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A CURSE OF COAL? EXPLORING UNINTENDED REGIONAL CONSEQUENCES OF COAL ENERGY IN THE CZECH REPUBLIC

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Abstract

Focusing on coal energy from a geographical perspective, the unintended regional consequences of coal mining and combustion in the Czech Republic are discussed and analysed in terms of the environmental injustice and resource curse theories. The explorative case study attempts to identify significant associations between the spatially uneven distribution of coal power plants and the environmental and socioeconomic characteristics and development trends of affected areas. The findings indicate that the coal industries have contributed to slightly above average incomes and pensions, and have provided households with some technical services such as district heating. However, these positive effects have come at high environmental and health costs paid by the local populations. Above average rates of unemployment, homelessness and crime indicate that the benefits have been unevenly distributed economically. A higher proportion of uneducated people and ethnic minorities in affected districts suggest that coal energy is environmentally unjust.

Shrnutí

Prokletí uhlí? Zkoumání nezamýšlených regionálních důsledků uhelné energie v České republice

Autoři se zaměřují na energii uhlí z geografické perspektivy, analyzují a diskutují nezamýšlené regionální důsledky těžby a spalování uhlí v České republice v kontextu teorií environmentální nespravedlnosti a prokletí zdrojů. Explorativní případová studie se snaží nalézt signifikantní vztahy mezi prostorově nerovnoměrným rozšířením uhelných elektráren a environmentálními a socioekonomickými kvalitami a vývojovými trendy dotčených území. Výsledky indikují, že uhelný průmysl přispěl k mírně nadprůměrným mzdám a penzím a širšímu rozšíření určitých technických služeb, například centrální vytápění. Tato pozitiva však lokální populace zaplatila vážnými environmentálními a zdravotními dopady. Nadprůměrná míra nezaměstnanosti, bezdomovectví a zvýšená kriminalita také indikují, že ekonomické benefity nebyly rovnoměrně distribuovány. Vyšší procento nevzdělaných lidí a etnických minorit v dotčených lokalitách naznačuje, že energie z uhlí je environmentálně nespravedlivá.

Keywords: *coal energy, environmental injustice, resource curse, spatial analysis, Czech Republic*

1. Introduction

"The coal business is archaic. It was good for the past, but it doesn't fit with the future. It's polluting, and it's polluting some more, and it's polluting some more beyond that."

(Vernon Lee, Moapa Paiute tribe member, Nevada, USA)[1]

Growing concerns over global climate change, future energy sustainability and energy security, have led to growing interest in the last few decades to develop domestically available renewable energy sources. Coal still plays a vital role in electricity generation worldwide, however. Coal-fired power plants currently provide about 40% of global electricity, but in some countries coal fuels more than fifty percentage of electricity production, e.g. South Africa (93%), Poland (87%), China (79%), Australia (78%), Kazakhstan (75%), Serbia (72%), India (68%), Israel (58%), including the Czech Republic at 51% (IEA, 2012). It has been even assumed (ibid.) that coal's share of the global energy mix will continue to rise, and by 2017 it will come close to surpassing oil as the world's primary energy source. It is expected that coal demand will increase in every region of the world except in the United States, where coal is being 'pushed out' by natural gas. These trends are close to peaking, however, and coal demand in Europe by 2017 is projected to drop to levels slightly above those in 2011 due to increasing renewables generation and the decommissioning of old coal-fired plants (IEA, 2012). On the other hand, the World Resources Institute identified some new 1,200 plants in the planning process across 59 countries, with about three-quarters of those projects in China and India, and 130 projects in Europe (Yang, Cui, 2012).

Even though the actual cost of renewable energy has already fallen below the cost of fossil fuels in some countries (e.g. in Australia, see BNEF, 2013), conventional public perceptions, perhaps supported by the coal industry lobby, prevail: that renewable energy is expensive and needs to be subsidized, while fossil fuels are cheap. It is necessary to differentiate between two principal issues: (a) the price of coal in the energy market that is, at the present, decreasing (being affected among other factors by the shale gas revolution in the USA and cheap exports of their

[1] Lee, V. (2012): The Cost of Coal. Sierra Club Photo Essay. Available at: http://www.sierraclub.org/sierra/costofcoal/nevada/vernon-lee.aspx

coal), but expected to increase in the future (as a result of limited and overrated resources and growing demand from developing economies, such as China or India (Heinberg and Fridley, 2010)); and (b) the cost of electricity generated from coal, which should include increasing transportation and construction costs (Schlissel et al., 2008; McNerney et al., 2011) and especially the so-called externalities in the form of the different disruptive influences of coal extraction, transportation and processing exerted on the physical and social environment (Budnitz, Holdren, 1976).

