Smart strategies for the transition in coal intensive regions

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TRACER

TRANSITION IN COAL INTENSIVE REGIONS

Projections for the transition to 2030 / 2050 in the target regions

WP 6 – Task 6.1 / D6.1

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Abbreviations

CCGT	Combined Cycle with Gas Turbine
CHPP	Combined Heat and Power Plant
DHS	District Heating System
DSO	Distribution System Operator
EE	Energy Efficiency
ELV	Emission Limits Values
ESIA	Environmental and Social Impact Assessment
FS	Feasibility Study
GHG	Green House Gas
HPP	Hydropower Plant
IED	Industrial Emissions Directive
IEP	Integrated Environmental Permit
LCP	Large Combustion Plant
LCT	Low Carbon Technologies
MHPP	Micro-Hydro Power Plant
MMC	Mine Methane Captured
NECP	National Energy and Climate Plan
NPS	National Power System
PV	Photovoltaic
PV-PP	Photovoltaic Power Plant
RES	Renewable Energy Sources
TM	Thermal Modules
TP	Thermal Plant
TPP	Thermal Power Plant
TS	Thermal Stations
UCG	Underground Coal Gasification
UN-ECE	United Nations – Economic Commission for Europe
WPP	Wind Power Plant

Executive summary

The first Task of WP6 "Strategies, Roadmaps, and Decision Support Tools" of the TRACER Project concerns the development of Research & Innovation (R&I) strategies for the nine (9) target regions of the project. It is foreseen to elaborate a set of nine (9) – i.e. one per target region involved – ***R&I strategies***, which will:

- focus on the issue of Smart Specialization;
- contribute to a better management and organisation of the changes that will arise in the structure of the new low-carbon economy status;
- be harmonised with the guidelines of the Strategic Energy Technology (SET) Plan.

The SET Plan is the R&I pillar of the EU's energy and climate policy, lined up with the Energy Union's R&I priorities. Fourteen (14) technology areas that have the highest innovation potential for delivering cost reductions and improvement of performance quickly, and which can contribute in this way to the decarbonisation of the European energy system have been defined and implementation plans have been created.

More precisely, these fourteen technology areas are the following (grouped according to the SET Plan's 10 key actions, divided into six domains):

- **Sustain technological leadership in renewables (RES)**
  1. Solar Photovoltaics (PV)
  2. Concentrated Solar Power / Solar Thermal Electricity (CSP/STE)
  3. Offshore Wind Energy
  4. Deep Geothermal Energy
  5. Ocean Energy
- **A smart consumer-centric energy system**
  6. Smart Solutions for Energy Consumers
  7. Towards Positive Energy Districts for Sustainable Urbanisation
  8. Energy Systems
- **Develop and strengthen energy efficient systems**
  9. Energy Efficiency in Buildings
  10. Energy Efficiency in Industry
- **Energy Options for Sustainable Transport Systems**
  11. Batteries for E-Mobility and Stationary Storage
  12. Renewable Fuels and Bioenergy
- **Carbon Capture Utilisation and Storage (CCUS)**
  13. CCS and CCU
- **Nuclear Safety**
  14. Implementation plan on nuclear safety

In addition, it must be mentioned that SET Plan steps up cooperation between governments, industry and research institutes to leverage the use of R&I funding schemes for clean energy. The "Clean Energy Transition Technologies and Innovations Report" and the national energy and climate plans set out the policies and financial measures that EU countries will take to reach the climate and energy targets.

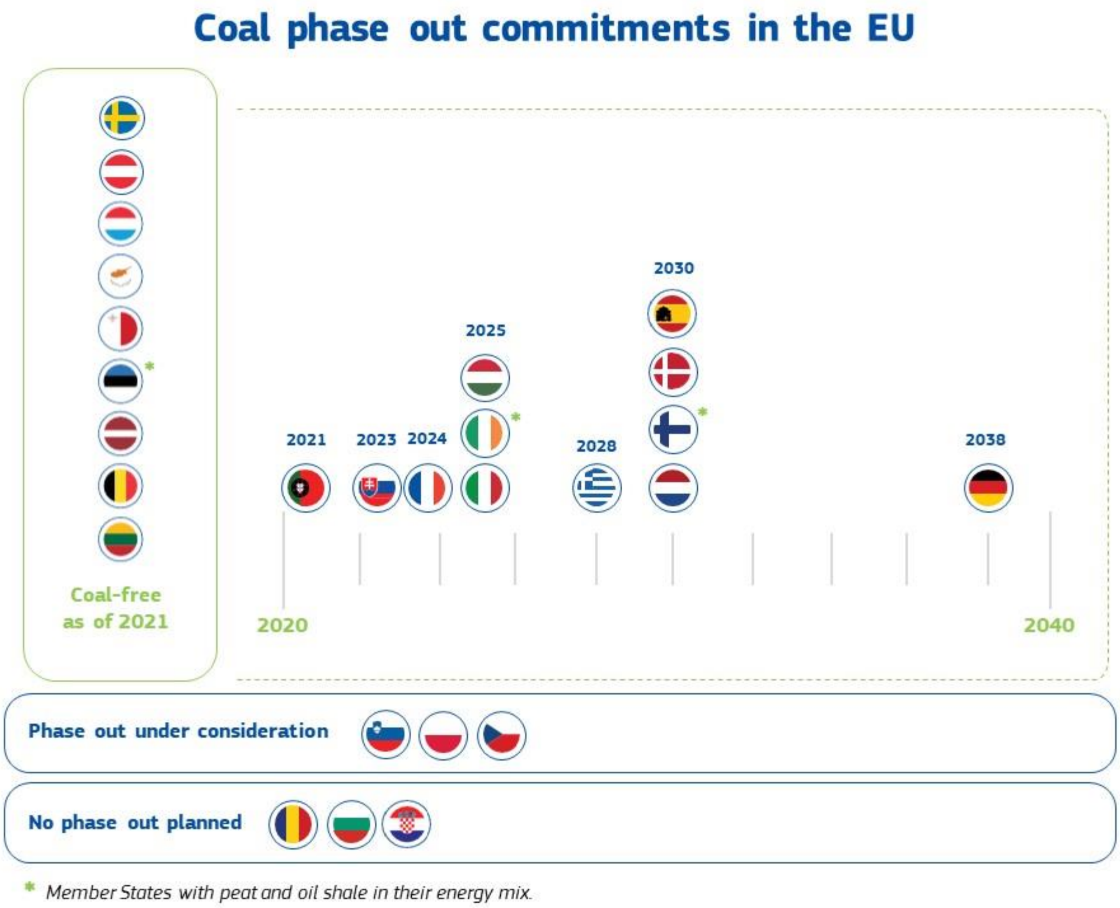
Thus, the R&I strategies that will be developed for the target regions in the frame of the TRACER Project need to be oriented to the energy technologies that will most probably be used by the target regions during their decarbonisation – or transition to a cleaner and more "sustainable" future – procedure. For doing so, it is necessary to know the current projections for the transition to 2030 at first, and to 2050 in the longer term, in the targeted coal intensive regions. These projections need to be focused on the energy mix of the region required to cover the regional and/or national needs after or during the decarbonization process.

In this way, and having defined the energy technologies that are projected to be used in the target regions for the transition, the relevant R&I priorities will be derived in order to form the corresponding R&I strategies.

1 Introduction

While coal remains a central fuel in the European energy mix, the transition to cleaner forms of energy (e.g. renewables) and innovative technologies (e.g. carbon capture and storage) is imperative to meet the EU's commitment to reduce CO_2 emissions by at least 55% by 2030 and to become the world's first climate-neutral bloc by 2050. The decline of coal-based energy production is an ongoing reality in Europe.

Since 2012, total coal power generation has dropped by almost a third in the EU. The declining use of coal has led to mines closing down and power plants being decommissioned in a number of regions across Europe. By 2030, approximately two thirds of the current coal-fired power generation capacity could retire, posing a key challenge on energy sufficiency. Moreover, around half of the relevant direct jobs could be lost by 2030, representing a major challenge in the transformation of coal regions. The graph below summarises the current state of play of national coal phase-out commitments in the EU.



Source: *EC's Coal regions in transition website, URL:* https://ec.europa.eu/energy/topics/oil-gas-and-coal/EU-coal-regions/coal-regions-transition_en

These commitments have already been part of the national policies of the EU Member States, as they have been included in the national energy and climate plan (NECP) that each EU Member State had to prepare and submit to European Commission. After the landmark year 2020, with the EU's "Energy and Climate Package" (i.e. the so called "20-20-20" targets), and in order to meet the EU's energy and climate targets for 2030, EU countries needed to establish a 10-year integrated NECP for the period from 2021 to 2030.

Introduced under the Regulation on the governance of the energy union and climate action (EU/2018/1999), the rules required that all EU countries submit their draft plans for the period 2021-2030 to the Commission by the end of 2018, and their final plans by the end of 2019 (taking account of the Commission's assessment and recommendations on the draft plans). The national plans outline how the EU countries intend to address:

- energy efficiency;
- renewables;
- greenhouse gas emissions reductions;
- interconnections;
- research and innovation

This approach required a coordination of purpose across all government departments. It also provided a level of planning that will ease public and private investment. In order for the Member States to set their own targets as regards renewable energy, energy efficiency, and – through them - greenhouse gas emissions reduction, energy scenarios had to be drawn up for developing an informed, internally-consistent and policy relevant view on the future developments of the corresponding energy system, transport system as well as of greenhouse gas emissions.

Thus, modelling-based projections (not "forecasts") of energy, transport and greenhouse gas emissions trends to the new landmark year 2030 at first (and to 2050 in a next step) have been made. It must be further mentioned that, in some cases (countries) - e.g. Greece, the UK, Ireland, Spain, etc. - the projections towards / scenarios for 2030 as regards the evolution of the energy system to match the targets set have been made on a regional basis. This was due to the type of model that has been used for modelling purposes (e.g. the TIMES modelling tool, developed by IEA-ETSAP).

Furthermore, under the governance regulation, and taking into account that the Commission has proposed the EU become climate-neutral by 2050, EU countries were also required to develop national long-term strategies by January 2020. Both the NECPs and the long-term strategies had to be developed in a complementary way, so as to ensure the consistency of the 2030 targets and long-term objectives. Meanwhile, more than half of the draft NECPs already include 2050 objectives or ambitions, albeit with varying degrees of detail.

Of course, the above stand for the EU Member States. For the two countries that participate in the TRACER Project and are not members of the EU (evidently before the Brexit), namely Serbia and Ukraine, the corresponding integrated National Energy and Climate Plans (NECP) are currently under preparation. In this case, but also in the case that the projections included in the existing NECPs are not so transparent, any available studies – prepared on a national and/or regional level - on the way to decarbonization (in terms of the projected energy mix) of the TRACER target regions with a horizon for 2030 first, and 2050 for the longer term, had to be sought.

To conclude, what is necessary to know in the first step is the already existing projections of the target regions' energy mix in 2030/2050 (according to the planning made in the frame of the NECPs), as well as any other kind of studies already made for decision support, e.g. for the exploitation of the locally available Renewable Energy Sources (RES) or the expansion of the natural grid in the regions that are under transition (to the post-lignite era), or even any potential plans for the development of power plants of different kind in the regions (nuclear energy, hydrogen, etc.).

By examining the projected energy mix (by source/fuel) in each target region, the energy technologies that are going to play a significant role in the area (by replacing the already existing and operating coal fired power plants, both for the region's power/energy coverage, but also for producing energy for the entire country) will be identified. With the cutting-edge technologies for the target regions known, the corresponding R&I activities in this region in the field of energy will have to focus on the improvement of the efficiency and/or functioning of these specific technologies. Thus, the stakeholders will be aware in which direction R&I (on national or regional level) will have to concentrate.

2 Bulgaria, Yugoiztochen Region

2.1 Projections for the energy generation technologies using coal for 2030

2.1.1 Coal driven thermal power (TP) and CHP plants

The National Energy and Climate Plan of Bulgaria 2021-2030 – NECP (ME, 2020) presents two scenarios: WAM (with additional policy measures) and WEM (with existing policy measures). WAM projection – the one of interest for the current report - is based on both existing and additional policy measures that need to be implemented to achieve the national targets set in the NECP. In WAM, the primary energy consumption of coal is projected to decrease from 65.1 TWh in 2020 to 48.3 TWh in 2030, but no details are provided.

The Commission assessment of the final NECP points out that "*Bulgaria does not plan to phase out coal yet*", there is "*lack of information on how and when the coal phase-out […] will take place*", and "*a more substantive analysis of the further use of coal-based electricity production is missing*" (EC, 2020).

There is consensus among energy experts in Bulgaria, confirmed at numerous events about the future of coal, that the WAM scenario in NECP is unrealistic and coal will be phased out much more quickly. According to Regulation (EU) 2019/943 of 5 June 2019, Art.22(4): "(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 kW_e shall not be committed or receive payments or commitments for future payments under a capacity mechanism." None of the coal capacities in Maritsa East complex would be able to meet these emission requirements (Mihaylov T., 2021), as they operate on poor quality lignite coal. This means that the coal capacities could rely only on energy trade, but not on capacity services, which would lead to their insolvency.

The result of this situation would be gradual, but speedy closure of the coal capacities in the region after mid-2025. Some experts (e.g., Mihaylov, 2021) expect that this process will be completed before 2030, others (e.g., Todorov, 2021) - in 2030.

Table 2.1: Expected end of life of Maritza East coal-fired capacities

	Thermal Power Plant	Capacity, MW	Expected end of life of coal capacities	Comments
1	Brickel (former Maritsa-East 1)	200	2025	The plant is obsolete, with exhausted technical resources
2	Maritsa 3-Dimitrovgrad	120	2025	The plant is obsolete, with exhausted technical resources
3	Maritsa-East 2	1,620	Until 2028	Overall good condition, different for different units
4	Maritsa-East 3 Contour Global	908	Until 2028	Overall good condition
5	AES-3C Maritsa-East 1 TPP	686	Until 2030	Modern, state-of-the-art technology

Source: expert estimates, expressed during TRACER workshops and interviews

2.1.2 Other coal-fired energy generation applications

The coal extracted in the Maritsa East Basin is not suitable for direct use in small heaters - stoves, boilers, fireplaces. After coal processing at Brickel Briquette Factory, the briquettes are used for: 1) heating with stoves from the population, and 2) burning in Brickel TPP, District Heating Sliven, and District Heating Pernik (the latter is outside South-East region). In addition, 2,000 households in the town of Galabovo are supplied with hot water from Brickel TPP. The Bulgarian government has repeatedly decided to suspend Brickel's work due to ecological violations, but the suspension has been postponed due to strikes (only temporary suspension has been imposed). The Brickel Briquette factory is expected to be closed before 2030 (Mihaylov T., 2021).

The two coal-fuelled district heating systems in South-East region (SER) – the ones in Galabovo and Sliven – would not continue the use of coal briquettes. The one in Galabovo is expected to stop operation together with Brickel briquette factory. The one in Sliven is going to switch to natural gas and steps in this direction have already been undertaken (Nikolaev I., 2021).

It is not feasible to expect that coal (briquettes) from other Bulgarian mines, such as the higher calorific value mines in Bobovdol, will be used in the region. Moreover, these mines are about to shut down too (Doczekal C., Radulov L., et al., 2020).

In the region, like anywhere else in Bulgaria, imported anthracite coal is preferred, due to its higher calorific value and low sulphur emissions. However, the import of such coal is expected to be restricted soon, due to environmental reasons (Mihaylov T., 2021). Additionally, the demand for coal in the residential sector is declining due to pollution, unpleasant service, and low efficiency; coal stoves are being gradually replaced by air conditioners, pellets, gas boilers (Doczekal C., Radulov L., et al., 2020).

In conclusion, in 2030, no coal is expected to be used in the region outside TPPs, neither for district heating nor for individual heating of homes.

2.2 Projections for the other energy generation technologies for 2030

2.2.1 Other fossil fuels powered energy generation technologies

Overview

Natural gas is most likely the only non-coal fossil fuel that would have a serious share for energy generation[1] in South-East region (SER) in 2030. Its use is expected to increase for power generation, district heating, and individual heating, as detailed in the below sections.

Petrol has a minor share in energy consumption – 1.5% in industry (mainly in the chemical industry), 0.9% in households, and 0.2% in services (NSI, 2021). Petrol has a declining share and this trend is expected to continue until 2030, due to the environmental targets and related policy instruments.

No nuclear energy is currently produced in the region. Potential investors have expressed interest to use Small Modular Nuclear Reactors in the territory of Maritsa East complex to produce chemicals and gaseous and liquid fuels from the mined coal. As small modular nuclear reactor technology is still not mature enough and would require substantial new regulatory framework at EU and national level, its presence in 2030 energy mix of the region is unclear.

Electricity for households in Bulgaria has the lowest price in the EU - about 100 €/MWh with VAT in the 1st half of 2020 (Eurostat, 2020) and is the main source of heating in the residential and service sectors. According to the last (2011) census data, 47.8% of households in Stara Zagora region rely on electricity for heating (NSI, 2011). As air conditioning is comfortable, clean, increasingly efficient, and very appropriate for the climate in the region, its share in the residential heating is increasing and expected to further increase until 2030 (ME, 2020).

Natural gas for electricity generation

One of the priorities of the National Recovery and Resilience Plan (Council of Ministers, 2021) is the design, construction, and operation of natural gas[2] infrastructure to fuel power plants (€ 244 million).

[1] Transport vehicles (relying also on petrol) are not within the scope of this report.
[2] The term is “hydrogen and low-carbon gaseous fuels”, but it actually refers to natural gas.

According to WAM scenario of the NECP, in the period 2021-2030 there would be an 840 MW increase of the gas-fired electricity generation capacity. The Plan specifies the following investments needed for the plants (ME, 2020):

- Combined cycle gas turbine (CCGT) plants - € 321 million
- Open cycle gas turbine plants, combustion plants and gas turbine plants - € 190 million

No regional distribution of the planned capacities and investments is specified in any Government plan.

An assessment of the opportunities to replace coal by gas-fired electricity capacities in Maritsa East region concluded that a good solution would be to install 2 combined cycle gas turbine (CCGT) plants with 400 MW electrical capacity each (Mihaylov T., 2021). The units would have a high number of operation hours, because this technology is typically used in both peak and off-peak periods. For the gas supply, a connection from "Balkan Stream" pipeline to Maritsa East 2 TPP could be established (Mihaylov T., 2021).

The large-scale gas-based generation can very well be combined with intermittent distributed generation (DG). However, currently households have no interest in producing electricity – neither for their own consumption nor for sale to the electricity system (Doczekal C., Radulov L., et al., 2020). The situation is similar for the industry and service sectors, although some investments may pay back. Stimuli are therefore needed to develop DG by 2030.

Natural gas for district heating and CHP

In Burgas city there is district heating that covers about 20% of the households in the city. The heating company in Burgas has available both dedicated heat (372 MW_{th}) and CHP (18 MW_{el} and 19 MW_{th}) units, all fuelled by natural gas. It plans to continue operation using this fuel, perhaps adding a minor biomass share. The coverage of the heating system is expected to remain unchanged, as investments in expansion of district heating systems (anywhere in the country) do not pay back yet. The heat demand is also expected to remain at its current level by 2030, because the energy efficiency improvements would be offset by a higher comfort (Nikolaev I., 2021).

In Sliven, the district heating company, also covering about 20% of the city's population, is expected to switch from coal to natural gas. Similarly to Burgas until 2030, neither change of the population covered by the heating network nor change in the heat consumption is expected. It is therefore reasonable to assume that after the fuel switch the heat production capacity will remain at its current level of 98 MW_{th}, including mainly dedicated heat units, but also small CHP units covering the base heat load (Nikolaev I., 2021).

It would not be economically feasible to build new district heating systems in the region, due to the current regulatory framework, the mild climate, and lack of such territory planning. For example, Stara Zagora is a large and densely populated city, but district heating has never been planned, which would make the construction of a pipe network very problematic (Nikolaev I., 2021).

Gas-fired CHP, except for the abovementioned CHP in Burgas district heating, have only a minor role in the region. On the other hand, it is an economically feasible option, provided that the produced heat can be consumed by a single heat consumer (e.g., a large industrial enterprise) with high base heat load. The comprehensive assessment of the potential for efficient heating and cooling in Bulgaria indicates that it is likely that there is promising potential for new CHPs in Burgas District and Stara Zagora District, but no detailed assessment at plant level is available (ME, 2016).

Natural gas for small-scale/individual heat production

In Bulgaria, the natural gas consumption is relatively small. Its share in the total sectoral energy demand in 2019 is as follows (NSI, 2021):

- Industry - 30.8%
- Households - 3.5%
- Services - 7.1%.

The share of households with access to natural gas in SER on 30th June 2018 was only 1.96%, where the specific shares in the 4 Districts in the region are (NTDC, 2019):

- Stara Zagora - 3.33%
- Sliven - 0.96%
- Yambol - 4.67%
- Burgas - 0.40%

During the period 2007-2013 the gasification in the residential sector increased by 50% and in the period 2014-2018 by another 30% (NTDC, 2019). It is expected that the trend of increased gasification in the sector would continue until 2030, as this is among the priorities in the national energy policy and subsidies for connection of new households are planned (ME, 2020).

There are no data about the gas consumption in the industry and service sectors in each SER district/municipality. It is unclear how the gas consumption in these sectors would evolve until 2030. The increase of natural gas utilization is one of the priorities of the draft Energy Strategy (ME, 2021) and NCEP (ME, 2020). For example, the NECP specifies that natural gas will be made accessible in a higher number of municipalities and to more final consumers. Increase in natural gas consumption in industry and services in SER is expected by energy experts too (Mihaylov T., 2021, Nikolaev I., 2021).

2.2.2 Renewable energy and other new energy generation technologies

Wind energy

According to WAM scenario projections in the NECP (ME, 2020), between 2020 and 2030 the electricity output of wind farms is expected to increase from 1450 GWh to 2049 GWh (i.e. by 43%).

The installed wind power capacity in the region is 120.7 MW, most of which is located in Stara Zagora district (see Table 2.2), where not only the technical wind potential is the lowest, but the wind speed in the areas with technical potential is relatively low. It cannot be expected, therefore, that Stara Zagora, being the main region affected by coal transition, will put a particular emphasis on wind, in the context of other promising electricity generation alternatives. The districts of Burgas, Yambol, and Sliven would be moderately affected by the coal transition and it is still unclear whether they would receive special support for green energy generation.

During a series of workshops, meetings, and interviews carried out within TRACER project, wind energy was not discussed as a promising energy option for the region, so it is not very likely that such projects will receive special support, e.g., through the inclusion in the respective territorial just transition plan of Stara Zagora. Therefore, an assumption can be made that wind energy would develop at the average rate. In other words, it is assumed that by 2030 the generation would increase by 43% (as mentioned above) and this increase would be allocated to each district in proportion to its untapped technical potential as of 2020. The relevant calculations and the result for 2030 is presented in Table 2.2.

Table 2.2: Distribution of wind power capacity (in MW) and potential in South East Region (SER) by NUTS3 districts

District	2020 capacity*	Technical potential**	Untapped technical potential in 2020	2030 (estimated)
Burgas	16.2	14,312	14,296	74.7
Yambol	10.6	6,205	6,194	35.9
Sliven	15.2	1,674	1,659	22.0
Stara Zagora	78.8	850	771	82.0
Total	**120.7**	**23,041**	**22,920**	**214.6**

** Source: SEDA Database ** Source: Radulov et al. 2012*

<u>Solar energy</u>

According to NCEP's WAM scenario (the one achieving the Plan targets), solar energy in Bulgaria is projected to grow 3 times during the period 2020-2030 and it will continue to be used mostly for electricity production, as shown in the below table.

