Smart strategies for the transition in coal intensive regions

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Research & Innovation strategy in the field of energy for North Bohemia

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TRACER website: www.tracer-h2020.eu

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Executive summary

North Bohemia represents coal intensive regions. All lignite in the Czech Republic is basically mined here. This lignite is contributing by 40% to the Czech Republic energy mix in 2020. Four mining companies mine coal in this region. Most of the coal is used in the power plant of CEZ largest energy company in the Czech Republic, which is partly government-owned.

Coal mining and coal processing caused environmental damage in the region. This was manifested in several parameters such as a lower life expectancy, higher occurrence of respiratory diseases and lower birth rate. Despite substantial improvements in air pollution and ecological indicators which are now close to the national average, there is persisting a belief that the region is not healthy.

Both districts suffer relatively higher unemployment rates compared to other districts of the Czech Republic. Despite the high importance of mining, only about 1% of the workforce is employed in the mining industry. However, mining may be indirectly important for customers from other businesses.

RTDI facilities in the target region are underdeveloped. There is only one university in the region, and in terms of number of research institutions, workers in RD, as well as investments in RD in the target region these are among the lowest in the Czech Republic. On the other hand, there are many universities, research institutions and large research infrastructures engaged in energy-related research or other technical and environmentally oriented research that is potentially relevant for the target region. Many of these institutions conduct their research in the target region already. Focusing future support of RD only on institutions that are located in the target region may face a problem of the low absorption capacity of these institutions.

RTDI strategy is affected by the expected development of coal mining driven by territorial limits, state energy concept and decision of coal commission. At the regional level, DR needs are summarized in RIS (research and innovation strategy of individual regions).

The most highlighted field of specialization are:

- Mechanical engineering, electrical engineering and mechatronics;
- Mobility including Automotive industry and autonomous transport;
- Traditional industries - ceramics, porcelain and glass;
- Energy transformation and new challenges related to the transition of coal intensive region and spa, balneology and tourism.

1 Introduction

1.1 Development of the Strategy: Overview of the process

This document was generated as a synthetic document of the TRACER project to describe the research and innovation landscape in North Bohemia and strategy its possible future development during the transition of this coal intensive region. TRACER is EU funded project which supports nine coal-intensive regions around Europe to design (or re-design) their Research and Innovation (R&I) strategies to facilitate their transition towards a sustainable energy system.

The major tasks of this project are:

1) Mobilisation of a wide range of stakeholders in nine European regions to discuss and agree on a shared vision and priorities for coal transition.
2) Identification and analysis of best practice examples of successful and ambitious transition processes in coal intensive regions.
3) Assessment of social, environmental and technological challenges.

4) Elaboration of guidelines on how to mobilise investments.
5) Fostering R&I cooperation among coal intensive regions in Europe and beyond.

1.2 Definitions and abbreviations

Economic Restructuring Strategy in which the government and the region would work together. By its Resolution No. 826 of 19 October 2015 SEC State energy concept (MIT, 2014) in Government document prepared by Ministry of industry and business to articulate the priorities and strategic intentions of the state within the energy sector.

Territorial limits of brown coal mining in Northern Bohemia are limits of lignite mines adopted by binding resolution of the Czech government No. 444 of 1991.

In terms of regional innovation prospects, Regional Innovation Strategies (RIS) are crucial, those have to be generated and approved by each district authority. In these documents has been used RIS of Karlovarský and Ústecký districts.

1.2.1 Other key abbreviations

CEZ ČEZ Group is a conglomerate of 96 companies, 72 of them in the Czech Republic. Its core business is the generation, distribution, trade-in, and sales of electricity and heat, trade-in and sales of natural gas, and coal extraction.

CHP Combined heat and power CHP plants can be located in an individual building or facility, or they can produce energy for a district or a utility.

CZSO Czech statistical office

RD Research and Development

RE:START2 (RE:START-Strategy for economic restructuring of Czech coal regions) Governance structure bringing together national decision-makers and regional expertise to implement a just transition in Czech coal mining regions.

RTDI Research, Technology Development and Innovation

UJEP University of Jan Evangelista in Ústí nad Labem

2 Setting the context

2.1 Regional profile and specialisation

In the Czech Republic, all active lignite mines are located in the North-west Bohemia region, which covers an area of 8.649 km^2. Two different districts form the North-west Bohemia study area: Karlovy Vary district and Ústí district. Both of these regions have been described in detail thanks to the initial analysis of the strategic r44estructuring plan.

The **Ústí Region** is located in the Northwest of the Czech Republic on the border with the German Land of Saxony. The border with Germany is made up of the Ore Mountains, in the interior there is the Central Bohemian Mountains, the rest of the region is predominantly flat. By the end of 2016, the Ústí Region had 821,337 inhabitants, making it fifth in the Czech Republic. Population density (154 inhabitants/km^2) is higher than the national average. The characteristic feature of the region is a relatively young population; the average age is 41.6 years. The Ústí nad Labem Region is ranked fourth in the number of live births per 1000 inhabitants (10.0), but there is the highest mortality rate in the Czech Republic (11.0 per 1 000 inhabitants) (CSO, 2021).

The **Karlovy Vary Region** is located in the westernmost part of the Czech Republic, adjacent to the Plzeň and Ústecký Regions, as well as Bavaria and Saxony. The relief of the region is characteristic of the lowlands, where the headquarters of the region are situated - Karlovy Vary,

Sokolov and Cheb, where the population and economic activity are concentrated. Karlovy Vary region is famous for its spa. In terms of population, the Karlovy Vary Region is the smallest region in the Czech Republic, with approximately 295,000 inhabitants. Population density is around 90 inhabitants/km^2, the highest density is in Sokolov (120 inhabitants/ km^2), where operating coal mines are located. Infant mortality rate of 5.2 is the 3rd highest in the Czech Republic, the national average is 4.1. The relative number of live births is also high, ranking second in the Ústí nad Labem Region, while the lowest in the Czech Republic is mortality (6.6% lower than the Czech average) (CSO, 2021).

The population and the structure of the region's settlement are still bearing signs of significant changes after 1945. The displacement of the German population and the subsequent resettlement especially for the needs of the heavy industry changed considerably the population of the region - the municipalities in the peripheral parts of the region were either extinct or marginalized, areas. Specific labour requirements resulting from decades of artificially supported industrial specialization have had and have implications for the socio-professional structure and education of the population.