In this sense, environmental economists distinguish between the apparent (explicit or internalized) costs and the hidden (secondary or externalized) costs, which together comprise the "true" social cost of energy (Butraw et al., 2012). Social costs arise when any costs of production or consumption are passed on to third parties, like future generations or society at large (Hohmeyer, 1988). In market economies, the structure and decisions of the energy system are usually determined by market prices and politics. If substantial cost elements are not reflected in the market prices of any energy technology, decision makers get wrong signals and take wrong decisions about energy use (Hohmeyer, 1988). Including all social, environmental and other costs in energy prices would provide consumers and producers with the appropriate information to decide about future fuel mix, new investments, and research and development (National Academy of Sciences, 1991; Viscusi et al., 1992). Then, one of the relevant energy policy instruments could be to introduce additional charges into the production cost of electricity that would reflect the cost of the associated impacts on human health, the built environment, and ecosystems (Mahapatra et al., 2012).

In this paper, we focus on coal energy not from the environmental-economic point of view but from a spatial or geographical perspective. The main objectives of our exploratory case study are to analyse unintended regional consequences of coal energy and to test the validity of the "resource curse" hypothesis (Ross, 1999), and the "environmental injustice of energy" hypothesis (Maxwell, 2004), in the conditions of the Czech Republic. Using a correlational analysis of regional data, we attempt to identify significant associations between the spatially uneven distribution of coal power plants and the environmental and socioeconomic qualities and development trends of related areas. In addition to population health characteristics, we focus also on locational attributes that have not been investigated in previous studies and that are hard to monetize, such as the quality of life, social capital and social cohesion.

Our case study area is the Czech Republic, which has been regularly among the three largest net exporters of electricity in Europe – in 2012 the net export exceeded 17 TWh, which became the historical maximum. This export represents approximately five million tons of brown coal being burned in Czech thermal power plants (Polanecký et al., 2010). Such electricity export can be considered a form of landscape commodification and exportation, which raises questions of environmental injustice or the uneven spatial and/or social distribution of benefits (economic profits for energy producers and stakeholders, available cheaper electricity for the general public) and costs (in the form of environmental, health, economic and social impacts) of electricity from coal. In the context of the Czech Republic, the question of negative consequences and the "true" social coast of coal energy is also relevant in practical terms for two on-going public debates: (i) about a possible change to the territorial ecological limits of brown coal mining in the North Bohemian coal basin; and (ii) about the potential adoption of a carbon tax for electricity which is produced from fossil fuels, and/or special taxes for electricity producers whose power plants do not achieve a set minimum of energy efficiency.

2. Theoretical background

Throughout modern history coal has played a key role in human development. Coal has transformed societies, expanded frontiers and sparked social movements, it has redefined the role of workers, changed family structures, altered concepts of public health and private wealth, crystallized debate over national values, and it still vitally powers electric grids (Freese, 2003). Coal-powered development has come with tremendous costs, however, including centuries of blackening both skies and lungs, and recently dramatically accelerating the global climate changes (ibid.).

The historical role of coal for industrialization and regional economic development is indisputable (e.g. Domenech, 2008; Latzko, 2011). The economic benefits of coal for host regions have been in the long term view outweighed by negative externalities, however, and they have been typically subject to "boom and bust" cycles (Black et al., 2005). In this sense, the coal industry is more often associated with the so-called "resource curse" hypothesis, suggesting that resource-dependent communities and regions whose development has been strongly dependent on the extraction of natural resources (specifically non-renewable resources like minerals and fossil fuels) and linked industries, are characterized by economic vulnerability, demographic instability, negative health impacts, higher poverty, increasing geographic isolation, imbalances of scale and power with respect to extractive industries, and the absence of realistic alternatives for diversified development (see, inter alia: Freudenburg 1992, 1998; Perdue and Pavela, 2012).

Coal mining traditionally took place underground. Since the late 1960s, surface mining methods have become more common, and today they account for more than half of total coal extraction (Maxwell, 2004). The methods of surface mining (including the strip mining, open-pit mining and mountaintop removal mining) have made the coal industry more effective (i.e. increasing production gained while reducing workforce), but they also drastically increased negative impacts on the topography, vegetation, and water resources of the affected areas. Although coal mining has always had a negative effect on the surrounding environment and people, surface mining has shown a notable increase in these ecologically damaging effects (Sipes, 2010). Subsequently, the massive coal combustion in modern thermal power plants has become the most polluting and extensive manner of electricity production (e.g. in the United States, coal produces just over 50% of the electricity, but generates over 80% of the CO_2 emissions from the utility sector, and 70% of overall rail traffic is dedicated to shipping coal (Epstein et al., 2011).

Environmental economists have applied different methods to account for externalities and to monetize the social cost of energy (Ottinger et al., 1990; Krewitt et al., 1999; Krewitt, 2002; Pearce, 2003; Rafaj, Kypreos, 2007; Mahapatra et al., 2012). Recently, Epstein et al. (2011) have provided the most comprehensive cost accounting for the life cycle of coal (from mining and transportation through combustion to waste disposal and electricity transmission), taking into account externalities, such as injuries and the mortality of mine workers, increased illness and mortality due to mining pollution, higher stress levels in communities proximate to mining, threats remaining from abandoned mine lands, particulates causing air pollution, infrastructure damage from mine blasting, impacts of acid rain resulting from coal combustion byproducts, water pollution, destruction of local habitat and biodiversity, loss of recreation availability in coal mining communities, loss of tourism income, lower property values for homeowners, damage to farmland and crops resulting from pollution, etc.

