this is the hard coal company OKD, which declared insolvency in 2016 – the Czech Republic call for CZK 1.9 billion claim that should cover the mine liquidation costs in case OKD will not be able to finance the liquidation process (10500 2016a). On the other hand, the liquidation procedure via state company DIAMO

seems to have been quite successful... that overtook the responsibilities arose before 1993.

Although coal represents a strategic resource and an important energy source from the perspective of employment, it is an issue of regional character since employees in the mining sector represent only 1% of all employees. Their total number between 1993 and 2015 decreased by approximately 86,800 people. More than double this number left agriculture during the same time period, while almost all others sectors experienced a rise in employee numbers, especially in the wholesale and retail market and in scientific and technical activities (Czech statistical office 2016b). From this perspective the transformation of the economy seems to have been successful; while in terms of the transition from coal, one has to focus on the region.

Regional support started after the creation of the administrative regions in 2001, followed by even more effective support after joining the European Union in 2004. This delay in support had an impact on the social isolation of regions, which became economically troubled areas (above-average unemployment, low living standards, low degree of economic performance,

low average income, and adverse demographic trends) as defined by the Ministry of Regional Development 2013. The unemployment rate in the population of Karvina in the west of the Czech Republic, one of the most impacted districts, once reached 11.5%, which is almost double that of the average rate in the Republic, but has decreased in the last decade by 1.6 percentage points (The Ministry of Labour and Social Affairs 2016). Furthermore, since 1971 Karvina has experienced negative migration rates (except during the early 1990s) reaching a low in 2010 of migration

drop of inhabitants by 2 501. Since 2009 the district left around 1700 net migrants (Czech statistical office 2016a).

The Czech experience teaches us that the transformation process takes a long time, and is far from completion in the Czech Republic. Very thorough preparation is vital, along with the provision of considerable amounts of support in many forms to the affected regions.

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Annex

Table A-1. Key economic indicators of the Czech Republic 1990 – 2015

	Energy intensity (gross inland consumption, kg oil equivalent, per €1 000 of GDP) ²	Energy dependency (net imports / gross inland energy consumption) ²	GDP per capita, real (2010 €) ²	Mining & quarrying (% GVA) ¹	Unemployment (% labour force) ²	Mining & quarrying (% all FTE employees) ¹
1990		15.4		3.71%		2.93%
1991		15.9		3.32%		2.77%
1992		16.0		3.25%		2.21%
1993		16.1		2.73%	4.3%	1.84%
1994		18.7		2.23%	4.3%	1.79%
1995	398.3	20.6	10 100	2.29%	4.0%	1.72%
1996	393.1	24.2	10 600	2.08%	3.9%	1.67%
1997	398.1	24.1	10 500	1.87%	4.8%	1.46%
1998	386.6	25.1	10 500	1.61%	6.5%	1.34%
1999	355.6	25.1	10 700	1.36%	8.7%	1.23%
2000	359.3	22.9	11 100	1.25%	8.8%	1.15%
2001	357.3	25.1	11 500	1.26%	8.1%	1.11%
2002	354.8	26.4	11 700	1.20%	7.3%	1.02%
2003	358.6	25.1	12 200	1.07%	7.8%	0.95%
2004	350.3	25.5	12 800	1.21%	8.3%	0.93%
2005	325.4	28.0	13 500	1.25%	7.9%	0.89%
2006	312.5	27.8	14 400	1.31%	7.1%	0.89%
2007	296.2	25.1	15 200	1.29%	5.3%	0.82%
2008	281.9	28.0	15 400	1.40%	4.4%	0.85%
2009	277.8	27.2	14 600	1.23%	6.7%	0.75%
2010	285.7	25.6	14 900	1.26%	7.3%	0.71%
2011	269.8	28.0	15 200	1.32%	6.7%	0.69%
2012	270.5	25.3	15 100	1.18%	7.0%	0.69%
2013	267.9	27.9	15 000	0.87%	7.0%	0.66%
2014	256.3	30.4	15 400	1.01%	6.1%	0.69%
2015			16 000	0.91%	5.1%	0.66%

Source: 1 Czech Statistical Office (2016), 2 Eurostat (2016).