Table 2.3: Forecast of solar energy utilization in Bulgaria (in GWh)

	2020	2030
Electricity (solar PV)	1,402	4,652
Heat (solar thermal)	262	346
Total solar energy	1,664	4,998

Source: ME, 2020; ME, 2021

Solar PV is becoming increasingly commercial on a large scale, while for small scale installations stimuli are available as well. Solar thermal is currently not supported, but subsidies are envisaged in the National Recovery and Resilience Plan (Council of Ministers, 2021).

The southern part of South East region, in which Maritsa East coal region is located, has significant solar energy potential (1450 – 1500 kWh/m^2 annually), as shown in Figure 2.1.

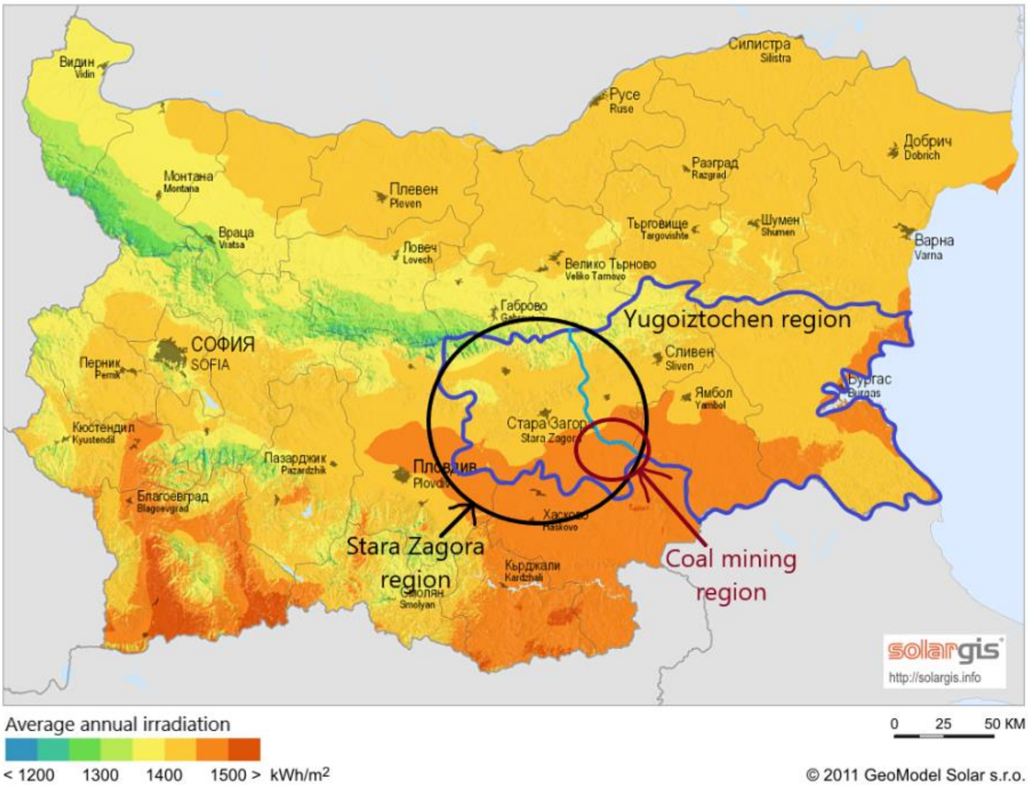


Figure 2.1: Horizontal solar irradiation in Bulgaria

Source: SolarGis.info

An opinion shared by many experts during TRACER workshops and interviews (e.g., Mihaylov T., 2021) is that large-scale solar PV is a good opportunity for the post-mining development of Maritsa-East area, as it would take advantage of the existing electricity infrastructure, the available engineer's workforce, and the unusable (degraded) land.

Table 2.4 presents data about the solar PV in South East region: 2020 capacity, 2020 energy generation, technical potential in the region, and estimated 2030 capacity. The study on the technical potential (Radulov L., et al., 2012) did not take into account the potential in the post-mining areas, as mine closure was not planned at that time, so the actual potential is higher in the 3 districts where Maritsa East is located: Yambol, Sliven and, especially, Stara Zagora.

The 2030 estimation considers the expected priority of solar PV in the 3 districts, especially in Stara Zagora, where more funding will be available through the Just Transition fund. For Burgas District, which is quite distant from the coal complex, the 2030 capacity is estimated considering the average utilization of the untapped national solar potential.

Table 2.4: Solar PV energy development in SER

	Burgas	Sliven	Stara Zagora	Yambol	SER Total
Capacity in 2020, MW*	87	92	132	110	421
Energy in 2020, GWh*	111	119	179	149	558
Technical potential, MW**	429	280	445	249	1403
Capacity in 2030, MW (estimate)	279	270	472	241	1262

** Source: SEDA, 2021*

*** Source: Radulov L., et al., 2012*

Biomass

According to the NECP, both the electricity and heat production from biomass in Bulgaria will grow during the period 2020-2030 and a part of the heat (and electricity) growth would come from the newly built biomass CHP plants, as shown in Table 2.5:

Table 2.5: Biomass-fueled electricity and heat in Bulgaria

	2020	2030
Electricity capacity (MW)	80	302
Electricity generation (GWh)	1,113	1,627
Heat production (GWh)	12,898	17,538
- incl. heat from CHP (GWh)	4	2,497

Source: ME, 2020

Although wood biomass is the most widely used fuel for heating in Bulgaria, it is less common in SER (NSI, 2011), due to the mild winters in the region and limited indigenous wood resources. There is a slow trend of replacement of inefficient firewood stoves with efficient boiler-based installations using wood pellets or chips.

Overall, biomass (unlike electricity, gas, and solar thermal) is expected to play less of a role for individual heating in the region by 2030, as users are expected to switch to more comfortable alternatives and there is increasing societal pressure to limit biomass combustion in cities, due to air pollution (Nikolaev, I., 2021, Mihaylov T., 2021).

Biomass (e.g., municipal solid waste) fueled electricity capacities are expected to increase at a rate similar to the country's average, but will continue to have a minor share.

Hydro energy

The current hydro generation capacity in SER is 57 MW, allocated per District as follows: 2 MW in Burgas, 18 MW in Sliven, and 37 MW in Stara Zagora (SEDA, 2021).

According to the NECP, during the period 2021-2030, hydroelectricity in Bulgaria is projected to stabilise at 2020 production levels (ME, 2020). This is applicable also for SER, where there is no significant potential for further hydro capacities (Mihaylov T., 2021; Doczekal C., Radulov L., et al, 2020).

Other new energy technologies

There are ongoing discussions about the opportunities to produce electrical batteries and hydrogen in Stara Zagora region, but the ideas are at a very initial stage. It is unlikely that the production of hydrogen will become commercially viable and play a serious role in the region until 2030 (Todorov T., 2021, Mihaylov T., 2021).

2.3 Projections for the energy mix of the region for 2050

The draft Strategy for Sustainable Energy Development of Republic of Bulgaria until 2030 with horizon until 2050 is the only Government document that contains clear directions for the development of the national energy sector until 2050. Key energy priorities of the draft Strategy are (ME, 2021):

- Development of electricity storage systems and better interconnections;
- Development of power-to-gas (hydrogen and methane) technologies;
- Increased distributed generation, renewables, and energy efficiency, including nearly zero energy buildings;
- Use of hydrogen for production of heat and electricity.

According to the draft Strategy, the final energy consumption of each sector – industry, residential, services, and transport – remains nearly constant during the period 2020-2050 (ME, 2021).

The draft Strategy provides the following forecasts for the gross final energy consumption and gross electricity generation in its WAM (with additional measures) scenario:

Table 2.6: Gross final energy consumption (in TWh) in Bulgaria

	2020	2030	2040	2050
Solid fuels	75	55	8	5
Petrol	51	47	42	37
Natural gas	31	36	33	47
Electricity	-8	-8	-8	-8
Nuclear energy	47	47	92	45
Hydro energy	5	5	5	5
Biomass, incl. waste	19	23	23	24
Wind energy	1	2	4	12
Solar energy	1	5	5	7
Geothermal energy	0	0	0	4
Total	**116**	**120**	**118**	**118**

Source: ME, 2021

Table 2.7: Gross electricity generation in Bulgaria (in TWh)

	2020	2030	2040	2050
Nuclear power plants	15.8	15.8	32.2	16.4
Hydro power plants	4.7	4.7	4.7	4.7
Wind power plants	1.5	2.0	4.4	11.7
Solar PV plants	1.4	4.7	4.7	6.8
Coal TPPs & CHP	22.6	16.8	1.4	0.7
Natural gas TPPs & CHP	2.2	5.1	4.2	11.4
Biomass TPPs	0.3	1.8	1.7	2.0
Total	**48.5**	**51.0**	**53.3**	**54.1**

Source: ME, 2021

Table 2.6 and 2.Table **2.7** show the serious decrease of solid fuel (coal), especially in the period 2031-2040. This is partly balanced by the increase of renewables - solar PV, wind, biomass, and geothermal – both in the electricity generation and elsewhere. New nuclear capacities are expected to be built before the shutdown of the existing ones and will compensate to some extent the closed coal TPPs. Natural gas consumption will generally increase in the period until 2050, but its use for electricity will be minor in the second half of that period.

Another study (Nikolaev A., Radulov L., 2018) provides somewhat similar results, but there are two results that are quite different from the draft Strategy. In particular, the study concludes that to fit within its (estimated) carbon budget for the period 2020-2050 at reasonable costs, Bulgaria must:

- Substantially reduce its total final energy consumption (in particular, the projected value for 2050 is by 34% lower than in 2020);
- Coal must be phased out until 2030. Respectively, much higher natural gas electric capacities would be needed by then.

There are neither specific plans nor advanced concepts for the energy development in SER beyond 2030. The natural gas electricity capacities, expected to start operation during the period 2025-2030, would gradually become less relevant with the development of better electricity interconnections, electricity storage (including electromobilies), power-to-gas (hydrogen), and expected increase of carbon emission allowances. Anyway, natural gas is expected to play an important intermediary role to balance the intermittent renewable energy generation until 2035-2040 (Nikolaev A., Radulov L., 2018).

Solar PV is expected to continue its sharp increase even beyond 2030, due to the high solar energy potential in the region. Wind is also expected to grow quickly in the eastern part of SER, where wind energy potential is significant, but no notable development is expected in the western part, where the coal mining complex is located.

During some of the TRACER workshops, it was discussed that the region can become specialized in the production and use of electric batteries and hydrogen technologies, taking advantage of the engineering traditions and available workforce.

In the heating sector, district heating holds a large untapped potential. It is expected that biomass CHP and solar thermal would become increasingly attractive sources for district heating (Nikolaev I., 2021). Additionally, the electrification of the individual heating using heat pumps is expected to continue beyond 2030 (Mihaylov T., 2021).

2.4 References

COUNCIL OF MINISTERS (2021) National recovery and resilience plan of the Republic of Bulgaria, Version 1.1 from 8th February 2021. https://www.nextgeneration.bg/upload/38/npvu08022021.pdf

DOCZEKAL C., RADULOV L., NIKOLAEV, A., ET AL. (2020) Technical concepts for the transition of the energy system into a smart, sustainable and renewable energy system in the TRACER target regions, Deliverable 3.2, Horizon 2020 project 836819 “TRACER”, https://tracer-h2020.eu/wp-content/uploads/2020/08/TRACER-D3.2-Technical-Concepts.pdf

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

EC (2020) COMMISSION STAFF WORKING DOCUMENT. Assessment of the final national energy and climate plan of Bulgaria, Brussels, 14.10.2020, SWD (2020) 901 final, https://ec.europa.eu/energy/sites/default/files/documents/staff_working_document_assessment_necp_bulgaria_en.pdf

EUROSTAT (2020) Electricity prices for household consumers, first half 2020. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Electricity_prices_for_household_consumers,_first_half_2020_(EUR_per_kWh) _v4.png

MIHAYLOV T. (2021) Personal interview with Mr. Todor Mihaylov, energy expert, held on 19th February 2021.

MINISTRY OF ENERGY (ME) (2016) Comprehensive assessments of the potential for efficient heating and cooling in the Republic of Bulgaria. https://ec.europa.eu/energy/sites/ener/files/documents/bul_chp.pdf

MINISTRY OF ENERGY (ME) (2020) Integrated energy and climate plan of the Republic of Bulgaria 2021–2030 https://ec.europa.eu/energy/sites/ener/files/documents/bg_final_necp_main_en.pdf

MINISTRY OF ENERGY (ME) (2021) Strategy for Sustainable Energy Development of Republic of Bulgaria until 2030 with horizon until 2050. Draft version, under public consultation.

NATIONAL STATISTICAL INSTITUTE (2011) Census data https://www.nsi.bg/census2011/indexen.php

NATIONAL STATISTICAL INSTITUTE (2021) 2019 National Energy Balances, published on 29.01.2021. https://www.nsi.bg/bg/content/4196/%D0%BE%D0%B1%D1%89-%D0%B5%D0%BD%D0%B5%D1%80%D0%B3%D0%B8%D0%B5%D0%BD-%D0%B1%D0%B0%D0%BB%D0%B0%D0%BD%D1%81

NIKOLAEV A., RADULOV L. (2018) MEDEAS Model and IOA implementation at country level: the cases of Austria and Bulgaria: Case study with LEAP-Bulgaria. Deliverable 4.3 (Confidential), Project Nr: 691287 MEDEAS.

NIKOLAEV I. (2021) Personal interview with Mr. Iliya Nikolaev, Chairman of the Bulgarian District Heating Association, held on 18th February 2021.

NTDC - NATIONAL TERRITORIAL DEVELOPMENT CENTRE (2019) Socio – economic analysis of the regions in Republic of Bulgaria. https://www.eufunds.bg/bg/oprd/node/2816

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

SEDA – SUSTAINABLE ENERGY DEVELOPMENT AGENCY (2021) Database for renewable energy by Districts. https://portal.seea.government.bg/bg/EnergyByRegionAndRip

TODOROV T. (2021) Personal interview with Mr. Todor Todorov, energy transition expert, held on 19th February 2021.

3 Czech Republic, North-West Bohemia

At the beginning, a summary of current energy consumption and production in the Czech Republic in 2019 is presented (ERO, 2020). Electricity consumption in the Czech Republic, after five years of continuous growth, which culminated in a new record in 2018, stagnated in 2019 and reached 73.9 TWh. Year-on-year, households consumed more electricity (+1.4%) and the consumption of large customers at the very high voltage level (+0.3%) also grew slightly. On the other hand, lower consumption was recorded by large customers at the high voltage level (-1.6%) and small business customers (-0.6%). Electricity production (gross) in the Czech Republic in year-on-year comparison in 2019 decreased by 1 TWh (-1.1%) to a total of 87 TWh. The largest decline in production is shown for steam power plants (-8.2%), while production in steam-gas power plants strengthened the most (+49.5%). Growing production in nuclear power plants (+1.1%) also counteracted the overall decline trend.

At the same time, a significant increase in renewables took place. Their production reached the limit of 10 TWh, which is the highest value ever measured. Production in large hydropower plants (+30.7%) strengthened by almost a third, followed by small hydropower plants (+17.1%), wind power plants (+14.9%) and biomass (+13.1%). Less electricity was produced by photovoltaic power plants (-2.3%) and plants burning biogas (-3.1%). Internationally, the Czech Republic still exports more electricity than it imports. However, cross-border flows of electricity weakened year-on-year in both directions. Imports fell by 5.3% and exports by 4.7%. In 2019, electricity exports reached the lowest value in the last ten years.

From the point of view of individual regions, as of 31 December 2019, more than a quarter of the nationwide capacity of the electricity system was installed in the Ústí nad Labem Region (5,659 MW), followed by the South Bohemian Region with a 13.2% share (2,899 MW) and the Central Bohemian Region with 12.7% share (2,789 MW). At the opposite end of the scale are the Capital City of Prague (200 MW, 0.9% of the total installed capacity) and the Liberec Region (1.1%, i.e. 234 MW).

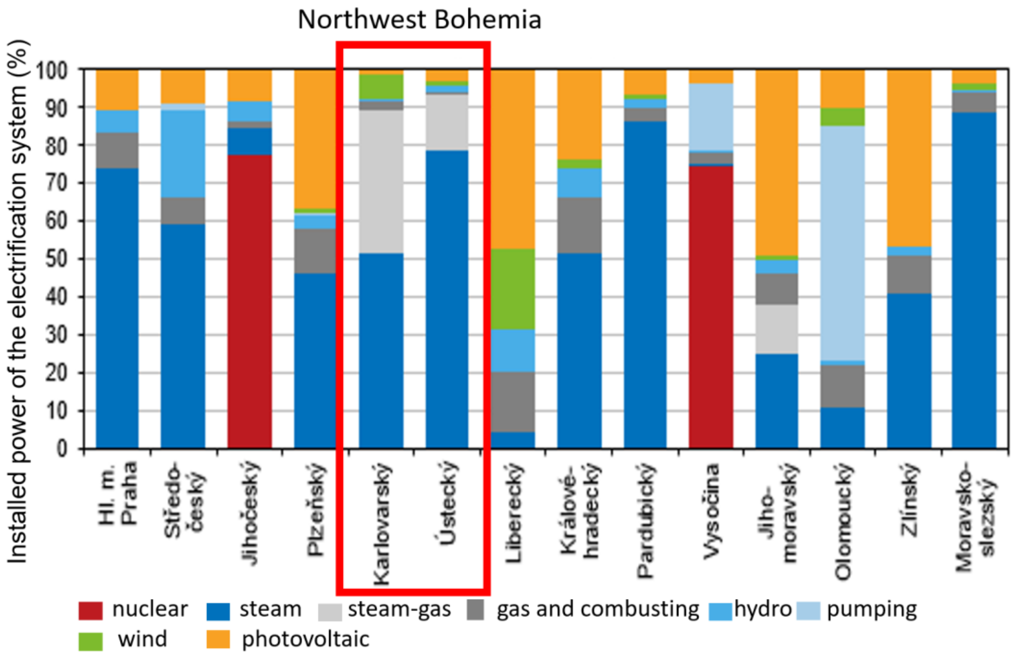


Figure 3.1: Electricity production in 2019 by region (CSO, 2020)

Gas imports to the Czech Republic (including transit) reached the value of 36,127 million m^3 in 2019, which corresponds to a year-on-year decrease of 9.2%. In addition to imports, the production of natural gas in the Czech Republic also decreased, falling to 131 million m^3. From the point of view of customer categories, the highest gas consumption has traditionally been achieved by the category of large customers (49.0%), followed by households (25.4%), small customers (14.0%) and medium-sized customers (9.8%). Although 2019 was again above average in temperature (average annual temperature reached 9.8°C), which caused lower gas consumption for heating, the growing needs of gas-fired power plants acted in the opposite direction. The increase was also evident in deliveries to CNG stations.

Almost 162 PJ of heat (gross) was produced in the Czech Republic in 2019, which means a year-on-year decrease of 0.8%. Heat supply also decreased to 87.5 PJ (-1.7%). Compared to 2018, the composition of resources changed only slightly, with brown coal (42%) continuing to play a significant role, followed by natural gas (19%) and biomass (12%). The Moravian-Silesian Region (19.1%) again took the lead in heat production, followed by the Ústí nad Labem Region (18.7%) and the Central Bohemian Region (17.1%). The combined production of electricity and heat, which produced 99 PJ of useful heat, fell more than the average of heating plants, which means a year-on-year decrease of 2.9%. The majority of heat was produced from brown coal (54.9%), followed by biomass (12.9%) and natural gas (11.6%). In terms of heat consumed, the largest customers are still households (42%), industry (28%) and the trade and services sector (23%).

The source of information on energy in North-West Bohemia is mainly the update of the Territorial Energy Concept of the Ústí nad Labem and Karlovy Vary regions, which were prepared on the basis of Section 4 of Act No. 406/2000 Coll. on Energy Management. Data from the State Energy Concept, publicly available information from the Coal Commission meetings and information obtained during interviews with relevant stakeholders (e.g., regional energy companies) were also used. An essential source is the State Energy Concept, with which both regional concepts are in agreement, also because the Karlovy Vary and Ústí nad Labem regions supply energy to the majority of the population of the Czech Republic.

Regional concepts analyse trends in the development of energy demand, settlement structure and climatic conditions, on the basis of which it is possible to analyse the possibilities of production and the extent of energy consumption. They also examine the structure of energy consumers (household, public and business sectors) and quantify the energy intensity of these sectors, analyse possible sources and ways of energy management, deal with energy availability, assess the usability of renewable and secondary sources, propose potential energy savings. The conception for the Ústí nad Labem region is elaborated for the period until 2044, while for the Karlovy Vary region until 2042.

3.1 Projections for the energy generation technologies using coal for 2030

3.1.1 Coal driven thermal power (TP) and CHP plants

The production and supply of heat has a local character, and therefore a local price, and is essential for both the economy and households. The main long-term goal is to maintain and repair existing energy supply systems and ensure the conditions for changing and increasing the efficiency of local heat production. The availability and preferential supply of coal to high-efficiency heat supply systems at the expense of low-efficiency sources will help ensure economic sustainability and increase competitiveness. Therefore, it appears to be significant support for cogeneration production, especially lignite heating plants with the use of heat pumps in all heating plants. The transition also refers to households that are expected to switch from direct heating and storage systems to heat pumps.

Legislative and administrative regulations are tools for favouring efficient resources. These will lead to the support of CHP in the heating industry and, on the contrary, to the penalty of condensing electricity production or higher mining fees. The orientation of households, micro-cogeneration sources, small and medium-sized heating systems will be to use natural gas, which will lead to a reduction in airborne dust concentrations. Natural gas will function as a stabilizing and supplementary fuel (MIT, 2014). The fuel mix in households in the Karlovy Vary region will change towards biomass and heat pumps with possible replenishment with natural gas (PECH, 2018).

Compared to 2000, the consumption of brown coal in households in the Ústí nad Labem Region decreased by 60%. It is mostly replaced by biomass and partly by natural gas. Targets in the area of coal energy transformation led to a reduction in coal consumption in primary energy consumption by 45% by 2044. Depending on the cessation of lignite mining, production will be shut down. With the help of the replacement of coal boilers in households and the use of former mining pits with emission-free sources, the energy focus of the region on the transition to carbon-free energy is being prepared. Reclamation of lignite quarries by wind farms in conjunction with pumped storage power plants is planned, which will significantly reduce air emissions (KLICPERA, 2019).