The impacts of coal energy production are cumulative, they extend well beyond the geographic locations of operating mines and power plants and bring about other direct, indirect and unintended consequences at higher spatial levels, from regional to global (Franks et al., 2010). Most of the impacts are also spatially and/or socially unevenly distributed, which raises questions of the environmental injustice of energy (Maxwell, 2004). Environmental justice has been defined as a "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA, 2004). The 'fair treatment' means that no group of people should bear a disproportionate share of negative environmental consequences resulting from industrial or other operations, programs and policies (i.e. distributional justice, including geographical/spatial justice). 'Meaningful involvement' is defined as situations in which potentially affected communities have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment, and that the concerns of all participants involved will be considered in the decision-making process (i.e. procedural justice; EPA, 2004).

The environmental (in)justice concept has been applied in the research of many current relevant topics, including the distribution and disposal of industrial toxics and hazardous wastes (Fisher et al., 2006; Oakes et al., 1996), transport planning (Forkenbrock et al., 1999), and the siting of nuclear power plants (Alldred, Shrader-Frechette, 2009), but topics also include renewable energy projects (Gross, 2007). Coal, as one the most concentrated and localized energy resources, can be regarded as a perfect subject of research into cumulative effects and environmental injustice. The proximity to energy resources was a significant location and development factor since the industrial revolution, powered by coal and steam. Many early industries began to set up in coalfield areas to minimize the transport costs of raw materials, and the clustering of industries around coalfields then led to the intensive development of neighbouring cities. Consequently the first coal-fired power plants were constructed near collieries to minimize the cost of transporting coal and to meet the energy demand of expanding industries and the increasing population of cities (Webb, 1967).

The existing literature dealing with environmental injustice related to coal mining and coal energy generation can be divided into two groups: (i) local case studies assessing the environmental, economic and socio-cultural impacts of coal mining on affected communities (e.g., Lockie et al., 2009; Petkova-Timmer et al., 2009; Shandro et al., 2011; Petrova, Marionova, 2013); and (ii) comparative studies mapping the spatial diffusion of air pollution and analyzing selected data about coal-affected and non-coal-affected populations (Armstrong et al., 2009; Higginbotham et al., 2010; Saha et al., 2011; Riva et al., 2011; Zullig, Hendryx, 2010; Weng et al., 2012). The majority of comparative regional studies, however, have only focused on negative health impacts of coal mining and coal combustion. The studies by Papyrakis et al. (2008) and Hajkowicz et al. (2011) involved selected socioeconomic indicators in their testing of the validity of the resource curse hypothesis in the USA and Australia, but their analyses dealt not exclusively with coal but with the regional abundance of different natural (mineral) resources.

3. Geographical context of the case study

The Czech Republic is a country with a significant coal mining and energy industry tradition (Kořan, Žebera, 1955; Smolová, 2008). During the socialist era (1948–1989), Czechoslovakia, as a member of the former East European COMECON group of countries, was designated the "forge of the socialist camp" with a dominance of metallurgical and energy-intensive heavy industries where coal was regarded the "life blood of industry" (Říha et al., 2005). Concentration on production with high energy consumption created a considerably higher demand for energy raw materials, namely brown coal. The production of brown coal increased about five times and electrical power generation about twenty times with respect to 1937 levels, whereas the production of bituminous coal increased by only 80% (Pešek, Pešková, 1995).

This planning orientation affected the overall national economy and resulted in the environmental devastation of several regions, especially in the Ostrava-Karviná black coal basin (part of the Upper Silesian basin, on the north-east border with Poland), and most extensively in the North Bohemian and Sokolov brown coal basins (located in the furrow along the Ore Mountains, which follows the north-west border with Germany). These regions were extensively developed on the basis of coal mining and linked industries at the expense of other economic activities, the natural environment, the existing built environment, social structures, and public health. The lignite surface mining, the construction of giant power plants and related infrastructural projects, eliminated human settlements (over 100 municipalities, including the historic city of Most, have been destroyed since 1949 – Fig. 1 – see cover p. 2), and over 90,000 people were relocated due to mining and related activities (e.g. the construction of dams). Several hundreds of square kilometres of cultural landscapes were destroyed, and drainage and water management systems, the ecological stability of landscape, and agricultural and forestry potential were disrupted (Říha et al., 2005). While land regeneration has been successfully carried out in many cases (e.g. the regeneration projects of a motor-racing circuit and hippodrome in Most city), the scope of devastation in the entire region is much greater.

After the fall of socialism in 1989, the newly-established Federal Ministry of Environment prepared programs to restore the environment of the North Bohemian and Ostrava-Karviná coal basins, the most environmentally affected areas. As a result, all operational coal-fired power plants were required to be desulphurized or shut down (the desulphurization program took place in the period 1992–1998, the most extensive and most rapid one in Europe (ČEZ, 2013)) and the so-called territorial ecological limits for mining were established (Government Decrees No. 331 and 444/1991). By restricting exploration, mining and other brown-coal mining-related activities beyond certain spatial limits, the government established a balance between economic and ecological interests, but it also ignited a fierce political debate that has been smoldering ever since (Kotouš, Jurošková, 2013).