Net migration showed clear/significant migration outside the region, but it was comparatively small and this emigration gradually decreased between 2015 and 2018 and eventually turned into net immigration. Both the Karlovarský and Ústecký districts have a percentage of the population who are more than 15 years old with a basic education only (19% and 20% respectively) higher than the national average (13% in 2018 based on CSO data). In contrast in both districts, there is a lower percentage of university graduates (12% and 11% for the Karlovarský and Ústecký districts respectively) than the national average (19%, in total in 2018 based on CZSO data). A particular problem namely in the Ústecký district is the existence of socially excluded communities mainly inhabited by the gipsy population. In this district, more than 60 such localities were identified where about 20,000 people live, and these localities face social problems such as isolation, lower education and higher criminality.

Looking at the overall salary level, in 2018 the Karlovarský district was the district with the lowest wages in the country, while the Ustecký district was close to the national median. In both districts, the wages in the mining sector were above the district average.

Concerning employment in individual sectors, manufacturing was the most important sector in both districts, followed by various services such as retail, health service, defence and other social services, accommodation, food and transportation. The mining sector employed only 2-3% of employees directly in both districts. This percentage was quite steady in the Ústecký district and decreased in the Karlovarský district. However, even though number of people employed in mining was rather low, mining companies still represent important customers for various services and many other jobs may rely on them, indirectly.

The general unemployment rate showed a dramatic decrease between 2015-2018 and reached 3.6% and 2.9% in the Karlovarský and Ústecký districts respectively, which is close to the national average (3.1 in Dec. 2018). However, the overall level of unemployment was close to natural minimum unemployment given by fluctuation and other natural causes. The highest unemployment was in young people and people with a basic education who in general have greater difficulty in being employed. However, a generally low level of unemployment is rather driven by a low tendency of people to search for jobs rather than insufficient offers in the job market. CoVid 19 and the consequent economic slowdown will likely change this positive picture, but there is not enough data to illustrate this. Despite the overall low level of unemployment, the percentage of long-term unemployment is above the national average.

At the same time, environmental impacts are evident, although, in the long run, it is improving and in some respects is among the best in the Czech Republic, there are still many local environmental burdens and brownfields in the region. In general, North-West Bohemia was known as a region with an unhealthy environment caused namely by air pollution. This was manifested in several parameters such as a lower life expectancy, higher occurrence of

respiratory diseases and lower birth weight as shown in a detailed health survey project "Teplice" in the 1990s (ŠRÁM, 1996). Nowadays most reported ecological indicators have improved substantially (fig 1), however, the Ústecký district still belongs to the region where health individual pollutants exceed official health limits (CÉZA, 2018). Despite the mining impact on ecosystems, due to extensive reclamation work, land use indicators have also improved substantially. The coefficient of ecological stability (based on the proportion of ecologically stable habitats to other less stable habitats) in the Karlovarský and Ústecký districts is 2.05 and 1.01, while the country average is 1.2.

Despite substantial improvements in air pollution and ecological indicators which are now further from the national average, there may persist a belief that the region is not healthy. There is also the possibility that the historical exposition of the population cannot affect the health of the next generation. This question is now the subject of intensive research, however, it would be premature to make any comprehensive conclusions (BINKOVÁ, 1999).

2.2 North Bohemia Region's energy and environment outlook

Brown coal is a major source of energy in the Czech Republic. In the Czech Republic, there are 55 known deposits of lignite out of which nine are mined, most of the ore of Miocene age. Sokolov and Most basins that formed North Bohemia, region, includes the majority of lignite deposits in the Czech Republic.

In 2005 lignite generated 43.1 TWh of electricity, which represented 52.2% of the total gross electricity production of 82.6 TWh. In 2013, lignite produced 35.9 TWh, which in total with electricity production of 87.1 TWh at 41.2%. For eight years, the total electricity production increased by 4.5 TWh, lignite electricity production decreased by 7.2 TWh, the average annual decrease in electricity production from lignite was 0.9 TWh (2.1%). The production of lignite electricity has been displaced mainly by growing production in nuclear power plants and renewable energy sources. In 2005, lignite was centrally produced and supplied with 58 PJ heat, of which the total output was 139.2 PJ accounted for 41.6%. In 2013, central heat production declined to 122.2 PJ, and lignite was down produced and delivered 53.4 PJ. In eight years total heat production decreased by 18 PJ. Heat production of lignite fell by 4.5 PJ, but the share of lignite in total heat production increased from 41.6% to 44.1%. Lignite is mainly used for the production of electricity and heat in a wide range of power plants when particularly large energy companies with consumption above 50 MWt are of decisive importance. These are, in total 47. The most important heat and energy producer is the semi-governmental Czech energetic company CEZ' (four heating plants and nine power plants). Among the biggest are Prunéřov II 1050 MW lignite consumption 2 442,0 thousand t y^{-1}, Počerady, a.s. 1000 MW using 5 417 thousand t lignite y^{-1} Tušimice II 800 MW, 4 577,0 thousand t y^{-1}.

The total known geological reserves of lignite are 9 055 mil tons. Not all of that coal is, however, technically mineable and mining of part of the mineable resources is banned by limits set by government decision no 444 from 1991. Consequently, the total mineable reserve in this region is 783.8 mil tons. The majority of that reserves occur in Most district 654.8 mil tons and a smaller part in Sokolovský district 129.0 mil tons. Share of individual companies and mines are as follows in millions of tons:

1) Sev.-energetická, a.s. company mine ČSA 27.7 and mine Centrum 3.8,
2) Vršanská uhelná, a.s.company mines Vršany Jan Šverma 277.0,
3) Severočeské doly, a.s. company mine Libouš 210.1, and mine Bílina 136.2 and
4) Sokolovská uhelná, a.s. company 129.0.

The heat capacity of the coal varies from 10-11MJ kg^{-1} in the Most region to 12-13 MJ kg^{-1} in some parts of the Sokolov region. Except for one mine, opencast surface mining does all mining. In 2014, 38.18 million tons of lignite were harvested and sold out of which, 98,2% was sold in the national market and 1.8% was exported.

In 2014, 38.18 million tons of lignite were harvested. However, these amounts are just a fraction of the amount mind in the peak of production in the ‘80s of the previous century, when the annual production exceeded 90 million tons. Lignite production in 2015-2020 is shown in Table 1. As Northwest Bohemia produces all lignite in CR, so lignite in the table means the production of the target region.