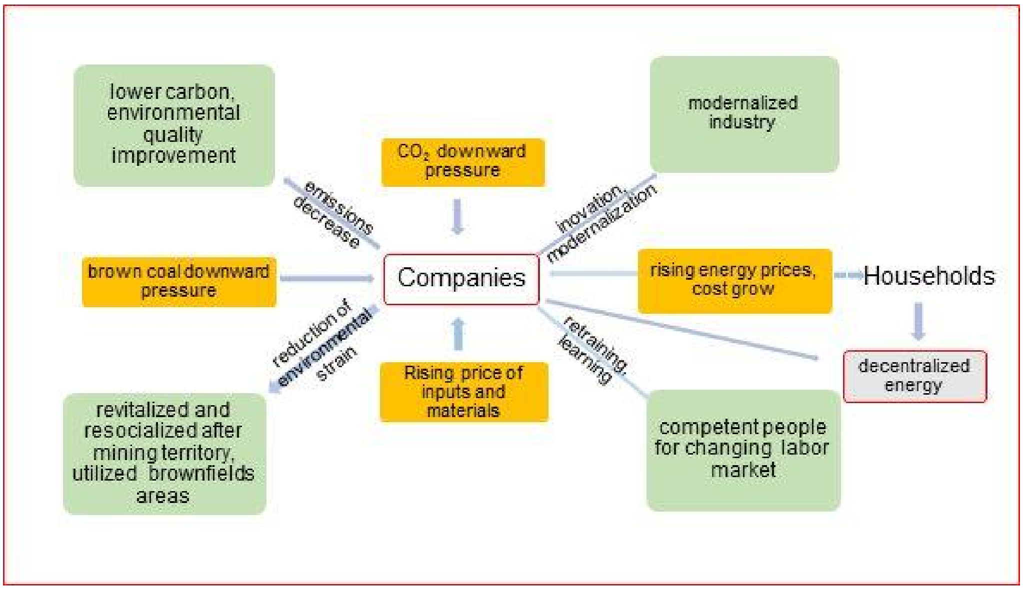


Figure 3.2 Simplified overview of external influences of economic transformation and basic directions of transformation

Source: Coal Commision, 2021a

Various scenarios of future development for the cessation of lignite mining are presented by the Coal Commission, which consider the years 2033, 2038 and 2044. In all assessed years, coal decline is possible, provided that self-sufficiency and safety will not be disrupted. However, the construction of sufficient production capacity is an essential condition. For example, in 2033, the cessation of coal mining will be associated with higher costs, while the impacts on accumulated emissions will not be so significant (Coal Commision, 2021, b). Transformation is not possible without new solutions in energy in general. Modernization of infrastructure, decentralization of existing and construction of new energy sources will require investments. The effects on the change in the business economy are shown in Figure 3.2 (above).

3.1.2 Other coal-fired energy generation applications

The Territorial Energy Concept of the Karlovy Vary Region (PECH, 2018) states the following diversification of electricity generation: steam power plants (production volume decreases), steam - gas power plants, wind power plants (with a high share of electricity production), gas and coal combusting power plants, hydroelectric power plants (including pumped storage), and photovoltaic power plants. The largest share of production from renewable energy sources stands for wind power with an installed capacity of 52.1 MW, followed by photovoltaics, hydro and biogas.

The Karlovy Vary region respects the concept of the development of the electricity system, which supplies the area with a 110 kV distribution network. In terms of electricity consumption, the largest consumers are the trade, services, education, and healthcare sectors. Other consumers are the industrial, household and energy sectors. The transport, construction and agriculture sectors account for around 1%, i.e., quite negligible electricity consumption. However, the transport sector is dominant in the consumption of energy in the form of fuels, in various types of means of transport.

The household sector is mainly equipped with central heating, single heating, single - storey heating or stoves. The supply of heat energy most often takes place from the boiler room outside the house, where coal, coke and coal briquettes are still widely used. The fuel mix of households varies from the consumption of brown coal to biomass, heat pumps and natural gas. Natural gas, electricity, wood and wood briquettes will increase their share in the future as the permitted emission class of boilers increases. From 2022, for example, it will no longer be possible to use boilers of the 1st and 2nd emission classes, but only of the 4th emission class and higher. Consumption of firewood will also stagnate, as it should gradually switch to pellets, whose modern automatic boilers will be more accessible. Most of the replacements for old coal sources and electric boilers are made thanks to grants.

Solar thermal systems, which are used to heat hot water, use storage tanks. These systems should replace automatic and manual feed solid fuel boilers that use exclusively coal or automatic biomass and coal boilers. To reduce the need for heating, the energy intensity of buildings should be reduced by improving their thermal properties via thermal insulation, replacement of openings and modernization of heat sources to more efficient ones. The development of the energy intensity reduction of the non-production area and the replacement of low-efficiency sources will depend on the economic situation of the region, energy and fuel prices, and grants.

The manufacturing sector is considering a similar as in the household sector forecast until 2030, especially in reducing the energy consumption of buildings and replacing existing boilers with more modern ones with higher efficiency. An example can be the construction of a 9 MW_{th} fluidized bed boiler with the expected use of 15-16 thousand tons/year of brown coal, i.e., a decrease in coal consumption by 2/3 from the original consumption of 50 thousand tons/year. The decommissioning of coal-fired boilers should take place by 2022. Until then, in addition to the modernization of cogeneration boilers, the construction of plants for the combustion of lignite dust and the greening with new furnace linings should also take place. All this should lead to compliance with emission limits, increased production efficiency and reduced operating costs.

3.2 Projections for the other energy generation technologies for 2030

3.2.1 Other fossil fuels powered energy generation technologies

Oil and its products are an important primary source of energy, despite the gradual reduction of their weight in the source mix. Utilization is also monitored in other related sectors, such as petrochemicals, with regard to fuels for the transport sector or to raw materials for the chemical industry. There are three ways to reduce transport sector's dependence on oil products:

1. Development of new fuels in transport from domestic sources or from areas with less political instability (coal, natural gas) and from renewable sources;
2. To increase energy efficiency (technical modifications to engines, hybrid engines, etc.);
3. To make greater use of those modes of transport that are more energy efficient.

Furthermore, fuel savings achieved by reducing the number of journeys or replacing shorter journeys for passenger transport with non-motorized modes of transport will make a positive contribution to reducing energy dependence and emissions from transport.

The Czech Republic is completely dependent on oil imports from abroad and, since it is a key commodity, it is necessary to maintain emergency stocks. Maintaining capacity self-sufficiency and transit of oil through the Czech Republic is an essential element of the Czech energy sector. The main goals were to use the available capacities of the IKL and the southern branch of Družba oil pipelines, to increase stocks with a view to up to 120 days of net imports, to support domestic oil processing and to reduce imports of oil products. On the contrary, it is essential to create conditions for the export of these products to the countries of Central and Eastern Europe (MIT, 2014).

By 2040, natural gas will be an important resource, enabling the gradual transition of solid fuels in final consumption and small heat supply systems, the partial offsetting of coal supply disruptions and the abandonment of liquid fuels in transport. To ensure security of supply, it is necessary to diversify sources and transport routes with increasing storage capacity. The completion of the N-1 infrastructure standard and the interconnection of the domestic system with foreign ones (Poland, Slovakia, Austria, and Hungary), including the possibility of reverse flow, will be helped by the completion of the Gazela gas pipeline and, then, of STORK II and BACI.

Even in the issue of the main objectives of the natural gas commodity, the renewal and development of distribution networks associated with the territorial protection of areas and corridors through the Territorial Development Policy of the Czech Republic and a high degree of operational cooperation are essential.

The energy conception of the Karlovy Vary region addresses the issue primarily from the point of view of oil security and reliability in gas supply, which most affect relations between the EU and the Russian Federation. The concept of emergencies is based on existing legislation, which is based on emergency measures of the International Energy Agency (IEA), the EU, the National Organization for Oil Strategy (NESO) and the national data collection system for relevant statistics (PECH, 2018).

Similarly, the concept of security is essential in the conception of the Ústí Region (KLICPERA, 2019). In the event of an oil emergency, the backup sources will be supplied from the warehouses of the State Administration of Material Reserves (SSHR), which are to contain a 90-day supply of oil and its products. The region has 550 petrol stations and 320 of them are public. Only a few of them are equipped with their own backup system, such as a backup generator or a hand pump, in case of long-term outages. The development of natural gas as an energy source is fully in line with the State Energy Concept.

Measures of the Ústí Region to reduce the effects of energy are already largely implemented. Combined heat and power generation is being developed, distribution is being modernized, thus reducing losses in the production and distribution of thermal energy and, last but not least, replacing old condensing systems with more powerful ones corresponding to emission class 3 and higher, in accordance with air protection legislation.

3.2.2 Renewable energy and other new energy generation technologies

The expected development and structure of renewable resources and secondary sources on primary energy sources in Czech Republic for 2010 – 2040 is shown in the following Table 3.1.

Table 3.8: Development and structure of renewable resources and secondary sources on primary energy sources in the Czech Republic (MIT, 2014)

Year	*2010*	*2015*	*2020*	*2025*	*2030*	*2035*	*2040*
	[PJ]	[PJ]	[PJ]	[PJ]	[PJ]	[PJ]	[PJ]
Biomass	82,7	92,7	104,7	116,6	130,4	144,6	159,9
Biogas	7,4	22,1	27,1	28,8	31,1	33,5	35,9
Biodegradable part of SMW	2,6	3,3	4,7	9,9	13,3	13,3	13,3
Biodegradable part of IW and AF	1	1	1	1	1	1	1
Biofuels	9,8	18,3	28,1	28,1	28,1	28,1	28,1
Water power stations	10	8,9	9,1	9,1	9,1	9,1	9,1
Wind power stations	1,2	2,3	3,6	4,8	5,8	7	8,2
Photovoltaic power stations	2,2	8,2	8,7	12,8	12,8	17	21,2
Geothermal energy	0	0	0,7	1	1,2	1,7	2,5
Heat pumps	1,8	3,7	6,6	8,9	11,2	13,4	15,7
Solar collectors	0,4	0,8	1,4	3	3,5	5	5
Total	**119,1**	**161,4**	**195,6**	**223,9**	**247,5**	**273,7**	**299,8**

Note: SMW – solid municipal waste, IW – industrial waste, AF – alternative fuels

As of 2016, 1,614 (small) hydropower plants with an installed capacity of up to 10 MW and a total capacity of 348 MW were in operation in the Czech Republic. In Karlovy Vary region, the energy potential of hydropower plants seems to be exhausted. Only small upgrades are expected to increase installed capacity and efficiency. The outlook for 2030 lies in the installation of modern and more efficient turbines to streamline the work of existing facilities. The construction of small hydropower plants up to 10 MW comes into consideration in the places of older water works, such as iron-mills, mills, etc. It is planned to build 9 small hydropower plants and 5 reservoirs for the accumulation of surface water. This would bring to the region a new capacity of 783 kW and an increase in production by 2,221 MWh/year, i.e. by 10.43%. The annual production of electricity from hydropower plants corresponds to 14% of electricity from renewable sources produced in the Karlovy Vary region.

Areas selected for the use of wind energy are localities with a measured average wind speed of 8.5 m/s. The frequency of wind energy use is unlikely to increase due to the flat terrain of the Czech Republic. As of 2016, 127 wind power plants with a total capacity of 285 MW were in operation in the Czech Republic. The annual production of electricity from wind power plants corresponds to approximately 57% of electricity from renewable sources produced in the Karlovy Vary region.

As of 2016, 28,341 photovoltaic power plants with a total output of 2,127 MWp were in operation in the Czech Republic. The annual production of electricity from photovoltaic power plants corresponds to approximately 8% of electricity from renewable sources produced in the Karlovy Vary region.

One of the most promising renewable sources is the use of biomass. This can be from waste biomass from agriculture, food industry, forest production, municipal organic waste, etc., or from energy crops. The most common is direct combustion of wood biomass as well as wood pellets and lump wood, totalling to a heat generation of 1434 TJ/year. As of 2016, 93 biomass power plants with a total output of 2,988 MW were in operation in the Czech Republic. The annual production of electricity from biomass represents approximately 2% of electricity from renewable sources produced in the Karlovy Vary region.

There is no facility in the Karlovy Vary region for the energy use of biodegradable municipal waste. With regard to the limitation of landfilling by 2024, there is a high potential for using it for energetic purposes. By 2030, the development will lead to a trend of pre-treatment and an increased level of biodegradable municipal waste utilization. At the same time, burning MSW in industrial facilities will replace the missing fossil fuels. Installations using biogas are mainly agricultural enterprises, wastewater treatment plants or landfills.

As of 2016, 422 biogas plants with a total capacity of 333 MW were in operation in the Czech Republic (PECH, 2018). The annual production of electricity from biogas represents approximately 20% of electricity from renewable sources produced in the Karlovy Vary region. A higher share of energy from renewable sources is being considered in the gradual transition to transport using fuels with increased share of renewable sources (MIT, 2017).

The current production of electricity from renewable sources has a lower average in the Ústí nad Labem Region compared to the Czech Republic. The most developed of all sectors is wind energy. However, the most important is the production of electricity from biomass for which there is also a high potential for future development. In the future, priority will be given to directing biomass to small stationary sources, where it will replace brown coal. The technically usable potential of the energy use of biomass reaches 10351703 GJ/year. The highest usable potential is for energy crops at 6268750 GJ/yr. The highest current use is achieved by biogas from maize and waste from animal production: 684360 GJ/yr. The price of thermal energy from biomass and other renewable sources ranges from CZK 116,953/GJ from the primary distribution system to CZK 635,245/GJ from the house transfer station.

Biogas from wastewater treatment plants is used in many cogeneration units as fuel for internal combustion engines. The production of 8314 MWh/yr of electricity is ensured by cogeneration units using landfill gas with an installed capacity of 2.0 MW_e.

An increase in photovoltaic power plants with installation on the roofs of houses, commercial buildings and industrial facilities is expected. Despite its potential, wind energy does not find suitable locations, so its further development is not expected. The intention of the region is the construction of pumped storage hydropower plants using mining lakes as a lower buffer tank. Since 2030, the operation of a plant using deep geothermal energy has been considered. Its installed electrical power will be 5 MW_e.

The goal of the Ústí Region is:

- Increasing the share of renewables by 11% in primary energy consumption by 2044;
- Increasing the energy use of wastes after material recycling;
- Developing the use of heat pumps, solar collectors, photovoltaic systems;
- Increasing the share of electricity production from CHP to 8% in 2044;
- Developing biogas plants in agricultural lands (KLICPERA, 2019).

The State Energy Concept of the Czech Republic (MIT, 2014) practically does not include the hydrogen-based technology, which however is becoming an increasingly interesting and discussed topic for the Ústí nad Labem Region. Despite the fact that no surplus of renewable energy from which green hydrogen could be produced is expected in the following period, it will be necessary to supplement it to the conception.

3.3 Projections for the energy mix of the region for 2050

The national strategy in the field of climate protection is heading towards 2030, with a view to 2050, and contributes to the long-term transition to a sustainable low-emission economy in the Czech Republic. The climate protection policy represents the concept of the government, which determines the basic and indicative goals of the Czech Republic's long-term strategy on low-carbon development until 2050. In the areas concerned, i.e. energy (in particular final energy consumption), industry, transport, agriculture and forestry, waste management, as well as science and research, it defines specific measures and instruments for the gradual reduction of greenhouse gas emissions, taking into account the economically viable potential. One of the tools for the transition to a low-carbon economy is energy savings (MoE, 2017).

Electricity will play a major role in the low carbon economy. In the future, it can partially replace fossil fuels in transport and heating, and its zero-emission production can be achieved by 2050.

In 2014, combustion processes accounted for 82% of total greenhouse gas emissions. The sector includes the entire energy industry, fuel combustion in transport, services and households. The industrial sector accounted for 11% of total emissions and the sector of agriculture for 6.5%. Compared to 2005, the main goal was to reduce the Czech Republic's emissions by 32 Mt CO_{2eq} by 2020 and by 44 Mt CO_{2eq} by 2030. The indicative long-term goals were set at the level of 70 Mt CO_{2eq} emissions in 2040 and 39 Mt CO_{2eq} in 2050. Compared to 1990, the Czech Republic has committed to reduce greenhouse gas emissions by 20% by 2020, by 40% by 2030 and by 80-95% by 2050 (MoE, 2017).

The State Energy Concept of the Czech Republic (MIT, 2014) incorporates the reduction of emissions produced by the energy sector and the pressure to increase efficiency and savings in production and consumption. It lists five main priorities of the Czech energy sector:

1. Balanced energy mix - expanding the portfolio of primary energy sources and electricity generation and their efficient use.
2. Savings and efficiency - increasing energy efficiency and achieving energy savings throughout the economy sectors and in households.
3. Infrastructure and international cooperation - support and development of the common energy policy of the EU and the network infrastructure of the Czech Republic.
4. Research, development and innovation – qualitative improvement of technical intelligence in the field of energy leading to higher competitiveness.
5. Energy security – strengthening the provision of the necessary energy supply in the event of accumulation of failures, fuel supply crises or attacks on critical infrastructure.

The main motive for the balanced mix of resources is the use of all domestic energy sources and the maintenance of a surplus power balance of the electricity system. This will lead to the maximum economically meaningful size of the system, which will gradually move from the combustion of coal and obsolete sources to other highly efficient fuels (MIT, 2017).

The strategy for the energy mix until 2040 envisages the gradual replacement of coal energy by nuclear production and an increase in the share of secondary and renewable sources. The development of renewable energy sources to achieve at least a 18% share in electricity generation will be conditional on state support. Waste-to-energy plants will significantly increase the use of waste and target up to 100% use of the combustible component. Sustaining electricity production from coal exclusively in high-efficiency sources will target values of approximately 9 - 14 TWh/year. Heat supply systems and their renewal and stabilization will be based primarily on domestic sources of nuclear energy, coal, renewable energy sources, and secondary sources, supplemented by natural gas. The storage capacity will be used together with heat pumps. The heating plants will gradually switch to cogeneration (combined heat and power) production.

The share of natural gas in electricity production will increase, as its importance in local consumption and use for CHP and partly also in condensing production will increase. Natural gas plants will be of small outputs, micro-cogeneration, or top or backup. On the contrary, the consumption of liquid fuels will gradually decrease, which will be caused by increased efficiency, increased electrification of public transport, increased use of LNG, CNG, and increased electromobility. Electricity exports will decline (MIT, 2014).

The optimized scenario of energy development until 2040 presents the expected development and structure of final energy consumption. The projected values are given in Table 3.2 and the structure in Figure 3.3 below.

Table 3.9: Development and structure of final energy consumption

Final consumption of energy [PJ]								
Year	Black coal	Brown coal	Natural gas	Crude oil and petroleum products	Electricity	Heat	Other fuels	Total
2020	30,9	44,8	276,9	329,1	218,8	116,4	139,4	1 156,20
2025	30,8	29,6	280,7	322,6	236,2	115,7	149,2	1 164,80
2030	26,7	26,2	289,7	304,8	248,8	112,2	155,6	1 164,00
2035	27,1	20,2	294,6	283,4	258,7	113,9	162,1	1 160,00
2040	26,7	11,3	298	260,5	266,7	113,7	169,6	1 146,40

Source: MIT, 2014

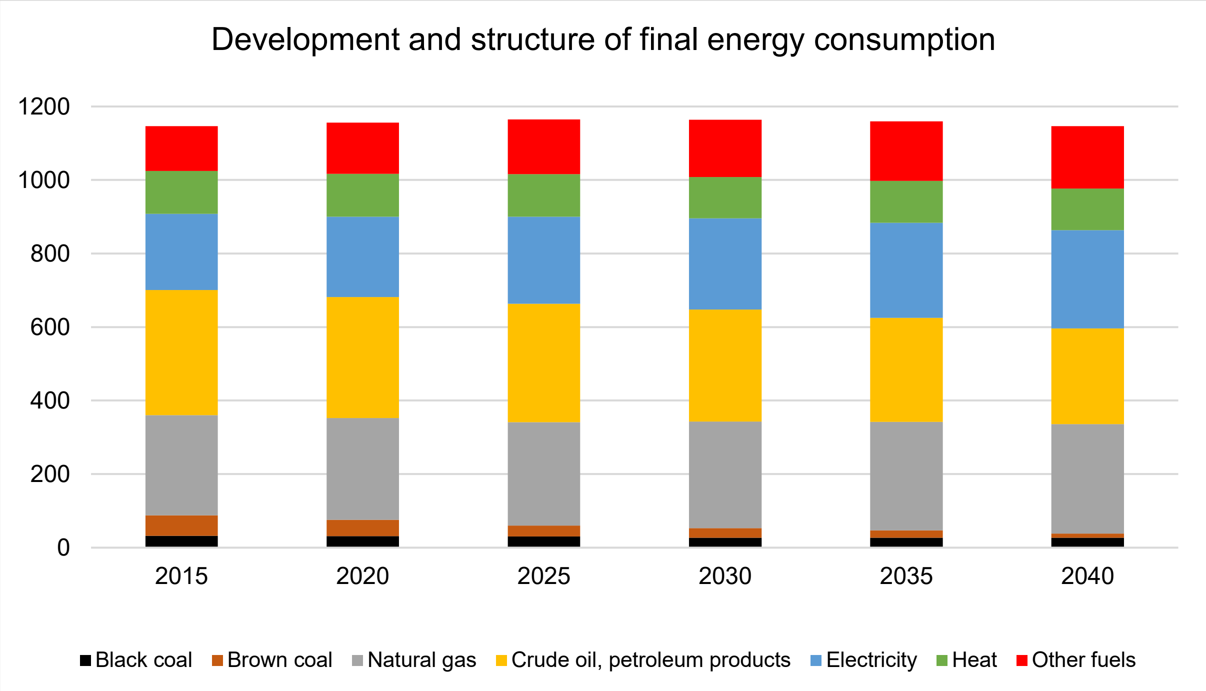


Figure 3.3: Projected distribution of final energy consumption until 2040

Source: MIT, 2014

As both regions, Ústí nad Labem and Karlovy Vary, participate in the energy supply of a large number of inhabitants of the Czech Republic, there is a need for decentralization of the distribution system. The Energy 4.0 concept (ICUK, 2020) addresses this issue. It states that the mainstays of the distribution system are smart and backbone networks, which will gradually reduce the share of energy consumption, and smart grids (divided into prosumers, consumers and resources). The transformation process should also include cooperation between energy and information networks. The use of smart grids within decentralization should take place in connection with cities and the National Action Plan for Smart Grids. This will enable effective negotiation of, among other things, the supplier-consumer profile between network elements in peer-to-peer mode (ICUK, 2020).

Long-term reduction of energy costs works as an important tool for higher economic competitiveness. A functional approach to reducing the use of fossil fuels as a result of quality implementation of renovation projects for both households and industrial buildings leads to a reduction in greenhouse gas emissions and local pollution.

The transport policy of Czech Republic for the period 2014 - 2020 with a view to 2050 aims at reducing dependence on oil imports and reducing carbon emissions in transport by 60%. Road transport has the most significant share in energy consumption in transport. Air transport is not yet performing as well as road transport, but air transport is growing the fastest. In the future, it is necessary to reduce dependence on oil in transport, respectively on petroleum-derived fuels, increase the share of alternative fuels in transport, and build sufficient infrastructure for alternative propulsion vehicles (natural gas, electricity). To reduce the environmental impacts arising in connection with this sector (emissions, migration permeability of the landscape, including watercourses), it is necessary to maintain or improve the mobility of the population not only within urban agglomerations but also at the regional, national or interstate level (MIT, 2014).

Approximately 2,000 heat plants are registered in the heat supply system, of which 1,800 have an output of more than 5 MW_{th}. The heat supply system can remotely supply approximately 40% of households and its length is close to 10,000 km. Less than 15% of it, i.e. 1458 km, consists of a steam network, 900 km of which needs reconstruction (switch to a hot water network could lead to annual savings of up to 5.2 PJ of energy). The cost of a complete reconstruction of steam pipelines to hot water pipelines is estimated to be between CZK 19 and 24 billion.