Current Czech energy policy is still dominantly based on traditional resources. Primary energy consumption, which amounted to 62.9 Mtce in 2010, was supplied as follows: 41% coal (total 25.5 Mtce, of which hard coal 6.5 Mtce and brown coal 19.0 Mtce), 19% natural gas (11.7 Mtce), and 20% oil (12.9 Mtce). This primary energy mix is supplemented by nuclear energy with a 17% share (10.4 Mtce), as well as by renewables and hydroelectric power, which together account for some 6% (4.0 Mtce) (Euracoal, 2011). About 24,000 people were employed directly in the coal mining industry in 2010. The Czech Republic's dependence on energy imports has been quite modest to date (circa 27% of energy demand is met by imports); however, imports are structurally unbalanced (the dependence on oil is about 97%, and in the case of natural gas it is about 96%) (Euracoal, 2011).

Overall electricity production is based predominantly (57%) on thermal power plants (burning primarily brown coal [46%], black coal [5.5%], gas [4%] and other fuels), nuclear power plants (33%), and renewable energy sources (10%) (ERU, 2012). The share of coal power plants in electricity production decreased by circa 10% during the last decade primarily due to the decommissioning of old plants and increased installed capacity from renewable energy, but it still represents the dominant energy source in the country. The Czech Republic, however, is among those countries with the worst air quality in the European Union (the positive trend of improving air quality from the 1990s stopped at the turn of the millennium) (MŽP, 2012). The most significant contributors to the worsening air quality, apart from surface coal mining and coal combustion in power plants, are the metallurgic and heavy chemical industries, car traffic, and the burning of coal in local heating systems.

Most electricity, then, is produced from fossil fuels and almost one third of it has been exported (mostly to neighbouring Germany, Austria and Slovakia) which makes the Czech Republic regularly one the three largest net exporters of electricity in Europe. The historically largest national net export of electric energy in 2012 (more than 17 TWh) represents approximately the entire production of the Temelín nuclear power plant, or 5 million tons of brown coal being burned in thermal power plants (Polanecký et al., 2010). The majority of the coal power plants are owned by the ČEZ joint-stock company, a semi-public enterprise which is the dominant energy producer in the Czech Republic (the state remains the company's largest shareholder with a 70% stake in the stated capital).

Opponents to coal energy have stressed that such energy export is just a continuation of the commodification and exportation of the Czech landscape, with economic benefits for a few shareholders of coal mining and energy companies, and negative environmental and socioeconomic impacts on large populations in the regions affected by coal mining and combustion. The question of distributional injustice is closely related to the currently prominent topic of the possible lifting of territorial limits of brown-coal mining in the Northern Bohemian basin (Fig. 2 – see cover p. 2). The main arguments used by supporters of coal, promoting a change in the mining limits and a continuation with coal energy production, are as follows: (i) to prevent price increases in electricity and district heating (in the case of further development and subventions for renewable energy and substitution of coal by natural gas in the systems of heating plants); (ii) to maintain employment in coal mining regions; and (iii) to keep a traditional Czech industrial sector running and to contribute to the state budget. On the contrary, the objectors to changing the coal mining limits stress the following factors: (a) the negative environmental and socioeconomic impacts of coal mining and coal combustion; (b) a continuation of regional resource-dependency with negligible long-term effects on employment rates; and (c) the low energy efficiency of coal-fired power plants (suggesting to save the coal for the future when economically and technologically more effective processing will be possible – see Komise pro životní prostředí Akademie věd ČR; KŽP AV ČR, 2013).

A study realized by the Czech non-governmental organization Hnutí Duha (Kubáňová, 2007) documented that the Ústecký region (as the one most significantly affected by the coal resource curse) is, in comparison to other Czech regions, still characterized by many negative attributes, including the highest concentration of areas of deteriorated air quality, the lowest life expectancy, a higher than average occurrence of allergic diseases, the highest rate of abortions, the highest unemployment rates, the lowest percentage of people with university degrees, a lower than average percentage of business activity, etc. The Ústecký region is the least attractive tourist destination in the country according to the number of arrivals per capita and total area, with the number of tourist accommodation facilities decreasing continually since 2000. The Ústecký and Moravian Silesian regions were the only two regions with a higher number of emigrants than immigrants (ibid.).

In this paper the authors attempt to contribute to current knowledge about the unintended regional consequences of coal energy production by providing a more complex and more sensitive comparative analysis, focusing on the level of districts (NUTS4 / LAU1).