Table 1. Production of brown coal (lignite) in Czech Republic, based on Czech statistical office data (CSO, 2021)

Year	2015	2016	2017	2018	2019	2020
Brown coal [10^3 t]	38 105	38 528	39 306	39 191	37 499	29 497

Brown coal is a major source of energy. The production of lignite electricity has been gradually displaced mainly by growing production in nuclear power plants and renewable energy sources (Table 2). In 2005, lignite was centrally produced and supplied with 58 PJ heat, of which the total output was 139.2 PJ accounted for 41.6%. In 2013, central heat production declined to 122.2 PJ, and lignite was down produced and delivered 53.4 PJ. In eight years total heat production decreased by 18 PJ. Heat production of lignite fell by 4.5 PJ, but the share of lignite in total heat production increased from 41.6% to 44.1%. Lignite is mainly used for the production of electricity and heat in a wide range of power plants when particularly large energy companies with consumption above 50 MWt are of decisive importance. These are, in total 47. The largest producer of electricity in the Czech Republic is the company CEZ a.s., which is partly government-owned.

CEZ group also operate the largest coal feed plant in the country namely:

- Počerady, a.s. (CZ0048, 2 830MWth, 1970),
- Dětmarovice, (CZ0047, 2201.096 MWth 1975, use mostly black coal),
- Tušimice (CZ0016, 1971.2MWth 1974),
- Prunéřov 2 (CZ0015, 1754.4 MWMWth, 1981),
- Ledvice 3 (CZ0011, 1690.387, 1998), and
- Mělník III (CZ0013,1356.4MWMWth, 1981).

Among other large players is noteworthy group Seven energy (Chvaletice, CZ0046, 2298.8MWth 1977) and Sokolovská uhelná a.s. A large amount of energy is produced by cogeneration during heat production and by company power stations.

Most of the large unit’s coal feed CHP come into service between the 1970s and 1980s. However, some of the large units were recently upgraded (namely Tušimice 2007-2012) or have a new source installed (Ledvice 2017). However, concerning the requirement of high fuel efficiency, the construction of any new sources or the reconstruction of existing sources cannot be expected without the application of a significant part of the waste heat for heat supply. The overall efficiency in recently upgraded CHP plants such as Tušimice is declared 39%, in other plants the efficiency may vary between 32 to 34%. All major CHP plants were desulfurized in the 1990s. were desulfurized in 1990s.

Target region contributes significantly to overall country electricity production, namely Ústecký district produces 30% and Karlovarský district 6% of overall electricity production. The installed power output of the plant in Ústecký district is 3,964.6 MW and in Karlovarský district 549 MW.

Especially as regards Table 2 (see below), it must be mentioned that major categories are given in bold, inside these categories only selected examples are shown (these may together not give the total of the category). Note that lignite contribution is the contribution of lignite mining in the target region

Table 2. Composition of the energy mix in the Czech Republic (MRD, 2021)

Year	2013	2014	2015	2016	2017	2018	2019	2020
Revewables	**5.68%**	**10.95%**	**11.77%**	**10.11%**	**7.60%**	**6.17%**	**3.90%**	**6.75%**
Solar	1.96%	2.63%	2.88%	2.77%	2.14%	2.07%	1.66%	2.27%
Wind	0.47%	0.57%	0.71%	0.63%	0.45%	0.22%	0.00%	0.43%
Hydro	1.93%	2.56%	2.67%	1.15%	1.43%	0.77%	0.44%	0.65%
Biomass	1.33%	2.19%	2.34%	5.57%	3.58%	3.11%	1.81%	3.40%
Fossil fuel	**57.65%**	**52.77%**	**55.10%**	**59.53%**	**57.40%**	**56.95%**	**57.01%**	**52.50%**
Lignite	40.71%	41.27%	42.15%	43.91%	43.77%	44.63%	46.18%	40.00%
Gass	8.30%	5.52%	6.41%	8.40%	5.45%	5.80%	7.74%	9.61%
Nuclear	**36.67%**	**36.28%**	**33.13%**	**30.36%**	**35.01%**	**36.88%**	**39.09%**	**40.75%**

As concern renewables solar, wind and biomass belong to the most important energy sources in the Czech Republic (Table 2). Northwest Bohemia belongs to areas with comparatively lower potential compared to the southern and southeastern parts of the Czech Republic (Figure 1). However, differences inside the country are not large and the availability of large areas in post-mining sites may be beneficial for solar plants namely in sites with suitable exposition.

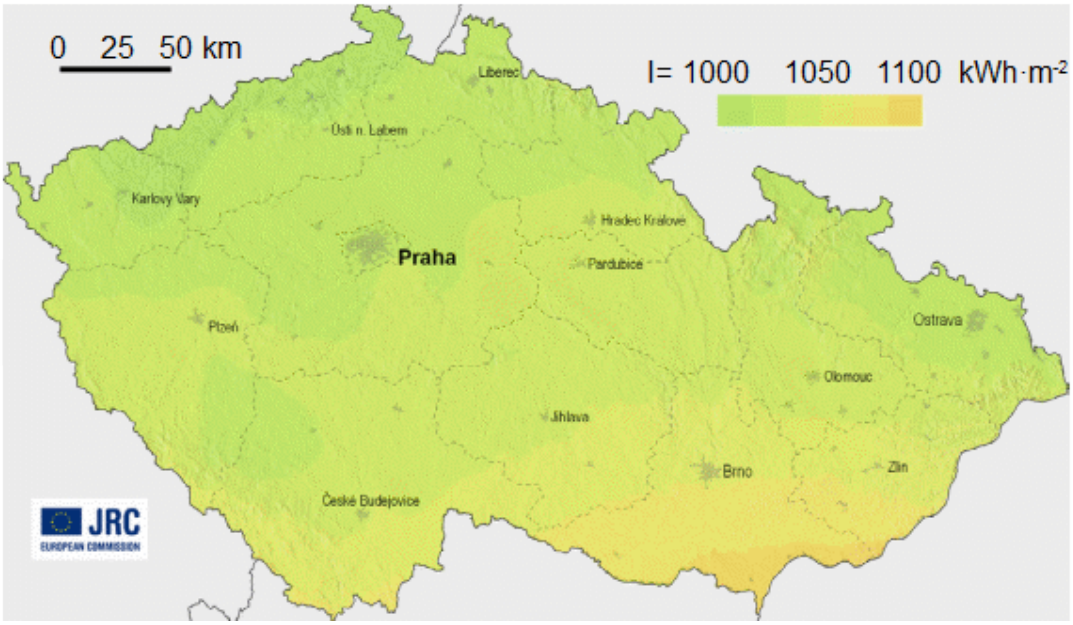

Figure 1. Amount of solar irradiation in various parts of the Czech Republic based on (ŠÚRI, 2010)

Most of the photovoltaic units in the target region were built after 2008 and 2009, on agricultural land. This was the consequence of the reduced price of solar panels in that period and the decision of the government of the Czech Republic form 2005 which highly limited possibilities to regulate prices of solar energy and by this fixed price of solar energy for a long-time frame.

