Smart strategies for the transition in coal intensive regions

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Technical concepts for the transition of the energy system into a smart, sustainable and renewable energy system in the TRACER target regions

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TRACER website: www.tracer-h2020.eu

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1 Executive summary

Energy generation technologies based on coal are still very widely used in the TRACER target regions. The transition can therefore be a long, technical way, with many other aspects to be considered.

The transition process has progressed very differently in the target countries. Some are well on the way to renewable energy generation on a central (large) or decentralized (small) level. Some countries use coal not only for electricity and heat generation in power plants, but also for heating purposes at the consumer level, e.g. single stoves in households.

The path to renewable energy generation is particularly difficult, since it is progressing too slowly in many countries and some countries therefore use natural gas as an intermediate route.

Concepts are therefore required that avoid or at least minimize this intermediate step and show implementation options for renewable energy (central, decentralized). This report analyses the current situation in the TRACER target countries and shows technical concepts for the transition from coal to renewable energy.

2 Introduction

This report shows a status on the current energy generation technologies using coal as feedstock for each TRACER target region. This includes the analysis of the coal driven power plants, CHP plants, as well as the use of coal for small applications, e.g. space heating. The investigations include the used technologies, age of the installations, efficiency, emissions, capacities and economies.

Furthermore, the current status of other energy generation technologies in the target regions, based on gas, oil and renewable energies is analysed. This report will determine the level of the energy transition from a fossil-based economy towards an emission-free economy. Thereby, the technological challenges and opportunities will be identified, e.g. the technical integration of decentralised renewable energy technologies in the existing infrastructure (e.g. district heating, power grid).

Another challenge may include the potential use of post-mining land for renewable energy installations, like PV or biomass production. Opportunities include all aspects related to the carbon-free and renewable technologies that could allow more participation of the public in the sector and having a large positive social impact.

The final outcome of this report is a technical transition concept for each TRACER target region, that includes proposals for the stepwise technical energy transition towards an efficient emission-free energy sector, using renewable energy technologies, such as solar, wind, hydropower or biomass.

3 Bulgaria, Yugoiztochen Region

3.1 Current energy generation technologies using coal

3.1.1 Coal driven power plants, CHP plants

Maritsa East Complex covers an area of 240 km^2 and is almost entirely located on the territory of Stara Zagora District (BG344, NUTS 3 level). Stara Zagora district occupies 5,129 km^2 - 26% of the territory of the Yugoiztochen Region, which has an area of 19,664 km^2 (about 18% of the territory of Bulgaria). The main settlements on the territory of the complex are the towns of Radnevo and Galabovo, located in the south-eastern part of the district.

Figure 1: Map of SE Region

The Maritsa East lignite basin has industrial reserves of more than 1,850 Mt. The economic analyses show that the extraction potential of the mines is in the range of 18 to 32 Mt per year. Extraction below 18 Mt is economically inefficient[1]. With an annual production of about 30 Mt it provides about 43% of the total domestic electricity consumption of Bulgaria.

Mining in the basin started in 1952 and by 2018 nearly 1,190 Mt of lignite had been extracted.

The coal produced is burnt in 5 power plants with different characteristics, depending on the years when they were built, their maintenance and their current state. For the period 1960 to 2018 about 500 TWh of electricity was produced in the power plants using this coal.

Today, Maritsa East complex, together with the Kozloduy nuclear power plant and the hydropower cascades, constitutes the backbone of the Bulgarian electricity sector.

3.1.1.1 Brickel TPP

The Brickel TPP was commissioned in the period 1959 - 1963 under the name "Maritza East 1" with 4 turbogenerators of 50 MW each and 5 steam generators with a thermal capacity of 670 MW_{th} in total. Dried lignites from the Maritsa East basin are burned. The turbines are back-pressure ones, with some of the heat extracted being used to enrich the fuel used in plant and for the central heating of the nearby town of Galabovo. Flue Gas Desulphurization (FGD) facilities

[1] These quantities are the sum of those of each mine – Troyanovo 1, 3 and North – which are specific and cannot be evenly distributed.

were installed, operating on calcium oxide. The power plant has exhausted technical, economic and moral resources and should not be taken into account for future operation.

3.1.1.2 Maritsa 3-Dimitrovgrad TPP

This is a condensing plant commissioned in the 1960s, but the still operating one single unit was commissioned in 1972 with an installed capacity of 120 MW. The TPP works with dried lignite from the Maritsa East complex (1,800 - 2,000 kCal/kg).

Its outdated resource renders any updating ineffective and the power plant has to be discontinued over the next few years.

3.1.1.3 AES-3C Maritsa-East 1 TPP

The AES-3C Maritsa-East 1 TPP was commissioned in 2011. There are two 343 MW units built using modern technology: the first was put into operation in 2011 and the second - in 2012. The facilities state of the art and the technology applied allow the power plant to produce 3.5 - 5.0 TWh annually, which will require 5.6 to 8.0 Mt of coal. The power plant has a highly efficient (98%) FGD installation. There is high flexibility for plants with such fuel, stable minimum load of 40% of the nominal.

Despite its high performance, sulphur oxides and mercury emissions do not meet the requirements of the Reference Document for Best Available Techniques for Large Combustion Plants (LCP BREF).

3.1.1.4 Maritsa-East 2 TPP

The Maritsa-East 2 TPP has been put into operation in several stages. *The first stage* covers the period 1967-1969, when 4 units of 150 MW each were built, which were then systematically rehabilitated in the periods 1980-1985, 2004-2009 and 2014-2018 with the replacement of steam generators and Japanese production turbines. The installed capacity has been increased to 1,620 MW. After replacement of the turbines, the modernization of the boilers and the installation of desulphurization installations, units 1, 2, 3 and 4 have an extended license until 2035 to 2038.

The condition of facilities and the respective technologies allow the power plant to generate 8.10 to 12.15 TWh of electricity, with an annual operating capacity of 5,000 to 7,500 h, which requires 12.98 to 19.46 Mt of coal.

During the second phase in 1985, units 5 and 6 of 210 MW each were built and put into operation. In 2010-2011, they were rehabilitated and their efficiency was enhanced, increasing their capacity to 227 MW. During the rehabilitation, FGD installations with efficiency of 98% were built.

In the third stage, units 7 and 8 were built: in 1991 - unit 7, and in 1995 - unit 8, and to both of them from 1998 to 2001 FGD installations were added, with 94% - 96%.

By enhancing efficiency, the capacity of the two units was increased from 215 to 235 MW in 2015-2016.

The combustion technology, especially at units 5, 6, 7 and 8, is in line with the available good techniques for lignite. Despite the low flexibility of the steam generators, the plant is partly involved in the primary regulation and has limited participation in the secondary regulation, also with contribution in controlling the minimum load of the electrical power system.

Despite the plants high performance, emissions of nitrogen and sulphur oxides and mercury do not meet the requirements of the Reference Document for Best Available Techniques for Large Combustion Plants (LCP BREF).

3.1.1.5 Maritsa-East 3 Contour Global TPP

The Maritsa-East 3 Contour Global TPP was put into operation in the period 1978 ÷ 1982 when 4 units of 210 MW were successively introduced. Rehabilitation was carried out in 2004-2008, increasing the capacity of the turbines from 210 to 227 MW with the retained performance of steam generators. The FGD installations efficiency is 94 - 96%.

With an annual operating capacity of 5,000 ÷ 7,500 h, the plant could produce 4.54 ÷ 6.80 TWh of electricity - gross, which would require 7.27 ÷ 10.91 Mt of coal.

The commercial life of the units expires in 2030, 2031, 2032 and 2033, when after certain repair and rehabilitation activities and investments the license is expected to be confirmed by 2040 and probably beyond.

In order to maintain and modernize production, the owner declares investment intentions up to 200 MEuro in the period up to 2027.

The flexibility and the emissions are similar to those of the Maritsa East 2 TPP.

The annual electricity generation of the power plants in Maritsa East coal mines sub-area is shown in the following Table 1.

Table 1: Selected parameters of ME power plants

	Thermal Power Plant	Capacity, MW	Generation, GWh	Efficiency,%	FGD Efficiency,%
1	Brickel (former Maritsa-East 1)	200	500 - 600	<30	-
2	Maritsa 3-Dimitrovgrad	120	300 - 400	<30	-
3	Maritsa-East 2	1,620	8,000 – 10,000	~33	96-98
4	Maritsa-East 3 Contour Global	908	4,000 – 5,000	~33	94-96
5	AES-3C Maritsa-East 1 TPP	686	2,500 – 3,500	~33	98

The efficiency of the large power plants is about 39% gross and 33% net.

3.1.2 Use of coal for small applications

The coal extracted in the Maritsa East Basin is not suitable for use in small heaters - stoves, boilers, fireplaces. The lignite of the Maritsa East deposit possesses an average calorific value 1,560 kcal/kg with high humidity (over 50%) and high ash content (32 ÷ 41%) and sulphur (over 2.2%). The possibility to burn them is provided by processing them in briquettes in the Briquette Factory at the Maritsa East 1 TPP (since June 30, 2000 both united in Brickel EAD), for which process coal is selected with higher calorific value – 1,750 kCal/kg and with sulphur up to 4.5% coals are dried, crushed, sieved and pressed to produce the specified briquette form. The calorific value achieved is about 4,500 kCal/kg.

The briquettes are used for two purposes: heating with stoves from the population and burning in Brickel TPP, District Heating Sliven and District Heating Pernik. About 2,000 households in Galabovo are supplied with hot water from Brickel.

Briquettes are fragile and in transport, the need to transfer them from one vehicle to another leads to a high percentage of losses. Their smoke has a sharp smell of sulphur. In households everyday use, briquettes should be burned with wood.

The Bulgarian government has repeatedly decided, on a proposal from the Ministry of Environment and Waters, to suspend Brickel's work, but the suspension is postponed due to strikes of the workers, encouraged by the owner of the plant and the briquette factory. Recently, the Regional Environmental Inspection temporarily suspended and fined them for trying to incinerate unregulated waste.

Coal from other mines, such as the higher calorific value mines in Bobovdol, are hardly used in the region. And these mines are about to shut down too.

In the region, like anywhere in Bulgaria, imported coal is preferred and sold in different packages, which cost around 170 - 200 €/t depending on the quantity, packaging, delivery station etc. The price for district heating of the companies operating in the cities Sliven and Burgas is about 50 €/MWh. It should be added that these prices are set by the Regulator (EWRC) based on the justification and proposal of the heating companies.

The prices of the stoves range from 100 – 1,000 € depending on the capacity, efficiency and quality. Commonly used stoves are old technology - there is a stove in every room that is used only when needed - for example, the bedroom is heated before going to bed.

High quality bituminous and anthracite coal combustion emissions are 0.37 kgCO_2/kWh (HVAC-eco 2020).

Due to pollution, unpleasant service and low efficiency, coal stoves are replaced when needed or purposefully by heaters with other technologies - air conditioners, pellets, gas boilers.

3.2 Current status of other energy generation technologies

The energy generation opportunities in the region, primarily from RES, are significant. Natural gas is currently of no interest for this purpose because there is enough cheap electricity produced from coal. Fuel cell technology is not yet sufficiently used in the region, but it can be expected in the future if there is a change in the economic factors and the regulatory system. The prospect of expansion is for RES.

The following chapter presents the achievements and the potential for development of RES generation. The section begins with a brief summary of the use of biomass, which is the traditional common heating in rural areas, but statistics provide information only at the highest level - for the country.

3.2.1 Biomass

The widely used wood-burning appliances are old and of low efficiency. For **individual heating** and small office buildings, mainly wood is used (in combination with high quality imported coal), less often pellets, coal briquettes (whose production cannot be considered even in the near term), natural gas, propane, butane, air conditioners. Use of firewood is increasing especially in small towns and by poorer people in cities.

The appliances are located in every room and work only when needed. They are used all over the country, but to a large extent this depends on various factors, such as the climate region and access to resources. The most common wood (and coal) stoves work with natural draft, their efficiency is low - about 30% and depends on a number of random factors: location, fuel quality (humidity), chimney shape and dimensions, chimney height, etc.

In rare cases small boilers of 6 - 20 kW, some with water heat exchangers, coil and radiators in individual rooms are used in individual buildings to increase efficiency. They are not determinative of the type and characteristics of heating in the region, neither in the country.

Wood in the country's total energy balance is about 10%. This energy resource should be expected to be in the same order in the SEE balance sheet and it is unlikely that this percentage will increase. Wood is not an attractive source of energy in households because it requires storage, stove maintenance, disposal of ash, systematic chimney cleaning, etc.

Very rarely, residential block buildings use local heating by small wood boilers, wood briquettes or pellets, with high efficiency exceeding 90%. The reason for the low popularity is the unfavourable attitude towards the common property that needs servicing, as well as some of the reasons mentioned in the previous paragraph. The efficiency of the boilers is higher indeed, but it decreases in the installation while the cost is increased by the need for service.

Wood pellets are also used, though infrequently, to heat single homes for more prosperous users. Wood pellets are more convenient for use in the service sector or in public buildings and offices of commercial organizations where servicing of boilers is not a problem. Capacity is in the range of 15 - 45 kW, efficiency is usually over 92% (class A +), CO_2 emissions - 160 mg/m^3, dust - 14.1 mg/m^3 prices of boilers range from 1,000 € to 3,500 €. Some boilers are combined for burning wood, pellets and briquettes. Capacities are similar.

Prices of best quality wood pellets are in the range 170 - 200 €/t with calorific value of 5 - 5.3 MWh/t, but there are some of lower quality depending on the material and moisture. The price of good wood briquettes is about 170 €/t, but it can also move within certain limits depending on the quality of the primary material.

3.2.2 Electricity

Electricity for households in Bulgaria has the lowest price in the European Union - about 100 €/MWh with VAT (Figure 2: Electricity prices for households consumers in Bulgaria).

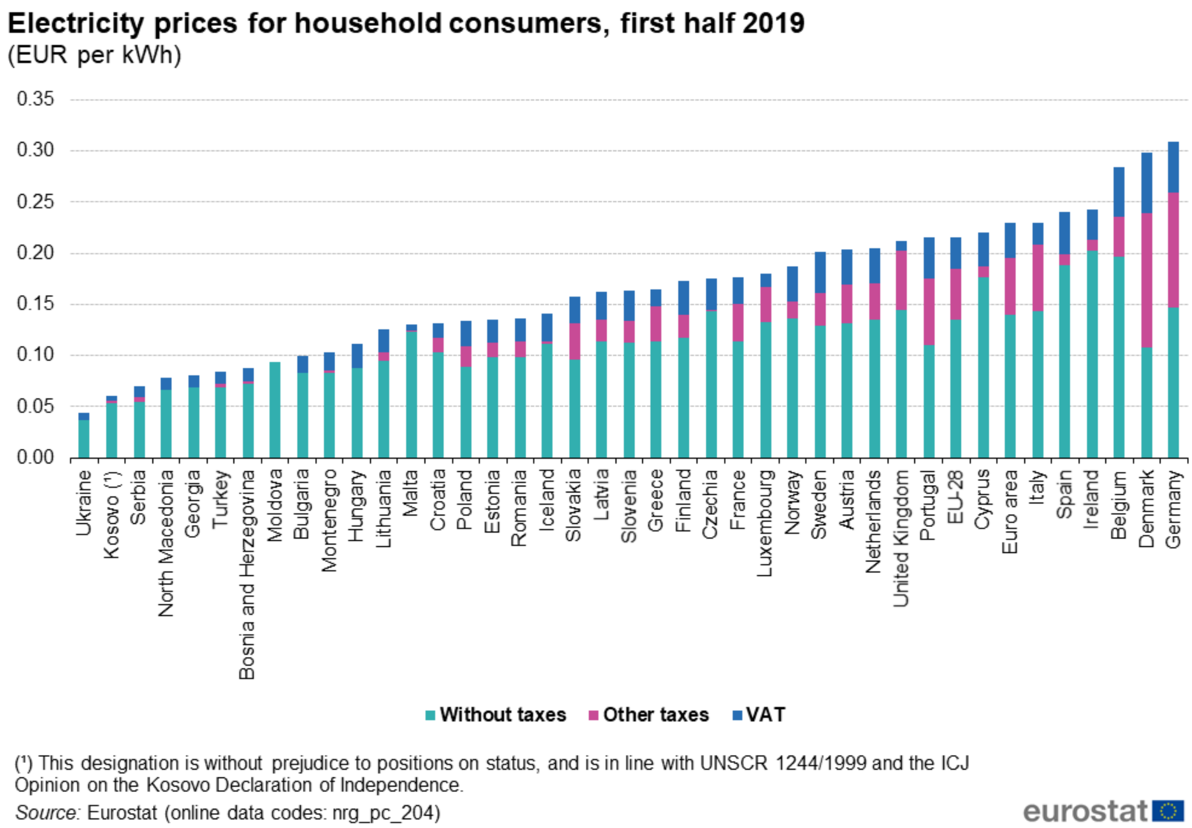

Figure 2: Electricity prices for households consumers in Bulgaria

Under these conditions, it becomes competitive with other energy sources, even in some cases compared to central heating from combined heat and power (CHP) plants, which is available in major cities. Households have no interest in producing electricity for their own consumption neither for export to the electricity system.

According to the last (2011) census data, Stara Zagora region has very high use of electricity for heating – 47.8% of the households in the region rely on that energy carrier, compared to only 28.6% country average (NSI, 2011).

3.2.1 Solar energy in the South East Region (SER)

In the period 2009 - 2012 high feed-in tariffs operate in Bulgaria, which give impetus to the construction of installations for the generation of wind and solar electricity (photovoltaics). As production and installation of such generators progress, their prices are rapidly declining, but the regulator does not comply with these developments and maintains the initially set high feed-in premiums. The rules also allow future projects to be engaged on favourable terms, but their implementation to be delayed. As a result, investor activity is increased to such an extent that the regulatory authority, forced by the circumstances, reduces prices and entitles the National Electric Company to have the final say when authorizing new capacity of systemic importance. An exception is made for small capacity installations.

The South East Region and the area of Stara Zagora, where the mining company "Mini Maritsa East" EAD is located, have significant solar resources - over 1,400 kWh/m^2 per year. The territory of the mining complex has among the highest solar potential in Bulgaria – nearly 1,500 kWh/m^2 per year. These can be seen in Figure 3 and in Table 2.

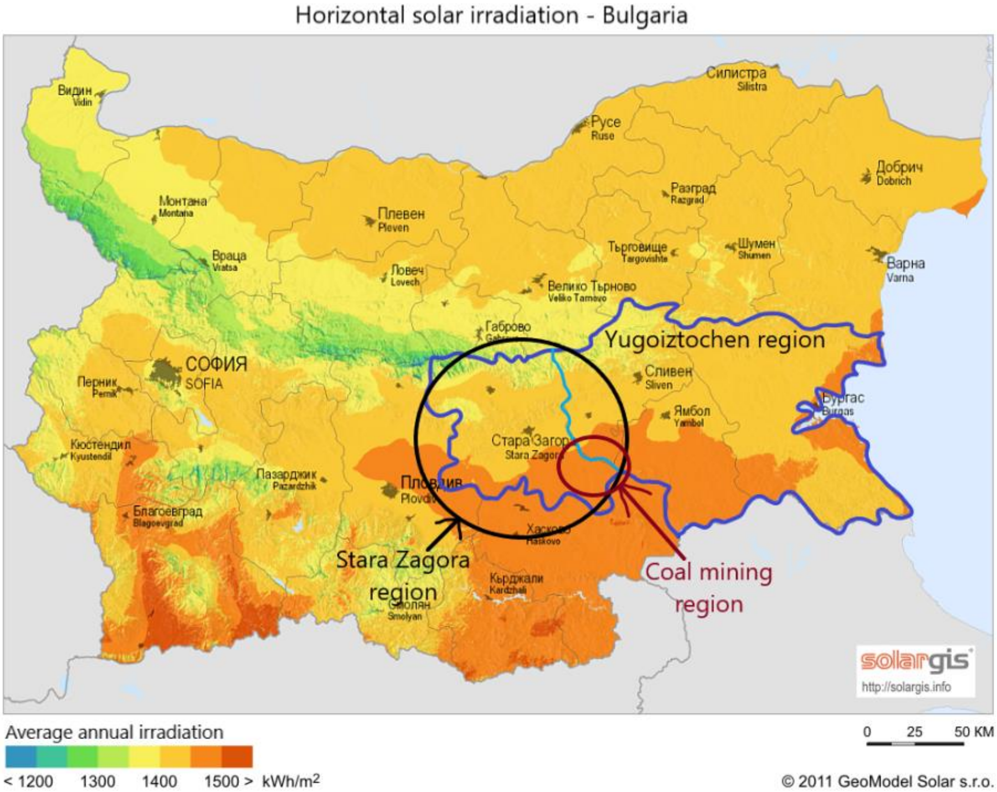

Figure 3: Solar energy potential without restrictions

Table 2: Solar energy potential in the South East Region (SER). Source: Radulov et al, 2012

District	Potential for solar energy		
	Power (MW)	Suitable territories	
		Area (km^2)	Relative share (%)
Burgas	429.2	225.2	2.9
Yambol	249.4	137.4	4.1
Sliven	280.5	140.9	4.0
Stara Zagora	445.3	240.1	4.7

During the period 2009-2012, a number of solar (total > 1,000 MW) and wind (total > 500 MW) parks were built at the high subsidized electricity prices determined by the Regulator (EWRC), especially in Eastern Bulgaria, including SER and the Stara Zagora Area (Table 3). However, with the increase of installed capacities it turned out that the electricity system was not prepared, did not develop in conformity with the requirements for control of a system with intermittent capacities, and the Regulator was forced to change the procedure for obtaining permits. The final word in this procedure has already the Transmission System Operator (TSO), in accordance with its possibilities to control capacities with such characteristics.

With the current regulatory framework, it is possible to build only small, distributed capacities that connect to the low-voltage distribution network. The rules are modified in line with policy decisions to promote one or the other technology, but in principle this does not have a major impact on the operation of the electrical power system, because of low interest.

Table 3: Solar facilities and electricity in the South East Region (SER), 2019. Source: SEDA Database

	Burgas	Sliven	Stara Zagora	Yambol	SER Total
Generators, pcs.	160	191	211	138	700
Capacity, MW	86.07	89.20	129.11	109.17	413.54
Energy, MWh	108,872.10	118,628.11	134,686.35	145,363.64	507,550.21

3.2.2 Hydropower in the South East Region (SER)

Hydropower has no significant potential for further development in SER.

Table 4 shows the parameters of the now existing plants, of which the larger ones were built in the past and are not the result of a supportive policy.

Table 4: Hydro Power Plants in the South East Region (SER), 2019. Source: SEDA Database

	Burgas	Sliven	Stara Zagora	Yambol	SER Total
Generators, pcs.	2	5	7	0	14
Capacity, MW	1.94	18.28	36.79	0	57.01
Energy, MWh	5,157.35	13,217.21	64,537.42	0	82,911.99

3.2.3 Wind power in the South East Region (SER)

The wind potential for electricity production in SER is significant, but so far, due to the limited possibilities of the electricity system, it is not possible to build large wind parks. Erecting of individual wind turbines/ is not of great interest due to the high additional costs of connection, control, security, as well as because of their lower efficiency. The areas near the sea have higher potential, but there are also more restrictions coming from resorts with their communications and because the migration of migratory birds, especially storks. Not all of such restrictions are taken in consideration to be shown on the map.

The municipalities of Radnevo and Galabovo, where the mines are located, are shown to the left of the South East Region outlined on the map, in the Stara Zagora region, where the wind potential is negligible. The average wind speed in 2007-2008, measured with masts at 10 m height, is between 2.5 and 5.5 m/s, with an average annual speed of 3.45 m/s for the first year and 3.87 m/s. for the second one, which makes it insufficient to generate electricity by large wind turbines.

The following map shows the potential estimates made in the study (Radulov & all 2012) based on information obtained from data base of 3TIER Inc. USA, developed by modelling of wind parameters on the basis of ground control points. It consists of a grid with a horizontal resolution of 5 km.

3TIER have used a complex interpolation technique to produce the annual average winds speed at an altitude of 80 meters above the surface. A direct enquiry for the concrete parameters of the data product has been addressed on behalf of BSERC to ensure the applicability of the source for the estimation needs of the potential wind speed. The results show that the 3TIER data is the best available source to show the potential.

Restrictions on connecting the large renewable parks to the transmission grid, have reduced the interest in the development of large renewable parks, reducing also the interest in such information and its improvement.

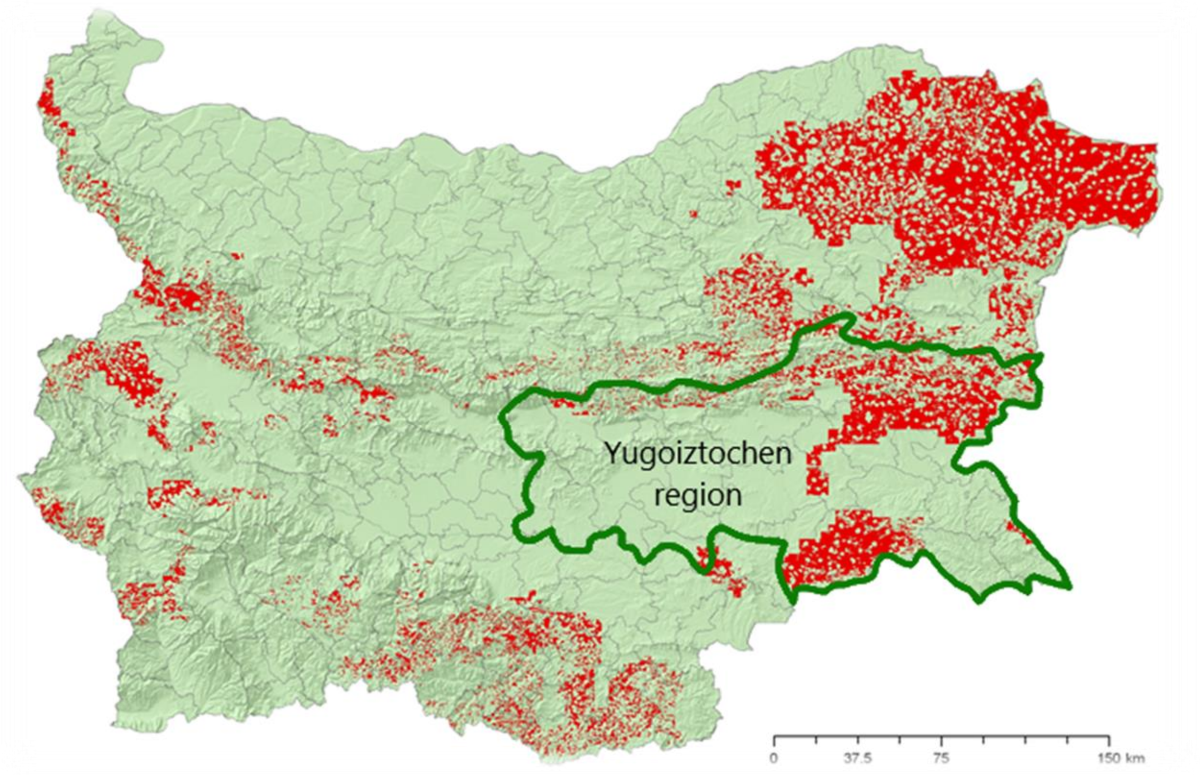

Figure 4: Wind energy potential - suitable places for utilization of wind energy, taking into account the main considered limitations. Source: Radulov et al. 2012

Table 5: Distribution of wind potential in the South East Region (SER) by districts (NUTS3)

District	Potential for solar energy		
	Power (MW)	Suitable territories	
		Area (km²)	Relative share (%)
Burgas	14,312	1,792.6	23.2
Yambol	6,205	775.6	23.1
Sliven	1,674	260.4	7.4
Stara Zagora	850	128.9	2.5

Table 6: Wind power generation in the South East Region (SER), 2019. Source: SEDA Database

	Burgas	Sliven	Stara Zagora	Yambol	SER Total
Generators, pcs.	26	17	5	14	62
Capacity, MW	16,18	15,18	78.80	10.58	120.74
Energy, MWh	18,205.57	20,657.88	129,739.09	9,087.56	177,690.09

3.2.4 Electricity generation from biogas in the South East Region (SER)

There is only one installation in the region for generating electricity on biogas. It is also the only one in Bulgaria. Its indicators are presented in Table 7.

Table 7: Biogas installations in SEE, 2019. Source: SEDA Database

	Burgas	Sliven	Stara Zagora	Yambol	SER Total
Generators, pcs.	0	1	0	3	4
Capacity, MW	0	1.50	0	2.22	3.72
Energy, MWh	0	10,279.50	0	14,367.45	24,646.95

3.2.5 Contribution of the South East Region (SER) to the generation of electricity in Bulgaria

The following Table 8 gives an overview of the contribution of the South East Region to the production of electricity from renewables in Bulgaria.

Table 8: Electrical energy generated on renewables in Bulgaria in 2019, MWh

		Wind	Hydro	Solar	Landfill gas	Biomass	Sewage waters	Biogas	Total
Bulgaria	Generators	191	271	2,162	1	4	2	30	**2,661**
	Capacity, MW	704,145	2,370.07	1,066.56	0.834	21,105	3,474	39,556	**44,205.75**
	Energy, MWh	1,282,534	2,566,310	1,386,215	247	85,658	2,319	210,288	**5,533,571**
	Energy, %	23.18%	46.38%	25.05%	0.00%	1.55%	0.04%	3.80%	100%
SE Region	Generators	62	14	700	1	0	0	0	**777**
	Capacity, MW	120.74	57.01	414	0	0	0	0	**591.75**
	Energy, MWh	177,690	82,912	507,550	247	0	0	0	**768,399**
	Energy, %	23.12%	10.79%	66.06%	0.03%	0.00%	0.00%	0.00%	13,36%

The territory of Bulgaria is divided to 6 regions, among which the South East Region is the third in electricity production from renewables.

3.2.6 Prices for heating comparison

The following table shows the costs of heating with different types of fuels and their respective heating appliances.

Prices (incl. VAT) in BGN per 1 MWh of real energy for residential use (taking into account calorific value and fuel efficiency) - as of 01.01.2020 are shown on the next Figure 5.

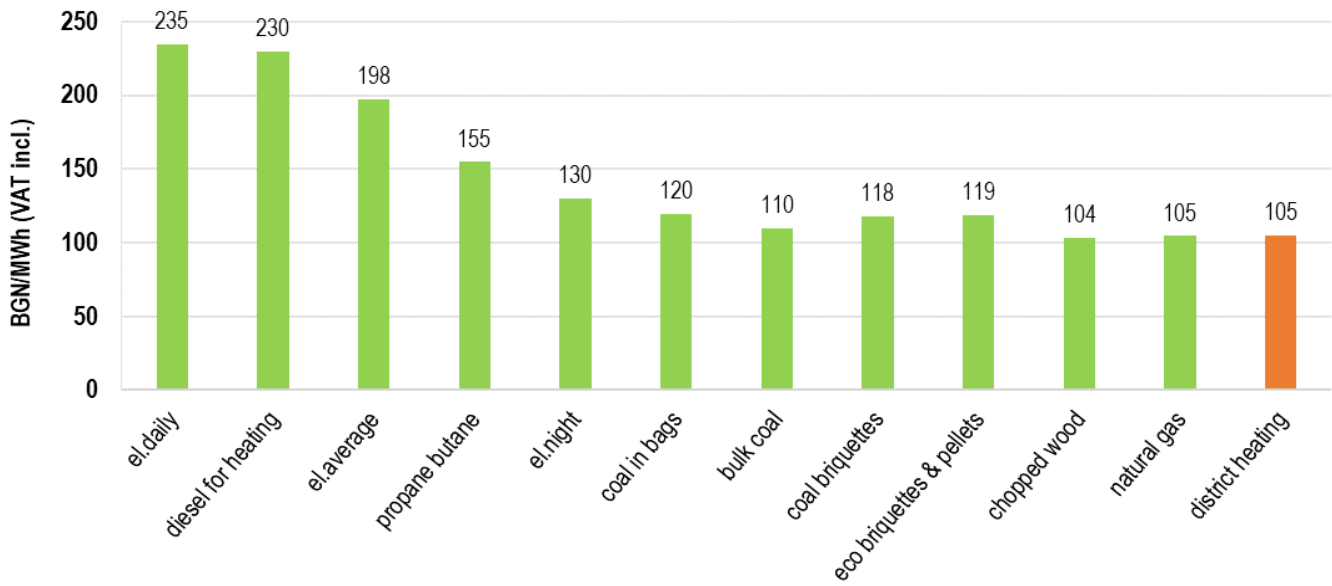

Figure 5: Prices (incl. VAT) in BGN per 1 MWh of real energy for residential use (taking into account calorific value and fuel efficiency) - as of 01.01.2020 г.

More details are shown in Table 9.

Table 9: Prices of fuels as of 1st of January 2020, Source: EWRC and BSERC estimates

Prices as of 01/01/2020	Units	Price with VAT	Typical Efficiency	Specific quantities	Price with VAT
			%	kg/MWh	€/MWh
Propane-butane	€/l	0.49	91.8	81	79.14
Diesel	€/l	1.02	88.5	95	117.38
Firewood cut	€/ton	99.70	70	523	52.13
Wood chopped	€/ton	107.37	71.5	493	52.93
Coal in bags	€/ton	227.52	71	269	61.24
Bulk coal	€/ton	201.96	71	278	56.24
Briquettes	€/ton	173.84	71	346	60.16
Eco briquettes and pellets	€/ton	224.97	81.5	271	60.87
Electric one tariff	€/kWh	0.120			120.14
Electric day and night	€/kWh	0.101			101.05
Electric night	€/kWh	0.067			66.51
Natural gas	€/1000 m^3		91.8		53.47
Central heating					53.56

The investments were not taken into account in the above comparison because of their diversity and the narrow limits in which they move. It can only be noted that the investment for natural gas is about 10% higher than the others.

Low electricity prices for households make air conditioning particularly attractive for the region that has relatively high summer and winter temperatures. Air conditioners provide comfort both in winter and summer and, in comparison to other sources, contribute to less air pollution with small dust particles and flue gases. Electricity use is comparable in price to natural gas.

In the big cities - Stara Zagora, Burgas, Sliven, Yambol - the buildings of the local administration, schools, kindergartens, social and health facilities, municipal sports facilities, etc., are gasified or combustion heating systems on diesel fuel are installed. Electricity is also used as an additional source of heating in public buildings.

The monthly amount of energy benefits for the low income households is 500 kWh (300 kWh daily and 200 kWh nightly), with its monetary value for electricity dependent on the tariff. By Decision of the Energy and water regulatory commission (EWRC) of 01/07/2019 (http://www.dker.bg/uploads/reshenia/2019/res_c-19_19.pdf) the price of electricity is set at 0.069219 €/kWh daily and 0.029021 €/kWh nightly tariffs.

3.2.7 Initiatives for better and greener heating

In the municipalities of Burgas and Stara Zagora a program (under Grant Agreement No. LIFE17 IPE / BG / 000012 - LIFE IP CLEAN AIR) is implemented with the Executive Agency for Small and Medium-Sized Enterprises of the European Commission, and co-financed by the municipalities and the beneficiaries. The program provides free replacement of old wood and coal heaters with greener sources of heating: gas, central heating and pellets, which reduce air pollution by fine dust particles and provide comfortable heating.

In 2015 was launched the project "Energy Efficiency Measures for End-Users of Natural Gas through Gas Distribution Companies in Bulgaria" (DESIREE GAS), funded by a EUR 10.9 million grant from the Kozloduy International Fund (KIDSF), administered by the European Bank for Reconstruction and Development (EBRD) and managed by the Ministry of Energy. It aims to stimulate domestic gasification by supporting the initial investment of around 10,000 households across the country. The aid provided, which should not exceed EUR 1,000 per household for high efficiency boiler systems and EUR 1,200 for condensing boilers, covers 30% of the investment value and 100% of the connection fee to the gas distribution network. The project will be completed in June 2020.

Its implementation will help to reduce air pollution by replacing high-emission pollutant fuels with natural gas.

In the cities of Burgas and Sliven there is regional heating, which covers about 20% of the households in these cities.

3.2.8 Distributed RES generation

The technological possibilities for the development of distributed RES generation in the South East Region of Bulgaria are wide enough, but the question is how much they are needed. Decentralized heating systems have so far not found application in Bulgaria due to a number of inconveniences – requirements for additional premises, unwillingness of households to cooperate, etc.

The greatest importance should be given to the future use of solar installations, but so far this process has hardly begun. The main reason is usually the more complex installation:

- For example, a thermal or electric storage system to overcome the diurnal differences
- Need for connection to the distribution network to exchange energy
- Installation of protection and automation - IT systems.

Electricity networks, as elsewhere in the country, are well developed. The price of electricity for the households is subsidized and does not predispose to a very lively interest in own electricity production. It is in the interest of some public organizations - for example, municipal authorities and more active commercial companies, to opt out of the services of the electricity supply company and to enter into a contract with an electricity producer or trader. But not all of them are exalted about the idea of producing electricity, they just want to get electricity at a lower price. The many installations that have been built so far have received high feed-in tariffs, but they are already drastically reduced, which came from the cost-cutting of the technologies and from the limitations of the electrical system[2].

Given the natural conditions and the potential it is clear that wind installations will not be able to develop significantly in the Stara Zagora region, but it will hold one of the first places among Bulgarian regions in the use of solar energy.

In terms of potential, analyses so far show that the opportunities for the development of renewable energy sources are very good. The problem is not the lack of places or opportunities to use renewable energy. As the information above shows, they are more than enough. The main problem is the workforce, as **renewable installations have a limited need for labour**.

Therefore, **other opportunities should be sought** on the basis of well-developed infrastructure, favourable for the development of various types of business - small or medium - production of electrical and electronic devices, machinery and equipment, ICT, production of second generation biofuels.

3.3 Clean Energy for All Europeans package

EU Member States are required to develop national long-term strategies on how they plan to achieve the greenhouse gas emissions reductions needed to meet their commitments under the Paris Agreement and EU objectives:

https://ec.europa.eu/clima/policies/strategies/2030_en

https://ec.europa.eu/info/energy-climate-change-environment/overall-targets/long-term-strategies_en

[2] Numerous small solar producers had the idea to sell to the electricity supply company at a feed-in tariff, but to receive for their own consumption electrical power at subsidized regulated tariffs.

To ensure the implementation of the Paris Agreement, the Junker Commission created and published a ***Clean Energy for All Europeans* package** aimed at clarifying the intentions of the member states and the degree of their commitment. The package covers a system of policies and actions of the member states, for which the EC requests information in order to assess their commitment and propose improvements and additions.

For this purpose the *Governance regulation*[3] requires Member States to draft ***"Integrated 10-year national energy and climate plans (NECPs) for 2021 to 2030"*** outlining how they will achieve their respective targets on all dimensions of the **Energy Union**, including a longer-term view towards 2050. It covers five dimensions: energy security; the internal energy market; energy efficiency; decarbonisation; and research, innovation and competitiveness, and is aimed at coordinating the actions of the **Energy Union** with those of the individual countries. Coal-fired power plants should be subject to restrictions on their participation in the electricity market:

The Energy Union and Climate Action (EU)Regulation 2018/1999 entered into force on 24 December 2018 as part of the *Clean Energy for All Europeans package*. This is the main document of the package, which calls on each Member State, within its capabilities and certain parameters, to contribute to the EU's climate protection objectives.

"EU Member States are required to develop *national long-term strategies* on how they plan to achieve the greenhouse gas emissions reductions needed to meet their commitments under the Paris Agreement and EU objectives".

Table 10: Clean Energy for All Europeans package

	OFFICIAL JOURNAL PUBLICATION	SHORT DESCRIPTION
Energy Performance in Buildings	19/06/2018 - Directive (EU) 2018/844	Specific measures to reduce energy consumption and CO_2 emissions (approximately 40% of energy consumption and 36% of CO_2 emissions in the EU)
Renewable Energy	21/12/2018 - Directive (EU) 2018/2001	Binding target of 32% for renewable energy sources in the EU's energy mix by 2030
Energy Efficiency	21/12/2018 - Directive (EU) 2018/2002	Binding targets of at least 32,5% energy efficiency by 2030, relative to a 'business as usual' scenario
Governance mechanism	21/12/2018 - Regulation (EU) 2018/1999	Required to draft integrated 10-year national energy and climate plans (NECPs) for 2021 to 2030 outlining how they will achieve their respective targets on all dimensions of the energy union, including a longer-term view towards 2050
Electricity Regulation	14/06/2019 - Regulation (EU) 2019/943	The electricity market design elements consist of four dossiers - a new electricity regulation, amending electricity directive, risk preparedness regulation and ACER Regulation
Electricity Directive	14/06/2019 - Directive (EU) 2019/944	
Risk Preparedness	14/06/2019 - Regulation (EU) 2019/941	
ACER	14/06/2019 - Regulation (EU) 2019/942	Agency for the Cooperation of Energy Regulators (ACER) is a central institution in the creation of a Single Energy Market will be granted with stronger role. https://www.acer.europa.eu/en/The_agency/Pages/default.aspx

[3] 21/12/2018 - Regulation (EU) 2018/1999

Together with the legislative package, a non-legislative initiative *"Coal region in transition platform*[4]" is also being launched to support the development of emissions-free energy. It is officially opened in December 2017 by Vice-president Maros Sevcovic and Commissioner Arias Canete and works as an open forum for local, regional and national authorities, businesses, trade unions, NGOs and academia. It encourages the exchange of knowledge and experience between EU coal regions and enables them to identify their transition difficulties and the need for assistance and funding. All coal regions are invited and have the opportunity to participate in the Platform initiative. It is bringing more focus to social fairness, structural transformation, new skills and financing for the real economy.

Although late, Bulgaria joins the Platform by declaring its intentions to use coal by 2050.

Among the 8 documents is the Governance mechanism[5] requiring MS to draft integrated 10-year national energy and climate plans (NECPs) for 2021 to 2030 outlining how they will achieve their respective targets on all dimensions of the energy union, including a longer-term view towards 2050. The **"Integrated Energy and Climate Plan of the Republic of Bulgaria 2021 – 2030"** of Bulgaria responds to the request of the REGULATION (EU) 2018/1999 of 11 December 2018 and showed that by mid-July 2025 the generation of electricity using Mini Maritsa Iztok EAD lignite will continue as usually, after which a gradual reduction of capacity will start with approximately 200 MW annually[6]. "The integrated 10-year national energy and climate plans for 2021 to 2030" outlining how they will achieve their respective targets on all dimensions of the ***Energy Union***, including a longer-term view towards 2050. Development by 2030 will rely on the technologies currently in use. Mini Maritsa Iztok EAD lignite complex, together with the Kozloduy NPP and the RES, constitutes the backbone of the Bulgarian electricity sector[7]. The reliability and adequacy of Kozloduy NPP are considered among the highest in the world.

In November 2017, the 5th unit of Kozloduy received a license for a new service life of 10 years. Its systematic extension for another 10 years until 2047 is possible. In October 2019, under similar conditions, the term for operation of Unit 6 was extended.

Having these technologies available the **Integrated Plan** follows the tradition - maximum production of electricity from the nuclear power plant and local coal, and increase of the participation of RES. The need of new technological decisions appears in 2025. According to REGULATION (EU) 2019/943 of 5 June 2019, Art.22(4)b the following requirement on the internal market for electricity comes into force: ***"(b) from 1 July 2025 at the latest, generation capacity that started commercial production before 4 July 2019 and that emits more than 550 g of CO_2 of fossil fuel origin per kWh of electricity and more than 350 kg CO_2 of fossil fuel origin on average per year per installed kWe shall not be committed or receive payments or commitments for future payments under a capacity mechanism."***.

The condition is strict and under no circumstances can it be achieved by Bulgarian power plants operating on poor quality lignite coal. Therefore, from this date the Bulgarian power system can **rely only on energy trade, but not on capacity services**. This market share will be taken by other systems / traders. In this way Bulgaria and countries with similar generation park will be forced to look for new more efficient and clean electricity generation technologies, selecting between large units or distributed facilities.

The result of this situation will be the gradual closure and replacement of inefficient plants by new emission-free generators[8].

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[4] https://ec.europa.eu/energy/topics/oil-gas-and-coal/EU-coal-regions/platform-for-coal-regions-in-transition_en

[5] 21/12/2018 - Regulation (EU) 2018/1999

[6] The national target of more than 27% of energy from renewable sources in gross final energy consumption by 2030 was required by EC

[7] Keep in mind that water cascades have low usability - about 2000 hours - due to limited rainfalls in the country

[8] Intermittency and capacity balances are not considered in the Plan

This process should lead to a reduction in the use of existing coal capacity, the decommissioning of older ones[9] and their replacement with **renewable generators** – Bulgaria is reach of solar and wind energy, question concerns the technologies for their **Integration in the Power System**.

More attention on the use of nuclear is necessary because it is considered dangerous by most of the countries in the European Union and its use is declining almost everywhere. This opinion is not universal; many countries along with Bulgaria are developing nuclear technology, because it is proved high safe, secure and reliable, despite the bitter experience in the 80s and 90s and will allow the transition to take place without fluctuations / inflection points in the economy.

EU Member States are required to develop national long-term strategies on how they plan to achieve the greenhouse gas emissions reductions needed to meet their commitments under the Paris Agreement and EU objectives

Next 2 tables show what are the current sources and technologies for electricity production of the Bulgarian electrical system, from which we can move forward to 2030. The plan reflects the vision of the Ministry of Energy regarding the development of Bulgarian energy technologies until 2030 and beyond - at least to 2050.

Table 11: Gross electricity generation, GWh

Gross	2010	2015	2020	2025	2030	2035	2040	2045	2050
Nuclear	15,249	15,379	15,800	15,800	15,800	24,018	32,237	32,237	16,437
Solids	22,606	22,564	21,803	21,718	16,843	8,522	1,424	916	734
Oil	393	206	199	0	0	0	0	0	0
Gas	1,967	1,810	2,031	2,273	5,148	7,099	4,201	3,197	11,422
Biomass	49	271	1,125	1,555	1,779	1,623	1,719	1,896	1,985
Hydro	5,057	5,660	4,707	4,707	4,707	4,707	4,709	4,713	4,713
Wind	681	1,451	1,451	1,564	2,049	2,049	4,394	6,883	11,719
Solar	15	1,383	1,402	2,506	4,652	4,652	4,652	4,747	6,759
TOTAL	**46,017**	**48,723**	**48,518**	**50,123**	**50,978**	**52,671**	**53,336**	**54,590**	**54,147**

Table 12: Capacities, GW

Gross	2010	2015	2020	2025	2030	2035	2040	2045	2050
Nuclear		1,889	1,889	1,889	1,889	1,889	2,889	3,889	3,889
Solids		4,301	4,301	3,431	2,519	2,519	1,453	1,453	1,076
Oil		1,909	1,909	2,084	2,052	2,052	1,807	1,790	1,881
Gas		0	0	0	422	422	843	843	843
Biomass		45	80	253	302	302	306	309	371
Hydro		2,355	2,508	2,508	2,508	2,508	2,508	2,508	2,508
Wind		699	699	709	719	948	948	1,811	2,723
Solar		1,029	1,042	1,785	1,785	3,216	3,216	3,216	3,277
TOTAL		**12,227**	**12,428**	**12,659**	**9,692**	**13,856**	**13,970**	**15,819**	**16,568**

Source: ME, Reporting of used parameters and variables included in Annex 1, part 2, of the Energy Union Governance as agreed in trilogue

Table 11 and Table 12 illustrate this development with one projection of the Ministry of Energy. It bases on the currently existing technologies and could serve only for comparison of more progressive scenarios by 2030 and projections for the period after that. The technologies are

[9] Given the existing ownership of the plants, as well as the restrictions on the amount of coal produced, this process is very complex and will be decided in practice, depending on the circumstances.

evolving more and more intensively, technological research is underway for application in all energy carriers, but primarily in electricity:

- Clean Energy for All Europeans package of regulations and directives: reduction of the specific electricity consumption – subject to the directives regarding buildings and energy efficiency
- Hydrogen energy – hydrogen as a tandem with electricity to replace fossil fuels
- Electricity and second and higher generation biofuels in transport
- Expanding the use of electricity in new areas that have so far been or are typical of fossil fuels - gas, oil, coal
- Control of intermittent generation - use, storage, conversion into other types of energy P-to-X
- Expanding the distributed generation of electricity to be used on the place of production - necessary modernization of the control, protection

In order to replace coal and nuclear power plants the expansion of power systems with distributed renewable generators require several times their total installed capacity. The same time due to various spatial constraints the electrical system must maintain its normal spatial dimensions. That's why the integration of distributed intermittent energy requires to achieve the greatest possible concise of the power system. An obvious first measure should be **consumption at the place of production**, which requires extremely high connectivity of the LV and MV system - with all the necessary tools for control, protection and other automation.

Given these opportunities, and despite the expected increase in energy efficiency electricity consumption will increase due to the need to replace fossil fuels.

Apart from that it should be assessed **whether nuclear energy has a place in the transition**. This depends to a large extent on the experience, opportunities and preferences (for now) of our country. And they are in favor of nuclear energy, after a long period of almost 20 years of hesitations, difficulties and, ultimately, disconnection from the power system of 4 units of 440 MW each - a cause of conflicting opinions and tensions between institutions, professionals, general public and national and European authorities.

The size of investments and the economic characteristics of nuclear power plants require a long period of operation in order to be competitive.Until then, the development of technologies will provide new opportunities for the use of nuclear energy by converting it into other types of energy - through **P-to-X processes**.

The following years are years of new technologies. Bulgaria can, as usual, on the basis of its limited resources, wait for the results of their successful implementation in other European countries. However, it would be much better if our country took a more active position and, despite its limited economic opportunities, even because of them, to **participate actively in research and the use of new technologies**. It may, it is time for this, to be actively involved in the efforts of the international scientific and technological community and to take a worthy place among other EU members. **Hydrogen technology is one of the most significant steps** towards the future of new technologies. The main advantage of hydrogen technology is its applicability in all technological areas and excellent opportunities for realising all other priorities - RES, energy efficiency, nuclear energy, biofuels.

The publication of *A hydrogen strategy for a climate-neutral Europe*[10] [11] is a remarkable event. Bulgaria has to show its creative potential and take a worthy place in this extraordinary technological development. The scientific society, together with the state institutions, the Ministry of Economy, the Ministry of Environment and Water, have to investigate carefully the strategy, and the possibilities to find their place in this accelerating European development instead of

[10] https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf
[12] https://www.bbc.com/news/uk-wales-politics-46447290.

waiting for its results. The passive behaviour similar to participation in the *Clean Energy for All Europeans* already demonstrates its inadmissibility.

3.4 Technical energy transition concept

EU policy pursuing the objectives of the Paris Agreement and Bulgaria's energy policy based on three energy sources - coal, nuclear energy and renewable energy - need strong coordination. Electricity Regulation (EC 2019a) and Electricity Directive (EC 2019b) requirements, as well as the requirements of the Governance Regulation (EC 2018) must be reflected in the country's energy policy.

The Ministry of Energy scenario relies on the ability of thermal power plants to operate intensively at the electricity market for more than 6,500 hours even beyond 2025. This seems doubtful, because even in the current situation the electricity produced by the Bulgarian power plants is difficult to find a market. **First of all,** the open electricity market is putting a lot of pressure on reducing prices. **Second**, the Regulator suppresses the prices of Maritsa East 2 TPP and the Minister suppresses coal prices. **Third,** the mining company “Maritsa East Mines” EAD has three independent branches: “Troyanovo-1” Mine, “Troyanovo-3” Mine and “Troyanovo-North” Mine, each producing coal for a particular plant. A gradual reduction, such as the reduction provided for in the Plan, cannot be allocated to the mines in total but specifically to each mine. **Fourth**, the drop of production at any mine below a certain limit makes it economically and even technically unbearable.

Due to the above, **urgent decisive measures are required to restructure and focus on social policy** affecting the directly employed nearly 20,000 people and, together with the indirectly employed, nearly 80,000 - 90,000 people.

The gradual transition of Bulgaria to new technologies for electricity generation is proving to be unavoidable and should start from now, but this requires the upgrade and introduction of new technologies for the Electrical Power System control.

This situation is well understood by most stakeholders, including trade unions, and a process of discussion and search for solutions is underway in the country. In this process, it is important to take into account all the factors - the benefits and the damages - that in the current tense situation in the country, Europe and the World, must be weighed carefully.

By 2030, in parallel with the coal-fired TPP decrease, the production of renewable energy is projected to increase, according to NECP. This increase is composed mainly of solar PV, while other RES, such as wind, biomass, and biogas grow slightly in absolute term (ME, 2020). In SER, as indicated above, there is very high solar energy potential and this is the most promising new energy resource in the region. Coal mining land that is not feasible to be fully restored to become agricultural, is particularly appropriate for solar PV. Although solar PV is not associated with labour intensive operation, employment can be created if the technology is produced locally. As specified in NECP (ME, 2020), it is necessary to train highly skilled professionals for the production and installation of solar PV.

During TRACER interviews (Personal communication, May 2020), several key ideas for the regional transition to new businesses have been outlined. The ones related to energy technologies are as follows:

Businesses, which would preserve coal mining:

- coal gasification, including carbon neutral gasification process technologies
- carbon capture and storage (CCS)
- use of coal as a fertilizer

Development of other energy technologies that would not preserve coal mining:

- transformation of the existing coal TPPs into highly manoeuvrable gas-firing TPPs
- production of energy storage solutions, such as batteries for electrical vehicles and large storage for electricity and heat
- production of hydrogen technologies

All these activities will contribute to the transition, but they can only be a supplement to an energy policy that leads Bulgaria to a transition based on modern technologies that already exist or are actively under development in **advanced countries**.

The *Clean Energy for All Europeans package*, despite its strength and expected impact, is not the limit that the EU is striving for and will achieve by 2050 and even 2030. In the future the new EU institutions – the Parliament, Council and Commission - basing on these achievements, will raise the requirements and the level of technologies that will achieve the goals of the Paris Agreement through the **unity of production, conversion and use** of energy and energy carriers - in an integrated energy complex **led by electricity and hydrogen.**

It was mentioned above Bulgaria's energy policy is based on three energy sources - coal, nuclear and renewable energy. According to the procedures of the Ministry of Energy the Belene NPP will be necessary and could be built after 2030. In the conditions of variable generation from intermittent sources and low minimum night loads, the nuclear power plant must participate in the primary regulation. It was explained already why this kind of operation of a NPP is not the best choice. In order to avoid the operation of NPP in variable mode a possible alternative is to use its electricity to produce alternative fuels P-to-X. For this orientation it will be necessary to have already developed technologies for converting its electricity into **other energy carriers**.

According to the first intentions of the European Commission, nuclear power plants will receive funding by 2028. For Kozloduy EUR 57 million are foreseen for 2021 - 2027 with a maximum EU contribution rate of 50%.

The new EU policy may put Bulgaria in a difficult choice - to give up nuclear energy and to be actively involved in the alternative *No region left behind* and to use the funding opportunities provided by the European Union - loans to Member States on favourable terms. The European Union will develop and provide opportunities for financing such projects, but how much Bulgaria will be able to take advantage of them is not clear, given the need to drastically change one long-term technology policy with another renewable electricity based.

Given Bulgaria's previous experience in the development of renewable electricity, the power system's ability to integrate new renewables, low tariffs and solvency, the need for renovation and modernization and a number of other factors, it is hard to believe that it will be able to take advantage. to the extent necessary of the funding opportunities provided by the EU.

3.5 Conclusion

Bulgaria is one of the countries whose electricity production relies on poor quality lignite and nuclear energy, and given that it is the poorest member state, without EU assistance it would not be able to make a successful transition to renewable energy. The European Union has developed and provided such countries with opportunities that, if actively used, will allow them to keep up and achieve its goals for Bulgaria and the EU for 2050 in accordance with the Paris Agreement.

In the Bulgarian energy strategy, nuclear energy has a significant role given the long-term experience of successful operation of Kozloduy NPP.

Low tariffs, the need to modernize the power system with new means of control and management in the conditions of intermittent production, require active work of the responsible institutions to ensure investment. For the time being, however, Bulgaria does not actively participate in the *Platform for Coal Regions in Transition* and other European mechanisms for information exchange and funding. This behaviour makes the prospect of Bulgarian institutions being able to take advantage of the opportunities provided by the EU to finance the transition uncertain.