4. Data and methods

More than 70 thermal power plants with installed capacity of more than 10 MW were in operation in the Czech Republic as of December 31, 2010 (ERU, 2011). The overall installed capacity of thermal power plants was 11,793 MW. More than one half of the installed capacity was represented by power plants operated by the ČEZ company. For the purpose of this analysis, we created a database of selected power plants which met the following conditions: (a) have a total installed capacity of at least 100 MW; and (b) the major fuel is brown or black coal. Altogether 28 power plants are included in the database (see Tab. 1), with total capacity of 9,679 MW which is more than 80% of the overall installed capacity of thermal power plants in the country. The power plants are located in 19 different localities (municipality cadasters) within 15 districts. The largest numbers (4) of power plants are located in the Sokolov district, while the highest installed capacity (2,290 MW) is in the Chomutov district. One power plant is located in the capital, Prague; however, the capital city was not included in the statistical analyses since it is characterized by outlying values with respect to the majority of the socioeconomic indicators, which would skew the results.

The brown coal from the Northern Bohemian basin is still the dominant fuel for most thermal power plants. Three plants in the Ostrava-Karviná basin are powered by local black coal. In some plants biomass and natural gas are used as secondary fuels. It is evident from the map (Fig. 3) that almost all power plants have been constructed close to coal basins. The majority of the installed capacity of power plants is concentrated in areas where coal mining is still in operation, including the Sokolov basin (Sokolov district), the

Name	Municipality	District	Installed capacity (MW)	Year of commissioning	Fuel 1	Operator
Pruněřov II	Kadaň	Chomutov	1,050	1981–1982	BrC	ČEZ, a. s.
Počerady	Výškov	Louny	1,000	1970–1977	BrC	ČEZ, a. s.
Tušimice II	Kadaň	Chomutov	800	1974–1975	BrC	ČEZ, a. s.
Dětmarovice	Karviná	Karviná	800	1975–1976	BlC	ČEZ, a. s.
Chvaletice	Chvaletice	Pardubice	800	1977–1978	BrC	Elektrárna Chvaletice a.s.
Mělník III	Horní Počaply	Mělník	500	1981	BrC	ČEZ, a. s.
Pruněřov I	Kadaň	Chomutov	440	1967–1968	BrC	ČEZ, a. s.
Opatovice	Opatovice n./L.	Pardubice	378	1960–1997	BrC	Elektrárny Opatovice, a.s.
Vřesová I	Vřesová	Sokolov	370	1996	BrC, G	Sokolovská uhelná, a. s.
Kladno-Dubská	Kladno	Kladno	366	1976–1999	BlC, BrC, B	Alpiq Generation, s.r.o
Mělník I	Horní Počaply	Mělník	352	1961–1995	BrC	Energotrans a.s.
Ostrava-Kunčice	Ostrava	Ostrava	254	1957–2000	BlC, G	Arcelor Mittal Energy a.s.
Komořany	Most	Most	239	1959–1998	BrC, G	United Energy, a.s.
Mělník II	Horní Počaply	Mělník	220	1971	BrC	ČEZ, a. s.
Vřesová II	Vřesová	Sokolov	220	1967–1991	BrC, G	Sokolovská uhelná, a. s.
Ledvice II	Bílina	Teplice	220	1966–1968	BrC	ČEZ, a. s.
Tisová I	Březová	Sokolov	184	1959–1960	BrC, B	ČEZ, a. s.
Třebovice	Ostrava	Ostrava	174	1961	BlC, L	Dalkia ČR, a.s.
Litvínov T200	Litvínov	Most	166	1942–1955	BrC	ČEZ, a. s.
Poříčí	Trutnov	Trutnov	165	1957	BrC, B, BlC	ČEZ, a. s.
Trmice	Trmice	Ústí n/L.	158	1974–1976	BrC	ČEZ, a. s.
Plzeň	Plzeň	Plzeň	149	1984–2008	BrC, G, B	Plzeňská teplárenská, a.s.
Praha-Malešice	Praha	Praha	122	1963–1971	BlC	Pražská teplárenská a.s.
Štětí	Štětí	Litoměřice	113	1984–2008	BrC, L, B	Mondi Štětí, a.s.
Litvínov T700	Litvínov	Most	112	1963–1995	BrC	Unipetrol RPA, s.r.o.
Tisová II	Březová	Sokolov	112	1961	BrC	ČEZ, a. s.
Ledvice III	Bílina	Teplice	110	1967, 1998	BrC	ČEZ, a. s.
Hodonín	Hodonín	Hodonín	105	1951–1957	BrC, B	ČEZ, a. s.

Tab. 1: Coal-fired thermal power plants with installed capacity over 100 MW. Notes: 1 BrC – brown coal, BlC – black coal, G – gas, B – biomass, L – light fuel oil. Source: Energy Regulatory Office (ERU, 2011)