On the contrary to solar, wind energy potential in mining areas and their close vicinity in northwest Bohemia may be comparatively more suitable for wind energy use. In some locations in the target area the density of wind power reaches 200-300 W/m^2 (ŠTEKL, 2006).

Also, some references (e.g. CHALUPA, 2015) indicate Northwest Bohemia as a suitable region for wind energy use (Figure 2). Economic return of wind power plant in Ústecký district is estimated to be 13 years.

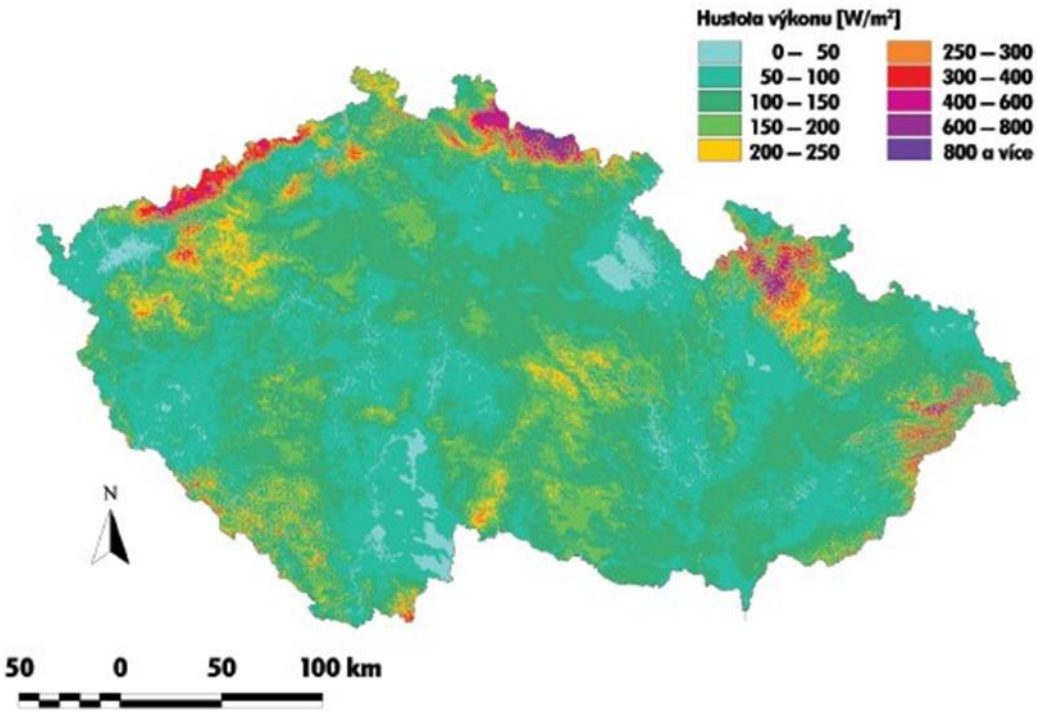

Figure 2. Spatial distribution of wind energy distribution in the Czech Republic based on (ŠTEKL, 2006)

Prevalence of wind is apparent also from table 3 showing installed power output MW of major renewable sources of electric energy in target regions. The target region, namely Karlovarsky and Ustecky District, are the leader in using wind energy in the Czech Republic. About 45% of all installed power output of the Czech Republic is located in these regions. In 2019 there were 40 windmills in Karlovarský and 43 in Ústecký district. Hydropower is given by existing reservoirs formed by dammed rivers.

Table 3. Installed power output (in MW) of major renewable sources of electric energy in target regions (KUBEŠOVÁ, 2017; HARNYCH, 2019)

	Karlovarský	Ústecký
Wind	51.2	87.8
Photovoltaics	13	17.7
Hydro	7.5	77.3

Both districts declare substantial potential of biomass production outside post-mining land as forest or agriculture. Post-mining sites have often lower fertility compared to mature soil. Despite that, an earlier study in Sokolov post-mining sites the potential for biomass production ranged from 1.9 t $ha^{-1} \cdot yr^{-1}$ dry weight (DW) on reclaimed sites to 2.6 t (DW) $ha^{-1}year^{-1}$ on un-reclaimed sites, and these estimates were within the range of biomass production previously reported for spontaneous re-growth forest on abandoned agriculture land. The potential production of trees and shrubs on post-mining sites, however, is less than that of poplar coppices on arable land (WERNER, 2012) or of other short-term rotation plan-stations on former arable land. Despite this, it is suggested that the woody vegetation on post-mining sites has substantial potential for bioenergy use. Moreover, in these sites, biomass production can be conveniently combined with soil improvement and sequestration of carbon in soil (CSO, 2021). This can be particularly cost-effective in the spontaneous regrowth on these sites

requires no cost for site establishment or maintenance but still supports biomass production comparable to that on plantations established on similar post-mining sites. Biomass production in meadows established in post-mining sites can be also interesting (ČÍŽKOVÁ, 2018) report overall aboveground biomass production in the established reclaimed meadow as 2.5 t (DW) $ha^{-1} \cdot yr^{-1}$.

2.3 North Bohemia Region's current energy related R&I landscape

In terms of research technology, development and innovation of the target region are underdeveloped in comparison to the rest of the country. This is in strong contrast with fact that region play important role in energetics, as well as in several industrial fields. As already mentioned, percentage of the workforce with university education is below the country average. Consequently, the target region is far below, country means in the number of institutions working in research and development number of workers in this sector as well as in spending on RD. This is true for absolute numbers but it gets even more pronounced when compared per 1000 inhabitants (Table 4).

Table 4. Number of research institutions, workers in RD and spending in thousands of euro in individual districts of the Czech Republic in 2020 (CSO, 2021)

	absolute numbers			per 1000 inhabitants	
	institutions	Workers	spending	workers	spending
Praha	690	14462	1646	10.9	1.24
Středočeský	311	2426	558	1.7	0.40
Jihočeský	147	1298	128	2.0	0.20
Plzeňský	137	1587	185	2.7	0.31
Karlovarský	27	101	9	0.3	0.03
Ústecký	121	677	53	0.8	0.06
Liberecký	130	850	135	1.9	0.30
Královéhradecký	150	1181	103	2.1	0.19
Pardubický	152	979	124	1.9	0.24
Vysočina	115	269	55	0.5	0.11
Jihomoravský	550	7398	772	6.2	0.65
Olomoucký	168	2003	163	3.2	0.26
Zlínský	220	844	137	1.4	0.24
Moravskoslezský	309	2117	226	1.8	0.19

There is one university in Ústecký district and no university in Karlovarský district. Several other universities have their outpost in those districts. The only University in target region is Jan Evangelista Purkyně University in Ústí nad Labem (UJEP). UJEP was established in 1991 currently have over 10 000 students and 900 employees.