In addition, the intentions of the new European Commission for nuclear power after 2028 - the end of the planning period - are unknown. It is possible to aim to exclude nuclear energy from electricity production in the EU.

3.6 Key Actions: PEST Analyses on using coal

The following brief analysis includes 4 perspectives: Political, Economic, Social and Technological, which are closely linked to addressing such a complex issue as using coal in the transition period of an EU Member State whose theoretical renewable energy resources are unlimited, but constructions encounter difficulties of different character. The question is: What would be the impact of the Bulgaria's electricity sector **transition** to RES, if it would start immediately.

Political factors	**Economic factors**
Ecological/environmental issues ○ *Environmentally friendly* Home market ○ *Manpower is released* Legislation role ○ *Creates a favourable for investment environment* International legislation ○ *Creates rules and puts pressure for transition* Government policies ○ *Must reflect EU policy in accordance with local conditions* Trading policies ○ *Trade in electricity that is not efficiently produced is restricted* Home market lobbying/pressure groups ○ *It has been hotly debated in the absence of mutual understanding and the pursuit of a balanced solution. The feud between political parties causes the renewal process to slow down.*	Home economy situation ○ *Provides good economic opportunities for new directions but difficult to use due to insufficient skills of manpower* Home economy trends ○ *Due to the above factor - the direction is downwards - need of favoured conditions to attract investment in recovered mines* Market and trade cycles ○ *The participation of the Bulgarian generators at the regional electricity market is very difficult, due to the low electricity prices for the households* Electricity market routes and distribution trends ○ *If gas control modules are built at the site of the coal plants, the South East Region (SER) will continue to play an important role in the electrical power system (EPS), but with significantly less manpower.* Customer/end-user drivers ○ *More energy and ingenuity are needed to find alternative employment* International trade/monetary issues ○ *Stopping electricity export (positive), should be replaced by export of modern technological goods*

Social factors	Technological factors
Lifestyle trends ○ *A significant change in lifestyle and a change in livelihood is required* Demographics ○ *Strong adverse impact on the workers at the mines and in the power plants, viewed with their families. Similar, but not to such an extent, impact on employees in service activities.* Consumer attitudes and opinions ○ *Will change* Law changes affecting social factors ○ *Above all, the families affected by the transformation need to be assisted by retraining and finding new jobs. A significant change in the legal environment is needed in order to attract investment.* Consumer buying patterns ○ *The reform cannot be implemented except by a significant increase in electricity prices, due to the transition to renewables with their intermittency requiring new means of control of the power system.* Buying access and trends ○ *A decrease is expected for the social groups affected by the transformation*	Competing technology development ○ *There are perspectives 1) to attract investments for replacement activities 2) to re-qualify the workforce 3) to support the market of new industries* Research funding ○ *Necessary research funding from local specific funds and active participation in European programs. To log without any delay into Platform Coal Regions in Transition. To propose projects for new technologies funded from EIB.* Associated/dependent technologies ○ *Service activities cease to exist and require support as well as those directly engaged* Replacement technology/solutions ○ *To create a favourable environment for the development of new technologies* Manufacturing maturity and capacity ○ *Some do exist, but to a limited extent or in the initial phase* Information and communications ○ *With the development of new technologies, IT technologies and innovations will inevitably evolve as they increasingly enter technological fields* Technology access, licencing, patents ○ *Closely related to the previous point*

It should be stressed here that the assumptions and recommendations made in this study do not reflect the inevitable changes that may be imposed as a follow up of the current pandemic situation. An assessment is yet to be made of its consequences for Bulgaria and the EU as a whole and the policy visions may undergo significant reconsiderations.

3.7 Key Actions: Development of Hydrogen Technologies

An investment agenda for the EU • Through the **European Clean Hydrogen Alliance,** develop an investment agenda to stimulate the roll out of production and use of hydrogen and build a concrete pipeline of projects (by end of 2020). • Support **strategic investments** in clean hydrogen in the context of the Commission's recovery plan, in particular through the **Strategic European Investment Window of InvestEU (from 2021)**.
Boosting demand for and scaling up production • Propose measures to facilitate the use of hydrogen and its derivatives in the transport sector in the Commission's upcoming **Sustainable and Smart Mobility Strategy**, and in related policy initiatives (2020). • **Explore additional support measures, including demand-side policies in end-use sectors,** for renewable hydrogen building on the existing provisions of Renewable Energy Directive (by June 2021).

- Work to introduce a common low-carbon threshold/standard for the promotion of hydrogen production installations based on their full life-cycle GHG performance (by June 2021).
- Work to introduce **a comprehensive terminology and European-wide criteria for the certification** of renewable and low-carbon hydrogen (by June 2021).
- Develop a pilot scheme – preferably at EU level – for a **Carbon Contracts for Difference programme**, in particular to support the production of low carbon and circular steel, and basic chemicals.

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Boosting demand for and scaling up production

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Designing an enabling and supportive framework: support schemes, market rules and infrastructure

- **Start the planning of hydrogen infrastructure**, including in the Trans-European Networks for Energy and Transport and the Ten-Year Network Development Plans (TYNDPs) (2021) taking into account also the planning of a network of fuelling stations.
- Accelerate the **deployment of different refuelling infrastructure** in the revision of the Alternative Fuels Infrastructure Directive and the revision of the Regulation on the Trans-European Transport Network (2021).
- Design enablin**g market rules to the deployment of hydrogen**, including removing barriers for efficient hydrogen infrastructure development (e.g. via repurposing) and ensure access to liquid markets for hydrogen producers and customers and the integrity of the internal gas market, through the upcoming legislative reviews (e.g. review of the gas legislation for competitive decarbonised gas markets (2021).

Promoting research and innovation in hydrogen technologies

- **Launch a 100 MW electrolyser and a Green Airports and Ports call for proposals** as part of the European Green Deal call under Horizon 2020 (Q3 2020).

- Establish the proposed **Clean Hydrogen Partnership**, focusing on renewable hydrogen production, storage, transport, distribution and key components for priority end-uses of clean hydrogen at a competitive price (2021).
- Steer the development of **key pilot projects that support Hydrogen value chains**, in coordination with the SET Plan (from 2020 onwards).
- Facilitate the demonstration of innovative hydrogen-based technologies through the launch of calls for proposals under the **ETS Innovation Fund** (first call launched in July 2020).
- Launch a call for pilot action on **interregional innovation under cohesion policy** on Hydrogen Technologies in carbon-intensive regions (2020).

The international dimension

- **Strengthen EU leadership in international fora for technical standards, regulations and definitions** on hydrogen.
- **Develop the hydrogen mission** within the next mandate of Mission Innovation (MI2).
- Promote cooperation with **Southern and Eastern Neighbourhood partners and Energy Community countries**, **notably Ukraine** on renewable electricity and hydrogen.
- Set out a **cooperation process on renewable hydrogen with the African Union** in the framework of the Africa-Europe Green Energy Initiative.
- Develop **a benchmark for euro denominated transactions** by 2021.

3.8 References

EBRD (2015) Demand Side Residential Energy Efficiency Through Gas Distribution Companies In Bulgaria (DESIREE GAS), funded by KIDSF, administrated by EBRD and managed by the Ministry of Energy, 2015-2020, https://desireegas.bg/en/about-the-project

EC, 2018, REGULATION (EU) 2018/1999 of 11 December 2018 on the Governance of the Energy Union and Climate Action

EC, 2019a, REGULATION (EU) 2019/943 of 5 June 2019 on the internal market for electricity (recast) (Text with EEA relevance), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0943&from=EN

EC, 2019b, DIRECTIVE (EU) 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0944&from=EN

EC, 2020, The European Green Deal, Brussels, 11.12.2019 COM(2019) 640 final ANNEX

EC, 2020, A hydrogen strategy for a climate-neutral Europe, Brussels, 8.7.2020 COM(2020) 301 final

Ecological HVAC Engineers Manual (2006), http://www.hvac-eco.com/bg/renewable-energy/32-bio-fuels/30-combustion-fuels-carbon-dioxide-emission.html

Maritsa Iztok Mines (2018) Resettlement Action Plan 2018, https://www.marica-iztok.com/cms/user/files/proekti/RAP%20MME_FINAL_BG_25%20May%202018.pdf

Ministry of Energy (ME) (2020) National Energy and Climate Plan of the Republic of Bulgaria (BG NECP), February 2020, https://www.me.government.bg/bg/theme-news/integriran-plan-v-oblastta-na-energetikata-i-klimata-na-republika-balgariya-2021-2030-2823-m374-a0-1.html

National Statistical Institute (2011) Census data https://www.nsi.bg/census2011/indexen.php

Personal communication with Valentin Kolev (TU-Sofia), Todor Mihaylov (Maritsa East 2 TPP), Oleg Stoilov (CCI-SZ), Rumyana Grozeva (SZEDA), Mihaela Dineva (SZEDA), Jordan Yankov (Nucleon), May 2020. Anonymous responses.

PRICES OF PELLETS AND BRIQUETTES (2020) HTTPS://PELETIMARKET.COM/?GCLID=EAIAIQOBCHMIW7A6_TWN6AIVL4BVCH3HGGEDEAAYBCAAEGICJPD_BWE

RADULOV L., KOTSEV A., ILIEV N., ANDREEVA M., NIKOLAEV A., GENADIEVA V. (2012) ASSESSMENT OF THE WIND AND SOLAR ENERGY POTENTIAL IN BULGARIA AND POLICY RECOMMENDATIONS FOR THEIR PROMOTION, ENVIROGRIDS – D5.6 FP7 EUROPEAN PROJECT

REGULATION (EU) 2018/1999 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL OF 11 DECEMBER 2018 HTTPS://EUR-LEX.EUROPA.EU/LEGAL-CONTENT/EN/TXT/PDF/?URI=CELEX:32018R1999&FROM=EN

TARGETED SOCIAL ASSISTANCE FOR HEATING (2019) HTTPS://DV.PARLIAMENT.BG/DVWEB/SHOWMATERIALDV.JSP;JSESSIONID=F71563D3441062C8B8C2C7E73E808797?IDMAT=138918

4 Czech Republic, North-West Bohemia

4.1 Current energy generation technologies using coal

4.1.1 Coal driven power plants, CHP plants

In general CHP units in 2016 provided 40% of electricity produced in Czech Republic, in 2010 it was 50%. Cogeneration is an important feature of electricity and heat production from coal. In large power plant, heat production represents only minor part of overall production. In large heating plants electricity proportion of coal used from heat and electricity is almost equal and in smaller sources hear prevail (Table 13).

Table 13: Lignite usage in CHP plants in 2016 and estimate for 2020 with division of proportion equivalent to electricity in heat production in millions t per year. Source: State Energy Policy of the Czech Republic (Ministerstvo průmislu a obchodu ČR 2015)

	Total		Electricity		Heat	
	2016	2020	2016	2020	2016	2020
Powerplant	23.23	23.84	22.59	23.19	0.65	0.65
Heating plants large	7.96	7.84	4.95	4.84	3.01	3.00
Heating plants medium	1.03	0.91	0.40	0.33	0.62	0.58
Heating plants small	0.48	0.40	0.16	0.14	0.30	0.26
Company CHP units	1.95	1.93	0.88	0.94	1.05	0.99
Total	34.64	34.92	28.97	29.43	5.64	5.48

Most of the CHP plants uses boilers, few newer units use gas turbines. Most of the large power plants and large heat plants use coal of lower quality (usually with caloric value below 14 GJ/t).

Most of the large unit's coal feed CHP come in service between 1970s and 1980s. However, some of the large units were recently upgraded (namely Tušimice 2007-2012) or have new source installed (Ledvice 2017). With regard to the requirement of high fuel efficiency, the construction of any new sources or the reconstruction of existing sources cannot be expected without application of a significant part of the waste heat for heat supply.

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 Pocerady, a.s. (CZ0048, 2,830 MW_{th}, 1970), Detmarovice, (CZ0047, 2,201.096 MW_{th} 1975, use mostly black coal), Tusimice (CZ0016, 1,971.2 MW_{th} 1974), Prunerov 2 (CZ0015, 1,754.4 MW_{th}, 1981), Ledvice 3 (CZ0011, 1,690.387 MW_{th}, 1998), and Melnik III (CZ0013, 1,356.4 MW_{th}, 1981). Among other large players is noteworthy group Seven energy (Chvaletice, CZ0046, 2,298.8 MW_{th} 1977) and Sokolovská uhelá a.s.

The overall efficiency in recently upgraded CHP plants such as Tušimice is declared 39%, in other plants the efficiency may very between 32 to 34%. All major CHP plants were desulfurized in 1990s.

Target region contribute significantly to overall country electricity production, namely Ústecký district produce 30% and Karlovarský district 6% of overall electricity production. Installed power output of the plant in Ústecký district is 3,964.6 MW and in Karlovarský district 549 MW. Characteristics of the largest sources in both districts are summarized in Table 14.

Table 14: Characteristic of the large CHP sources in the target region. Source: Ministry of Environment ČR 2010

name	MW_{th}	Start of op.	Sector	Liquid fuels (TJ)	Natural gas (TJ)	Coal (TJ)	Lignite (TJ)	SO_2 (t)	NO_x (t)	Dust (t)
Karlovarský District										
Elektrarna Tisova, a.s. - source A	291.6	1966	chp	0.0	6.7	0.0	7114.8	2503.8	861.2	29.9
Elektrarna Tisova, a.s. - source B	573.1	1995	chp	0.0	39.1	0.0	7391.5	1181.4	505.9	14.7
Sokolovska uhelna, pravni nastupce, a.s. Vresova A	1250.0	1967	other	0.0	0.0	0.0	26607.4	1916.1	1572.0	29.5
Sokolovska uhelna, pravni nastupce, a.s. Vresova B	840.0	1996	other	0.0	127.8	0.0	0.0	0.0	662.5	10.7
Ústecký disrict										
CEZ, a.s. - Elektrarna Ledvice 3	1690.4	1998	chp	0.0	118.0	0.0	25899.1	1109.6	1900.7	109.0
CEZ, a.s. - Elektrarna Prunerov 1	1238.4	1967	chp	17.4	0.0	0.0	21208.4	1933.0	1731.9	150.8
CEZ, a.s. - Elektrarna Prunerov 2	1754.4	1981	chp	0.0	80.7	0.0	29914.8	1180.3	2154.5	123.4
CEZ, a.s. - Elektrarny Tusimice	1971.2	1974	chp	0.0	42.3	0.0	43158.5	1917.8	2754.6	236.7
Elektrarna Pocerady, a.s.	2830.0	1970	chp	0.0	43.0	0.0	61611.9	5436.3	5518.4	265.3
CEZ, a.s. - OJ Elektrarna Melnik - Teplarna Trmice	562.0	1948	chp	13.8	0.0	0.0	5426.9	3074.7	1020.8	14.4
United Energy, a.s. - Teplarna Komorany	1202.3	1951	chp	0.0	16.3	27.2	12570.6	4299.1	881.5	112.5

4.1.2 Use of coal for small applications

As shown in table 1 smaller CHP units heating plants and company units represent important share in energy and heat production.

Large lignite heating plants (280 MW_{th} and a coal consumption over 350,000 tons per year). Consumption of coal for electricity production is usually comparable to consumption for heat production. Most of the heat is supplied for use in buildings (population, tertiary sector). In most cases, it is technically possible to use lower quality coal (so-called cold coal). The quality of coal used is currently higher in some cases with regard to its availability and economic acceptability. A substantial part of the sources has an input of more than 500 MW, and therefore they are more significantly affected by the reduction of the ceilings for nitrogen oxide emissions, similarly to the power plants.

Medium lignite heating plants (from 200 to 280 MW_{th} with an annual coal consumption up to 350,000 tons per year). In these sources, the consumption of coal for heat production usually outweighs the consumption for electricity production. Most of the heat is supplied for use in buildings (population, tertiary sector). The price of heat from these sources is usually currently competitive, but given the necessary investments and the development of the price of allowances and the price of substitutes, this position may be lost. Usually, higher quality coal (so-called hot coal) is used, the use of lower quality coal (so-called cold coal) is usually problematic.

Small lignite heating plants (up to 200 MW_{th} with a coal consumption of up to 150,000 tons per year). In these sources, the consumption of coal for heat production usually significantly outweighs the consumption for electricity production. The vast majority of heat is supplied for use in buildings (population, tertiary sector). The price of heat from these sources is already in some cases on the very edge of competitiveness. Usually, higher quality coal (so-called hot coal) is used, including sorted coal, the use of lower quality coal (so-called cold coal) is practically excluded.

Small company CHP units are operated by various companies, for which energy is not major part of business, represent very diverse group of sources.

Characteristics of the most important small application using coal in target region is summarized in Table 15.

Table 15: Characteristic of important small application coal units in target region. Source: Ministry of Environment ČR 2010

name	MW_{th}	Start of op.	Sector	Liquid fuels (TJ)	Natural gas (TJ)	Coal (TJ)	Lignite (TJ)	SO_2 (t)	NO_x (t)	Dust (t)
Karlovarský district										
Synthomer a.s.	86.0	1967	other	0.0	0.0	0.0	525.9	147.5	53.8	0.1
Ostrovska teplarenska, a.s. - Teplarna Ostrov	97.9	1973	dh	0.0	1.9	0.0	310.0	227.7	57.0	7.0
Ústecký district				0.0	0.0	0.0	0.0	0.0	0.0	0.0
ACTHERM, spol. s r.o. - o.z. Chomutov, teplarna	140.1	1963	other	0.0	2.4	0.0	1429.2	828.8	165.7	1.0
ENERGY Usti nad Labem, a.s.	292.8	1969	other	0.0	2.5	0.0	1266.2	398.0	200.7	5.5
Lovochemie, a.s. - Lovosice	185.9	1960	other	0.0	16.1	0.0	2051.5	363.9	276.7	7.6
Mondi Steti a.s. - Energetika	347.0	1973	chp	20.5	320.4	0.0	2655.3	504.8	181.2	2.5
TERMIKA Varnsdorf a.s.	88.3	1972	other	0.0	68.9	0.0	226.6	78.1	40.8	0.8
UNIPETROL RPA, s.r.o. - Teplarna T 700	860.8	1962	other	0.0	0.0	0.0	12806.0	2639.5	1267.8	19.3
UNIPETROL RPA, s.r.o. - Zavod 01 Petrochemie - etylenova jednotka	170.0	1979	other	2408.6	0.0	0.0	0.0	135.9	311.7	38.6

Some coal is used for household heating. In 2017 it has been estimated that households use about 300,000 t of black coal and about 1,500,000 t of brown coal for local heating (TZ info 2020).

4.2 Current status of other energy generation technologies

As mentioned above important part of heat production is obtained by cogeneration where electricity and heat is produced in the same time. This is namely the case of all medium sized heat plants where electricity and head are produced in about the same extend.

Concerning renewable sources of energy nationwide the most important source of energy, considering both heat and electricity production, is burning of biomass, mainly for household use but also for other usages (Table 16) which together form more than 65% of all renewables. Biogas represent another important share. Among other heat pumps and solar thermal systems are mainly used for household use.

Table 16: Percentage of individual receivables in total renewables contribution to energy production (considering both heat and electricity combined) in 2017 Anonymous 2018

Category	Percentage
Biomass burning (other than household use)	25.21
Biomass burning (household use)	40.18
Hydropower	3.57
Biogas	13.49
Household waste burning	2.04
Biodiesel and other liquid biofuels	6.99
Heat pumps	2.77
Solar thermal systems	0.44
Photovoltaic	4.18
Wind	1.13
Total	100

Composition of most important other sources of electrical energy production in target region of NV Bohemia is apparent from Table 17. Gas is an important part of these sources (Oenergetice.cz 2020). The most important unit is gas plant in Počerady with two gas turbines with an output of 284 MW and one 270 MW steam turbine. The total powerful output means that 838 MW The net efficiency of power plants is 57.4% This plant is designed to use natural gas. Another important unit is Vřesová with installed capacity 2x 200 MW, located in Karlovarský kraj natural gas isused together with furnance gas produced from coal.

Table 17: installed power output MW of other sources of electric energy in target regions. Source: Kubešová a Karel 2017, Harnych, et al., 2019

	Karlovarský	Ústecký
Gas powerplant*	420	890
Wind	51.2	87.8
Photovoltaics	13	177
Hydro	7.5	77.3

* including biogas and coalgas produced from coal

Wind is another important part of other energy sources. The target region, namely Karlovarsky and Ustecky District, are leading 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. Photovoltaic is another important part of renewables. Most of these units were build after 2008 and 2009, on agricultural land. This was consequence of reduced price of solar panels in that period and decision of government of the Czech Republic form 2005 which highly limited possibilities to regulate prices of solar energy and by this basically fix price of solar energy for long time frame. Hydropower is given by existing reservoirs formed by dammed rivers.

4.3 Technological challenges and opportunities

In **large power plants** there is expected a gradual decline in production. Coal consumption is fundamentally affected by electricity generation, and thus by the situation on the electricity market and emission allowances. To some extent, partial substitution of the fuel used with biomass, or even fuel from waste, is possible, but this substitution cannot have a significant impact on coal consumption in this segment. Partial substitution with biomass (co-incineration) would be economically viable in the 2020 horizon only in the event of a significant increase in the price of emission allowances. In most cases, it is possible for sources in this category to adapt to coal that is worse in quality than what is currently used.

Large lignite heating plants

Coal consumption in this segment will be fundamentally affected by the situation on the electricity market and emission allowances, as well as by heat savings for customers (building insulation). It is possible to expect a partial reduction of electricity production in connection with the development of the electricity market, especially in the summer period, when in some cases the combined production of electricity and heat may be limited in favor of mono heat production. The risk of this segment is relatively high fixed costs both in sources and in large heat networks (approximately 1,925 km, which corresponds to 25% for the Czech Republic as a whole) and the resulting vulnerability in the event of a significant decline in heat consumption or negative developments in the electricity market. It is therefore necessary to take into account the fundamental sensitivity of this segment to the price of fuel. The possibilities of fuel substitution in this segment are relatively limited. It can be co-incineration of biomass or waste fuel. Another option is to replace part of the heat supply from these sources by building separate facilities for energy use, especially municipal waste. However, the potential for substitution is in the order of hundreds of thousands of tons of coal and probably does not reach even 10% of consumption in 2020. The use of poorer quality coal (so-called cold coal) is possible in most cases and does not require major investments.

Medium lignite heating plants

In connection to the overall restructuring of the economy, there may also be a significant decrease in the heat consumption of some industrial customers. The main production technologies will mostly be substantially modernized by 2020, and therefore no further significant efficiency gains can be expected. A significant potential for reducing fuel consumption can be found in the reconstruction of heating networks, especially the transition from steam distribution to hot water distribution. The possibilities of fuel substitution in this segment are significant. It can be co-incineration of biomass or waste fuel. Another possibility is to replace part of the heat supply from these sources by building separate facilities for energy use, especially municipal waste. Challenge is that recent policy, however rather expect shift to other fossil fuels such as co-firing of hard coal may also be increased in some sources. In part, it is necessary to take into account the substitution with natural gas, which will be more used in top sources or in the nonproduction of heat in the summer. The potential for lignite substitution by 2040 can be estimated at 20 to 30% of 2020 consumption. The use of inferior coal (so-called cold coal) is difficult and in most cases only possible to a limited extent within mixtures (slight decrease in fuel calorific value).

Small lignite heating plants

Since 2018, national legislation provides for a significant tightening of emission limits, but at the same time, at the EU level, the directive on medium combustion sources is affecting the segment with an input of 1-50 MW, which will probably further tighten these requirements after 2020. The portfolio of possible strategies is thus relatively wide for sources with a potential reduction in power input below 50 MW, but it is burdened by considerable uncertainty regarding the future development of air protection legislation. After 2030, with regard to legislative requirements, high specific investment costs of abatement equipment (especially desulphurization) and higher burden of brown coal by tax externalities, its further use in this segment will be significantly suppressed, if at all economically viable. Coal consumption in this segment will be fundamentally influenced mainly by heat savings at customers (building insulation). Disconnection may also occur due to an increase in the price of heat above the competitiveness limit due to an increase in the price of fuel, the price of emission allowances and heat savings. The possibilities of fuel substitution in this segment are very wide. It can be the co-incineration of biomass or waste fuel or the transition to clean biomass combustion. Again recent policy rather shifts to renewables expect substitution of one fossil fuel to another namely natural gas, which will be more used in top sources or in the nonproduction of heat in the summer. The potential for brown coal substitution by 2040 can be estimated at 60-70% of consumption by 2020.

Concerning **small company CHP** units, operated by various companies, for which energy is not major part of business, it can be expected that by 2020, in connection with the requirements for the application of the best available technologies not only in combustion sources, but also in subsequent technological processes, decisive modernization investments will be made. In the forecast period, there may be rather a sharp decline in lignite consumption, which is difficult to predict, because they will be related to the overall development of the industry and the success of the company within it. The reduction in consumption resulting from investments in technological change will not play a significant role, as will the potential savings in supplied buildings (population and tertiary sector). Depending on the situation on the electricity market and in the plants' own consumption, electricity production may be reduced. The possibilities of fuel substitution in this segment are relatively significant. In other cases, a significant amount of biomass is already in use today, which can be further increased in the future. In the future, the use of waste fuels can also be increased.

Potential for renewable resources

Here the potential for renewable resources in Northwest Bohemia is explored. There is a potential for solar energy use, as shown in Figure 6.

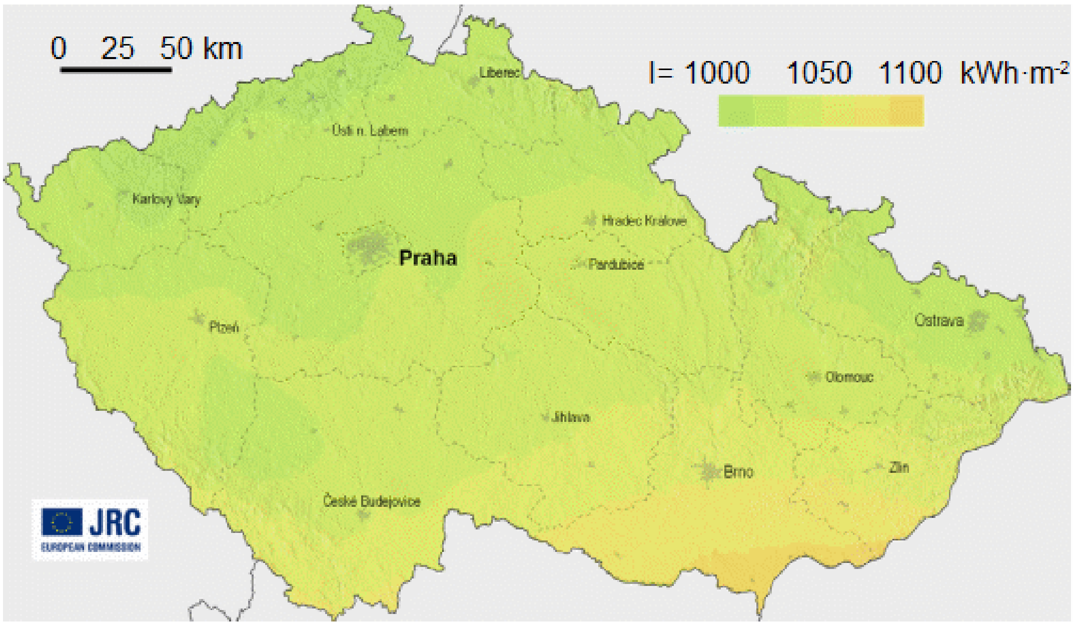


Figure 6: Amount of solar irradiation in various parts of the Czech Republic based on Suri et al., 2010

Post mining sites in Northwest Bohemia belong to areas with comparatively lower potential compared to the southern and south eastern parts of the Czech Republic. However, differences inside country are not large and availability of large areas in post mining sites may be beneficial of solar plants namely in sites with suitable exposition.

In 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 location in target area density of wind power reach 200-300 W/m^2. Štekl (2006) and also Chalupa and Hanslian (2015), indicated Northwest Bohemia as a suitable region for wind energy use (Figure 7). Economic return of wind power plant in Ustecký district is estimated to be 13 years.

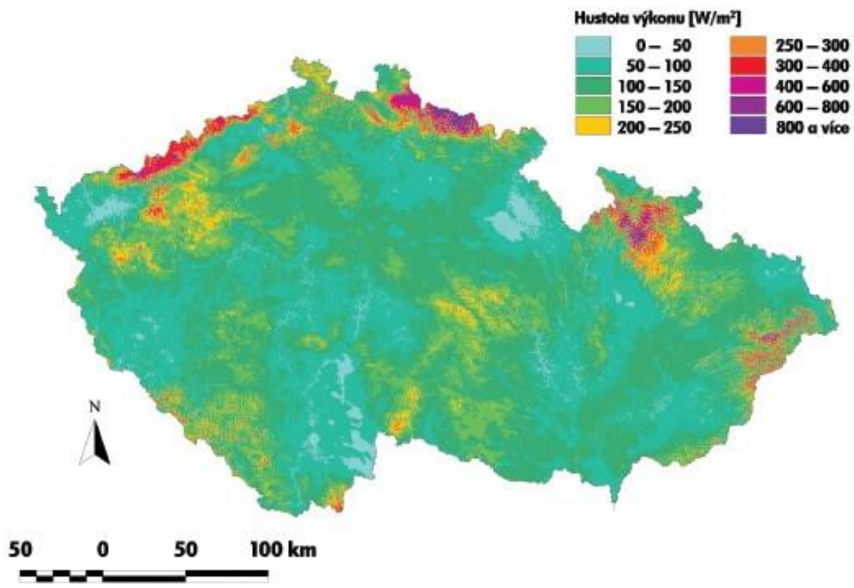


Figure 7: Spatial distribution of wind energy distribution in the Czech Republic based on Štekl (2006)

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 $ha^{-1}year^{-1}$ 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 (Frouz et al., 2015). The potential production of trees and shrubs on post-mining sites, however, is less than that of poplar coppices on arable land (Werner et al., 2012) or of other short-term rotation plan-stations on former arable land. Despite this, we suggest 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 (Frouz et al., 2013). 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, Člžková et al., (2018) report overall aboveground biomass production in the established reclaimed meadow as 2.5 t (DW) ha^{-1} y^{-1}.

4.4 Technical energy transition concept

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

Traditionally biofuel has dominant position among renewables in the Czech Republic and as already explained above post mining sites provide opportunities to increase of biofuel production, which may even bring benefits in terms of ecosystem restoration and carbon sequestration in soil at the same time (see part 4.2 and 4.3 for more details).

Among other renewables potential for solar energy in terms of natural conditions is similar as in rest of the country of slightly below average. However large area 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 flooding of residual mining pit (idnes.cz.2019).

In contrary to solar natural conditions for use of wind energy is exceptionally good in the target region also 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 good location for new windmill farm (see part 4.3 for more details).

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

Among other renewables with have decent and largely underexplored potential in Northwest bohemia is geothermal energy (Litoměřice, 2013). Town Litoměřice is recently building geothermal heat plant using hot dry rock system with expected production of 15-30 MW_{th}.

4.5 References

ANONYMOUS 2018. STATISTIKA, BIOM 3-2018.

BOSE, S.K., BARBER, V.A., ALVES, E.F., KIEMLE, D.J., STIPANOVIC, A.J., FRANCIS, R.C. (2009) ANIMPROVED METHOD FOR THE HYDROLYSIS OF HARDWOOD CARBOHYDRATES TO MONOMERS.CARBOHYDR. POLYM. 78, 396–401.

ČÍŽKOVÁ, B., WOŚ, B., PIETRZYKOWSKI, M., FROUZ, J. 2018. DEVELOPMENT OF SOIL CHEMICAL AND MICROBIAL PROPERTIES IN RECLAIMED AND UNRECLAIMED GRASSLANDS IN HEAPS AFTER OPENCAST LIGNITE MINING. ECOLOGICAL ENGINEERING 123, 103-111.

FROUZ, J., LIVEČKOVÁ, M., ALBRECHTOVÁ, J., CHROŇÁKOVÁ, A., CAJTHAML, T., PIŽL, V., HÁNĚL, L., STARÝ, J., BALDRIAN, P., LHOTÁKOVÁ, Z., ŠIMÁČKOVÁ, H., CEPÁKOVÁ, Š. 2013. IS THE EFFECT OF TREES ON SOIL PROPERTIES MEDIATED BY SOIL FAUNA? A CASE STUDY FROM POST-MINING SITES. FOREST ECOLOGY AND MANAGEMENT, 309: 87-95.

CHALUPA S, HANSLIAN D. (2015) ANALÝZA VĚTRNÉ ENERGETIKY V ČR. KOMORA OBNOVITELNÝCH ZDROJŮ ENERGIE – ČESKÁ SPOLEČNOST PRO VĚTRNOU ENERGII 21PP.

HARNYCH J, SPITZ J, PŘIBYL E., HENELOVÁ V. 2019. AKTUALIZACE ÚZEMNÍ ENERGETICKÉ KONCEPCE ÚSTACKÉHO KRAJE, ÚSTECKÝ KRAJ ÚSTÍ NAD LABEM

IDNES.CZ.2019. HTTPS://WWW.IDNES.CZ/USTI/ZPRAVY/MISTO-RYPADEL-SOLARNI-PANELY-USTECKY-KRAJ-BYVALE-DULNI-VYSYPKY-REKULTIVOVANE-SKLADKY-OPUSTENE-TOVARN.A190531_479457_USTI-ZPRAVY_PAKR

IUHLÍ.CZ 2018 HTTPS://IUHLI.CZ/NA-REKULTIVACNICH-JEZERECH-MUZE-VYRUST-ELEKTRARNA/

KUBEŠOVÁ A A KAREL K., 2017 ÚZEMNÍ ENERGETICKÁ KONCEPCE KARLOVARSKÉHO KRAJE AKTUALIZACE 2017-2042. KARLOVARSKÁÝ KRAJ, KARLOVY VARY

MINISTERSTVO PRŮMISLU A OBCHODU ČR (2015) STÁTNÍ ENERGETICKÁ KONCEPCE ČR. MINISTERSTVO PRŮMISLU A OBCHODU ČR, PRAHA.

MINISTRY OF ENVIRONMENT OF THE CZECH REPUBLIC ˇCVR 2010.AVAILABLE IN HTTP://CDR.EIONET.EUROPA.EU/CZ/EU/LCP_IED/ENVXEWYBG/

ŠÚRI, M., CEBECAUER, T., HULD, T., DUNLOP, D. (2010) GLOBAL IRRADIATION AND SOLAR ELECTRICITY POTENTIAL – CZECH REPUBLIC, 2010. EUROPEAN COMMISSION JOINT RESEARCH CENTRE.

ŠTEKL J., (2006) VĚTRNÁ ENERGETIKA NA ÚZEMÍ ČR A U SOUSEDŮ. ALTERNATIVNÍ ENERGIE 6/2006

TBZ INFO 2020 HTTPS://ENERGETIKA.TZB-INFO.CZ/19810-UHLI-V-CESKE-REPUBLICE

WERNER, C., HAAS, E., GROTE, R., GAUDER, M., GRAEFF-HONNINGER, S., CLAUPEIN, W.,BUTTERBACH-BAHL, K. (2012) BIOMASS PRODUCTION POTENTIAL FROM POPULUS SHORTROTATION SYSTEMS IN ROMANIA. BIOENERGY 4 (6), 642–653.

5 Germany, Lusatian Lignite District/Economic Region Lusatia

5.1 Current energy generation technologies using coal

The total gross electricity generation in Germany amounts to 646.80 TWh in 2018 (Statistisches Bundesamt, 2020). Thereof, 22.5 % is covered by lignite-fired power plants, which corresponds to 145.5 TWh or 1.331 PJ. As compared with other fossil energy sources this is the highest share (Figure 8).

On the other hand, renewable energies contribute to 226.2 TWh of the electricity supply covering about 35.0 % of the total demand. From that, wind energy on land and on sea together has the highest proportion, with 101.5 TWh.

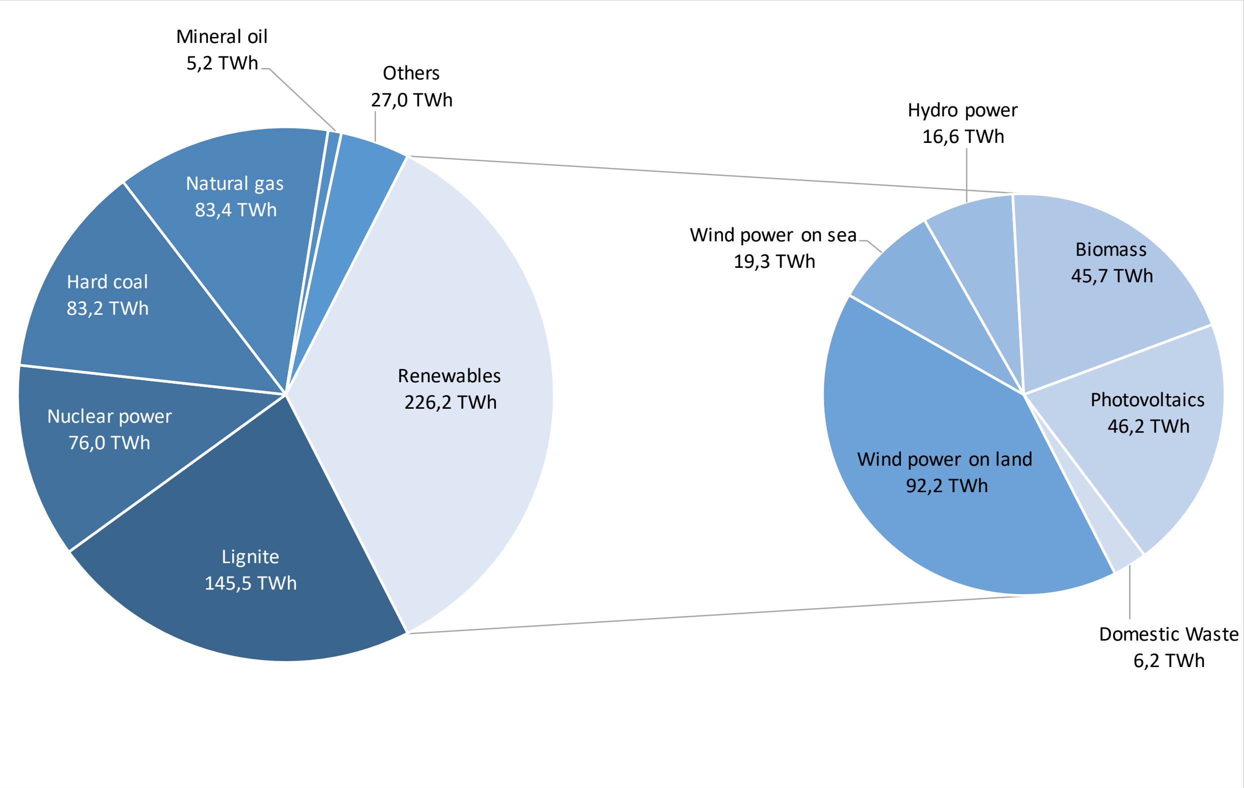


Figure 8: Share of energy sources to gross electricity generation in Germany in 2018 (TWh) (Data source: Statistisches Bundesamt, 2020).

The *Lausitz Energie Kraftwerke AG* is currently the only power producer in the Lusatian region - running three lignite-fired power plants over there. Together with the *Lausitz Energie Bergbau AG* it is part of the LEAG consortium founded in 2016. Both companies belong to each half to the Czech companies *Energetický a Průmyslový Holding* (EPH) and *PPF Investments*. The major owner and holding company of the two LEAG companies is *Lausitz Energie Verwaltungs GmbH*. For its part, it belongs to the *LEAG* Holding a.s. based in Prague.

The Lausitz Energie Verwaltungs GmbH accounts for selected services such as accounting and taxation for the mining and power station sectors (Lausitz Energie Bergbau AG, 2020). The company took over the mining and power generation activities in East Germany from the Swedish state-owned company *Vattenfall* AB, who sold its power plants and lignite mines already in 2016.

LEAG is the second largest electricity producer in Germany with an installed net nominal power of more than 7,000 MW_{el} alone in the Lusatian region (Table 18). Another power plant of LEAG, Lippendorf, (1,750 MW_{el} and 330 MW_{th}) is located in the Central German mining region 15 km south of Leipzig.

Table 18: Overview about lignite-fired power plants in the Lusatian region (Data source: LEAG, 2020).

Power plant	Electrical power	Heat capacity
Schwarze Pumpe	1,600 MW	120 MW
Jänschwalde	3,000 MW	349 MW
Boxberg	2,575 MW	125 MW

In 2018 about 33,780,000 tons of lignite are mined alone in the Brandenburg part of Lusatia (Amt für Statistik Berlin-Brandenburg, 2019), with the the opencast mines Welzow-Süd and Jänschwalde, both located in the district Spree-Neiße. On the other hand, the Saxonian part of Lusatia produces 29,760,000 tons (Sächsisches Oberbergamt, 2020). This amount is provided by the mines Nochten and Reichwalde, which are located within the district Görlitz. Thus altogether, 63,540,00 tons of lignite are mined in the Lusatian territory in the reference year 2018 corresponding to 449,086 TJ.

Lignite is used for production of electricity and heat in cogeneration plants and for the production of briquettes in the refining facility *Schwarze Pumpe*. In Brandenburg the share of lignite to gross power generation in 2017 was 57,3 %, which means 32,477 GWh (Statistisches Landesamt Bremen, 2020).

The two lignite power plants in Brandenburg Schwarze Pumpe and Jänschwalde supply an electrical power of about 4.6 GW (Lausitz Energie Bergbau AG, 2020). The plant Boxberg in Saxony contributes additional 2.6 GW. Have a closer look at Figure 9 to get an overview of their spatial distribution.

The former lignite cogeneration plant in Cottbus is currently refitted until the end of 2022. The part of the plant previously fired with lignite, will be replaced by new gas engines (HKW Heizkraftwerksgesellschaft Cottbus mbH, 2018). The plant is owned by the *Stadtwerke Cottbus GmbH*.

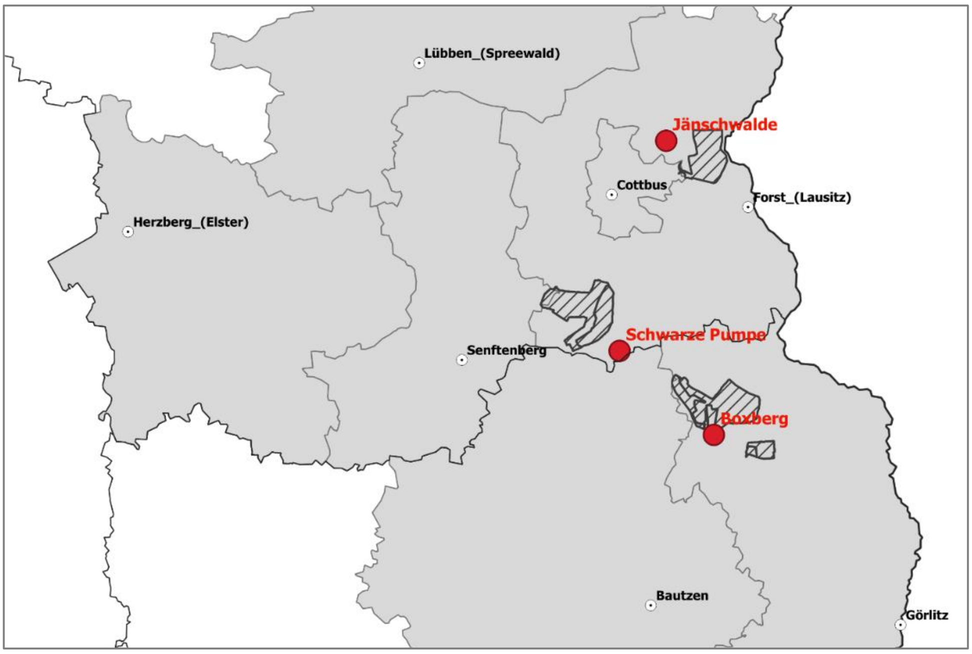


Figure 9: Lignite-fired power plants and active lignite opencast mines in the Lusatian region; from north to south: Jänschwalde, Welzow-Süd, Nochten and Reichwalde (Data source: Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen, 2019).

Power plant Jänschwalde

The power plant site Jänschwalde (Figure 10) was developed since 1976. Between 1981 and 1989, six power plant units (block A-F) came into the grid - each with a capacity of 500 MW. The site underwent a comprehensive modernisation program for an efficient and environmentally sound continued operation in the 1990s. In 2014, another multi-year program for the modernisation of all steam turbines operating in the power plant was completed. Actually, raw lignite from the opencast mine Jänschwalde, but also - to a lesser extent - from Welzow-Süd and Reichwalde is converted into electricity.

Moreover, the power plant supplies heat for the industrial location and Business Park Jänschwalde as well as for the neighbouring cities Cottbus and Peitz. As part of the national security reserve for lignite power plants prepared by the German Federal Government, block F was taken out of service on October 1, 2018. Block E followed on October 1, 2019. Both units are held for another four years on stand-by mode until final shut down.

The currently installed electrical power is 3,000 MW. About 19.5 TWh of electricity are produced in 2018. Besides each of the six blocks can provide 58.2 MW of heat for the district heating supply.

From 1991 to 1995 all power plant units were upgraded with modern flue gas desulphurisation. In addition, steam generators were refitted for a coal combustion with low NO_x emissions and the electrostatic precipitators had been modernised, so that pretreated municipal and industrial waste can be co-fired.Some ecological sounding synergies on-site: Food fish have been bred at the power plant site for more than 30 years. Today the *Fish Farm Jänschwalde GmbH* works here. The company uses the warm cooling water, for example, to overwinter carp and then to expose it to the ponds nearby the small city of Peitz. Each year, fishermen produce about 60 tons of carp, 60 tons of salmon trout and char and ten tons of other species. Aside, special nesting boxes for peregrine falcons were installed at the former chimneys at blocks A and D, which had become obsolete after the retrofitting of flue gas desulphurisation plants. Per box up to three hawks are fledged per year. And there is also a brood raft on the power plant site for common terns - a seagull species that is on the red list of endangered species.

Figure 10: Power plant complex Jänschwalde in June 2010. Picture: J.-H. Janßen [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)].

Power plant Schwarze Pumpe

The Schwarze Pumpe power plant (Figure 11) with its industrial complex is located 30 kilometres south of Cottbus, not far from the city of Spremberg in Brandenburg. i. It is located in the *Industrial Park Schwarze Pumpe* and was built up starting in 1993. The first block went to the electric grid in 1997 - with an installed electrical power of 800 MW. The second block followed half a year later, also with 800 MW electrical power.

Schwarze Pumpe is the first Lusatian coal power plant projected and constructed with several new and environmentally friendly technologies, *inter alia* low-tickle combustion, flue gas desulphurisation or dust separation with electrostatic precipitators. With a high-end combustion technology, it achieves an efficiency level of 40 % - as one of the first lignite-fired coal power plants in Europe.

The currently installed electrical power is 1,600 MW in sum or 11.6 TWh of electricity (2017). In the process of power generation hot steam is decoupled with a capacity of 2 x 300 t/h. A part of it is delivered as process steam to neighbouring industrial companies. In the processing plant of *Lausitz Energie Bergbau AG*, it is used, for example, for the drying of lignite in the connected briquette production. Another part of the steam is converted into district heating, supplying the *Industrial Park Schwarze Pumpe* and the bordering cities of Hoyerswerda and Spremberg, including the district of Schwarze Pumpe (60 MW_{th} per power plant block).

Both power plant units are running in a flexible mode, which means that they can be operated in a power range from 310 MW to 800 MW. Such a short-time flexibility is a basic precondition for the smart integration of weather-dependent renewable energies into the grid, like wind turbines and solar plants, because these have priority for the feed into the power grid in accordance with the *German Renewable Energy Act* (EEG).

The major portion of lignite is provided by the mines Welzow-Süd, Nochten and Reichwalde. At full load, the power plant needs around 36,000 tons of lignite per day.

At the other end of the processing chain gypsum is produced as a by-product when cleaning the flue gases in the flue gas desulphurisation plant (FDG) of the power plant. With regard to its composition and processability, this gypsum is at least equal to that from natural deposits and can be used well in the building materials industry. Currently 70 % of the FRG gypsum is used by the *KNAUF Deutsche Gipswerke KG* with its plant in the *Industrial Park Schwarze Pumpe* in the production of plasterboards.

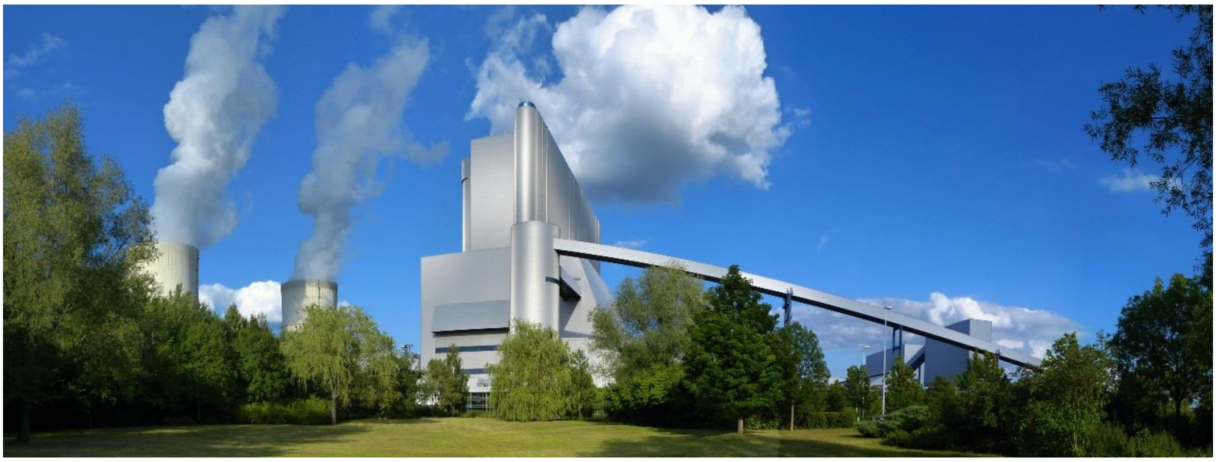


Figure 11: Power plant Schwarze Pumpe in August 2005, Picture: I, SPBer [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)].

Power plant Boxberg

The Boxberg power station is located in the district Görlitz (Saxony), the construction started in 1968. It was originally contained 12 units with 210 MW electrical power (facility I and II) and two 500 MW units (facility III). Boxberg was until the late 1990s the biggest lignite coal power plant in Germany (Figure 5). In 2000 the facilities I and II were replaced by a modern 900 MW unit. The remaining two 500 MW blocks were retrofitted in the 1990s with a modern environmental technology for ongoing operation. In 2012 a new unit with an electrical power of 675 MW and an efficiency of 43.7 % was built (additional block R). The installed electrical power amounts to 2,575 MW. In 2018 17.9 TWh of electricity are produced (Lausitz Energie Bergbau AG, 2020). In addition to that, 125 MW of thermal energy is available.

The feeding lignite is delivered by the open pits Nochten and Reichwalde. Around 65,000 tons of raw lignite are needed daily, at full capacity. Part of the heat generated during power generation is decoupled from the process and used for district heating at the close *Industrial Park Boxberg* as well as for the municipality of Boxberg and the city of Weißwasser.

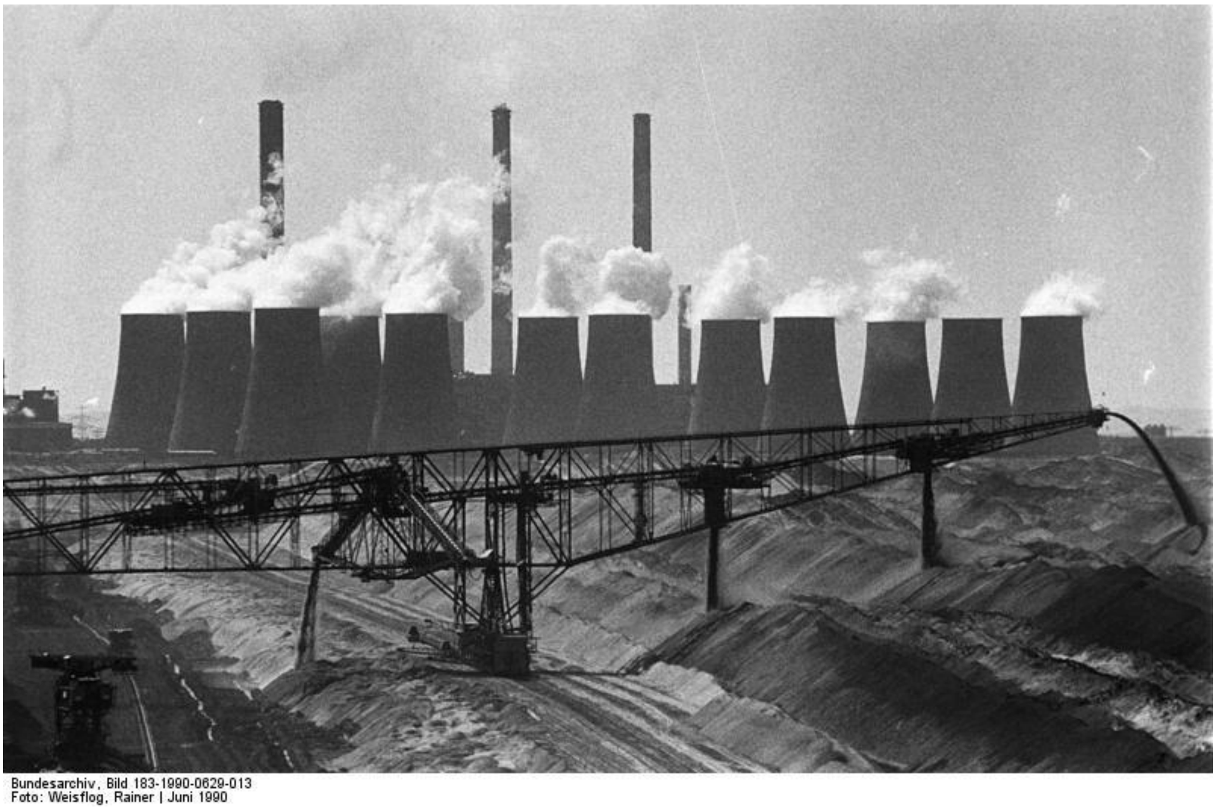


Figure 12: Power plant complex Boxberg in June 1990. Picture: Bundesarchiv, Bild 183-1990-0629-013 [CC-BY-SA 3.0, CC BY-SA 3.0 de, (https://commons.wikimedia.org/w/index.php? curid=5347973)].

The specific CO_2 emissions from power generation amounts to 694.5 g CO_2/kWh in Brandenburg and 758.5 g CO_2/kWh in Saxony for the reference year 2016 (Agentur für Erneuerbare Energien e.V., 2020). In the same year the gross electricity generation from lignite is 33,741 m kWh in Brandenburg, which comes all from the power plants in the Brandenburg part of Lusatia and 32,689 m kWh in Saxony, provided from one power plant in the Saxonian part of Lusatia and another one nearby the city of Leipzig. For a better classification: In 2019 17,400 m kWh have been produced in the plant Boxberg (Lausitz Energie Bergbau AG, 2020).

Table 19 shows a selection of the annual pollutant emissions from the three Lusatian coal power plants in 2017 (European Pollutant Release and Transfer Register, Umweltbundesamt, 2020). Beside others thermal power stations and combustion installations with a heat input of 50 MW from the energy sector within the European Union are obligated to report harmful emissions to the competent authorities, if these exceed dedicated limit values of the EU-directive 166/2006 (Regulation (…) concerning the establishment of a European Pollutant Release and Transfer Register).

Table 19: Selected annual pollutant emissions from the three Lusatian coal power plants in 2017 (Data source: Umweltbundesamt, 2020).