Table A-2. Key economic indicators of Czech Mining 1993 - 2015

Coal and lignite	Output CZK million (real (2010))	Gross value added CZK million (real (2010))	Net value added CZK million (real (2010))	Mining & Quiring (Gross Value added rate by Ownership)		
				Public	National private	Foreign controlled
1993	87411	68310	63187	65.2%	34.6%	0.2%
1994	81633	64736	59530	67.4%	32.1%	0.5%
1995	99908	79290	73381	66.0%	33.1%	0.9%
1996	94874	70141	63657	57.3%	42.0%	0.7%
1997	90364	62837	56251	20.6%	78.6%	0.8%
1998	84338	55824	49128	19.5%	79.4%	1.1%
1999	72715	47600	40983	30.1%	67.9%	2.0%
2000	75256	53416	46725	36.9%	60.2%	2.9%
2001	77878	52275	45232	33.9%	48.3%	17.8%
2002	78201	50699	43612	30.3%	51.0%	18.7%
2003	75295	45993	38977	31.8%	50.1%	18.1%
2004	72980	49066	42219	25.6%	58.5%	15.9%
2005	65308	39317	32594	15.4%	78.4%	6.2%
2006	72460	45560	38707	14.2%	65.0%	20.8%
2007	75459	44204	37610	13.8%	20.5%	65.7%
2008	74708	38102	31446	14.0%	20.8%	65.2%
2009	62129	33279	26402	18.5%	55.9%	25.6%
2010	63393	34126	26728	15.7%	61.6%	22.7%
2011	60579	31979	24788	16.1%	24.3%	59.6%
2012	59668	30222	23367	17.9%	63.0%	19.1%
2013	51810	21662	14720	25.3%	40.3%	34.4%
2014	50446	30523	23275	20.5%	31.2%	48.3%
2015	45784	29020	21802			

Source: Czech Statistical Office (2016).

Table A-3. Prices of Hard and Brown coal at domestic market 2007– 2014

Coal type*	2007	2008	2009	2010	2011	2012	2013	2014
Hard Coal								
Coking coal EUR/t	86	137	87	138	177	125	98	85
Steam coal EUR/t	48	69	72	60	67	74	56	54
Brown coal - Severočeské doly								
Cube Coal II; 17.6 MJ/kg; CZK/t	1707-2045	1707-2045	1847-2143	1868-2143	1900-2150	1930-2170	2135-2150	2165-2170
Nut Coal I; 17.6 MJ/kg; CZK/t	1619-1942	1619-1942	1748-1942	1742-1937	1730-1950	1730-1950	1800-1850	1910-1920
Nut Coal II; 17.6 MJ/kg; CZK/t	1325-1586	1325-1697	1461-1782	1461-1782	1470-1790	1490-1810	1700-1800	1870-1900
Exchange rate CZK/EUR	27.8	24.9	26.4	25.3	24.6	25.1	26	27.5

Source: Yearbook Mineral Commodity summary 2012 and 2015; * Prices given without taxes on solid fuels; Regular grain size (mm): cube = 40 - 100, nut I = 20 - 40, nut II = 10 - 20.

Table A-4. Coal reserves in the Czech Republic

Mine	Extractable reserves (Mt)	Production (Mt)	Mining	Number of mines	Calorific value (MJ/t)
Hard coal					
OKD, a.s.	56.5	8.3	Underground	Four	19-36
Brown coal					
Severočeské Doly (SD)	346.4	21.7	Opencast	Two	11-13
Severní Energetická (SEAS)	27.7	3.8	Opencast	One	10-18
Vršanská Uhelná (VUAS)	265.9	6.5	Opencast	One	10-18
Sokolovská Uhelná (SUAS)	131.3	6.4	Opencast	Two	12-13
Důl Kohinoor a.s.	0.5	0.5	Underground	One	15

Note: MJ/t = megajoules per tonne. Source: MIT, IDR country submission.