In the future, it seems essential to ensure operational support for high-efficiency CHP and heat from RES (MIT, 2015).

The Czech Republic is a country with a developed chemical industry which, in our conditions, is practically the only producer and consumer of hydrogen. The average emission footprint of hydrogen produced in the Czech Republic is currently 116 gCO_2/MJ. Hydrogen is formally anchored in Czech legislation only as a fuel for transport. It is not one of the gases defined in the Energy Act, while there is no certification tool for guaranteeing the origin of low-emission hydrogen, distribution standards or safety regulations for technologies. Legislative changes and awareness-raising are therefore needed, inter alia, to facilitate cross-border cooperation with future partners who already make greater use of water.

The Ministry of Industry and Trade is currently finalizing the Hydrogen Strategy of the Czech Republic 2021. Hydrogen is to be used in transport, where it will gradually replace diesel (petrol), in industry, where it will replace coal, natural gas, oil fractions and other fuels, or in metallurgy, where it will serve as a substitute for coal as a reducing agent in iron production. Over time, the ratio between hydrogen imported into and produced in the Czech Republic will probably change. In the initial stages, it will be necessary to produce low-emission hydrogen directly in the Czech Republic, because imports would significantly increase its price. In 2030, the Czech Republic is expected to produce and consume around 57,000 tons/yr of hydrogen, while in 2050 the production will be 350,000 tons/year, but consumption will be over 500,000 tons/yr.

For the development of the use of hydrogen, it will be necessary to ensure not only the production and use of hydrogen, but also the production and service of hydrogen technologies, for which it will be necessary to support research & development and education. In the transport sector, the commercial use of hydrogen is expected to take place between 2032-35. In the chemical industry, grey hydrogen could be replaced by green also after 2030, with natural gas replacement only after 2040. It will be more problematic to transport hydrogen for possible use in households as, based on previous tests, it is possible to mix a maximum of 2% of hydrogen into natural gas distribution systems without the need to make any changes to the terminal equipment. There is currently ongoing work on technologies where energy produced from renewable sources could be stored in hydrogen and then electricity can be produced from it again. From 1 GWh of electricity, it is possible to produce almost 18 tons of hydrogen using 159 m^3 of water. Combustion of 1 kg of hydrogen in the same technological plant where natural gas is burned saves about 6.7 kg of CO_2.

There is a Hydrogen Platform in the Ústí Region, which shapes current and future hydrogen producers. The first hydrogen fuelled bus and its filling station are already in trial operation. Research projects are being prepared, such as testing of floating solar power plants in combination with hydrogen technologies on water surfaces created by reclamation of a lignite dump.

3.4 References

COAL COMMISSION (2021) Summary outputs of working group No. 1, Annex No. 2 of the material Interim outputs and recommendations of the Coal Commission, Prague, Czech Republic, [online]: https://www.komora.cz/legislation/15-21-prubezne-vystupy-a-doporuceni-uhelne-komise-t15-2-2021-do-12h/

COAL COMMISSION (2021) Mechanism of action of energy transformation and abatement of coal mining (based on the description in the Strategic Framework for Economic Restructuring), Annex No. 3 of the material Interim outputs and recommendations of the Coal Commission, Prague, Czech Republic, [online]: https://www.komora.cz/legislation/15-21-prubezne-vystupy-a-doporuceni-uhelne-komise-t15-2-2021-do-12h/

CZECH STATISTICAL OFFICE - CSO (2020) Gross electricity production by region in 2018, CSO, Prague, Czech Republic, [online]: https://www.czso.cz/csu/czso/14-energetika-yt0py7cf5u

ENERGY REGULATION OFFICE – ERO (2020) Electricity consumption in the previous year's record in 2019 stagnated, ERO, Jihlava, Czech Republic, [online]: https://www.eru.cz/cs/-/spotreba-elektriny-po-predlonskem-rekordu-v-roce-2019-stagnovala

INOVATION CENTER OF ÚSTECKÝ REGION (ICUK) (2020) Introduction to the topic Energy 4.0, ICUK, Ústí nad Labem, Czech Republic, [online]: https://icuk.cz/wp-content/uploads/2020/11/energetika-4.0-analyza.pdf

KLICPERA, J. (2019) Update of the territorial energy concept of the Ústí Region - SEA evaluation, Enviros s.r.o., Praue, Czech Republic, [online]: https://www.kr-ustecky.cz/assets/File.ashx?id_org=450018&id_dokumenty=1748686

MINISTRY OF INDUSTRY AND TRADE – MIT (2014) State Energy Concept of the Czech Republic, MIT, Prague, Czech Republic, [online]: https://www.mpo.cz/assets/cz/energetika/statni-energeticka-politika/2016/12/Statni-energeticka-koncepce-_2015_.pdf

MINISTRY OF INDUSTRY AND TRADE – MIT (2015) National Action Plan of the Czech Republic for Energy from Renewable Sources, MIT, Prague, Czech Republic, [online]: https://www.mpo.cz/assets/dokumenty/54909/62718/649151/priloha001.pdf

MINISTRY OF INDUSTRY AND TRADE – MIT (2017) Update of the National Action Plan for Energy Efficiency of the Czech Republic III, MIT, Prague, Czech Republic, [online]: https://www.mpo.cz/cz/energetika/energeticka-ucinnost/strategicke-dokumenty/narodni-akcni-plan-energeticke-ucinnosti-cr--150542/

MINISTRY OF ENVIRONMENT – MoE (2017) Climate protection policy in the Czech Republic, Managerial Summary 2017, Ministry of the Environment, Prague, Czech Republic, [online]: https://www.mzp.cz/C1257458002F0DC7/cz/politika_ochrany_klimatu_2017/$FILE/OEOK_POKMS_20180105.pdf

PECH, D. ET AL. (2018) Territorial energy concept of the Karlovy Vary region, E-resources, s.r.o., Czech Republic, [online]: https://www.krkarlovarsky.cz/samosprava/dokumenty/Documents/koncepce/OZZ_uzemne_energeticka_koncepce.pdf

4 Germany, Lusatian Lignite District/Economic Region Lusatia

4.1 Projections for the energy generation technologies using coal for 2030

4.1.1 Coal driven thermal power (TP) and CHP plants

The German act for the reduction and ending of coal-fired power generation (“Coal Power Generation Termination Act”) from August 2020 regulates the gradual and steady reduction and termination of electrical energy generation through coal.

In line with EU “New Green Deal”, its purpose is to reduce and end the generation of electrical energy through the use of coal in a socially acceptable, step-by-step and as steady as possible manner in order to reduce emissions, while ensuring a safe, inexpensive, efficient and climate-friendly - in its best “sustainable” - supply of electricity. The remaining net nominal electrical output of systems for generating electrical energy through the use of coal should therefore be reduced gradually and as steadily as possible, as follows:

- in the year 2022 to 15 gigawatts (GW) of hard coal and 15 GW of lignite;
- in the year 2030 to 8 GW of hard coal and 9 GW of lignite;
- at the latest by the end of the year 2038 to 0 GW of hard coal and 0 GW of lignite.

In order to reduce and terminate the generation of electricity from lignite, the plant operators will finally shut down their lignite plants at the latest by the point in time noted as the final decommissioning date for the respective lignite plant (shutdown time) and convert them to an extended shutdown beforehand. Dates of decommissioning for the affected lignite plants in the Lusatian region are listed in Table 4.10.

All power stations are operated by the Lausitz Energie Kraftwerke AG. The mining and electricity company operates three plants, each with several blocks, in Lusatia, of which two are located in the Federal State of Brandenburg and one in the Federal State of Saxony. All four blocks in the power plant Jänschwalde are scheduled to shut down until the end of 2028. However, Jänschwalde A and B are additionally intended for an extended shut down. During the remaining running time, plant operators must ensure at all times that the lignite plants are ready for operation within 240 hours in the event of an advance warning by the responsible transmission system operator and, once they are ready for operation, within 11 hours for minimum partial output and within a further 13 hours to approach the net rated power. Two blocks of the power plant Boxberg will shut down until the end of 2029. The two remaining blocks of Boxberg and both blocks of Schwarze Pumpe have to shut down until the end of 2038. Thus, these four will still be in operation in 2030. Moreover, there is no chance to start up new coal power plants after August 14, 2020.

Table 4.10: Shutdown times for the lignite plants in the Lusatian region

Power plant block	MW_{el} (net)	Date of transition to extended shutdown ("transition time")	Final shutdown date ("shutdown time")
Jänschwalde A	465	31. December 2025	31. December 2028
Jänschwalde B	465	31. December 2027	31. December 2028
Jänschwalde C	465	-	31. December 2028
Jänschwalde D	465	-	31. December 2028
Boxberg N	465	-	31. December 2029
Boxberg P	465	-	31. December 2029
Schwarze Pumpe A	750	-	31. December 2038
Schwarze Pumpe B	750	-	31. December 2038
Boxberg R	640	-	31. December 2038
Boxberg Q	857	-	31. December 2038

Schwarze Pumpe (engl. “black pump”) was the first Lusatian lignite power plant that was built on the basis of new, environmentally friendly, technologies after the reunification of the two German states in 1990 (LEAG, 2021). Its characteristics are low NOx combustion, flue gas desulphurisation and dust separation with e-filters. Moreover, Schwarze Pumpe was one of the first lignite-fired plants to achieve an efficiency of 40%. The first block has an installed capacity of 800 MW and began its continuous operation in 1997. The second 800 MW unit followed six months later. The coal currently comes from the neighbouring lignite mines, Welzow-Süd, Nochten and Reichwalde. That's around 36,000 tons of lignite every day, at full load. Hot steam is extracted in the process of generating electricity. The process steam capacity amounts to 2 x 300 tons per hour. Part of this is supplied to neighbouring industrial companies as process steam, for drying lignite in the production of briquettes for example.

Another part of the steam is used to supply the Schwarze Pumpe industrial park and the cities of Hoyerswerda and Spremberg with district heating (60 MW_{th} per power plant block).

4.1.2 Other coal-fired energy generation applications

Briquettes of lignite dust are currently still used for heating in small solid fuel boilers in private households, workshops or storage halls. One differentiates between single room fireplaces and boilers for central heating systems.

Single room fireplaces usually have a nominal heat output below 15 kW. The operation of these combustion systems, which do not require a permit according to § 4 of the "Federal Immission Control Act", is regulated by the "First Ordinance for the Implementation of the Federal Immission Control Act" of March 14, 1997 ("Ordinance on Small Firing Systems - 1st BImSchV").

Special data for Lusatia are not available, but in the Federal State of Saxony, for example, 1.46 Mio small boilers were installed in 2019 (LfLUG, 2019). Thereof 16% are using lignite as fuel, only 0.1% use hard coal and nearly 25% are using solid biofuels. The rest is fired with heating oil and natural gas. 84% of the solid fuel (lignite, solids biofuels) driven boilers are single room fireplaces. 41% of the single room fire places are using coal as fuel (e.g., 16% as tiled stoves, 10% as long-burning stoves and 9% as stoves). The rest use biofuels like wood, in particular.

Other small solid fuel boilers are systems used in central heating, like heating boilers for logs or pellet boilers. Their thermal power ranges from less than 10 to more than 50 kW.

Almost all lignite briquettes for these systems originate from the two German lignite mining areas, the Lusatian area (marketed under the label "Rekord") and the Rhenish area (marketed under the label "Union"). According to Statistik der Kohlewirtschaft e.V. (2019), 0.5 Mio tons of briquettes have been produced in the Lusatian area in 2019 and about 1.5 Mio tons in Germany in all. Only 2,000 tons have additionally been imported from outside the EU. 600.000 tons of these were utilised in small solid boilers in private households and 400,000 tons in other applications.

The briquettes of Lusatia are produced at the LEAG refining company Schwarze Pumpe (LEAG, 2012). Their production will be reduced and finally discontinued. Due to the projected shut-down of the lignite power stations, as mentioned above, the production of lignite from the three existing mines (Welzow-Süd) will logically also be stopped. Currently, it can only be expected what will happen to the future briquette market: potentially the German briquettes will be substituted by imported products.

4.2 Projections for the other energy generation technologies for 2030

4.2.1 Other fossil fuels powered energy generation technologies

The two most important fossil primary energy sources are oil and gas in Germany. Oil is mainly used in the transport sector as fuel (BMWi, 2020). It is also still used for heating and warm water production in the building stock. Nevertheless, the market share of oil heating systems has been falling since 1998. This illustrates the increasing displacement of oil-fired systems from the market and the decline in importance of heating oil in heating supply (dena, 2016).

About 75% of the new installed heating systems were based on gas in 2015 (dena, 2016). In new buildings, the heat pumps have the second largest share of heat generators at 30%. In the existing buildings, the heat pumps play a minor role at 4% (dena, 2019). The importance of heat pumps in the construction of single- and two-family houses will increase significantly in the coming years (dena et al., 2017).

The importance of gas in the German energy supply will continue to be high in the coming decades. About 90 percent of the annual volume is mainly imported from Russia, Norway and the Netherlands via pipelines. Germany owns the largest storage facilities for gas in the EU and the fourth largest in the world. The German gas pipeline network and the downstream distribution network have a length of 511,000 kilometres (BMWi, 2020). The most important market for gas is currently the heating market. However, gas can also play an important role as a bridge between fossil and renewable energies in the electricity sector (BMWi, 2020). Actually, Germany has gas-fired power plants with a gross capacity of approx. 30 GW in operation. This amount will increase to around 37 GW by 2040. Gas power plants have the advantage that they can be deployed flexibly and used as peak load power plants. They also have around 30% lower CO_2 emissions than coal-fired power plants. Against the background of the reduction in generation capacities of the nuclear and coal-fired power plants, as well as the targeted high share of renewable energies and the consequent increasing fluctuating power generation capacity, controllable gas-fired power plants will take on an important balancing function (Ammon et al., 2019).

Even in the city of Cottbus, where the headquarters of the local mining company is situated, a new gas power plant will be put in operation and coal will not be used anymore for the energy production. The power plant is equipped with an additional pressurised heat storage unit, which can store the heat of the power plant at low demand situations. Due to this an increase of the plant's efficiency from 70 up to 90% is expected (Kompalla, 2019).

4.2.2 Renewable energy and other new energy generation technologies

Projections for the Lusatian region must consider national and European goals and regulations. The European Council agreed to reduce greenhouse gas emissions by at least 40% within the EU by 2030, compared to 1990 levels. The same stands for Germany. This sets the framework for all measures within the renewable energy sector. Moreover, one has to divide between energies for electricity and for heat production.

Brandenburg had adopted an "Energy Strategy 2030" already in 2012. It was evaluated in 2016/2017 and an updated catalogue with measures was released in 2018. A main goal in reducing energy consumption is to increase the share of renewable energies in final energy consumption by up to 40% (MWAE, 2021). Electricity from windmills, solar modules and biomass power plants are the primary technologies here. The final energy demand for electricity shall decrease by 9% from 2007 to 2030 and shall be covered 100% by renewable energies. Heat consumption shall drop by almost 34% by 2030 compared to 2007 due to efficiency improvements in the industry, thermal insulation measures in private households and others. The share of renewables in the heating demand shall increase to 39%.

At the end of 2018, power generation systems mainly based on sun, wind and biomass with more than 11,200 MW were installed in Brandenburg. They produced an estimated 18 billion kWh of electricity (MLUK, 2021).

An energy and climate programme was adopted in 2012 also in Saxony, which is currently being revised (SMWA & SMUL, 2013). The report outlines expansion targets for various RES for the next 10 years - i.e., until 2022. In the area of electricity generation, the focus was particularly on the expansion of solar energy to provide 1,800 GWh/yr (from 900 GWh/yr in 2012). The use of biomass for electricity generation is to be increased to 1,800 GWh/yr (from 1,385 GWh/yr in 2012). An expansion of wind energy to 2,200 GWh/yr (from 1,700 GWh/yr in 2012) was also planned.

Saxony aims to develop an "Energy and Climate Programme 2020 – 2030" and to publish it within the next month (Sächsische Staatskanzlei, 2021). The most important point of the concept will be the expansion of renewable energies. Additionally, 4 TWh of electricity shall be generated from renewables annually until 2024, by 2030 it shall be additional 10 TWh annually. In 2017, the power generation from renewable energies was about 6 TWh (6 billion kWh). 20.4% of the gross electricity consumption in 2016 was ensured by renewable energies.

The coalition agreement of the current state government in Saxony (Staatsregierung Sachsen, 2019) stipulates that the revised energy and climate programme is to be based on an additional expansion of 10 TWh of annual generation from renewable energies by 2030. An interim expansion target of 4 TWh was defined for 2024, of which the main part is to be generated by wind energy.

The information and data about the current situation in both federal states are quite extensive. Many different studies with different numbers, reference years and units are challenging. The master data of all players in the German electricity and gas market are recorded in the market master register (so-called “Marktstammregister”, Bundesnetzagentur, 2021). They can be considered and downloaded for own analysis.

Provision of electricity

The “German Electricity Feed Act” of December 7, 1990, obliged energy supply companies to purchase electricity from renewable sources. It guaranteed minimum payments per kWh send to the grid and was the starting point for the expansion of renewable energy in Germany (Fraunhofer IEE, 2021). The current version (“Law for the Expansion of Renewable Energies”, from 2021) aims to increase the share of electricity generated from renewable energies in gross electricity consumption to 65% in 2030. Additionally, by the year 2050 all electricity in the national territory of Federal Republic of Germany that is generated or consumed must be generated in a greenhouse gas neutral manner.

The “Federal Government's Climate Protection Plan” (BMU, 2019) provides that the share of wind and solar power in total electricity production increases significantly. Because these technologies currently have great, cost-effective potential, they should dominate and shape the system until 2030.

The share of renewable energies in gross electricity consumption in 2019 was 42% in Germany. About 242 billion kWh of electricity were generated from wind energy, biomass, photovoltaics, hydroelectric power and deep geothermal (BMWi, 2021). Wind energy with an amount of 125.9 billion kWh delivered the highest share (51.9%) of all renewables (see Table 4.11). On-shore wind turbines contributed to four fifths of the total electricity produced by wind energy (not shown). Photovoltaics and Biomass were also significant energy sources.

Table 4.11: Gross electricity generation from renewable sources in Germany in 2019

Renewable energy source	Gross electricity generation (billion kWh)	Share (%)
Wind energy	125.9	51.9
Photovoltaics	46.4	19.1
Biomass	50.2	20.7
Hydroelectric power	19.7	8.1
Deep Geothermal	0.2	-

Source: BMWi, 2021

53.2 GW of wind power capacity were installed in 2019, onshore and offshore, in Germany (BMWi, 2021). The current act for the expansion of RES until 2021 (so-called “EEG 2021”) provides an increase in the installed capacity of onshore wind turbines to 71 GW in 2030 (§4). The installed capacity of offshore wind turbines is to be increased to a total of 20 GW by 2030 (§1(2) “Act on the Development and Promotion of Wind Energy at Sea”). However, several barriers complicate the expansion of wind energy. Lawsuits are often taken against the construction of new plants. Common grounds for complaint are the protection of species, especially the protection of birds and bats, and noise protection (Peters et al., 2014, Quentin, 2019).

Also, the availability of potential areas onshore gets increasingly limited due to stronger restrictions for minimum distances to residential developments (BDEW, 2019). Moreover, there are already bottlenecks in power distribution in the existing power grid. In 2018, around 3.6% of the electricity from wind turbines on land and at sea and from photovoltaic systems was curtailed as part of network and system security measures by the network operators (Bons et al., 2020). In order to promote the expansion of the grid, the German Federal Government passed the “Energy Industry Act” in 2005, the “Energy Line Expansion Act” in 2009 and the “Grid Expansion Acceleration Act” in 2011.

In the Federal State of Brandenburg 7,162 MW of installed nominal power through 3,909 wind turbines existed in 2018 (Fraunhofer IEE, 2021). Brandenburg thus had the second-highest share of the installed net output of wind energy in Germany, after the Federal State of Lower Saxony. Until 2030, an installed nominal power of 10,500 MW from wind turbines is targeted (MWAE, 2012). About 75% of the wind turbines are located on agricultural sites, the majority of the rest built in forests. The average performance of new turbines in Brandenburg was 3.56 MW in the first half of 2020 (Deutsche Windguard, 2020). The average rotor diameter was 126 m and the average height of the hub was 136 m.

In the Federal state of Saxony 1,272 MW of installed nominal wind power through 927 wind turbines existed in 2018 (Fraunhofer IEE, 2021). The plants are smaller, than in Brandenburg. The average performance of new wind turbines in Saxony was 2.7 MW in the first half of 2020 (Deutsche Windguard 2020). A problem is that, currently, no new areas are available for further development of wind turbines (Bundesverband WindEnergie, 2020). After the expiry of the 20-year EEG feed-in tariff, a large number of plants in Saxony will not be economically viable from 2021 onwards.

The main share (64%) of gross electricity production from biomass in Germany was provided by biogas. It delivered about 11.9% of the gross electricity generation in 2019 (BMWi, 2021). Originally livestock manure and organic waste were used as feedstock, but meanwhile agricultural crops, cultivated especially for this biogas production, are the main input material. Crops for biogas have been produced on 1.35 Mio ha agricultural land in Germany in 2018, thereof about 900 million hectares silage maize. 9,494 biogas plants with a cogeneration capacity existed in 2018 (FNR, 2019). The installed electric capacity from these was 4.8 GW. Germany aims to enhance it to 8.4 GW by 2030 (EEG 2021).

In 2021, the first plants will leave the 20-year funding from the first “Renewable Energy Sources Act” of 2010, while the continued operation without state funding is not always possible. Therefore, biogas industry is looking for viable, forward-looking solutions (Neumann, 2020). Future perspectives strongly depend on the funding law and policy, as Daniel-Gromke et al. (2019) point out. A conversion of the on-site power generation systems to systems with biogas processing to biomethane turned out to be one of the best rated operating models from an economic and energy system perspective.

In Brandenburg, 254 biogas cogeneration plants with an electric capacity of 128.6 MW were installed in 2020 (Bundesnetzagentur, 2020), while 192 cogeneration plants with an electric capacity of 72 MW were installed in Saxony. The future projections of biogas as a source for renewable energy in these federal states underlie the same restrictions and opportunities, as in Germany as a whole. For example, the states’ biomass strategy from 2010 (MLUK, 2010) already considers the retrofitting of existing biogas plants with new technologies to increase the gas yield - provided that the regional humus turnover can be balanced out to avoid soil degradation. In farms with animal husbandry, the manure produced should be used as much as possible for biogas production.

When building new biogas plants, the reduction of environmental pollution is of particular importance. Plants with electricity generation and provisions for heating/cooling as well as plants with gas processing and feeding into the natural gas network should preferably be built.

As regards photovoltaics (PV), the law for the expansion of renewable energies (EEG, 2021) aims for an installed nominal capacity of 100 GW of photovoltaic modules in 2030. In 2020, according to initial projections, photovoltaics covered 9.3% of gross electricity consumption in Germany with electricity generation of 50 TWh (Wirth, 2021). 2 million PV modules with a nominal capacity of 53 GW were in operation. Due to this, photovoltaics are able to cover about 67% of the electricity demand at sunny days.