Pollutant	Power plant Jänschwalde	Power plant Schwarze Pumpe	Power plant Boxberg
Carbon dioxide (CO_2)	24,000,000,000 kg	11,500,000,000 kg	19,100,000,000 kg
Nitrogen oxides (NO_x/NO_2)	19,000,000 kg	7,280,000 kg	13,500,000 kg
Sulphur oxides (SO_x/SO_2)	15,100,000 kg	5,690,000 kg	11,600,000 kg
Carbon monoxide (CO)	10,800,000 kg	788,000 kg	5,500,000 kg
Particulate matter (PM10)	535,000 kg	67,900 kg	353,000 kg
Nitrous oxide (N_2O)	295,000 kg	111,000 kg	207,000 kg
Chlorine and inorganic compounds (as HCl)	64,800 kg	50,700 kg	73,300 kg
Nickel and compounds (as Ni)	260 kg	109 kg	612 kg
Mercury and compounds (as Hg)	672 kg	256 kg	536 kg
Lead and compounds (as Pb)	1,780 kg	335 kg	504 kg
Copper and compounds (as Cu)	658 kg	198 kg	427 kg
Arsenic and compounds (as As)	208 kg	114 kg	72 kg

Stadtwerke Cottbus mbH

The *Stadtwerke Cottbus mbH* operates a smaller cogeneration plant (see Figure 13) which used refined lignite of the Lausatin region until 2020 but also natural gas and crude oil as fuels (Stadtwerke Cottbus GmbH, 2020). According to the list of power plants from the German Federal Network Agency (Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen, 2019) it has a net nominal power of 74 MW. The individual power plant data are based on the annual monitoring surveys of the Federal Network Agency. Until 2022 the coal driven part will be replaced by new gas engines. In addition, heat accumulators will be installed. The aim of this measures is, to reduce the emissions of carbon dioxide up to 30 %. Since December 1999, the combined heat and power plant has been generating heat at the site with a fluidised bed boiler and electricity with connected flue gas and steam turbines.

Figure 13: Cogeneration plant Cottbus, Picture: Trio3D [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)].

Selected data of emissions from the cogeneration plant Cottbus listed by the European Pollutant Release and Transfer Register can be found in Table 20.

Table 20: Selected annual pollutant emissions from the cogeneration plant Cottbus in 2017 (Data source: Umweltbundesamt, 2020).

Pollutant	Amount
Carbon dioxide (CO_2)	163,000,000 kg
Nitrogen oxides (NO_x/NO_2)	103,000 kg
Nitrous oxide (N_2O)	47,000 kg

5.1.1 Use of coal for small applications

The *Lausitz Energie Bergbau AG* produces briquettes in their refinery *Schwarze Pumpe* from raw lignite for a small application use (Lausitz Energie Bergbau AG, 2020) - the last operating briquette factory in the region. The so-called “Rekord-Briketts" can be used as solid fuel in single-room firing systems e.g. in private households and in other firing systems for solid fuels. They are part of the assortment of e.g. DIY stores or in the fuel trade in different container sizes and different price categories.

Background: About 11,170,000 single-room firing systems for solid fuels and additional 914,000 firing systems for solid fuels (excepted single-room systems) exist in Germany (Bundesverband des Schornsteinfegerhandwerks, 2018). Approximately 410,000 single-room firing system are operating in Brandenburg. Data only for Lusatia are not public available. The single-room systems are mostly used as an additional opportunity for heating to an existing gas or oil heating, especially because they provide a cozy a feel. Old tiled stoves as the only heat source are largely are only rarely used, mainly in old houses.

5.2 Current status of other energy generation technologies

In addition to coal, regional wind and solar energy, biomass, waste, natural gas, gas from purification plants, landfill gas and geothermal heat are used for energy generation, what means in case of some of this sources both, electricity and heat. The installed net electrical power from these "alternative" energy sources in Lusatia amounts to over 1,500 MW in sum (Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen, 2019). The proportion in Brandenburg is 1,068 MW, in Saxony it is 473 MW.

In Lusatia wind energy is converted into electricity by on-shore wind turbines. They are often placed in groups of several turbines (from 1 to several dozen), the so-called "wind parks" or "wind farms". The typical output of current systems is around 2 to 5 MW per each wind turbine (Internationales Wirtschaftsforum Regenerative Energien (IWR) / IWR.de GmbH, 2020).

Photovoltaic systems to convert solar energy into electricity are either build up as small facilities with a few to hundreds of modules on roofs of houses or as more or less complex associations of hundreds or thousands of modules in solar parks. These are placed at underutilised and contaminated land, e.g. former military properties, landfills or even at common bur marginal agricultural sites. The electricity is fed into the grid. An excellent example is the solar park Meuro - one of the largest in Germany - with more than 600,000 modules on an area of 352 ha (Gemeinde Schipkau, 2013, see also Tracer Deliverable 2.1 Fact-sheet “Solar-park complex Senftenberg”). The plant performance is 166 MW_{el}. It is located at the site of the former lignite mine Meuro.

Biomass like wood chips and resides from landscape management, waste, natural gas, gas from purification plants and landfill gas can be used for both electricity and heat generation. For example, the waste incineration plant in Großräschen - the power plant “Sonne” - burns waste to produce electrical and heat energy. It has a capacity of 175,000 MWh electricity per year and delivers heat to the close community Freienhufen (EEW Energy from Waste Großräschen GmbH, 2020).

Actually, in Brandenburg wind and solar energy provide the largest share of electric power within the renewable energy sources This two sectors provide in Brandenburg more than twice as much energy as compared to Saxony. The cogeneration plant in Cottbus mainly uses lignite but also natural gas and fuel oil as additional fuels. Nevertheless, it is not considered in this compilation. In Saxony the proportion between natural gas, wind and solar energy is comparatively similar.

Lusatia spreads out over six districts and one district-free city. Table 21 and Figure 14 provide data of the installed electric power of wind turbines, photovoltaic plants, biomass plants and hydroelectric power plants in the region. The biomass data include biogas, gas from purification plants and landfill gas as well as thermal power pants with biomass as fuel, e.g. wood chips.

Table 21: Installed electric power of wind turbines, photovoltaic plants, biomass plants and hydroelectric power plants in the Lusatian districts / counties and the district-free city of Cottbus, sum per technology and district (Data sources: Will et al. , 2019, Landkreis Görlitz, 2018, Ministerium für Wirtschaft, Arbeit und Energie Brandenburg, 2020).

District	Installed electric power (MW)				
	Wind Energy	Photovoltaics	Biomass	Hydroelectric Power	Topicality of data
Bautzen	141.921	254.019	17.385	2.183	2017
Görlitz	252.742	272.209	35.911	4.972	2016
Spree-Neiße	479.35	275.038	11.302	2.629	2015, 2016
Oberspreewald-Lausitz	563.175	283.9	15.513	0.014	2015, 2016
Dahme-Spreewald	776.7	88.862	34.302	0.304	2015, 2016
Elbe-Elster	669.98	100.041	25.829	0.018	2015, 2016
District-free City Cottbus	0.064	24.028	1.612	0.28	2015, 2016

In sum about 4,350 MW of renewable electric power is installed in Lusatia covering 38 % of the 11,525 MW of the overall installed amount in Lusatia. As Figures 7 and 8 show, wind turbines and photovoltaics are the dominant technologies. Biomass contributes to less than 2 %.

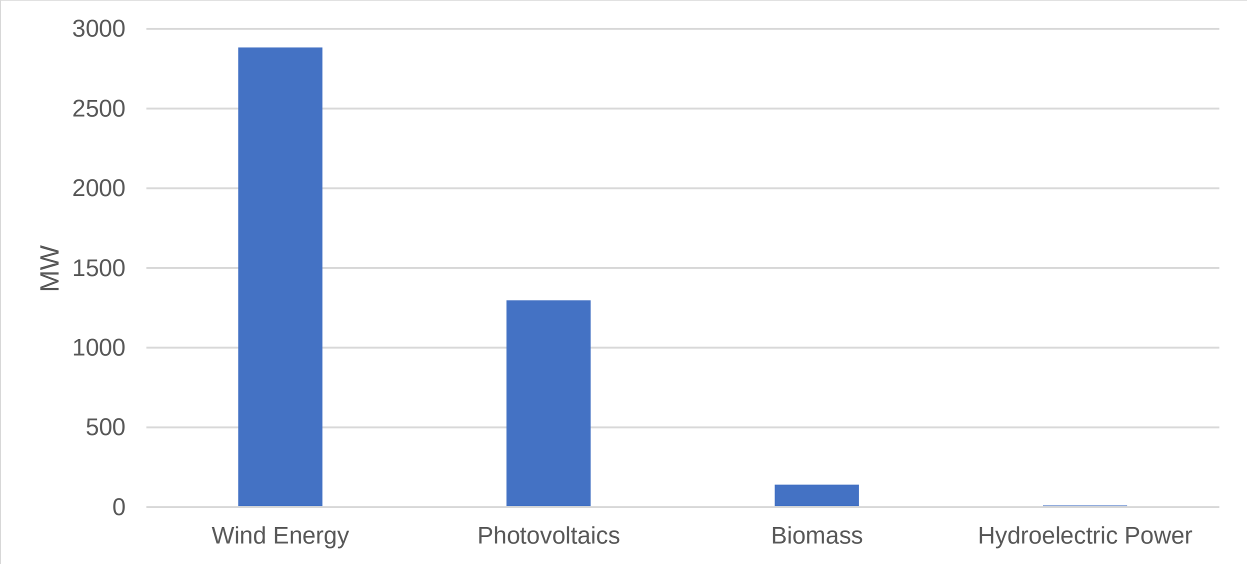


Figure 14: Installed electric power of wind turbines, photovoltaic plants, biomass plants and hydroelectric power plants in the Lusatian region, sum per technology (Data based on: Will et al., 2019, Landkreis Görlitz, 2018, Ministerium für Wirtschaft, Arbeit und Energie Brandenburg, 2020).

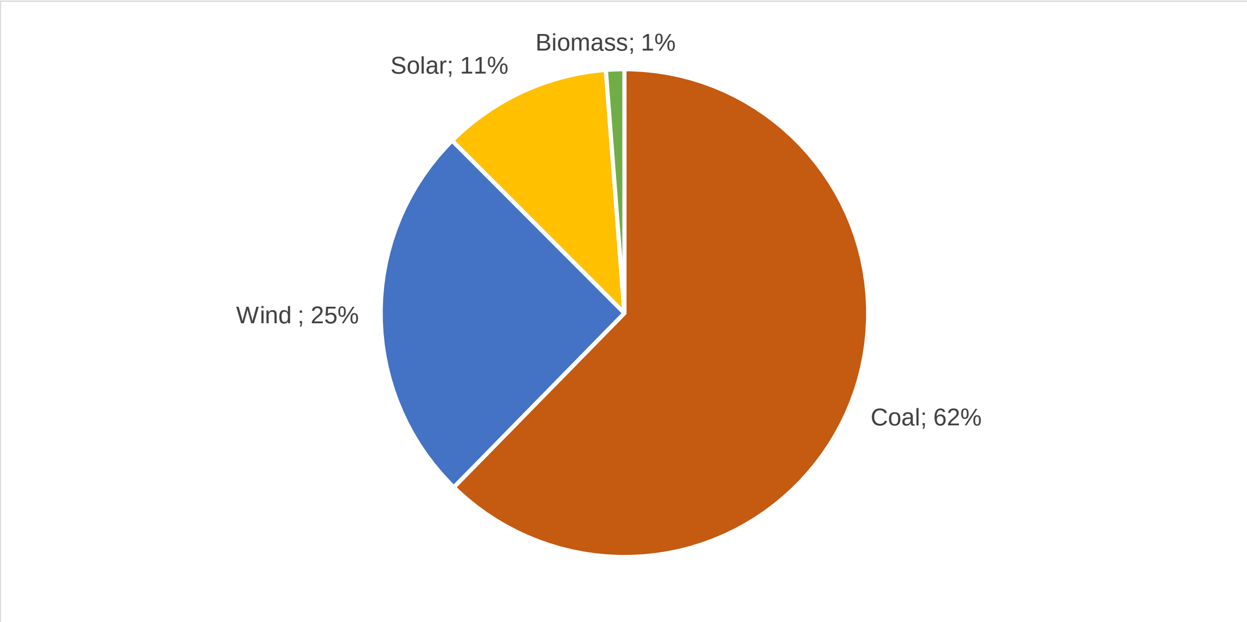


Figure 15: Share of installed electrical power by coal and the main renewable energy sources in Lusatia.

The number and the power of small wood-fired heatings in the Brandenburg part of Lusatia (Table 22) can be found in the Energy and Climate Protection Atlas of Brandenburg (Ministerium für Wirtschaft, Arbeit und Energie Brandenburg (2020). Thus, 2,759 heatings with a thermal power of 64,472 kW are in operation. These systems are commonly installed in private households: Fireplaces use firewood and briquettes as fuel, pellet boiler use wood pellets. Their thermal net capacity ranges from about 2 to 15 kW.; they don’t generate electricity.

Table 22: Number and thermal power of small wood-fired heatings in the Brandenburg districts of Lusatia (Data source: Ministerium für Wirtschaft, Arbeit und Energie Brandenburg, 2020).

District	No. of small wood fired heatings	Thermal power (kW)
Spree-Neiße	574	13,665
Oberspreewald-Lausitz	413	8,826
Dahme-Spreewald	729	17,133
Elbe-Elster	982	23,367
District-free City Cottbus	61	1,481

Larger biomass cogeneration plants produce both, electricity and heat. One possible operating principle of this systems is, that biomass is fired and heats steam in a boiler, which drives an electric generator to produce electricity. The exhaust heat is utilised for heating or drying purposes, additionally. Another possibility is the gasification of biomass, followed by the combustion of the gas in a gas engine, which drives a generator, like it takes place at the plant in the Saxonian part of the *Industrial Park Schwarze Pumpe* in Spreetal.

In the Brandenburg part of Lusatia 6 biomass-cogeneration plants are located (Table 23). Two of them have an electric power below 1 MW, the most powerful plant is the Biomasse-HKW Königs Wusterhausen with 20,000 kW. It supplies a number of households and flats with its heat, by feeding-in to the local heat network.

Table 23: Biomass cogeneration plants in the Brandenburg part of Lusatia (Data sources: Ministerium für Wirtschaft, Arbeit und Energie, 2020a, Danpower GmbH, 2020, MATEC Elektro- und Automatisierungsanlagenbau GmbH, 2020, GMB GmbH, 2020).

District	Name and location	Electric power	Heat, thermal power and utilisation
Dahme-Spreewald	Biomasseheizkraftwerk Königs Wusterhausen	20,000 kW	-, feed-in to the local heat network of the city
Elbe-Elster	Biomasse-HKW Elsterwerda	12,600 kW 80 GWh/a	22 GWh/a; feed-in to the local heat network of the city
Elbe-Elster	Biomasseheizkraftwerk Großbahren	380 kW	-
Oberspreewald-Lausitz	Biomasseheizkraftwerk Calau	3,540 kW	heat is utilised for pellet production
Spree-Neiße	Biomasseheizkraftwerk Sellessen	2,570 kW 20 GWh/a	5,600 MWh/a; supplies 110 family homes and 180 rented flats
District-free City Cottbus	Biomasseheizkraftwerk Ströbitz	900 kW	-

In the Saxon part of Lusatia 15 biomass-cogeneration plants are operating at the moment (Table 24). In comparison to Brandenburg, most of them are much smaller in size with less electrical power, except the facilities in Spreetal, Niesky and Rothenburg. An interesting energy technology offers the new gasification-based plant in Spreetal, mentioned above, which is operated by the Blue Planet Bio-Energy Deutschland GmbH.

Table 24: Biomass-cogeneration plants in the Saxon part of Lusatia (Data sources: Sächsische Energieagentur - SAENA GmbH, 2020, GETEC BBE GmbH, 2020).

District	Name and location	Electric power	Heat, thermal power and utilisation
Bautzen	Biomasseheizkraftwerk Spreetal	2,500 kW	-
Bautzen	Biomasseheizkraftwerk Lauta	150 kW	-
Bautzen	Biomasseheizkraftwerk Hochkirch	79 kW	-
Bautzen	Biomasseheizkraftwerk Weißenberg	40 kW	-
Bautzen	Biomasseheizkraftwerk Weißenberg	8 kW	-
Bautzen	Biomasseheizkraftwerk Obergurig	7.5 kW	-
Bautzen	Biomasseheizkraftwerk Weißenberg	7.5 kW	-
Bautzen	Biomasseheizkraftwerk Großharthau	7 kW	-
Bautzen	Biomasseheizkraftwerk Neschwitz	5.5 kW	-
Görlitz	Biomasseheizkraftwerk Niesky	4,993 kW	10 MW_{th}
Görlitz	Biomasseheizkraftwerk Rothenburg	2,185 kW	-
Görlitz	Biomasseheizkraftwerk Schöpstal	150 kW	-
Görlitz	Biomasseheizkraftwerk Löbau	25 kW	-
Görlitz	Biomasseheizkraftwerk Jonsdorf	25 kW	-
Görlitz	Biomasseheizkraftwerk Zittau	19 kW	-

The geothermal potential in the Brandenburg part of Lusatia is described in Table 25. The data is collected from the "Energy and Climate Protection Atlas of Brandenburg" (Ministerium für Wirtschaft, Arbeit und Energie Brandenburg, 2020). Also for Saxony maps of the geothermal potential are available at:

https://www.umwelt.sachsen.de/umwelt/infosysteme/ida/pages/map/default/index.xhtml.

Table 25: Geothermal potential in the Brandenburg part of Lusatia (Data source: Ministerium für Wirtschaft, Arbeit und Energie, 2020a).

District	Geothermal potential
Dahme-Spreewald	328,908 MWh/a
Elbe-Elster	122,955 MWh/a
Oberspreewald-Lausitz	83,535 MWh/a
Spree-Neiße	62,045 MWh/a
District-free City Cottbus	16,619 MWh/a

5.3 Technological challenges and opportunities

The exit from a coal-fired power generation in Germany comes in addition to the nuclear phase out, decided already in 2011. With this, the two main power generation technologies until then, are no longer available in the future - standing for a complete reorganisation of the national energy industry. The historically unique transition process poses a great challenge with large effects on several areas, like power supply and labour market, which are not only related to Lusatia but also to Germany as a whole.

The joint initiative of the German Foundation Mercator and the European Climate Foundation "Agora Energiewende" plots 12 theses on energy system transformation (Agora Energiewende, 2013). These do not refer especially to the situation in the Lusatian region but are also valid here, in general. According to this, wind and solar energy have the greatest potential in the technological challenge and are the most cost-effectives technologies to produce renewable energy. Other technologies, based on water, biomass or geothermal are more expensive or have less potential due to limited natural availabilities or are still in a stage of research and not ready for implementation. And Lusatia is a trendsetting energy region going ahead: As described before, wind and solar energy currently already provide a share of about 36 % to the installed electrical power, despite the still high installed capacity of lignite-fired power plants.

Nevertheless, a main challenge with wind turbines and photovoltaics is their dependence on the supply of wind and solar radiation, because these fluctuate in a daily schedule and differ day by day. Additionally, they complement each other, because the wind is blowing, when the sun doesn`t shine, ordinarily. To ensure a constant amount of electrical energy, the system must be developed, to compensate for short-term fluctuations and forecast uncertainties. A higher flexibility of the power system is necessary.

As Agora Energiewende (2013) already points out, technical solutions are available running CHP and biomass plants according to the electricity demand. They are making fossil power plants more flexible, avoid generation peaks of wind power and photovoltaics or use them for heat or load shifting of disconnectable loads in the industry, for example.

The development of wind energy in Germany is clearly slowing down at the moment, however. Besides declining feed-in remuneration, as major problem turns out the acceptance of wind turbines by local residents. Therefore, authorisation procedures often take too long - despite the political support on federal and regional level.

Last year only 85 new wind turbines with a power of 283 MW have been built in Brandenburg and Saxony. For comparison, in 2017 584 MW units were installed (Bundesverband WindEnergie e.V., 2019). Inversely, the construction of additional wind turbines is nationwide in 2019 even 80 % less than 2017 (Bundesverband WindEnergie e.V., 2020). Nevertheless, Brandenburg is still a driving force for wind energy. Together with Saxony actually 8,587 MW wind power are installed at the end of 2019.

The German government has set itself the goal of achieving a 65 % share of renewable energies in electricity consumption by 2030 (Presse- und Informationsamt der Bundesregierung, 2018). The Federal Ministry of Economics and Energy suggests a schedule with several measures to create more acceptance and legal certainty for existing and future wind energy projects (Bundesministerium für Wirtschaft und Energie, 2019a). A new regulation on the distance between wind turbines and settlements, which is expected to greatly reduce a further increase, is already particularly criticised from representatives of the wind energy industry and environmental associations. According to wind energy estimates, an increase of around 5,000 MW per year will nationwide be necessary to reach the 65 % target as gross electricity demand grows (Bundesverband WindEnergie e.V., 2020).

5.4 Technical energy transition concept

In January 2020 the German Federal Government and the Prime Ministers of the Federal States Brandenburg, Saxony, Saxony-Anhalt and North Rhine-Westphalia agreed on the structural strengthening of their lignite regions, an exit path from lignite-based electricity generation and the associated climate protection (Presse- und Informationsamt der Bundesregierung, 2020).

A main result of negotiations between the government representatives and the operating companies of coal power stations is a so-called “path of shutdown”, where decommissioning dates are defined for each plant in Germany (Bundesministerium für Wirtschaft und Energie, 2020a). This schedule is part of a new law, which still has to pass the German parliament.

The schedule provides, that all four blocks of the power plant Jänschwalde will be closed at 31.12.2028 latest and two blocks of the plant Boxberg may work until 31.12.2029 (Table 26). The decommissioning of the other two blocks in Boxberg and the whole power plant Schwarze Pumpe is scheduled to 31.12.2038. With regard to the decommissioning envisaged after 2030 revision dates in 2026 and 2029 are intended. Then it will be checked whether the decommissioning can be brought forward by 3 years and the closing date 2035 can be reached.

Table 26: Decommissioning dates for the Lusatian power plants, as part of the German coal ”phase out" or ”path of shutdown” (Data source: Bundesministerium für Wirtschaft und Energie, 2020a).

<table>
<tr><th>Block name</th><th>Federal State</th><th>Latest date of decommissioning</th></tr>
<tr><td>Jänschwalde A</td><td rowspan="4">Brandenburg</td><td>31.12.2025 (security attendance)</td></tr>
<tr><td>Jänschwalde B</td><td>31.12.2027 (security attendance)</td></tr>
<tr><td>Jänschwalde C</td><td rowspan="2">31.12.2028</td></tr>
<tr><td>Jänschwalde D</td></tr>
<tr><td>Boxberg N</td><td rowspan="2">Saxony</td><td rowspan="2">31.12.2029</td></tr>
<tr><td>Boxberg P</td></tr>
<tr><td>Schwarze Pumpe A</td><td rowspan="2">Brandenburg</td><td rowspan="4">31.12.2035</td></tr>
<tr><td>Schwarze Pumpe B</td></tr>
<tr><td>Boxberg R</td><td rowspan="2">Saxony</td></tr>
<tr><td>Boxberg Q</td></tr>
</table>

In addition to the exit from energy generation by lignite or hard coal, the remaining six nuclear power plants (Brokdorf, Grohnde, Grundremmingen C, Emsland, Neckarwestheim 2, Isar 2) will close already at the end of 2022 latest, according to the “law on the peaceful use of nuclear energy and protection against its dangers” (*Nuclear Power Act* (AtG)). The power supply in Germany will in the future base upon renewable energies (Bundesministerium für Wirtschaft und Energie (2020b): A share of 40 % to 45 % of renewable energies at the electricity supply is aimed already for 2025. Following the arrangement of the government coalition, greenhouse gas emissions are to be reduced by 40 % in 2020 and, according to the target formulation of the industrialised countries, by at least 80 % until 2050 - in each case compared to the baseline situation of the German reunification in 1990.

This comprehensive structural conversion will be accompanied by measures to increase the energy efficiency for electricity and heat in different sectors, e.g. the building sector. Moreover, an extension of the grid and from storages is necessary and intended (Bundesministerium für Wirtschaft und Technologie, 2010). The implementation of renewable energies in Germany is not a result of the current and tangible schedule of transition from coal. It already started earlier: hydropower plants, geothermal, landfill gas and sewage gas were more or less the only renewable energy source before wind turbines, photovoltaics and biogas plants were expanded in the late 1980´s and early 1990s essentially.

The development of renewable energies was founded in the environmentalism and anti-nuclear movement of the 1970s. In 1990 the renewable energies delivered 18,935 million kWh of gross electric energy, which was about 92 % power from hydropower plants and only 0.004 % from wind turbines (Federal Ministry for Economic Affairs and Energy, 2019). In 2018 it is 224,738 million kWh - more than ten times more. Renewable energies provide 122 PJ of electricity, which is about 2.3 % considering all energy sources for electricity (5,413 PJ), in 2018 it amounts to 37.8 % or 1,023 PJ (Federal Ministry for Economic Affairs and Energy, 2019; Bundesministerium für Wirtschaft und Energie, 2019b).

Figure 16 illustrates the development of the generation of electricity by wind, photovoltaics and biogas plants in Germany from 1990 to 2018: As the share of renewable energies in gross electricity generation was 3.4 % in 1990, it increased to 37.8 % in 2018. At this point 15.2 % are produced by onshore wind turbines, 7.7 % by photovoltaics, 4.9 % by biogas, 3.3 % by off-shore wind turbines and 3 % by hydropower plants. Other energy sources like biogenic solid fuels or sewage gas contribute less than 2 %.

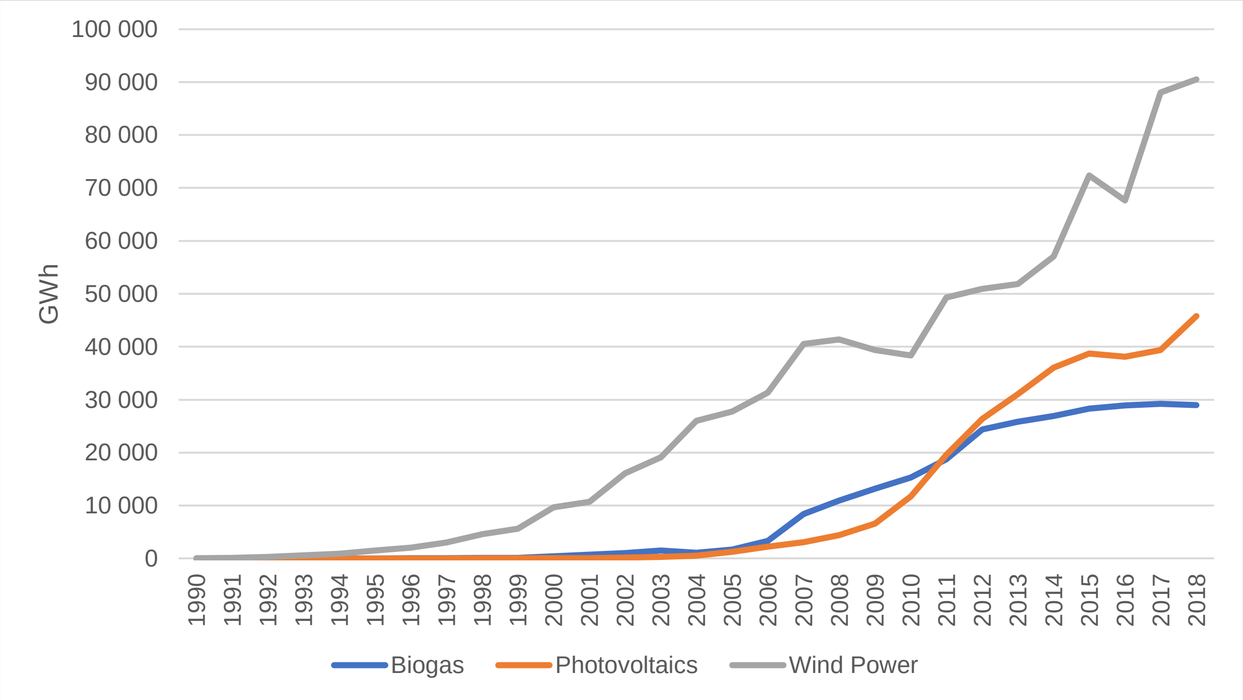


Figure 16: Increase of gross electricity generation from renewable energies in Germany from 1990 to 2018 (Data source: Bundesministerium für Wirtschaft und Energie, 2019c).

This transition process was supported by several legal and political instruments. In 1991 the *Act on Feeding Electricity from Renewable Energies into the Public Grid* was introduced initially. The law required network operators to purchase electricity and guaranteed producers a minimum remuneration, that was calculated as a share of the average electricity revenue obtained two years earlier. The initial regulation was replaced in 2000 by the *Act for the Expansion of Renewable Energies* with several substantial modifications. A main aspect of that so-called *Renewable Energies Act* (EEG) is the guiding principle of priority for the feeding-in of electricity generated from renewable sources. The legal provision was amended in 2004, 2009, 2012, 2014 and 2016/2017. Changes in the several versions of the act always concerned the amount of the feed-in tariffs for the different renewable energy source, particularly.

Figure 17 shows a comparison of the electricity generation in the different Federal States of Germany. It gives an overview of the gross generation and the amount generated from renewable sources. In 2017 Brandenburg has (with 18,376 million kWh) the fourth highest share in gross electricity generation from renewables of all federal states in Germany. Larger amounts only come from Lower Saxony, Bavaria and Schleswig-Holstein - hence Federals States with a high proportion of wind energy due to their privileged location at a cost (on- and offshore windmills) or their high share of hydroelectric power (Bavaria) and additionally high shares of energy from biomass.

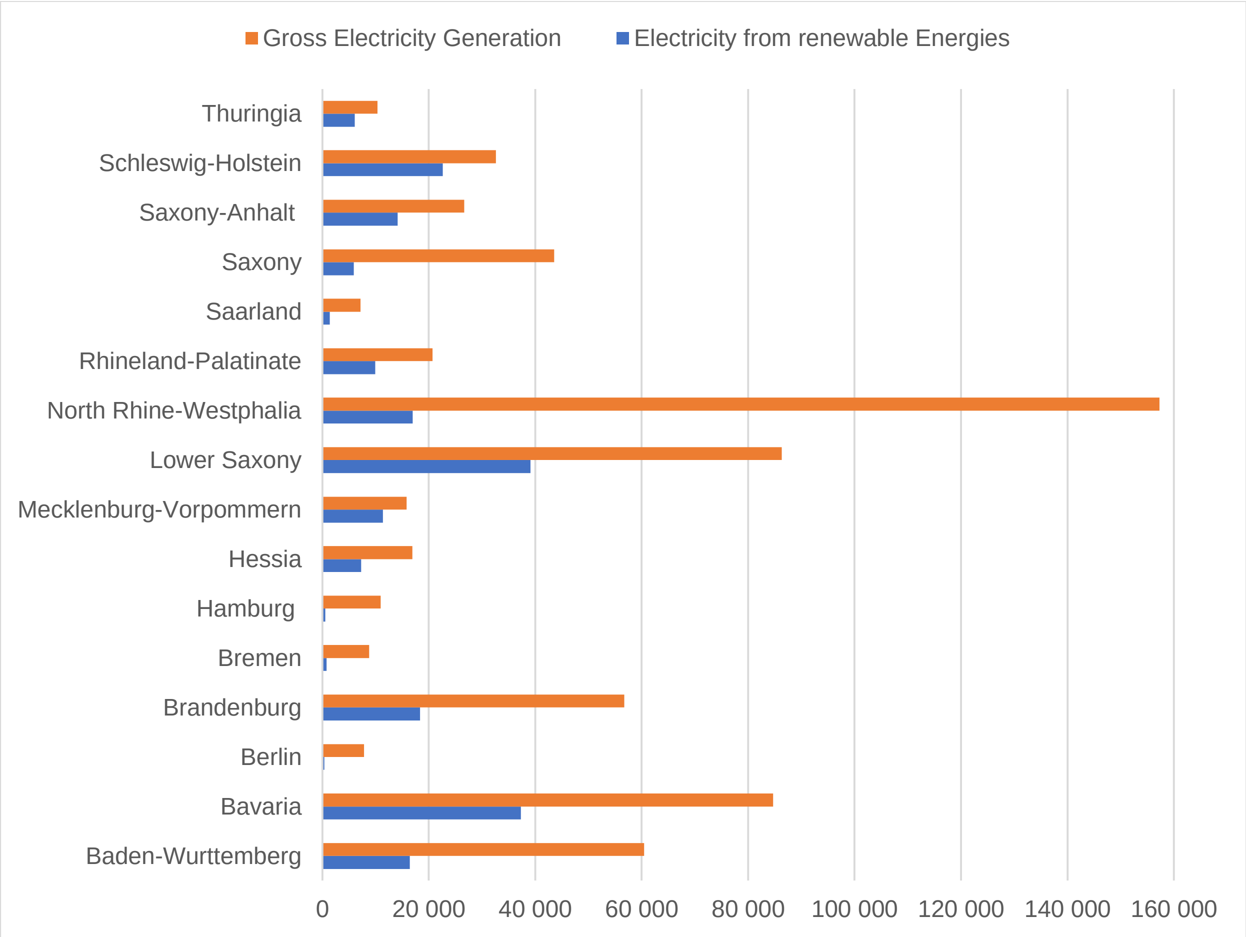


Figure 17: Gross electricity generation and electricity from renewable Energies (millions kWh) all over Germany - 2017 (Data source: Agentur für Erneuerbare Energien e.V., 2020).

Brandenburg has the second highest share of electricity generation from renewable energies per person (Figure 18), due to its high share of wind energy and relatively low population, compared to other Federal States.

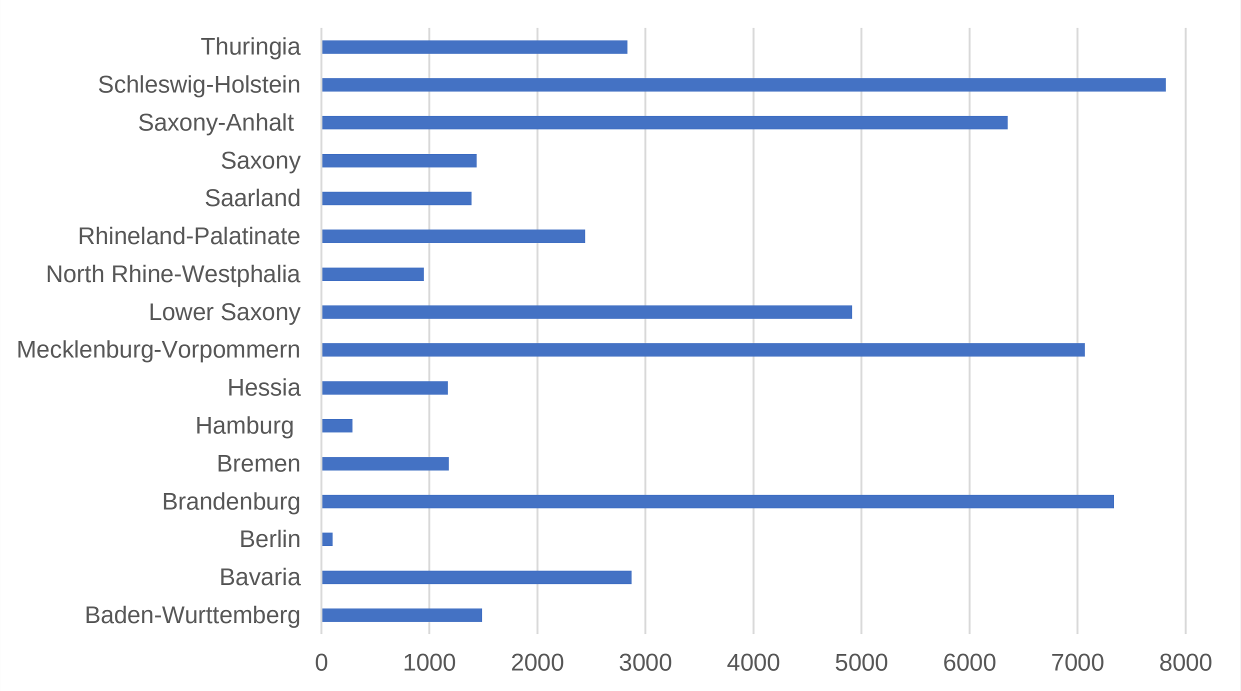


Figure 18: Gross electricity generation from renewable energies per person (kWh) in the Federal States - 2017 (Data source: Agentur für Erneuerbare Energien e.V., 2020)

The EEG targets the electricity market, but also the expansion of renewable heat was taken into account, with the *Act for the Maintenance, Modernisation and Expansion of Cogeneration* (Kraft-Wärme-Kopplungsgesetz), which was introduced already in 2002. The purpose of the law is to contribute the increase of power generation from cogeneration to 25 % by 2020.

In 2018 the share of renewable energies to the heat generation in Germany is about 14.4 % Federal Ministry for Economic Affairs and Energy (2019b). Most of it (37.6 %) comes from solid biofuels and charcoal, used in households (Table 27).

Table 27: Use of renewable energies for heat generation in Germany - 2018 (Data source: Bundesministerium für Wirtschaft und Energie, 2019b).

Renewable energy source	GWh	%
Solid biofuels & charcoal (households)	63,889	37.6
Solid biofuels & charcoal (GHD)	16,960	10.0
Solid biofuels & sewage sludge (industry)	24,522	14.4
Solid biofuels & sewage sludge (HW / HKW)	5,489	3.2
Biogenic liquid fuels	2,275	1.3
Biogas	13,066	7.7
Biomethane	3,117	1.8
Sewage gas	2,498	1.5

Landfill gas	111	0.1
Biogenic share of waste	14,131	8.3
Solar thermal	8,875	5.2
Deep geothermal energy	1,294	0.8
Near-surface geothermal and environmental heat	13,504	8.0
Sum	169,731	100.0

Measures to improve the assured capacity from renewable sources are highly required. Schwarz (2019) lists among others, gas-fired gas- and steam-combined cycle power plants in which excessive regeneratively produced hydrogen is co-combusted. Also batteries could be utilized in future as a fast compensation for fluctuations in electricity production by renewable sources as well as so-called vehicle-to-grid technologies which are able to return electric power from batteries from electric vehicles to the public power network. Power-to-Gas technologies can transfer surplus renewable electricity into hydrogen or methane, which could be used in several ways. Power-to-heat-technologies transfer electrical energy into heat with the help of electric boilers and heat pumps. Even though these options are already developed in a small scale and as prototypes, it will require high investments a time to set them up for a practical application.

5.5 References

AGENTUR FÜR ERNEUERBARE ENERGIEN E.V. (2020): BUNDESLÄNDER-ÜBERSICHT ZU ERNEUERBAREN ENERGIEN, DATENBLATT STROM, WEBSITE AT HTTPS://WWW.FOEDERAL-ERNEUERBAR.DE (ACCESSED AT 14 FEBRUARY 2020)

AGORA ENERGIEWENDE (2013): 12 THESEN ZUR ENERGIEWENDE. EIN DISKUSSIONSBEITRAG ZU DEN WICHTIGSTEN HERAUSFORDERUNGEN IM STROMMARKT (KURZFASSUNG). BERLIN, 19 S., DOWNLOAD AT HTTPS://WWW.AGORA-ENERGIEWENDE.DE/FILEADMIN2/PROJEKTE/2012/12-THESEN/AGORA_12_THESEN_KURZFASSUNG_2.AUFLAGE_WEB.PDF

BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE (2019A): STÄRKUNG DES AUSBAUS DER WINDENERGIE AN LAND. AUFGABENLISTE ZUR SCHAFFUNG VON AKZEPTANZ UND RECHTSSICHERHEIT FÜR DIE WINDENERGIE AN LAND. BERLIN, DEN 07. OKTOBER 2019, DOWNLOAD AT HTTPS://WWW.BMWI.DE/REDAKTION/DE/DOWNLOADS/S-T/STAERKUNG-DES-AUSBAUS-DER-WINDENERGIE-AN-LAND.PDF?__BLOB=PUBLICATIONFILE&V=12

BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE (2019B): EINSATZ VON ENERGIETRÄGERN ZUR STROMERZEUGUNG IN DEUTSCHLAND. TABELLE 23 DER GESAMTAUSGABE ENERGIEDATEN. WEBSITE AT HTTPS://WWW.BMWI.DE/REDAKTION/DE/INFOGRAFIKEN/ENERGIE/ENERGIEDATEN/ENERGIETRAEGER/ENERGIEDATEN-ENERGIETRAEGER-29.HTML (ACCESSED AT 11 FEBRUARY 2020)

BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE (2019C): ZEITREIHEN ZUR ENTWICKLUNG DER ERNEUERBAREN ENERGIEN IN DEUTSCHLAND. DOWNLOAD AT HTTPS://WWW.ERNEUERBARE-ENERGIEN.DE/EE/REDAKTION/DE/DOWNLOADS/ZEITREIHEN-ZUR-ENTWICKLUNG-DER-ERNEUERBAREN-ENERGIEN-IN-DEUTSCHLAND-1990-2018.PDF?__BLOB=PUBLICATIONFILE&V=24

BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE (2020A): STILLLEGUNGSPFAD BRAUNKOHLE, 15.01.2020, DOWNLOAD AT HTTPS://WWW.BMWI.DE/REDAKTION/DE/DOWNLOADS/S-T/STILLLEGUNGSPFAD-BRAUNKOHLE.PDF?__BLOB=PUBLICATIONFILE

BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE (2020B): WEBAUFTRITT, UNSERE ENERGIEWENDE: SICHER, SAUBER, BEZAHLBAR, WEBSITE AT HTTPS://WWW.BMWI.DE/REDAKTION/DE/DOSSIER/ENERGIEWENDE.HTML (ACCESSED AT 9 MARCH 2020)

BUNDESMINISTERIUM FÜR WIRTSCHAFT UND TECHNOLOGIE (2010): ENERGIEKONZEPT FÜR EINE UMWELTSCHONENDE, ZUVERLÄSSIGE UND BEZAHLBARE ENERGIEVERSORGUNG, 36 P., DOWNLOAD AT HTTPS://WWW.BMWI.DE/REDAKTION/DE/DOWNLOADS/E/ENERGIEKONZEPT-2010.PDF?__BLOB=PUBLICATIONFILE&V=5

BUNDESNETZAGENTUR FÜR ELEKTRIZITÄT, GAS, TELEKOMMUNIKATION, POST UND EISENBAHNEN (2019): KRAFTWERKSLISTE, STAND: 11.11.2019, DOWNLOAD AT HTTPS://WWW.BUNDESNETZAGENTUR.DE/DE/SACHGEBIETE/ELEKTRIZITAETUNDGAS/UNTERNEHMEN_INSTITUTIONEN/VERSORGUNGSSICHERHEIT/ERZEUGUNGSKAPAZITAETEN/KRAFTWERKSLISTE/KRAFTWERKSLISTE-NODE.HTML

BUNDESVERBAND DES SCHORNSTEINFEGERHANDWERKS (2018): ERHEBUNGEN DES SCHORNSTEINFEGERHANDWERKS 2018, DOWNLOAD AT HTTPS://WWW.BING.COM/SEARCH?Q=ERHEBUNGEN+DES+SCHORNSTEINFEGERHANDWERKS+2018&FORM=EDGEAR&QS=PF&CVID=E3A99E9DEB1F41F1B63D77BC22CE0676&CC=DE&SETLANG=DE-DE&PLVAR=0

BUNDESVERBAND WINDENERGIE E.V. (2019): DIE BUNDESLÄNDER IN ZAHLEN. DIE DEUTSCHEN BUNDESLÄNDER IM VERGLEICH. WINDENERGIE IN BRANDENBURG. WEBSITE AT HTTPS://WWW.WIND-ENERGIE.DE/THEMEN/ZAHLEN-UND-FAKTEN/BUNDESLAENDER/ (ACCESSED AT 9 MARCH 2020)

BUNDESVERBAND WINDENERGIE E.V. (2020): WINDENERGIE AN LAND – HISTORISCHEN TIEFSTAND DURCH MEHR GENEHMIGUNGEN UND FLÄCHEN SCHNELLSTMÖGLICH ÜBERWINDEN, PRESSEMITTEILUNG VOM 28.01.2020., WEBSITE AT HTTPS://WWW.WIND-ENERGIE.DE/PRESSE/PRESSEMITTEILUNGEN/DETAIL/WINDENERGIE-AN-LAND-HISTORISCHEN-TIEFSTAND-DURCH-MEHR-GENEHMIGUNGEN-UND-FLAECHEN-SCHNELLSTMOEGLICH-UE/ (ACCESSED AT 28 FEBRUARY 2020)

DANPOWER GMBH (2020): ELSTERWERDA, BIOMASSEHEIZKRAFTWERK, WEBSITE AT HTTPS://WWW.DANPOWER.DE/DE/KOMPETENZ-UND-SERVICE/STANDORTE/ELSTERWERDA (ACCESSED AT 12 FEBRUARY 2020)

EEW ENERGY FROM WASTE GROẞRÄSCHEN GMBH, WEBSITE AT HTTPS://WWW.EEW-ENERGYFROMWASTE.COM/DE/STANDORTE/GROSSRAESCHEN.HTML (ACCESSED AT 11 FEBRUARY 2020)

FEDERAL MINISTRY FOR ECONOMIC AFFAIRS AND ENERGY (2019): TIME SERIES FOR THE DEVELOPMENT OF RENEWABLE ENERGY SOURCES IN GERMANY. DOWNLOAD AT HTTPS://WWW.ERNEUERBARE-ENERGIEN.DE/EE/REDAKTION/DE/DOWNLOADS/ZEITREIHEN-ZUR-ENTWICKLUNG-DER-ERNEUERBAREN-ENERGIEN-IN-DEUTSCHLAND-1990-2018-EN.PDF?__BLOB=PUBLICATIONFILE&V=9

GEMEINDE SCHIPKAU (2013): SOLARPARK MEURO WURDE ALS BESTES SOLAR-PROJEKT DES JAHRES 2012 AUSGEZEICHNET, WEBSITE AT HTTP://WWW.GEMEINDE-SCHIPKAU.DE/NEWS/1/187877/NACHRICHTEN/187877.HTML (ACCESSED AT 11 FEBRUARY 2020)

GMB GMBH (2020): BIOMASSEHEIZKRAFTWERKE SELLESSEN, AT HTTPS://WWW.GMBGMBH.DE/GESCHAEFTSBEREICHE/STROM-WAERMEERZEUGUNG/BIOMASSEHEIZKRAFTWERK/ (ACCESSED AT 12 FEBRUARY 2020)

GETEC BBE GMBH (2020): WÄRME, AT: HTTPS://WWW.BESTENERGY1.DE/KONTAKT.HTML (ACCESSED AT 05 MARCH 2020)

HKW HEIZKRAFTWERKSGESELLSCHAFT COTTBUS MBH (2018): HEIZKRAFTWERK MORGEN, WEBSITE AT HTTPS://HEIZKRAFTWERK-COTTBUS.DE/HEIZKRAFTWERK-MORGEN/ (ACCESSED AT 14 FEBRUARY 2020)

INTERNATIONALES WIRTSCHAFTSFORUM REGENERATIVE ENERGIEN (IWR) / IWR.DE GMBH (2020): WINDBRANCHE.DE, DAS BRANCHENPORTAL RUND UM DIE WINDENERGIE, WEBSITE AT HTTPS://WWW.WINDBRANCHE.DE/NEWS/NACHRICHTEN/ARTIKEL-6428-OSTWIND-NEUE-WINDPARK-PROJEKTE-IN-DER-LAUSITZ (ACCESSED AT 11 FEBRUARY 2020)

LANDKREIS GÖRLITZ (2018): SACHBERICHT ENERGIE LANDKREIS GÖRLITZ, STAND AUGUST 2018, SERVICESTELLE ENERGIE – LANDKREIS GÖRLITZ, ENTWICKLUNGSGESELLSCHAFT NIEDERSCHLESISCHE OBERLAUSITZ MBH, WEBSITE AND DOWNLOAD AT HTTPS://WWW.KREIS-GOERLITZ.DE/CITY_INFO/WEBACCESSIBILITY/INDEX.CFM?MODUL_ID=5&RECORD_ID=89104 (ACCESSED AT 12 FEBRUARY 2020)

LAUSITZ ENERGIE BERGBAU AG (2020): DAS UNTERNEHMEN, LEAG – DIE NEUE LAUSITZER ENERGIE, WEBSITE AT HTTPS://WWW.LEAG.DE/DE/UNTERNEHMEN (ACCESSED AT 11 FEBRUARY 2020)

GESETZ ÜBER DIE FRIEDLICHE VERWENDUNG DER KERNENERGIE UND DEN SCHUTZ GEGEN IHRE GEFAHREN (ATOMGESETZ) („ATOMGESETZ IN DER FASSUNG DER BEKANNTMACHUNG VOM 15. JULI 1985 (BGBL. I S. 1565), DAS ZULETZT DURCH ARTIKEL 2 DES GESETZES VOM 12. DEZEMBER 2019 (BGBL. I S. 2510) GEÄNDERT WORDEN IST") (LAW ON THE PEACEFUL USE OF NUCLEAR ENERGY AND PROTECTION AGAINST ITS DANGERS), DOWNLOAD AT HTTPS://WWW.GESETZE-IM-INTERNET.DE/ATG/ATG.PDF#PAGE=1&ZOOM=AUTO,-274,189

GESETZ FÜR DEN AUSBAU ERNEUERBARER ENERGIEN (ERNEUERBARE-ENERGIEN-GESETZ - EEG 2017) („ERNEUERBARE-ENERGIEN-GESETZ VOM 21. JULI 2014 (BGBL. I S. 1066), DAS ZULETZT DURCH ARTIKEL 3 DES GESETZES VOM20. NOVEMBER 2019 (BGBL. I S. 1719) GEÄNDERT WORDEN IST") (LAW FOR THE EXPANSION OF RENEWABLE ENERGIES), DOWNLOAD AT HTTPS://WWW.GESETZE-IM-INTERNET.DE/EEG_2014/EEG_2017.PDF

GESETZ FÜR DIE ERHALTUNG, DIE MODERNISIERUNG UND DEN AUSBAU DERKRAFT-WÄRME-KOPPLUNG (KRAFT-WÄRME-KOPPLUNGSGESETZ - KWKG) („KRAFT-WÄRME-KOPPLUNGSGESETZ VOM 21. DEZEMBER 2015 (BGBL. I S. 2498), DAS ZULETZT DURCH ARTIKEL 4 DES GESETZES VOM 20. NOVEMBER 2019 (BGBL. I S. 1719) GEÄNDERT WORDEN IST") (LAW FOR THE MAINTENANCE, MODERNISATION AND EXPANSION OF COGENERATION), AT HTTPS://WWW.GESETZE-IM-INTERNET.DE/KWKG_2016/

MATEC ELEKTRO- UND AUTOMATISIERUNGSANLAGENBAU GMBH (2020): BIOMASSEHEIZKRAFTWERK, B&B BIOENERGIE, CALAU, AT HTTP://WWW.MATEC-ONLINE.COM/REFERENZEN/RETROFIT/BIOMASSEHEIZKRAFTWERK-BB-BIOENERGIE-CALAU.PHP (ACCESSED AT 12 FEBRUARY 2020)

MINISTERIUM FÜR WIRTSCHAFT, ARBEIT UND ENERGIE BRANDENBURG (2020): ENERGIE- UND KLIMASCHUTZATLAS BRANDENBURG (EKS), AT HTTPS://EKS.BRANDENBURG.DE/ (ACCESSED AT 12 FEBRUARY 2020)

LEAG (2020): BUSINESS FIELD POWER PLANTS. LAUSITZ ENERGIE BERGBAU AG, INTERNETAUFTRITT, AT HTTPS://WWW.LEAG.DE/EN/BUSINESS-FIELDS/POWER-PLANTS/ (ACCESSED AT 8 JULY 2020)

PRESSE- UND INFORMATIONSAMT DER BUNDESREGIERUNG (2018): EIN NEUER AUFBRUCH FÜR EUROPA, EINE NEUE DYNAMIK FÜR DEUTSCHLAND, EIN NEUER ZUSAMMENHALT FÜR UNSER LAND, KOALITIONSVERTRAG ZWISCHEN CDU, CSU UND SPD 19. LEGISLATURPERIODE 175 P., BERLIN, 12. MARCH 2018, DOWNLOAD AT HTTPS://WWW.BUNDESREGIERUNG.DE/RESOURCE/BLOB/975224/847984/5B8BC23590D4CB2892B31C987AD672B7/2018-03-14-KOALITIONSVERTRAG-DATA.PDF?DOWNLOAD=1

PRESSE- UND INFORMATIONSAMT DER BUNDESREGIERUNG (2020): BUND-/LÄNDER-EINIGUNG ZUM KOHLEAUSSTIEG, PRESSEMITTEILUNG 22, DONNERSTAG 16. JANUAR 2020, WEBSITE AT HTTPS://WWW.BUNDESREGIERUNG.DE/BREG-DE/AKTUELLES/BUND-LAENDER-EINIGUNG-ZUM-KOHLEAUSSTIEG-1712774 (ACCESSED AT 12 FEBRUARY 2020).

SÄCHSISCHE ENERGIEAGENTUR - SAENA GMBH (2020): ENERGIEPORTAL SACHEN, ERNEUERBARE ENERGIEN – BIOMASSEANLAGEN. ONLINE-GIS AT: HTTP://WWW.ENERGIEPORTAL-SACHSEN.DE/ (ACCESSED AT 05 MARCH 2020)

SÄCHSISCHES OBERBERGAMT (2020): ZAHLEN UND FAKTEN, BRAUNKOHLENFÖRDERUNG IN SACHSEN IM JAHR 2018, WEBSITE AT HTTPS://WWW.OBA.SACHSEN.DE/278.HTM (ACCESSED AT 12 FEBRUARY 2020)

SCHWARZ, H. (2019): OHNE SICHERE VERSORGUNG GEHT ES NICHT. BTU NEWS 17/54, P.12

STADTWERKE COTTBUS GMBH (2020): HEIZKRAFTWERK HEUTE, HEIZKRAFTWERK MORGEN, WEBSITE AT HTTPS://HEIZKRAFTWERK-COTTBUS.DE/ (ACCESSED AT 11 FEBRUARY 2020)

STATISTISCHES LANDESAMT BREMEN (2020): LÄNDERARBEITSKREIS ENERGIEBILANZEN, ERGEBNISSE DES DATENABRUFES, BRUTTOSTROMERZEUGUNG NACH ENERGIETRÄGERN. WEBSITE AT HTTPS://WWW.LAK-ENERGIEBILANZEN.DE/ERGEBNISSE-DES-DATENABRUFS/?A=E350&J=2017&L=1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16&V=ANM,INSGESAMT,AGG_STEINKOHLE,AGG_BRAUNKOHLE,MINOEL_HEIZOEL,GASE_ERDGAS,AGG_STRERZ_BRUTTO_EE,ANDERE_KERNENERGIE,ANDERE_ANDERE_SW,STAND (ACCESSED AT 11 FEBRUARY 2020)

STATISTISCHES BUNDESAMT (2019): BRUTTOSTROMERZEUGUNG IN DEUTSCHLAND, BRUTTOSTROMERZEUGUNG IN DEUTSCHLAND FÜR 2016 BIS 2018, WEBSITE AT HTTPS://WWW.DESTATIS.DE/DE/THEMEN/BRANCHEN-UNTERNEHMEN/ENERGIE/ERZEUGUNG/TABELLEN/BRUTTOSTROMERZEUGUNG.HTML (ACCESSED AT 9 MARCH 2020)

UMWELTBUNDESAMT (2020): THRU.DE, EUROPEAN POLLUTANT RELEASE AND TRANSFER REGISTER, WEBSITE AT HTTPS://WWW.THRU.DE/INDEX.PHP?ID=421 (ACCESSED AT 11 FEBRUARY 2020)

WILL, M., LÄSSIG, J., BESOLD, J., BELLMANN, M. (2019): ENERGIE- UND TRIEBHAUSGASBERICHT 2018 LANDKREIS BAUTZEN, DOWNLOAD AT HTTP://WWW.TGZ-BAUTZEN.DE/FILEADMIN/MEDIA/PDF/ENERGIEAGENTUR/PUBLIKATIONEN/ENERGIE-_UND_TREIBHAUSGASBERICHT_2018_DES_LANDKREISES_BAUTZEN.PDF

6 Greece, Western Macedonia Region

6.1 Current energy generation technologies using coal

6.1.1 Coal driven power plants, CHP plants

The five (5) main lignite-mining fields that exist in the Western Macedonia Lignite Centre (WMLC), which is the biggest in Balkans, the 2nd biggest in the European Union and the 6th all over the world, used to provide fuel to six (6) Thermal Power Plants (TPPs) with 18 units and total installed capacity of 4,438 MW. In the following table (Table 28) an overview of the lignite technology status in Western Macedonia (the WM 'Energy Centre') in the beginning of the previous decade is given.