Table A-5. Electricity generation by fuel 1990 - 2015

	Hydro	Wind	Solar	Other renewables	Bituminous coal	Lignite/ Brown coal	Nuclear	Gas	Oil	Total gross production (ktoe)
1990	2%	0%	0%	0%	9%	66%	20%	2%	1%	5379
1991	2%	0%	0%	0%	9%	66%	20%	2%	1%	5205
1992	3%	0%	0%	0%	9%	65%	21%	2%	1%	5098
1993	3%	0%	0%	0%	9%	64%	21%	1%	1%	5063
1994	3%	0%	0%	1%	9%	63%	22%	2%	1%	5048
1995	4%	0%	0%	1%	11%	61%	20%	2%	1%	5232
1996	4%	0%	0%	0%	11%	59%	20%	4%	1%	5525
1997	3%	0%	0%	1%	7%	64%	19%	5%	1%	5554
1998	3%	0%	0%	1%	7%	63%	20%	5%	1%	5599
1999	3%	0%	0%	1%	7%	62%	21%	6%	1%	5563
2000	3%	0%	0%	1%	8%	64%	18%	5%	1%	6317
2001	3%	0%	0%	1%	8%	63%	20%	5%	1%	6419
2002	4%	0%	0%	1%	7%	58%	25%	5%	1%	6565
2003	2%	0%	0%	1%	7%	54%	31%	5%	0%	7156
2004	3%	0%	0%	1%	7%	53%	31%	5%	0%	7251
2005	4%	0%	0%	1%	7%	53%	30%	5%	0%	7100
2006	4%	0%	0%	1%	7%	52%	31%	5%	0%	7254
2007	3%	0%	0%	1%	8%	53%	30%	5%	0%	7584
2008	3%	0%	0%	2%	7%	51%	32%	5%	0%	7181
2009	4%	0%	0%	2%	7%	49%	33%	5%	0%	7072
2010	4%	0%	1%	3%	7%	48%	33%	5%	0%	7387
2011	3%	0%	2%	3%	7%	47%	32%	5%	0%	7529
2012	3%	0%	2%	4%	6%	45%	35%	4%	0%	7530
2013	4%	1%	2%	5%	6%	42%	35%	5%	0%	7486
2014	3%	1%	2%	5%	6%	42%	35%	5%	0%	7397

Source: Eurostat (2016).

Table A-6. Maximum electrical capacity 1990 - 2015

	Hydro	Wind	Solar	Steam gas, coal, oil ...)	Nuclear	Mixed plants	Combined Cycle	Biogases	Municipal waste	Electrical capacity (MW)
1990	9%	0%	0%	79%	12%	0%	0%	0%	0%	15 279
1991	9%	0%	0%	79%	12%	0%	0%	0%	0%	14 965
1992	10%	0%	0%	78%	12%	0%	0%	0%	0%	14 456
1993	13%	0%	0%	75%	12%	0%	0%	0%	0%	14 718
1994	13%	0%	0%	74%	12%	0%	0%	0%	0%	14 343
1995	13%	0%	0%	74%	12%	0%	0%	0%	0%	14 294
1996	17%	0%	0%	69%	11%	3%	0%	0%	0%	16 119
1997	17%	0%	0%	69%	11%	3%	0%	0%	0%	16 248
1998	17%	0%	0%	69%	11%	3%	0%	0%	0%	16 038
1999	17%	0%	0%	69%	11%	3%	0%	0%	0%	16 362
2000	17%	0%	0%	68%	11%	3%	1%	0%	0%	16 471
2001	17%	0%	0%	66%	11%	3%	4%	0%	0%	16 591
2002	16%	0%	0%	61%	16%	3%	4%	0%	0%	17 458
2003	15%	0%	0%	58%	20%	2%	4%	0%	0%	18 585
2004	15%	0%	0%	57%	20%	2%	4%	0%	1%	18 712
2005	15%	0%	0%	57%	20%	2%	4%	0%	1%	18 695
2006	15%	0%	0%	57%	20%	2%	4%	0%	1%	18 823
2007	15%	1%	0%	57%	20%	2%	4%	0%	1%	18 934
2008	15%	1%	0%	56%	20%	2%	5%	0%	1%	19 006
2009	15%	1%	2%	54%	19%	2%	5%	0%	1%	19 827
2010	14%	1%	8%	50%	18%	2%	5%	1%	1%	21 409
2011	13%	1%	9%	49%	18%	2%	5%	1%	2%	21 855
2012	13%	1%	9%	49%	18%	2%	5%	1%	2%	22 270
2013	13%	1%	9%	47%	19%	2%	6%	2%	2%	22 916
2014	13%	1%	9%	47%	19%	2%	6%	2%	2%	23 077

Source: Eurostat (2016).