UJEP consists of eight faculties:

- Faculty of Art and Design,
- Faculty of Arts,
- Faculty of Education,
- Faculty of the Environment,
- Faculty of Health Studies,
- Faculty of Mechanical Engineering,
- Faculty of Science and
- Faculty of Social and Economic Studies.

There are bachelor and master study programs in energy technologies at the Faculty of Mechanical Engineering.

Here should be stressed that the Czech Republic is a rather small country geographically and students often conduct their university education outside their home district. Traditionally most of the universities as well as research institutes are located in several major cities. Also, universities in these major cities namely Praha and Brno take a large share or high proportion of university students in the country. In this aspect, it is noteworthy, that there are 32 universities in the Czech Republic, which offer some kind of technical education.

As an example, several major technical universities which conduct some research in the field of energy technologies are listed here:

- Czech technical University in Prague (https://www.cvut.cz/en),
- Brno University of Technology (https://www.vut.cz/en),
- Technical University of Ostrava (https://www.vsb.cz/en),
- University of West Bohemia (https://www.zcu.cz/en/index.html) and
- Technical University of Liberec (https://www.tul.cz/en/home-page/).

Besides universities stands Czech Academy of Sciences harbour Institute of thermomechanics (https://www.it.cas.cz/en/homepage-en/) which deals with basic research related to energy technologies. There are six large research infrastructures (supported by the Ministry of education) that provide services to the research community in various aspects of energy-related research (https://www.vyzkumne-infrastruktury.cz/en/energy/).

Large interests of research institutions outside the region can be seen also in cooperation with mining companies. There is no publicly available statistics describing such cooperation but Web of science record 57 papers where Czech mining companies are mentioned, most of them coming from an institution outside the target region and 14 papers published in the past 10 years explicitly acknowledge mining company as a funding source.

Funding opportunities expected concerning green deal and transformation of coal intensive region represent an opportunity for energy-related research in the Czech Republic as well as in the target region as summarized in SWOT analysis (Table 5).

Table 5. SWOT analysis of regional innovation potential and specialisation

Strengths Established energy related research in the Czech Republic outside target region. Generally good level of research in the Czech Republic Established system of research funding in the Czech Republic.	**W**eakness Weak developed research infrastructure in target region Lack of highly qualified and educated workers Low experience with R&D project in target region
Opportunities Large industrial facilities in target region Large investments planned (expected) in coal region transformation Coal region transformation and associated opportunities may attract RD and educational institution from rest of the country	**T**reats Mismanagement due to low-experience with R&D project in target region Low attractively of the region for highly qualified workers Obstacles in R&D projects due to low development of infrastructure in target region Many funding opportunities are targeting local institution in target region, which are limited in terms of their absorption capacity. This may also limit participation of R&D capacities coming from rest of the country

3 R&I in Energy and Environment: Vision for 2030 & 2050

3.1 Objectives and outcomes

The most important framework for future coal usage on the national level is the territorial limits of brown coal mining in Northern Bohemia adopted by binding resolution of the Czech government lead by Petr Pithart, No. 444 of 30 October 1991. It defines the lines for which mining in individual North Bohemian mines is not allowed. These limits were with some corrections respected by the next governments. In 2008, the government led by Mirek Topolánek, confirmed the limits by resolution no. 1176/2008, modifying the line of the Bílina mine. Further adjustments to the limits at the Bílina mine in 2015 by Government Resolution 827/2015, when the lines were mostly further shifted in favour of future mining, however in some places, namely near the village of Braňany the mining space was reduced.

Another key document on the national level is “State energy conception of the Czech Republic” adopted by the Czech government in 2015. The main mission of the State Energy Conception (SEC) is to ensure reliable, safe and environmentally friendly energy supply for the needs of the population economy and the Czech Republic at competitive and affordable prices under standard conditions. At the same time, it must ensure an uninterrupted energy supply in crises to the extent necessary for the functioning of the most important components of the state and the survival of the population. The vision thus defined is summarized in a triad the top strategic goals of the Czech energy industry, which are security – competitiveness - sustainability. The conception defines corridors that determine the expected and desirable development of energy mix until 2050 (MIT, 2015).

Conception expects decommissioning old coal-fired power plants (from 2016 to 2025), commencing operation of new nuclear units and replacing decommissioned units Dukovany nuclear power plant with new nuclear unit sources (between 2033 and 2037). The main changes in the balance of electricity production are gradual a decrease in production from lignite power plants and an increase in production from nuclear power plants. It is also planned reduction of electricity surplus, which is now realized as export of electricity.

In terms of coal important are namely plants in the area of energy and heat production, which are often coupled in the Czech Republic.

In the field of electricity generation and supply, it is essential to transform by 2040 ensuring a change in the structure of production and renewal of the old production plants with significantly higher efficiency, by a partial exit from coal towards nuclear power, natural gas and renewables. In the sector of coal energy following steps are emphasized in particular: Provide conditions for the reconstruction of existing large condensation coal sources exclusively for high-efficiency sources according to best available technical standards and their operation within the SEC horizon for the availability of brown coal and without negative impact on coal supplies for energy-efficient systems. Possible new coal sources should be oriented to high-efficiency or cogeneration production with a minimum annual energy conversion efficiency of 60% or best available technical standards efficiency if any higher, in the overall range of the coal power industry corresponding to the target range solid fuels. Effective penalties for low-efficiency condensation-generated electricity should be introduced since 2015 with increasing progress. Within the framework of the Czech Republic's raw material policy, ensure a sufficient supply of brown coal for the needs of heating plants with preferential access to fuel only to the extent of high-efficiency cogeneration production versus condensation sources. State energetic policy expects also increase the proportion of renewables in electricity production.

3.2 Key guiding principles

Many documents drive energy transformation and consequently related support to DR in this field. State energy concept SEC and conceptual documents about using EU funds for the fair transformation of coal intensive region highlight the following principles.

State energy policy highlights need for security - competitiveness - sustainability. This is manifested by an emphasis on a reliable, affordable and long-term sustainable supply of energy to households and the economy. The next principle highlighted in SEC is to ensure economic return on investment of all types of resources and networks. Also, emphasis is given to the following:

- Ensuring complementarity of support from various sources.
- Creating a balance between research and innovation.
- Adopting a nexus approach.
- Ensuring coordination and cooperation between public, private and research entities.
- Including local stakeholders in the decision-making process.