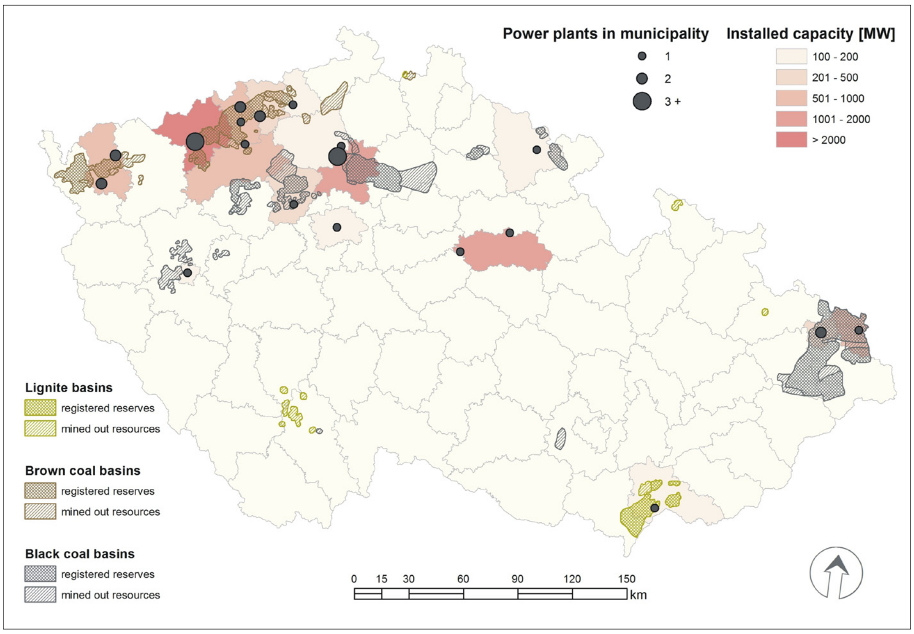

Fig. 3: Registered coal resources, functional large coal-fired power plants and their total installed capacity in districts of the Czech Republic. Source: Czech Geological Survey, Energy Regulatory Office;apping and design by authors

North Bohemian basin (districts of Chomutov, Most, Teplice, and partly also Louny and Ústí nad Labem), and the Ostrava-Karviná basin (Fig. 4 – see cover p. 4). Black coal mining had been already stopped in the districts of Brno-venkov (1992), Trutnov (1995), Plzeň-sever (1995) and Kladno (2002), and the lignite mining in Hodonín district was finished in 2009. The key location factors for five power plants (Opatovice and Chvaletice in Pardubice district, and three plants in Mělník district) have been proximity to good water resources (Labe river) and proximity to large cities (Hradec Králové, Pardubice and Prague), and/or specialized industries (i.e., factors of electricity demand and the use of heat in district heating systems as a plant by-product).

Subsequently we created a database of selected variables representing the most relevant characteristics of districts, including population vital and health statistics, quality of life indicators, labour market data, social capital and social cohesion indicators, and environmental indicators. The selection of indicators was determined by the availability of statistical data for the spatial level of districts in the Czech Republic and by the potential comparability of results with previous studies (Armstrong et al., 2009; Hajkowicz et al., 2011). For the complete list of 33 indicators, see Tab. 2.

The hypotheses that drive this study were defined as follows:

- H1: The areas affected by coal mining and coal combustion are characterized by worse environment, population health status and quality of life, and lower socioeconomic potential (resource curse hypothesis)
- H2: The areas affected by coal mining and coal combustion are characterized by higher concentration of ethnical minorities and/or socially deprived population (environmental injustice hypothesis)

Then we carried out statistical testing for relationships between the above listed indicators as dependent variables and the number of power plants within districts as the independent variable. The number of power plants was chosen as an adequate independent variable since it was

Factor	Indicator	Measure
Population vital statistics and health	Population increase	Annual population natural increase per 1,000 population
	Age index	{Number of persons (65+ years)/number of persons (0–14 years} * 100
	Life expectancy	Male life expectancy at birth 2007–2011
	Abortion rate	Abortions per 1,000 population
	Divorce rate	Divorces per 1,000 population
	Infant mortality	Infant mortality [‰]
	Congenital anomalies	Congenital malformation per 10,000 live births
	Respiratory diseases	Deaths per 100,000 population of respiratory diseases
	Sickness rate	Average duration of annual incapacity for work (days)
Life quality	Health care	Health care establishments per 1,000 population
	Social care	Social service establishments per 1,000 population
	Average monthly wage	Average monthly wage in 2005 (CZK)
	Average monthly pension	Average monthly pension revenue (CZK)
	Car ownership	Number of cars per 1,000 population
	District heating	Percentage of inhabited flats with district heating
	Internet connection	Percentage of inhabited flats with PC/internet connection
	Property value	Average price of flats (millions CZK)
	Homelessness	Number of homeless people per 1,000 population
	Population density	Population per km2
Labour market	Unemployment	Unemployment rate [%]
	Job vacancies	Job applicants per vacancies
	Business activity	Total business units registered per 1,000 population
Social capital and social cohesion	Education level I	Persons with basic or no formal education [%]
	Education level II	Persons with university education [%]
	Political involvement	Turnout in regional elections in 2012 [%]
	Crime rate	Ascertained offences per 1,000 population
	Alcohol abuse	Car accidents due to alcohol abuse per 1,000 population
	Proportion of natives	People with permanent living at the place of their birth [%]
	Proportion of minorities	Number of Roma ethnic people per 1,000 population
	Net migration	Number of immigrants less number of emigrants per 1,000 pop.
Environmental restoration	Air quality	Main pollutant emissions (SO2+NOx+CO tones/km2)
	Environmental restoration	Environmental protection expenditure per 1,000 population
	Renewable energy development	Installed capacity of wind energy [MW]