Table 28: PPC lignite-fired power plants in the WMR (Karampinis and others, 2011; Roques and others, 2014)

No	Power plant name	Plant capacity / unit power (MW)	Technology type	Lower heating value (LHV) (kJ/kg)	Start of operation	Efficiency (%)	Specific CO_2 emissions (tCO_2/ MWh)
1	Agios Dimitrios Power Station	1,595 5 Units (2 x 300 + 2 x 310 + 1 x 375)	Steam turbine generating units with condensing system and feed water heating systems	5,276 - 6,757	1984-1996	37.3 (gross)	0.982
2	Amyntaio Power Station	600 2 Units (2 x 300)	Steam turbine generating units with condensing system	4,079 - 5,774	1986	32.0	1.122
3	Florina (Melíti) Power Station	330 1 Unit	Steam turbine generating units with condensing system - FGD*	8,062 – 9,443	2003	36.2	1.015
4	Kardia Power Station	1,250 4 Units (2 x 300 + 2 x 325)	Steam turbine generating units with condensing system and feed water heating systems	5,276 - 6,757	1974-1981	36.5 (gross)	1.050
5	Liptol Power Station	43 2 Units (10 + 33)	Steam turbine generating units with condensing system	5,276 - 6,757	1959-1965	Not available	Not available
6	Ptolemaida Power Station	620 4 Units (1 x 70 + 2 x 125 + 1 x 300)	Steam turbine generating units with condensing system	5,276 - 6,757	1959-1972	32.0	1.116

**FGD: flue gas desulphurisation*

However, the unit of 70 MW (Unit I) of the Ptolemaida Power Station ceased its operation in 2011. Units III and IV were destroyed in a fire in November 2014, while Unit II is on standby mode since 2013. Finally, the Liptol Power Station (2 Units) was decommissioned in June 2013. Thus, a total capacity of 663 MW has already been shut down in the Region between 2011 and 2014.

In addition, due to the need to comply with the new, stricter EU Directive 2010/75/EC on industrial emissions, PPC had to put six (6) lignite units of the WMLC of a total capacity of 1,850 MW under restricted operation. Thus, from January 2016, these units operate around a third of the time they used to, before completely withdrawing at some point until 2023 at the latest. So, currently in WMR operate at full power only the remaining six (6) of the above-mentioned 18 units, with a total capacity of 1,925 MW.

Another important aspect of lignite fired TPPs in the region is that PPC SA made a series of investments in energy supply in the form of hot water for urban district heating purposes, via a number of Power Plants: Ptolemaida III (50 MW_{th}), Agios Dimitrios III (67 MW_{th}), IV (67 MW_{th}), V (70 MW_{th}), Amyntaio (20 MW_{th}), and LIPTOL (25 MW_{th}). The expansion of the Municipality of Kozani's district heating from Ag. Dimitrios TPP (maximum district heating capacity: 137 MW_{th}) was concluded in 2008, while the district heating interconnection of the Municipality of Ptolemaida and Kardia TPP was made in 2009. Furthermore, the district heating of Florina city from Meliti TPP (70 MWth) was concluded in 2010.

Thus, about 100,000 citizens of Kozani, Ptolemaida and Amynteo are heated by district heating systems from lignite power plants. The cessation of the operation of Unit III in Ptolemaida plant since the accident, had an additional negative impact, since 50 MW_{th} of thermal energy for district heating, provided to the nearby city of Ptolemaida were lost, causing a gap to the energy needed for the heating of city's households. This was the case with the Unit I of Liptol lignite-fired power plant, which provided 25 MW_{th} of thermal energy to the city of Ptolemaida (decommissioned in 2014). It is obvious that closing down the aforementioned TPPs that are currently providing thermal energy to the towns of Western Macedonia will create the need to identify and develop alternative sources of energy.

Ptolemaida V is to be the fifth coal-fired unit at the Ptolemaida power station, with a generating capacity of 660 MW. The total projected budget for the construction of the plant is 1.32 billion Euros, of which German investment bank KfW will provide 700 million Euros. The plant was permitted in March 2013. The plant is constructed on the site of a dismantled lignite mine. Construction was set to begin in 2015, and the plant was scheduled to begin commercial operation in 2019, but, due to the economic tightness of PPC, construction on the new unit began in 2016 and it is now planned for 2022.

In the mid-term planning of PPC it was foreseen the construction of a second unit in Meliti - Florina (Meliti II) of 450 MW gross nominal capacity (already included in PPC's investment programme), while PPC has revealed publicly its plans to extensively upgrade the Amyntaio Power Station in order to extend its operation beyond 2023. There is also provision for energy supply for district heating from the new Ptolemaida V Unit (660 MWe_l): 140 MWth, and the new Unit II of Meliti TPP (450 MWe_l): 70 MWth.

However, the plans for Meliti II will no longer go ahead, as Greece's Supreme Administrative Court, the Greek Council of State, has annulled the environmental permit for this lignite-fired power plant. Also, in the end of 2019, PPC announced it would cease operating all of its existing lignite-fired power plants by 2023. PPC's decision came after the Greek government committed to phasing out lignite from its energy mix by 2028 at the latest, setting the path towards a cleaner energy system for the country.

As regards the economics of power generation through the use of the extracted lignite, it must be mentioned that, in 2014 the Public Power Corporation (PPC) commissioned a study to Booz & Co Consultants in order to compare the costs of lignite-fired power generation in the lignite-mining European countries (Germany, Poland, Greece, Turkey, Czech Republic, Romania, Bulgaria, Serbia). This, in view of identifying the key cost parameters and the differences among the various lignite systems in Europe.

According to the findings, and as is shown in Figure 19, in 2012 the cost of lignite extraction in Greece (at € 2.12 per ton) was the lowest, comparable to that in Germany. However, if the extremely low calorific value of Greek lignite (approximately 1,200 kcal/kg) is taken into consideration, together with other variable production cost parameters, then lignite-fired power generation in Greece proves to be the costliest in Europe, at 59.93 €/MWh, compared to a range between 31.57 €/MWh (Bulgaria) and 54.19 €/MWh (Romania) in the other countries of the study.

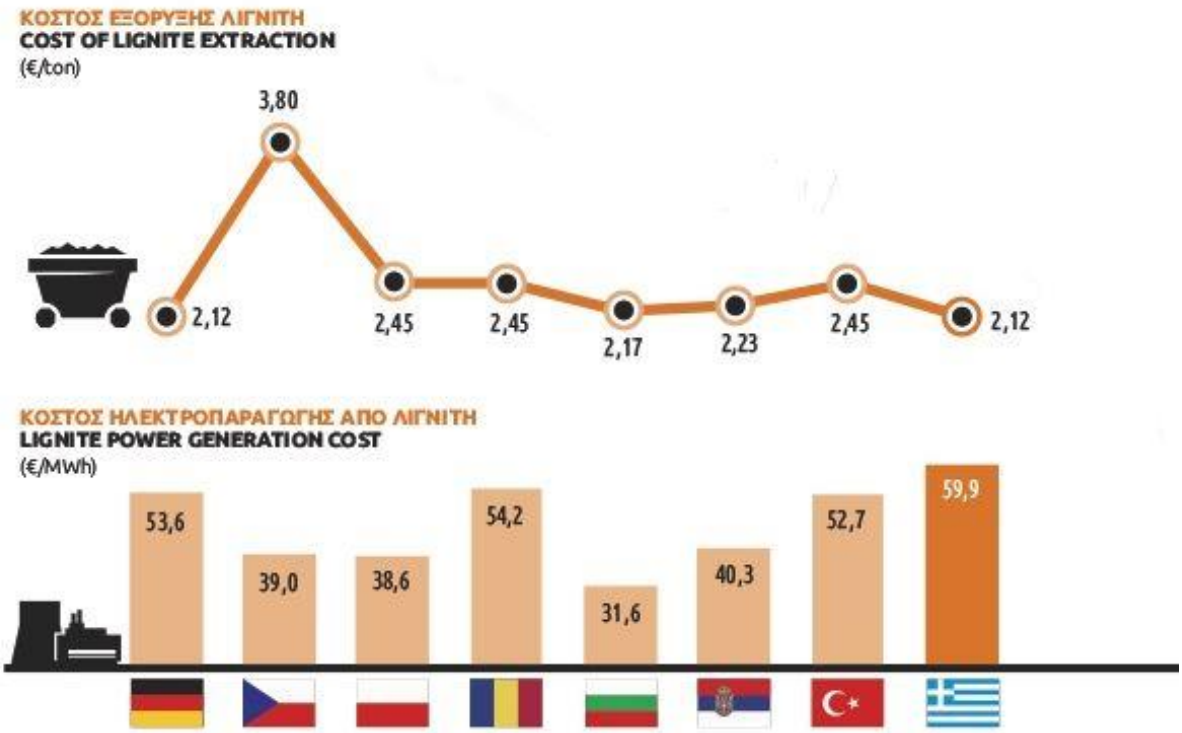


Figure 20: Source: Heinrich-Böll-Stiftung, Thessaloniki office – Greece (https://gr.boell.org/en/2015/12/16/cost-lignite-fired-power-generation)

6.1.2 Use of coal for small applications

As already mentioned in section 6.1.1, lignite is used in parallel of power generation for the provision of heating to many towns in the region of Western Macedonia. The method of 'producing' the heat transferred from the power stations of PPC to the cities is the use of the waste water from the power plants to heat the water that is transferred to the establishments for space heating purposes. Thus, this 'application' of the energy generation using coal (lignite in our case) has been included in the previous section (i.e. the whole procedure works as in the case of CHP technologies).

On the other hand, and due to the low quality (i.e. calorific value) of Greek lignite, its use for other energy related activities is practically impossible. The usual way to cover the needs for industrial heating/process-heat or space heating (households, flats, public buildings, tertiary sector) is the use of heating oil, except from very limited cases (e.g. individual households in rural areas) where locally existing biomass fuels (logwood, residues) are used.

6.2 Current status of other energy generation technologies

There are approximately 530 MW of installed hydro power in WMR, which correspond to approximately 16% of the total installed capacity in the country and produce, bearing annual variations, approximately 740 GWh per annum. More specifically:

1. Polyfyto Hydroelectric Power Plant, located at Kozani, West Macedonia (Aliakmonas river). This infrastructure is of Dam on river with reservoir Hydro Power Plant with a design capacity of 375 MW_{el}. It has 3 units. The first unit was commissioned in 1974 and the last in 1975. It is operated by Public Power Corporation (PPC / DEH).
2. Ilarion Hydroelectric Power Plant, located at Kozani, West Macedonia (Aliakmonas river). This infrastructure is of Dam on river with reservoir Hydro Power Plant with a design capacity of 154 MW_{el}. It has 2 units. The first unit was commissioned in 2011 and the last in 2011. It is operated by Public Power Corporation (PPC / DEH) since 2014.

Apart from the Ilarion large hydropower plant (HPP) in Aliakmonas River, there is also a small hydropower plant (SHPP) operated by PPC that harnesses the ecological supply of the Ilarion Dam. It has an installed capacity of 4.2 MW and an average annual power output of 22 GWh. Apart from that, and according to the most recent available data [*RES Manager & Guarantee of Origin* (DAPEEP SA), January 2020], there are 12 more small hydroelectric power plants (i.e. with an installed capacity of < 15 MW, as is the definition of SHPP in Greece), with a total capacity of 18.9 MW in Western Macedonia.

As regards wind energy, there are currently in operation six (6) wind parks with a total installed capacity of 146.5 MW, while there are another 66.6 MW with installation licence (i.e. already installed or under installation) waiting for the operation licence. It is important to mention that, in the recent auctions held between 7/2018 and 7/2019 another 100.95 MW of wind energy projects were selected at a weighted average of 66,8 €/MWh.

As for the solar energy, in January 2020 there are 133.33 MW of PV systems installed in Western Macedonia, from which:

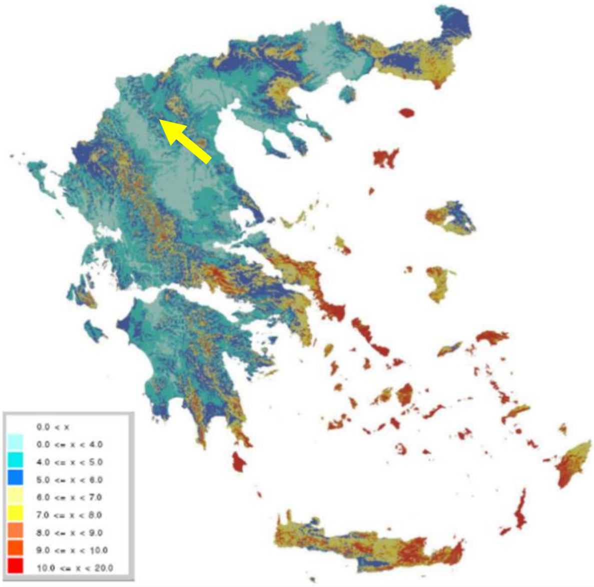
1) 19.49 MW is the total capacity of PV units that have been installed in the frame of the special programme of "PV rooftop systems", which supports electricity generation by rooftop PV installations of up to 10 kW_p through a guaranteed feed-in tariff (since February 2017: € 105 per MWh),
2) the 41.69 MW correspond to installations of ≤ 100 kW (the 8.65 MW of them with an installed capacity of < 20 kW, i.e. units that do not require an installation licence),
3) 34.1 MW is the installed capacity of PV systems in the category of > 100 kW and ≤ 500 kW,
4) another 15.28 MW are installations of > 500 kW and ≤ 1 MW,
5) 16.77 MW of the total correspond to PV systems with capacities > 1 MW and ≤ 5 MW;
6) There is also one PV park of 6 MW installed capacity.

In addition, there are five (5) units installed and developed for the production and exploitation of biogas from biomass (agro-wastes treatment) for the purpose of cogeneration of electric and thermal power, of 1.48 MW_{el} installed capacity.

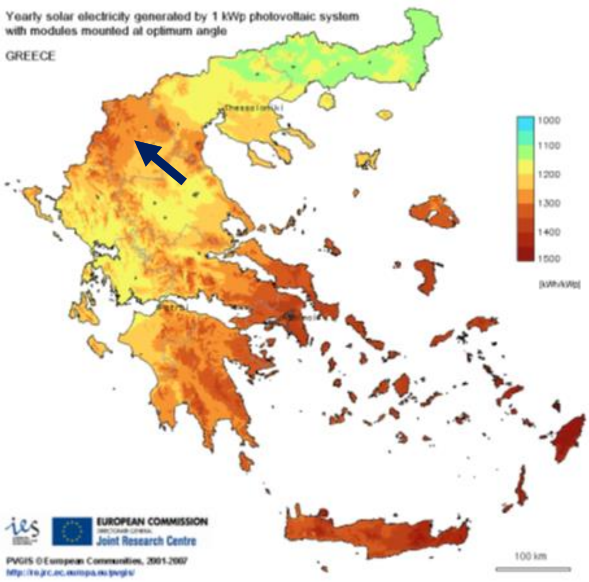
As regards the use of other technologies / fuels / energy sources for heating and cooling purposes, it must be mentioned that in Western Macedonia, as is the case with all over Greece, a significant number of households (but also, hotels, and other buildings of the tertiary sector) use solar water heating (SWH) systems for the preparation of domestic hot water (DHW). Also, in many cases, basically in rural areas, households use wood stoves and/or boilers for covering their space heating needs. However, it is extremely difficult to provide data on such technologies (i.e. number of SWH systems installed, square meters of collectors area, type of systems or number of stoves / biomass boilers, type of biomass fuel used, etc.).

6.3 Technological challenges and opportunities

Region of Western Macedonia has a huge unexploited capacity in wind and solar energy. The wind and solar energy potential of the region are clearly shown in the below maps, from which the left one is the wind atlas of Greece (prepared in various stages by CRES), showing the average annual wind speed at 40 m a.g.l. (above ground level), and the right one corresponds to the yearly solar electricity generated by a 1 kW_p PV system with modules mounted at optimum angle.



Wind map of Greece [*Source: CRES, 2015*]



Solar power potential [*Source: JRC PVGIS*]

Western Macedonia presents moderate levels of solar radiation in the range of 1,500 kWh/m^2 (yearly sum of global irradiation on a horizontal surface). A calculation with the Photovoltaic Geographical Information System (PVGIS) - an online free solar photovoltaic energy calculator for stand-alone or connected to the grid PV systems and plants developed by JRC for the EC - for the city of Kozani results in a total yearly production of 1,390 kWh per 1 kWp.

With regards to wind energy, and according to a study by the Centre for Renewable Energy Sources and Saving (CRES), in which thematic maps for the assessment of the technically and economically exploitable wind power potential in Greece have been produced, the region's contribution can reach 500 MW and a 4.67% share in the country's total installed capacity by 2020. This assumption is made based on the existing dense power transmission network in WMR. In addition, based on the region's carrying capacity, it is estimated that there can be approximately 6,246 ‘typical’ wind turbines installed.

It must be noticed that, apart from the above mentioned (Section 6.2) 213.1 MW of wind parks that are already in operation or under installation in the region, as well as the 100.95 MW of wind energy projects selected in the recent auctions, there are another 795.7 MW of wind energy projects with approval of their Environmental Impact Assessment (EIA), as well as a number of projects of 746.5 MW capacity that have obtained Production License. Last, there are also another number of wind energy projects that have applied for granting a Production License, with a total capacity of 377.6 MW. In other words, wind energy projects being in various stages of the licensing procedure in WMR (including those with Operation License) rise to 2,132.9 MW of capacity.

In order to assess the available biomass capacity in Western Macedonia and especially in the areas of interest for the DH networks of Ptolemaida, Amynteo and Kozani, several studies have been conducted and the available data have been presented in publications and one-day conferences. According to the Public Enterprise for District Heating in Ptolemaida (DETIP), the available biomass capacity in Western Macedonia mainly originates from forest biomass (125,000 tons/year) and agricultural residues (201,000 tons/year) with a respective total thermal content of 1,630 GWh/year.

The Public Enterprise for District Heating in the Greater Area of Amynteo (DETEPA) estimates that the biomass capacity in the greater area of Amynteo, Florina and Eordaia amounts to approximately 146,000 tons or 730 GWh/year, with the largest part originating from corn crops (about 66,000 tons/year). Particularly for the Kozani Prefecture, where the city of Ptolemaida belongs in administrative and geographical terms, the available biomass quantities amount to approximately 279,000 tons/year with a thermal content of 1,435 GWh/year, according to another study.

Although the various studies greatly differ in their estimate of the biomass capacity, and this estimate refers either to the greater area of Western Macedonia or the Kozani Prefecture or parts thereof, it is still sufficient to meet e.g. the thermal needs of the DH networks of the region. Moreover, the option to develop energy crops must be taken into account, if there is additional demand for biomass for other cities. Cardoon crops are particularly interesting since, according to a series of studies, it is the most suitable plant given the prevailing weather conditions in Greece, as well as due to the plant's endurance and the limited requirements for its cultivation.

As an indication of the RES potential of WMR and of the interest to develop RES projects there, it is mentioned that PPC Renewables SA, a wholly-owned subsidiary of PPC, has commenced to develop a project with an intention to construct Greece’s largest biomass combined heat and power (CHP) plant. The plant, which will provide 25 MW_{el} of electricity and 45 MW_{th} of heat, is planned to be installed at an area reserved for PPC Renewables of approximately 58,000 m^2, near the PPC’s existing TPP of Amynteon and will be using the existing facilities in order to be connected to the electrical and district heating grids. PPC Renewables has already obtained a Production License from the Regulatory Authority of Energy and has conducted a number of different studies during the past several years.

The unit, whose license for power production was approved by RAE at the end of 2015, will cost €80 million and produce 186,150 MWh per year. The project can accommodate up to 225, 000 metric tonnes of biomass annually, while approximately 10,000 hectares of land will be required for the cultivation of the required energy plants. PPC Renewables is seeking a strategic partner who will hold a majority stake and take over the planning, funding, construction and operation of the unit. A total of 12 companies or joint ventures have expressed interest in a tender launched by PPC Renewables in December 2017 for this purpose.

Also, the Greek subsidiary of German RE project developer juwi and the Hellenic Petroleum (ELPE) Group signed a purchase agreement for a portfolio of photovoltaic plants in the final licensing stage, in the region of Kozani. The project, totalling 204.3 MW, is the largest renewable energy project in Greece and among the five largest PV parks in Europe. After its completion, the park will produce about 300 million kWh of climate-friendly electricity – enough to power 75,000 Greek households. It will also save 300,000 tons of greenhouse gas emissions annually.

The total investment will amount to 130 million Euros. The transaction is expected to be closed during the second quarter of 2020. Construction will begin in the third quarter of 2020 and will take about 16 months. The project is expected to be put into operation in the 4th quarter of 2021. The Kozani solar park will also have a significant impact on the local economy, particularly in the area of Western Macedonia, as more than 300 jobs will be created during the construction. The project comprises three chunks of generation capacity – 139.24 MW, 27.68 MW and 37.37 MW – with the largest slice having negotiated a tariff of €0.05446/kWh for the solar power it will supply. The other two sections each secured a price of €0.06472/kWh.

At the same time, PPC is moving “rapidly” in Western Macedonia to create large photovoltaic parks in mines that have been closed or will be shut down in the near future along with lignite plants in the area. As it was announced recently, PPC’s goal is to install a massive 2 GW solar project in Ptolemaida in the Kozani region of northern Greece and a 1 GW installation on the Peloponnese peninsula in the south of the country (Megalopoli area).

PPC Renewables SA has already submitted, in December 2019, applications to the Regulatory Authority for Energy (RAE) for photovoltaic parks with a capacity of approximately 1,500 MW. This is a continuation of the effort that PPC has begun since 2018 to exploit depleted mines in the area and convert them into photovoltaic parks. "PPC Renewable SA" submitted in 2018 applications for 19 photovoltaic projects totaling 360 MW.

The plan to create a mammoth photovoltaic park in the areas of Kozani and Ptolemaida is much older. Investments had been under way since 2010. The initial planning was for the entire project to be awarded directly to the US company Sunedison, a total investment of € 1 billion. Eventually, the direct assignment scenario was abandoned and PPC launched an international competition that was unsuccessful. The project, which envisioned a photovoltaic park on an area of 5,000 acres of 200 MW capacity, has been on the shelf for nearly six years. In 2017, PPC brought the project back to the table, and received RAE's approval for the project, which was estimated to be able to act as a compensatory measure to the at that time plan for sale of PPC’s lignite units in Western Macedonia.

Now, PPC Renewables plans to stage a tender in spring 2020 for this solar energy project, which, when completed, promises to rank among Europe’s biggest. The overall project will be comprised of three packages – two small units totalling 30 MW whose tenders have either already been launched, as well as a major 200 MW facility that will be constructed in four plots with a total area of 500 ha on reclaimed waste heaps surfaces of Ptolemais lignite mines. The project will offer a total capacity of 230 MW, create at least 300 jobs during construction and, once launched, will generate 390,000 MWh capable of covering the needs of approximately 290,000 consumers.

PPC’s goal is to install a massive 2 GW solar project in Ptolemaida in the Western Macedonia region of northern Greece. Construction works at Ptolemaida could start as early as 2021.

6.4 Technical energy transition concept

Western Macedonia Region (WMR) supplies electricity to the Greek interconnected system since 1960 acting for several decades as the Greek energy pillar of economic growth, due to the low electricity production cost through the utilization of local energy sources. Four (4) lignite fired power plants are in operation representing the 40% of thermal units and 20% of the total installed net capacity of the interconnected system in Greece. Also, approximately 100,000 citizens of Kozani, Ptolemaida and Amyntaio use district heating systems powered by lignite power plants.

Lignite Industry started its decline in 2010 initiating the request for transition to a new economic model for the Region. Three main phases characterize the lignite utilization shrinkage.

- The first phase has already occurred during the period 2010 – 2015, when the four (4) oldest units ceased operating.
- In 2020, the second phase is expected when six (6) units will terminate their operation, according to the existing environmental limitations.
- It was expected that, four (4) more units would reach their lifetime by 2030, leaving only three (3) units or 30% of the initial lignite capacity in the region, having taken into account the new unit, which will start its operation in 2022. However, in September 2019, the Greek Prime Minister has announced at the UN Climate Action Summit in New York that Greece will close all its lignite-fired power plants by 2028 at the latest.

Note: The phase-out deadline matches the expiration date of the environmental permits of all of Greece’s lignite plants and mines.

Western Macedonia’s contribution to the overall national electricity production has been severely diminished. The Region’s input to the Greek energy mix has been reduced from almost 50% (2009) to less than 30% (2016). New capacity building mainly on Wind and PV brings new challenges for Regional energy profile diversification.

Also, according to the Municipal Enterprise for Water Supply and Sewage in Kozani (DEYAK), i.e. the operator of the district heating (DH) network in Kozani, and based on PPC's planning, it is estimated that after 2020, only one system for hot water generation for DH will remain active at unit V of the steam-electric power station Agios Dimitrios. Therefore, the remaining heat load will have to be covered either by another PPC's unit or by other independent heat generation systems (boilers, CHP, etc.).

The Western Macedonia Region production model based on conditions of one-dimensional growth presents a limited range of flexibility in terms of its sectoral structure. The system is extremely vulnerable either to the declining economic activities or, even more, to situations of general economic crisis. For example, decommissioning of 300 MW capacity would deprive the local economy by 83 million EUR on annual basis. It is estimated that in case of no Regional supporting actions, the unemployment in Western Macedonia in 2050 will rise above 40%.

According to the proposed National Strategy for Adaptation Measures to Climate Change (2015), the local negative impact could possibly be fourfold compared to other Greek regions, mainly derived from the reduction of lignite mining activity. The radical restructuring of the regional economy is of major importance, on the one hand, in areas and sectors that capitalize the existing human resources experience in the energy sector and on new activities that set high income and employment multipliers to achieve the goal of combating high existing and emerging unemployment and safeguarding social cohesion.

However, to ensure an easier transition to a clean energy economy, some challenges need to be overcome. They are related not only to the technology, but also to society. The region has been supplying lignite to the energy industry for more than seven decades, enough to shape a specific coal oriented mentality of the local population. It seems to be very difficult to persuade employees, miners, engineers that this specific activity will stop. If the support consists in an early retirement bonus for the generations close to retirement age, then the younger generations will need to learn a new profession.

In concluding, WMR is starting its transition to a low carbon economy under the following conditions:

Strengths	**Weaknesses**
• High concentration of specialized human resources	• One–dimensional characteristics of labour force
• Industrial culture	• Continuing decrease of lignite production
• Important energy and environmental infrastructure	• Ongoing decommissioning of lignite units
• Diversification of energy resources	• High rates of unemployment
• Primary sector with perspective	• Energy poverty
• Academic and research structures	• Low diversification of productive model
• Strategic geographic position in South-East Europe area	• Low innovation rates

The regional strategy for the transition should fulfil the following specified three main axes:

1) <u>Business</u>
   - Strengthening business activities;
   - Enhancing the region’s productive baseline with innovative and competitive actions.
2) <u>Environment</u>
   - Protection, promotion and enhancement of the natural and human environment;
   - Development of favourable living conditions.
3) <u>Skills</u>
   - Capacity building and human skill development in areas directly linked to the region’s productive environment.

Taking into account the strategic planning required for the transition as well as the goals to be achieved for a viable new regional economy structure, the **priority axes under discussion and evaluation** are the following:

- Support for district heating operation, substituting lignite dependency with alternative energy sources, over the next decade.
- Energy upgrade of the private and state owned building sector, promoting energy saving and renewable energy utilisation.
- Promotion of Renewable Energy Sources and development of Energy Communities.
- Support for the primary sector, focusing on infrastructure improvements, production process vertical integration and extraversion.
- Re-skilling, training of staff and support of job creation.
- Industrial Heritage.

One of the most crucial issues ahead is to **plan the next National Strategic Reference Framework and Smart Specialisation Strategy** so as to include priorities that will support the transition process.

The Greek Ministry of Environment and Energy submitted to the EC's Structural Reform Support Programme, on behalf of the Regional Government of Western Macedonia, a request for assistance to develop an economic transition path for the region. The World Bank has been asked to analyse the regional assets with the local stakeholders, the capabilities, possible future energy resources, alternatives to compensate for the loss of energy, jobs and income during this transition process.

The outputs of the World Bank's Technical Assistance Project have been presented recently and are as follows:

- land could be used for PV and wind, perhaps land **repurposed** from lignite mines;
- land could be used for **batteries** to store PV and wind and provide a service to the power system;
- lakes (or flooded land) could be used for **pumped storage projects** or for floating PV;
- PV and wind could produce **green hydrogen** to be used in power plants instead of lignite;
- PV and wind could provide electricity so cheap that it could fuel power plants instead of lignite, utilizing **molten salts tanks** to store energy so that the plant could continue to provide **baseload power** and heat post-lignite;
- Biomass has the potential to provide heat and power in Western Macedonia, creating income in the agricultural sector.

Some of these are ideas where the economics could work today, and some maybe a little in the future. All are ideas worth studying in-depth to determine the feasibility. All depend on taking existing assets in Western Macedonia – power plants, transmission lines, land, lakes, labor – and seeing what can be done to preserve and enhance their value. In this way, Western Macedonia could remain an energy hub at the centre of Greece's recovery and prosperity, serving also power systems in neighboring countries, but with alternative energy and energy storage, rather than lignite, as the hub of the future.

Last, and according to the authorities' announcements, Greece's post-lignite transition plan for West Macedonia, concerning land owned by power utility PPC estimated to measure between 15,000 and 20,000 hectares, will be carried out through three concurrent cycles:

1) The **first** of these three cycles will purely concern development of energy projects such as solar parks, waste-to-energy plants to be operated by power utility PPC, biomass facilities at Ptolemaida V following 2028, as well as hydrogen infrastructure. This part of the overall effort will require a total expanse of between 4,000 and 5,000 hectares, according to early estimates. Thousands of jobs are expected to be created during the next five years.
2) The **second** cycle, expected to require 15 years (i.e. until 2035) to fully develop, entails land reinstatement of huge areas, including plantations.
3) The overall effort's **third** cycle concerns National Transition Plan investments in the primary, secondary and tertiary sectors. This could include alternative farming, wine production, marble processing and agritourism. This third cycle is expected to require at least ten years to complete.

The land needed for the overall effort is owned by PPC, according to a series of decisions delivered by the Council of State, Greece's supreme administrative court, meaning the project should not face obstruction issues, as is often the case in Greece with major projects. However, the threat of resistance by local authorities cannot be ruled out.

The Greek government is considering a **solar-based hydrogen production initiative** through **major-scale photovoltaic facilities** planned at **state-controlled power utility PPC's lignite fields in Ptolemaida area**, on the way out as a result of Greece's decarbonization plan.

6.5 References

Karampinis E, Grammelis P, Kakaras E, Fuller A, Miller E, Maier J, Kalivodova J, Michel M, Tsolakidis I (2011) Greek lignite/cardoon co-firing at PPC Kardia PP. 2nd International Workshop on BioCCS, Cardiff, Wales, UK, 25-26 October 2011, 38 pp

Roques F, Perekhodtsev D, Verhaeghe C (2014) Response to the RAE consultation on CRM [Capacity Remuneration Mechanism]. Report for PPC. Washington, DC, USA, FTI-CL Energy, 61 pp

Booz & Co. (2014) Understanding Lignite Generation Costs in Europe, on behalf of PPC, Athens, Greece

WWF (2016) Road Map for transition of Western Macedonia towards the post-lignite era, WWF Greece, Athens

WWF (2016) Alternatives to the District Heating Systems of W. Macedonia – The case of Ptolemaida, WWF Greece, Athens

Dionysios Giannakopoulos (2018) The state of play on transition planning in the Region of Western Macedonia, Central European Energy Conference CEEC 2018. Bratislava, Slovak Rep. (18-20 November 2018)

Jonathan Walters (2019) Region of Western Macedonia Roadmap on Clean Energy Transition, Balkan Clean Energy Transition International Conference & Fair, Kozani, Greece (19 – 22 September 2019)

7 Poland, Upper Silesia Region

The basis of the Polish energy industry are conventional energy sources, such as hard coal and lignite. The Śląskie voivodeship is the most important domestic source of hard coal extraction, crucial for ensuring the country's energy security. The highest consumption of hard coal in the country is in the Śląskie voivodeship as well. Most hard coal is consumed in power plants and combined heat and power plants (58.5%), in industry and construction (29.9%). In terms of hard coal consumption, the following places are occupied by:

- small consumer sector, including households (7.7%),
- heating plants (2.3%),
- commercial heating boilers (1.6%),
- non-professional heating plants (0.1%).

The Śląskie voivodeship produces ca. 19% of the domestic electric energy. The installed power in the voivodeship is ca. 7,300 MW. The share of renewable sources in electric energy produced in the Śląskie voivodeship averages ca. 6%. According to the register kept by the Energy Regulatory Office, there are 47 enterprises in the Śląskie Voivodeship with a license to produce the heat energy and 88 enterprises with a license to produce electricity. The most important power plants and CHP plants are listed below.

7.1 Current energy generation technologies using coal

7.1.1 Coal driven power plants, CHP plants

Jaworzno III Power Plant in the city of Jaworzno belongs to the holding company TAURON Polska Energia S.A. It consists of two power plants (Power Plant III and Power Plant II) with a total capacity of 1,535 MWel and 371 MWth, respectively using hard coal and biomass as fuel.

There are currently six units at the Power Plant III with a total capacity of 1,345 MWel and 50.6 MWth (five 225 MW blocks and one 220 MW block). It is a professional thermal and condensing power plant, working in a block system with boilers with inter-steam superheaters and with a closed cooling circuit equipped with three cooling towers. Power Plant III was launched in the years 1977 - 1978; the first power unit was commissioned in May 1977, and the last in December 1978.

The Power Plant II has two blocks of 70 MW_{el} each, with coal fluidized bed boilers commissioned in 1999, and a block of 50 MW_{el}, with the biomass fluidized bed boiler launched in December 2012. The total power of the plant is 190 MW_{el} and 321 MW_{th}. Power Plant II acts as a municipal CHP plant, producing combined electricity and heat. Its annual gross electricity production is ca: 1,137,000 MWh and annual gross thermal energy production ca. 1,100,000 GJ. Unit consumption of chemical energy of fuel for gross electricity production is 9,687 kJ/kWh and unit fuel chemical energy consumption for heat production 1,110 MJ/GJ. Gross electricity production from biomass averages ca.: 220,000 MWh thus the share in total gross electricity generated is 19.2%. Electricity consumption for own needs is ca. 156,900 MWh (13.8% of total gross electricity generated). :

Power Plant III has installed power of 1,345 MWel and achievable power 1,345 MWel. Its annual gross electricity production averages 4,800,000 MWh. Unit consumption of chemical energy of fuel for gross electricity production is 9,617 kJ/kWh. The use of electricity for own needs ca 488,000 MWh (ca. 10% of electricity generated in general).

Power plant Łagisza in the city of Będzin belongs to holding TAURON Polska Energia S.A. Its installed electrical power is 700 MW_{el} in three blocks (2 x 120 MW_{el} + 460 MW_{el}) = 700 MW_{el}. The efficiency of electricity generation is 36% for 120 MW blocks and 45% for 460 MW block. Achievable thermal power in the source - 279.2 MW_{th}. Two 120 MW blocks were built in years 1967 – 1970. The 460 MW block was built in 2009. It is the first energy block in the world with a fluidized bed boiler for supercritical parameters. Currently, this block is one of the most modern units of this type, and the fluidized bed boiler used in it is, due to its size, the largest boiler in the world. Annual gross electricity production is ca. 2,365,000 MWh and annual gross heat production ca. 1,083,000 GJ.

Łaziska Power Plant in Łaziska Górne belongs to holding TAURON Polska Energia S.A. It uses fuel hard coal and optionally biomass (up to 10% of the mass share of fuel supplied for combustion). Currently, six power units with a total capacity of 1,155 MW work at the Power Plant (2 blocks of 125 MW, 3 blocks of 225 MW and 1 block of 230 MW). The power plant also provides heat from sources with an installed capacity of 196 MW. All units of the power plant were rebuilt and revitalized in nineties of XX^{th} century. This led to total power increase of 115 MW without construction of new production facilities. The 125 MW blocks were equipped with bag filters and semi-dry flue gas desulphurization using the NID method. In 2000, the wet flue gas desulphurization installation was commissioned for 225 MW blocks. Currently, Łaziska Power Plant meets all emission standards.

Rybnik Power Plant belongs to PGE GiEK S.A. It is a condensing and block power plant. The main activity of the plant is the production of electricity for the needs of the National Power System. The power plant has a production capacity of 1,775 MW installed in eight blocks and is the largest power plant in Upper Silesia. The first four power units were launched in 1972 - 1974, and the next in 1978. The plant's cooling system is based on an artificial water reservoir with an area of 550 ha and two cooling towers with a height of 120 m. The Rybnik power plant uses the highest quality management system confirmed by ISO 14001, ISO 9001 and PN-N-18001 / OHSAS 18001 standards. Its annual energy production is about 9.44 TWh. The power plant has 8 power blocks of 225 MW. Each block consists of: OP-650k steam boiler made by Rafako in Racibórz, 13K215 steam turbine made by Zamech in Elbląg, GTHw-225 MW generator manufactured by Dolmel in Wrocław. The power plant works based on hard coal, whose annual consumption is about 4-4.5 million tonnes.

The Chorzów heat and power plant (**CEZ Chorzów S.A.)** belongs to the CEZ energy group. This is one of the most modern power plants in Poland, built to restore the production capacity of Elektrownia Chorzów S.A. - one of the oldest (1898) power plants in Poland. The Chorzów CHP plant was built in 2003 by the American concern PSEG. In 2015, Elektrociepłownia Chorzów ELCHO changed its name to **CEZ Chorzów S.A.** CEZ Chorzów consists of two bleed-condensing power units with 2 x 113 MW_{el} gross power at full condensation and 2 x 180 MW_{th} heat capacity at full cogeneration. In addition, CEZ Chorzów has two peak heat exchangers that enable it to achieve a thermal power of 500 MW_{th}. Fluidized bed boilers installed in CEZ Chorzów have been designed for combustion of low calorific hard coal with high S content. The CHP plant was designed and built based on strict ecological standards regarding the emission of dust, sulfur and nitrogen compounds into the air. Since 2008, it has started co-firing coal with biomass. Currently, the share of biomass in energy production is about 16%. In 2015, the "green" energy produced at CEZ Chorzów reached its maximum, i.e. 450,000 MWh. In the meantime, a reverse osmosis plant was launched, which reduced the use of water treatment chemicals by 70%. In 2017, a DeNOx installation was created that adjusted nitrogen oxide emissions to the emission limits of the IED Directive and the BREF / BAT conclusions in force since 2021. The CHP plant has the following characteristics: installed electric power 330 MW_{el}, electrical power achievable in condensation: 220 MW_{el}, installed heat capacity: 588 MW_{th}, maximum thermal power achievable in water: 438 MW_{th}, maximum thermal power achievable in technical steam 54 MW_{th}. Basic manufacturing equipment consists of 8 steam boilers and 3 turbine sets. Primary fuels used to generate heat include hard coal (more than 99.7%) and heavy fuel oil.

The CHP plant Elektrociepłownia "Będzin" S.A. is a parent company of the Elektrociepłownia „Będzin" S.A. Group of Companies. Basic power generation equipment in Elektrociepłownia BĘDZIN includes: two power boilers: OP-140 with rated capacity 145 t/h each (in total 290 t/h), turbine set 13UCK80 and heating boiler WP-70. Installed electrical power is 81.5 MW and installed heat capacity is 306.2 MW. Achievable electric power is 78 MW and achievable heat power 414 MW.

The CHP plant Elektrociepłownia Marcel S.A. is located in the city of Radlin. Hard coal supplied from a nearby mine and waste coke oven gas from JSW KOKS S.A. are used as the basic fuels for steam production. These fuels are subject to combustion in power boilers, where technological steam is created with a pressure of 3.2 to 3.3 MPa and a temperature of 430 - 440° C. This steam is directed to the TG-1 and TG-2 turbine sets, and then to:the EC regeneration system, heat exchangers and process steam recipients. The plant is equipped with four VKW 75 boilers with a total achievable capacity of 200 t/h or 195.6 MW of achievable thermal power, AEG's TG-1 turbine set with a rated power of 15 MW (achievable 12.5 MW), and TG- turbine set 2 by CKD with a rated power of 22 MW (achievable 22 MW) and two KAESER Kompressoren DSD 281 and DSD 281 SFC compressors with max. capacity 1,500 m^3/h each.

The Bielsko-Biała CHP plant belongs to the Tauron Polska Energia S.A. holding. The Bielsko-Biała CHP plant consists of two combined heat and power generation installations:

- Bielsko-Biała EC-1 heat and power plant, located in Bielsko-Biała
- Bielsko-north EC-2 heat and power plant, located in Czechowice-Dziedzice

The capacity of ZEC Bielsko-Biała is following: installed electrical power - 136.2 MW, installed thermal power - 447 MW. The EC-1 heat and power plant was built in the years 1960 - 1973. It works in a collector system. Four steam boilers are installed here: two types Op120, one Op140 and one Op230 as well as 3 turbine sets: two types TUK 25 (bleed-condensing) and one tp 30 (back pressure). Its electricity output is 77 MW, thermal power achievable - 275 MW. Annual electricity production is around 140,000 MWh and annual heat production about 1,300,000 GJ. The EC-2 combined heat and power plant was built in the years 1975–1997. A BC50 heating unit with an OFz230 thermal boiler and two OO70 steam oil heating boilers are installed here. Its electricity output is- 55 MW and achievable thermal power 172 MW. Annual electricity production is ca. 236,000 MWh and annual heat production ca. 1,000,000 GJ. Both plants supply the common water heating network of the city of Bielsko-Biała. The EC-2 heat and power plant also supplies the water heating network of the city of Czechowice-Dziedzice.

7.1.2 Use of coal for small applications

Power plants and CPH plants use the largest share of hard coal in Śląskie Voivodship. Large amounts of coal are used in the metallurgy industry for firing blast furnaces as well. After these two sectors the small consumer sector (including households) is the third consumer of hard coal in Silesia. There are three groups of small consumers: households, agriculture and so-called other consumers. The most significant of are the households (ca. 85% of annual consumption of coal across the sector) followed by agriculture and the other consumer group (Stala-Szlugaj, 2017).

In households, coal is most often used for heating purposes. The energetic efficiency of buildings is related to the age of buildings. In the oldest buildings the primary energy (EP) and final energy (EK) demand exceed 350 and 300 kWh/m^2 per year, respectively whereas in the newest buildings these values are ca. 100 – 150 and 90 – 120 kWh/m^2 per year, respectively. In Śląskie Voivodship ca. 21% of buildings were built before 1945 and thus have low energetic efficiency, slightly higher is the share of buildings built between 1945 and 1970 (ca. 26%), and the largest share (ca. 38%) is of buildings built between 1970 and 1998.

Currently in Poland 72% of energy is used for heating and ventilation of rooms in residential buildings, and according to the recommendations of the International Energy Agency IEA it should be 37% lower. Thus the energetic effectiveness of households is rather low. However, the indicators of energetic effectiveness have been improving over last years. For instance, the energy efficiency index for energy consumption for heating one square meter decreased from 15.8 to 11.9 kgoe/m^2 (kilogram of oil equivalent per square meter) in the period 2002 – 2015 (data for the whole Poland).

The largest group of coal boilers are hand-fed boilers (ca. 80%), the share of automatic retort boilers is <20 % and the share of tiled stoves is 1-2%. In terms of age - medium boilers (4-9 years old) dominate – ca. 35%, followed by old boilers (10-19 years) - 27% and the share of new boilers (under 3 years old) is ca. 21% and very old boilers (older than 20 years) - 16%.

A characteristic feature of the Polish coal market is the diversified coal production structure. Domestic sale is dominated by culm (84 – 88%), and the share of other assortments: coarse, medium and small is around 11–14%. The most popular coal grades purchased by small recipients are coarse, medium and fine ones. Coarse assortment prices were higher than the average price of steam coal by about 160–190%. For instance, in the years 2007–2016 they varied from 315 to 489 PLN/ton (around 70 to 110 EUR). Prices of medium and small grades ranged from 270 to 455 PLN (60 to 102 EUR) and were higher than the average price of coal by 150-180%. The price of coal offered on the domestic market depends on the situation on international coal markets. However, hard coal prices for small consumers in Silesia are 12 – 14% lower than in the rest of Poland. A comparison of three energy carriers consumed by households: electricity, natural gas and hard coal, whose prices are expressed in PLN/kWh, shows that the prices of hard coal, natural gas and electricity show a similar trend of change in time and that hard coal remains the cheapest source of heating for households. For example, in 2015 energy prices were: 0.17 PLN/kWh (0.04 EUR/kWh) for hard coal, 0.21 PLN/kWh (0.05 EUR/kWh) for natural gas and 0.65 PLN/kWh (0.15 EUR/kWh) for electricity (Stala-Szlugaj, 2017).

Combustion of coal by consumers from the small consumer sector is accompanied by the emission of pollutants resulting from inefficient fuel combustion. These include dusts (including PM 10 and PM2.5) and sulphur dioxide. Due to the fact that the emitters are located at a height not exceeding 40 m, it is called low-stack emission. In the small consumer sector, low-heat boilers (not exceeding 5 MW) are used. These are usually stoker-fired boilers without dust removal equipment. Depending on the calorific value of coal, its combustion results in the emission of 10 to 24 kg of dust and 40 to 96 kg of ash per ton of coal. Emission of sulphur dioxide ranges from 6 to 26 kg SO_2 per ton of coal. Boilers or furnaces used in households are not equipped with flue gas desulphurization installations. Therefore, the only way to reduce SO_2 emissions is to use high-quality fuels with low sulphur content. The waste generated as a result of coal combustion (ash) partly serves for microleveling of the area, or as an anti-slip material for snow-covered backyard paths and driveways. Some of them feed into the municipal waste stream, while the rest are collected at illegal landfills (Stala-Szlugaj, 2017).

7.2 Current status of other energy generation technologies

Energy production is Silesia (as in the whole Poland) is by far dominated by hard coal. However, there are some attempts to use also other technologies. Currently, there are ca large scale installations producing electricity from renewable sources in the Śląskie Voivodeship, with a total capacity of ca. 73 MW. The largest parts of installations are those using energy from biomass (including biogas), as well as hydropower. However, in terms of installation capacity, the largest share of renewable energy is installed in hydroelectric power plants – ca. 37 MW. The least installations are installations using solar radiation - 3, which together also have the lowest power - 0.093 MW**.**

The Porąbka-Żar hydroelectric power plant is the fifth largest electricity supplier in the voivodship. It is the second largest pumped storage power plant in Poland, located in Międzybrodzie Bialskie, within the Soła River cascade. The first hydropower unit was synchronized with the state network on January 6, 1979. It was built in 1979 and now is operated by PGE holding company. The power plant is equipped with four reversible turbine sets having Francis type turbines. The generator power of each turbine set is 125 MW, and the pump power 135.5 MW.

PGE S.A. owns also a 0.6 MW **photovoltaic plant on Góra Żar in Międzybrodzie Żywieckie**. This power plant is located at an altitude of 740 m a.s.l., which makes it the highest installation of this type in Poland. 2,400 photovoltaic panels were installed in located in 16 rows - each with a power of 250 W. The total area of the panels is 3,500 m^2. Due to its location, the power plant is protected by a special lightning protection system consisting of 200 masts 4 m high each.

7.3 Technological challenges and opportunities

The major potential renewable energy sources in Śląskie Voivodship include hydropower, wind, solar energy and biomass. The voivodship has average natural conditions for renewable energy production.

Windiness analysis in Poland shows that Silesia is a voivodship in which favourable conditions prevail only in mountainous regions (Beskid Żywiecki), in other places that make up the majority of the voivodship's area, conditions are not favourable. Assuming 100% efficiency of wind energy conversion in the Śląskie Voivodeship, it is possible to you can achieve from 150 – 1,900 kWh/m^2 at an altitude of 18 m over terrain to -250 - 4,500 kWh/m^2 at 60 m over terrain (Eurocentrum-PNT, 2013).

In the Śląskie Voivodeship, areas located at its southern end are most predisposed to using hydropower. This is because the river network is very well developed there and in the mountainous terrain the rivers have considerable longitudinal fall. In the central part of the voivodship, the terrain varies in height, which favors obtaining energy from hydropower plants, however, the river network is not developed as in the case of the southern parts. The theoretical potential of hydropower in the Śląskie Voivodeship is 460 GWh/m^2. Currently, there are 132 hydrotechnical facilities in the voivodship and the Śląskie voivodship is able to generate ca. 90 GWh/m^2 per year (total production of hydropower plants of the Śląskie voivodship), which is about 20% of theoretical potential (Eurocentrum-PNT, 2013).

Silesia has average insolation level. The best conditions prevail in the south of the voivodship, where the annual energy of solar radiation is above 1,000 kWh/m^2. In the remaining part, the sun can generate more than 875 kWh/m^2 per year. Considering these values with efficiency of solar collectors and photovoltaic cells, the achievable energy production varies from 150 to 180 kWh/m^2 per year for electric energy and from 1.5 to 1.8 GJ/m^2 of heat per year (Eurocentrum-PNT, 2013).

Production of energy from bio-resources includes the use of biogas and biomass. Biomass is an alternative energy source with the largest theoretical potential in the Śląskie Voivodeship. Biomass is a product of processing of animal or plant residues. It has a low bulk density, that impedes its transport and therefore, biomass is primarily used locally. The average area of an individual farm in the voivodship is 3.7 ha, and there are than 110,000 farms in the voivodship. However, only those with area over 10 ha have really good conditions for biomass production. The largest technical potentials have the poviats of Częstochowa, Gliwice, Kłobuck and Racibórz. Forests occupy about 26,761,000 ha in the Śląskie Voivodeship. Potentially the most energy can be produced in the: Częstochowa, Lublin, Zawiercie and Żywiec poviats (Eurocentrum-PNT, 2013).

Although professional energy production as well as energy production for households are dominated by the use of hard coal the market of renewable energy sources in Śląskie voivodship have been gradually increasing for several years. Solar radiation energy can be used by solar collectors and photovoltaic cells. The solar collector market in Poland is well developed and the Śląskie Voivodeship is a country leader in this aspect. The use of collectors to support heating installations and not only for preparation of hot utility water may further boost demand for this technology in Silesia.

Photovoltaic installations have recently shown an upward trend, although the Polish solar market is at a very early stage of development. Households are the main energy producers in micro-installations, but more and more often such installations are created in enterprises. Smaller installations dominate in households - micro-installations up to 10 kW constitute over 90% of all micro-installations installed in households. In turn, entrepreneurs usually develop larger micro-installations - installations above 10 kW (Eurocentrum-PNT, 2013).

The biogas plant market is one of the most underrated and at the same time promising markets for the development of energy production from renewable sources. The slow development of the Polish biogas market is mainly due to high investment costs and low public interest in this technology. This sector needs an active participation of the state for development (Eurocentrum-PNT, 2018).

Heat pumps have been gaining popularity in recent years. This is due to the tendency to build smaller houses without basements and space for boilers for solid fuels and solid fuel, the approaching investment costs in the installation of heat pumps for installations using gas or biomass boilers and the need to decrease house exploitation costs. An important aspect is also the stability of energy production from heat pumps, independent of the weather, season or time of day. The development prospects for the heat pump market in the Śląskie Voivodeship are promising. The sale of heat pumps in 2010-2017 shows continuous growth in Poland and in the Śląskie Voivodeship. For example, in 2017 the market for heat pumps for space heating increased by 30% and in every eighth new building heat pump heating was installed (Eurocentrum-PNT, 2018).

Energy-efficient building can be one of the elements of creating the economy's emissivity. It is a technology of building based on intelligent solutions that allows achieving high comfort of living with low energy consumption. Important aspect of this technology is the use renewable energy sources (solar, wind, biomass, geothermal). Energy-efficient buildings reduce energy consumption and operating costs, increase the comfort of living (optimal room temperature, better air quality thanks to effective ventilation) and contribute to improving air quality on a local scale. Zero-energy construction in Poland is only at the initial stage of development and only 1% of all residential buildings in Poland can be considered energy-efficient (as of 2016). The analysis of the energy-saving construction market indicates its very high development potential - up to 88% of Poles would like to live in an energy-efficient home. The main barriers to the development of energy-efficient construction in Poland are the low level of awareness of the benefits of constructing energy-efficient buildings, the investors' conviction of the high costs of constructing energy-efficient buildings, the lack of knowledge and experience on the part of investors and contractors necessary for the implementation of such projects and the lack of appropriate financial incentives and legal (Eurocentrum-PNT, 2018).

Energy-efficient building can be one of the elements of creating the economy's emissivity.

7.4 Technical energy transition concept

The development of the energy sector in Poland has been described in the document “Polish Energy Policy until 2040” (Ministerstwo Energii, 2019). In the current strategy until 2040, hard coal will play an important role in the energy mix. A total departure from hard coal as a source of electricity is not currently planned, although it is planned to increase the importance of renewable energy sources in the energy mix. The directions of actions indicated in the “Polish Energy Policy 2040” emphasize above all the need to improve energy efficiency, increase security of fuel and energy supplies, diversification of the structure of electricity generation through the introduction of nuclear power, development of the use of renewable energy sources, development of competitive fuel and energy markets, as well as limiting the impact energy industry on the environment. Within this long term transition process to renewable energy and to meet the above challenges, it is necessary to modernize and expand existing power plants and combined heat and power plants across the country. In the Śląskie Voivodeship, the following construction of new and expansion of existing power plants and combined heat and power plants are planned for the coming years:

- CHP “Zabrze” (new cogeneration unit)
- “Łagisza” Power Plant (new cogeneration unit, gas)
- “Koksownia Przyjaźń” in Dąbrowa Górnicza (power unit for cooking gas)
- “Dąbrowa Górnicza” (construction of a turbogenerator at „Zakład Wytwarzania Nowa”)
- CHP “Katowice” (new gas block)

- Jaworzno power plant
- Power plant Jaworzno III (new unit)
- CHP “Tychy” (new block)
- CHP “Zakład Wytwarzania Tychy” (new cogeneration unit)
- Power plant in Radlin (gas fired)
- CHP “Zofiówka” (fluidized power unit)

A strategy for reducing the emissivity of the economy has been developed for Śląskie voivodship. The assumptions of this strategy are presented in the document "Low-emission economy policy for the Śląskie voivodeship" (Zarząd Województwa Śląskiego, 2016). This document adopted by the voivodship board presents a development strategy towards a low-carbon economy. Particular attention has been paid to the elimination of so-called low-stack emission, which is the main cause of poor air quality in the Silesia region.
The analysis of the conditions of the low-carbon economy in Silesia allowed for their grouping in five fields of activity:

- energetic efficiency
- energy production and distribution
- clean energy
- rational management of raw materials and resources
- sustainable transport

The first three fields of activity are directly related to energy production technologies.

The basic directions of activities in the field of energetic efficiency include among others:

- Lowering energy consumption of industry.
- Implementation of new energy-saving production technologies.
- Supporting the development of innovation in energy saving in the economic process.
- Supporting the development of low carbon products.
- Optimization of the waste gas combustion process.
- Modernization of group and individual heating nodes and heating networks.
- Modernisation of heating and technological insulation in industry.
- Raising the energy standard of existing and newly built buildings, including support for thermo-modernization activities in individual and public buildings as well as energy-saving and passive construction.
- Improving the standard and quality of construction and design works in the field of improving energy efficiency.
- Implementation of energy management systems in the stock of public and multi-family buildings.
- Supporting the development of intelligent energy management systems in buildings.
- Promotion of replacing old devices with energy-saving ones.

In the field of clean energy, the basic directions of activities will include among others:

- Support for solutions using high-efficiency cogeneration technologies.
- Support for the development of prosumer energy, including the creation and implementation of technologies.
- Support for generating energy in a distributed system (based on renewable energy or energy recovery).
- Support system for investments in renewable energy sources.
- Development of biogas plants, including the use of existing water and sewage facilities for biogas plants.