4 Support framework for R&I in Energy and Environment

4.1 Multi-level governance structure for R&I policies in the North Bohemia Region

Most of the problems of future development of the target region were already described above. Mining in past attracted a large amount of less qualified workers to the region. Social situation and lower quality of environments force part of a more adaptable and more educated portion of citizens to leave the region. This causes that the target district has the lowest proportion of university-educated people in the population in the Czech Republic. Moreover, fact that most of the people come here after WWII caused that there are very few people which would have family roots in the region. The latter was caused not only by mining but also complex development of the region before and after WWII. The reduction of mining during the last decade of the previous century largely increased the unemployment rate. Moreover, the most affected were people with lover education and socially less adaptable. This results in the formation of socially excluded locations increase criminality and other unfavourable social effects, which make the region even less attractive for developers and people starting new businesses. This was enhanced by infrastructure, which was generally outdated by the end of the last century and specialized in need of mining industry. This was enhanced by fact that the mining company was able to build its infrastructure if needed. All this create very complex conditions for future development.

There has been several regional targeted efforts attempting to improve the situation, some of them coming from the national level. Based on government decision No 952 from 11th December of 2013 was established government commissioner for coal region in transition, namely for Moravskoslezký and Ústecký district. Later on, from 1st November of 2015, the jurisdiction of the commissioner was enlarged to include also Karlovarský district. Priority topics of the government commissioner are:

1) employment and entrepreneurship,
2) technical education,
3) science, research and innovation,
4) energy and environment,
5) building infrastructure.

The Ústí nad Labem, Moravskoslezský and Karlovy Vary Regions, through the Office of the Government, applied for financial and systemic support for specific measures that will help restart the economy of these regions. The Office of the Government Plenipotentiary proposed the creation of an Economic Restructuring Strategy in which the government and the region would work together. By Resolution No. 826 of 19 October 2015, the Government decided on the economic restructuring of the Ústí, Moravskoslezský and Karlovy Vary Regions. The government has indicated that it is aware of the problems in these structurally affected areas and has committed itself to halting their backwardness and to starting their prosperity. The Ministry for Regional Development commissioned an input analysis which assessed in detail

the current situation, the most serious problems and the development potential of the regions concerned. This important document was based not only on extensive macroeconomic analysis but also on the collection of impulses and experience, which took place directly in individual regions. Based on the input analysis, a strategic framework was created. This important document does not yet contain a proposal for concrete measures but identifies their basic principles common to all regions. The Strategic Framework expresses the government's long-term strategy to support, facilitate a accelerate the restructuring of the economy in structurally affected regions. According to this, the regions concerned, in cooperation with the government, will take actions in all key areas. The strategic framework is structured into several levels. At the highest level, they are divided into thematic pillars, which include desirable changes in individual thematic areas. Each thematic pillar has several strategic objectives.

The strategic objectives are designed in such a way that their fulfilment will lead to the realization of the key changes described both in the individual thematic pillars and for each strategic objective separately. For each strategic objective, several types of measures/ activities are proposed that describe in more detail the possible interventions through which changes can be made and the strategic objectives can be achieved. Typical measures/ activities are mainly illustrative in nature and are intended to show that there are tools to achieve the proposed changes. In the introductory part of each pillar of the Strategic Framework for Economic Restructuring, the content of the thematic pillar is briefly presented. The Strategic Framework also includes, as a special pillar of the Implementation Framework, which describes and explains the concept of implementation mechanisms and rules, the institutional framework of implementation and also deals with the principles for future financing of the implementation of the Economic Restructuring Strategy, resp. measures in the action plan.

Strategy is approaching this issue in a very complex way and focal at all-major issues, which can be, separated into following major categories: enterprise and innovation, direct foreign investment, research and development, human resources, environment, social stabilizations and infrastructure and public administration. In the next text, major targets in individual fields will be described in more detail.

4.1.1 Enterprise and innovation

The basis for economic restructuring is successful businesses or enterprises in the region, when enterprises grow, employ people, invest, generate and realize a profit, they at the same time form basic conditions for improving the quality of life in regions. Target regions are more dependent on one large traditional (mining) companies. That is why the uncertain future of large traditional enterprises has a negative impact on the whole economy. In addition, the target region has the lowest intensity of entrepreneurial activity and low dynamics of start-ups of new enterprises of all regions in the Czech Republic. This strengthens the trend of leaving younger, more educated people. In addition, remote, areas of a rural nature still exist in the target region, which is among the least developed. During the preparation of the smart specialization strategy, the target regions identified key sectors that represent a balanced mix between traditional industries (energy, metallurgy, engineering) and new ones (information technology, biotechnology, renewable energy use, reclamation), existing farm structure and change it completely.

Direct foreign investment, is another sector that may help substantially increase economic growth or target region however the creation of a suitable environment for investment is reputed to offer suitable spaces, infrastructure and a stable economic environment.

4.1.2 Research and development

The major target here is to support research with a direct effect on enterprises, promote partnership of research and development companies with the business and also support academic start-ups.

4.1.3 Human resources

Human resources are key to the successful development of the region. They were negatively affected in past as described above which generate self-enhancing interactions between low economic growth low salaries and low offer of highly qualified jobs, low quality of the workforce. Solution closely corresponds with previous tasks, research and development enterprises and foreign investment.

4.1.4 Environment

Investments in the revitalization and regeneration of territories and settlements alone will not contribute to the restructuring of the economy, but they are a precondition for carrying out activities supporting the development and growth of enterprises (brownfields regeneration, business premises), foreign investments (brownfields, industrial zones and lands) human resources development, social stabilization and research and development. Reconstruct unused areas and territories to implement significant investment activities with higher added value in connection with services for investors and entrepreneurs. We should (1) revitalize and regenerate areas in regions heavily affected by the mining and industrial activities, in particular, to enable new activities to be located and given new functions, and (2) regenerate development, deprived or peripheral areas in settlements with a high population concentration to achieve substantial complex changes with a significant impact on the life of the whole city, which will also manifest themselves in improving the image of regions externally and it will have an impact on stabilizing the population and improving the social stability of the territory. As was mentioned above environment was one of the factors that enhance the migration of people out for the target region.

4.1.5 Social stabilizations

Social instability is one of the factors resulting from the slow economic development of target regions and is a factor that complicates this development. On average, the lower quality of human resources and the greater number of socially disadvantaged and excluded people limit the development of local businesses, create local social problems and negatively affect the image of regions. The human dimension of social stabilization is aimed at motivating the population in the regions concerned to increase their activities.