Tab. 2: List of indicators included in statistical analyses
Source: Czech Statistical Office, Institute of Regional Information (data are relevant for 2011 unless otherwise indicated)

shown to have strong correlations to both the total installed capacity [MW] of power plants within districts (Pearson's R = 0.84**) and the current status of mining (active/finished) in the district (point bi-serial coefficient) (R = 0.74**). Statistical testing was carried out with the SPSS program, using a bivariate cross-correlation analysis of all dependent variables against number of power plants. The strength of association and statistical significance was tested using the classical Pearson's R correlation coefficient, and examining the p-value for each pair of variables. To better demonstrate the associations, we then provided a comparison of mean values of indicators that proved to be statistically significant within categories of districts (Tab. 3).

5. Results

Out of 33 indicators, we have found statistically significant correlations with the distribution of coal power plants for 19 indicators. The differences between district categories with their mean values of the relevant indicators are summarized in Tab. 3.

The most significant differences among districts are according to air quality, with respect to the concentration of basic pollutants. The highest mean values of pollutants are in the category of districts with two power plants, including the district of Ostrava city which reported absolutely the highest concentrations of pollutants (213.5 tones per sq. km) among all areas in the Czech Republic. Air quality in this area, however, is significantly affected by the location of the Arcellor Mittal steelworks factory which is considered to be the biggest polluter in the region.

There are significant associations between coal energy production and some population vitality and health indicators, including higher rates of abortions, higher infant mortality and lower male life expectancy. On the contrary, we have found no statistically significant differences among districts according to occurrence of congenital anomalies, respiratory diseases and the general sickness rate in terms of average days lost. The analysis also did not reveal any significant differences according to selected indicators of the population's socioeconomic well-being (measured by the provision of health care and social services establishments, availability of ICT in households, and personal car ownership). The coal industry has contributed to the fact that central (district) heating is more obvious in related districts. There is a significant negative association between the number of power plants within a district and the average price of flats; however, it cannot be regarded as direct evidence of better affordability or some worse quality of flats.

Significant differences among districts are related to one key labor market characteristic, the unemployment rate, which is higher in districts whose economy has been dependent on the coal industry. The results also indicate the unemployment rate is likely connected with other negative social phenomena such as the higher percentage of homeless people, higher rates of crime, divorces, and annual out-of-district migration. On the other hand, the higher than average incomes and pensions indicate that the coal industry has brought about positive economic effects to local employees. We can assume that the above-mentioned negative social phenomena indicate that economic benefits have been socially unevenly distributed. Moreover, although

Dependent variables[1]	District category according to number of plants (number of districts within category)				Pearson´s R[2]
	0 (N = 61)	1 (N = 8)	2 (N = 3)	3+ (N = 4)	
Air quality	4.2	12.6	92.1	36.2	0.52**
Proportion of minorities	0.4	0.5	0.8	2.0	0.51**
Life expectancy	74.2	73.3	73.0	72.3	– 0.45**
Political involvement	38	35	34	31	– 0.44**
Crime rate	23	29	39	33	0.43**
District heating	70	73	75	81	0.42**
Abortion rate	3.6	4.1	4.1	4.9	0.41**
Renewable energy development	2.1	1.3	2.7	18.8	0.38**
Infant mortality	2.6	4.0	3.4	4.9	0.33**
Property value	1,303	1,138	0.995	0.780	– 0.32**
Education level I.	19	20	19	23	0.31**
Unemployment	8.9	10.9	10.0	12.2	0.30**
Average monthly wage	16,372	16,926	16,996	17,954	0.29*
Average monthly pension	10,134	10,259	10,294	10,320	0.29*
Divorce rate	2.6	2.8	2.8	3.0	0.27*
Homelessness	0.9	1.6	1.8	1.1	0.25*
Environment restoration	1.968	1.801	3.365	2.959	0.26*
Population density	131	300	486	163	0.22*
Net migration	1.75	– 0.23	– 0.37	– 0.33	– 0.21*

*Tab. 3: Relationship between distribution of power plants and mean values of selected indicators ([1]Dependent variables are listed according to their descending correlation value; [2]Correlations are significant at the levels of **0.01; *0.05)*
Source: Czech Statistical Office, Institute of Regional Information; calculations by authors

the differences in average incomes and pensions were shown to be significant statistically, they are negligible in terms of practical life.

Our analysis has also demonstrated that districts with higher concentrations of thermal power plants are characterized by a higher concentration of ethnic minorities, specifically by the Roma minority. At the same time, the coal-affected districts are characterized by higher proportions of people with basic education and uneducated people ('Education level I'). On the contrary, there are no differences with respect to proportions of persons with university education.

A retrospective analysis of data (2005–2011) showed a positive development trend in relation to local air quality and most of the population health and socioeconomic indicators (see Tab. 4). The numbers still remain significantly worse compared to rest of the country, however. But the unemployment rate in coal-affected districts decreased while it increased slightly in the rest of the country. Whereas the number of workers in the coal mining industry has been continually decreasing during the last decade, this can be regarded a sign of economic diversification. Risk factors for further positive economic development of affected districts are the higher concentrations of low educated people and ethnic minorities. Lower social capital is also indicated by lower political involvement of people measured by the election turnout.