Table A-7. Fossil fuel support

Support	Short description	Years	Amount
Diesel or blended diesel tax refund	The partial tax refund for diesel or blended diesel (B30) used in crop production and partially forestry activities	2000-2009	Between 1,477 and 1,824 million CZK (€50 to €74 million)
Energy-tax repayments	Can obtain consumers of mineral oil used for heating	2008-2011	Annually between €23 and €27 million
Reduced VAT on Energy-Efficient Heating	Reduced VAT on heating (and cooling) delivered through district heating -- 9 % in 2008, 10 % in 2010, 14 % in 2012 and to 15 % from 2013	2008-	n.a.
Energy tax exemptions	For certain uses of Natural Gas and Solid Fuels		In 2011 around €100 million
Phasing-out of the Coal- Mining- Industry			In 2011 € 64 million
Elimination of Past Environmental damages		2006-2009	€ 102 million
Remediation of Ecological Damage	Remediation of Ecological Damage Caused prior to 1994		In 2011 € 73 million
Remediation of Environmental Damage	Remediation of Environmental Damages Caused by Mining Funded from Royalties on Coal Extraction		In 2011 € 7 million
Compensation of Municipalities	Compensation of Municipalities Affected by Mining Funded from Royalties on Mining Leases		In 2011 € 0.6 million

Table A-8. Direct and indirect support of renewables

Support	Short description	Years	Amount
Reduced excise tax for Biofuels	Set for diesel blended with fatty acid methyl- or ethyl-esters (<30%, sometimes denoted as B30)	2004 -	In 2011 amounted to CZK 1.1 billion (€45 million).
Direct transfers RES	A guaranteed feed-in tariff or a green bonus (feed-in-premium) paid on top of the regular electricity price achieved in the market paid mostly by consumers.	2001-2012 2013	€5 billion until 2012 (assumed to be increasing by almost €2 billion each year)
Green Savings Program	Subsidize energy savings in heating through thermal insulation, construction of new houses to the passive energy standard, and switch to renewable energy sources for space and water heating, including combinations of these measures.	2009 - 2012	Around € 155 million for replacement of fossil fuel heating and solar panels installation .
Exemptions from energy tax on electricity	Tax on natural gas and tax on solid fuels since 2008 includes exemptions for renewable electricity, to electricity used for passenger and freight transport by rail, tramway and trolleybuses, for metallurgy, and for electrolyses.	2008 -	n.a.
Biofuel Obligation	The minimum volumes of biofuels to be put on the market – currently 4.1% for petrol and 6% for diesel replaced in 2014 with obligation to reduce GHG emissions from motor fuels (by 2% in 2014, 4% by 2017 and 6% by 2020).		n.a.
Priority grid access	Plant operators are entitled against the grid operator a) to priority connection of a renewable energy plant to the grid (§ 4 par. 1 RES Act), b) to the expansion of the grid, if the expansion is necessary to satisfy the terms of a connection agreement (§ 45 par. 1 Energy Act), and c) to non-discriminatory use of the grid for the transmission or distribution of electricity from renewable sources.		n.a.
Exemption from real estate tax	Households that transform the heating system of their house from solid fuels to RES are not obliged to pay the real estate tax for 5 years.		n.a.
Energy efficiency upgrade	Support for home solar power and solar thermal systems. Financed from the sale of carbon allowances.	2016	€ 105 million

COAL TRANSITIONS: RESEARCH AND DIALOGUE ON THE FUTURE OF COAL

COAL TRANSITIONS is a large-scale research project led by Climate Strategies and The Institute for Sustainable Development and International Relations (IDDRI) and funded by the KR Foundation.

The project's main objective is to conduct research and policy dialogue on the issue of managing the transition within the coal sector in major coal using economies, as is required if climate change is to be successfully limited to 2°C.

THIS PROJECT BRINGS TOGETHER RESEARCHERS FROM AROUND THE GLOBE, INCLUDING AUSTRALIA, SOUTH AFRICA, GERMANY, POLAND, INDIA AND CHINA.

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