In this context, three different groups must be supported in somewhat different ways:

1) to encourage naturally active citizens who are already contributing to the development of regions and who will be permanent leaders and natural authorities for the rest of the population and will contribute to the transformation of regions;
2) increase the motivation of passive individuals, who have relatively high development potential and can form a critical mass of long-term active residents in the region.

4.1.6 Infrastructure and public administration

Investing in infrastructure and quality of public administration creates the conditions for more efficient or successful interventions in other areas. These investments alone will not lead to the restructuring of the economy; however, they are important supportive measures for investment in other areas, especially business and foreign investment, such as key transport infrastructure connections or offering efficient public administration services.

The basic and interconnecting element of all the above-mentioned pillars to change the structure of the economy, accelerate economic growth and stop regions lagging behind is the implementation pillar including multi-level cooperation of public administration, use of existing programs and financial resources, supplemented, if necessary, by new ones, professional implementation management and responsibility for results. All pillars should lead to strengthening the identity, belonging and increasing the self-confidence of local people, improving the image of the region among investors, tourists, talents.

It is the base for project RE:START2. The RE: START program is an open and publicly discussed process of restructuring the three regions concerned with the involvement of hundreds of actors, is managed at the government level and is subject to regular evaluation and updating flexibly responding to socio-economic developments in the regions concerned. As a result, governments and regions are given a transparent, systemic and long-term tool to address the specific problems of a large area. This eliminates the fact that dozens of regional actors submit individual requirements which, when implemented separately, are usually not subject to impact assessment and often require the adoption of non-systematic exceptions. The system created in this way is also positively evaluated by the European Commission, which continuously monitors the progress of the RE: START program and supports it in the framework of the Platform for Coal Regions in Transition. On January 1, 2019, new implementation policies came into force, responding to the need for several changes. The Office of the Government Plenipotentiary was abolished, the coordinating role at the central level was transferred to the Ministry for Regional Development, within which the National Executive Team RE: START was established. At the same time, by the principle of subsidiarity, the involvement of individual regions was strengthened through the Regional Permanent Conferences. The aim of the new implementation structure is to maintain a centrally coordinated approach, but to maximize the absorption capacity in the territory and strengthen the individual approach to individual regions. These new implementation policies have been valid for the following years of RE: START since their approval.

3rd updated Action Plan10 is currently approved based on the principles defined by the Strategic Framework for Economic Restructuring of the Ústí, Moravian-Silesian and Karlovy Vary Regions. It is a set of concrete measures that the government requires the relevant ministers to implement. Measures are in the form of financial support or systemic changes. Funds are allocated through individual grant programs/ministries/managing bodies of operational programs. If approved, the proposed measures will be implemented in the years 2019 - 2030. The implementation of all measures to this extent represents a claim for funds amounting to CZK 10,090 million.

Finally, there are Regional innovation strategies (RIS) which reflect all above mentioned documents as well as analysis of workforce actual enterprises and other local factors. Here is presented the major outcome of RIS for Karlovarský and Ústecký district (KVBDA, 2020; UD, 2020).

Major regional domains of specialization in Karlovarský region identified in RIS are:

1) Mechanical engineering, electrical engineering and mechatronics;
2) Automotive industry and autonomous transport;
3) Traditional industries - ceramics, porcelain and glass;
4) Energy transformation and new challenges;
5) Spa, balneology and tourism.

In terms of coal transition number of obstacles are mentioned, but also some opportunities such as the release of large areas equipped with technical infrastructure with the possibility of use for new activities, new business opportunities (eg new ways of producing energy, installation of RES) or new industrial activities. In fact, not mentioned in the RIS, but an important example is maz by the building of BMW testing facility in Podkrušnohorská Heap (I-DNES.CZ , 2021).

In addition to classical renewables such as wind, solar or biomass Sokolov district has the strategic advantage of Lake Medard and also planned in the future lake in the locality of the current Jiří quarry in the form of a strategic water reservoir. An example of the transformation of the area affected by mining activities can be mentioned in the project greenhouse economy. This project could be implemented on a brownfield after the termination of mining activities using the potential of Lake Medard, both for supply heat through heat pumps, as well as for irrigation and also for use other renewable energy sources.

Major regional domains of specialization in Ústecký region identified in RIS are:

1) Energy; resources, supply and related fields
2) Organic and inorganic chemistry
3) Glass and ceramics
4) New opportunities, namely machinery industry, automotive, mobility

In terms of new energy sources, new ways of energy utilization (smart technologies of energy transmission, storage and consumption, geothermal energy and other renewable sources, battery storage, utilization of waste heat) are mentioned in particular.

4.2 Funding opportunities

As concern funding, besides private funding and funding coming from European sources described in part 4.4 major source of funding in technologically oriented research and development in the Czech Republic is the Technology Agency of the Czech Republic (TACR). TACR is an organizational unit of the state that was founded in 2009 by Act No. 130/2002 Coll. The creation of TA CR is one of the cornerstones of the fundamental reforms in research and development (R&D) in the Czech Republic. The key feature of the reform is the redistribution of financial support from the national budget. The Technology Agency of the Czech Republic simplifies the state support of applied research and experimental development which has been fragmented and implemented by many bodies before the reform. Czech science foundation (GACR) is a principal government-funded agency that supports targeted basic researches some of which may have some relation to energy research. Besides TACR and GACR several ministries may potentially support energy-related research. Noteworthy is the Ministry of Education, Youth and Sport of the Czech Republic which administers most of EU funded research programmes targeting basic research.

4.3 Priority areas for Research and Innovation

Considering the large share of coal in the energy production of the Czech Republic, replacement energy provided by coal will represent the complex issue. So far State energy policy count on partial replacement of coal by other fossil fuels namely by natural gas. In the sector of smaller energy sources that use cogeneration to produce heat and electricity, there is already use of other fuel namely biomass and household waste and it is expected that share of these fuels in the mix will increase over time (see part 3.1 for more details).

Traditionally biofuel has a dominant position among renewables in the Czech Republic and as already explained above post-mining sites provide opportunities to increase biofuel production, which may even bring benefits in terms of ecosystem restoration and carbon sequestration in the soil at the same time (see part 1.2 and 1.3 for more details).

Among other renewables potential for solar energy in terms of natural conditions is similar as in the rest of the country of slightly below average. However, a large areas of post-mining heaps may offer possibilities for large scale installations. There are even plants to install floating power plants in lakes which will be formed by the flooding of residual mining pit (I-DNES.CZ , 2019).