- Support for the production and use of biomass and energy crops.
- Development of installations enabling the use of biodegradable waste for energy production (organic recycling).
- Support for the use of heat pumps and ground heat exchangers for heating purposes.
- Support for cross-sectoral cooperation and cooperation of public and private entities in the field of establishing cooperatives and energy agreements.

In the field of energy production and distribution the most important directions of activities are:

- Modernization of the electricity system infrastructure.
- Supporting the development of installations based on the use of alternative energy sources.
- Increasing the use of alternative fuels.
- Improving operational safety of waste recovery installations and equipment for the energy sector in accordance with environmental protection requirements.
- Increased use of post-production waste and gases for energy purposes.
- Popularization of waste incineration and co-incineration.
- Increasing the scale of energy crops.
- Supporting research into the development of high energy fuels.
- Development of competitive fuel and energy markets.
- Increased security of supply and handling of fuels.
- Construction and modernization of dust and gas pollution reduction systems.
- Support for environmentally friendly energy and heat production for the needs of individual households.
- Ensuring the security of energy transmission and distribution for the needs of households and residents (ensuring energy security).
- Improving security and efficiency of transmission via gas and energy networks.
- Implementation of solutions limiting transmission losses of electricity.
- Development and improvement of the efficiency of local heat supply systems from municipal heating systems.
- Support and promotion of connecting individual households to the collective energy, gas and heat supply system.
- Development of intelligent power networks and their management.
- Improving the efficiency of managing energy sources in the network.
- Raising the ecological awareness of the inhabitants.
- Building partnerships in the field of effective energy management in local and regional system

The above described assumptions have been published only recently and actual document describing the policy is yet to be prepared. The document development process, followed by its implementation will be in line with the principles ensuring effective workflow as well as the optimal use of available resources, allowing for comprehensive achievement of the document's objectives. In addition, compliance with these principles will ensure respect for all parties who may be affected by the implementation of the document.

Promotion of prosumer energy production will contribute to reduction of hard coal consumption and will improve local air quality.

7.5 References

EUROCENTRUM-PARK NAUKOWO-TECHNOLOGICZNY (2013) RYNEK ODNAWIALNYCH ŹRÓDEŁ ENERGII W WOJEWÓDZTWIE ŚLĄSKIM. KATOWICE, POLAND.

EUROCENTRUM-PARK NAUKOWO-TECHNOLOGICZNY, AGENCJA ROZWOJU REGIONALNEGO W CZĘSTOCHOWIE (2018) RAPORT SPECJALISTYCZNY DLA OBSZARU TECHNOLOGICZNEGO ENERGETYKA ZA ROK 2017.

MINISTERSTWO ENERGII (2019) POLITYKA ENERGETYCZNA POLSKI DO 2040 ROKU.

STALA-SZLUGAJ K. (2017) OCENA PERSPEKTYW ZAPOTRZEBOWANIA DROBNYCH ODBIORCÓW WĘGLA W POLSCE. WYDAWNICTWO INSTYTUTU GOSPODARKI SUROWCAMI MINERALNYMI I ENERGIĄ PAN, KRAKÓW, POLAND.

ZARZĄD WOJEWÓDZTWA ŚLĄSKIEGO (2016) POLITYKA GOSPODARKI NISKOEMISYJNEJ DLA WOJEWÓDZTWA ŚLĄSKIEGO. ZAŁOŻENIA PROGRAMOWE.

8 Romania, West Region / Jiu Valley

8.1 Current energy generation technologies using coal

8.1.1 Coal driven power plants, CHP plants

In Jiu Valley micro-region, organised hard coal exploitation started in 1840, summing up, according to Jiu Valley National Mines Closure Society (SNIMVJ), at the end of IX century mining perimeters of about 90 km^2. The companies currently operating in the mining industry, in Jiu Valley are:

- Hunedoara Energy Holding (CEH) – state owned company
- Jiu Valley National Mines Closure Society (SNIMVJ) – state owned company
- Energomec Transind - a private SME with an exploration concession license since 2016 for a hard coal open pit in Balomir-Uricani

Related to the businesses in the mining field, **Hunedoara Energy Holding (CEH)** (**Table 8.1.a**) includes the following subsidiaries:

- hard coal underground Mining Exploitation – Lonea, Lupeni, Vulcan and Livezeni Mines Subsidiaries covering about 51.17 km2 of mining perimeters;
- services – PrestServ Petroșani Subsidiary (Jiu Valley coal mining operation and the mining rescue station).

SNIMVJ which is currently managing the state aid granted for the mines closure, according to the legislation in force, of 3 non-competitive mines: Petrila, Paroșeni and Uricani, in compliance with GEO no. 69/13.11.2019 (GEO no. 69, 2019), during 2019-2024, summing up 19.2 km^2 of former mining perimeters with 85 % of reclaimed land (Table 8.1.b). SNIMVJ produced hard coal until 2017, when the reserves were exhausted, starting in parallel a safe closing and remediation procedure. Related to the private investor **Energomec Transind** - the operation of Balomir-Uricani hard-coal open pit lasted only one year, having legal issues of non-compliance with the legislation in force. According to the National Agency for Mineral Resources (ANRM, 2019) - the mining industry regulator, the only exploitation licenses in the Jiu Valley are held by CEH and SNIMVJ.

The total mining perimeter in Jiu Valley has a surface of about 90 km^2, of which the total reclaimed land is estimated at 38 km^2 (42%). CEH Mining Subsidiary holds an operating license for concessional perimeters by 2024.

In terms of energy generation facilities **Hunedoara Energy Holding (CEH)** is the only power and heat producer in Hunedoara County, including Jiu Valley micro-region. CEH has a strategic role in the Romanian National Power System in terms of security of electricity supply and geographic location, having 1,225 MW installed in the following hard coal-based Power and Heat Generation Subsidiaries:

- Deva TPP Subsidiary (4 x 210 MW + 1 x 235 MW) – located in Mintia village, in the North part of Hunedoara county;
- Paroşeni CHPP Subsidiary (1 x 150 MW) – located in Vulcan municipality, inside Jiu Valley – TRACER target region.

Paroşeni CHPP Subsidiary has in operation (Phoebus Adviser, 2018):

- 1 x power unit (no.4) equipped with Turboatom extracting steam turbine type, having an installed capacity of 150 MW_{el} and 174.4 MW_{th} (150 Gcal/h) at the steam bleed, and a Babcock-Hitachi steam boiler (540 t/h, 138 bar, 541 °C), PCC type, running on hard coal; this power unit had completed an upgrading and retrofitting program in 2007, being qualified as highly efficient cogeneration unit;
- 1 x hot water boiler (HWB) from IMUC Pitesti, running on hard coal, with an installed capacity of 120 MW_{th} (103,2 Gcal/h, 70/150 °C), capable of supplying 4 DHSs (Lupeni, Vulcan, Aninoasa, Petroșani);
- 1 x TP for start-up, LOSS International, equipped with 2 x 20 t/h steam boilers (28 MW_{th} installed capacity), running on natural gas.

Table 8.1.a Technical features for the hard coal mining industry – CEH – Mining Division, Jiu Valley micro-region

Mining Division		Underground hard-coal mines	Hard coal production (tons/year) 2016	2017	2018	Annual average calorific value (kcal/kg) 2016	2017	2018	Hard coal productivity (tons/employees) 2016	2017	2018	Hard coal supply for energy use at Paroșeni CHPP (tons/year) 2016	2017	2018	Annual average sales price, at coal mines, for energy use (€/tons) 2016	2017	2018	Mining waste dumps surface (ha) Total / reclaimed	Operating Permits
Hunedoara Energy Holding (CEH)	Mining Exploitation Subsidiaries	Total, of which:	754,269	588,427	538,092	3623	3602	3641	203	176	186	178,112	110,964	133,078	84	109	120	0.3337 / 0.1141	-
		Lonea Mine	132,453	102,707	90,861	3615	3626	3750	148	133	144	52,842	26,613	17,942	110	150	138	0.0684 / -	Issued in January 2013 valid until 31.01.2023
		Livezeni Mine	189,628	110,503	120,452	4052	4043	4051	211	136	161	14,495	8,419	42,483	81	137	145	0.0646 / -	Issued in January 2020 valid the entire operation period with annual approval
		Vulcan Mine	194,336	157,453	142,558	3570	3632	3626	268	242	227	92,956	64,716	45,229	68	89	98	0.0333 / -	Issued in January 2013 availability until 31.01.2023
		Lupeni Mine	237,852	217,764	184,221	3330	3330	3330	198	196	209	17,819	11,219	27,424	96	106	104	0.1664 / 0.1141	Issued in January 2013 availability until 17.01.2023

Source: Hunedoara Energy Holding, TRACER data collecting, March 2020

Table 8.1.b Technical features for the hard coal mining industry – SNIMVJ, Jiu Valley micro-region

Underground hard-coal mines		Hard coal production (TH tons/year) 2016	2017	2018	Annual average calorific value (kcal/kg) 2016	2017	2018	Hard coal productivity (tons/employees) 2016	2017	2018	Hard coal supply for energy use at Paroșeni CHPP (TH tons/year) 2016	2017	2018	Annual average sales price, at coal mines, for energy use (€/tons) 2016	2017	2018	Mining waste dumps surface (ha) Total / reclaimed	Closed mining surface (ha) Total / reclaimed
SNIMVJ	Total, of which:	314.24	196.01	-	3370	3467	-			-	214.84	131.52	-	37	47	-	36.96 / 25.76	19.19 / 16.44
	Petrila Mine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.76 / 25.76 (reclaimed in 2018)	16.44 / 16.44 (reclaimed in 2018)
	Paroseni Mine	207.43	122.69	-	3262	3400	-	361	281	-	NA	NA	-	-	-	-	6.26 / - (only ecologized)	0.65 / - (only ecologized)
	Uricani Mine	106.81	73.32	-	3580	3580	-	251	220	-	NA	NA	-	-	-	-	4.57 / -	2.10 / - (only ecologized)

Source: SNIMVJ, TRACER data collecting, March 2020

Table 8.1.c Technical features for hard coal-based energy generation facilities CEH-Paroșeni CHPP, in Jiu Valley micro-region

Energy Division	Energy generation units	Used technology	Commissioning year	Installed / available capacity (MW)		Efficiency (%)				Hard coal-based power generation - electricity (MWh/year)			Hard coal-based heat generation - thermal energy (MWh/year)			Total energy generation (MWh/year) electrical & thermal energy			Annual average fuel consumption (toe) hard coal and support fuel (n.g.)			Fuel consumption structure (%) hard coal / n.g.			Electricity supply (MWh/year) NPS* / others			Heat and hot water supply (MWh/year) households / non-households			Total energy supply (MWh/year) electrical & thermal energy		
				running on hard coal	running on other fuel	designed	Annual average in operation 2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
Hunedoara Energy Holding (CEH) Paroșeni CHPP	Total, of which	-	-	270 / 270	-	-	-	-	-	425,528.0	314,034.0	239,220.0	150,823.6	146,788.1	106,526.2	576,351.6	460,822.1	345,746.2	178,283.4	133,145.4	102,851.2	98 / 2	98 / 2	98 / 2	380,613.0 / 80.0	279,994.0 / 109.0	211,460.0 / 157.0	13,928.2 / 21,888.2	11,142.2 / 20,730.6	9,997.0 / 18,429.7	416,509.4	311,975.8	240,043.7
	Power unit no. 4	PCC	2007	150 / 150	-	40.9	38.5	37.6	36.0	425,528.0	314,034.0	239,220.0	111,720.1	43,309.0	23,040.2	537,248.1	357,343.0	262,260.2	171,436.0	116,725.8	89,394.5	98 / 2	98 / 2	98 / 2	380,613.0 / 80.0	279,994.0 / 109.0	211,460.0 / 157.0	10,702.0 / 17,110.6	3,797.0 / 6,826.3	4,278.5 / 6,997.4	408,505.6	290,726.3	222,892.9
	HWB	PCC	1998	120 / 120	-	88.5	70.1	77.4	76.0	-	-	-	39,103.5	103,479.1	83,486.0	39,103.5	103,479.1	83,486.0	6,847.4	16,419.6	13,456.7	98 / 2	98 / 2	98 / 2	-	-	-	3,226.2 / 4,777.6	7,345.2 / 13,904.3	5,718.5 / 11,432.3	8,003.8	21,249.5	17,150.8
	TP**		2010	-	28 / 28	NA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-/100	-/100	-/100	-	-	-	-	-	-	-	-	-

*) NPS – National Power System; **) Thermal Plant for start-up operational only in 2010 *Source: Hunedoara Energy Holding, TRACER data collecting, March 2020*

Table 8.1.d Environmental protection aspects related to hard coal-based energy generation facilities CEH-Paroșeni CHPP, in Jiu Valley micro-region

LCP in Paroșeni CHPP	Measured emissions - values for pollutants concentrations daily average (max / min) | annual average (mg / Nmc)							BAT* associated emissions levels for coal fired plant (mg / Nmc)	Ash and slag dumps (km²)	Environmental protection technologies installed	Environmental Permits
	Pollutant	2016		2017		2018					
Large Combustion Plant - LCP Power unit nº. 4 and HWB	NO_x	183.6 / 132.5	160.9	176.3 / 139.7	156.4	187.3 / 151.4	161.4	200	Căprișoara Valley (0.48 km²) tailing pound, located at about 2 km from Vulcan city Emergency tailing pound (0.10 km²), located at about 400 m from Paroșeni CHPP both still operational	Low NOx burners and Overfire Air (OFA) FGD System commissioned at end of 2018 Electro-static Precipitators (ESP) Dens Slurry System (DSS) for ash & slag evacuation	IEP Integrated Environmental Permit nº.3/02.05.19
	SO_2	4,157.2 / 3041.0	3,540.9	4,228.9 / 3,569.8	3,758.9	4,918.0 / 139.7	3,367.1	200			
	PM	30.7 / 23.9	25.9	26.0 / 19.9	20.5	23.8 / 4.1	19.3	20			

*) Thierry Lecomte et all., Publications Office of the European Union, 2017, Best Available Techniques (BAT) Reference Document for Large Combustion Plants, EUR 28836 EN; doi:10.2760/949 https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/JRC_107769_LCPBref_2017.pdf *Source: Hunedoara Energy Holding, TRACER data collecting, March 2020*

Hard coal production, productivity and supply to local energy producers, economics and environmental related historical data (2016, 2017 and 2018) are presented in **Table 8.1.a for CEH – Mining Exploitation Subsidiaries and** Table 8.1.b **for SNIMVJ**.

The average calorific value of the Romanian hard coal is estimated at 3,500-4,000 kcal/kg. Jiu Valley hard coal, even if it is devoid of pyrite, has a high sulphur content being energetically weak with no export market potential, being strictly used for the domestic electricity and heat generation and supply.

From **Table 8.1.a** and **Table 8.1.b** it can be observed that the hard coal production decreases at CEH by 30% and the productivity with about 10% in 2018 compared to 2016, and the trend does not change even in 2019, considering retirements and planned layoffs. The inefficient exploitation of the 4 active underground mines also results from the average annual sale prices, which shows an increase of 40%, reaching 120 €/tons of hard coal which is not competitive at all. At SNIMVJ hard-coal exploitation ceased in 2018 at all 3 underground mines (Petrila, Paroșeni and Uricani), the activity being concentrated on post closure management for mining surfaces and tailings dumps.

Practically the 4 underground hard coal mines, Lonea, Lupeni, Vulcan and Livezeni - subsidiaries of Hunedoara Energy Holding, are still active only through State Aid, considering both social issues related to the households thermal energy supply (heat and hot water) and the maintenance of an adequate slow tertiary reserve to ensure a safe, secure and reliable power grid operation.

In terms of energy generation facilities located in Jiu Valley micro-region, **Paroșeni CHPP Subsidiary subordinated to CEH** is presented in **Table 8.1.c** with historical data (2016, 2017 and 2018) regarding the main technical features and **Table 8.1.d** about environmental aspects.

Power unit nº.4 obsolescence level is about 30%, and at the HWB it is quite advanced at approx. 50%.

According to data collected in **Table 8.1.c** the generated, as well as the supplied electricity decreased by 44% in 2018 compared to 2016, a trend that will continue.

Electricity sales price at CEH level are presented in **Table 8.1.e.**There is an increasing trend with 40-70% in 2018, 2017 compared to 2016, but nevertheless the cost of production is not even 50% covered in 2018 - which mirrors the inefficient operation of all CEH subsidiaries (mining and energy generation).

Table 8.1.e Electricity prices - hard coal-based energy generation facility CEH, in Jiu Valley micro-region

Economics	CEH (Paroșeni CHPP and Deva TPP)		
	2016	2017	2018
Electricity sales price (electricity trading price on the competitive markets) (€/MWh)	36.71	62.73	52.47
Coverage degree of the production price (%).	49.80	74.40	45.00

Source: Hunedoara Energy Holding, Administrators Reports 2016, 2017, 2018 (CEH, 2016, 2017, 2018)

Electricity prices, once the market liberalization was completed, are calculated according to the Competition Component Market (CPC) price, according to the regulatory schedule approved by the National Regulatory Authority for Energy (ANRE). Consumers can choose any electricity supplier authorized by ANRE (ANRE, 2019), and decide between contracting the electricity supply services at a regulated tariff (TR); or on a competitive basis (liberalized market), at an offer negotiated with the supplier.

For example, in the Jiu Valley micro-region, where the DSO is ENEL Distribuție Banat, the main contracted supplier is ENEL Energie Banat (FUI type – supplier of last resort) that practices the following regulated tariffs (sem.I 2025 0): 72.49 €/MWh (MV) and 95.58 €/MWh (LV) without taxes. On the electricity invoice the consumers will identify separately taxes added as: green certificates, contribution for highly efficient cogeneration, excise, VAT. These taxes are shown separately in the invoice and will be included in the total amount of payment. There is also a social tariff applied under certain conditions for vulnerable consumers.

In terms of compliance with environmental requirements, in 2018 in Paroseni CHPP two major environmental investments were completed: the FGD installation, being now in compliance with Directive 2010/75/EU on industrial emissions (IED), and the ash & slag removal system in dens slurry. In **Table 8.1.d** the values of the polluting emissions are within the limits imposed by Law 278/2013 regarding industrial emissions, except for SO_2 and PM that exceed the recommended values. In this respect, CEH – Paroseni CHPP has completed the works to the FGD plant, and BAT-ELVs will be observed for both pollutants. Paroseni CHPP has, starting with 2019, an IEP (Integrated Environmental Permit). The problems remains related to post-mining land use management: besides the land reclamation process, with issues related to the proper observance of the legislation in force, the land was affected by the subsidence phenomenon (0.51 km^2) that led to the destruction of a large number of households and the cultural centre in Dâlja Mare commune; and demolition of a large number of miners colony "80 houses" in Lupeni municipality due to safety issues.

8.1.2 Use of coal for small applications

According to ANRSC, at national level in 2016, centralise DHSs were still in operation in 62 urban areas, compared with 315 in 1989, 80% of DHSs being abandoned. According to the "Energy Strategy of Romania 2019-2030, with prospect 2050", the DHSs fuel used is mainly natural gas, only a few localities using lignite, hard coal, fuel oil or biomass, and this status is expected to persist until 2030. Out of the total thermal energy delivered at national level approx. 85% goes to domestic consumers (residential buildings), 5% to public buildings and 10% to industry and other businesses (Romanian Parliament, 2006).

Theoretically the public utility service, related to thermal energy generation, transport, distribution and supply at the level of the territorial administrative units (cities, municipalities), are under the leadership, coordination and responsibility of the local public administration or the community development associations, aiming to provide the necessary thermal energy (heating and hot water) for the population (residential buildings), public institutions and the economic sectors. But on-site each municipality/city has its own specificity.

From the regulatory point of view, until 2016, this public utility service was under the competence of ANRSC, when it was taken over by ANRE in November 2016, once the Law 51/2006 on community services of public utilities was amended and completed. To this aim, the responsible local public administrations are free to decide on the way of managing, directly or by delegation, this public utility service.

In 2016, in the West Region, the following companies were active in the field of DHS (Consiliul Concurentei, 2018):

- CEH (cogeneration and transmission networks operator - Deva TPP and Paroseni CHPP) running on hard coal;
- Termoficare Petrosani; Termoficare/Edil Therma/Pregoterm Vulcan, Citadin Aninoasa and Universal Edil Lupeni (DHS operators);
- Arad CHPP and Arad Hidrocarbons CHPP (cogeneration and DHS operators) running on lignite and hydrocarbons;
- Apoterm Nadlac (DHS operator);
- Colterm - local DHS company Timisoara (2 cogeneration sources and DHS operator) running on lignite,

of which for Jiu Valley micro-region:

- Paroseni CHPP (cogeneration and transmission networks operator);
- Termoficare Petrosani; Termoficare/Edil Therma/Pregoterm Vulcan, Citadin Aninoasa and Universal Edil Lupeni (DHS operators).

The hard coal produced in Jiu Valley, mainly from the unique producer CEH, and until 2017, also from SNIMVJ (2 underground mines before final closure), is used only for energy purposes (power and heat generation) at CHPP Paroșeni and Deva TPP. The former hard coal quota allocated to CEH employees was transformed in the so called “heating aid” during 2 winter months out of 5 on average per season.

In Hunedoara County exists two major DHSs on hard coal, one supplied by CEH - Deva TPP for Deva municipality, under CEH management, and the other one connected with CEH - Paroseni CHPP for Jiu Valley urban areas Petrosani, Aninoasa, Lupeni and Vulcan (since 1981), both delivering thermal energy (heat and hot water) to residential, public and commercial customers.

The heat related public utility service management in Jiu Valley is split in two:

- Thermal energy cogeneration and transmission networks are under the responsibility of CEH - Paroseni CHPP;
- Thermal energy DHS (TP and distribution networks to connected consumers) is under the responsibility of each local administration/mayoralties.

After the ’90 the unique DHS operator in the Valley “IGCL Petrosani” supplying about 35,000 consumers (CEH, 2018), splits in 4 utility services companies, having as main shareholder each Local Councils. Hard coal use for domestic purposes (households’ heating in the urban areas) has been cut gradually due to the aggressive lobby of companies delivering individual n.g. heating systems, the lack of investments – maintenance works and the high losses, generating inefficient heating services: it started before 2016 with Aninoasa city, then Lupeni and Vulcan municipalities having only public buildings still connected to the DHS network, and before the last winter 2019-2020 CEH - Paroseni CHPP stopped supplying all types of consumers from Jiu Valley urban areas, including Petrosani municipality (13,717 consumers).

Table 8.1.f DHS supplied consumers - hard coal-based thermal energy generation facility CEH - Paroseni CHPP; Dwellings stock in Jiu Valley micro-region

<table>
<tr><th rowspan="2">Jiu Valley UATs</th><th colspan="4">DHS supplied consumers - hard coal-based thermal energy generation facility CEH - Paroseni CHPP (no.)</th><th colspan="3">Dwellings stock at the end of the year (no.)</th></tr>
<tr><th>in the ‘90</th><th>2007</th><th>2016</th><th>2018 – last year of supply</th><th>2016</th><th>2017</th><th>2018</th></tr>
<tr><td>All 4 urban centers with DHS</td><td>35,268 unique DHS operator</td><td>NA</td><td>NA</td><td>2,502</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Petrosani</td><td>13,717</td><td>NA</td><td>2,460 apartments in collective dwellings; 33 individual houses
11 public buildings
182 companies.</td><td>last winter (2018-2019) of heat supply for
2,265 apartments in collective dwellings; 33 individual houses
11 public buildings
187 companies
Termoficare Petrosani - DHS operator</td><td>17,936</td><td>17,944</td><td>17,949</td></tr>
<tr><td>Lupeni</td><td>9,020</td><td>NA</td><td>last winter (2015-2016) of supply for all consumers
Universal Edil Lupeni - DHS operator</td><td>-</td><td>4,221</td><td>4,227</td><td>4,228</td></tr>
</table>

Jiu Valley UATs	DHS supplied consumers - hard coal-based thermal energy generation facility CEH - Paroseni CHPP (no.)				Dwellings stock at the end of the year (no.)		
	in the '90	2007	2016	2018 – last year of supply	2016	2017	2018
*Vulcan**	*8,290*	*NA*	*last winter (2015-2016) of supply for residential buildings and companies Termoficare / Edil Therma / Pregoterm Vulcan - DHS operator*	*last winter (2018-2019) of heat supply for 6 public buildings Termoficare Vulcan - DHS operator*	*11,381*	*11,386*	*11,392*
Aninoasa	*4,241*	*last year of supply for all consumers Citadin Aninoasa - DHS operator*	-	-	*2,046*	*2,046*	*2,048*
Petrila	-	-	-	-	10,205	10,235	10,244
Uricani	-	-	-	-	11,831	11,836	11,843
Bănița* Commune	-	-	-	-	564	564	564
Total	**-**	**-**	**-**	**-**	**58,184**	**58,238**	**58,268**

*Source: Hunedoara Energy Holding, press release 13.04.2018; National Institute of Statistics (LOC101B); TRACER data collecting**

The DHS obsolescence level jumps to 90-95% for the transport infrastructure and approx. 50% for the TPs and distribution networks. In terms of environmental protection, according to the Site Report (Phoebus Adviser, 2018) requested by Hunedoara Environmental Protection Agency, CEH-Paroseni CHPP holds an Environmental Authorization valid until 11.10.2022 for cogeneration and DH.

In Jiu Valley the DHS infrastructure includes:

- 2 arborescent transmission networks (primary circuit) of 34 km length between Paroseni CHPP and Petrosani Municipality, and 10 km length between Paroseni CHPP and Vulcan Municipality;
- the thermal energy distribution systems (secondary circuit) connecting the heat & hot-water transmission networks from the TSs to the DHS consumers, comprising:
  - in Petrosani 33 TS and about 54.8 km of networks,
  - in Vulcan 14 TS, 5 TM and about 34 km of networks,
  - in Lupeni 14 TS and about 52 km of networks,
  - in Aninoasa 1 TS, 3 TP and distribution network, with no length available data.

According to **Table 8.1.c** both the generated and supplied thermal energy decreased up to 30% in 2018 compared to 2016, a trend that continued until winter 2019, when CEH – Paroseni CHPP stopped delivering heat in Jiu Valley. Considering the population and the living standard decreasing trends, the dwellings stock was not developed, as presented in **Table 8.1.f**, the solution that the population was forced to adopt was the individual heating systems.

Although CEH-Paroseni CHPP cogeneration source was qualified every year (2016-2018) for the high efficient cogeneration bonus according to ANRE methodology, due to the massive number of consumers' disconnection from the DHSs, none of the 4 urban centres in Jiu Valley (Petrosani, Vulcan, Lupeni and Aninoasa) have been qualified for accessing EU funds for DHS retrofitting and upgrading program. On this background all DHS operators in the Valley were declared bankrupt and the domestic and non-domestic consumers had to deal with this situation, adopting alternative heating solutions depending on each financial capacity. In addition, ESIF 2014-2020 accession rate is very low due to both lack of capacity and competences at local administrations level, but also to financial difficulties met when ensuring the local contribution / co-financing rate.

Of concern is the reduction of the amount of thermal energy delivered to both households and non-households' consumers in Jiu Valley, which means a constant number of consumers disconnecting from the DHS (10-20% per year), the connection rate reaching only 20%. All, due to inefficient DHS services and high losses in the transport network. Switching from the centralised thermal energy supply to individual systems on fossil fuels (natural gas) or firewood can lead to acceleration of air quality deterioration and to the occurrence of unwanted events (e.g. risk of installations' explosion or poisoning with CO emissions due to installations improper use, without periodic checking). **Currently (winter 2019-2020) Paroseni CHPP, due to CEH financial situation of insolvency, stopped supplying thermal energy for citizens in Petrosani and Vulcan municipalities.**

The thermal energy sales price in **Table 8.1.g** includes the high efficient cogeneration bonus.

If the sales price for the thermal energy supplied is approved by ANRE, the Local Councils calculate and decide on the local billing price for each type of consumers, considering also to add the heating distribution costs and, for the population, to include the subsidy supported by the Local Councils **Table 8.1.h.**

Table 8.1.g Thermal energy sales prices - hard coal-based energy generation facility CEH, in Jiu Valley micro-region

Economics	CEH (Paroșeni CHPP and Deva TPP)		
	2016	2017	2018
Heat and hot water sales price (€/MWh)	26.54	27.08	26.06
Coverage degree of the production price (%).	64.77	30.27	23.25

Source: Hunedoara Energy Holding, Administrators Reports (CEH, 2016, 2017, 2018)

Romania grants for households heating aids according to GEO no. 70/2011, replaced by Law no. 196/2016 on the minimum income for social inclusion, which should take effect from April 1, 2021. To this aim, the subsidy, which currently applies to all DHS consumers, as presented in **Table 8.1.h** will further be granted only to vulnerable consumers identified by responsible authorities (in Jiu Valley around 4% out of the total resident population). Currently, Law no. 123/2012 on electricity and natural gas, with subsequent amendments and completion, offers the possibility of establishing a solidarity fund for vulnerable consumers' financial support.

High-efficient cogeneration is the green way to generate both electricity and heat, but as long as this technological solution is not supported enough at government level by appropriate policies, in Romania it will be difficult to win the households supply prices competition against individual thermal installations on natural gas (**Table 8.1.h**).

Table 8.1.h Households supply prices, in Jiu Valley micro-region

Economics	2016	2017	2018
Electricity supply price (€/MWh) *Average price between regulated & the competitive market prices*	91.6 / 126.2 without / with taxes	91.3 / 124.9	97.6 / 132.3
Natural Gas supply price (€/MWh), VAT not included *Regulated market price (e.g. ENGIE ÷ E.ON)*	23.8 ÷27.5	23.9 ÷27.8	28.5 ÷ 30.5
Firewood price (€/MWh), VAT included *Romsilva – Hunedoara Forests Division*	13.71	14.72	18.14 58.46 pellets 57.60 wheat/straw briquettes
DHS Heat & hot water supply price (€/MWhl), VAT included *= generation + transport + distribution + supply prices - local subsidy*	30.91 of which 45.58 generation-transport-distribution-supply price and 14.67 local subsidy	31.13 of which 45.55 generation-transport-distribution-supply price and 14.42 local subsidy	29.06 of which 43.21 generation-transport-distribution-supply price and 14.15 local subsidy

Source: Calculations based on ANRE National Reports 2017, 2018; Preliminary examination of the firewood sales market, 2018, Competitiveness Council; Petrosani Local Council Decisions no.335/2015, no.11/2017, no.3/2018

We estimate that heating and cooling will continue to account for over 50% of the final energy consumption - so solutions must be identified to meet energy needs, based on new technologies and the use of local and sustainable energy resources.

8.2 Current status of other energy generation technologies

Electricity

According to Transelectrica in the net electricity production mix 2017-2018, the largest share (42%-40%) is represented by the energy from fossil fuels (coal, hydrocarbons mainly natural gas), followed by hydro (24%-29%), RES and nuclear with a share of about 16%-14% and 18%-17% respectively. So, at national level the green energy had a similar contribution in the net electricity production, with a share of 40%-43%, as fossil fuels.

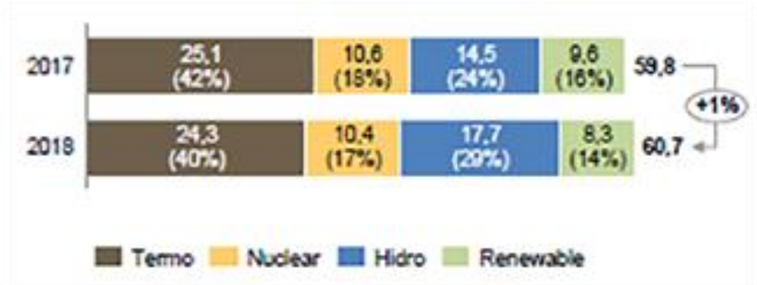


Figure 21: Net electricity production mix at national level (TWh)

Source: Economic and Financial Preliminary Report, 2018, Transelectrica

The national energy production park is relatively constant in 2018 compared to 2017, the hydro and RES installed capacities (46%-45.6%) being almost near fossils with a share of 48.3%-48.6%.

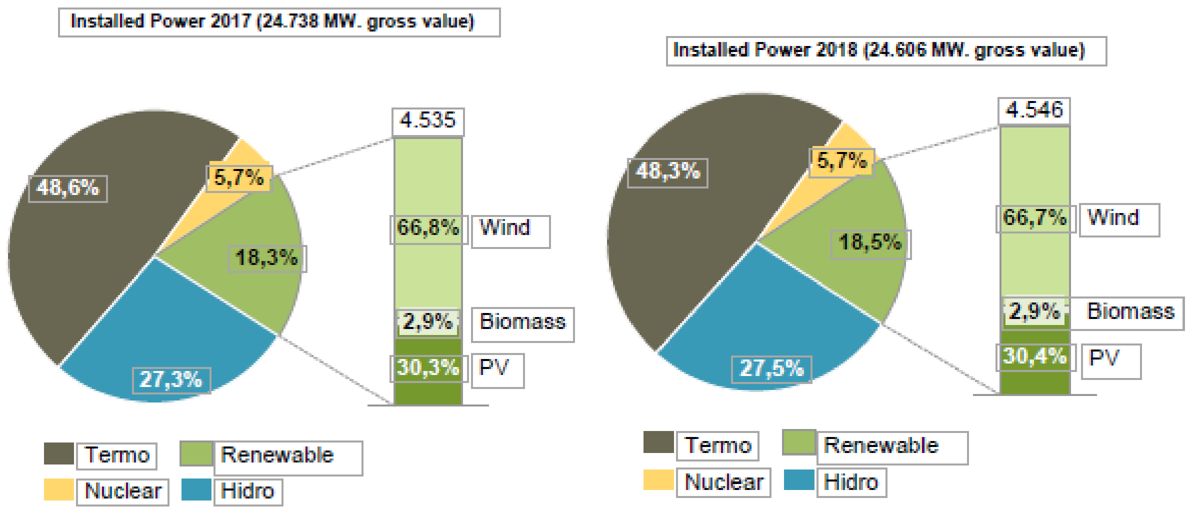


Figure 22: National energy production park (TWh)

Source: Economic and Financial Preliminary Report, 2018, Transelectrica

The West Region (Arad, Timis, Caras-Severin and Hunedoara counties), in terms of installed power capacities (ANRE, 2020) for electricity generation, has the following structure: 56% coal, 2% hydrocarbons, 35% hydro, 3% wind and 4% solar (PV). The greener county is Caras-Severin (79% hydro, 21% wind) and at the opposite pole is Hunedoara with 69.37% coal, 30.51% hydro, 0.0002% wind, 0.03% biomass & biogas and 0.08% solar (**Figure 23**).In the following we will estimate as accurately as possible, based on the available data, the energy structure of Jiu Valley micro-region.

Hydro

Hidroelectrica, a state-owned company, is the main producer and supplier of hydro power at national level, and has in operation in Hunedoara County under Hateg Subsidiary management (Hidroelectrica, 2019), the following large-small-micro hydro capacities (Table 8.2.a: Existing RES - Hunedoara county - Jiu Valley micro-region**Table 8.2.a**):

- Hydropower systems summing up 520.1 MW installed:
- Small and micro sized HPPs with a total of 5.12 MW installed, with 0.93 MW in Jiu Valley.

According to ANRE private investors in Hunedoara (2.184 MW) are in Simeria, Baru and Cincis; and in Jiu Valley the water management company **Apa Serv Valea Jiului** is operating 3 micro-HPPs (0.434 MW). Other private investor in Taia, Petrila but the projects were stopped in court by environmental activists from Bankwatch.

Wind and Solar

In Hunedoara County (nothing in the Jiu Valley), according to Transelectrica and ANRE, there is a single wind energy producer in operation to supply electricity into the distribution grid (20 kV OHTL) Marga WPP (0.0038 MW), Baru.

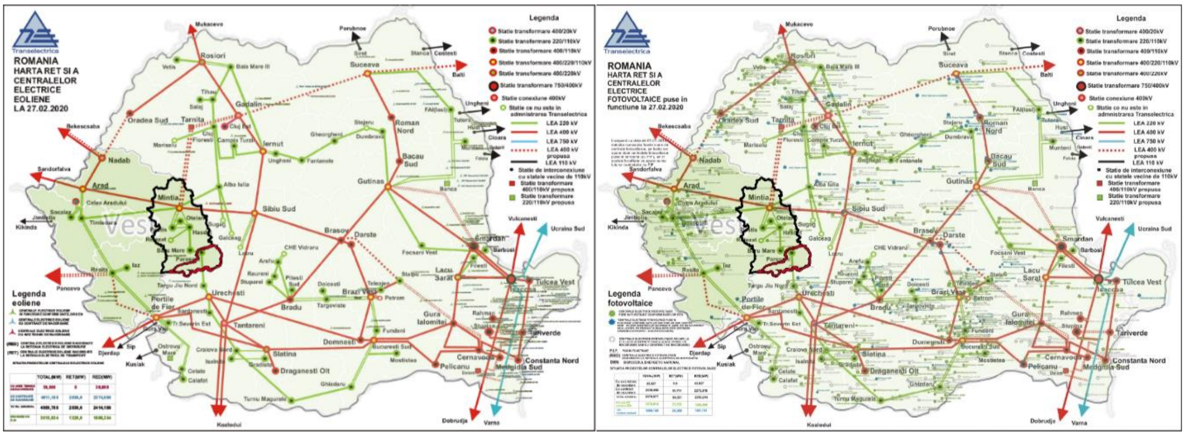


Figure 23: Electricity Transmission Network, PV-PP and WPPs

Source: Transelectrica TSO, 2020 http://www.transelectrica.ro/en/web/tel/productie

At Hunedoara County level, solar energy is more and more used by private investors for electricity generation and by individuals for thermal energy. According to our energy market regulatory authority ANRE and Transelectrica TSO in operation we have the following PV-PPs with an estimated total capacity of 1.4 MW (**Table 8.2.a**).

In addition, the Environmental Fund Administration (AFM, 2019) registered:

- 21 funded projects in Hunedoara – Bosorod locality, under the "Photovoltaic systems for insulated households" Financing Program, funding a PV kit of minimum 1 kW/household; nothing in Jiu Valley;
- 5,300 approved individual projects to be financed at national level (PV kit of minimum 3 kW/household), under “Photovoltaic Green House” Financing Program, but without a clear geographical distribution of projects by regions…probably also in Jiu Valley;
- 93 individual contracts (2016) for solar thermal energy in Hunedoara county were approved to be financed under "Classic Green House" Program - for the installation of renewable heating systems, including the replacement or completion of the classic heating systems, but nothing in the Jiu Valley.

Few positive examples for solar energy use in public buildings (30% in Vulcan, 16% in Uricani) and 1 residential-collective dwellings in Uricani.

Biomass - Biogas

Even if the potential of wood biomass exists in Hunedoara county, the restrictions imposed by the presence of large environmental protected areas limit the volume of wood harvested for processing, and still furniture manufacturing is in the top 5 turnovers. Currently, there are 3 projects of biomass or biogas-based cogeneration plants:

- Apa Serv Valea Jiului, 2 x biogas-based micro-CHPP summing up 0.38 MWel, 0.436 MWth by revaluating the Danutoni WTP sewage sludge in Petrosani municipality, Jiu Valley;
- Energy Serv (0.160 MW), Brad locality – not yet in operation (Transelectrica, 2020);
- Biomass-based cogeneration unit in Aninoasa city, Jiu Valley – under development with ESIF 2014-2020 support.

Geothermal

In Hunedoara county, near Deva municipality low temperature geothermal springs are exploited for therapeutic spa purposes – Geoagiu-Băi, Vaţa, Călan-Băi and Bobalna (APM-Hunedoara, 2014). In Jiu Valley there are no available information about such geological resources.

Table 8.2.a: Existing RES - Hunedoara county - Jiu Valley micro-region

County / Micro-region	Owners	RES type technology/system		Installed capacity (MW)	Location
Hunedoara, of which:	Hidroelectrica	Hydropower systems 1 x Gura Apelor dam, Retezat HPP Clopotiva HPP	HYDRO PPs	335 14	Raul Mare river – Retezat
		Hydropower systems 3 x hydro accumulations (Ostrovul Mic, Paclisa and Hateg), 1 x dam 6 x HPPs Ostrovul Mare, Carnesti I, Carnesti II, Totesti I, Totesti II and Orlea		134.3	Raul Mare river – Aval
		Hydropower systems Subcetate HPP Plopi HPP Bretea HPP and a future development of 4 new HPPs		12.2 12.0 12.6	Strei river
		Dobra 1	Small and micro sized HPPs	0.81	Cerbal locality
		Godeanu 1 Godeanu 2		0.4 0.66	Orastioara de Sus locality
		Valea Cracului 1 Valea Cracului 2 Valea Cracului 3 Zeicani		0.54 0.42 0.56 0.37	Zeicani locality
		Baru Mare		0.44	Baru locality
	Private investors	Aqua Ecoenerg		0.107	Simeria locality
		Renewable Invest		0.99	Baru locality
		Uzinsider General Contractor		1.087	Cincis locality
	Local Council	Marga WPP	WPP	0.0038	Baru locality
	Private investors	MASIN Energy SWISS Trade	PV-PPs	0.05 0.05	Hunedoara municipality
		AUTO Schunn SAVA Exim ROMSTAL Imex		0.07 0.1 0.12	Deva municipality
		REFRACERAM Factory		0.5	Baru locality
		FERO Romid		0.06	Călan locality
		Restart Energy One		0.44	General Berthelot locality

County / Micro-region	Owners	RES type technology/system		Installed capacity (MW)	Location
	AFM / individua	21 x Photovoltaic systems for insulated households		Min. 0.021	Bosorod locality
		93 x contracts	Solar thermal	NA	Several localities
	Energy Serv	Biomass-based microCHP	Biomass	0.16	Brad locality
Jiu Valley	Hidro-electrica	Livezeni	Small - micro sized HPPs	0.24	Aninoasa city
		Buta		0.49	Campul lui Neag locality
		Valea de Pesti		0.2	Uricani city
	Apa Serv Valea Jiului	Polatistea		0.2	...
		Valea de Pesti		0.2	Uricani city
		Brazi - Vulcan		0.034	Vulcan municipality
		Biogas-based microCHP	Biogas	0.38	Petrosani municipality
	Local Council	Biomass-based CHP (under development)	CHP	NA	Aninoasa city

Source: ANRE, AFM, Transelectrica TSO, 2020 http://www.transelectrica.ro/en/web/tel/productie

The structure of the energy park in Jiu Valley demonstrates the dominance of the coal-based installed capacities for electricity generation and the very low development of RES (**Figure 24**).

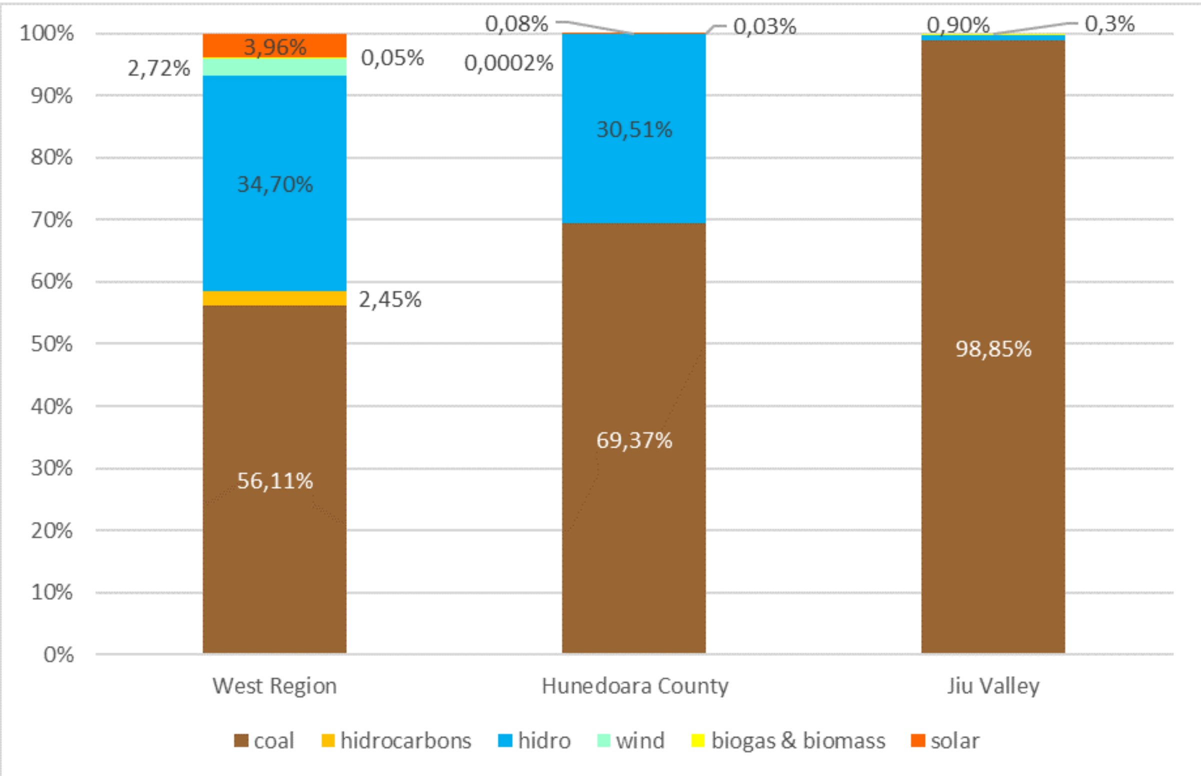


Figure 24: Installed power capacities, West Region – Hunedoara County – Jiu Valley

Source: Assessment based on ANRE data, 2020 (ANRE, 2020)

Related to the thermal energy generation technologies used, mainly for heating purposes and few industrial processes (e.g. steam for wood industry), the available data were poor, insufficient answers received to the TRACER questionnaires from half of the analysed urban centres, and no inventory for the thermal plants per district or per collective dwellings at regional or county level.

At county level a single centralised DHS was identified:

- Termica Brad, Hunedoara - TP running on fuel oil and DHS

As presented in **Chapter 8.1,** the DHSs being bankrupt Jiu Valley population was forced to adopt the following heating systems technologies, in residential buildings switching from DHS to:

- 75% natural gas - individual thermal installations or thermal plant per block of flats / collective dwellings / residential building (95%-99% efficiency) and stoves (low efficiency 40%);
- 20% of the households on firewood and sometimes hard-coal - individual thermal installations (90% efficiency) and stoves (very low efficiency 20%-30%);
- 5% of the households on electric heating, fossil liquid fuels stoves, or stoves with other type of biomass as wood pellets and wheat/straw briquettes.

A similar process has been started for the public buildings, disconnecting from the DHS and installing individual heating systems mainly on natural gas. Positive examples for heating systems rehabilitation in public buildings (80% in Vulcan and 75% in Uricani).

<u>Natural gas infrastructure</u>

The Energy Department, inside the Ministry for Economy, Energy and Business Environment, estimates that until 2030, the modelling results indicate a transition to natural gas-based heating in urban and semi-urban areas, gradually giving up to firewood and coal-based heating in inefficient stoves for reasons of air pollution and thermal comfort. In rural areas, without additional support measures, this transition will take place much more slowly. To this aim, in order to support the population by providing the necessary natural gas distribution infrastructure for heating and, thus, preserving the existing forests wood, as well as protecting the environment, the Ministry of European Funds announced (Agerpres, 2020), starting May 15, 2020, the call for projects proposals to be launched for the implementation of the Natural Gas National Program. The beneficiaries of the program are: administrative-territorial units (UAT) and members of the Inter-community Development Associations (ADI), the households' connection to the n.g. distribution grid being considered eligible expenditure.

According to **Table 8.2.b** in Jiu Valley the development of the natural gas pipe-line length was modest during 2016-2018, under 7%, of interest being the peri-urban and rural areas with no DHS and where vulnerable families usually live.

Table 8.2.b: Natural gas distribution infrastructure for households use, West Region - Hunedoara county - Jiu Valley micro-region

Jiu Valley UATs	natural gas distribution pipe-line length (km)			natural gas distribution for households (thousand Nm³/year)		
	2016	2017	2018	2016	2017	2018
West Region	4280.2	4392.3	4517.2	305,165	315,356	306,353
Hunedoara county	846.5	843.4	857.2	76,981	76,714	73,734
Jiu Valley micro-region, of which:	146.9	147.4	156.8	19,794	20,699	20,116
Petrosani	39.20	39.30	44.80	7,023	7,165	6,863
Lupeni	25.90	26.00	27.30	3,763	3,946	3,806
Vulcan	25.70	25.70	25.80	4,523	4,862	4,651
Aninoasa	31.50	31.60	32.10	134	165	260
Petrila	12.60	12.70	12.90	3,264	3,368	3,341
Uricani	12.00	12.10	13.90	1,087	1,193	1,195
Bănița	-	-	-	-	-	-

Source: National Institute of Statistics (GOS116A, GOS118A)

<u>Firewood</u>

At the last official census in 2011, in Romania 45% of the households were heated with stoves burning firewood and coal. The current situation has changed, but there are no official statistical data in this regard. In Hunedoara county, the restrictions imposed by the presence of large environmental protected areas limit the volume of wood harvested for processing. Firewood and biomass represent the quantities of wood and wood waste provided by Romsilva (e.g. Hunedoara Forestry Department) to the population, as well as firewood, wood and agricultural wastes resulting from wood industrial processing and agricultural products purchased directly by the population. According to the Romsilva Annual Reports (Table 8.2.c), the volume of firewood produced for population use (heating and cooking) to be traded at regulated prices, doesn't cover at all the demand, which led to uncontrolled and illegal deforestation and huge sales prices variations. The state is slowly changing since the substantial amendments brought in 2018 to Law no. 46/2008 - Forestry Code.

Table 8.2.c: Firewood for population use – demand, Hunedoara county & production, national level

Year	Firewood and biomass* – population consumption estimated for Hunedoara county (thousand m³)	Romsilva firewood production for population use at national level (thousand m³)
2016	390.67	838.6
2017	400.7	735.371
2018	NA	1,137.284

**) pellets and wheat/straw briquettes*

Source: Examinare preliminară pe piaţa comercializării masei lemnoase cu destinaţia lemn de foc, 2018, Consiliul Concurentei; Romsilva http://www.rosilva.ro/rnp/rezultate_licitatii_vanzare_masa_lemnoasa__p_1033.htm

The Energy Department estimated that the firewood demand will enter a downward slope both as an effect of buildings thermal insulation, diversification of heating technologies with the support of AFM (AFM, 2019) financing programs and due to the National Natural Gas Program launch.

Without being further supported by national policies, heating systems with the use of either DHS, electricity or RES technologies will not be sufficiently competitive given the natural gas low price in Romania, a trend that is not expected to change fundamentally by 2030 (**Table 8.1.h**).

8.3 Technological challenges and opportunities

8.3.1 Energy Technologies – Challenges

Closure of mining exploitations and the mono-industrial specificity of Jiu Valley micro-region generated a "domino" effect in terms of: unemployment; social vulnerability and depopulation; decrease in population incomes, in quality of life and local budget revenues; deterioration of education, health and utilities services; air quality deterioration etc. Increased dependence of Hunedoara Energy Holding (CEH) on subsidies despite mass layoffs, lack of investments, high unemployment rates and constant social protection generated a decline of former miners' life quality, which deepened the inertia of non-engagement and the lack of entrepreneurial initiatives.

8.3.1.1 Political-Administrative-Legislative

- Difficulties in local taxes collecting generating administrative/institutional financial instability;
- Lack of institutional capacity and competences at local administration level (the territorial administrative units inside Jiu Valley) generating low ESIF 2014-2020 accession rates; lack of institutional ability to attract investors having a negative impact on the economic development;
- Local economic development suffering due to insufficient financial incentives / specific "transition" regulations and support policies, Jiu Valley micro-region being judged, in

terms of eligibility rules (e.g. State aid rules with high co-financing rates for SMEs), as the rest well-developed West Region;
- Reduced cooperation initiatives between Jiu Valley territorial administrative units slowing down the transition process planning;
- Existing pro-SRE policies and legal framework not being enough promoted; no local public outreach campaigns (e.g. prosumers legislation, energy efficiency, energy savings etc.).

8.3.1.2 Infrastructure-Utilities

- Non-payment of taxes by the mining companies (CEH) having a negative impact on the ability of local authorities to maintain local infrastructure (energy, roads, railways, communication etc.);
- Local economic development suffering due to lack of connectivity (roads, railways and communication infrastructure);
- The existing DHS of about 185 km network length (transmission and distribution system) that supplied in the '90s around 35,000 consumers, has an obsolescence level of 90-95% for the transmission infrastructure and approx. 50% for the TPs and distribution;
- Population's major negative impact generated by CEH insolvency is switching from centralised DHS to individual systems on fossil fuels (natural gas) or firewood leading to: acceleration of air quality deterioration, occurrence of unwanted events, decreasing of households heating comfort, and increasing the risk of energy poverty;
- Over 20% of Jiu Valley households using, for heating, firewood and hard-coal based stoves with low and very-low efficiency;
- Ensuring the security of electricity supply and the NPS balanced and safe operation (e.g. according to Transelectrica (Transelectrica, 2018) peak of electricity demand in case of CEH closure generating overloads in the 220 kV OHTLs in the W – SW regions).

8.3.1.3 Technology-Environment

- The dominance in Jiu Valley of the hard coal-based installed capacities (99.1%) for electricity generation and the very low development of RES (0.9% hidro); Has Jiu Valley enough RES potential to replace the hard coal-based installed capacity of 150 MWel and 294.4 MWth
- Unpredictable operation and variations in the power system induced by wind and solar power plants, and the possibility of heat accumulation in summer for frosty winters, are aspects that emphasize the importance of developing storage capacity for both electricity and heat;
- Low local economic development having a negative impact on SMEs and large companies' capacity of covering co-financing rates for projects related to research and innovation in fields of interest (e.g. energy efficiency, alternative energy resources, energy storage etc.);
- SNIMVJ had and has no prospect of cooperating with University of Petrosani or research facilities in Jiu Valley for the development and implementation of innovative solutions during mine closure procedure, as for example: proper use of former mines lands or former administrative buildings, tailings dumps fertilization and reclaiming or solar energy use onsite; there are no recent collaborations in this respect with CEH either;
- According to PNIESC around 30% of the GHG emissions in Romania are generated by the coal mining and manufacturing industries (MEEMA, 2020);
- Monitoring and assessing the air quality in Jiu Valley micro-region;
- Paroseni CHPP has, starting with 2019, an IEP (Integrated Environmental Permit) observing all BAT-ELVs for NO_x, SO_2 and PMs; remaining issues are the post-mining land use management with the subsidence phenomenon and the unproper observance of the legislation in force regarding the land reclamation process.

8.3.1.4 Resources

Resources-Energy

- Lack of field data regarding both the energy consumption / production in Jiu Valley, and the inventory of existing RES per households or per companies, making the assessment and monitoring process difficult;

Resources-Human-Education-Research-Innovation

- With a low GDP per capita of about 3,400 € (2018), Jiu Valley stands out as one of the poorest regions in Romania with high risk of energy poverty and social vulnerability (PwC, 2020);
- Labour migration, mainly young people, leading to depopulation and aging citizens; lack of young people engagement due to no technological and intellectual challenges, perspectives and predictability;
- After the 90's, restructuring measures were inadequately planned and did not sufficiently support former miners' professional reconversion programs or the curricula were not market oriented;
- Most of the existing companies in Jiu Valley operate in fields that require intensive labour and not in high-tech sectors (PwC, 2020), the current economic profile being dominated by the services (trade), followed by the manufacturing sector, transport, construction and hotels-restaurants;
- Underdeveloped dual education system; managing and promoting the high-tech potential of the secondary education system;
- Capacity building programs and assistance at institutional and corporate levels mainly on topics as strategic planning, project financing, etc.

Resources-Financial resources

- Local economic development suffers due to insufficient capital, financial incentives / specific "transition" fiscal regime;
- Non-payment of taxes by the mining companies (CEH) having a negative impact on the ability of local authorities to cover ESIF co-finance for projects on energy efficiency in buildings, on environment & urban regeneration etc.;
- Lack of needed skills to access funding sources, attract investments, create fiscal facilities to encourage young people to return, settle down and get involved in the economic and social transformation of Jiu Valley in a recovered and safe environment.