Brandenburg aims for an installed electric capacity from photovoltaics (PV) of 3,500 MW in 2030 (MWAE, 2012). In 2018, 3,673 MW have already been installed (Meierrose-Feige &

Kuschke, 2018). In Saxony 35,651 photovoltaic modules with a nominal power of 1,635 MW were installed in 2016. They produced 1,463 GWh of electricity per year (Fritzsche et al., 2018). 2,200 GWh per year are stated as the target value by 2022 in Saxon "Energy and Climate Programme 2012" (SMWA & SMUL, 2013).

Provision of heat and cold

The German government's national energy and climate plan (BMWi, 2020) envisages a share of renewable energies in the provision of heat and cold of 19.2% in 2030. This share was about 14.5% in 2019 (AEE, 2020). 181.7 billion kWh of heat from renewable sources were consumed in this year. Biogenic solid fuels made up the highest proportion with 66.3%. Others were biogas, solar thermal and near-surface geothermal energy.

In Brandenburg, 39% of the heat consumption is to be covered by renewable energies by 2030 (MWAE, 2012). The share of renewable energies to the gross energy consumption of heat and cold in 2016 was 18.3%, with 54.6 billion kWh (AEE, 2021).

The share of renewable energies in heat production in Saxony was 11.5% in 2016 (Fritzsche et al., 2018). The majority (more than 80%) was made up of biomass. In the "Saxonian Energy and Climate Programme 2012" no clear target values for the share of energy for heat and cold from renewable energies are defined. It's only pointed out that the further development of the existing potential has a high priority (SMWA & SMUL, 2013).

Renewables in the traffic sector

In the German traffic sector, 5.6% of the final energy consumption (36 billion kWh) was provided by renewable sources in 2019, namely biodiesel (61%), bioethanol (23%), electricity (14%), as well as vegetable oil and biomethane (2%) (BMWi, 2020).

According to the "National Energy and Climate Action Plan" (BMWi, 2020), 7 to 10 million electric cars should be registered in Germany by 2030. The goal is to increase the share of motor vehicles with alternative and environmentally friendly drive technologies in new and replacement purchases to as much as possible 40% by 2025 and to as much as possible 100% by 2030. This includes battery electric vehicles, fuel cell vehicles, externally rechargeable hybrid electric vehicles that meet the minimum criteria according to §3 EmoG ("Law to give Priority to the Use of Electrically Powered Vehicles"), as well as vehicles that can be proven to run 100% on biogas. The publicly accessible charging infrastructure is to be further expanded so that a total of one million charging points will be available by 2030. Additionally, in road freight transport, the share of vehicles powered electrically or on the basis of CO_2 -free or CO_2 -neutral fuels should amount to about one third of all mileage in 2030.

Compared to that, 136,617 electric cars and 539,383 hybrids were registered nationwide in 2019 (KBA, 2021), thereof 2,521 electric cars in Brandenburg and 3,438 in Saxony. The share of renewables in the energy consumption of transport - including air traffic - should reach 8% by 2030 in Brandenburg (MWAE, 2012). The share of renewable energies in the traffic sector of Saxony was 3.4% in 2016 (Fritzsche et al., 2018). Concrete targets for the use of renewable energies in the transport sector in Saxony until 2030 were not set in the "Energy and Climate Programme 2012".

The development of liquid and gaseous renewable fuels from biomass and their large-scale production in biogas and synthesis plants are supported in order to be able to use them in certain segments of the transport sector in the medium and long term. First-generation biofuels based on food and feed crops will not receive additional support. In the future, the production of bioenergy is to be based more on waste and residual materials.

4.3 Projections for the energy mix of the region for 2050

Germany's first climate protection plan aims to reduce greenhouse gas emissions by at least 55% from the 1990 levels by 2030, and by at least 70% by 2040 at the latest. Greenhouse gas neutrality is to be largely achieved by 2050 (BMU, 2019). In the long term, electricity generation should be based almost entirely on RES. Thereby, EU and national guidelines towards green energy find themselves in the regional transformation of the energy sector. Legal specifications and action plans define the future scope of activities, but taking a closer look, target values remain imprecise, e.g., regarding the share of different RES. Thereof, it is difficult at the moment, to make reliable projections on the implementation of concrete investments in the regional energy sector for the upcoming 30 years.

Despite all prognostic uncertainties, a coordinated, consistent and overall binding roadmap / master plan for Lusatia's energy transition as a whole - apart from the decided coal phase-out and successive decommissioning of lignite mines and coal-based power plants - is still missing. Up to now, there is no statistical data preparation for the target region across the federal borders. The same applies for action plans, which are in general on a federal state scale. What is striking: Lusatia is in a wide-ranging search phase, not only considering the energy sector and transition.

The single steps and actions in transition are uncertain, but what is definite are the targets set:

- The share of wind and solar power in total electricity production has to increase significantly. They will dominate and shape the system. Biomass will contribute to a limited extent to energy supply by 2050, mainly based on the energetic use of waste and slurry, digestate and residues, in local applications to provide thermal energy for the industrial sector, commerce, trade and services, and the heating sector.
- Combined heat and power generation (CHP), preferably based on natural gas, is to continue to play an important role. It is becoming increasingly flexible, with lower emissions, and should increasingly integrate renewable heat production.
- Decarbonisation in the electricity sector will be driven by energy efficiency and the expansion of RES. In the areas of heating and cooling as well as in transportation (propulsion), the emission reductions by 2050 can only be achieved if the energy demand is covered with electricity from RES – as is the case, for example, in heat pumps, electric vehicles.
- Sector coupling can provide more flexibility in the electricity market, if demanders in the heat and transport sectors increase or reduce their demand by many gigawatts very quickly. Fluctuations in the electricity supply from wind or sun can thus be balanced out.
- The "Climate Protection Action Programme 2020" (BMU, 2014) sets out a strategy for climate-friendly construction and housing with the aim of getting cities and communities climate-neutral by 2050. This requires both demanding new building standards, long-term renovation strategies for the existing building stock and a move away from fossil heating systems.
- For new buildings, the lowest-energy building standard ("Niedrigstenergiestandard") that will apply from 2021 will be gradually developed further. New installations of heating systems that make efficient use of renewable energies will then be significantly more attractive compared with heating systems using fossil fuels. To this end, suitable incentives will be examined for the use and construction of buildings that generate more energy than is required for operation.
- Existing buildings are also to be renovated by 2050 through energy efficiency measures and increased use of renewable energies in such a way that they meet the requirement of a virtually climate-neutral building stock. If new heating systems are installed or replaced in existing buildings, appropriate incentives must be put in place to ensure that as much heat as possible is provided by RES.
- In 2050, the transport system is to be virtually independent of fossil carbon fuels and thus largely greenhouse gas neutral. The vision also includes a transport system in which air pollutants and noise emissions will be significantly reduced and land consumption will be lower than today.
- Mobility will change fundamentally through automation and networking. Digitisation will make it possible to increase efficiency. Increasingly automated and networked mobility will optimise traffic flows and promote congestion avoidance, thus helping to save energy. Rush-hour traffic is to be reduced with the help of modern forms of working (home office,

mobile working). Logistics processes are to be further optimised and the number of necessary transports reduced.

- The energy supply of road and rail transport, as well as parts of air and sea, is to be switched to biofuels and, otherwise, largely to electricity from renewable sources and other GHG-neutral fuels.
- Combustion engines are an indispensable option in the switch to alternative drives or energy sources. As regards fuels, eFuels/Power-to-X are to be increasingly used. The GHG quota sets clear incentives for the use of biofuels with relatively high GHG reduction values. This stimulates a development towards advanced biofuels mainly based on residues and waste materials and with high GHG reduction values.

For those applications where electricity cannot be used directly, for example in aviation, biogenic fuels can play a role. The energy system, which is geared to renewable electricity, is intended to combine the electricity, transport and heating sectors, which are still separate today, into an efficient overall system in which the energy infrastructures are also coordinated with one another (sector coupling).

4.4 References

AMMON ET AL. (2019) ENERGIEWENDE im Kontext von Atom- und Kohleausstieg, Perspektiven im Strommarkt bis 2040, download at 16.02.2021: http://docplayer.org/197403626-Energiewende-update-im-kontext-von-atom-und-kohleausstieg-perspektiven-im-strommarkt-bis-2040.html

AEE - AGENTUR FÜR ERNEUERBARE ENERGIEN E.V. (2020) Anteile der Erneuerbaren Energien in den Sektoren Strom, Wärme und Verkehr in Deutschland 1990-2019. download at 15.02.2021, at: https://www.unendlich-viel-energie.de/media/image/52661.EE-Anteile-Energieverbrauch1990-2019_Aug20_72dpi.jpg

AEE - AGENTUR FÜR ERNEUERBARE ENERGIEN E. V. (2021) Bruttoendenergieverbrauch Wärme und Kälte (2016, in Mrd. kWh). download at 17.02.2021, https://www.foederal-erneuerbar.de/landesinfo/bundesland/BB/kategorie/waerme/ausgabe/drucken

BDEW - BUNDESVERBAND DER ENERGIE- UND WASSERWIRTSCHAFT E.V. (2019) Maßnahmen zum Abbau von Hemmnissen für den weiteren Ausbau der Windenergie an Land. Positionspapier. Berlin, 12p., download at 08.02.2021, https://www.bdew.de/media/documents/Stn_20190926_Ma%C3%9Fnahmen-Abbau-Hemmnisse-Wind.pdf

BMU - BUNDESMINISTERIUM FÜR UMWELT, NATURSCHUTZ UND NUKLEARE SICHERHEIT (2016) Klimaschutzplan 2050, download at 16.02.2021 https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_bf.pdf

BMWI- BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE (2020): Konventionelle Energieträger, download at 16.02.2021 https://www.bmwi.de/Redaktion/DE/Dossier/konventionelle-energietraeger.html

BONS, M., KNAPP, J., STEINBACHER, K., GREVE, M., GRIGOLEIT, J., KIPPELT, S., BURGES, K. (2020) Verwirklichung des Potenzials der erneuerbaren Energien durch Höherauslastung des Bestandsnetzes und zügigen Stromnetzausbau auf Verteilnetzebene. Climate change 51. Umweltbundesamt (Hrsg.), Dessau-Rosslau, 122 p., download at 08.02.2021, https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2020_12_14_cc_51-2020_zuegiger_ausbau.pdf

BUNDESFÖRDERUNG FÜR EFFIZIENTE GEBÄUDE" (BEG): https://www.bafa.de/DE/Energie/Effiziente_Gebaeude/effiziente_gebaeude_node.html

BUNDESNETZAGENTUR (2020) EEG-Anlagenstammdaten aus dem MaStR-Webportal. download at 05.02.2021, https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/ErneuerbareEnergien/ZahlenDatenInformationen/EEG_Registerdaten/EEG_Registerdaten_node.html;jsessionid=F68354DE8042158224AE13C9BC04E00C

BMU - BUNDESMINISTERIUM FÜR UMWELT, NATURSCHUTZ, BAU UND REAKTORSICHERHEIT (2014) Aktionsprogramm Klimaschutz 2020. Kabinettsbeschluss vom 3. Dezember 2014, Berlin, 84 p., download at 18.02.2021, Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit: Aktionsprogramm Klimaschutz 2020 - Kabinettsbeschluss vom 3. Dezember 2014 (bmu.de)

BMU - BUNDESMINISTERIUM FÜR UMWELT, NATURSCHUTZ UND NUKLEARE SICHERHEIT (2019) Klimaschutzplan 2050. Klimaschutzpolitische Grundsätze und Ziele der Bundesregierung. 2. Auflage, 92 p., download at 05.02.2021, https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_bf.pdf

BMWI - BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE (2020) Integrierter Nationaler Energie- und Klimaplan. download at 16.02.2021, https://www.bmwi.de/Redaktion/DE/Textsammlungen/Energie/necp.html#:~:text=Der%20integrierte%20Nationale%20Energie-%20und%20Klimaplan%20ist%20ein,EU%20-2030-Ziele%20f%C3%BCr%20erneuerbare%20Energien%20und%20Energieeffizienz%20umzusetzen

BMWI - BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE (2021) Entwicklung der erneuerbaren Energien in Deutschland im Jahr 2019, download at 16.02.2021 https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/entwicklung-der-erneuerbaren-energien-in-deutschland-2019.pdf?__blob=publicationFile&v=31

BUNDESNETZAGENTUR (2021) Marktstammregister. download at 15.02.2021, https://www.marktstammdatenregister.de/MaStR/

Bundesverband WindEnergie (2020) Der Landesverband Sachsen. Website. download at 16.02.2021, https://www.wind-energie.de/verband/lvs/sachsen/

DANIEL-GROMKE, J., RENSBERG, N., DENYSENKO, V., BARCHMANN, T., OEHMICHEN, K., BEIL, M., BEYRICH, W., KRAUTKREMER, B., TROMMLER, M., REINHOLZ, T., VOLLPRECHT, J., RÜHR, C. (2019) Optionen für Biogas-Bestandsanlagen bis 2030 aus ökonomischer und energiewirtschaftlicher Sicht. Abschlussbericht. Umweltbundesamt (Hrsg.), Dessau-Roslau, 246 p., download at 08.02.2021, https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020-01-30_texte_24-2020_biogas2030.pdf

DEUTSCHE ENERGIE-AGENTUR (2016) Der dena-Gebäudereport 2016.Statistiken und Analysen zur Energieeffizienz im Gebäudebestand, download at 16.02.2021 https://www.dena.de/fileadmin/user_upload/8162_dena-Gebaeudereport.pdf

DEUTSCHE ENERGIE-AGENTUR ET AL. (2017) GEBÄUDESTUDIE - Szenarien für eine marktwirtschaftliche Klima- und Ressourcenschutzpolitik 2050 im Gebäudesektor download at 16.02.2021 https://www.dena.de/fileadmin/dena/Dokumente/Pdf/9220_Gebaeudestudie_Szenarien_Klima-_und_Ressourcenschutzpolitik_2050.pdf

DEUTSCHE ENERGIE-AGENTUR (2019) dena-GEBÄUDEREPORT KOMPAKT 2019 „Statistiken und Analysen zur Energieeffizienz im Gebäudebestand”, download at 16.02.2021: https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2019/dena-GEBAEUDEREPORT_KOMPAKT_2019.pdf

DEUTSCHE WINDGUARD (2020) Status des Windenergieausbaus an Land in Deutschland, Erstes Halbjahr 2020. Deutsche WindGuard GmbH, Varel, 12p., download at 05.02.2021, https://www.windguard.de/veroeffentlichungen.html

FNR - FACHAGENTUR FÜR NACHWACHSENDE ROHSTOFFE (2019) Basisdaten Bioenergie Deutschland 2019. 27 p., download at 05.02.2021, https://www.fnr.de/fileadmin/allgemein/pdf/broschueren/basisdaten_bioenergie_2019_web.pdf

FRITZSCHE, A., KLUGE, U., REINER, M., THIEME-CZACH, S. (2018) Gutachten EE-Ausbaupotenziale in Sachsen. Sächsische Energieagentur GmbH, Sächsisches Staatsministerium für Wirtschaft, Arbeit und Verkehr. Dresden, 69 p., download at 12.02.2021, https://www.energie.sachsen.de/download/energie/Gutachten-EE-Ausbaupotentiale-in-Sachsen-final.pdf

FRAUNHOFER IEE - FRAUNHOFER INSTITUT FÜR ENERGIEWIRTSCHAFT UND ENERGIESYSTEMTECHNIK (2021): Wind Monitor. download at 05.02.2021, http://windmonitor.iee.fraunhofer.de/windmonitor_de/index.html

IWU - INSTITUT WOHNEN UND UMWELT (2018) Datenerhebung Wohngebäudebestand 2016; Datenerhebung zu den energetischen Merkmalen und Modernisierungsraten im deutschen und hessischen Wohngebäudebestand: download at 16.02.2021 https://www.iwu.de/fileadmin/user_upload/dateien/gebaeudebestand/prj/Endbericht_Datenerhebung_Wohngeb%C3%A4udebestand_2016.pdf

KBA - KRAFTFAHRTBUNDESAMT (2021) Bestand an Personenkraftwagen am 1. Januar 2020 nach Bundesländern und ausgewählten Kraftstoffarten absolut. Statistics. download at 17.02.2021, https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Umwelt/fz_b_umwelt_archiv/2020/2020_b_umwelt_dusl.html?nn=2601598

KNORR, K., HORST, D., BOFINGER, S., HOCHLOFF, P. (2017) Energiewirtschaftliche Bedeutung der Offshore-Windenergie für die Energiewende. Studie im Auftrag der Stiftung Offshore Windenergie, Update 2017. Fraunhofer-Institut für Windenergie und Energiesystemtechnik. Kassel. 44 p., download at 08.02.2021, https://www.offshore-stiftung.de/sites/offshorelink.de/files/documents/Studie_Energiewirtschaftliche%20Bedeutung%20Offshore%20Wind.pdf

KOMPALLA, P. (2019): Neues Gaskraftwerk: Stadtwerke Cottbus investieren 75 Millionen, download at 16.02.2021, https://www.lr-online.de/lausitz/cottbus/vertrag-unterzeichnet-neues-gaskraftwerk_-stadtwerke-cottbus-investieren-75-millionen-38137714.html

LFLUG - LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE (2019) Kleinfeuerungsanlagen in Sachsen, download at 18.02.2021, https://slub.qucosa.de/api/qucosa%3A71366/attachment/ATT-0/

MEIERROSE-FEIGE, C., KUSCHKE, A. (2020) Energiestrategie des Landes Brandenburg – 10. Monitoringbericht – Beirchtsjahr 2018. Wirtschaftsförderung Land Brandenburg GmbH (Hrsg.), Potsdam, 134 p., download at 16.02.2021, https://energieagentur.wfbb.de/de/system/files/media-downloads/10._monitoringbericht_zur_energiestrategie_-_berichtsjahr_2018.pdf

MLUK - MINISTERIUM FÜR LANDWIRTSCHAFT, UMWELT UND KLIMASCHUTZ DES LANDES BRANDENBURG (2021) Erneuerbare Energien, Website. download at 17.02.2021, https://mluk.brandenburg.de/mluk/de/klimaschutz/klimaschutz/erneuerbare-energien/

MLUK - MINISTERIUM FÜR LANDWIRTSCHAFT, UMWELT UND KLIMASCHUTZ DES LANDES BRANDENBURG (2010) Biomassestrategie des Landes Brandenburg. Potsdam, 43 p., download at 08.02.2021, https://mluk.brandenburg.de/media_fast/4055/bmstrategie.pdf

MWAE - MINISTERIUM FÜR WIRTSCHAFT UND EUROPAANGELEGENHEITEN DES LANDES BRANDENBURG (2012) Energiestrategie des Landes Brandenburg 2030. Potsdam, 6 p., download at 17.02.20:12, https://mwae.brandenburg.de/media/bb1.a.3814.de/Energiestrategie2030_2012.pdf

NEUMANN, H. (2020) Ideen für die Biogasanlage der Zukunft. topagrar online from 15.05.2020. download at 08.02.2021, https://www.topagrar.com/energie/news/ideen-fuer-die-biogasanlage-der-zukunft-12086483.html

PETER, W., ROSENTHAL, S., VOLMER, M., HANUSCH, BOVET, J., KINDLER, L., TWELE, J., BUDDEKE, M., WAGNER, P. (2014) Untersuchung von speziellen Hemmnissen im Zusammenhang mit der Umweltbewertung in der Planung und Genehmigung der Windenergie an Land und Erarbeitung von Lösungsansätzen. Schlussbericht im Auftrag des Umweltbundesamtes. Umweltbundesamt (Hrsg.), Dessau-Roßlau, 175 p., download at 08.02.2021, https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/climate_change_23_2013_planung_und_genehmigung_der_windenergienutzung_0.pdf

QUENTIN, J. (2019) Hemmnisse beim Ausbau der Windenergie in Deutschland. Ergebnisse einer im 2. Quartal 2019 durchgeführten Branchenumfrage in Zusammenarbeit mit dem Bundesverband WindEnergie. Fachagentur Windenergie an Land (Hrsg.), Berlin, 31 p., download at 08.02.2021, https://publikationen.windindustrie-in-deutschland.de/hemmnisse-beim-ausbau-der-windenergie-in-deutschland/63501706

ROHRIG, K., RICHTS, C., BOFINGER, S., JANSEN, M., SIEFERT, M., PFAFFEL, S., DURSTEWITZ, M. (2013) Energiewirtschaftliche Bedeutung der Offshore-Windenergie. Studie im Auftrag der Stiftung Offshore Windenergie, Kurzfassung. Fraunhofer-Institut für Windenergie und Energiesystemtechnik. Kassel. 21 p., download at 08.02.2021, https://www.fraunhofer.de/content/dam/zv/de/forschungsthemen/energie/Energiewirtschaftliche-Bedeutung-von-Offshore-Windenergie.pdf

SMEKUL - SÄCHSISCHES STAATSMINISTERIUM FÜR ENERGIE, KLIMASCHUTZ, UMWELT UND LANDWIRTSCHAFT (2021) Das neue Energie- und Klimaprogramm für den Freistaat Sachsen. download at 17.02.2021, https://www.staatsregierung.sachsen.de/download/staatsregierung/energie-und-klimaprogramm.pdf

SMWA & SMUL - SÄCHSISCHES STAATSMINISTERIUM FÜR WIRTSCHAFT, ARBEIT UND VERKEHR & SÄCHSISCHES STAATSMINISTERIUM FÜR UMWELT UND LANDWIRTSCHAFT (2013) Energie- und Klimaprogramm Sachsen (2012). Dresden, 88 p., download at 15.02.2021, https://www.smwa.sachsen.de/download/Energie_und_Klimaprogramm_Sachsen_2012_20130312_v2.pdf

STATISTIK DER KOHLEWIRTSCHAFT E. V. (2019) Braunkohle im Überblick; download at 18.02.2021 https://kohlenstatistik.de/

STAATSREGIERUNG SACHSEN (2019) Koalitionsvertrag 2019 bis 2024, 134 p., download at 15.02.2021, https://www.staatsregierung.sachsen.de/download/Koalitionsvertrag_2019-2024-2.pdf

WIRTH, H. (2020) Aktuelle Fakten zur Photovoltaik in Deutschland. Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg, 99 p., Download at 08.02.2021, https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf

5 Greece, Western Macedonia Region

The National Energy and Climate Plan (HMEE, 2019a) is the Greek government's strategic plan for climate and energy issues, setting out a detailed roadmap regarding the attainment of specific energy and climate objectives by 2030. The NECP (which was submitted to the EU in December 2019) sets out and describes priorities and policy measures in respect of a wide range of development and economic activities intended to benefit Greek society, and therefore it is a reference text for the forthcoming decade.

The objectives set in the context of the NECP are quantified and cost-accounted, and intermediate milestones have been defined, allowing for following up on the progress made in attaining the objectives and relating to the successful adoption and functioning of a mix of policies and measures. More specifically:

(a) With regard to renewable energy sources (RES), an objective for a minimum share of 35% in gross final energy consumption has been set (much higher than the core EU objective for RES of 32%). It should also be stressed that energy transformation will take place in power generation, as provision has been made for the RES share in electricity consumption to exceed 60%. In this context, specific initiatives are already being promoted and implemented by the government, e.g., simplifying and speeding up the licensing framework, ensuring optimal integration of RES in electricity networks, operating storage systems and promoting electro-mobility.