In contrary to solar natural conditions for use of wind energy is exceptionally good in the target region also a number of windmills already installed is higher than in other parts of the country and post-mining heaps namely those having hill like character may potentially represent the good location for new windmill farm (see part 1.3 for more details).

Hydropower is given by existing reservoirs formed by dammed rivers; however, there are plants to use the difference in water level between some already projected post-mining lakes (formed by the flooding of mining pits for pumped-storage hydroelectricity (IUHLÍ.CZ, 2018).

Heat pumps are also often mentioned. Among other renewables with have decent and largely underexplored potential in Northwest Bohemia is geothermal energy (Litoměřice, 2013). Town Litoměřice is recently building a geothermal heat plant using a hot dry rock system with

expected production of 15-30 MWt. In Karlovy Vary are the hot springs used for a bath and various balneogical applications, this may prevent their more extensive uses for energy.

Despite fact that energy storage is often mentioned in RIS strategies particular projects aiming in this direction are rare.

Besides energy production, RIS in Northwest bohemia emphasize specialization in glass and ceramics, which are traditional field here, and various aspect of mechanical engineering namely associated with the automotive industry and mobility. Recreation and bath are mentioned in the Karlovarský district.

4.4 Evaluation and Monitoring

There are several ministries in the Czech Republic which are responsible for distribution and monitoring of the fund potentially useable for RD investment during the transformation of coal intensive regions. Ministry of Regional Development is responsible for the coordination of all funds coming from the EU, providing methodical support and ensuring coordination, however individual programs are in the hand of individual field specific ministries. However, in the forthcoming period 2021-2027 monitoring scheme for most of the programs has not yet been established. In subsequent programming period 2021-2027, which will be co-funded from the European Structural and Investment Funds (ESIF) following programmes may be relevant to support RTDI in coal intensive region:

- Operational Programme Technologies and Application for Competitiveness, managed by the Ministry of Industry and Trade;
- Operational Programme John Amos Comenius, managed by the Ministry of Education, Youth and Sports;
- Operational Programme Transport, managed by the Ministry of Transport;
- Operational Programme Environment, managed by the Ministry of the Environment;
- Integrated Regional Operational Programme, managed by the Ministry of Regional Development;
- Operational Programme Just Transition Fund, managed by the Ministry of the Environment;
- Operational Programme Technical Assistance, managed by the Ministry of Regional Development;
- Interreg V-A Czech Republic – Poland, managed by the Ministry of Regional Development;
- Cooperation Programme Free State of Saxony – Czech Republic, coordinated, in the territory of the Czech Republic, by the Ministry of Regional Development
- Interregional cooperation programme INTERREG EUROPE, coordinated, in the territory of the Czech Republic, by the Ministry of Regional Development;

Among those Operational Programme Technologies and Application for Competitiveness, managed by the Ministry of Industry and Trade and Operational Programme Just Transition Fund, managed by the Ministry of the Environment seems to be the most relevant. Monitoring schemes although they follow similar principles differ between ministries. The Operational Program Technologies and Application for Competitiveness (OP TAC) is the direct successor of the Operational Program Enterprise and Innovation for Competitiveness.

Its priorities are:

- Research and innovation;
- Digitization and development of the internet;
- Skills for smart specialization, industrial transformation and entrepreneurship;
- Enhancing the competitiveness of small and medium-sized enterprises;
- Increasing the added value of products and services in the production chain;
- Introducing advanced technologies and Industry 4.0 principles in companies;
- Modernizing and streamlining the production, distribution and storage of energy;

- Increasing the energy efficiency and energy savings;
- Deploying innovative low-carbon technologies; Effective and thrifty use of renewable energy sources;
- Introducing modern and highly efficient methods of production, distribution and storage of heat energy;
- Use of brownfields for business activities.

The Fair Transformation Operational Program is completely new in the period 2021–2027 aimed at addressing the negative effects of coal diversion in the most affected regions. In the Czech Republic, this applies to the Karlovy Vary, Moravian-Silesian and Ústí regions. The support aims to enable regions and people to address the social, economic and environmental impacts of a transformation aimed at achieving the Union's 2030 energy and climate goals and the Union's climate-neutral economy by 2050. A wide range of topics can be supported in this programme: small and medium enterprises, research and innovation, digitization, clean energy and energy savings, circular economy, reclamation and new land use, retraining and job search assistance. The program aims to direct resources from the Fair Transformation Fund to areas not covered by other operational programs. These are extra resources for the regions concerned compared to other regions. The exact wording of the program is under preparation, and the draft program will be published in the first half of 2022. The program will be based on the Plan of Fair Territorial Transformation, which is prepared by the Ministry of Regional Development in cooperation with members of the so-called Transformation Platform.

In addition to these programmes supported by individual ministries, the government established program RE:START to support coordination of funding from various sources and to give governments and regions a transparent, systemic and long-term tool to address the specific problems of coal intensive regions. The RE: START program is an open and publicly discussed process of restructuring the coal intensive regions concerned with the involvement of many stakeholders, RESTART is managed at the government level and is subject to regular evaluation and updating flexibly responding to socio-economic developments in the regions concerned.

5 Concluding note

North Bohemia represents coal intensive regions which contain most of the mineable lignite resources in the country and all lignite in the Czech Republic is mined here. At the same time lignite mined in this region is an important part of the Czech Republic energy mix contributing 40% in 2020. Four mining companies mine coal in this region. Most of the coal is used in the power plant of CEZ largest energy company in the Czech Republic, which is partly government-owned.

RTDI facilities in the target region are underdeveloped. There is only one university in the region and in numbers of research institutions, workers in RD, as well as investment in RD in the target region, belong to the lowest in the Czech Republic. On the other hand, there are many universities, research institutions and large research infrastructures engaged in energy-related research or other technical and environmentally oriented research that is potentially relevant for the target region. Many of these institutions conduct their research in the target region already. Focusing future support of RD only on institutions that are located in the target region may face the problem of the low absorption capacity of these institutions.

RTDI strategy is affected by the expected development of coal mining driven by territorial limits, state energy concept and decision of coal commission. At the regional level, DR needs are summarized in RIS (research and innovation strategy of individual regions).

The most highlighted field of specialization are:

- Mechanical engineering, electrical engineering and mechatronics;
- Mobility including Automotive industry and autonomous transport;
- Traditional industries - ceramics, porcelain and glass;

- Energy transformation and new challenges related to the transition of coal intensive region and spa, balneology and tourism.

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6.1 Tables and figures

6.1.1 Tables

6.1.2 Figures