8.3.2 Energy Technologies - Opportunities

- Jiu Valley micro-region is included in the EC Coal Region in Transition Platform (EC-CRIT); on this background, the Romanian Government (Ministry of European Funds - MFE) gained EC support for financing Jiu Valley Transition Strategy (MFE, 2019), via EC-SRSS (Structural Reforms Supporting Service); the document will be worked out by EC designated consultant PricewaterhouseCoopers, under the coordination of MFE and has to be completed in 9-12 months from the start (December 2019);
- For the financial year 2021-2027, MFE is envisaging Jiu Valley micro-region to benefit from ITI allocations - Integrated Territorial Investment mechanism; thus, replicating the good practices in the Danube Delta, through customised financing programs structured according with Jiu Valley specificities and needs;
- EU Just Transition Fund will provide other investment opportunities in areas such as: - site regeneration and decontamination, land reclamation; - implementing LCT and infrastructure for clean and affordable energy supply, reducing GHG emissions, increasing energy efficiency and RES use; - SMEs, including start-ups, which support economic diversification and transition; - creation of new companies, including consulting services and "business incubators"; - R&I, including advanced technologies transfer; - workers' re-skills / new competencies development; - job search assistance; - technical assistance and supervision;

- RES potential (GD no.1535, 2003) (hydro, wind, solar, biomass, geothermal) based on specialized studies performed in 2003-2006 by prestigious R&I institutions ICEMENERG, ICPE, INL, ISPH, ENERO (Figure 25): installed hidro power capacities in Hunedoara county (HD) of about 528 MW, of which 1.4 MW in Jiu Valley; wind speed annual average estimated in HD at 3-4 m/s in the centre up to over 10 m/s in S-W, while in Jiu Valley starts in Petrosani-Petrila at 3-4 m/s up to 9-10 m/s near its administrative boundaries in S-E and N-W; solar irradiation of around 1,200-1,250 kWh/m^2/year in HD and <1,200 kWh kWh/m^2/year in Jiu Valley; estimated biomass potential for about 2,370 TJ in HD (78% agricultural, 22% forestry), Jiu Valley no data available; no available data related to prospect drillings performed for geothermal.

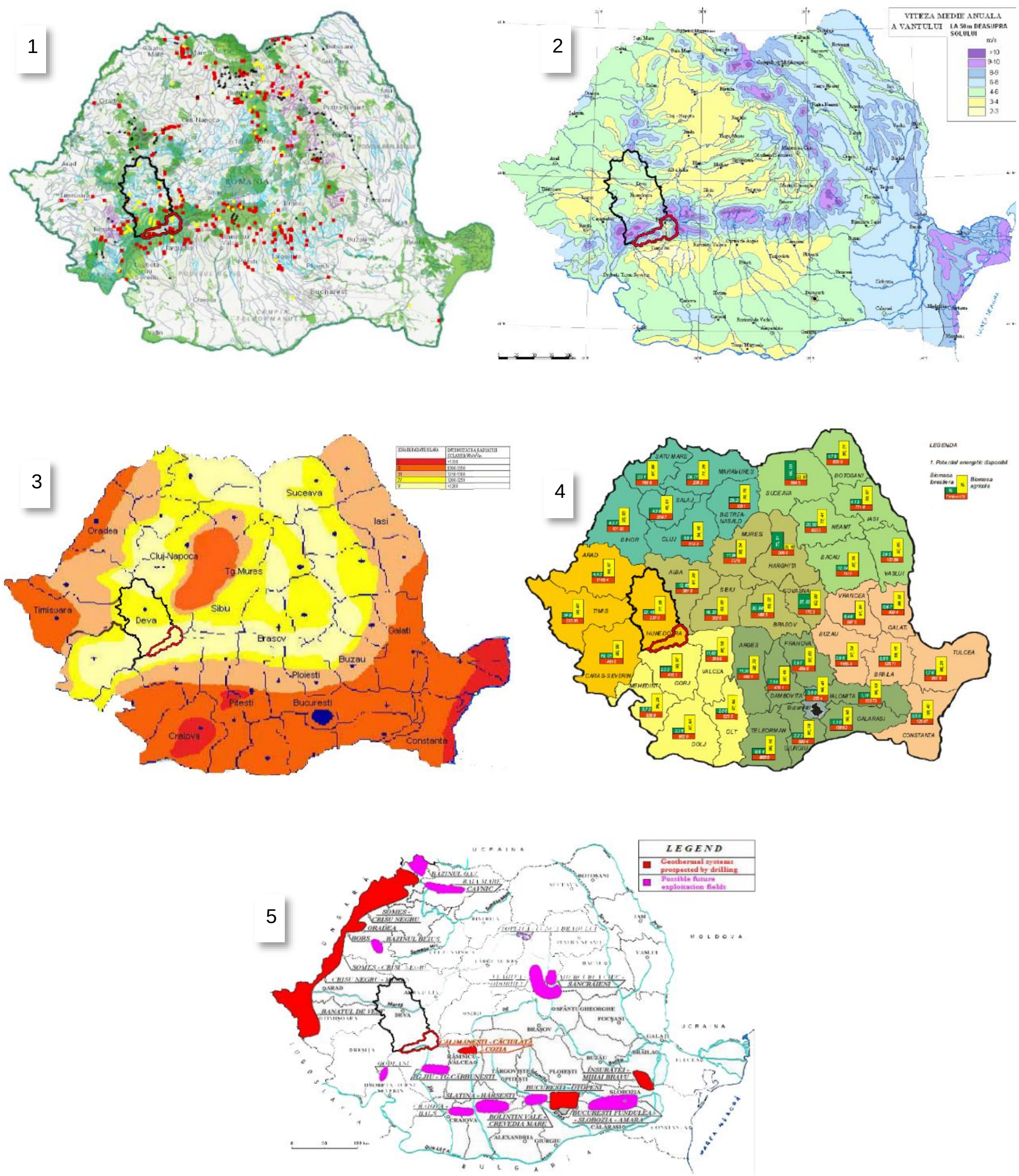


Figure 25: RES potential at national level, Hunedoara County – Jiu Valley (1 – hidro systems, 2 – wind annual average speed, 3 – solar radiation intensity, 4 – biomass, 5 – geothermal)

Source: GD no. 1535/2003 and specialised studies ICEMENERG, ICPE, INL, ISPH, ENERO, 2006

- Jiu Valley micro-region becoming members of Covenant of Mayors for Climate & Energy (EU-CoM, 2008) initiative and performing the SECAP (Sustainable Energy and Climate Action Plan);

- The existence of a centralized DHS in Jiu Valley, including a network of approx. 185 km (primary and secondary circuit), can be the starting point for the transition to a semi-decentralized DHS, by implementing a retrofitting & upgrading program, including the transformation of TS into micro-CHP or TP, RES and/or natural gas based, and, if available, the surplus heat recovered from industrial processes (TRACER, 2019) to be injected to the DHS network; or, if the potential and characteristics of mine waters (TRACER, 2019) are appropriate, it could be injected in the existing DHS network as a thermal agent; this transition to households' heating based on RES technologies, represents an opportunity to assess the potential of wood, agriculture and wood waste biomass (TRACER, 2019); or electricity based heating in peri-urban areas, if the air-to-ground heat pumps (TRACER, 2019) with high energy efficiency, accompanied by heat accumulators, is proven feasible and AFM financing program "Casa Verde Plus" will still be available;
- After a proper assessment of the solar energy potential, geomechanical stability and constructions' resistance analysis of the targeted reclaimed surfaces (former mining lands and tailings dumps) or buildings, PV-PPs, Hybrid PPs (TRACER, 2019), including storage batteries and smart energy management systems can be developed as a follow-up to the hard-coal underground mines post-closure process, contributing to urban regeneration – an alternative to agricultural oriented former mining land reclamation; similar opportunities for ash & slag dumps; additionally a techno-economic assessment of different solutions to revaluate both the existing minerals inside the mining wastes dumps and the ash & slag in construction materials could be of interest; in parallel the assessment of the electricity transmission and distribution infrastructure needs to be performed and smart grid and meters investments to be planned and accomplished;
- Romania encourages and supports domestic, industrial and agricultural prosumers (<27 kW installed), simultaneously with the development of smart grids and meters for the integration of distributed production systems and prosumers in the electricity system, through Law no.184/2018 which amends and completes Law no.220/2008 for RES promotion; thus, it is estimated that, in the coming years, photovoltaic capacities will develop both as medium-capacity solar parks, built on degraded or poorly productive land, and as small, dispersed prosumers' capacities; once performed - a proper assessment of the solar and wind energy potential and the analysis of the ownership and stability of the targeted reclaimed surfaces or buildings, projects can be developed by individuals or SMEs; AFM (AFM, 2019) financing programs support small-medium sized RES projects via "Casa Verde Plus" and "Sisteme Fotovoltaice";
- Other opportunities for alternative energy resources could be MMC (UN-ECE, 2010) – underground mines methane capture using specific boreholes designs, in order to use this gas for micro-CHP, to prevent risks and secure miners' safety, and to reduce GHG emissions;
- Jiu Valley micro-region could become the future hub for electricity and heat storage; using former mining & energy industries sites for developing a demo project for a storage battery system (TRACER, 2019) with high-voltage grid connection, that buffer temporarily electric energy from different sources in the electricity grid; using the former underground mines as a storage medium for thermal energy or thermal batteries (storage of heat and cold) (TRACER, 2019);
- Energy efficiency - energy savings and RES use in buildings, public lighting and industry are issues that can be of interest by creating jobs, developing innovative solutions within the Research Center for building materials in UPET (e.g. insulating materials - sheep wool fibres) and organising public outreach "science to community" type with the engagement of University of Petrosani;
- Considering the ongoing projects aiming to diversify the natural gas pipelines routes from Caspian Sea to Central Europe, and to exploit new offshore natural gas resources in the Black Sea perimeters, Transgaz (Transgaz, 2017) started the construction of the new corridor Bulgaria-Romania-Hungary-Austria "BRUA" (estimated completion date 2022), included in CESEC (Central East Europe Gas Connectivity) priority list, which

will cross Hunedoara and Jiu Valley; Romania's energy strategy (Ministerul Energiei, 2018) provides the use of natural gas as a transition fuel to a low-carbon economy with high RES share; thus, the government adopted the draft GEO for launching the National Program for natural gas distribution networks expansion, with priority in communities with solid or liquid fossil fuel based heating, in order to preserve the existing wooden mass and protect the environment; beneficiaries of this national program (500 million € for 200,000 households) will be the administrative-territorial units, as well as members of the Inter-community Development Associations; in this context, the feasibility analysis of Paroseni CHPP switching from hard-coal to a flexible cogeneration CCGT (combined cycle gas turbine) plant is not excluded either;

- At the initiative of the private environment, the Ministry of Economy, Energy and Business Environment (MEEMA), in partnership with the local civil-society representatives, will support the development of a re-skilling centre in Jiu Valley, aiming to relocate, re-train and improve workers' skills and competences (e.g. job search, entrepreneurial initiatives and start-ups, etc.); economic sectors in search for workers will be targeted as construction, railway and road infrastructure; the financing sources will be the Modernization Fund within the EU-ETS Mechanism, Phase 4 (2021-2030); adding also the opportunity of developing apprenticeship programs and institutional capacity building and skills development programs on projects financing could be an asset for this centre;
- MFE will launch new calls, this year, under the Human Capital Operational Program (POCU 2014-2020), with 2 million € allocated budget, targeting the improvement of the professional skills, and increase the employment rates in Jiu Valley (maximum grant per project 400,000 €, for re-skilling at least 100 people; future projects are expected to be implemented in Petroșani, Vulcan, Petrila, Aninoasa, Lupeni and Uricani; other 20 million € for students in their final years "Innotech-Student", for grants up to 100,000 € per start-ups in high-tech fields like IT, robotics or industrial automation; 30 million € in call for projects proposals via "Romania is waiting for you" program addressed to young Romanians from abroad to support their entrepreneurial initiatives back home; TECH-Nation for SMEs and large enterprises with a grant estimated at maximum 40,000 € for around 5,000 winning companies; and support for young people NEETS – financing opportunities which could bring hope to Jiu Valley young generation.

TOP 10	
Challenges	**Opportunities**
1. Inexistent heating and hot water households supply, despite 185 m length of DHS network; 2. Constant number of consumers disconnection from the DHS (10-20% per year), the connectivity rate reaching only 20%; 3. Inappropriate post mining land & buildings use management, legal disagreements and no formally temporary exemption from taxes at ownership transfer; 4. Lack of RES related field data, no regional / local potential assessment studies; 5. Poor connectivity infrastructure (roads, railways, ICT); obsolete energy infrastructure (electricity distribution); 6. Deficit of institutional capacity, competences & abilities to attract funds and investors; no cooperation between local administrations; 7. High unemployment and energy poverty rates; 8. SMEs incapacity of covering co-financing rates; 9. Low economic development affecting the local budget and no specific “transition fiscal regime”, incentives etc.; 10. Retraining and reskilling programs not oriented to market or investors needs and under developed dual education or apprenticeship system.	1. Transition to a semi-decentralized DHS, with the transformation of TS into micro-CHP or TP, RES and/or natural gas based, provided there is enough heat demand; or 2. Use of natural gas as a transition fuel; FS “Paroseni CHPP switching from hard-coal to a flexible cogeneration CHP-CCGT plant, provided again there is enough heat demand; change coal & firewood-based heating with natural gas where no DHS exists; 3. R&I projects on topics as surplus heat recovery, heat storage and mine waters potential; MMC living lab; 4. PV-PPs, Hybrid PPs potential use on former mining lands, tailings, ash & slag dumps, and buildings, in parallel with electricity distribution grid retrofitting; 5. Jiu Valley a future electricity storage HUB, including also investments in smart grid and meters; 6. Increasing EE, energy savings and RES use in buildings, public lighting and industry; 7. Supporting and encouraging domestic, industrial and agricultural prosumers; 8. EC-SRSS and ITI allocations for Jiu Valley micro-region; several other financing programs (ESIF, Just Transition Fund, Modernisation Fund, Horizon Europe, LIFE, Danube Interreg, Innotech-student, TECH Nation etc.) to be launched; 9. Defining specific Jiu Valley “transition eligibility rules” and fiscal regime (facilities & incentives package) to attract the young diaspora back home and stimulate investments, and sustainable employment; 10. Jiu Valley re-training centre for market-oriented re-skilling programs, including institutional capacity / competence / ability programs and project financing assistance.

8.4 Technical energy transition concept

Jiu Valley micro-region future concept for the technical energy transition towards an efficient, smart and emission-free energy sector, is recommended:

- to be a realistic one, integrated in the global vision of Jiu Valley Just Transition, for which key stakeholders are willing to get involved;
- to be motivating and to inspire key stakeholders towards commitment in following the common vision and opportunities, in the sense of achieving the proposed goal;
- to be ‘step by step’ strategically planned, considering the background, the current state of play, the challenges and opportunities previously analysed;
- to consider the micro-region specificities in terms of socio-cultural heritage.

The transformation into a RES-based sustainable energy system with low carbon emissions, will be made gradually, with natural gas (n.g.) as a transition fuel, in order to provide a time buffer for upgrading and retrofitting the electricity distribution networks, as many of them are obsolete.

The gradual transition of Jiu Valley micro-region to a RES-based energy system, by switching power/cogeneration units from hard-coal to n.g. is also necessary, knowing that wind and solar energy are variable resources, unable to ensure the entire energy demand, especially in extreme weather conditions generated by the increasing negative impact of climate change.

The draft technical energy transition concept for Jiu Valley micro-region is presented in **Table 8.4.a** below:

Table 8.4.a: Draft technical energy transition concept, Jiu Valley micro-region, West Region, Romania

Major steps **Areas of action**	**2020-2021** **Diagnosis and Planning** *Public consultation and Decision making* *Project financing*	**2021-2027/2030** **Implementation and Management** *R&I* *Feasibility studies / Engineering / Permitting / O&M*	**2030-2040-2050** **Monitoring, assessment / reporting and rising effectiveness**
Constant and most effective stakeholders' information, education, awareness and engagement campaign			
Political-administrative-legislative	▪ EC – SRSS completion of „Jiu Valley Transition Strategy" ▪ Defining and establishing transition KPI per specific areas of action ▪ Formally and legally approval of the integrated administrative structure of Jiu Valley micro-region (including or not Banita commune) and deepen cooperation ▪ Planning the ITI mechanism and governance structure ADI-ITI Valea Jiului ▪ Active involvement of TRACER/WP5 working group for defining Jiu Valley energy transition common vision and priorities ▪ Planning for future development of Industrial Parks and defining a fiscal incentives package to stimulate and attract investors capable of delivering sustainable employments ▪ Registering the new governance structure to the Covenant of Mayors Initiative for Energy and Climate (CoM)	▪ Gradually cutting of subsidies and state aids until 2024, defining of a regulated support scheme for the massive layoffs that will follow, integrated with market-oriented retraining programs, synchronized with the needs of potential future investors and energy poverty risk reduction policies & concrete solutions ▪ Solving the legal disagreements and formally approve a temporary exemption from taxes when the new governance structure takes over the former mining assets (lands, buildings) belonging to MEEMA (e.g. post-closure property regime, tax regime, etc.) ▪ Delivering TRACER/WP6 – R&I Strategy and Roadmap for Transition towards sustainable energy systems ▪ Starting the implementation of the strategic step by step energy transition strategy	▪ Proceeding with the implementation of planned actions ▪ Monitoring KPI for 2020-2030 and 2030-2050 ▪ Periodic evaluation and improvement
Infrastructure	▪ Planning at local and county level the needs for investment projects (roads, railways, natural gas – n.g. transport and distribution, telecommunications, tourism) ▪ Utilities planning for future industrial parks ▪ Preparing and submitting financial applications ▪ Development of EV charging infrastructure	▪ Preparing the necessary ESIF documentation (e.g. Feasibility Studies (FS), Expert appraisals, etc.) ▪ Preparing and submitting financial applications ▪ Implementing the National program for n.g. distribution networks expansion ▪ Implementing investment projects with already secured financing	▪ Proceeding with the implementation of planned actions ▪ Monitoring KPI for 2020-2030 and 2030-2050 ▪ Periodic evaluation and improvement
Energy Technologies	▪ Performing CEH restructuring plan, including 3 major analyses: a. final technical and juridical / ownership (MEEMA or Local Councils) solutions for Deva TPP and future Jiu Valley Energy Holding (Paroseni CHPP + 4 underground mines), to be addressed in a stakeholder's consultation session; b. FS + ESIA for Deva TPP switching to n.g. (CHP-CCGT); c. comparative FS + ESIA for Jiu Valley Energy Holding: the resumption of DHS and hard-coal based Paroșeni CHPP switching to n.g. (CHP-CCGT) vs. DHS decentralisation with micro-CHPs on n.g. and / or RES ▪ Development of SECAP (Sustainable Energy and Climate Action Plan) as CoM members at micro-region level ▪ Extending Energy Efficiency (EE) programs to increase the energy performance of public & residential buildings and public lighting, including RES use ▪ Planning and formally - legally approval of a cooperation protocol between MEEMA - SNIMVJ – Petrosani University (UPET) - new governance structure - other stakeholders (local NGOs, SMEs, large enterprises etc.), for R&I and / or investment projects development	▪ Performing energy system diagnosis in Jiu Valley micro-region, with the assessment of the RES use potential ▪ Analysis of the electricity transmission and distribution infrastructure – needs for retrofitting & upgrading projects, as smart grid and meters, storage HUB ▪ Implementing the information-awareness campaigns ▪ European partnerships for R&I projects for MMC (underground mines methane capture), heat & cold storage using former underground mines as a thermal battery, PV-PPs on former mining lands, RES in DHS ▪ Former Paroseni CHPP (future Jiu Valley Energy Holding) continues to operate until mining exploitation licenses expires (2024); while planning the conversion to n.g. in order to assess the techno-economic feasibility of this transition solution vs. DHS decentralisation with micro-CHPs on n.g. and / or RES ▪ Preparing the necessary ESIF documentation (e.g. Feasibility Studies (FS), Expert appraisals, etc.) ▪ Preparing and submitting financial applications	▪ Proceeding with the implementation of planned actions ▪ Monitoring KPI ▪ Periodic evaluation and improvement ▪ Increasing each year RES share, gradually

Major steps **Areas of action**	**2020-2021** **Diagnosis and Planning** *Public consultation and Decision making* *Project financing*	**2021-2027/2030** **Implementation and Management** *R&I* *Feasibility studies / Engineering / Permitting / O&M*	**2030-2040-2050** **Monitoring, assessment / reporting and rising effectiveness**
	▪ Preparing and submitting financial applications ▪ Planning the information-awareness campaigns on topics as: prosumers, energy efficiency, energy savings, climate change, etc.	▪ Start implementing the investment projects with secured financing (e.g. decentralized DHS and RES, energy efficiency, smart grid and meters, storage HUB) and R&I projects (MMC, electricity and H&C storage HUB etc.) from "living-labs" to "commercial-ready" stage	
Environment	▪ Performing studies on air quality in Jiu Valley micro-region ▪ Assessment of the carbon footprint for Jiu Valley micro-region ▪ Planning the FS for assessing the techno-economic viability of the different opportunities to revaluate both the existing minerals inside the mining wastes dumps and the ash & slag in construction materials ▪ Planning and formally - legally approval of a cooperation protocol between MEEMA - SNIMVJ - UPET - new governance structure - other stakeholders (NGOs, SMEs, large enterprises etc.) for R&I and / or investment projects as urban regeneration, agriculture land reclamation and/or for energy use and/or touristic purposes	▪ R&I projects, specific analyses and opportunity studies for: former mining land / tailings and ash & slag dumps reclamation and buildings use reconversion (e.g. geomechanical stability, solar irradiation, soil fertility, etc.) ; revaluating both existing minerals inside the mining wastes dumps and the ash & slag in construction materials ▪ Preparing the necessary ESIF documentation (e.g. Feasibility Studies (FS), Expert appraisals, etc.) ▪ Preparing and submitting financial applications ▪ Start implementing urban regeneration projects ▪ Start implementing land reclamation investment projects on former mining surfaces, tailings and ash-slag dumps	▪ Proceeding with the implementation of planned actions ▪ Monitoring KPI for 2020-2030 and 2030-2050 ▪ Periodic evaluation and improvement
Human Resources	▪ Highly efficient accession of all POCU 2014-2020 calls (Innotech, TECH Nation programs etc.) useful for Jiu Valley in fields as ICT - robotics - industrial automation oriented towards the transition to a coal-free economy ▪ Creating a fiscal facilities and incentives package to attract the young diaspora back home; and promoting the call for projects proposals within "Romania is waiting for you" financing program (POCU 2014-2020) ▪ Planning institutional capacity and competencies building programs on project financing	▪ Preparing and submitting financial applications ▪ Developing and implementing the proposed actions ▪ KPI analysis	▪ Proceeding with the implementation of planned actions ▪ Monitoring KPI and accession rates for 2020-2030 and 2030-2050 ▪ Periodic evaluation and improvement
Education-retraining-R&I	▪ Dual education system restructuring and development planning ▪ Engagement with potential employers to identify needed skills ▪ Apprenticeship and retraining programs compatible with employers' needs ▪ Planning updating the University curriculum and development of the R&I contracts with the industry (ICT, robotics, construction materials, etc.) ▪ Accelerating and multiplying the R&I partnerships in energy and environment (Horizon Europe, LIFE etc.) projects ▪ Defining the concept of the information-awareness campaign, including KPIs	▪ Preparing and submitting financial applications ▪ Involving UPET in campaign planning and implementation ▪ Monitoring the impact of the campaign through public opinion surveys ▪ Impact assessment after updating the university curriculum, developing the dual education system and the retraining programs	▪ Proceeding with the implementation of planned actions ▪ Monitoring KPI for 2020-2030 and 2030-2050 ▪ Periodic evaluation and improvement
Financing	▪ Performing a complete inventory of available financing sources (TRACER / WP4 Guide) ▪ Planning and legally approval of specific "transition eligibility rules" for Jiu Valley micro-region (e.g. State aid rules with adequate co-financing rates for local SMEs) ▪ Preparing the list of projects, writing financing applications for all national and European, bilateral or IFC programs in energy – environment and related fields	▪ Preparing project proposals and submitting financial applications for the implementation of projects proposals: - SRSS „Jiu Valley Transition Strategy" - TRACER / WP6 Roadmap for Transition towards sustainable energy systems	▪ Proceeding with the implementation of planned actions ▪ Monitoring KPI, accession and signed contracts rates for 2020-2030 and 2030-2050 ▪ Periodic evaluation and improvement

Major steps Areas of action	**2020-2021** **Diagnosis and Planning** *Public consultation and Decision making* *Project financing*	**2021-2027/2030** **Implementation and Management** *R&I* *Feasibility studies / Engineering / Permitting / O&M*	**2030-2040-2050** **Monitoring, assessment / reporting and rising effectiveness**
	▪ Preparing the 2021 local budget structure knowing future needs for ESIF documentation ▪ Organization TRACER / WP4 funding sources Conference		
Context	▪ *Romanian n.g. market will be fully liberalized starting with July 1, 2020 (including domestic consumers, for non-domestic consumers the process ended in 2015)* ▪ *Preparation for the programming period 2021-2027* ▪ *COVID-19 pandemic* ▪ *According to MEEMA, CEH restructuring plan envisage splitting in two new entities, the future switch to n.g. being made public:* - *Deva TPP transferred ownership to Hunedoara county or Deva municipality* - *Paroseni CHPP and the 4 mining perimeters will create the new Jiu Valley Energy Holding*	▪ *GEO no. 69/2019 for the application of social protection measures granted to massive layoffs are carried out on the basis of SNIMVJ and CEH Plans during 2019-2024* ▪ *Starting with January 1, 2021, the complete liberalization of the electricity market will be granted* ▪ *New n.g. based CHPP in Deva, Hunedoara (inside CEH precinct) - Romgaz investment* ▪ *New n.g. corridor Bulgaria-Romania-Hungary-Austria "BRUA" (estimated completion date 2022) crossing Hunedoara county and Jiu Valley micro-region* ▪ *Starting offshore n.g. resource exploitation*	*After 2030* ▪ *50% decrease in domestic crude oil production and depletion of proven reserves* ▪ *20.5% coal contribution in the total primary energy production* *After 2040* ▪ *Depletion of n.g. resources and proven onshore reserves* ▪ *50% decrease in coal (lignite) production* *Coal will still play until 2050 an important role in Romania (17.3% contribution in the total primary energy production), for ensuring this energy independence and security of electricity supply.*

Source: TRACER project best practice platform https://tracer-h2020.eu/best-practice-platform/ ANRE; ANRM; MEEMA

8.5 References

AFM. (2019). SISTEME FOTOVOLTAICE, SISTEME FOTOVOLTAICE PENTRU GOSPODARII IZOLATE SI CASA VERDE. RETRIEVED FROM ADMINISTRATIA FONDULUI DE MEDIU: HTTPS://WWW.AFM.RO/SISTEME_FOTOVOLTAICE.PHP, HTTPS://WWW.AFM.RO/CASA_VERDE.PHP, HTTPS://WWW.AFM.RO/FOTOVOLTAICE_IZOLATE_CERERI_APROBATE.PHP

AGERPRES. (2020). RACORDAREA LA GAZ A GOSPODARIILOR. PRESS-RELEASE. RETRIEVED FROM HTTPS://WWW.AGERPRES.RO/POLITICA/2020/02/20/BOLOS-RACORDAREA-LA-GAZE-A-GOSPODARIILOR-CHELTUIALA-ELIGIBILA-CERERI-DE-FINANTARE-PENTRU-AUTORITATILE-LOCALE-DIN-15-MAI--452512

ANRE. (2019). ORDER NO. 127/2019 FOR THE APPROVAL OF THE METHODOLOGY FOR ESTABLISHING THE REGULATED TARIFFS AND PRICES APPLIED BY THE SUPPLIERS OF LAST RESORT TO THE FINAL CUSTOMERS. BUCHAREST: AUTORITATEA NATIONALA DE REGLEMENTARE IN ENERGIEI.

ANRE. (2020). POWER INSTALLED IN ELECTRICITY PRODUCTION CAPACITIES IN COMMERCIAL OPERATION (VALID LICENSES). BUCHAREST: AUTORITATEA NATIONALA DE REGLEMENTARE IN ENERGIEI. RETRIEVED FROM HTTPS://WWW.ANRE.RO/RO/ENERGIE-ELECTRICA/INFORMATII-DE-INTERES-PUBLIC/INFO-LICENTE-AUTORIZARI/TITULARI-LICENTE-EXPLOATAREA-COMERCIALA-A-CAPACITATILOR-DE-PRODUCTIE

ANRM. (2019). LICENTE EXPLOATARE JUDETUL HUNEDOARA. RETRIEVED FROM AGENTIA NATIONALA PENTRU RESURSE MINERALE: HTTP://WWW.NAMR.RO/WP-CONTENT/UPLOADS/2019/12/ET_JUD_HUNEDOARA.HTM

APM-HUNEDOARA. (2014). ANNUAL REPORT REGARDING THE ENVIRONMENT STATUS IN HUNEDOARA . DEVA: ENVIRONMENTAL PROTECTION AGENCY – HUNEDOARA.

CEH. (2016, 2017, 2018). CEH – ADMINISTRATORS REPORTS. PETROSANI: COMPLEXUL ENERGETIC HUNEDOARA. RETRIEVED FROM HTTP://WWW.CENHD.RO/INDEX.PHP/SITUATII-FINANCIARE/

CEH. (2018, 04 13). CEH PRESS RELEASE. RETRIEVED FROM CEH: HTTP://WWW.CENHD.RO/INDEX.PHP/COMUNICATE-DE-PRESA/

CONSILIUL CONCURENTEI. (2018). NOTĂ PRIVIND MECANISMUL ECONOMIC AL PRODUCTIEI SI DISTRIBUTIEI DE ENERGIE TERMICA DIN ROMANIA SI POLITICA DE SUBVENTIONARE DIN ACEST DOMENIU. BUCHAREST: CONSILIUL CONCURENTEI - DIRECTORATUL PENTRU INDUSTRIE SI ENERGIE.

EU-COM. (2008). RETRIEVED FROM COVENANT OF MAYORS FOR CLIMATE & ENERGY: HTTPS://WWW.COVENANTOFMAYORS.EU/EN/

GD NO.1535. (2003). GD NO.1535/2003 REGARDING THE APPROVAL OF THE STRATEGY FOR RES CAPITALISATION. BUCHAREST: ROMANIAN GOVERNMENT.

GEO NO. 69. (2019). GOVERNMENTAL EMERGENCY ORDINANCE NO. 69/13.11.2019 FOR PROVIDING SOCIAL PROTECTION MEASURES TO PERSONS AFFECTED BY THE COLLECTIVE LAY-OFF PLANS WITHIN THE ECONOMIC OPERATORS FOR WHICH IT WAS APPROVED THE GRANTING OF THE STATE AIDS FOR FACILITATING THE CLO. BUCHAREST: ROMANIAN GOVERNMENT.

HIDROELECTRICA. (2019). HIDROELECTRICA - SUCURSALA HIDROCENTRALE HATEG. BUCHAREST: HIDROELECTRICA. RETRIEVED FROM HTTPS://WWW.HIDROELECTRICA.RO/ARTICLE/36

MEEMA. (2020). PLANUL NATIONAL INTEGRAT ENERGIE SCHIMBARI CLIMATICE (PNIESC). BUCHAREST: MEEMA. RETRIEVED FROM HTTP://ECONOMIE.GOV.RO/IMAGES/TRANSPARENTA-DECIZIONALA/PNIESC%202020/PNIESC_SEA_23.04.2020.PDF

MFE. (2019). INITIATIVA VALEA JIULUI. BUCHAREST: ROMANIAN GOVERNMENT. RETRIEVED FROM HTTP://MFE.GOV.RO/INITIATIVA-VALEA-JIULUI/

MINISTERUL ENERGIEI. (2018). STRATEGIA ENERGETICA A ROMANIEI 2019-2030, CU PERSPECTIVA 2050. BUCHAREST: MINISTERUL ENERGIEI. RETRIEVED FROM HTTP://ENERGIE.GOV.RO/TRANSPARENTA-DECIZIONALA/STRATEGIA-ENERGETICA-A-ROMANIEI-2019-2030-CU-PERSPECTIVA-ANULUI-2050/

PHOEBUS ADVISER. (2018). RAPORT DE AMPLASAMENT PENTRU AIM - AVIZUL INTEGRAT DE MEDIU AL CEH – SUCURSALA CET PAROSENI . TIMISOARA: PHOEBUS ADVISER SRL.

PWC. (2020). JIU VALLEY STRATEGY FOR TRANSITION FROM COAL 2021-2030 – ANALYSIS OF THE MAIN CHALLENGES AND OPPORTUNITIES IN THE JIU VALLEY - PRELIMINARY REPORT. BUCHAREST: PRICEWATERHOUSECOOPERS.

ROMANIAN PARLIAMENT. (2006). LAW 325/2006 ON THE PUBLIC UTILITY SERVICE RELATED TO THERMAL ENERGY SUPPLY. BUCURESTI: ROMANIAN PARLIAMENT.

TRACER. (2019). TECHNOLOGIES BEST PRACTICES FACT SHEET: HEAT STORAGE. BRUXELLES: TRACER PROJECT. RETRIEVED FROM HTTPS://TRACER-H2020.EU/BEST-PRACTICE-PLATFORM/

TRACER. (2019). TECHNOLOGIES BEST PRACTICES FACT SHEET: SMART CITIES. BRUXELLES: TRACER PROJECT. RETRIEVED FROM HTTPS://TRACER-H2020.EU/BEST-PRACTICE-PLATFORM/

TRACER. (2019). TECHNOLOGIES BEST PRACTICES FACT SHEET: DESCENTRALISED ENERGY. BRUXELLES: TRACER PROJECT. RETRIEVED FROM HTTPS://TRACER-H2020.EU/BEST-PRACTICE-PLATFORM/

TRACER. (2019). TECHNOLOGIES BEST PRACTICES FACT SHEET: HEAT STORAGES. BRUXELLES: TRACER PROJECT. RETRIEVED FROM HTTPS://TRACER-H2020.EU/BEST-PRACTICE-PLATFORM/

TRACER. (2019). TECHNOLOGIES BEST PRACTICES FACT SHEET: INNOVATIVE ELECTRIC ENERGY STORAGE "BIGBATTERY LAUSITZ". BRUXELLES: TRACER PROJECT. RETRIEVED FROM HTTPS://TRACER-H2020.EU/BEST-PRACTICE-PLATFORM/

TRACER. (2019). TECHNOLOGIES BEST PRACTICES FACT SHEET: SOLAR PARK COMPLEX "SENFTENBERG" AND PHOTOVOLTAICS AND WIND POWER . BRUXELLES: TRACER PROJECT. RETRIEVED FROM HTTPS://TRACER-H2020.EU/BEST-PRACTICE-PLATFORM/

TRACER. (2019). TECHNOLOGIES BEST PRACTICES FACT SHEET: USAGE OF SURPLUS HEAT. BRUXELLES: TRACER PROJECT. RETRIEVED FROM HTTPS://TRACER-H2020.EU/BEST-PRACTICE-PLATFORM/

TRANSELECTRICA. (2018). PLANUL DE DEZVOLTARE A RET 2018-2027. BUCURESTI: TRANSELECTRICA. RETRIEVED FROM HTTP://WWW.TRANSELECTRICA.RO/DOCUMENTS/10179/6507897/PLANUL+DE+DEZVOLTARE+A+RET+2018_2027_REVIZIA+0_FINAL_10.09_CLEAN.PDF/7A2EA9E4-B627-4AF8-9DD5-64ADA59E1447

TRANSELECTRICA. (2020). NEW POWER PLANTS WITH TECHNICAL PERMITS FOR GRID CONNECTION. BUCURESTI: TRANSELECTRICA. RETRIEVED FROM HTTP://WWW.TRANSELECTRICA.RO/AVIZE-CONTRACTE

TRANSGAZ. (2017). PLANUL DE DEZVOLTARE A SISTEMULUI NATIONAL DE TRANSPORT GAZE NATURALE 2018 - 2027. MEDIAS, ROMANIA: SN TRANSGAZ SA.

UN-ECE. (2010). BEST PRACTICE GUIDANCE FOR EFFECTIVE METHANE DRAINAGE AND USE IN COAL MINES. NEW YORK AND GENEVA: UN PUBLICATION.

9 Serbia, Kolubara region

9.1 Current energy generation technologies using coal

9.1.1 Coal driven power plants and CHP plants

Used technologies

Coal driven power plants and CHP plants in the Kolubara basin use conventional pulverized coal firing technology with subcritical steam parameters. Out of the existing 14 units at four sites, 9 use river water for the once-through condenser cooling, while 5 small units sited at the mine mouth use the forced draft cooling towers for recirculation cooling. Originally, all 14 units were of the condensing type, but two of them at the Obrenovac site are converted to CHP and generate heat for the local district heating system.

At the time when these power plants have been built, the existing environmental legislation was applied to limit the emissions of particulate matter and sulphur-dioxide from the flue gasses. For that purpose, the plants have been equipped by high chimneys to dissipate flue gasses away from the site. Currently, the EU standards on emission control have been implemented into the Serbian legislation, and the modern electrostatic precipitators and flue gas desulphurization and denitrification facilities are being introduced into the power plants that are planned to operate beyond the year 2023. By then 6 smaller old units will be shut down as their modernization to satisfy new environmental standards is not considered feasible.

Age of the systems

The age of the existing 14 units of power plants fired by lignite from the Kolubara coal basin is within the range between 35 and 64 years, as presented in Table 30.

Table 30: Age of the existing units fired by coal from Kolubara mines; Source: Annual Technical Report, Electric Power Utility of Serbia, 2006

Plant name and site	"Nikola Tesla" A Obrenovac	"Nikola Tesla" B Vorbis	Kolubara A Vreoci	Morava Svilajnac
Start-up year of particular units	A1: 1970 A2: 1970 A3: 1976 A4: 1978 A5: 1979 A6: 1979	B1: 1983 B2: 1985	A1: 1956 A2: 1957 A3: 1961 A4: 1961 A5: 1979	1969.

According to the recently (6 February 2020) adopted National Emissions Reduction Plan of Serbia, all units at sites of Kolubara A and Morava power plants are scheduled for closure by the year 2023. The rest is planned to continue operation after being thoroughly refurbished (with both the life extension and capacity increase measures) and equipped with modern facilities for environmental protection.

Efficiency

Net efficiency of conversion to the electricity of the primary energy contained in the coal (lignite) mined in the Kolubara basin is rather low, as presented in Table 31.

With combined heat and power generation made available by reconstruction of steam turbines at the units A1 and A2 of "Nikola Tesla A" power plant, efficiency of the primary energy use has considerably been increased by heat supply to the district heating system of Obrenovac city. Further improvement in the overall efficiency of other four units (A3-A6) is expected to be achieved by their reconstruction to generate electricity and base-load heat for the district heating system of the capital city of Belgrade.

Table 31: Net efficiency of the existing units at power plants (2016 data); Source: Annual Technical Report, Electric Power Utility of Serbia / Thermal Power Plants Branch, 2016

Power plant	Nikola Tesla A	Nikola Tesla B	Kolubara A	Morava
Net efficiency (%)/ net heat rate (kJ/kWh) of the units in operation during 2016	A1: 30.9/11,642 A2: 31.0/11,608 A3: 32.9/10,955 A4: 32.7/11,016 A5: 32.8/10,969 A6: 32.7/11,026	B1: 33.2/10,847 B2: 32.8/10,982	A1:, A2:, A3: 23.2/15,497 A4: Not in use A5: 28.8/12,501	27.9/12,903

Emissions

Due to low efficiency and poor quality of lignite from the Kolubara basin, considerable amounts of waste heat as well as of gaseous and particulate pollutants is emitted to the environment from power plants. Emissions of sulphur, nitrogen and carbon oxides (SO_2, NO_x and CO_2, respectively) and fly ashes and other particulate matters (PMs) to the atmosphere with flue gases from the power plants are presented in Table 32.

Table 32: Emissions of pollutants to the air from thermal power units burning lignite from Kolubara coal basin (2016 data); Source: Annual Technical Report, Electric Power Utility of Serbia / Thermal Power Plants Branch, 2016

Power unit	Unit	Emissions to the atmosphere, t/a			
		SO_2, t/a	NO_x, t/a	PM, t/a	CO_2, t/a
"Nikola Tesla" A	A1	11,708	1,892	957	1,236,416
	A2	14,358	2,320	1,600	1,514,068
	A3	22,115	3,574	306	2,332,565
	A4	21,233	3,028	546	2,311,568
	A5	22,282	3,178	435	2,422,878
	A6	22,020	3,140	282	2,394,161
"Nikola Tesla" B	B1	39,900	7,990	612	4,734,075
	B2	19,563	3,918	447	2,318,490
Kolubara A	A1-A3	4,159	839	2,981	629,310
	A5	762	227	198	384,048

Currently a set of measures is being implemented in to meet requirements of the local and EU standards. For reduction of emissions of sulphur-dioxide, wet limestone/gypsum technology is being installed at power plants that remain in operation after 2023 ("Nikola Tesla" A and "Nikola Tesla" B). Also, for NO_x emissions reduction from these plants primary measures with SNCR are being applied. For the fly ash collection from the "Nikola Tesla" B power plant, electrostatic precipitator of 99.8% efficiency is used to keep ELVs at 30 mg/m^3. The efficiency of the electrostatic precipitators at "Nikola Tesla" A is being upgraded (from 98% for units A1&A2 and 99.5%) to satisfy 20 mg/m^3 ELVs at the first step and 8 mg/m^3 at the next step (with hybrid type filter).

To cope with its very high emissions of CO_2 Serbia has drafted Strategy on low-carbon economy. The Strategy is expected to be adopted by the Government in line with the Paris Agreement, as well as with the National Determined Contribution under the UNFCCC protocol, also enforced by the Agreement on Establishing Energy Community in the South-East Europe.

When adopted, this Strategy will drive the transition of the Serbian energy sector away from coal, with high implications on the Kolubara coal basin.

Capacities

Nominal (nameplate) capacities of major power plants fired by lignite from the Kolubara coal basin have been changed following an effort of the Electric Power Industry of Serbia to extend the life and increase the rated power of the existing power plants. The nominal capacities before and after refurbishment and upgrades (where applicable) are presented in Table 33. Electricity generation (gross/net) during the year 2016 in particular units is presented in Table 34.

Table 33: Nominal capacities of thermal power plants fired by lignite from Kolubara basin; Sources: Annual Technical Report, Electric Power Utility of Serbia / Thermal Power Plants Branch, 2016, and Technical documentation for TPP Nikola Tesla A and TPP Nikola T

Power plant	"Nikola Tesla" A	"Nikola Tesla" B	Kolubara A	Morava
Nominal installed capacity of units before/after their modernization, MW	Unit A1: 210/225 Unit A2: 210/225 Unit A3: 305.5/329 Unit A4: 308.5/345 Unit A5: 308.5/340 Unit A6: 308.5/347	Unit B1: 618/670 Unit B2: 618/670	Unit A1: 32 Unit A2: 32 Unit A3: 65 Unit A4: 32 Unit A5: 110	125

Table 34: Electricity production by power plants fired by lignite from Kolubara basin in 2016; Source: Annual Technical Report, Electric Power Utility of Serbia / Thermal Power Plants Branch, 2016

Power plant	"Nikola Tesla" A	"Nikola Tesla" B	Kolubara A	Morava
Gross/net electricity production GWh/year	A1: 1145.7/1050.7 A2: 1397.0/1290.6 A3: 2268.4/2097.8 A4: 2284.0/2074.6 A5: 2400.1/2184.1 A6: 2361.7/2146.6	B1: 4593.5/4323.6 B2: 2221.1/2094.7	A1: 29.8/28.3 A2: 101.8/101.1 A3: 294.3/272.7 A4: 0/0 A5: 331.4/304.0	

Economics

The Electric power industry of Serbia (EPS) suffers both from its old and inefficient generating fleet requiring a lot of investment in maintenance and upgrades of the facilities, and from low regulated selling prices of electricity for about a half of its generation being delivered to the eligible customers (mainly households). This makes it difficult for EPS to acquire enough funds for inevitable modernization of the obsolete facilities, which even fall below the due annual amortization rate.

During the first decade of this century, a total of € 450 million has been invested (from donations and own resources) in modernization and life extension with an increase of energy efficiency of the power plants fired by the lignite from Kolubara coal basin. As a result of that investment, the units A3, A5 and A6 at "Nikola Tesla" A power plant and units B1 and B2 units at "Nikola Tesla" B power plant gained an increase in production of 3.2 billion kilowatt-hours a year, with savings of about 400,000 tonnes of coal, the effect that compares with a new 400 MW_{el} unit which would cost about twice that amount.

In 2011, the refurbished units fired by lignite from Kolubara coal basin reached the highest ever record of 20.2 TWh of annual electricity generation, and, related to this, the rail transport also broke the record in coal transport (more than 29 million tons), with the highest so far annual production (31 million tons) of lignite. However, in May 2014, heavy rains hit the Kolubara lignite basin, where an artificial lake of 20 square kilometers and 50 meters depth formed at the open-pit mine Tamnava West Field. Mining machinery and equipment was trapped underwater, affecting loss of production there for almost a year. The flood damage was estimated at € 100 million and cut Serbian power generation by 40%, forcing the country to boost electricity and coal imports. The World Bank approved a $ 300 million (€ 230 million) loan for the flood mitigation and supported Serbia in meeting the critical need for electricity generation and supply infrastructure. Some € 1.2 billion has already been invested in development of coal mining and rehabilitation, procurements of modern equipment and environmental protection.

After many years when available funds were invested only in the maintenance and upgrades of the production capacities, environmental protection has become a priority in Serbia. Besides continued investments in generating and control equipment of power plants and in open-cast mines, a particular emphasis is placed on the urgent investment in improving the environmental protection facilities. To stimulate investment in the low-carbon energy sector during this decade (until 2027), the priorities of EPS are focused on supply stability, meeting environmental requirements, modernization, economic sustainability and implementation of renewables, the planned investments amount € 4.9 billion euros, of which € 1.1 billion will be invested in mining, € 1.7 billion in the thermal section, € 0.7 billion in renewable resources and € 1.4 billion euros in distribution and corporate projects. Bearing in mind that more than a half of the total electricity generation in Serbia comes from Kolubara basin, the major portion of these investments is aimed for the projects to be implemented there.

Social issues

In spite of the environmental improvements, there are various negative consequences of the mining work in Kolubara coal basin, such as pollution of water supply and deterioration of the ground. Also, public safety is sometimes endangered by the overburden when overloaded dump field cause the collapses and landslides that destroy houses and roads in the vicinity. Of particular concern is the expansion of surface mining towards the human settlements. In the last decade this expansion has moved hundreds of households, two complete villages and partially 10 villages. One of them (Vreoci) was even required to relocate local graveyard and more than 1,000 households. With continued expansion of the mine, the relocation of households became urgent and residents were under enormous pressure to accept financial compensation and leave the territory designated for coal excavation. The value of their property was often considered by the owners as underestimated, involving an additional dimension to the social impact of coal mining.

9.1.2 Use of coal for small applications

Used technologies

Technologies that use about 10% of coal from Kolubara mines for purposes other than for power plants (power plants consume about 90% of total coal mined) include the heat-only boilers used to produce either steam or hot water for technological and mining purposes, as well as a variety of technologies for space heating. One larger two boiler units plant is in Vreoci to deliver process steam, and 21 smaller boiler units are distributed over the mining fields “B”, “D” and “Tamnava”.

A large number of space heating facilities (single boilers, furnaces, stoves, etc.) are distributed within and outside the region, dominantly in suburban and rural settlements and used in households for space heating, as well as for cooking in many cases. There is sometimes several different spare technologies in use for individual heating, depending of the seasonal variation market prices of particular fuels. Also, there are certain of these facilities adjusted for dual fuels (coal and wood, for example), as well as some for both primary and supplementary heating and cooking (electrical, for example). Such a variety of combinations make it difficult to determine a dominant technology for small applications in the region. However, when coal fired facilities are in question, the stoves dominate, that may use both, coal and wood either logs or (in rare cases) wood pellets.

Age of the systems

The steam boiler plant in Vreoci is in operation from 1979, one year since nine boiler units have been commissioned in the mining field “D” and a couple of years more since three boilers begun operation in the mining field “B”. The last two boiler units in the field “D” precede commissioning of the first two boiler units in the field “Tamnava” during 1980. The first of the next five boiler units in “Tamnava” field was commissioned in 1987. All of the boiler units are nearing to the end of their useful operational life.

The age of the coal fired facilities for space heating spans from one year to many decades, depending on the type, consumer, and many other possible circumstances. Relatively recent are only the systems for burning pellets that are growing fast in number, thus replacing more and more the oldest small coal fired facilities. However, larger ones for space heating in individual houses, stores or elsewhere, still remain although several decades old.

Efficiency

Generally, the technologies for small applications, particularly ones that are rather obsolete, are with considerably lower efficiency than larger ones. While the boiler plants efficiency is above 80%, some smaller facilities for space heating have several times lower efficiency (e.g. some very old stoves have efficiencies even below 20%). Newer technologies of domestic furnaces reach 55% efficiency. Recent development of the more efficient burning processes is driven much more by environmental than energy efficiency standards.

The efficiency of heating devices is mostly influenced by the location of the dwelling (urban-rural), age and structure of the family, as well as of fuel availability and price. Apart from old fashioned stoves, fired by coal, located in the kitchens and living rooms in rural households, consumption of coal in modern, technically improved and more efficient furnaces is rising mostly in urban areas.

Emissions

Owing to its larger capacity and annual operation, the steam boiler plant in Vreoci emits much more pollutants than the boiler units in use in mining processes, Table 35.

Table 35: Pollutant emissions from small coal applications in Kolubara basin; Source: Report on Emissions to Air from Steam Boiler Plants within Kolubara Basin Open Pit Mines, Laboratory for Environmental Protection and Protection on Work, Belgrade, 2011

Source of pollution	Pollutant, t/year					
	SO_2	NOx	PM	CO	CO_2	Ash
Open pit mine “Filed B”	0.470	0.037	0.031	1.174	206.58	173
Open pit mine “Filed D	4.250	0.404	0.350	13.125	2310	193.4
Open pit mine “Tamnava”	8.166	0.627	0.544	20.415	2179.32	182.3
Steam boilers in Vreoci	669.35	228.43	72.79	N/A	161,265	N/A

Small coal fired facilities for space heating have much higher specific emissions of each of the pollutants, including particularly considerable amounts of carbon-monoxide as well as the particles of unburnt coal, fly ashes and dust. In majority of cases no filters or any protection devices are installed. Unfortunately, emissions from vast majority of small heating facilities are rarely (if at all) controlled, and therefore the reference could only be made on the producer’s declaration, which is missing in many cases. There are often cases that, under specific atmospheric conditions, pollution from such sources becomes visible and even felt when inhaled. In such circumstances the health of the population in the area becomes endangered. This is particularly the case within the areas with densely built houses with low chimneys, usually located along the roads or narrow streets with frequent traffic.

Capacities

The capacity of process steam boiler plant in Vreoci is 2 x 60 tonnes of steam per hour. The capacities of the heat and steam boilers used for the needs of mining processes within three open pit mines are presented in Table 36. Most of them use locally dried lignite from Kolubara coal basin.

Table 36: Capacity data on the coal fired boilers in operation within open pit mines; Sources: Report on Emissions to Air from Steam Boiler Plants within Kolubara Basin Open Pit Mines, Laboratory for Environmental Protection and Protection on Work, Belgrade, 2011. And Soil Pollutant Inventory in Kolubara Coal Basin, Phase I, Volume 2, Book 1: Open Pit Mines, Institute Kirilo Savic, a.d. Beograd, (2012)

Open pit mine	Boiler house	Capacity, MW_{th}	Coal type	Coal use, t/a
Field "B"	Barosevac	2 x 0.525	Dried lignite	76.0
	Rudovci	0.334	Dried lignite	80.5
Field "D"	Stara Montaza	7 x 0.525	Dried lignite	800
	Medosevac	2 x 0.525	Dried lignite	370
	Junkovac	0.525	Dried lignite	220
	Zeoke	0.542	Dried lignite	360
Field "Tamnava"	Kalenic	2 x 2.500	Raw lignite	1071
	Zeoke workshop	1.600	Dried lignite	200
	Zeoke office	0.400	Dried lignite	80
	Barosevac office	2 x 0.221	Dried lignite	300
	Rudovci	0.259	Dried lignite	70

Capacities of a variety of facilities used for space heating based on lignite from Kolubara coal basin are quite different, depending on how and where this service is organized. While the minor unit capacities in rural areas are of the order of several kilowatts only, capacities in use in urban areas may range from tens of megawatts (in central heating systems) to several hundred megawatts (in district heating systems). Yet, in the urban areas a considerable percentage of households have small capacity devices installed to heat their flats or single rooms. An estimate of the share of installed types of heating spread over typical urban and rural areas is shown in Table 37.

Table 37: Estimated structure of the space heating installations in Serbia, %; Source: Statistical Office of the Republic of Serbia, Belgrade, (2013): Dwellings by the Type of Energy Raw Material Used for Heating (Data by municipalities/cities)

Area	District heating	Central heating	Individual heating
Urban area	36 %	19 %	45 %
Belgrade city	46 %	17 %	37 %
Rural area	0 %	23 %	77 %
Target area	7 %	26 %	67 %
Overall region	**22 %**	**20 %**	**58 %**

The share of coal in space heating differs across the region. The municipalities within or adjacent to the mining area are the major consumers of coal from the Kolubara mines. Table 38 presents the number of dwelling houses/flats that use coal for heating through different modes of heat supply. The estimated area per dwelling is around 60 m^2 and annual consumption of heat about 150 kWh per m^2.

Table 38: Number of dwellings in the closest municipalities; Source: Statistical Office of the Republic of Serbia, Belgrade, (2013): Dwellings by the Type of Energy Raw Material Used for Heating (Data by municipalities/cities)

Municipality	Dwellings with district heating	Dwellings with central heating	Dwellings with individual heating
Obrenovac	9,096	3,576	8,910
Lazarevac	4,963	6,073	4,715
Ub		2,158	5,594
Lajkovac		1,370	1,901
Arandjelovac		5,891	10,465

Economics

A good large stove from reputable manufacturers averages about € 2,500 to € 3,500, including the stovepipe and installation. Smaller stoves for households are almost an order of magnitude less costly. Estimated annual cost of coal used for space heating are comparable with the natural gas and lower than costs of other energy sources such as biomass (wood chips or pellets), fuel oil or electricity. Calculated with actual prices on the Serbian market and mean annual energy consumption per dwelling (~60 m^2), estimated annual expenditures per household are presented in Table 39.

Table 39: Annual cost of space heating in households by the use of coal; Source: Households Heating Costs in Serbia in 2016/2017, Energy Agency of the Republic of Serbia, 2017

Energy source	Energy price	Consumption per household	Expenditure per household
Coal, raw lignite	65 €/t	6.5 t/a	422.5 €/a
Coal, dried lignite	100 €/t	3.5 t/a	350.0 €/a

9.2 Current status of other energy generation technologies

Used technologies

There are no other than coal fired technologies for utility scale electricity generation except a very small number of mini hydro and rooftop photovoltaic installations. These small installations are not used for the own purposes, but are connected to the national power grid. That is because of an attractively high subsidized price is still paid (under the existing feed-in tariffs scheme) to the privileged producers of electricity from renewable energy sources and efficient cogeneration.

The most frequently used energy generation technologies for small applications other than those burning coal are stoves and other facilities burning wood (chips and pellets), and water heating boilers burning natural gas and fuel oil. Relatively small number of users outside the capital city of Belgrade have gas installations. However, the use of electricity for space heating and cooking is very significant. Besides conventional electrical heaters and stoves, there may also be found hybrid installations for heating and cooling, based on air or (very rarely) ground based heat pumps.

Typical field of application

Besides cooking and space heating and cooling, there are numerous other applications, particularly when electrically driven appliances are in question, either in businesses and offices or in households. Even in case of developed district or central heating systems, sanitary hot water is typically prepared by the use of electricity. In cases when natural gas is made available, it is mostly used for heating, and rarely for cooking. In rural areas the use of wood fired appliances is often combined for cooking and for space heating purposes.