(b) With regard to improving energy efficiency, there is a quantitative objective for final energy consumption in 2030 to be lower than that recorded in 2017. Therefore, the NECP's objective is fully compatible with the relevant EU indicator. There is also a 38% qualitative energy efficiency improvement achieved in final energy consumption, in accordance with a specific EU methodology, compared to the corresponding core EU objective of 32.5%. The NECP sets out a set of energy efficiency improvement measures, the most ambitious ones relating to buildings and transport.

In addition, and under the governance regulation, Greece (as was the case for all EU member states) was required to develop its national mid-century, long-term low greenhouse gas emission development strategy by 1 January 2020 and ensure consistency between long-term-strategies and the 10-year NECPs. This strategy (HMEE, 2019b) had to cover, with a perspective of at least 30 years, among others the emission reductions and enhancements of removals in individual sectors, including electricity, industry, transport, the heating and cooling and buildings sector (residential and tertiary), agriculture, waste and land use, land-use change and forestry (LULUCF).

It must be further mentioned that, as part of the program for the smooth transition to the post-lignite age, the European Commission has commissioned a study by the World Bank on lignite substitution and economic activity in Western Macedonia and Silesia (Poland). The main scenario considered by the World Bank for Western Macedonia is the utilization of the infrastructure of PPC lignite plants that will begin to be gradually withdrawn from the first half of 2020 for the installation of energy storage systems (World Bank, 2020).

5.1 Projections for the energy generation technologies using coal for 2030

5.1.1 Coal driven thermal power (TP) and CHP plants

A key objective in the context of the new revised government strategy for the National Energy and Climate Plan (NECP) is the highly ambitious, but realistic programme for sharply and definitively reducing the share of lignite in power generation, i.e., the so-called lignite phase-out, by implementing a relevant front-loaded programme in the following decade and putting a complete end to the use of lignite for power generation in Greece by 2028. Whichever the case, the process of decarbonization has already started in the early 2010s with the gradual reduction of lignite activity. Specifically, according to data from the Public Power Corporation (PPC), in the period 2011-2019 the costs related to lignite activity have decreased by about 10% per year in the lignite centres of Western Macedonia and Megalopolis respectively. Also, the average variable cost of electricity production from lignite is ~ €80/MWh (September 2020), when the System Limit Price rose to ~ €45/MWh (average in 2020).

The NECP also sets out the timeframe for shutting down the lignite-fired power plants that are currently in operation, which will be completed by 2023, as follows:

Table 5.1: Timeframe for shutting down lignite-fired plants

Lignite-fired plant / unit	Net / Installed capacity (MW)	Year of shutdown
Kardia 1	275 (300)	2019
Kardia 2	275 (300)	2019
Kardia 3	280 (325)	2021
Kardia 4	280 (325)	2021
Agios Dimitrios 1	274 (300)	2022
Agios Dimitrios 2	274 (300)	2022
Agios Dimitrios 3	283 (310)	2022
Agios Dimitrios 4	283 (310)	2022
Agios Dimitrios 5	342 (375)	2023
Amyntaio 1	273 (300)	2020
Amyntaio 2	273 (300)	2020
Meliti (Florina)	289 (330)	2023
Megalopolis 3	255 (300)	2022
Megalopolis 4	256 (300)	2023

It is important to mention that all the above lignite-fired plants are located in Western Macedonia, except from the last two (i.e., Megalopolis 3 & 4) that are located in the region of Peloponnesus (south Greece). In addition, in the plants/units that will be closed the relatively recent Meliti 1 (330 MW) unit, which was put into operation in 2002, and Agios Dimitrios 5 (375 MW) unit, which was put into operation in 1997, are included, the closure of which is considered as premature if examined from purely technical-economic criteria. The only exception is the new Ptolemaida 5 unit, with a generation capacity of 660 MW, which is expected to be put into commercial operation in 2022. This unit is expected to operate until 2028 with lignite and/or a mixture of fuels.

5.1.2 Other coal-fired energy generation applications

Lignite is used in parallel of power generation for the provision of heating to many towns in the region of Western Macedonia. Actually, the region of Western Macedonia is the first region in Greece where district heating systems were designed and installed for the needs of citizens (providing heating and hot water to them) in three cities (Ptolemaida, Kozani and Amyntaio). Specifically, about 42 thousand households and businesses use district heating with a total demand of ~ 600 GWh (IENE, 2020). 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.

More specifically, PPC SA made a series of investments in energy supply in the form of hot water for urban tele-heating purposes, via a number of Power Plants: Ptolemaida III (50 MW_{th}), Agios Dimitrios III (67 MW_{th}), IV (67 MW_{th}) and V (70 MW_{th}), Amyntaio (25 MW_{th}), and LIPTOL (25 MW_{th}). The expansion of the Municipality of Kozani's tele-heating from Ag. Dimitrios TPP (maximum tele-heating capacity: 137 MW_{th}) was concluded in 2008, while the tele-heating interconnection of the Municipality of Ptolemaida and Kardia TPP was made in 2009.

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 also 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).

The current status of the Western Macedonia tele-heating systems is as follows:

- District heating of Ptolemaida: The Municipality of Ptolemaida, today Municipality of Eordaia, has installed and put into operation since 1994 the first district heating system in Greece, which operates the Municipal District Heating Company of Ptolemaida-DETIP (IENE, 2020). During the first 25 years of operation of district heating in Ptolemaida, the connection of over 3,800 buildings and almost 15,000 apartments was achieved, providing heating and hot water for the residents of the area, at prices lower than other alternative fuels, while the reduction of emissions was significant, in relation to the possible combustion of oil for heating and hot water.
- District heating of Kozani: It has been operating since 1993, heating about 25,000 apartments, in a total of about 4,900 buildings, while consuming 340 GWh per year (IENE, 2020).
- District Heating of Amyntaio: It started its operation in 2005 and is the main activity of the Municipal District Heating Company of the Greater Amyntaio Area (DETEPA), established in 1997. The supply of thermal energy is provided by the lignite power plant Amyntaio of PPC SA. with the technology of cogeneration of electricity and heat. Amynteo is estimated to have about 2,000 district heating connections, with an annual consumption of ~ 40 GWh.

It is obvious that closing down the 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. As it was decided, in the transitional period for Western Macedonia, the district heating will be provided through the interconnection of Amyntaio, Ptolemaida and Kozani with a network of hot water pipes, as well as a connection with a new CHP unit. This unit will be operating according to the decarbonization plan, it will be supplied with natural gas from a

DESFA pipeline and will provide the required thermal energy for the uninterrupted operation of district heating.

More precisely, after 2023, the plan to ensure district heating envisages the creation of a thermal hub in Western Macedonia, which will consist of:

- The modified unit of Ptolemaida 5, with installed capacity 140 MWth and estimated annual production 300-400 GWh/year (expected to be operational in the first half of 2022; base load PP)
- New high efficiency CHP unit using natural gas in Kardia PP, with installed capacity 60 MWth and estimated annual production 270-350 GWh/year (expected by 2023);
- Gas boiler in Kardia, with installed capacity 100 MWth and estimated annual production 10-125 GWh/year (expected by 2023)
- Electric boiler in Kardia PP with installed capacity 100 MWth and estimated annual production of 20-125 GWh/year (expected to be operational in the second half of 2021; initially a base load PP – peak load PP from 2022 onwards)

For the Amyntaio DH, the thermal energy production unit will be a mixed biomass combustion with a small amount of lignite, with a total capacity of 30 MW_{th} that will meet the thermal needs of Amyntaio, Filota and Levaia, as well as future thermal needs of the area and was expected to become operational in late 2020.

The total available thermal power will initially rise to 400-420 MW_{th}. The system backup will amount to approximately 120-140 MW_{th}. In the proposed project of a common district heating system, a network of thermal energy transmission pipelines will be developed, which will connect all consumption points (cities) and production points (Kardia substation, Ptolemaida 5, Amyntaio boilers).

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.

5.2 Projections for the other energy generation technologies for 2030

5.2.1 Other fossil fuels powered energy generation technologies

In drawing up the programme for shutting down lignite-fired plants, account was taken of the unhindered operation of the district heating systems used to cover thermal needs in the energy areas. In this context, all alternatives, such as the development of a natural gas network in these areas, will be looked into.

According to the 10-year investment plan of DESFA for the period 2020-2029, which includes projects with a total budget of € 300 million, there are projects in the foreground, such as the development of the gas transmission network in new areas and specifically the planned extensions for Western Macedonia. More specifically, these are three new metering and regulating stations, which will be created in Perdika Eordaia (€ 3 million), Poria in Kastoria (€ 2 million) and in Aspros in Edessa, Naoussa and Giannitsa (€3 million). From these three measuring/regulating stations it will then be possible to build the medium and low-pressure network, which will transport the natural gas to the cities of the region.

According to DESFA sources, the specific projects in Western Macedonia are expected to be completed by the end of 2022, in line with the delignification program. The same sources of DESFA note that for the region of Western Macedonia, in addition to the construction of metering stations that will be created at points where the TAP pipeline passes, the creation of a new extension pipeline of the National Natural Gas System (NSF) is being considered. The project is under study as there are plans for the construction in the region of Western Macedonia of a new power plant with natural gas as fuel.

Taking into account the above, it is planned to cover the thermal needs of the city of Florina with the development of a medium and low-pressure gas network, with a construction schedule until the end of 2023, while at the same time the connections for the city's consumers will be implemented. More precisely, the Teleheating Florina project entailed the development of a thermal energy-based district heating network to supply heat and hot water to 2,534 residential buildings in Florina, a city of 23,000 inhabitants in West Macedonia region. Funded by the EU, the project will replace the burning of fossil fuels with a "clean" source of energy. However, works have not finished due to the necessity for change in "fuel", as according to the withdrawal schedule of the lignite units, the Meliti TPP will be withdrawn in 2023.

Regarding the heating systems used, according to a recent survey made (Boemi, S.N. et al. 2017), almost 29% use district heating system in the specific area (as it was expected), 8% electrical heating, while 20% are also using an auxiliary secondary heating equipment (Figure 5.1). Analytically, 19% of the dwellings are heated with oil system alone, 2% use only natural gas, 18% use only pellet or wood, and 8% only electrical heating. Turning to mixtures of energy sources, it was found that 20% of the households used more than one heating system, two or three heating sources (oil, gas and air conditioning), and 1% did not heat at al.

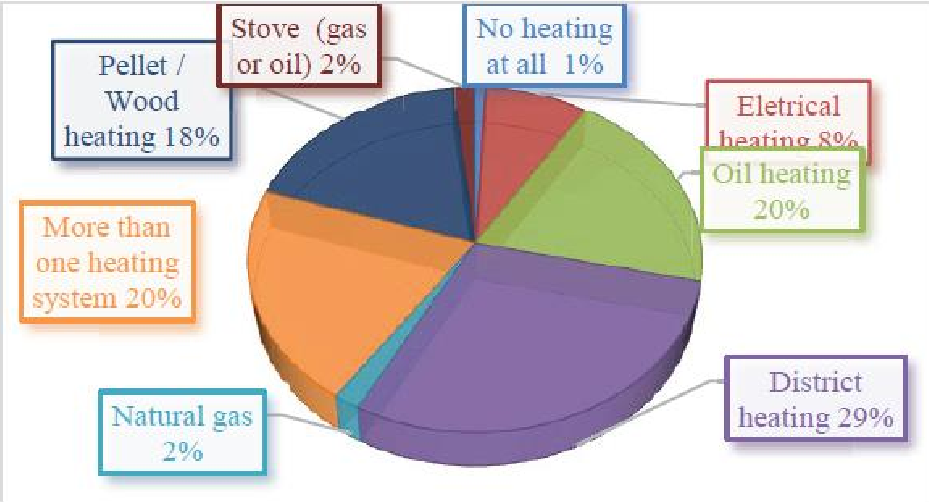


Figure 5.1: Type of heating systems in Western Macedonia

Source: Boemi, S.N. et al. 'Residential heating under energy poverty conditions: a field study' (2017)

Thus, it is evident that, apart from district heating, oil is the dominant fuel used for space heating and domestic hot water production purposes in Western Macedonia, followed by biomass (pellets/logwoods). This situation, according to the scenarios run for the region of Western Macedonia in the frame of the NECP, is not expected to change dramatically until 2030 (probably except from a foreseen increase in the use of heat pumps, from 2027 and afterwards).

As for the other sectors of economic activity, according to the ELSTAT data used for running of the scenarios related to the energy projections under the Greek NECP, the tertiary sector uses electricity (76%), petroleum products (13%) and heat pumps/geothermal (11%). This situation is not expected to change significantly by 2030.

In the activities of the industrial sector mainly petroleum products (56%) are used, together with electricity (31%) and biomass fuels (13%). In this case, the situation is expected to change, with an increasing trend shown in the use of electricity (doubling the rate by 2030). In the agricultural sector, the predominant fuel is again petroleum products (84%), with the rest being covered by electricity. This situation is not expected to change significantly by 2030, with only one projected increase in the use of bioenergy from 2024 onwards.

Finally, in the transport sector, petroleum products (gasoline, diesel) still prevail, with a percentage of about 95%, followed by biofuels (5%). In this case, for 2030, an increase in the use of biofuels is expected (7.5% in 2030), with a parallel occurrence of electromobility (approximately 4% in 2030), which in recent years has been promoted nationally (with the remaining percentage to be covered by petroleum products).

From the available data of ELSTAT on energy consumption, it appears that the region of Western Macedonia consumes 3.0-3.5% of total oil consumption in Greece, with Kozani receiving a share of more than 50%, due to industrial infrastructure and the largest numerical population. Regarding the consumption mixture, most of it concerns oil consumption (72.7%), followed by gasoline with 19.3% and LPG with 7.8%.

5.2.2 Renewable energy and other new energy generation technologies

In the lignite areas of Kozani, Ptolemaida and Florina, RES have low penetration for the time being and are under development, given the saturation of networks due to the until recently high utilization of existing lignite fired thermal units. But this situation is expected to radically change in the near future, with the phasing out of the majority of TPPs that exist in Western Macedonia.

As regards wind energy, there are six (6) wind parks in operation 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. In addition, there are another 795.7 MW of wind energy projects with a Decision of Approval of Environmental Conditions (AECO), as well as a number of projects of 746.5 MW capacity that have obtained Production License. There is also a 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 app. 2,132 MW of capacity. It is important to mention that, in the last auctions held between 7/2018 and 7/2019, 100.95 MW of wind energy projects were selected.

The small hydroelectric projects (SHPP), which are in a mature licensing stage, 8 are in the lignite region of Western Macedonia, with a total capacity of 9.14 MW. Six (6) mature biomass projects are located in the lignite regions of Western Macedonia, with a total capacity of 40.67 MW. Finally, 38 projects of solar thermal units, located entirely in the lignite fields of Western Macedonia, total 102 MW, are in a mature licensing stage, with 36 of them, with a total capacity of 94.9 MW, located in the area of the Amyntaio lignite mine, in the prefecture of Florina, having already secured AECO.

Especially as regards biomass, it must be mentioned that there is a theoretical potential for residual biomass in the Region of Western Macedonia that, according to conservative estimates, amounts to 500,000 tons of dry biomass/year, with a fuel energy content of 2,600 GWh / year. By exploiting part of these quantities, it is possible to set up a 25 MW_e power plant, corresponding to at least 50 jobs. In addition, absolute priority is given to the development of energy crops in the mines soils in order to produce biomass fuel for Ptolemaida 5 and for advanced biofuels. This activity matches the specialties of the human resources of the region, has a great leverage of economic activity and employment, utilizes the restoration of lands that is required by PPC and is of great energy and environmental importance.

With regard to photovoltaics, it must be mentioned that, as early as February 2020, the Ministry of Environment and Energy presented a long-term plan of 12 (twelve) points for the smooth and fair transition to the post-lignite era for Western Macedonia and Megalopoli. This plan, especially as regards the energy situation/investment projects in Western Macedonia, is summarized as follows:

1. Rapid maturation and installation of photovoltaic parks of ~1.9 GW in Western Macedonia (e.g., partnership between PPC and RWE)
2. Agreement between ELPE and the German company Juwi for the immediate construction of a 204 MW photovoltaic park in Kozani

In this context, the tender of PPC Renewables for the first mega-photovoltaic to be built in Ptolemaida and which, when completed, will be among the largest in Europe, is of great importance. In essence, this first mega-project will concern three different “packages”, two small ones, with a total capacity of 30 MW, which have already been announced and a large one, of 200 MW, for which the start of the tender by PPC Renewables took place in mid-April 2020 with the publication of the relevant notice.

In December 2019 cycle of auctions, the number of applications for PVs to the Regulatory Authority for Energy (RAE) for Western Macedonia increased from 3 GWp to 7.2 GWp, which shows the intense market interest. This accounts for 25% of current PV pipeline for Greece (26 GWp pending applications). The high demand is directly related to the vacuum in the electrical space that is expected to create the withdrawal of lignite plants in Western Macedonia in 2023.

Most applications have been submitted by PPC Renewables and relate to projects located in the areas of lignite mines, which are expected to utilize the connection infrastructure of the withdrawing thermal units. Among these are the 99 applications of PPC for photovoltaic parks in the open lignite mines of Ptolemaida and Amyntaio, with a capacity of 550 MWp and 350 MWp respectively, which, however, presuppose the restoration of the lignite mines. Among the rest, the photovoltaic projects at Perdikkas, Eordaia Amyntaio, with a total capacity of 204.76 MW, the PV parks Amyntaio I & II, with a capacity of 100 MWp and 75 MWp respectively, as well as the 8 PV parks at Exochi in Kozani at the Ptolemaida lignite mine stand out, with a total capacity of 173 MWp. All these projects are expected to receive soon all necessary licences; thus, it will be made possible to be functioning by 2030.

5.3 Projections for the energy mix of the region for 2050

With the completion of the elaboration and adoption of the NECP, which analyses the energy and climate goals set by the country as well as the policy priorities and measures for their implementation, Greece also explores the optimal mix of structure and evolution of the energy system up to 2050 to achieve specific climate targets in order to set the framework for its long-term energy and climate strategy for 2050. It is clear that the Long-Term Energy Strategy was developed in addition to the NECP, as well as that the decade 2030-2040 will be a decade of choosing the mature for adoption technological solutions, but also of continuing the successful policies and measures that will contribute to achieving the goals of 2050, with even greater intensity and pace of implementation.

The Long-Term Energy Strategy analyses scenarios for the evolution of the energy system and the pattern of consumption in the final sectors, with the ultimate goal of transition to a climate-neutral economy by 2050, without presenting specific specialized measures. These scenarios will be further discussed and elaborated in the future, in order to select the appropriate policy measures and corresponding technologies that will change the operating model of the consumption and production system. However, no specific reference to the Western Macedonia Region is made (only in country level).

Natural gas has been identified in the NECP, appropriately, as a transition fuel which will likely play a key role. However, special attention is required to the changing role of gas. Whereas in the past, it provided energy, firm capacity, and ancillary services, in the future, its primary role will be to provide firm capacity and ancillary services. This has important ramifications on the way power plants are designed and commercial agreements are structured, particularly to allow for increased flexibility of these assets as time goes on, and as more renewables are integrated in the power system. If the final goal is decarbonization by 2050, gas would most likely need to be replaced by hydrogen, energy storage, and other options during the 2040s.

Specifically, as regards the Western Macedonia, the “future” of the under construction lignite unit of PPC “Ptolemaida 5”, which is supposed to use lignite until 2028, is an issue of great interest nowadays and a lot of discussions and studies are made on that. The unit is scheduled to be completed in 2022 and, according to recent announcements by the president and CEO of PPC, it will start with lignite fuel but will be converted earlier than planned, in the middle of the decade, into a gas unit, a combined movement by increasing its power to 1,000 MW.

A study, conducted by the German energy consulting company Enervis, examines four alternative conversion options for the unit (Green Tank, 2021):

(a) the use of carbon dioxide capture and storage (CCS) technology in conjunction with the continuation of the plant's lignite operation;

b) the conversion of Ptolemaida 5 TPP into a biomass combustion plant;

(c) its replacement by a combined cycle unit with natural gas fuel (CCGT);

d) its conversion into a storage unit of electricity derived from RES in the form of heat, utilizing the technology of molten salts.

For each technological solution, the effect of a number of parameters on the weighted cost of electricity generation (LCOE) was analyzed, while the four technologies were evaluated comparatively in terms of their ability to maintain or create jobs. The analysis shows the following:

- CCS technology has proven to be the most expensive with a weighted cost of electricity generation (LCOE) ranging between € 122 / MWh and € 158 / MWh for a wide range of CO_2 capture and storage rates between 30% and 90%.
- Biomass combustion is economically competitive (LCOE lower than 80 € / MWh) only for low levels of combustion in combination with very low CO_2 values.
- Replacing lignite with mineral gas is the cheapest option (65 € / MWh) only for scenarios that combine lower fuel supply prices than those provided in the NECP, low CO_2 prices and increased operating hours of 6000 hours per year
- The conversion of Ptolemaida 5 into a thermal storage unit of electricity derived from RES makes the operation of the unit completely independent of fluctuations in the prices of CO_2 rights or specific fuels, while at the same time helping to meet the increased energy storage needs of the country. The results of the analysis show that this solution is very competitive as it is characterized by a weighted cost of electricity production ranging between 91 and 106 €/MWh, with the most advantageous prices corresponding to a participation of PV of 70% in mixture of RES electricity stored.

The last solution - according to the study - leads to a cost of energy production of 91-106 euros per megawatt hour and creates 1,247 jobs (along with the jobs that will be created in the construction of wind and photovoltaic plants that will be combined with the unit).

A new industry for the near future would be related to hydrogen production, which seems to be a profitable fuel for buses or trucks covering long distances. It can also be used on an industrial scale, as a compound of other chemical materials. Thus, the Greek government and the Ministry of Environment and Energy (HMEE) are considering a solar-based hydrogen production initiative through major-scale photovoltaic facilities planned at state-controlled power utility PPC’s lignite fields in northern Greece’s Ptolemaida area, on the way out as a result of Greece’s decarbonization plan.

Discussions for solar-based hydrogen production are still at an early stage. The construction of PV Parks provides the possibility of the research and development of hydrogen units that will be connected to renewable energy sources and for which investment interest has been expressed:

- Since April 2020 Solaris Bus & Coach has expressed interest in investing ~ € 1 billion in a green hydrogen production unit through RES
- The “White Dragon” project that undertakes investments of €2.5 billion in 1.5 GW electrolytes and estimates 5,000 direct jobs. This project is designed by 4 countries, one of which is Greece. It competes for funding for another 7 projects under Hydrogen Europe.

With the “White Dragon”, and with the expression of interest already for this important project of common European interest, Western Macedonia expects to settle in an area of twenty-five thousand acres of land that will restore a large PV system, of the order of 1 GW, which will produce electricity and this through the process of electrolysis will produce -in turn- “green” hydrogen, which will be stored by compression. Hydrogen will then be both a fuel and energy storage and can be used either for electricity generation, or for heat production, or for heating or for movement with the appropriate infrastructure and support networks. As a next step, a quantity of the “green” hydrogen produced will be able to reach other European countries with the help of the Trans Adriatic Pipeline (TAP). The documentation of the participation dossier is expected to be completed in April 2021, and to enter an evaluation process by the summer of the same year.