The positive development trends in air quality and population vital statistics were supported by higher investments in environmental protection (by business companies with registered offices in the districts) which have been continually increasing during the last four years. The significantly higher installed capacity of wind energy[2] can be regarded as demonstrating that local communities and decision makers living in environmentally affected areas are more likely to support alternative technologies (Fig. 5 – see cover p. 4). This finding is in accordance with studies of Toke (2005), Frantál and Kunc (2011) and others (Van der Horst, 2007, p. 2709), which found a relationship between the industrial character and environmental degradation of a location and the local population's more positive attitudes towards renewable energy projects.

6. Discussion and conclusions

The results of this case study support the hypotheses of the resource curse and environmental injustice of coal energy. Although the coal mining and coal combustion (together with linked industries) contributed to slightly above average incomes and pensions (which are actually significant statistically but not of practical relevance), and provided households with some technical services (district heating), these positives have come at high environmental and health costs paid by the local population, such as significantly worse air quality, lower life expectancy, higher rates of infant mortality, etc. Above average rates of unemployment, homelessness and crime also indicate that the economic benefits have been unevenly distributed. In this sense, our study has confirmed the findings from previous studies made at the regional level (Kubáňová, 2007).

As compared to the few foreign studies on the issue, our findings are partially in accordance and partially in conflict with results reported by Hajkowicz et al. (2011), which affirmed positive impacts of mining activities on incomes, housing affordability, communication access, education and employment across regions in Australia, but negative impacts on life expectancy. They did, however, highlight the fact that while their data were valid at an aggregate level, there is often an uneven income distribution within mining regions and that certain sub-groups in regional and remote communities are more vulnerable to mining activities (ibid.). Another Australian study (Taylor, Scambary, 2005, cited by Hajkowicz et al., 2011) reported that indigenous communities, resident in mining regions, in particular were excluded from the socio-economic benefits of adjacent mining operations.

This study detected a higher proportion of uneducated people and ethnic minorities in affected districts, which suggests that coal energy is environmentally unjust. This finding, however, does not confirm the theory of disproportionate siting, i.e. that polluting industries are proposed for areas with a high concentration of poor or minority residents (see e.g. Pastor et al., 2001). Most of the thermal power plants in the Czech Republic were constructed between the 1950s and 1980s, at locations within the main

Dependent variables	Coal-affected districts		Coal-free districts	
	2005	2011	2005	2011
Air quality	63.2	34.8	3.7	4.2
Life expectancy (2004–2008 / 2007–2011)	72.1	72.9	73.2	74.1
Political involvement	27	34	30	38
Crime rate	34	32	23	23
Abortion rate	4.6	4.3	3.8	3.7
Infant mortality	5.1	4.1	3.3	2.6
Unemployment	12.7	11.1	8.4	9.0
Environmental restoration	2.020	2.423	1.350	1.968
Population change (2005–2011) per 1000 population	+ 23.6		+ 16.4	

Tab. 4: Development trend in most relevant indicators (note: Coal-affected districts are all districts with at least one coal-fired power plant). Source: Czech Statistical Office; calculations by authors.

[2] The actual installed capacity of wind energy [MW] in districts correlates more strongly (R = 0.54**) with the actual installed capacity of coal energy [MW] than with the numbers of district realizable wind potential (R = 0.48**), as assessed by Hanslian et al. (2008).

coal basins (Northern Bohemian and Northern Moravian Regions). These border areas were typically characterized on the one hand by large depopulations due to the expulsion of the German population after WWII, and on the other hand by increasing demand for labour by massively expanding mining and metallurgical industries. As a result less educated minority populations have moved into extensively industrialized and urbanized areas (i.e. disproportionate minority in-migrants).

Finally, our findings have demonstrated a slightly positive trend in improving indicators of environment and population health. Regardless, the numbers still remain significantly worse compared to the rest of the country, even though the negative impacts are mitigated by increasing investments in environmental protection and the efficiency of thermal power plant technologies. In other words, the coal-affected regions still suffer from the historic "curse of coal". In the context of on-going public debates about possible changes to the current territorial limits of mining and about the potential adoption of a carbon tax for electricity produced from fossil fuels, our findings suggest that the actual long-term environmental and socioeconomic cumulative effects of coal mining and coal combustion should be taken into account more responsibly, and that market prices should reflect the real social price of coal energy to a greater extent. In terms of environmental justice, the economic profits from coal should be more fairly redistributed to compensate for the negative impacts in affected regions. As a final cautionary note, in terms of procedural justice, the residents of affected regions should have the last word in decision-making processes about future coal energy policy.

The main focus of this case study was at the regional level; however, the impacts of coal energy exceed regional and national levels. The emphasis paid to coal by McKibben (2003, as cited by Freese, 2003), given the particular chemistry of global warming, is instructive: it is possible that the decisions we make about coal in the next two decades may prove to be more important than any decisions we have ever made as a species.

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