Efficiency

The efficiency spans over a wide range, depending of both the technology and the energy source. The efficiency of appliances based on burning fuel wood is similar as in case of burning coal, except when efficient modern appliances for wood pellets are in question. Gas fired appliances are generally more efficient, about 90% or more. Electrically driven appliances are also highly efficient. This is particularly the case when ground-based heat pumps are in question, when their COP ("coefficient of performance") may be 3-5 or higher, meaning that one kWh used to drive compressor may give back 3-5 kWh of heat (this gain is on the account of the energy taken freely from the environment).

Capacities

Capacities of a variety of facilities used for different services in businesses, offices or in households for cooking, space heating and cooling based on other energy sources are generally similar to those based on coal. Also, they depend on how and where these services are organized. While the capacities of minor unit of wood fired stoves or electric heaters in rural areas are of the order of several kilowatts only, unit capacities fired by natural gas or fuel oil in use in district heating systems in urban areas may range from tens to over hundred megawatts.

In both urban and rural areas a considerable share of installed capacities is in households. Households usually have small capacity stoves installed to heat their dwellings by the use of fire wood, natural gas or a variety of electric heaters. To show their estimated capacities per energy source used for heating (assuming again the average area of 60 m^2 per dwelling and annual consumption of 150 kWh per m^2), the number of dwellings in municipalities within or adjacent to the Kolubara mining area is presented in Table 40Table.

Table 40: Number of dwellings in the nearest municipalities; Source: Statistical Office of the Republic of Serbia, Belgrade, (2013): Number of dwellings (Data by municipalities/cities)

Municipality	Dwellings with central heating			Dwellings with individual heating		
	Wood	Gas	Electricity	Wood	Gas	Electricity
Obrenovac	2,807	35	256	7,963	22	834
Lazarevac	2,958	23	148	4,292	8	280
Ub	1,952	6	114	5,709	6	365
Lajkovac	975	17	56	2,760	6	296
Arandjelovac	2,662	2,746	451	7,821	833	1,648

Economics

Kolubara target region is characterized by the country's largest energy supply services, both from the point of view of quantity of the coal excavation and of power generating capacities. In that respect it is also the largest single employer in Serbia. In addition, the capital city of Belgrade is the country's administrative, financial and educational center. Nevertheless, there are also rural areas where the ability to buy expensive facilities and to pay for energy and other services is somewhat lower. The same is valid for the household appliances.

A wood fired stove for space heating including the stovepipe and installation may have cost the same as the coal fired one. Gas fired boilers for central heating with automatic controls and other accessories would cost even more. Smaller capacity stoves for households cost considerably lower. Estimated annual cost of other than coal energy sources used for space heating (natural gas, wood chips or pellets, fuel oil or electricity), calculated with actual prices on the Serbian market and mean annual energy consumption per dwelling (~60 m^2), are presented in Table 41 together with the estimated annual expenditures per households.

Table 41: Comparative annual costs of space heating per household; Source: Households Heating Costs in Serbia in 2016/2017, Energy Agency of the Republic of Serbia, 2017

Energy source	Energy price	Consumption per household	Expenditure per household
Wood chip	50 €/m^3	8.5 m^3/a	425.0 €/a
Wood pellet	200 €/t	2.5 t/a	500.0 €/a
Natural gas	0.35 €/m^3	1,100 m^3/a	385.0 €/a
Electricity	70 €/MWh	9.9 MWh/a	693.0 €/a

Even with low regulated prices of electricity in Serbia, space heating by the use of electrical heaters appears to be the most expensive, unless specific conditions are provided (night tariffs, heat pumps, etc.). Nevertheless, the use of electricity for space heating is still high thanks to a comfortable handling and avoidance of local pollution from burning fuels. However, with growing concerns about climate change, the electricity prices are expected to raise and only highly efficient devices such as heat pumps could be considered appropriate when compared with wood and gaseous fuels.

9.3 Technological challenges and opportunities

Energy related challenges and opportunities

As contaminated soil degraded by mine activities are often not suitable for cultivation of crops used for human or animal nutrition, the idea of its use for production of energy crops may be more promising. Production of energy crops in the areas of abandoned mines or in the vicinity of active ones is one of the most acceptable options. There are possibilities to use the forest waste biomass for briquetting for space heating. Also, there have already been early examination of the possibilities to cultivate some new plants types, including afforesting of rapidly-growing cultures such as *Miscanthus giganteus*.

Apart from biomass production, the solar energy production is one of the most challenging possibilities to support a sustainable development of the region after mine used up. Average annual quantity of daily solar radiation on a horizontal plane in the target region is 3.8 kWh/m^2 per day (13,5 MJ/m^2 per day), ranging from 3.6 kWh/m^2 per day to 4.0 kWh/m^2 per day (from 1.3 kWh/m^2 per day to 1.5 kWh/m^2 per day in January and from 6.1 kWh/m^2 per day to 6.3 kWh/m^2 per day in July). Average solar energy that may be harvested annually is about 1.4 MWh/m^2. Possible ways of use of solar radiation for utility scale electricity generation include both direct conversion in photovoltaic (PV) installations and concentrated solar power plants. Suitable for these purpose are large surfaces of the overburden dumps and/or hardened ash dumps. In small scale electricity generation one could look both for roof top PV and/or building integrated PV (BIPV) solutions. Also, solar radiation may be found suitable for water heating in sanitary applications or in space heating provisions for residential and/or public buildings.

Wind velocity has already been measured on top of the ash dumps of the “Nikola Tesla” power plants in the target region, but its potential in the target region is considered less attractive (~3 m/s) than in northern part of Serbia (Province of Vojvodina), where several wind parks with total installed capacity about 500 MW are already on the grid. Average wind velocity on top of the high in the south-east part of Serbia is above 6 m/s, but these locations are less suitable to approach than those in Vojvodina.

Kolubara target region lacks potential for hydro-electric production. As far as geo-thermal energy is concerned, certain resources are found to exist in the region (in Rudovci - Mali Crljeni sites), but are not used yet (chemical composition of the underground hot water is not found suitable for application other than for open systems (sports, recreation, spa systems, etc.).

Land restoration challenges

Open cast mines in Kolubara coal basin are in intensive exploitation for over a half of century and as a consequence the original landscape has been largely modified and degraded as well. This modification of morphological characteristics in terms of modifications of terrain results in creation of large-scale depressions and formation of outside overburden dumps, causing changes and deterioration of the morphological and aesthetic characteristics of the landscape. Considering that the character and scope of mining works are such that the previous morphological appearance of the degraded areas cannot be completely restored, the exploitation process including overburden removal and disposal activities and land reclamation left the existing environment change in terms of functionality and aesthetics. In fact, the disposal of overburden was performed non-selectively and the surface has not been preserved for further use. This may later cause a number of complex problems in making the overburden suitable for herbal production, and in bringing the land back to its previous status. Besides, the result of open-cast coal mining creates disturbance of geological layers which means that a completely new, anthropogenic land, i.e. substratum, is created, without any resemblance to the original land.

Bearing in mind its obligation to provide sustainable development of the region influenced by activities related to coal generation and processing, both during coal production and after the mine’s closure, the operator already organized various activities during the past decade in order to mitigate harmful consequences of mining works to human health and environment. These activities included organization of certain green surfaces as a part of area protection business policy, as well as different measures for protection of the ground and surface waters and preserve the quality of soil in the vicinity of mines.

Development and introduction of new technologies for selective excavation of the layers covering the coal layer (use of the material of the layers covering the coal layer and the layers beneath the coal layer as non-metallic mineral resources) is in line with land remediation process requirements. Such technologies are increasingly used for reclamation of degraded land (phytoremediation). This makes it challenging for this reason, some investigations have already been carried out on degraded land within Kolubara coal basin mines, to define types of plants that can be grown on contaminated soil, together with necessary agro-technical measures that have to be applied.

Post-mining challenges and opportunities

There is a large number of post-mining challenges and opportunities that would be on the disposal in the Kolubara target region. Traditionally highly qualified and experienced workers are one of the major driving forces that could guarantee another future for the region, irrespective of the kind of technological development that would be directed by the post-mining strategy of the Republic of Serbia. Strong attitude towards social progress and collective consciousness of the local population would help the region to overcome inevitable transitional stresses of all kinds, including transition to new business environment.

Post-mining will leave the landscape considerably altered so that a return to the original status of field activities (agriculture, forestry, etc.) could hardly be achieved. Instead, along with the previously mentioned restoration process, new kinds of land use could appear (e.g. creation of artificial lakes for public recreation, or facilities for tourism). Of course, priority may be given to the new energy sources and make use of the existing energy network infrastructure that was developed for coal fired plants.

9.4 Technical energy transition concept

Smart specialization strategy

The Republic of Serbia has joined the EU Platform of the regions and countries that have entered into development of the Smart Specialization Strategy. By targeting resources in areas that have the most competitive and innovative potential, the Smart Specialization Strategy of the Republic of Serbia (4S) for the period 2020-2027 helps its domestic economy to more effectively utilize its potential and better position itself in global markets. Developing innovation in identified priority areas (4S) creates the preconditions for sustainable development in different areas. Many among these areas are found in the Kolubara target region and present excellent opportunities for regional development in the post-mining period. To support such a development, continued energy production and supply is considered to be crucial, which is presently based on the indigenous coal resources.

The Kolubara target region spreads over Belgrade ([RS11]) and Sumadija and Western Serbia ([RS21]) statistical regions of Serbia. In the [RS11] region a strong development potential is identified in the areas of information and communication technology (ICT), scientific research and innovation (R&I), education, as well as in some areas of the manufacturing industry. The [RS21] region is characterized by agriculture (including food production), the automotive industry, a strong science base in the fields of mechanical engineering and pharmacy, as well as the production of general-purpose machinery. Based on the EC methodology for developing national smart specialization strategy and the entrepreneurial discovery process (EDP), the Smart Specialization Strategy of the Republic of Serbia identifies national priority areas for Serbia, for which a strong development potential is available in the Kolubara target region. These priority areas include Key development technologies, Food for the future, ICT, Machines and manufacturing processes of the future (manufacture of machinery and electronic devices), The creative industries, as well as Environmental protection and Energy efficiency.

Climate change mitigation policy

The energy transition in Serbia is due to be in line with the country's obligations regarding climate change mitigation policy, defined according to the Paris Agreement and the UN Framework Convention on Climate Change (UNFCCC). Serbia is also signatory country to the Kyoto Protocol as a Non-Annex I Party of the UNFCCC. In this respect, Serbia is actively contributing to the global efforts to prevent climate change beyond repair, based on the principle of common but differentiated responsibilities.

The Serbian National Determined Contribution (NDC) to the climate change mitigation submitted to the UN provides reduction in emissions of greenhouse gases (GHGs) by 9.8% until 2030 relative to the 1990 emissions. However, it seems not sufficient, and new target is expected to be defined for Serbia in line with the EU energy and climate policy under the framework of the Energy Community (EnC) Treaty of the South-east Eropean countries with the EU.

Recently presented draft of the Low Carbon Development Strategy of Serbia financed by the EU defines several scenarios to achieve carbon-neutral economy and society, through the proposed Action Plan. Strategy proposes gradual replacement of coal in energy generation by natural gas and renewable energy sources. The expected adoption and implementation of the Low carbon srtategy could strongly hit the energy sector and the future use of coal in Serbia, that would strongly affect the Kolubara target region in many aspects.

Renewable energy sources

Under the present Action plan to increase the share of renewable energy sources (RES) in gross final energy consumption, Serbia was expected to reach 27% target in 2020, but it fails to do so, although subsidies are provided by law. New target to increase its use of RES in electricity production by 2030 in Serbia is yet to be set. Some estimates of the expected new target for Serbia under the Energy Community (EnC) Treaty translates to at least 5,037 MW generation capacity on RES, of which 3,409 MW on hydro, 869 MW on solar photovoltaic, 723 MW on wind and at least 36 MW on biomass. A considerable portion of these new capacities, particularly those based on biomass and solar potentials, may be constructed within the Kolubara target region.

Taking into account difficulties to reach 2020 RES target for Serbia, the above-mentioned capacities might be subject to change downwards. Once the new RES target for Serbia by the EnC is set, National Energy and Climate Action plan for the period 2021-2030 would potentially adjust the capacities in order to correspond to agreed RES share in 2030. In order to promote the implementation of this measure, it is necessary to remove administrative barriers, increase permitting capacities at the level of relevant authorities (local and governmental level) and provide long-term investment environment to achieve needed increase of RES capacity.

Energy efficiency

Serbia is known as the country struggling to improve its low energy efficiency both in generation and consumption. To promote the use of efficient cogeneration of heat and electricity (CHP), subsidies are provided in the form of feed-in tariffs for gas or biomass fired heating systems. A large share of single-family houses in the target region predominantly uses old inefficient boilers on coal and wood biomass. To support substitution of old inefficient solid fuel boilers, subsidies should be provided to households for the purchase of new wood fired boilers which meet Eco-design standards or, alternatively, heat pumps. Connection to the existing local district heating systems should also be supported, especially in agglomerations with recorded exceedance of particulate emissions.

Another important measure to increase penetration of RES for heating in buildings is the definition of minimum requirements for use of RES in new and renovated buildings, which should be included in the legislation on energy efficiency in buildings. Improving energy efficiency and use of RES in the tertiary sector is desirable. This equally targets governmental, services and commercial buildings. A particular objective is to reduce consumption of electricity for space heating. As the higher energy efficiency means lower emissions, replacing coal with lower emitting fuels for heating purposes is desirable.

Transitional challenges

Energy transition towards the non-carbon energy technologies is not an easy endeavor for Serbia due to the fact that its major primary energy source is the indigenous coal-lignite, which is used to generate three quarters of the country’s electricity. With an aim to ensure security of energy supply, especially of electricity and heat, the transition away from coal will mean closure of the coal fired thermal power plants before the expiration of their (and of coal mines) lifetime. For an expected country’s economic growth and continuous raise of power demand, adequate measures and activities should be undertaken to ensure that a substitute with the low-carbon generation could be realized in the meantime.

According to the current Energy development strategy of the Republic of Serbia by 2025 with *a projection to 2030*, coal extraction from Kolubara coal mines would remain and increase towards the end of this decade when a new coal fired power plant (Kolubara B), currently under detailed consideration, could be on the grid. With that plant built at a mine-mouth site and the existing fleet of 8 units with extended operational life span, coal from Kolubara mines would probably last up to 2050. With the proposed Low carbon strategy in force, a considerable amount of coal would remain underground.

A concept of the energy transition

While the Energy development strategy of the Republic of Serbia is for a very short period (only 5 – 10 years), and the draft of the Low Carbon Development Strategy is for the period of 30 years, these two strategies do not match in time, nor their strategic projections pair. Therefore, in order to define technical transitional concept, both strategies must be respected. In addition, the positions of various stakeholders must equally be taken into account. The stakeholders have been consulted on different occasions, and their positions carefully studied. It appears that their positions may roughly be grouped in two groups, one, larger, in favour of coal use in the target region by the end of the exploitation (about 2050) and/or by the end of the operational lifetime of the power generating equipment, and another supporting the EU climate policy calling for an urgent transition away from coal towards natural gas and renewables.

Replacement of coal fired power and heat generation capacities in the target region with ones fired by natural gas and/or using RES in a relatively short time (to reach net zero emissions by 2050) seems unrealistic for Serbia, bearing also in mind both availability of the alternative resources and low economic strenght, that would be endangered by the increase of import dependency. On the other side, the new power plant (Kolubara B) under consideration of construction in the target region would require longer time to pay off. The same applies to the investment in new environmental protection currently under construction, as well as in the conversion of the condensing to the cogeneration units at „Nikola Tesla“ A power plant and in the huge about 30 km long double pipeline to transport hot water to the districict heating system in the city of Belgrade.

The Kolubara target region has strong and well developed energy networks, the largest in Serbia. Also, two well developed infrastructures at sites of "Nikola Tesla" A and B thermal power plants are of value for possible later construction of other than coal fired generating capacities, particularly so as the once-through cooling capabilities are ensured. This makes it valuable potential site(s) for eventual latter construction of nuclear power plant(s) to ensure base-load power supply to the national power system. In case of utility scale gas fired power generation using combined (gas and steam) cycle, adequate capacities for heat consumption are limited to a small number of cases, ones where the district heating systems may be found to exist.

With all above taken into consideration, the inevitable transitional process would result in a **significant shift** of the current Energy development strategy of Serbia towards the Low-carbon development strategy. This would mean a shift towards climate adaptable economy in the Kolubara target region. However, **required dynamics of the transition could hardly be achieved**. Rather a slower, stepwise energy transition towards an efficient carbon-free energy sector should be provided in Kolubara target region. According to the current position of the stakeholders in the region, this may be the **only way to meet the required goal**, while maintaining the security of energy supply and social welfare.

9.5 References

JAKOVLJEVIĆ, M., ET AL.: BIOMASS PRODUCTION AS RENEWABLE ENERGY RESOURCE AT RECLAIMED SERBIAN LIGNITE OPEN-CAST MINES, THERMAL SCIENCE, VOL. 19, NO. 3, PP. 823-835

KALABIĆ, D., DRAŽIĆ G., DRAŽIĆ N., IKANOVIĆ J., (2019): PRODUCTION OF AGRI-ENERGY CROP MISCANTHUS GIGANTHEUS ON LAND DEGRADED BY POWER INDUSTRY: SWOT ANALYSIS, POL. J. ENVIRON. STUD. VOL. 28, NO. 5, 3243-3251

RISTOVIĆ I., STOJAKOVIĆ M., VULIĆ M., (2010): RECULTIVATION AND SUSTAINABLE DEVELOPMENT OF COAL MINING IN KOLUBARA BASIN, THERMAL SCIENCE 2010. VOL. 3, NO. 14, P. 759–772.

Statistical Office of the Republic of Serbia, Belgrade, (2013): Dwellings by the Type of Energy Raw Material Used for Heating (Data by municipalities/cities)

Institute of Architecture and Urban & Spatial Planning of Serbia, (2017): Kolubara Coal Basin Spatial Plan

https://www.paragraf.rs/propisi_download/uredba-o-utvrdjivanju-programa-ostvarivanja-strategije-razvoja-energetike-republike-srbije-do-2025-godine-sa-projekcijama-do-2030-godine-za-period-od-2017-do-2023-godine.pdf

Institut Kirilo Savic, a.d. Beograd, (2012): Soil Pollutant Inventory in Kolubara Coal Basin, Phase I, Volume 2, Book 1: Open Pit Mines

National Emissions Reduction Plan for Pollutants from Large Furnances, Official Gazette no. 10 of 6 February, 2020.

http://www.eps.rs/En/news/Pages/conference-investments-serbia.aspx

www.mre.gov.rs/doc/medjunarodna-saradnja/Single Project Pipeline in Energy Sector.pdf

Smart Specialization Strategy of the Republic of Serbia (4S) for the period 2020-2027, Official Gazette no. 13 of 18 February, 2020

GFA Consulting Group led consortium, (2019): Low Carbon Development Strategy with Action Plan – Draft, Project Identification No. EuropeAid/1365966/DH/SER/RS

Report on Emissions to Air from Steam Boiler Plants within Kolubara Basin Open Pit Mines, Laboratory for Environmental Protection and Protection on Work, Belgrade, 2011.

Annual Technical Report, Electric Power Utility of Serbia, 2006

Annual Technical Report, Electric Power Utility of Serbia / Thermal Power Plants Branch, 2016

Technical documentation for reconstruction and repowering of TPP Nikola Tesla A and TPP Nikola Tesla B Units', prepared in period 2006-2017, Energoprojekt Entel, Belgrade

Households Heating Costs in Serbia in 2016/2017, Energy Agency of the Republic of Serbia, 2017

10 Ukraine, Donetsk region

Donetsk region is located in the south-eastern part of Ukraine. In the east, its borders partially coincide with the state borders of Ukraine. In the south the region has access to the Azov Sea. The length of the area from north to south – 240 km, from west to east - 170 km. Area – 26.5 thousand square km, or 4.4% of the country.

According to the administrative-territorial organization in Donetsk region, there are 52 cities, of which 28 are of regional significance, 24 towns of regional level, 21 urban areas, 18 districts, 131 urban-type settlements, 253 rural councils and 1118 rural settlements. The largest cities are the regional centre - Donetsk (with a population of 927.9 thousand people), Mariupol, Makiivka, Horlivka, Kramatorsk.

Due to the current hostilities in this area, the State controls only half of the area. Donetsk region is part of the Donbas coal basin. After Ukraine gained independence in 1991, coal production in the Donetsk region was about 40-50 million tons per year.

After 2014, due to warfare in the East of Ukraine, the situation with mining in the regional context has changed dramatically. Thus, in 2015, the mines of the Donetsk region provided extraction of 14.4 million tons of coal (-44.9% relative to 2014). Indicators of 2016: Donetsk region mines extracted 15.6 million tons of coal. Coal mining in the Donetsk region located on the territory controlled by the Ukrainian authorities in 2017 amounted to 11.4 million tons, and in 2018 - 11.1 million tons. At the same time, in 2018 the volume of coking coal production amounted to 5.6 million tons, which is 10.8% less than in 2017; 5.5 million tons of power coals were extracted, which is 21.1% more than in 2017.

10.1 Current energy generation technologies using coal

10.1.1 Coal driven power plants, CHP plants

One of the main consumers of coal in Ukraine are the large electricity producers – coal thermal power plants (TPP) and heat and power plants (CHP). The total number of coal-fired TPPs is 14, and large coal-fired CHPs – 8. Of these, 6 TPPs are located in the Donetsk region (Kurakhivska – installed electric capacity of 1,470 MW, Slovianska – 880 MW, Vuhlehirska – 1,200 MW, Starobeshivska – 2,010 MW, Zuivska – 1,200 MW and Myronivska – 115 MW) and 1 CHP (Kramatorska). Starobeshivska and Zuivska TPPs are now located occupied non-controlled territory.

Myronivska TPP. The main equipment of Myronivska TPP includes a turbine unit KT-115-8.8 with an electric capacity of 115 MW for a nominal steam consumption of 446 t/h, as well as boilers with a nominal steam capacity of 230 t/h. - TP-230-3 (design fuel – bituminous coal) and two Ep-230-10-510 (design fuel - anthracite). With the cessation of supplies of anthracite, the only gas-fired boiler taking into account the selection of heat for heating the village of Myronivske is not able to provide even 50% of the turbine load. In addition, the operation of the power plant during the heating season on one boiler is associated with a high risk of complete shutdown of the TPP in case of an emergency situation on the boiler.

Slovianska TPP. Installed capacity - 800 MW. Project fuel: anthracite with a calorific value of 5,600 kcal/kg. Slovianska TPP is located in the northern part of the Donbas power system. The thermal capacity of the power plant is 1121.1 GJ/h. Both stages of the TPP were designed to operate on anthracite coal and the possibility of using seasonal surpluses of natural gas.

In the 1980s, the 800 MW unit was converted to co-firing of coal and fuel oil. At this time, after re-marking, the capacity of the units was 2x80 MW, 1x720.

Vuhlehirska TPP. Installed Capacity is 3,600 MW. Number of power units is 7.

Design Fuel: Power units 300 MW - bituminous coals with heat combustion 5,000 kcal/kg; Power units 800 MW - gas.

The power plant was built in two stages: the first stage with a capacity of 1,200 MW consists of four power units of 300 MW each with single-case pulverized-coal boilers with steam capacity of 950 t/h and turbines with a capacity of 300 MW each; As part of the second stage with a capacity of 2,400 MW, there are three 800 MW power units with single-case gas-oil boilers with steam capacity of 2,650 t/year and turbine units with a capacity of 800 MW. Each turbine unit has a heating installation with a capacity of 15 Gcal/h. The units are designed to provide thermal energy to the satellite city of Svitlodarsk and the industrial site.

Now 800 MW power units are in a state of long-term reserve with conservation elements due to a shortage of gas-oil fuel.

The managers and specialists of TPPs have formed a technical program that provides for the technical re-equipment and rehabilitation of existing equipment. The ultimate goal of the program is to increase the efficiency of power units by 4-5%, reduce atmospheric emissions and extend the life of equipment by 15-20 years.

Kurakhivska TPP is a thermal power plant located in the city of Kurakhovo, in the Maryinsky district, Donetsk region of Ukraine. Electric power is 1,527 MW. Most languid - Gas, peat, coal.

On July 6, 1941, the first stage of the state district power station was put into operation. In 1969-1975, the power plant was reconstructed - one power unit with a capacity of 200 MW and six power units of 210 MW each were installed. After the last turbine No. 7 was commissioned in 1975, the capacity of the state district power station increased to 1,460 MW

The modernization increased the capacity of power units from 210 to 225 MW (222 MW for power unit No. 5, 220 MW for power unit No. 8), expanded the range of maneuverability from 80 to 120 MW, increased the efficiency of power units by 12%, and significantly improved environmental performance.

Kramatorska CHP is located in the city of Kramatorsk, Donetsk region.

The company was originally founded as a thermal power plant of the Novokramatorsk Machine-Building Plant in 1937. In 2006, OJSC Kramatorskteploenergo was established on the basis of the CHP, the founders of which are the Kramatorsk City Council and the American company ContourGlobal. In March 2018, E.CONNECT Group finalized the acquisition of a 60% stake in Kramatorskteploenergo LLC (Kramatorsk, Ukraine), which was previously owned by the international energy holding ContourGlobal.

In the current state, the actual installed electric capacity of CHP is 120 MW with the following composition of the main equipment:

- steam boiler type TP-170-110 (1955) - in the cold reserve;
- four boilers of the BKZ-160 type. (1972-1977) - in operation;
- two turbines PT-60-90 / 13 / 1,2 LMZ with a nominal capacity of 60 MW, with adjustable production and district heating selections of steam - in operation.

10.1.2 Use of coal for small applications

Energy coal of the Donetsk region is mainly used at thermal power plants and combined heat and power plants to generate heat and electricity by powerful boilers with a steam capacity of 500 to 2,550 tons per hour. Much less coal is used at district CHPs in medium-capacity boilers with a steam capacity of 200 to 420 tons per hour. The share of coal used in low-power boilers and household furnaces is very small.

Low-power boilers that burn coal are represented by: BKZ-75-39 FB single-drum, with natural circulation, with pulverized coal combustion, steam capacity is 90 tons per hour in the amount of 3 pcs., PK-19-2 vertical water-pipe, single-drum boiler unit, with natural circulation, steam capacity is 110 tons per hour in the amount of 4 pieces, NZL-80-34M with steam productivity of 80 tons per hour in the amount of 2 pieces, and TP-120 with a steam capacity of 120 tons per hour is only one piece. In the Donetsk region, these boilers are installed in district CHPs and most of them now operate in hot water mode. CHP boilers that were designed for coal combustion (for example, NIISTU boilers with a capacity of 0.3-0.6 Gcal per hour) were converted to natural gas combustion for environmental reasons.

The most of boilers installed at the Ukrainian CHPs have used for 40-60 years and do not meet the current requirements for emissions of harmful substances into the atmosphere, primarily nitrogen oxides, sulfur oxides, and particulate matter. Emissions of harmful substances from boilers during coal combustion, O_2=6%, dry gases: solid particles – 1,500 to 4,000 mg per m^3, SO_x – 800 to 9,000 mg per m^3 and NO_x – 500 to 1,600 mg per m^3.

In the Donetsk region coal is used to heat rooms or households. Non-modern stoves sometimes are used in old houses to heat living spaces. For the most part, modern coal-fired boilers with a capacity of 10 to 100 kW and a cost of 1,000 to 3,000 euros are used to heat residential and industrial premises. The cost of coal in the Donetsk basin for household consumers varies depending on market situations. As of the end of 2019, it was 140 euros per ton.

10.2 Current status of other energy generation technologies

The economy of Donetsk region is mainly based on the use of non-renewable energy sources. Thus, the energy system of the region is characterized by a low share of alternative and renewable energy sources in total electricity supply and its gradual reduction (in 2013 - 0.09%, in 2015 - 0.86%, in 2018 - 0.08%). In general, during 2015-2018, the volume of electricity production from renewable energy sources decreased by 175.7 million kWh, or almost 16 times. The decrease in the production of electricity from alternative energy sources is due to the ATO / JFO in the Donetsk region.

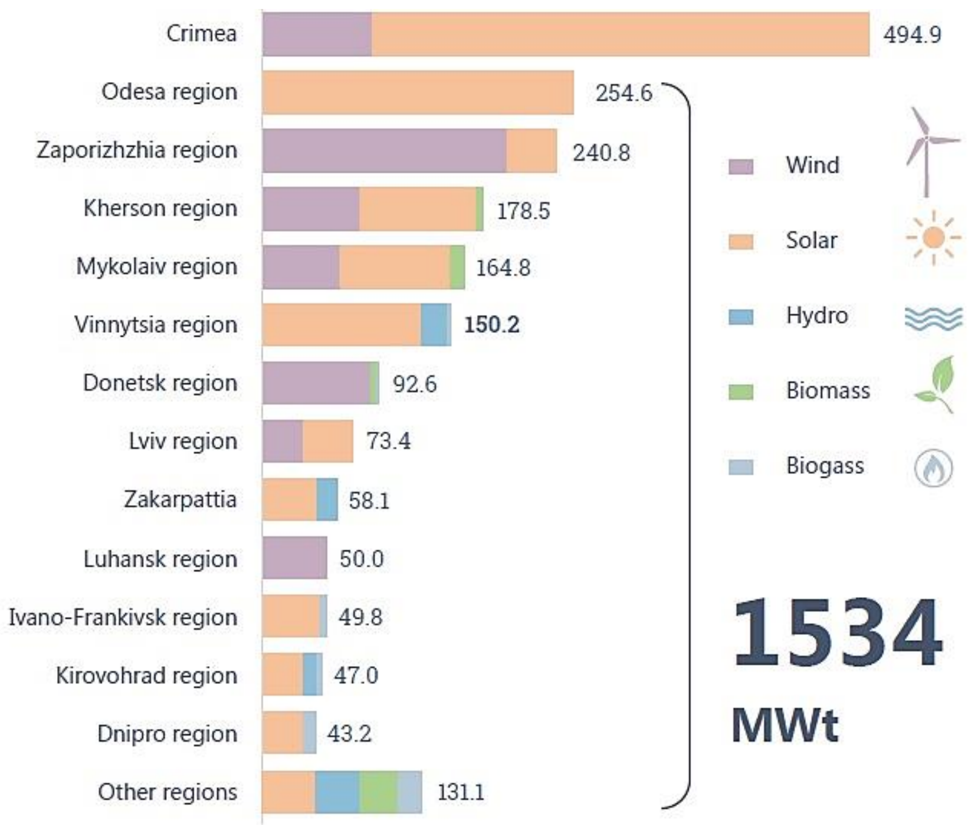


Figure 26: RES production by regions as of the first quarter of 2018; source: Renewable energy sector: Unlocking sustainable energy potential, National Investment Council of Ukraine, 2018

In cities, districts, united territorial communities of the region, alternative energy is used for outdoor lighting, heat supply and hot water supply. Every year the number of such projects increases. Thus, from 2013 to 2018, the installed capacity of alternative energy facilities increased by 18.2 MW (or 19.9%).

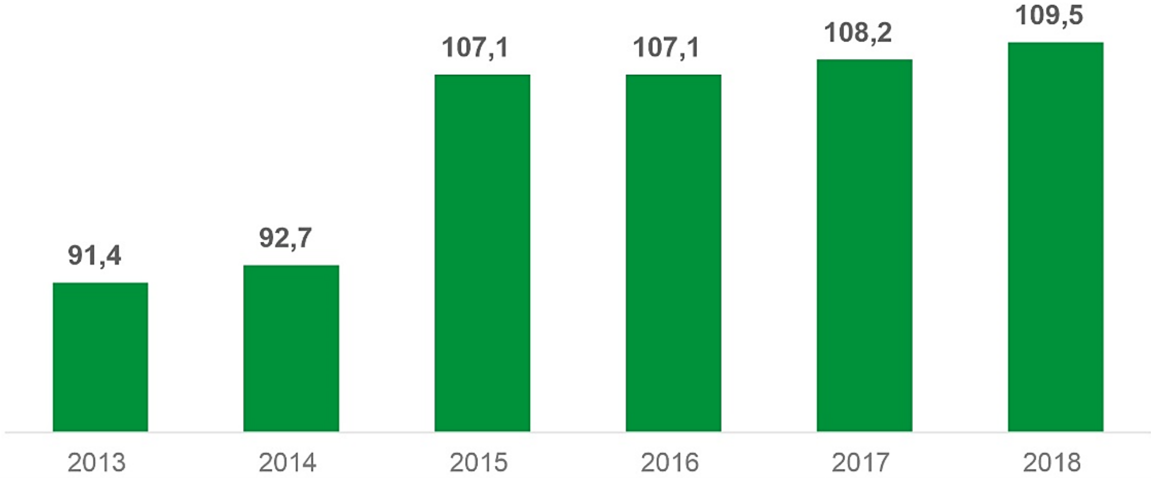


Figure 27: Dynamics of installed capacity of alternative energy facilities in Donetsk region; source: data of the department of development of basic industries of the regional state administration

10.2.1 Solar energy in the Donetsk Region

Photovoltaic energy projects have been actively implemented in Ukraine since 2010. The reform of the Energy Market in Ukraine has enabled household consumers to install in their private households generating electrical installations designed to produce electricity from solar radiation and / or wind energy, with a capacity of up to 30 kW. The generated electricity is used by the household consumer for their own needs and its "balance" is sold to the universal service provider at a "green" tariff.

As of April 2019, there are about 70 such household consumers in the Donetsk region, and their number is constantly increasing. The volume of electricity sold at the "green" tariff is (depending on the season) about 100-200 thousand kWh, which is 0.1-0.2% of electricity consumption in the Donetsk region.

Currently, the construction of a solar power plant in Bakhmut with a capacity of 13 MW (LLC "Energo Industry"), the implementation of which is planned for 2019-2020.

10.2.2 Wind power in the Donetsk Region

Donetsk region has significant prospects for the development of wind energy due to the development of wind potential of steppe areas. As of April 2019, a modern wind power plant was being built between Slovyansk and Kramatorsk in the village of Yasnohirka. This project is being implemented by AtomWindKramatorsk in one of the most investment-attractive industries. The supplier of equipment for the wind power plant is Furlander Windtechnology LLC, located in Kramatorsk, a leading Ukrainian manufacturer of multi-megawatt-class wind power plants in the post-Soviet space. The project envisages the construction of 14 wind power plants with a total capacity of 66 MW.

10.2.3 Biogas power in the Donetsk Region

On the territory of the region there is a biogas plant owned by PJSC "Ecoprod". It was developed by the German engineering firm Carbo Cycle Ingenieurbüro, has an electrical capacity of 1,500 kW and 1,200 kW of thermal power. Ekoprod Biogas Plant produces 5,992,900 cubic meters of environmentally friendly biogas per year. And the production of liquid biofertilizers from waste is 45,350 tons per year.

10.2.4 Electricity in the Donetsk Region

The economy of Donetsk region is characterized by significant energy intensity. In 2018, the region took second place in terms of heat consumption (9.7% of total consumption in Ukraine) and third place - in terms of electricity use (9.3%). At the same time, the energy system of the region is able not only to meet the needs of domestic and industrial consumers in full, but also to transfer surplus electricity to the integrated energy system. Thus, during 2016-2018, the actual volume of electricity consumption averaged 85% of the volume produced by generating enterprises located in the territory controlled by the Ukrainian authorities. At the same time, this trend was due to a significant decrease in electricity consumption and a gradual increase in its production.

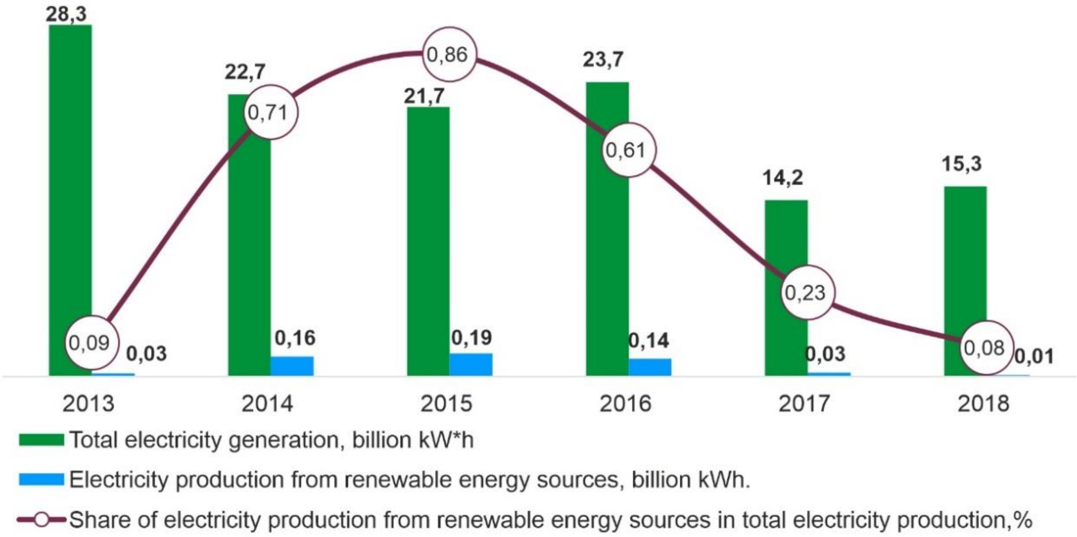


Figure 28: Dynamics of electricity production from renewable energy sources in Donetsk region; source: data of the State Statistics Service of Ukraine, the Department of Development of Basic Industries of the Regional State Administration

Compared to other European countries, Ukraine has the lowest cost of electricity for household consumers, which is 4.4 eurocents / kWh.

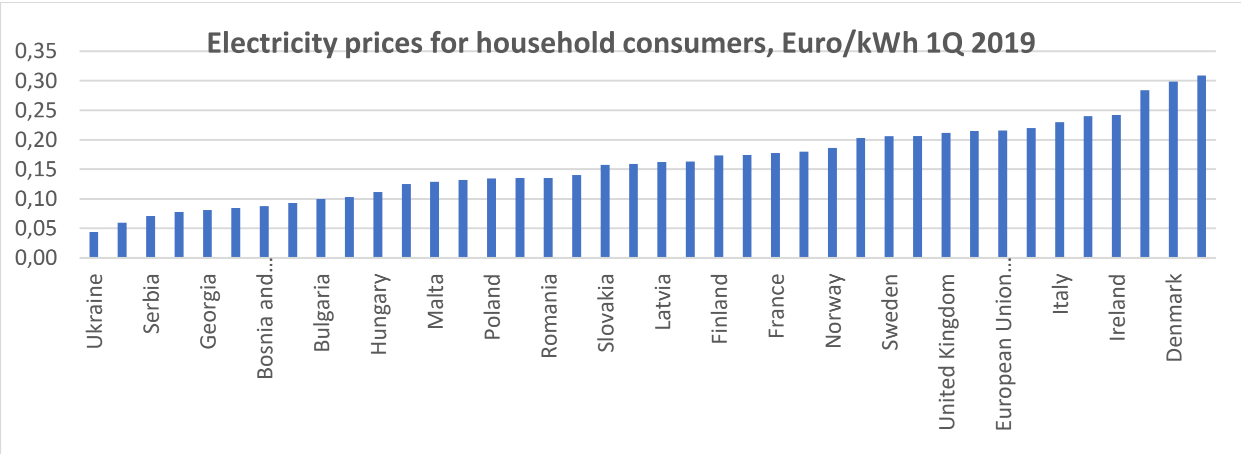


Figure 29: Electricity prices for household consumers in Europe; source: data of the State Statistics Service of Ukraine, the Department of Development of Basic Industries of the Regional State Administration

10.2.5 Biomass for heating in the Donetsk Region

The use of biomass for home heating is only beginning in the Donetsk region. The number of households that have installed biomass boilers is not significant yet.

At the end of 2012 in Sloviansk Local education Department and LLC "Promshlennoe Oborudovanie" established boilers on biofuel in two schools of the city.

Thanks to the support of the United Nations Development Programme in Ukraine within the framework of the project "Development and commercialization of of bioenergy technologies in the municipal sector in Ukraine", implemented with the support of the Global Environment Fund, in 2017 the installation of new boilers working on agricultural biomass, at the objects of social infrastructure in the village of Cherkasy of Slavic district of Donetsk region has started.

10.3 Technological challenges and opportunities

In general, the potential of Donetsk region allows efficient use of renewable energy sources. Thus, according to experts, the technically achievable potential of the region is 25.4 billion kWh. for a year. The largest share in its structure belongs to environmental energy (42.4%), biomass (32.9%) and geothermal energy (10.3%).

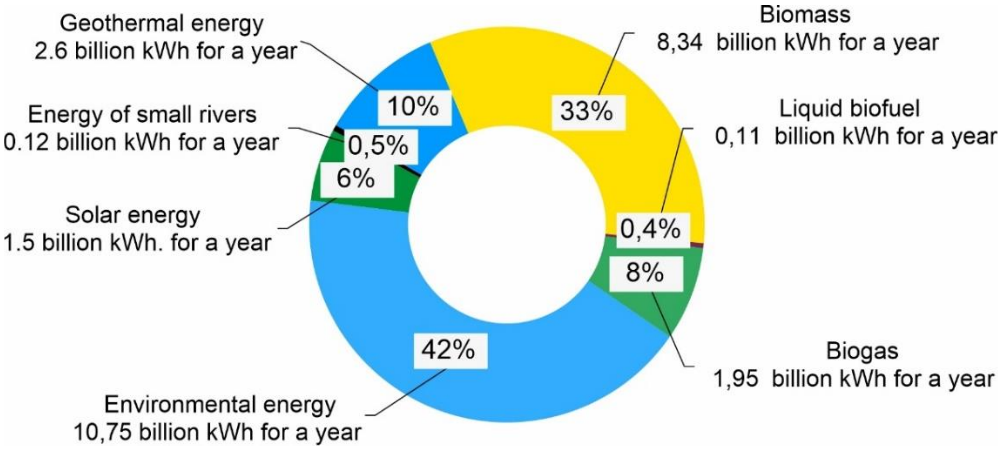


Figure 30: The structure of technically achievable energy potential of Donetsk region in terms of alternative energy sources; source: data from the project "Improving energy efficiency and incentives use of renewable energy in agri-food and other small and medium enterprises of Ukraine", performed by the UN Agency for Industrial Development with the support of the Global Environment Facility

In particular, solar energy in the Donetsk region has not yet gained widespread economic use, but there are prerequisites for this. The natural and climatic conditions of the region make it possible to use solar energy quite efficiently. The level of solar insolation in the Donetsk region is 1,250 kWh/m^2 per year or more than 2,000 hours of sunshine per year and in recent years this level is increasing. It is able to save up to 6 million tons of conventional fuel per year, the potential for its development is provided by its own scientific and industrial bases, design bureaus that design solar collectors, the availability of the necessary metal products and more.

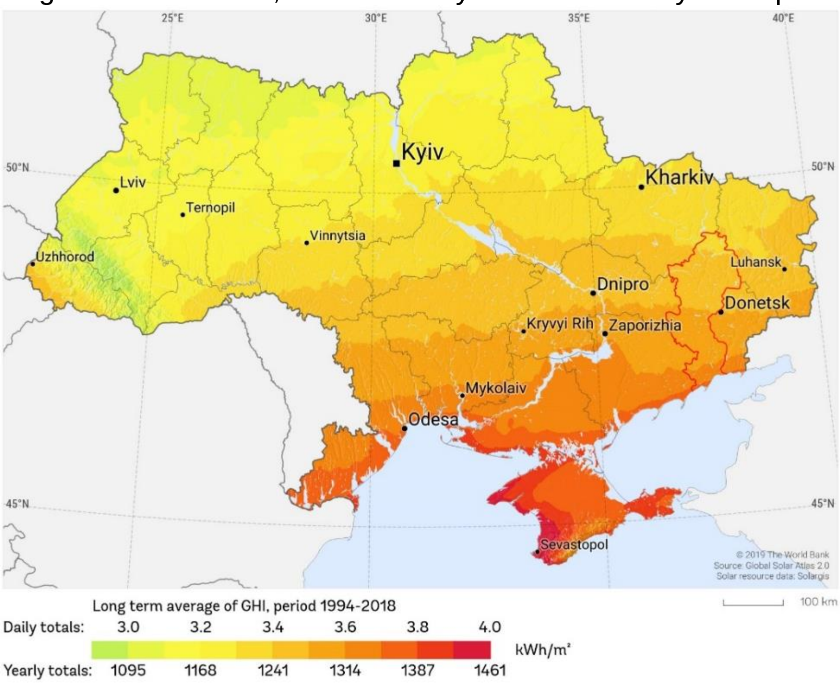


Figure 31: Solar energy potential of Ukraine and Donetsk region in particular; source: https://solargis.com/maps-and-gis-data/download/ukraine

Geological and physical conditions in the Donetsk region are quite favorable for the development of renewable energy. The relief of the region is mostly flat (up to 200 m high), the region is located within the Donetsk ridge. A characteristic feature of the relief of the region is the presence of forms of anthropogenic origin, in particular, heaps. This creates additional opportunities for the placement of solar collectors and wind turbines on the heaps, which at the same time creates additional opportunities for their reclamation. Man-made landscapes in the Donetsk region cover an area of over 11,000 hectares or 0.42% of the region's territory, taking into account the occupied territories. Thus, the environmental factor is one of the most important for the region, because the current environmental situation in Donetsk region can be defined as a crisis, due to the high man-made load on the region's environment.

Thus, Donetsk region has a powerful energy complex that is able to meet the needs of domestic and industrial consumers in full. At the same time, the region is characterized by a significant energy intensity of the economy, which is based on the use of traditional, non-renewable energy sources.

Geological and physical conditions in the Donetsk region are quite favourable for the development of renewable energy

10.4 Technical energy transition concept

Energy strategy of Ukraine till 2035 is aimed at innovative development of the energy sector and construction of a new generation, investment in new generation capacity to replace decommissioning one. The choice of the type of generation will depend on the forecast price situation for fuel and the intensity of development of each type of generation, which will increase the level of competition between them, from the introduction of smart technologies to equalize consumption peaks.

In the field of energy efficiency and environmental protection, it is envisaged to achieve the targets for reducing SO_2, NO_x and dust emissions in accordance with the National Plan for Reducing Emissions from Large Combustion Plants and introducing a greenhouse gas emission quotas trading system in Ukraine.

Measures to close / conserve unprofitable state-owned mines are scheduled to be completed by 2025. A social and environmental mitigation plan will be adopted for each site. This work should take into account (involving large-scale international assistance) the world's best practice in social mitigation, which includes severance pay, advice to redundant staff, professional training and retraining.

A set of measures to mitigate the social consequences of the restructuring of the coal industry will be implemented in close connection with the programs of social reconstruction of the regions of mine closure / conservation, which should also be prepared and implemented with large-scale international assistance. Such programs in accordance with European best practices include the organization of public works on infrastructure reconstruction, job creation, advisory and financial support for business initiatives, the creation of business incubators, the introduction of temporary special economic regimes in mine closure areas.

In 2015, according to the State Statistics Service of Ukraine, the structure of primary energy was characterized by a high share of natural gas 28.9%, the share of nuclear energy was 25.5%, coal - 30.4%, crude oil and petroleum products - 11.6%, biomass (biomass, fuel and waste) - 2.3%, HPP - 0.5%, thermal energy (thermal energy of the environment and waste resources of man-made origin) - 0.5% and Wind power plants and Solar Plants together - 0.1. The total share of all RES was only 4%.

It is envisaged to constantly expand the use of all types of renewable energy, which will become one of the tools to ensure the energy security of the state. In the short and medium term (until 2025), the share of renewable energy in Ukraine is projected to increase to 12% of primary energy and at least 25% - by 2035 (including all hydropower and thermal energy). At the same time, the share of energy produced from coal is planned to be reduced to 12% by 2035.

In Donetsk region development strategy is planned to ensure the transformation of the coal industry and to increase the efficiency of management of traditional energy resources, including through:

- promoting the restructuring of human capital involved in the coal industry;
- introduction of energy management system;
- introduction of modern systems for monitoring and control of energy consumption;
- popularization of energy saving technologies among the population;
- introduction of energy saving measures in all spheres of the economy, in particular, on objects of communal property and housing stock;
- stimulating the reduction of consumption of natural gas, heat and electricity (in particular, through the introduction and improvement of accounting and control system over energy costs), etc.
- The development of alternative energy should be implemented by:
- popularization of ideas of "green" and circular economy;
- development of non-traditional and alternative energy sources (solar, wind, etc.);
- creation of a register of lands suitable for placement of alternative energy facilities by its types;
- support for the use of alternative energy in the region, including utilities and budget institutions (schools, kindergartens, etc.);
- attraction and support of investment projects in the field of alternative energy, including the creation of a regional bank of investment projects, etc.

As a result, it is planned to increase the supply of electricity produced from alternative and renewable energy sources from 0.08% in 2018 to 1.54% in 2023 and to 3.00% in 2027.

The development of alternative energy should be implemented by popularization of ideas of "green" and circular economy

10.5 References

RENEWABLE ENERGY SECTOR: UNLOCKING SUSTAINABLE ENERGY POTENTIAL, NATIONAL INVESTMENT COUNCIL OF UKRAINE (2018)

IMPROVING ENERGY EFFICIENCY AND INCENTIVES USE OF RENEWABLE ENERGY IN AGRI-FOOD AND OTHER SMALL AND MEDIUM ENTERPRISES OF UKRAINE (2014) HTTPS://WWW.UNIDO.ORG/SITES/DEFAULT/FILES/2015-01/UKR_GFUKR11A04-MTE_140704_0.PDF

DONETSK REGIONAL STATE ADMINISTRATION (2020) STRATEGY OF DONETSK REGION DEVELOPMENT FOR THE PERIOD UNTIL 2027. 319 P. HTTPS://DN.GOV.UA/UA/STRATEGIYA-ROZVITKU-DONECKOYI-OBLASTI-NA-PERIOD-DO-2027-ROKU/PROEKT

MINISTRY OF ENERGY AND COAL INDUSTRY OF UKRAINE (2017) ENERGY STRATEGY OF UKRAINE TILL 2035 (2017) HTTP://MPE.KMU.GOV.UA/MINUGOL/DOCCATALOG/DOCUMENT?ID=245239554

11 United Kingdom, Wales

Wales is one of four nations in the United Kingdom (UK) and comprises the NUTS2 territorial units West Wales & the Valleys (UKL1) and East Wales (UKL2). Under the UK's devolution settlement and the Wales Act 2017, the elected Welsh Assembly can make laws on matters that are not reserved to the UK Parliament. Energy policy, including electricity, oil and gas, coal, nuclear energy, heat and cooling, and energy conservation, is largely reserved to the UK Government, but the Welsh Government has powers in relation to certain specific policy dimensions related to energy policy and climate change. For example, the Wales Act 2017 (Section 67) inserted section 26A of the Coal Industry Act 1994, which states that any licence that authorises operations in relation to coal in Wales can only have effect with the approval of the Welsh Ministers.

In April 2019, the Welsh Minister for Environment, Energy and Rural Affairs declared a climate emergency for Wales, and in June 2019, the Minister set out Welsh Government's ambition to bring forward a target for Wales to achieve **net-zero emissions** by no later than 2050. This builds on the UK Committee on Climate Change report, which recommends a 95% reduction in Welsh 1990 emissions by 2050 (UKCCC 2019).

These measures follow on from previous ministerial announcements that set a **70% renewable electricity target** for Wales by 2030, a commitment which is recognised through the Welsh Planning Policy. The 20-year National Development Framework (2020-2040) will reflect the changes that will be required across Wales to mitigate climate change, with one of the national priorities being decarbonisation of its energy production. The decisions made in recent years, as well as the chosen trajectory of decarbonisation, have initiated a process of large-scale changes to energy generation technologies used.

These decarbonisation measures are summarised in the leading policy document *Prosperity for All: A Low Carbon Wales. Wales' commitment to tackling climate change* (Welsh Government 2019a). This commitment is based on the projected negative climate change effects for Wales , but also motivated by economic and equality-related reasons. It identifies pathways for each high-emission sector, including power generation, transport, industry and agriculture. The following two sections outline the current status of the different energy generation technologies in Wales, and Section 11.3 summarises the challenges and opportunities that are specific to the country. The future pathway for energy generation and its proposed methodology is further developed in Section 11.4.

It needs to be emphasised that Welsh planning permissions on **new coal mining sites are effectively halted**, on the grounds of the stricter and legally-binding climate change emissions reductions targets that came into force in the first half of 2019. The withdrawal of planning permissions, as described in the 2018 Planning Policy, applies to the extraction of all fossil fuels, including shale gas, coal bed methane and underground coal gasification (Welsh Government 2018). If the Welsh Coal Authority puts forward applications to open new mining sites, the Welsh Minister will seek public advice on possible acceptance, in the form of citizen consultation.[12] This is expected to happen in Spring 2020.

[12] https://www.bbc.com/news/uk-wales-politics-46447290.

11.1 Current energy generation technologies using coal

11.1.1 Coal driven power plants, CHP plants

December 2019 marked the end of Welsh coal driven power plants for commercial energy generation. Coal is still mined in Wales, but only one out of eight licensed coal extraction sites is in production, and the mine is close to exhaustion. The only remaining active underground mine is the Aberpergwm Mine near Glynneath, which is operated by Energybuild Ltd (see Knoche, Rademacher & Schlepphorst 2020; Section 4.9). The main remaining active surface mining sites are Celtic Energy's East Pit and Nant Helen, near Ystradgynlais. The mining licence of the latter site is set to expire after 2021.[13] The extraction volume was reported at c. 450,000 tonnes in 2019, but the coal was not used in power plants.[14] For these reasons, this section describes the features of the last-closed power station in general terms, the considerations that led to the plant's closure, as well as the trends that are witnessed in energy generation technologies in Wales.

The Aberthaw Power Station, located on the Welsh south coast near Cardiff, had a long-term output capacity of 1,560 MW. Its average efficiency was 36%, and it generated c. 350 direct jobs when it was in operation. At the time of closure, 180 jobs were lost in the direct operation of the plant. When Aberthaw opened in 1971, fossil fuel driven power plants (coal and oil) accounted for 88% of electricity supplied in the whole of the UK. Nowadays, coal-driven electricity production has been reduced to around 5% of total UK electricity (see Figure 32).

The Aberthaw Power station has been subject to various studies into its emission levels, and the findings of these studies were eventually used to rationalise its closing. A joint report by environmental organisations Greenpeace and Friends of the Earth (FoE Cymru 2016) calculated that:

- the annual societal cost of nitrogen dioxide pollution caused by the Aberthaw Power Station was £37.9 million in Wales alone. Furthermore, it cost 3,000 premature deaths within its 45 years of operation;
- the accumulated effects of SO2, NO2 and particulates led to an estimated £950 million of societal costs for the entire southern UK;
- various Welsh cities and towns measured a 24-hour maximum NO2-pollution of 10-55 µg/m3;
- Aberthaw breached the EU pollution threshold between 2008 and 2011, emitting up to double the maximum permitted amount of NO.15

In early 2016, RWE Group, the owner of the power plant, announced further investment in NO_x emission-saving improvements to all units, in order to comply with the IED regulations. From an economic point of view, the two main RWE businesses that operated the plant were not profitable in their latest years of operations. They made an aggregate loss of £154 mln in 2015: £99 mlm at Npower and £55 mln at RWE Generation.

To characterise decline of coal-driven electricity generation in the UK (incl. Wales), Figure 32 and Figure 33 show the share of coal in the total energy production. Figure 32 shows that the coal share has been steadily declining since the mid-90s, with a sharp drop after 2012. At the same time, **renewable energy sources and gas-powered turbines largely replaced coal**,

[13] https://www.bbc.com/news/uk-wales-politics-52992868.
[14] Wales' main coal consumption business is Tata Steel in Port Talbot; see TRACER Deliverable 3.1 (Section 11) and Deliverable 3.3 (Section 4.9) for further information.
[15] The Guardian, 21 September 2016: https://www.theguardian.com/environment/2016/sep/21/aberthaw-power-station-breached-emissions-limit-rules-eu-court.

whereas the total energy production levels slightly decreased since the late 2000s. The same picture is seen in Figure 34, although it provides more detail about the sharp reduction in latest years. As of 2019, the share of coal has dropped under 2% in the UK as a whole. Specifically to Wales, the share of coal in electricity generation has dropped from 9 TWh per year in 2006 (c. 28% of total consumption) to virtually none in 2019. Meanwhile, the overall electricity consumption slightly decreased (Welsh Government 2019b).