In addition, and in connection with the increase of the generated power, the latest list of projects of common interest (PCI) of the European Organization of Electricity System Operators (ENTSO-E) includes for the first time the installation of lithium-ion batteries in the region of Western Macedonia, in Ptolemaida, a project of a Greek company Eunice, capacity 250 MW and a budget of approximately € 320 million. The project’s business plan is expected to be prepared in 2021, as effort is currently being made to advance the licensing pillar.

At this point, it should be mentioned that all the above are in full compatibility with the World Bank’s strategy for the decarbonisation model of Western Macedonia, as this was proposed to the Greek Government and the European Commission (World Bank, 2020). More specifically, one of the decarbonisation scenarios the World Bank has presented is the so called “Western Macedonia Alternative Energy and Energy Storage Pathway”.

The basic idea behind this concept is that the variability in generation from RES technologies (basically solar and wind) can be compensated by producing surplus energy with PV panels when the sun is shining and wind turbines when the wind is blowing, and then storing that surplus. The stored surplus can then be used when the sun and wind are not generating enough electricity. It can be stored as pumped storage hydro, molten salts thermal storage, electro-chemical batteries, or eventually as green gas (hydrogen) produced from electrolysis. That combination of variable generation and stored energy could produce baseload and flexible electricity, and also district heating, as reliably as lignite, certainly much cleaner than lignite, and probably also cheaper than lignite.

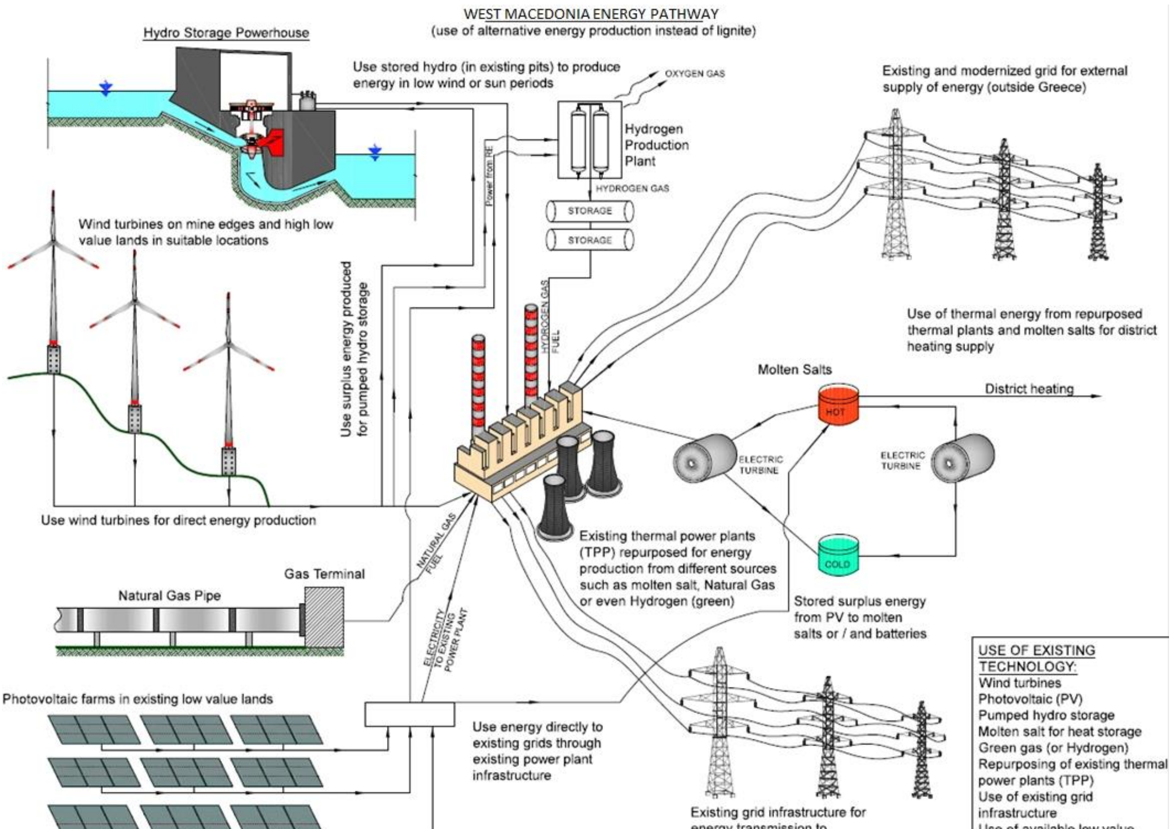


Figure 5.2: Representation of World Bank’s Western Macedonia Alternative Energy and Energy Storage Pathway

Source: Regional Economic Transition Strategy for Western Macedonia, World Bank (2020)

Like variable RES generation, energy storage technologies are rapidly evolving. Efficiencies are increasing and costs are decreasing rapidly, making previously expensive solutions more and more competitive. In addition to storing energy, many storage solutions also provide essential grid services such as reactive power and primary, secondary and tertiary reserve. For Western Macedonia, a feasibility assessment of pumped hydropower, electrochemical batteries, molten salt storage (conversion of lignite power plant) and green hydrogen shall be done. The emphasis shall be on the storage services that the Western Macedonia could provide to the power system of Greece (and of neighbouring countries) in order to enable an increase in the grid penetration of variable renewables.

5.4 References

BOEMI, S.N.; PANARAS, G.; PAPADOPOULOS, A.M. (2017) Residential heating under energy poverty conditions: a field study. PROCEDIA ENVIRON. SCI. 2017, 38, 867–874.

HMEE (2019a), "National Plan for Energy and Climate", Athens, December 2019, https: //ec.europa.eu/energy/sites/ener/files/documents/el_final_necp_main_en.pdf

HMEE (2019b), "Long-term Strategy for 2050", http://www.opengov.gr/minenv/wpcontent/uploads/ downloads/2019/12/%CE%9C%CE%A350_091219_public-consultation.pdf

IENE (2020) Current situation and prospects for areas in energy transition in Greece (EN), https://www.sdam.gr/sites/default/files/consultation/Current_situation_and_prospects_for_areas_in_energy_transition_in_Greece_EN.pdf

WORLD BANK (2020) A Road Map for a Managed Transition of Coal-Dependent Regions in Western Macedonia, https://www.sdam.gr/sites/default/files/consultation/Western_Macedonia_Final_Roadmap_Coal_Report.pdf

THE GREEN TANK. (2021) https://thegreentank.gr/2021/04/20/ptolemaida_5_enallaktikes_lyseis/

6 Poland, Upper Silesia Region

6.1 Projections for the energy generation technologies using coal for 2030

In 2018, the Polish economy used nearly 171 TWh of electric power. The installed capacity in the national power system (NPS) at the end of 2018 amounted to nearly 46 GW, of which over 36.6 GW was from utility power plants fired mostly by coal and lignite; over 6.6 GW from utility power plants using renewable energy sources and the rest, approx. 2.7 GW, from industrial power plants (various fuels). At the end of 2018 the installed capacity of all the renewable sources amounted to 8.5 GW (including 5.8 GW of wind capacity), of which 5.2 GW came from independent sources, i.e., those operating outside the structures of the power sector companies (Ministry of Energy 2019).

In 2017, a total of 27,834.2 GWh of electric power was produced in the Silesia region which puts it in the second place nation-wide. Most of the power produced was generated by coal-fired power plants. Despite high power generation, a low share of RES is evident. In 2017 it amounted to only 2.8%, the lowest in the country. This is due to the fact that the Silesia Region has a limited potential for the development of renewable energy sources (Silesia Region 2019).

6.1.1 Coal driven thermal power (TP) and CHP plants

From 2015 to 2030 coal production in Poland (excluding coking coal) will drop from 59.6 million tonnes to 41.6 million tonnes and from 2030 to 2040 to 29.8 million tonnes. After 2030, acceleration is expected to the process of permanent shutdown of old coal-fired generating units and their elimination from the domestic power industry. The construction of new coal-fired units (apart from those where the investment decision has already been made) will be difficult in the conditions of rising prices for CO_2 emission allowances, the gradually more stringent environmental requirements and the trends in the EU climate and energy policy (Ministry of Energy 2019).

The draft Polish Energy Policy indicates that by 2030 the share of coal will drop to approximately 56-60% in electric power generation. Investments in new coal-fired units made after 2025 will be based on cogeneration or another technology that meets the emissions standard at the level of 450 kg CO_2 per MWh of generated power. In order to make the best use of the raw material and to reduce the environmental impact, new methods of coal use and processing will be sought and implemented, including gasification, oxy-combustion and other clean coal technologies (Ministry of Energy 2019).

Due to the high share of coal the current power generation source mix in Silesia provides energy security of the region and balances production with the regional demand for power. Decarbonization of the energy sector requires reorganization of the production system while maintaining continuity of power supplies. Energy balance analyses commissioned by the Silesian region local government assume a reduction in the production of electric power and heat from coal by 28.3% compared to 2017. Coal-fired power plants and combined heat and power plants should be replaced with units producing energy from cold gas (increase in energy production from gas by 126.6%).

By 2030, the amount of energy produced from ecological sources will have also increased with the largest amount of RES energy coming from biomass, solar energy, wind and heat pumps. A significant increase in the share of energy produced from municipal waste is also expected which is important as the Silesian region has the largest number of inhabitants and the highest population density in the country.

The central and local authorities are speculating about the possibilities of using coal in “clean coal” technologies including Carbon Capture and Storage (CCS). CCS is still a new technology with unrecognized technical risk, lack of social acceptance and high costs. Also, there is a risk that it will be unviable to develop this technology and implement it. The first Polish pilot CCS installation was to be built at the Bełchatów Power Plant and was to be integrated with the new 858 MW unit, but due to the unprofitability of the CCS technology and failure by the European Commission to grant funding for the project in December 2012, the PGE authorities withdrew from its implementation. There is currently one pilot installation with the CCS technology being built at the Łaziska power plant in Upper Silesia. It is a mobile installation and was installed for research purposes on a conventional unit with a capacity of 200 MW. Another possibility is the CCU technology designed to capture carbon dioxide, similarly to CCS, and then transform it into a form that can be used in the production of plastics. However, this technology is yet to be researched and there is not enough data about it.

Underground coal gasification is one of the considered options for using coal in power generation in 2030. This process is being investigated at the Centre for Clean Coal Technologies in Silesia (a consortium of the Central Mining Institute from Katowice and the Institute for Chemical Processing of Coal from Zabrze). Underground coal gasification (UCG) is an unconventional method of mining coal deposits comprising the in-situ conversion of coal into gas with a composition suitable for industrial applications (H_2, CO, CH_4). UCG is not a new technology, however it has undergone a significant transformation in recent years due to the introduction of new technological solutions. The main advantages of UCG are: partial or complete elimination of mining, reduction of initial investments and operating costs, reduction of contaminant emissions into the air as well as reduction of the amount of solid waste generated by mining and energy generation processes.

The solutions considered in the future also include IGCC power plants that generate syngas from coal, with the gas then burned. IGCC technology blocks are therefore similar in structure to the widespread, typical gas-steam units using natural gas, the backup fuel for IGCC installations. The main difference is an extensive system of syngas production from solid fuel and its integration (through heat exchange) with gas-steam turbines and an oxygen generating plant. In addition to coal, many installations use petroleum coke and other petrochemical products for gasification. Experts have high hopes for further development of coal gasification technology in the power industry. It is estimated that in few years these units will achieve 52% efficiency, 99% desulphurization efficiency, 90% flue gas denitrification and 95% CO_2 removal.

In the near future, efforts will be made to expand and improve efficiency in the heating sector. In Poland it is expected that by 2030 at least 85% of the heating or cooling systems with the installed capacity of over 5 MW will meet the criteria of an energy-efficient heating system. The following measures will play a decisive role in achieving this aim:

- Development of cogeneration as the most environmentally efficient way of using fossil fuels. To compensate for higher cost of such installations, subsidies for electric power produced by high-efficiency cogeneration will be maintained.
- Increasing the use of renewable energy in system heating, mainly through the use of local renewable energy sources, i.e., biomass, biogas or geothermal energy, as well as solar collectors, especially in clusters.
- Increasing the use of waste in system heating (mainly in CHP). Waste incineration plants are provided with highly efficient flue gas cleaning installations wile very high temperatures ensure that the most volatile parts are burnt.
- Connecting power plants with district heating systems - to achieve the highest possible efficiency of fuel use the heat produced in the production of electric power should not be wasted. The potential for the development of the local heat market will be analysed in cooperation with communes.
- Modernization and expansion of the heat and cooling distribution system - to reduce losses, the heating medium should be transported via pre-insulated networks. In order to increase the range of heating networks, it is also necessary to simplify the investment process of their construction.

6.1.2 Other coal-fired energy generation applications

The aim of the Polish Energy Policy is to cover the heating requirements of all the households by system heat (i.e., heat produced and delivered by communal enterprises) and by zero- or low-emission heat sources by 2040. In recent years, there has been a decline in demand for coal in industrial sectors and for household needs. In order to reduce smog in towns and cities, households and services will gradually replace ineffective charging boilers with boilers meeting the highest environmental standards (with high energy transformation efficiency) while coal-based technologies will be replaced with more environmentally friendly ones (system heat, renewable energy) (Ministry of Energy 2019).

Locally, coal is mainly used to heat households or small businesses. Before 2014, a large part of the boilers did not meet any standards. Since 2014, only class-3 boilers or better are on sale (class 3 is the lowest class of boilers). Ecological central heating boilers have specially designed furnaces, the so-called muffle furnaces that operate mainly on eco-pea coal, which in itself is a very efficient and ecological material as it does not produce a large amount of ash, while it has a reduced amount of sulphur compounds and other substances harmful to the environment. As a result, combustion in ecological boilers is very efficient - even up to 85%. The latest coal stoves on sale burn coal efficiently and their users need not operate them daily as they are fitted with feeders. Stoves with the so-called heat buffer may also be used. This means that there is no need for a separate DHW heater, as the buffer may have an integrated water heating function, and most probably the costs of flue modernisation may be eliminated as furnaces with heat buffer always operate at full power resulting in high flue gas temperature. Cheap and available fuels, e.g., large-chunk coal, may be used.

6.2 Projections for the other energy generation technologies for 2030

6.2.1 Other fossil fuels powered energy generation technologies

Poland has significant coal and lignite deposits on the European scale. Other energy sources (crude oil, natural gas) in the country are limited. The closest crude oil deposits to the Silesia region may be found in Małopolska and slightly further in Podkarpacie, but they are small, with the largest (over 70% of all Polish deposits) located in the Polish Plain. On the other hand, mining of the Baltic deposits, which contain 25% of the total resources, is on the rise. There are some sources of natural gas in Silesia, but they are unable to meet the energy requirements of the region. In the whole of the country, gas deposits cover 12% of the demand. Due to the fact that most of the gas used in Poland is imported, mainly by sea, which in the future is expected to increase even more, gas-fired power plants will be located predominantly in the north of Poland. Nevertheless, also in the region of Silesia, investments in power plants using natural gas, methane from mines and coke oven gas are planned.

Methane occurs in the coal seams of the Upper Silesian Coalfield (Polish acronym GZW). The potential resources of methane in the coal beds are estimated at approx. 350 billion m^3. Recoverable resources amount to approximately 96 billion m^3, including 48.61 billion m^3 in 33 mined coal deposits and over 26 billion m^3 in 11 deposits where methane is considered as the main mineral. According to the Polish Geological Institute, the Upper Silesian Coalfield has the greatest Coalbed Methane extraction (CBM) potential. According to recent studies, this coalfield has prospective resources estimated at approx. 254 billion m^3, including balance recoverable resources which may amount to approx. 150 billion m^3.

The gas captured by methane drainage can be used to a large extent as a low-methane fuel for various types of heating and electric power installations. For instance, in the case of gas and coal-gas boilers, gas is used in the coal mines in engines, gas turbines and gas dryers. Electric power and heating devices powered by gas require stabilized fuel in terms of quality and quantity. Low-methane gas captured by methane drainage displays high variability of these two parameters due to the dependence of methane drainage efficiency on mining. Fluctuations in fuel quality and quantity have a negative impact on the reliability and continuity of operation of heating and electric power gas installations. One of the possible solutions used in practice to stabilize the quality and quantity is the storage of methane in underground storage facilities (UGS) and surface tanks.

In 2016, a 50 MW coal and gas-fired installation in Dąbrowa Górnicza was opened. In 2015, Przyjaźń Coking Facility in Dąbrowa Górnicza launched a power unit with a capacity of 71 MW_e fired with coke-oven gas. JSW Koks company has invested in units for the production of electric power and heat for its own needs and for sale and is planning to build a power unit fired with its own coke-oven gas with a thermal capacity of 104 MW_{th} and electric capacity of 28 MW_e which will ensure the supply of electricity, steam and heat for the Radlin coking plant, heat for the nearby Marcel Coal Mine and for the residents of the town of Radlin. In 2012, Tauron and PGNiG signed a letter of intent for the construction of a gas-fired 413 MW cogeneration unit at the Łagisza Power Plant. After the withdrawal of PGNiG, the project has been suspended until 2025. It may be launched in the event of favourable regulatory and market conditions.

6.2.2 Renewable energy and other new energy generation technologies

It has been decided that the target renewable energy sources (RES) share in gross final energy consumption in 2030 will be 23% in Poland, which translates into approx. 32% share of RES in net electricity production. The development of photovoltaics (especially after 2022) and offshore wind farms (the first offshore wind farm will be launched around 2025) will play a key role in meeting the target in the power industry, due to an increase in profitability of these sources and the expected increase in market flexibility, necessary for the development of renewable energy sources (Ministry of Energy 2019).

In 2018, the share of RES in gross final energy consumption in Poland amounted to 10.9%. The largest volume of renewable energy is used in the heating and cooling sectors, followed by electric power supply, and the least in transport. The share of production from renewable sources in these sub-sectors amounts to 14.6% in heating and cooling, 13.91% in electricity generation and 3.6% in transport, respectively. It is estimated that, taking into account the competitiveness of renewable sources, the technical capabilities of their operation in the National Power System (NPS), as well as the challenges related to the development of RES in the transportation and heating sectors, it is possible to achieve a 21% share of RES in the final gross energy consumption by 2030 (Ministry of Energy 2019).

Technological progress will have a significant impact on the scale of RES use, both in terms of currently known methods of energy production (e.g., increasing the use of wind-by-wind turbines or solar radiation by photovoltaic panels), and in completely new technologies, but also in energy storage technologies. The implementation of the RES target will be possible by increasing the use of RES in all the three sub-sectors, although it will be most difficult to increase the share of RES in the transportation sector, especially the first years (Ministry of Energy 2019).

According to the EU regulations, Poland must achieve a 14% share of renewable energy in the transportation sector by 2030. The use of bio-components (added to liquid fuels and liquid biofuels used in transport) will contribute to the implementation of these goals, with an increasing emphasis on the use of advanced (non-food) biofuels and recycled carbon fuels, as well as the use of electricity in the means of transport. This signifies an increasing impact of RES on the fuel market dominated by petroleum fuels.

The share of RES in the heating and cooling sectors will increase nationwide by about 1.1% annually. According to the Ministry of Energy the production of renewable energy in this sub-sector will be facilitated by the use of the following:

- Energy from biomass (and heat from waste) – this source will work well in households and in cogeneration; it has the biggest potential for achieving the renewable energy target in heating due to the availability of fuel and the technical and economic parameters of the installation. Generating units using biomass should be located in the vicinity of its production and in places where it is possible to maximize the use of primary energy from fuel to minimize the environmental cost of transport.
- Energy from biogas - the use of biogas will be particularly useful in the combined production of electric power and heat. The advantage is the possibility of storing energy in biogas, which can be used for regulatory purposes. In terms of general economic use, biogas is an additional added value, as it enables the management of particularly troublesome waste (e.g., animal waste, landfill gases).
- Geothermal energy - although its current use is relatively low, an upward trend is expected. Determining geothermal potential requires extensive costs with a high degree of uncertainty, but the use of this type of energy may determine the development of a given area (such as holiday resorts).
- Heat pumps - their use is becoming more and more popular in households and their potential is assessed at a level similar to that of geothermal energy. Electric power is necessary to use them, therefore it is a good solution to combine the installation with another RES source that generates electricity.
- Solar energy - a significant increase in its use for heating purposes depends on technological development due to the inverse correlation between insolation and heating needs. However, this type of energy will play a key role in covering the cooling requirements - solar panels will cover summer electricity peaks for air conditioning purposes.

In the coming years, the increase in the use of renewable energy sources in electric power generation will remain stable but a growth has been predicted after 2025 due to the expected achievement of technological and economic maturity of individual technologies. It is estimated that by 2030 the share of renewable energy in the electric power sector on the national scale will have reached approx. 32%, and by 2040 almost 40%. The following technologies will contribute to the growth in the share of RES in the electric power sector:

- Solar energy (photovoltaics) - the advantage of this technology is the positive correlation between the intensity of insolation and daily demand for electricity, as well as increased generation in summer correlated with the demand for air conditioning. These are installations with relatively small power, but the total installed capacity will grow in importance for the NPS. The installations may be mounted on post-industrial sites and poor-quality land, as well as on house and building roofs. It is estimated that photovoltaic technologies will reach economic and technical maturity after 2022.

- Offshore wind energy - offshore wind reaches relatively high speeds and does not encounter obstacles (low roughness), hence offshore wind farms are more productive than the ones located on land. The commencement of investments into this technology depends on the expansion of the transmission network in the northern part of the country to transmit electric power into the interior of the country. It is expected that the first offshore wind farm will be included in the electricity balance around 2025. The Polish shoreline allows for the implementation of further installations at sea, but the possibility of balancing them in the NPS will be of key importance for the investment. It is expected that in the 2040 perspective these sources will be responsible for the largest volume of electricity generated from RES.
- Onshore wind energy - it is expected that in the medium term an increase in the share of this technology in the energy balance will be less dynamic than in previous years. A significant obstacle in the use of onshore wind energy is lack of correlation between their operation and energy demand, therefore the pace of their development will depend on costs and balancing. Another problem is fluctuating acceptance for the construction of wind farms by local communities. In order to reduce potential conflicts, investors should set up systems to allow residents' participation in the implementation of projects.
- Energy from biomass and biogas - their potential will be used primarily in heating, but some resources will also be used to generate electricity, especially in cogeneration and the transportation sector. The advantage of biogas is that it may be used for regulatory purposes, which is particularly important for the flexibility of NPS operation.
- Hydropower - due to the limited domestic water potential, a significant increase in the use of flowing water energy is not expected. In the long term, the development of hydropower may be impacted by the development of inland waterways and the revitalization of water dams which are important from the point of view of watercourse regulation and flood management. Pumped storage hydroelectric power plants are not classified as RES but have a regulatory function for the NPS.

Generation of power - in particular electric power - from RES should also be considered in terms of entities. In addition to the installations set up as part of business projects implemented by various companies, the so-called distributed energy based on installations with relatively low capacities has started to develop. It is intended to cover, in the first place, own energy needs, while the surplus is to supply the nation-wide system. One of the types is biogas in small centres and in the country where wind energy is combined with biogas. In the smallest centres with a demand of up to 1 MW, the solution is to build wind turbines with an installed capacity of 4 MW, balanced by a power plant and a biogas plant with a capacity of 1 MW. Establishing 500 installations of this type will allow to increase the system's achievable power by 2500 MW. Out of this, 500 MW would remain in the power reserve, allowing to make up for losses in the absence of wind, and the 2000 MW of achievable power with the maximum use of wind power should be balanced by excluding power generated from other sources.