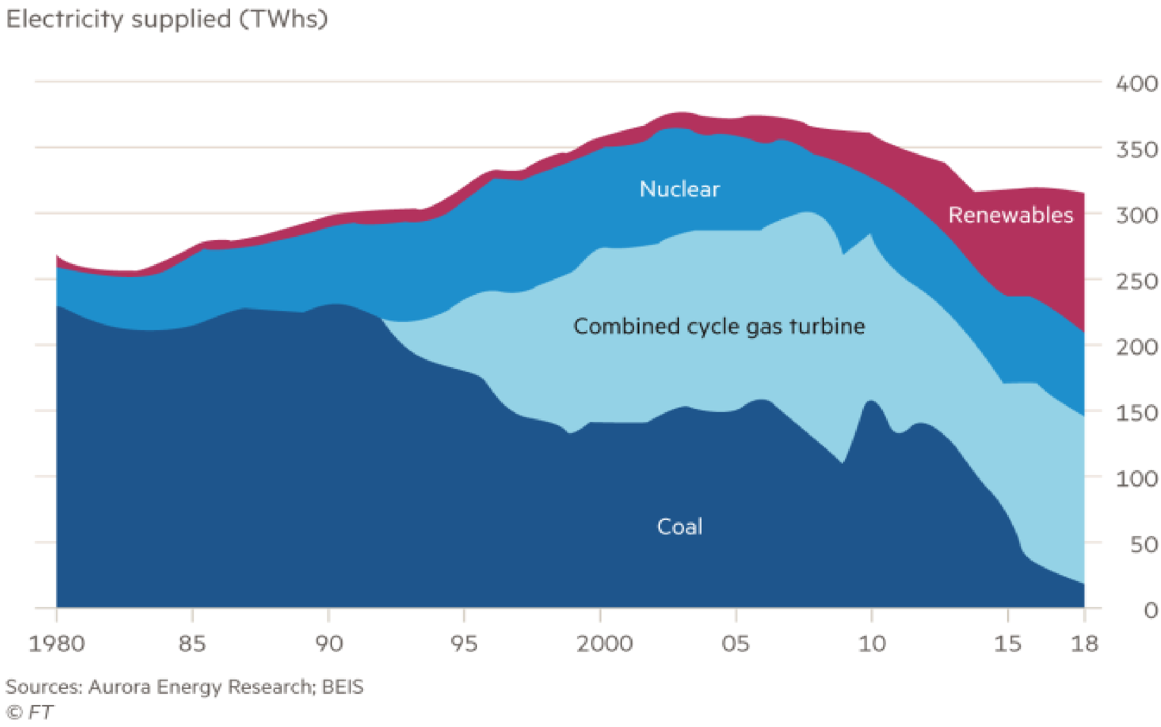


Figure 32: Share of coal in UK energy production (in TWh's supplied), 1980-2018, Source: https://www.ft.com/content/a05d1dd4-dddd-11e9-9743-db5a370481bc.

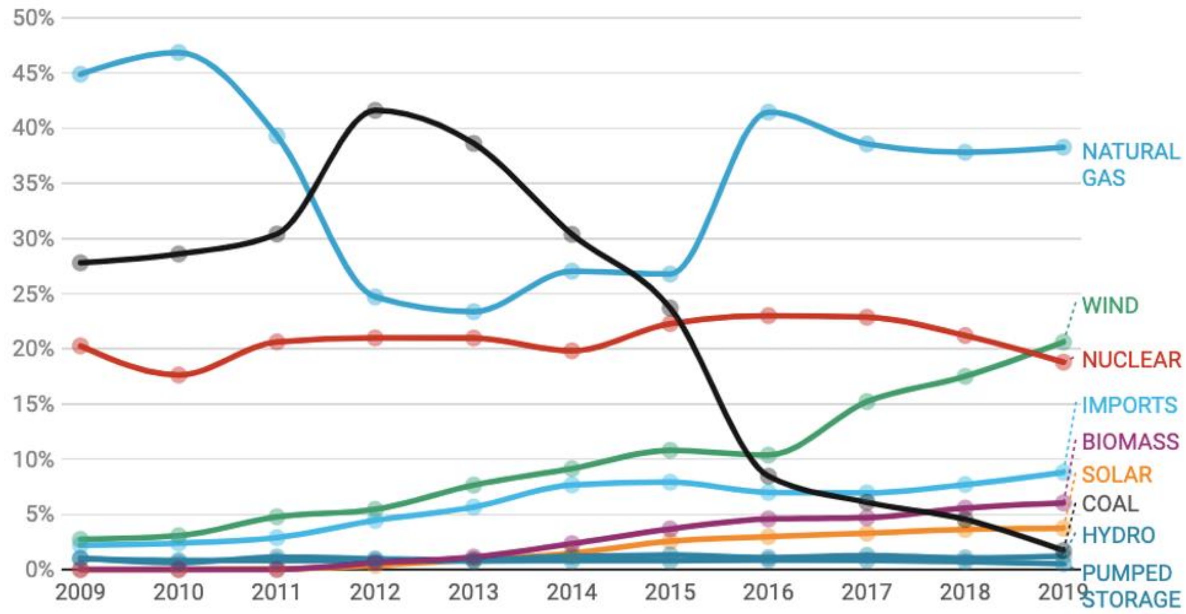


Figure 33: Share of coal respective to other fuel types (in % of total production), 2009-2019, Source: **https://theconversation.com/britains-electricity-since-2010-wind-surges-to-second-place-coal-collapses-and-fossil-fuel-use-nearly-halves-129346**

11.1.2 Use of coal for small applications

Small or domestic applications are not powered by coal in Wales. After a gradual decrease in coal use, the last coal-fired power plant (Aberthaw) shut in 2019.

11.2 Current status of other energy generation technologies

As Figure 34 shows, other prominent fuel types in the UK as a whole are **natural gas** (38% of total electricity generation), **wind, and nuclear power** (both around 20%). Natural gas is particularly prominent in fuelling gas boilers in households and other buildings. Welsh total gas consumption accumulates to a 24 TWh in 2018/19 (BEIS 2019). In southern Wales, gas is taken from the national grid that transports liquefied natural gas throughout the UK. Importantly, an estimated 19% of Welsh properties is not connected to the national gas grid.

While natural gas is the largest energy source for heating, the energy sources for electricity are more mixed. Based on the most recent data from 2018, 25% of all energy generated in Wales is from renewable sources. Their growth has accelerated since 2014 (see Figure 34). Renewable sources with a substantial share in Welsh electricity generation are on-shore and off-shore wind, solar PV, biomass and Combined Heat and Power (CHP). In turn, nuclear energy generation has entirely disappeared in Wales after 2016, due to the suspension of a nuclear plant in the northwest (Trawsfynydd). It is important to note that of all electricity generated (30.2 TWh in 2018), **more than half is exported** to England, Ireland and the rest of Europe.

Table displays the share of each energy generation technology (renewable and fossil fuel based), as well as number of active energy projects per technology. The last two columns provide the total share per technology, within their category and as share of all electricity and heating sources. Since the most recent data originate from 2018, coal is still mentioned among the energy generation technologies (Welsh Government 2019b).

Box 1: Caerau mine water project

As part of the Welsh Smart Living programme, a geothermal energy project is developing in one of Wales' most deprived villages. By utilising groundwater in the former mine shafts of the Llynfi Valley and installing heat pump technology, it will provide heat to the Caerau community by winter 2021. The technology involves a pump system to recover c. 42 MW of heat, and a heat exchange that would be fitted in individual homes. The water is located at a depth of 224 metres and has a temperature of 20.3°C. The rest water level within the borehole lies at 92 m below ground level. Upon completion, the project has scope to heat 1,000 homes.

Sources: https://www.bbc.com/news/uk-wales-south-east-wales-42702581, see also Brabham et al. (2020).

The data in Table 42 shows that the renewable energy generation sector in Wales is quite diversified, with **solar, wind and biomass energy generating over 200 MW of electric or thermal energy**. Also, just three off-shore wind projects were responsible for 30% of renewably generated electricity. The final part of the table also shows that natural gas is very dominant in Welsh energy generation, although Welsh Government (2019b) has indicated that the four active stations operate as 'peaking plants' that only generate power during periods of peak prices or in response to UK national grid demands.

Table 42: Energy generation (electricity and heat) by energy source in 2018

Category	Source	Number of projects	Capacity (MW_{el} & MW_{th})	MW of source category (%)	MW of all sources (%)
Renewables	On-shore wind	740	1,106.9 MW_{el}	28.6%	10.2%
	Solar PV	54,560	977.5 MW_{el}	25.3%	9.1%
	Off-shore wind	3	726.0 MW_{el}	18.8%	6.7%
	Biomass heat	3,345	443.3 MW_{th}	11.5%	4.1%
	Biomass electricity and CHP	48	131.3 MW_{el} & 119.1 MW_{th}	6.5%	2.3%
	Hydropower	364	182.1 MW_{el}	4.7%	1.7%
	Heat pumps	4,928	56.0 MW_{th}	1.4%	0.5%
	Energy from waste	1	30 MW_{el}	0.8%	0.3%
	Landfill gas	24	31.4 MW_{el}	0.8%	0.3%
	Anaerobic digestion (AD)	45	18.7 MW_{el} & 7.9 MW_{th}	0.7%	0.2%
	Sewage gas	6	9.3 MW_{el} & 11.2 MW_{th}	0.5%	0.2%
	Solar thermal	4,664	13.2 MW_{th}	0.3%	0.1%
Fossil Fuels	Gas	78	5,860.3 MW_{el}	77.3%	54.3%
	Coal	1	1,586.0 MW_{el}	20.9%	14.7%
	Diesel and unknown	13	133.6 MW_{el}	1.8%	1.2%

Notes: (1) In 2018, the Aberthaw coal-fired power station was still open and so is included in the data. **(2)** The totals indicate the share of an energy source in the total power generated by the renewables (MW_{el} and MW_{th}) or fossil fuels category.

Source: Welsh Government (2019b).

Besides wind and solar power, other renewable sources are in early stages of deployment or only operate at a very local level (see for example Box 1 on geothermal energy). The capacity of 'smaller' energy generation sources, such as anaerobic digestion, heat pumps, sewage gas and waste energy, has sharply increased since 2012 (Welsh Government 2019b). For example, a single (municipal) waste energy project started in 2015 in Cardiff, Trident Park, generating 30 MW in electricity and 25 MW of heat. Using a twelve kilometre-long insulated pipeline from the newly built incinerator, an annual 425,000 tonnes of non-recyclable waste is converted in heat energy for c. 20,000 homes (National Assembly 2018). There are also pilot project relating to district heating and peer-to-peer energy generation (see Box 2).

Box 2: Bridgend district heating

The town of Bridgend is selected to become one of the low-carbon heat authorities in the UK, as part of the national Smart Systems and Heat programme. The town has a stable funding pipeline to construct a district heating system and develop its Smart Energy Plan. A variety of district heating demonstrator projects are developing, involving public buildings, leisure centres and residential areas. In addition, the 'Energy Systems Catapult' pilots software that assists the authorities with monitoring and understanding local energy use.

Using further funding from the Welsh authorities, Bridgend also develops Flexible Residential Energy Efficiency Demand Optimisation and Management (FREEDOM) project, a 'living heat laboratory'. Using an air-source heat pump and a high-efficiency gas boiler hybrid system in 75 residential properties, the project integrates low-carbon smart technologies and green gas.

Sources: https://es.catapult.org.uk/wp-content/uploads/2019/02/ESC_SSH2_D37-D38-Smart-Energy-Plan-Bridgend.pdf; Welsh Government (2019a).

11.3 Technological challenges and opportunities

Wales' geographical location, with a long coastline and on the north-western edge of Europe, offers great opportunities for **off- and on-shore wind power generation and tidal energy**. Regarding wind energy, particular on-shore opportunities are centred on former mining sites, whereas Wales already has the fifth-largest off-shore wind farm worldwide in Gwynt y Môr (*Sea Wind*). Both the doubling of the current capacity (576 MW) and the leasing of two new sites are currently under consideration. The off-shore wind opportunities are summarised as follows:

Table 43: Off-shore wind opportunities

TIMEFRAME	OPPORTUNITY	ADDED CAPACITY
MID-2020S	Site extensions	0.5-0.6 GW
BY C. 2030	New leasing	1-3 GW
BEYOND 2030	Floating wind parks	Multi-GW

Source: Welsh Government 2019a.

Regarding on-shore wind energy generation, several **former mining sites** have been identified as locations for development of wind farms, including Oakdale Colliery and Maesgwyn. The former Oakdale Colliery coal mine covers approximately 162 hectares in South Wales (The Valleys). It has a 4 MW capacity (2 Senvion MM100 wind turbines of 2 MW rated power each), generating c. 10 GWh/year.[16] The Maesgwyn wind farm in the area of

[16] https://www.theguardian.com/environment/2014/jun/05/windfarm-opens-on-former-welsh-coal-mine-site.

Neath Port Talbot was commissioned in 2011 and has a nominal power of c. 32 MW (17 turbines ranging between 1.7 and 2.5 MW each).[17]

The opportunities of wind farms on former mining sites not only lie in the generated energy, but also in **potential social and economic benefits** for local communities. The Oakdale Colliery project is a public-private partnership between Partnerships for Renewables and a Welsh local authority. In addition to providing local benefits in terms of job creation, the project will provide additional revenues to the local community (Alves-Dias et al. 2018). The Oakdale partnership pays rent to the local council to use the area, as well as a community benefit package of c. €11,000 per year during the lifetime of the project, which is to be invested in projects with social, economic or environmental benefits. Equally, the Maesgwyn farm operator has supported 18 community projects through its Community Benefit Fund (incl. a skate park, road infrastructure, solar panels).

Moreover, where wind farms on former coal mining sites provide assets to the local community, they are likely to achieve a higher **social acceptance** of new technologies compared to wind farms placed on greenfield sites (see Box 3 for the Welsh policy on local ownership).

Contrary to the developments in wind energy, **tidal energy projects are in a less advanced stage**. This is reflected by the total current capacity of hydropower energy (Table). Two demonstration zones have been assigned to test wave and tidal stream technologies. Using EU funding, these projects support making the technology more cost-competitive, however further investment is required to generate revenue as a sector. At the same time, an earlier impact study revealed that on the longer term, wave and tidal stream energy could account for 1 GW of marine energy capacity (Regeneris Consulting 2013).

Box 3: Local ownership of renewable energy projects

An important aspect of renewable energy projects, particularly in comparison with a fossil fuel-based system, is their degree of local ownership. This covers projects owned by Welsh households, communities, local authorities, housing associations, charities (including religious organisations), education establishments, and Wales-based businesses, farms and estates. Data sources usually underestimate their numbers, but locally owned renewable energy project accumulated to an amount of over 64,000 in 2018, with a total capacity of 540 MWel and 243 MWth (Welsh Government 2019b). This is respectively 17% and 37% of the total renewable electrical and heat energy capacity. In comparison, 19% of gas and coal electricity generation capacity is locally owned.

One of the key principles of the Welsh energy strategy is the support of local ownership, in order to reduce costs, climate change effects and reliance on import. In addition, community ownership delivers key opportunities for changing local attitudes towards new renewable energy developments, such as wind farms. Concrete local ownership targets include:

- All new energy projects in Wales should have an element of local ownership from 2020;
- at least 1 GW of renewable energy capacity should be locally owned by 2030;
- concrete investment in public sector organisations, using interest-free loans, to finance renewable energy installations (in particular solar PV).

Sources: Llewellyn, Rohse, Day & Fyfe (2017); Welsh Government (2019b).

[17] https://www.thewindpower.net/windfarm_en_16295_maesgwyn.php.

The installation of on-shore wind and solar energy developments entails a large space-claim on (built-up) land. In preparation of the National Development Framework 2020-2040, a study was undertaken to identify **Welsh priority areas** for these developments. Based on an analysis of landscape and visual assessments, centres of population, vehicular access, ecosystem services and resilience, heritage designations, aviation constraints, the 15 zones highlighted in Figure 34 were identified as priority areas.

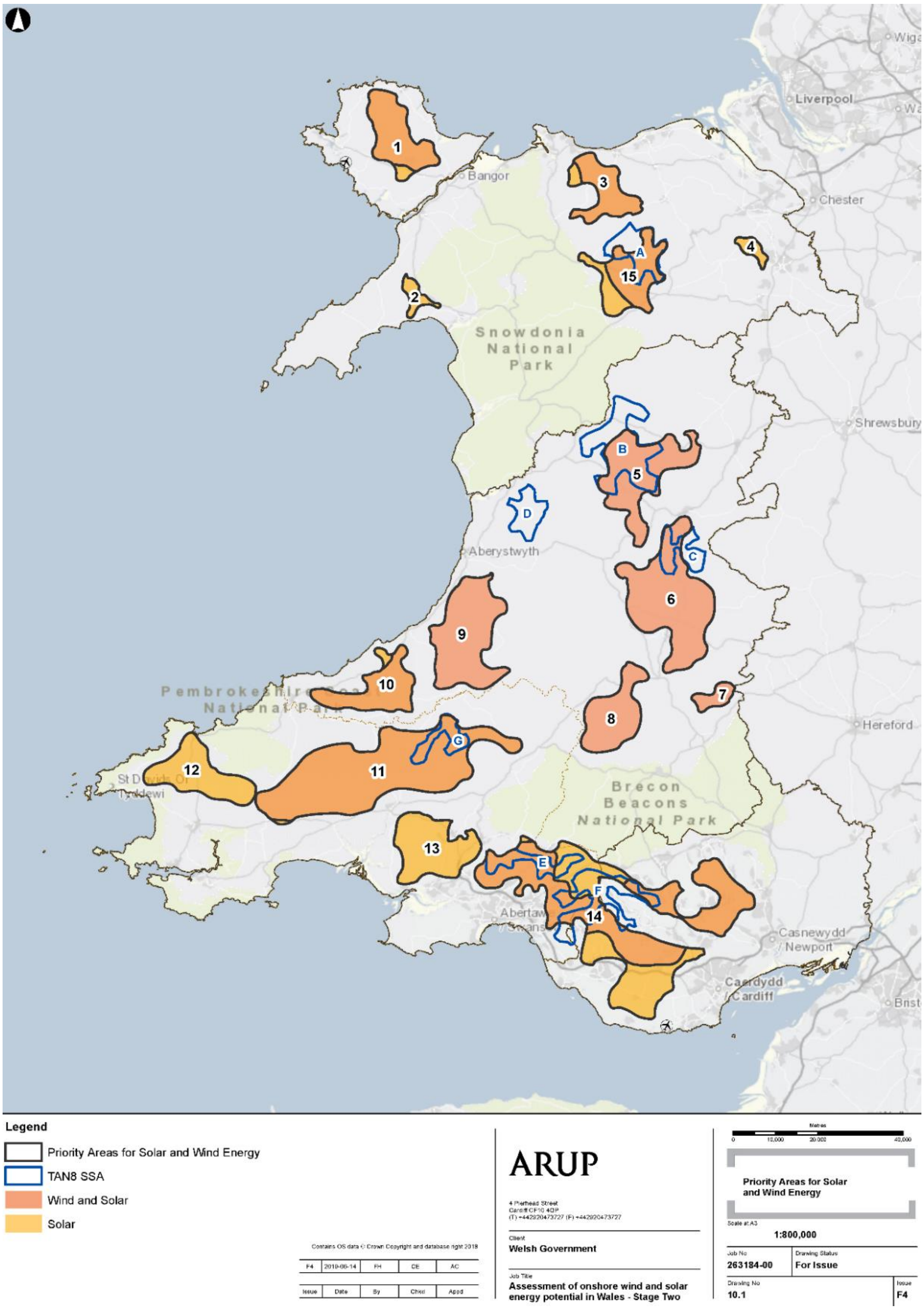


Figure 34: Priority areas for solar and wind energy, Source: Welsh Government (2019c).

The opportunities for new energy technologies in Wales also include the utilisation of its existing **historical industrial background**. Wales has a tradition in iron and steel production, which has created local industrial strengths. Furthermore, **academic expertise** in coating technologies was boosted by new research projects that focused on the commercial exploitation of integrating solar technology into housing and public buildings. An example of this was the research centre SPECIFIC (Sustainable Product Engineering Centre for Innovative Functional Industrial Coatings), which ran between 2011 and 2019 at Swansea University.[18]

One potential energy source, which is unlikely to be exploited, is the shale gas field that lies beneath the coal field of South Wales, potentially holding nearly a trillion m^2, 37.6% of which would be recoverable. Although the UK government has stressed its support to exploiting shale gas, Welsh Government has imposed a moratorium since 2015, which means that fracking shale gas is banned for now.[19]

The **challenges to the potential use and expansion of the clean energy technologies** mentioned above are diverse, and largely depend on the specific type of renewable energy. For example, constructing wind farms on former mining sites has several benefits, but also runs into **soil-related challenges**. The ground conditions of former mining sites are not always suitable for wind farm construction. Analysis of these conditions and possible restoration lead to costs that can make construction of wind farms elsewhere (e.g. on greenfield locations) more economical. The Klettwitz example (Lusatia, eastern Germany)[20] shows a possible solution using pile-raft foundations. Other solutions include the dynamic compaction method, which was used in the Welsh Maesgwyn wind farm, and the installation of weights and a tilt sensor under each turbine, as was done at the Somerset wind farm in Pennsylvania (USA).

Other **technological challenges around constructing on-shore wind farms** focus on the existing infrastructure and buildings, including roads, rail tracks, underground pipes and overhead wires. These are often more dense than elsewhere, given the previous use of this space for mining production. In general, the electricity network infrastructure produces a wider problem, since it is not always linked to the areas of future developable on-shore wind resources. For example, a 32 MW wind farm in Powys already received planning consent in 2015 to re-power with a smaller number of more efficient turbines, but grid connection issues meant that the project will be delayed until 2025. From a social point of view, wind developments at these locations may also lead to controversy, given the **disturbance for housing** near opencast mines and wind farms on the same place.

A last **infrastructure-related challenge** is the lack of east-west rail or road links in former coal mining area of The Valleys. Due to the rugged topography, transport links have historically developed on a north-south axis, in line with the valleys and towards the southerly ports of Newport, Cardiff and Swansea and the main east-west road and rail routes.

Furthermore, as Figure 34 showed, the areas identified for large scale on-shore wind and solar energy developments will avoid **National Parks** or so-called Areas of Outstanding Natural Beauty or Natura 2000 sites (Welsh Government 2019c). Radical landscape changes are also known to interact with social acceptance of new energy technologies, especially in former coal mining areas. This could pose a challenge to renewable energy developments if they go hand-

[18] https://www.specific.eu.com/.
[19] https://www.bbc.com/news/uk-wales-politics-41489253; see also Welsh Government (2018).
[20] See TRACER Best Practice fact sheet: http://tracer-h2020.eu/wp-content/uploads/2019/10/TRACER_D2.1-Wind-Park-Klettwitz.pdf.

in-hand with disconnect from the local community. Communities' landscape perceptions, valuation and functional use will have new existential identities, which need to be understood and accommodated in new policy and economic activity (Llewellyn et al. 2019).

Box 4: Bridgend demonstrator projects

The Smart Energy Plan in the town of Bridgend develops a variety of demonstrator projects on low-carbon heat. Aside from political, economic, environmental and social challenges (including fuel poverty), a number of technical factors also limits the immediate potential of wider deployment of the Plan. These factors are:

- Gas network coverage: although 97% of Bridgend's households are served by the network, some concentrations of 'off-gas' properties are not within reach of the new system.
- Electricity network limitations: reinforcement of the network would be required to increase electrical capacity, e.g. through electrification of heating and transport.
- Digitalisation: the monitoring and understanding of households' energy usage as part of the Smart Systems programme will have to go hand-in-hand with increased digitalisation and connectivity.

Source : https://es.catapult.org.uk/wp-content/uploads/2019/02/ESC_SSH2_D37-D38-Smart-Energy-Plan-Bridgend.pdf.

Other renewable energy sources are experiencing stagnation or fail to achieve a critical mass for future deployment. For example, a high number of solar thermal projects were deployed in the past decade. Small installations (e.g. on buildings) have led to a total thermal energy generation of 13 MW. However, the initial **momentum has faded**: the number of new installations in 2018 was 64, which is the lowest number since 2005, due to a change in UK government subsidies for small-scale solar energy installations, so that tariff levels are now proving to be insufficient for increasing uptake (Welsh Government 2019b).

For entirely different reasons, biomass, generating over 6% of Welsh energy (Table), is also stagnating as an energy generation technology. According to Welsh Government (2019b), **the pathway for decarbonising heat by using biomass as fuel is unclear**. Major concerns are the emissions associated with long-distance transport and the air quality impacts of burning biomass in power stations. Although the UK-wide government identified its value as a transition technology, subsidy incentives are ending in 2021 and tariff cuts have curtailed the number of new projects.

The range of political, economic, social, technological, environmental and legal challenges is summarised in Table 44, which outlines the technological limitations mentioned above, but also the economic and funding constraints, and the social challenges of ensuring acceptance of different energy technologies in individual homes and local communities. An important economic factor will be the development of **carbon price support**. Carbon dioxide emissions have been taxed since 2013, and are currently capped at £18 until 2021. This measure has driven coal energy off the grid, but in other heat technologies, its benefits are less obvious. For example in the case of heat pumps, the lower potential savings due to the lack of a carbon price on domestic gas consumption may slow down further deployment.[21] It is important to note

[21] https://www.ucl.ac.uk/news/2020/jan/british-carbon-tax-leads-93-drop-coal-fired-electricity.

that technological constraints are not related to energy technologies themselves, but rather to wider infrastructural issues and/or the economic viability to improve these.

Table 44: PESTEL summary of challenges

Politics	Economy	Social
Political stability	Economic growth	Acceptance and citizen engagement
Devolution structure (UK Government and WG)	Employment & energy demand by local employment sectors	Deprivation, incl. fuel poverty
Ambitious target-setting, incl. adoption at local level	Energy tariffs and taxes (incl. carbon price support)	Ensuring community benefits (lower bills, warm homes)
Commitment to integrated approach towards social, economic and environmental well-being	Funding opportunities at Welsh, UK and European levels	Other social, incl. quality of housing stock, skill levels
Technology	**Environment**	**Legal**
Network constraints (coverage of gas network, capacity of electricity grid)	Geography: rugged valley structure in South Wales, high tidal difference in coastal zones	Responsibilities of devolved and local governments
Network unavailability	Restoration of mining sites and heavy-industry plants	Planning regulations (incl. permits)
Digitalisation	Water discharging from abandoned mines is often acidic	Liability for pollution of closed mines
	Protecting ecological zones	

Sources: National Assembly (2018); Welsh Government (2019a); https://es.catapult.org.uk/wp-content/uploads/2019/02/ESC_SSH2_D37-D38-Smart-Energy-Plan-Bridgend.pdf.

11.4 Technical energy transition concept

Because the share of coal in electricity generation has decreased to virtually none, the Welsh Government does not have current policies or proposals explicitly related to the transition out of coal. Instead, the existing plans focus on a full transition towards a **net carbon-free economy**, which includes reliable and cost-optimal renewable energy sources, and does not resort to high-risk carbon-free technologies such as nuclear power. Geographically, the transition affects former coal regions, such as The Valleys, as well as other Welsh territories both on- and off-shore (see e.g. Figure 35). A range of policy strategies assess the opportunities for a technical energy transition in Wales, some of which are already part of national legislation. Most strategies already involve proposals that identify the steps or pathways to be taken to achieve **Welsh Government's 2030, 2040 or 2050 climate change targets**. The leading knowledge advisor on Welsh Government regulations is the UK-wide Committee on Climate Change (UKCCC), which has set the Welsh targets as follows:

- 2030: 45% reduction of overall emissions (1990 baseline);

- 2040: 67% reduction;
- 2050: 80% reduction, as required by the 2016 Environmental Act.

The UKCCC (2017) highlights that an 80% reduction in Wales could be more challenging than elsewhere in the UK due to Wales' greater share of 'hard to reduce' emissions and its fewer suitable sites for CO_2 storage. However, in May 2019 the Committee reached the view that a 95% reduction on Welsh 1990 emissions could be achieved by 2050 (UKCCC 2019). The Welsh Ministry for the Environment, Energy and Rural Affairs has transposed this target into an even higher ambition of net-zero emissions by before 2050.[22] This is in line with UKCCC's recommendation on a new UK-wide emissions target of net-zero by 2050. The current statutory obligation is displayed in Figure 35.

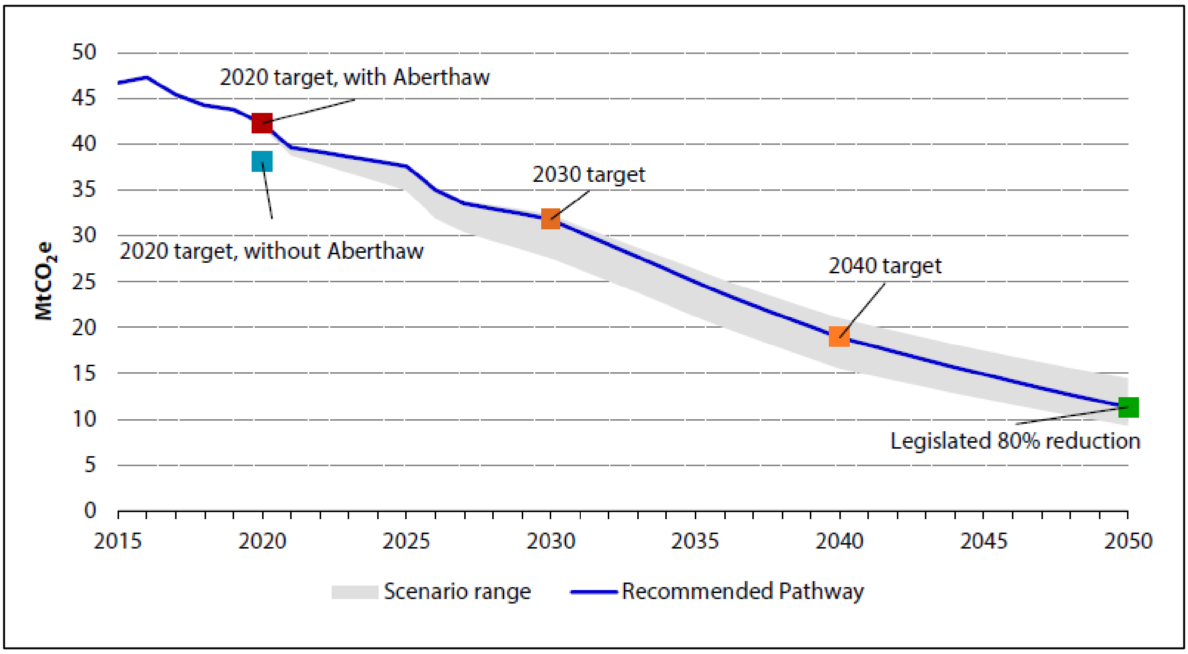


Figure 35: Emissions scenarios and recommended targets for Wales (2015-2050), Source: UKCCC (2017)

The power sector is the second largest contributor to Wales' current greenhouse gas emissions (29%, compared to 33% by the industrial sector and 12% by agriculture). A **transition of the power system** itself, towards producing and distributing clean energy, is thus imperative for meeting the legal and desired reduction ambitions. At the same time, the emissions from energy generation since 1990 have increased only in Wales (+44% until 2016) and not in the rest of the UK (-60%). This was mainly due to earlier closure of coal-fired power plants elsewhere in the UK and the addition of fossil fuel generation capacity in Wales by the UK government. The energy sector's pathway to 2030 has been set to a 37% reduction compared to 1990 levels. By 2020, the target was set at +2%, which is largely achieved by the closure of Aberthaw power station. It does so by reducing the overall emission intensity, but also by boosting renewable energy deployment and increasing innovation support.

As noted at the start of this Chapter, the Welsh Government's decision-making capacities are limited by the UK governmental devolution settlement. **The UK national government is responsible for energy policy** and nationally significant infrastructure decisions. In 2019,

[22] https://gov.wales/written-statement-response-committee-climate-changes-net-zero-report.

Welsh Government has received greater permitting and consenting powers, following the Wales Act of 2017.[23] This included devolution in the areas of transport, energy and the natural environment. These changes slightly increase the influence of the devolved government over emission levels from the power sector for developments with an installed capacity of under 350 MW. In addition, the Wales Act 2017 (Section 67) inserted section 26A of the Coal Industry Act 1994, which states that any licence that authorises operations in relation to coal in Wales can only have effect with the approval of the Welsh Ministers.[24] The Coal Authority determines applications for new licences or extensions in accordance with its statutory duties, which includes "to secure, so far as practicable, that an economically viable coal mining industry is maintained and developed". Specifically regarding renewable energy, the Wales Act 2017 amended the Government of Wales Act 2006 to devolve legislative powers in relation to: heat and cooling networks (except their regulation); schemes providing incentives to generate or produce heat or cooling from energy sources other than fossil or nuclear fuel; the encouragement of energy efficiency (otherwise than by prohibition or regulation).

The **main policy documents** setting out the technical energy transition for Wales are the following:

- The UK-wide UKCCC report, recommending a 95% reduction on Welsh emissions by 2050 (UKCCC 2019);
- The Welsh Prosperity for All plan, committing to net-zero emissions by no later than 2050 (Welsh Government 2019a);25
- Planning Policy Wales, setting out the land use planning policies of the Welsh Government (Welsh Government 2018);
- the UK-wide Clean Air Strategy (Department for Environment, Food and Rural Affairs 2019);
- the Welsh National Development Framework (NDF) 2020-2040, which is still a draft (Welsh Government 2019d). Based on new Welsh legislation (the Well-being of Future Generations Act), the NDF reflects the planning changes that will be required across Wales to require public organisations of all levels to consider the long-term impact of their decisions, i.e. relating to poverty, health inequalities and climate change.

The **key steps** envisioned in the technical energy transition in Wales are as follows. The first two steps **widen the significance of restructuring the energy sector** as a societal need that affects, and requires support of, other sectors and the wider population:

- A **Whole Energy System Approach** to the energy transition: a system change from separate and centralised provision of power, heating and transport fuel towards energy generation and delivery being distributed in the communities where energy is used. This 'multi-vector system' will have to be committed to fully exploiting the synergies between the power, heat and transport sectors, which includes energy transfer between them (Welsh Government 2019a).
- A widely shared low-carbon pathway provides opportunities to maximise the seven **well-being goals** that are defined in the Welsh Future Generations Act. These include: prosperity, resilience, health, equality, community cohesion, thriving language and culture, and global responsibility.

[23] https://law.gov.wales/environment/energy-and-climate-change/renewable_energy_efficiency/?lang=en#/environment/energy-and-climate-change/renewable_energy_efficiency/?tab=overview&lang=en.
[24] https://www.gov.uk/guidance/devolution-settlement-wales.
[25] https://gov.wales/written-statement-response-committee-climate-changes-net-zero-report.

The all-systems approach is also reflected by the leading policy document in the UK. Although Wales has a number of devolved powers that enable changes and investments in the energy sector, the wider context (e.g. target minimums, sectoral approaches) is set by the UK national government. Figure 36 identifies the **scenarios** designed by the UKCCC, based on existing research, current consumer behaviour and known and deployable technologies. Specific to energy generation, it foresees to “largely decarbonise” electricity, provide (existing) buildings with heat pumps, and start hydrogen production throughout the 2020s.

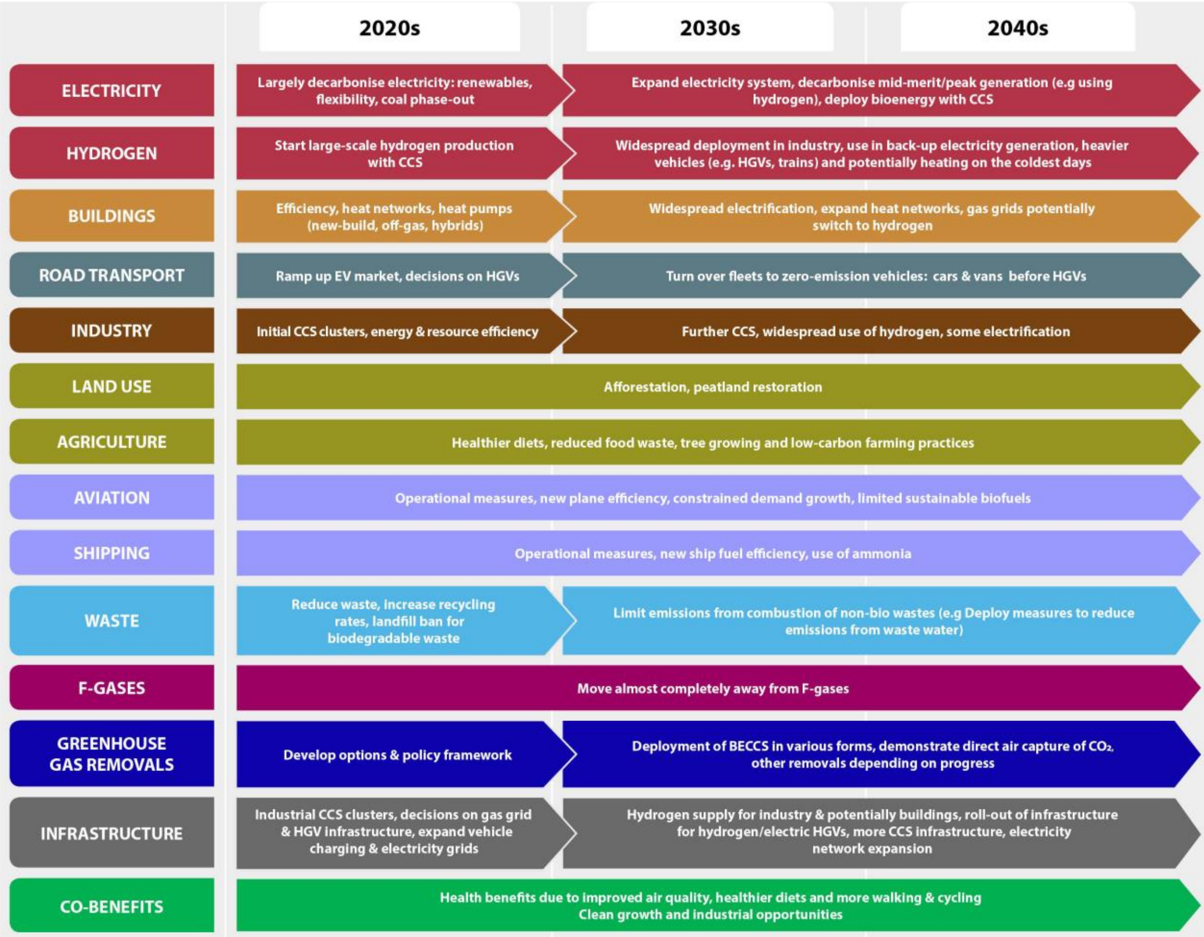


Figure 36: UK scenarios for net-zero greenhouse gas emissions (2020s - 2040s), Source: UKCCC (2019)

The following steps outline the **pathways that each industry should take** (incl. the energy production industry). They include concrete targets, as well as stepwise plans.

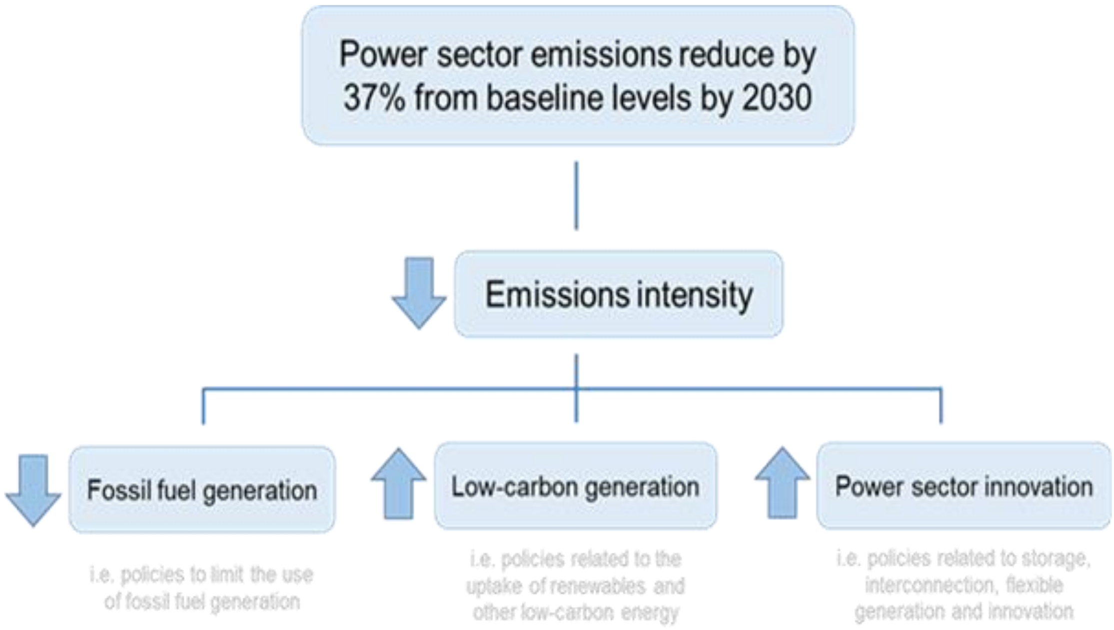
- 70% electricity generation should come from renewables in Wales by 2030 (Welsh Government 2018).
- Setting “sectoral **“emission pathways”**: divide actions, ambitions and emission profiles across energy-heavy sectors, by allocating emission budgets that will reduce over time. For the power sector, they are:
    - 2020: emissions to be 29% lower than in 2016. This will mean that power sector emissions are 2% greater than the baseline year (1990);
    - 2030: emissions will reduce by 37% from baseline levels by: **reducing energy generation from fossil fuels; increasing the deployment of renewable energy** (towards 70% target); and **increasing support for innovation**.

- 2040: emissions will reduce by 65% from baseline levels.
- 2050: emissions will reduce by 94% from baseline levels.

To meet the targets of the 2030 pathway, all energy-related policies are streamlined into an overarching **policy framework** for the energy sector.

Figure 37 outlines the framework and the specific sectoral policies that follow for the three steps identified.

Figure 37: Policy framework for the energy sector (2030 pathway) and specific policies; Adapted from: Welsh Government (2019a)



Fossil fuel generation reduction	Low-carbon generation increase	Power sector innovation
Implementing Energy Consenting, Planning & Permitting policy	Delivery of Renewable Energy Targets	Energy innovation (e.g. upscaling of demonstrator projects)
Removing barriers to consenting for storage by removing batteries as part of the Development of National Significance process.	Developing Routes to Market for Renewable Technologies	Market regulation and investment
Phasing out unabated coal	Increasing local ownership of energy generation	Ensuring community benefits (lower bills, warm homes)
Developing a Policy on Combustion of Fuels for Power	Maximise Welsh benefit from major infrastructure projects in Wales	Housing stock
Continuing to be a part of the EU Emissions Trading System to the end of Phase III (2020)		

- Although the specific policies in the energy sector (13 in total) contain too many precise targets to list here, they are significantly influenced by the greater **devolved powers** in Wales. Planning permits for renewable energy developments now have a 350 MW upper limit, instead of 50 MW for onshore developments only. Equally, permits for fossil fuel-based projects under this limit can now be reconsidered. On the other hand, capital investments, carbon pricing and potential subsidies for renewable projects are responsibilities of the UK government.
- Specifically to **renewable energy sources**, generation will be increased through a combination of targets-per-technology and support for local authorities and communities. Acceleration of low-carbon technologies will be achieved by:
  - fully focusing on **current growth markets**, such as onshore and offshore wind and large-scale solar PV, and to a smaller extent on biomass, wave and tidal stream energy.
  - offering **technical, financial and commercial support** through the WG Energy Service and Local Energy Fund;[26] supporting local and regional authorities to develop their own, localised, energy plans.
- **Other sectors** with "emission pathways" are Buildings, Transport, Industry, Land Use, Agriculture, Waste and F-Gases. Their transition pathways will also affect the energy sector to an extent. Welsh Government (2019a) has identified the following pathways for the sectors that exceed 10% of total CO_2 emissions:
  - Buildings. Sector emissions will reduce by 40% from baseline levels by 2030 through: increasing energy efficiency; **low-carbon heating and cooling**; and behavioural change to the use of buildings. Planned measures include maximisation of district heating, CHP schemes and the use of water and waste heat.[27]
  - Transport. Sector emissions will reduce by 43% from baseline levels by 2030 through: modal shift; increasing uptake of electric vehicles; vehicle and fuel efficiency measures. In particular, the step towards new car sales that must be ultra-low emission vehicles by 2030 (60%) entails a higher **electricity demand** and the roll-out of public charging infrastructure.
  - Industry. Sector emissions will reduce by 43% from baseline levels by 2030 (already -35% by 2020) through: energy efficiency measures of material, energy and processes, innovation and waste heat; low-carbon heat and industrial process measures. Oil and gas extraction for the iron and steel industry (the heaviest polluters) will be restricted by new planning permissions (Onshore Petroleum Licensing). Furthermore, large (UK and Welsh) funding programmes are in place for **industrial heat recovery** projects and environmental protection.
  - Agriculture. Sector emissions will reduce by 28% from baseline levels by 2030 (-17% by 2020) through: improved efficiency of livestock production; improved crop and nutrient management; and farm fuel and energy efficiency. The energy demand is thus expected to reduce, for instance through offering energy audits to individual farms. Some farms are identified as sites for **anaerobic digestion**.

[26] For instance, the Community Energy Toolkit explains how to run a project to install new renewable energy generation: https://gov.wales/community-energy-toolkit.

[27] Examples of low-carbon heating innovations are the FREEDOM project (Box 2) and projects in the Heat Networks Innovation Programme, a £320 million programme to build capacity in heat network delivery in England and Wales.

- Until 2030, the energy transition is thus largely committed to exploiting existing low-carbon energy generation technologies, such as wind and solar power. Since its effects clearly go beyond the energy sector, the NDF also prepares a strategy on **visual effects and landscape** changes. This makes those technologies geographically selective: the design and micro-siting must minimise the landscape and visual impact, particularly those in close proximity to built-up areas (Welsh Government 2019d).
- Although documents above frequently mention emission reduction targets for 2050, their pathways do not yet contain specific policies. Energy technologies that are more difficult to widely deploy in the next decade may therefore appear in future scenarios and policies, including hydropower and hydrogen. Figure 36 shows the current scenarios related to hydrogen energy and the need to adjust energy distribution grids accordingly. In case of hydropower (wave and tidal), global estimates of potential volumes are reaching 10%, with a favourable marine climate in Wales.[28]

The **methods** for achieving the energy transition are:

- Fully focus on current growth markets in renewable energy technologies, i.e. onshore and offshore wind, and large-scale solar PV developments. See for example the map of priority areas as part of the NDF (Figure 34) and Gwynt y Môr capacity opportunities (Table 2).
- Develop more detailed steps to large-scale deployment of other clean energy technologies, including hydropower and hydrogen.
- Making **connections between measures in the energy sector and wellbeing goals** (Future Generations Act). Technical energy transition policies (e.g. the pathway of the energy sector) thus also consider their cultural, social, economic and environmental effects on Welsh communities and individuals, both now and in the future. Examples of connections between sectoral policies and increased wellbeing are: improving energy efficiency in buildings will prevent cold, damp housing; decentralised power systems contribute to keeping economic benefit within local communities and businesses; a shift to active travel reduces air pollution and supports health. Similarly, renewable energy generation projects can provide wider environmental benefits, such as resilient ecological networks, restoring peatlands and semi-natural grasslands.[29]
- Developing a **Monitoring, Reporting and Verification** (MRV) system to track progress and adding new policy performance indicators that relates to the wider well-being benefits of each sectoral transition. The MRV will operate at three levels (Welsh Government 2019a):
    - Tier 1. Emission estimates which are consistent with the Environment Act target definition for each sector;
    - Tier 2. Specific activity data, or emission factors, that provide information on the underlying drivers of GHG in Wales. Data will generally come directly from the database compiling the GHG inventory for Wales (see below); and
    - Tier 3. Policy-tier indicators monitor the policies and proposals which WG is actively doing or aiming to do to reduce GHG emissions. This includes monitoring UK-wide policy delivery if it contributes to the Welsh targets.
- The **Greenhouse Gas Inventory** (GHGI) periodically assesses the territorial effects of the transition measures. After each year, the reporting term is 18 months. The data are

[28] https://tradeandinvest.wales/inside-story/marine-power-systems.
[29] http://tracer-h2020.eu/wp-content/uploads/2019/12/TRACER_D-2.5_Best_practice_environmental_protection_FIB-2.pdf.

based on a modelled estimate of GHG emissions (e.g. known emissions per energy technology).

- Related to this, an important method to guide and 'control' the transition is to create high **data availability**: power companies, renewable energy registers, smart meter data must be openly consulted by research organisations. Verifying the data with stakeholders and industry is an important part of the method when data are collated from different information sources (Welsh Government 2019b).
- The local ownership targets (Box 3) are a key addition to the Welsh energy transition concept. This is not only beneficial to social acceptance of new technologies, but collaboration with local stakeholders changes work as a government, to limit further effects of climate change and avoid unintended consequences. As Figure 34 showed, some of the priority areas for renewable energy developments are located in the former hard coal mining area of The Valleys, South Wales. It will be particularly crucial to create local ownership here, after decades of status quo around coal mining and industrial activity as social and economic driver.

11.5 References

ALVES DIAS, P. ET AL., (2018) EU COAL REGIONS: OPPORTUNITIES AND CHALLENGES AHEAD. LUXEMBOURG: PUBLICATIONS OFFICE OF THE EUROPEAN UNION. ISBN 978-92-79-89884-6, DOI:10.2760/064809, JRC112593.

BEIS (2019) SUB-NATIONAL ELECTRICITY AND GAS CONSUMPTION SUMMARY REPORT 2018. DEPARTMENT FOR BUSINESS, ENERGY AND INDUSTRIAL STRATEGY, LONDON, UNITED KINGDOM. 19 DECEMBER 2019. HTTPS://WWW.GOV.UK/GOVERNMENT/STATISTICS/SUB-NATIONAL-ELECTRICITY-AND-GAS-CONSUMPTION-SUMMARY-REPORT-2018.

BRABHAM, P., MANJU, M., THOMAS, H., FARR, G., FRANCIS, R., SAHID, R. & SADASIVAM, S. (2020) THE POTENTIAL USE OF MINE WATER FOR A DISTRICT HEATING SCHEME AT CAERAU, UPPER LLYNFI VALLEY, SOUTH WALES, UK. QUARTERLY JOURNAL OF ENGINEERING GEOLOGY AND HYDROGEOLOGY, 53(1), 145-158.

DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (2019) CLEAN AIR STRATEGY, JANUARY 2019: HTTPS://WWW.GOV.UK/GOVERNMENT/PUBLICATIONS/CLEAN-AIR-STRATEGY-2019.

FOE CYMRU (2016), AIR QUALITY AND HEALTH IMPACTS OF ABERTHAW POWER STATION. CARDIFF, WALES: FRIENDS OF THE EARTH CYMRU. HTTPS://FOE.CYMRU/SITES/DEFAULT/FILES/FOE_APS_REPORT_FINAL.PDF.

KNOCHE, D., RADEMACHER, A. & SCHLEPPHORST, R. (2020), REPORT ON THE ENVIRONMENTAL IMPACTS AND SUSTAINABLE RECLAMATION SOLUTIONS IN THE TRACER TARGET REGIONS. TRACER DELIVERABLE D3.4.

LLEWELLYN, D., ROHSE, M., DAY, R. & FYFE, H. (2017) EVOLVING ENERGY LANDSCAPES IN THE SOUTH WALES VALLEYS: EXPLORING COMMUNITY PERCEPTION AND PARTICIPATION. ENERGY POLICY, 108, 818-828. HTTPS://DOI.ORG/10.1016/J.ENPOL.2017.04.028.

LLEWELLYN, D., ROHSE, M., BERE, J., LEWIS, K. & FYFE, H. (2019) TRANSFORMING LANDSCAPES AND IDENTITIES IN THE SOUTH WALES VALLEYS. LANDSCAPE RESEARCH, 44(7), 804-821. DOI: 10.1080/01426397.2017.1336208.

NATIONAL ASSEMBLY (2018) RESEARCH BRIEFING: LOW CARBON HEAT. CARDIFF: NATIONAL ASSEMBLY FOR WALES. HTTPS://WWW.ASSEMBLY.WALES/RESEARCH%20DOCUMENTS/18-042%20-%20LOW%20CARBON%20HEAT/18-042-WEB-ENGLISH.PDF.

RAM M., BOGDANOV D., AGHAHOSSEINI A., GULAGI A., OYEWO A.S., CHILD M., CALDERA U., SADOVSKAIA K., FARFAN J., BARBOSA LSNS., FASIHI M., KHALILI S., DALHEIMER B., GRUBER G., TRABER T., DE CALUWE F., FELL H.-J., BREYER C. (2019) GLOBAL ENERGY SYSTEM BASED ON 100% RENEWABLE ENERGY - POWER, HEAT, TRANSPORT AND DESALINATION SECTORS. LAPPEENRANTA / BERLIN: LAPPEENRANTA UNIVERSITY OF TECHNOLOGY AND ENERGY WATCH GROUP:

HTTP://ENERGYWATCHGROUP.ORG/WP-CONTENT/UPLOADS/EWG_LUT_100RE_ALL_SECTORS_GLOBAL_REPORT_2019.PDF.

REGENERIS CONSULTING (2013) THE ECONOMIC IMPACT OF THE DEVELOPMENT OF MARINE ENERGY IN WALES. LONDON/MANCHESTER: REGENERIS CONSULTING LTD: HTTPS://GOV.WALES/SITES/DEFAULT/FILES/PUBLICATIONS/2019-06/ECONOMIC-IMPACT-OF-THE-DEVELOPMENT-OF-MARINE-ENERGY-FINAL-REPORT.PDF.

UKCCC (2017) BUILDING A LOW-CARBON ECONOMY IN WALES: SETTING WELSH CARBON TARGETS. LONDON: UK COMMITTEE ON CLIMATE CHANGE, DECEMBER 2017. HTTPS://WWW.THECCC.ORG.UK/WP-CONTENT/UPLOADS/2017/12/CCC-BUILDING-A-LOW-CARBON-ECONOMY-IN-WALES-SETTING-WELSH-CLIMATE-TARGETS.PDF.

UKCCC (2019) NET ZERO – THE UK'S CONTRIBUTION TO STOPPING GLOBAL WARMING. LONDON: UK COMMITTEE ON CLIMATE CHANGE, MAY 2019: HTTPS://WWW.THECCC.ORG.UK/PUBLICATION/NET-ZERO-THE-UKS-CONTRIBUTION-TO-STOPPING-GLOBAL-WARMING/.

WELSH GOVERNMENT (2018) PLANNING POLICY WALES. EDITION 10, DECEMBER 2018. HTTPS://GOV.WALES/SITES/DEFAULT/FILES/PUBLICATIONS/2019-02/PLANNING-POLICY-WALES-EDITION-10.PDF.

WELSH GOVERNMENT (2019A) PROSPERITY FOR ALL: A LOW CARBON WALES. ISSUE MARCH 2019. HTTPS://GOV.WALES/SITES/DEFAULT/FILES/PUBLICATIONS/2019-06/LOW-CARBON-DELIVERY-PLAN_1.PDF.

WELSH GOVERNMENT (2019B) ENERGY GENERATION IN WALES 2018. REGEN, EXETER, UNITED KINGDOM. ISSUE SEPTEMBER 2019. HTTPS://GOV.WALES/SITES/DEFAULT/FILES/PUBLICATIONS/2019-10/ENERGY-GENERATION-IN-WALES-2018.PDF.

WELSH GOVERNMENT (2019C) PRIORITY AREAS FOR SOLAR AND WIND ENERGY. EXECUTIVE SUMMARY STAGE 1 AND 2. OVE ARUP & PARTNERS LTD, BRISTOL, UNITED KINGDOM. ISSUE 12 JULY 2019.

WELSH GOVERNMENT (2019D) NATIONAL DEVELOPMENT FRAMEWORK 2020-2040, CONSULTATION DRAFT. AUGUST 2019: HTTPS://GOV.WALES/SITES/DEFAULT/FILES/CONSULTATIONS/2019-08/DRAFT%20NATIONAL%20DEVELOPMENT%20FRAMEWORK.PDF.