Another option is the development of agricultural biogas plants in locations where wind farms are impossible. The capacities from agricultural biogas may also be used to balance the already existing wind farm capacities. By building 500 biogas plants with an average capacity of 1 MW, it is possible to add 500 MW of locally available power. Biogas is a better solution than burning biomass for environmental reasons. Above all, biogas-based sources have lower pollutant emissions. They are virtually dust-free, while biomass sources produce high dust emissions. Additionally, gasification residues can be used in agriculture with a demand for fertilizers.

Biogas plants can also be developed in towns and cities to produce electricity or system heat, especially in high-efficiency cogeneration. The sources of biomass for gas production are common but they remain unused. This may be changed by recovering gas from sewage sludge through installations fitted at wastewater treatment plants. The use of appropriate catalysis technology allows for a return on investment within 7-10 years, which is very short in the case of municipal administration. The residues from the gasification of sludge may serve as a source of phosphorus to be used in agriculture. Gasification of the organic fraction of municipal waste, mainly the fraction that is unsuitable for composting, including organic waste from households, restaurants, caterers, and waste from urban greenery, is also proposed. It is also possible to combine multiple biomass sources and feed them to a biogas installation. Another option is gas recovery installations at existing landfills. In a medium-sized city, it is possible to cover approx. 10% of the demand for electricity and heat in such a manner. Potentially, installing this type of system in regional and district capital cities could bring up to 500 MW of available capacity.

The Polskie Sieci Elektroenergetyczne electric power generation network suggests the necessity to connect photovoltaic (PV) installations to the power system due to the increasing demand for energy used by air-conditioning in the summer season. It is estimated that approximately 2000 MW of power from PV panels could be added to the system. One of the measures to achieve the necessary installed capacity is the development of prosumerism, i.e., power generated by individual users which due to technical limitations would primarily include photovoltaic projects.

6.3 Projections for the energy mix of the region for 2050

In the next years (especially after 2029) a significant part of the currently operated coal-fired units will be withdrawn from the system. According to forecasts, in 2040 the share of coal in electric power generation in Poland will be from 28% to even 11% in the high-price scenario. Coal will be replaced mainly by renewable and nuclear energy.

There are a number of scenarios for electric power generation by 2050 in Poland. In 9 reports, a total of 22 models are considered, where the most optimistic indicate the possibility of reducing CO_2 emissions by 97%. Many reports and forecasts indicate the possibility of reducing coal-fired energy to zero. However, in a region where coal is the main power source and some deposits have not been mined yet, it is unlikely that it will be possible to eliminate power from coal-based installations. The power generation source mix will also depend to a large extent on the introduction of nuclear energy to the market.

The forecast market attractiveness of individual technologies until 2050 shows that renewable sources are becoming more and more profitable, and after 2030 their profitability will exceed the profitability of coal and gas units. According to a “diversified scenario”, excluding nuclear energy, of the “Polski sektor energetyczny 2050. 4 scenariusze” (“Polish energy sector 2050. 4 scenarios") analysis, the share of individual electricity sources in 2050 on the national scale will be: coal 8.3 GW_e, gas 26.1 GW_e and RES 47.7 GW_e. However, due to the number of domestic coal sources (particularly in Silesia), the likely mix for Poland will be: coal 28.5 GW_e, gas 11.5 GW_e and RES 15.3 GW_e.

In order to achieve emissions at the level required by the EU, the power plants will use CCS/ CCU technologies, which can reduce CO_2 emissions by up to 91% compared to 1990. Another possibility are steam power plants with supercritical parameters and power plants using IGCC technology ensuring low emissivity. In the case of heating plants and CHP plants using biomass, the largest share will probably be from biogas, which emits less solid particles when burned. Last, the “RES scenario” assumes that there will be no coal-fired power plants in Poland in 2050. In this scenario gas-fires power plants will generate 30 GW_e and RES power plants 68.6 GW_e.

Some of the analyses carried out on the basis of historical trends and detailed forecasts of the profitability of mining in Upper Silesian mines indicate that by 2050 the production of energy using coal in the region will have ceased. Only the most efficient coking coal mines have a chance to survive in the mid-century, but they will also have to improve efficiency and significantly reduce employment.

According to the project of Polish energy policy (PEP) to 2040, the national power generation mix in 2050 will be significantly impacted by the planned implementation of nuclear energy in 2033. The first unit of a nuclear power plant in Poland (with a capacity of approx. 1-1.5 GW) will be commissioned around 2033. Another 5 units with a total capacity of 5 - 7.5 GW will be launched every 2-3 years.

Expert analyses for Silesia assume a reduction in the share of hard coal in the production of electricity and heat until 2030 (a decrease of 28.3% compared to 2017). Coal-fired power plants and thermal power plants should be replaced by entities producing energy from cold gas (increase in energy production from gas by 126.6%). The implemented climate policy and the decrease in the cost of energy production from RES may result in a significant increase in the amount of energy produced from emission-free sources by 2030. Most of the energy produced by RES in the region will come from biomass, solar energy, wind and heat pumps. It is also expected that the share of energy produced from municipal waste will increase.

6.4 References

BUKOWSKI M., ŚNIEGOCKI A., WETMAŃSKA Z. (2018). Od restrukturyzacji do trwałego rozwoju. Przypadek Górnego Śląska. WiseEuropa Report for WWF Polska, Warszawa, Polska. Ministerstwo Energii 2019. Polityka Energetyczna Polski do 2040 r. Projekt.

ECKE J., STEINERT T., BUKOWSKI M., ŚNIEGOCKI A. (2017) Polski sektor energetyczny 2050. 4 scenariusze. Forum Energii

ENGEL H., PURTA M., SPEELMAN E., SZAREK G., VAN DER PLUIJM P. (2020) Neutralna emisyjnie Polska 2050. Jak wyzwanie zmienić w szansę. McKnisey & Company

WOJEWÓDZTWO ŚLĄSKIE. (2019). Plan działań transformacji regionu. Załącznik nr 1 do Uchwały Zarządu Województwa Śląskiego nr 1485/53/VI/2019 z dnia 3.07.2019 r.

REFERAT REGIONALNE CENTRUM ANALIZ I PLANOWANIA STRATEGICZNEGO (RCAS), Departament Rozwoju Regionalnego, Urząd Marszałkowski Województwa Śląskiego. Polityka gospodarki niskoemisyjnej dla województwa śląskiego. Regionalna polityka energetyczna do roku 2030. Załącznik nr 1 Do Uchwały Zarządu Województwa Śląskiego Nr 2873/194/VI/2020 z dnia 9.12.2020 r.

7 Romania, West Region / Jiu Valley

7.1 Projections for the energy generation technologies using coal for 2030

In order to forecast coal-based energy production for 2030, a series of factors and reference documents were taken into account and hypotheses were established. Thus, the factors and reference documents considered are the following:

- forecast of the evolution of electrical and/or thermal energy consumption at national level;
- diversification of primary energy sources and the transition from coal to a sustainable energy system;
- existing state of the energy generation technologies and compliance with European environmental requirements;
- restrictions in fossil fuels use due to international commitments;
- EC Green Deal policy initiatives, including the European Green Deal Investment Plan and Just Transition Mechanism;
- Romanian Energy Strategy 2019-2030, with forecast to 2050 (ME, 2018);
- 2020-2050 Long Term Renovation Strategy (MLPDA, 2019);
- National Energy & Climate Plan (MEEMA, 2020);
- Report on projections of GHG emission in accordance with article 14 of Regulation (EU) no. 525/2013 (Draft version 2020) (MMAP, 2020), including the evolution of the energy needs at national level in compliance with the National Commission for Prognosis;
- Jiu Valley Strategy for economic, social and environmental development (2021-2030), Draft version 2021 (MIPE, February 2021).

Projections have been performed for two scenarios:

- **SCENARIO A** "with RES and transition fossil fuel" - scenario including policies and measures to reduce GHG emissions, as EE, RES, syngas and/or mine methane recovery and natural gas substitute as transition fuel from coal (new CCGT-CHP unit);
- **SCENARIO B** "with RES and alternative energy sources" - scenario including few additional measures and biomass substitute for coal (new CHP unit) instead of natural gas.

The following key hypotheses were established in order to define the 2 scenarios (A, B):

- 2016 starting year for field data collection; for 2019 and 2020 data were estimated and/or field collected; 2025-2030-2040-2050 forecasts were based on the Report on projections of GHG emissions (MMAP, 2020) and on the method of historical data extrapolation;
- transition from coal commitment according to the Jiu Valley Strategy for economic, social and environmental development (2021-2030), Draft version 2021 (MIPE, February 2021); coal gradually substituted with RES, for electricity and/or heat generation, depending on each analysed scenario;
- natural gas production, at national level, does not go through any significant increase (e.g., determined by the opening of new deposits);
- energy consumption efficiency goes through a rate of improvement both national and regional/local;
- substitutions, but not significant, of the resources used by households as a result, for example, of the expansion of gas supply, electrification of household consumption, etc.;
- increase of electricity production from renewable sources gradually accompanies the increase of renewable generation capacities at national level.

Establishing the structure of energy production projection at the level of Jiu Valley micro-region, starting from the national level, was extremely difficult, and that's the reason why the figures further presented in the following paragraphs are purely indicative.

A series of uncertainties, as below, underline the indicative character of the forecasts made in the next sections:

- fuel prices on international markets;
- long term COVID-19 pandemic impact on the energy sector at national, regional (NUTS2 and NUTS3) and local (Jiu Valley micro-region) levels;
- the local socio-economic environment evolution with direct influence on the electricity demand, and the willingness of Jiu Valley population to re-connect to a retrofitted and upgraded DHS;
- the ability of local, county and regional authorities to access all future funding sources for the proper implementation of Jiu Valley Strategy and Action Plan 2021-2030 developed by the Ministry of Investment and European Projects (MIPE, February 2021).

Both analysed scenarios (A and B) for Jiu Valley micro-region will aim the transition from coal to a sustainable energy system through:

- economic transformation and growth;
- increase of RES and alternative energy sources use;
- reduction of energy intensity in buildings and industry;
- social development;
- better living standards.

In terms of technical solutions recommended for A and B analysed scenarios, these took into consideration the analysis performed in TRACER D3.2 Report (TRACER, 2020), mainly the draft technical energy transition concept updated and improved, after several stakeholders' consultations. Both scenarios are targeting the ETS industry - Jiu Valley Energy Holding, local public authorities, non-ETS industry, SMEs and individuals, and consider the following:

Forecast period	**SCENARIO A** "with RES and transition fossil fuel"	**SCENARIO B** "with RES and alternative energy sources"
2020 2025 2030	▪ Mines' closure and reclamation procedure, ▪ New CCGT-CHP on natural gas (40 MW_e and 50 MW_{th}) ▪ PVP on unproductive lands and electricity storage (1 x 25 MW_e) ▪ New MHPP Baleia (2 MW) ▪ Building's renovation campaign through EE in existing public buildings and residential individual households or collective dwellings ▪ Thermal RES in public buildings and residential individual households ▪ Roof-PV for public buildings, individuals and SMEs (around 1.5 MW_e) ▪ Small insulated retrofitted DHS with former DHS Thermal Stations (TS) transformation (around 1.5 MW_{th}) into: ✓ TP or micro-CHP on natural gas ▪ UCG (syngas recovery) and/or micro-CHP running on mine methane captured (MMC)	▪ Mines' closure and reclamation procedure, ▪ A new biomass based CHPP unit (25 MW_e and 50 MW_{th}) ▪ Thermal energy storage in former underground mines, associated with mine water heat pumps systems ▪ WPP on unproductive lands (2 x 3 MW_e) ▪ PVP on unproductive lands (1 x 25 MW_e) and electricity storage ▪ New MHPP Baleia (2 MW) ▪ Building's renovation campaign through EE in existing public buildings and residential individual households or collective dwellings ▪ Thermal RES in public buildings and residential individual households ▪ Roof-PV for public buildings, individuals and SMEs (around 1.5 MW_e) ▪ Small insulated retrofitted DHS with former DHS Thermal Stations (TS) transformation (around 1.5 MW_{th}) into: ✓ TP or micro-CHP on natural gas ▪ UCG (syngas recovery) and/or micro-CHP running on mine methane captured (MMC)
2030 2040	▪ Building's renovation campaign through EE in existing public buildings and residential individual households or collective dwellings ▪ Thermal RES in public buildings and residential individual households ▪ Small insulated retrofitted DHS with former DHS Thermal Stations (TS) transformation (1.5 MW_{th}) into: ✓ TP with heat pumps systems (heat recovery of the groundwater or/and mine water thermal potential) and/or ✓ green biomass based Thermal Plants (wood wastes resulting from wood industrial processing and agricultural wastes)	▪ Additional PVP on unproductive lands (1 x 25 MW_e) and electricity storage ▪ Building's renovation campaign through EE in existing public buildings and residential individual households or collective dwellings ▪ Thermal RES in public buildings and residential individual households ▪ Small insulated retrofitted DHS with former DHS Thermal Stations (TS) transformation (1.5 MW_{th}) into: ✓ TP with heat pumps systems (heat recovery of the groundwater or/and mine water thermal potential) and/or ✓ green biomass based Thermal Plants (wood wastes resulting from wood industrial processing and agricultural wastes)
2040 2050	No additional measures	▪ Other alternative energy sources, as the development of a green hydrogen plant – on the background of future Jiu Valley Hydrogen HUB, the natural gas still used for heating purposes being gradually replaced by hydrogen, once the National Strategy on Hydrogen will be approved and start to be implemented.

7.1.1 Coal driven thermal power (TP) and CHP plants

According to the 2021 draft version of Jiu Valley Strategy for economic, social and environmental development (2021-2030) (MIPE, February 2021), the only coal based installed and in operation capacities at NUTS3 level – Hunedoara County - are belonging to Hunedoara Energy Holding (CEH), namely:

- Deva TPP Subsidiary: 1 x 235 MWe power unit no.3 hard-coal based, with a completed retrofitting and upgrading program in 2009, but with no IEP (Integrated Environmental Permit) and no compliance with European ELV; located in Mintia village, in the North part of Hunedoara county;
- Paroşeni CHPP Subsidiary: 1 x 150 MWe power unit no.4 running on hard-coal, with IEP and compliance with European ELV, as presented in Table 7.1; located in Vulcan municipality, inside Jiu Valley – TRACER target region.

Table 7.1: Emissions of pollutant substances from coal-based LCP, Paroseni CHPP, 2020

Pollutant substances	M.U.	IED Directive 2010/75/EU	Annual average measured emissions	BAT conclusions for large combustion plants
NO_x	**mg / Nmc**	200	116.425	130
SO_2	**mg / Nmc**	200	162.446	150
PM	**mg / Nmc**	20	2.332	12

Source: Hunedoara Energy Holding, December 2020

CEH includes also in its structure the Mining Division:

- Hard-coal underground mining exploitations – Lonea, Lupeni, Vulcan and Livezeni covering about 51.17 km^2 of mining perimeters;
- PrestServ Petroșani Subsidiary (Jiu Valley coal mining operation and the mining rescue station).

Jiu Valley National Mines Closure Society (SNIMVJ) produced hard coal until 2017 and today (2021) finalised the closure and post-closure processes for all 3 former underground mines Petrila, Paroșeni and Uricani. According to the Romanian Government, as highlighted in the National Investment and Economic Recovery Plan (Guvernul Romaniei, 2020), CEH restructuring plan envisage splitting in two new public entities (TRACER, 2020):

- Deva TPP transferring ownership to Hunedoara county or Deva municipality, with the perspective for ROMGAZ – the largest and main natural gas producer and supplier in Romania (ROMGAZ, 2020) to develop there, a new 400 MW CCGT-CHP until 2030;
- Paroșeni CHPP and the 4 mining perimeters (Lonea, Lupeni, Vulcan and Livezeni) creating a new entity, the "Jiu Valley Energy Holding".

Focusing on Jiu Valley micro-region, the projections are presented in Table 7.2 for this new power generation entity Jiu Valley Energy Holding:

- Paroseni CHPP
  - 1 x power unit (no.4) equipped with Turboatom extracting steam turbine type, having an installed capacity of 150 MW_e 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 completed an upgrading and retrofitting program in 2007, being qualified as highly efficient cogeneration unit; in 2019 this LCP received an IEP observing all BAT-ELVs for NO_x, SO_2 and PMs;
  - 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.
- Mining Division
  - All 4 mines (Lonea, Lupeni, Vulcan and Livezeni) have an environmental permit issued by Hunedoara Environmental Protection Agency valid until 31.01.2023; an operating license issued by ANRM valid until 2024 with 5 years extension, if required; Lonea and Lupeni underground mines are already unrolling a closure program, in safety until 2024, with post-closure and reclamation until 2027.

Table 7.1: Coal generation sector's projections, Jiu Valley micro-region

Paroseni CHPP (ETS industry)	M.U.	2016	2017	2018	2019	2020	2025	2030	2040	2050	2025	2030	2040	2050
							SCENARIO A				SCENARIO B			
Installed capacity (electric)	MW_e	150	150	150 + 120	150 + 120	150	150	40	40	40	150	25	25	25
Installed capacity (thermal)	MW_{th}	174 + 120	174 + 120	174 + 120	174 + 120	174	174	50	50	50	174	50	50	50
Total energy production, from which	GWh	576	461	346	206	107	107	261	261	261	107	218	218	218
- **Electric energy**	GWh	426	314	239	141	107	107	116	116	116	107	73	73	73
- **Thermal energy**	GWh	151	147	107	65	0	0	145	145	145	0	145	145	145
Total fuels consumption, from which	th. Toe	125	93	72	43	29	29	28	28	28	29	208	208	208
- **Hard coal**	%	98	93	96	94	95	95	0	0	0	95	0	0	0
- **Natural gas**	%	2	7	4	6	5	5	100	100	100	5	0	0	0
- **Biomass**	%	0	0	0	0	0	0	0	0	0	0	100	100	100

Source: TRACER data collecting and ISPE data processing, February 2021

Power unit no. 4 in Paroşeni CHPP is qualified for providing the following NPS technological services:

- frequency-power secondary control reserve;
- active power fast tertiary control reserve;
- active power slow tertiary control reserve;
- reactive power and voltage control in secondary band.

The existence of this power source is ensuring and maintaining the power transfer capacity from Romania to Hungary-Serbia axis, and the NPS adequacy level, especially in winter and during severe drought.

According to the Report on projections of GHG emissions in accordance with article 14 of Regulation (EU) no. 525/2013, draft version 2020 (MMAP, 2020), at national level the structure of the electricity generation by type of fuels highlights that, starting from 2030, solid fossil fuels will no longer be used in both scenarios (A and B); and for liquid fuels the last year is 2025.This perspective is conditioned by accessing all available funding sources in the programming period 2021-2027 in order to properly carry out the investment program and implement the planned policies and measures, so as to ensure the stability and security of the NPS. Thus, in Jiu Valley micro-region, for both analysed scenarios (A, B), hard coal will no longer be used for energy generation purposes starting from 2030.

Considering Paroșeni CHPP compliance with IED Directive 2010/75/EU and EU Decision 2017/1442, derogation from the EC could be obtained for two more years of operation, in order to close the power unit life cycle of 25 years (2007-2032), if economically feasible.

It must be highlighted that one of the main goals of Jiu Valley (R&I) Strategy and Action Plan to facilitate transition towards green energy systems is to propose policies and measures for generating sustainable jobs for about 2800 former coal industry employees and other existing unemployed able and eager to retrain and work. It is recommended to consider future potential developments in the fields of production and/or services in renewable and alternative energy, bio-economy (e.g. biomass collection and processing for supplying a new CHP, new bioethanol plant using energy crops planted on tailings dumps), construction, and tourism sectors. Table 7.3 provides the coal generation sector's employment projections for the Jiu Valley micro-region, while Table 7.4 provides the projections for the electricity consumption.

Table 7.13: Coal generation sector's employment projections, Jiu Valley micro-region

Annual average number of employees	M.U.	2016	2017	2018	2019	2020	2025	2030	2040	2050	2025	2030	2040	2050
							SCENARIO A				SCENARIO B			
Total, from which	no.	5563	4685	3810	3331	3234	2530	1050	550	200	2530	1100	600	500
- **Paroșeni CHPP**	no.	468	359	331	315	303	300	400	400	150	300	450	450	450
- **Mining Division**	no.	4083	3552	3072	2866	2901	2200	650	150	50	2200	650	150	50
- **SNIMVJ**	no.	1012	774	407	150	30	30	0	0	0	30	0	0	0

Source: TRACER data collecting and ISPE data processing, February 2021

Table 7.1: Electricity consumption projections, Jiu Valley micro-region

Consumers categories	M.U.	2016	2017	2018	2019	2020	2025	2030	2040	2050	2025	2030	2040	2050
							SCENARIO A				SCENARIO B			
Total, from which	GWh	239	278	229	226	201	177	168	163	163	177	168	166	170
- **Residential buildings**	GWh	76	92	70	69	69	66	65	64	64	66	65	64	64

Source: TRACER data collecting and ISPE data processing, February 2021

7.1.2 Other coal-fired energy generation applications

The hard coal produced in Jiu Valley micro-region, mainly from the unique producer CEH and, until 2017, also from SNIMVJ, was used only for energy purposes (power and heat generation) at Paroșeni CHPP 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.

At NUTS3 level - Hunedoara County - two major DHSs on hard coal exist, 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. According to TRACER Report D3.2 (TRACER, 2020), Jiu Valley DHS infrastructure includes ~185 km of transport and distribution networks, 62 TS, 5 TM and 3 TP.

Currently (winter 2020-2021), due to CEH financial situation of insolvency and constant miners strikes, the two DHSs are in the following situation:

- Deva TPP is intermittently delivering thermal energy for Deva municipality DHS (~4000 consumers) due to lack of hard-coal supply from Jiu Valley active underground mines;
- Paroșeni CHPP stopped supplying thermal energy for citizens in Jiu Valley micro-region since 2018; the thermal energy supplied in 2019, as presented in Table 7.2, is just for internal use (inside CHPP precinct).

Focusing the analysis to Jiu Valley micro-region, here 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 centralised district heating.

Although CEH - Paroseni CHPP was qualified every year (2016-2018) for the highly efficient cogeneration bonus, 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. Due to this, all DHS operators in the Valley were declared bankrupt and the consumers had to deal with this situation, adopting alternative heating solutions depending on each financial capacity. In addition, ESIF 2014-2020 accession rate is practically zero in this sector, 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.

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, will further be granted only to vulnerable consumers identified by responsible authorities. 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.

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.

The low living standard, for a significant part of the population in Jiu Valley micro-region, makes a stronger mark on a number of households with extremely difficult adaptation to this current situation (2019-2020-2021 winters), due to the impossibility of purchasing high-performance heating installations. Technical solutions found were improvised and inefficient, with a health impact on already vulnerable groups in poverty (over 10% of Jiu Valley population).

7.2 Projections for the other energy generation technologies for 2030

At national level, first there is the trend in the installed capacities for the period 2021-2030, which indicates, according to the Integrated NECP (MEEMA, 2020), an increase compared to the total installed capacities in 2018, considering the tendency of increase in the electricity demand. Projections for 2030 reflect an increase of up to 5,255 MW in the wind capacities and to 5,054 MW in the PV capacities, as shown in Figure 7.1, but 60% of the lignite-based power plants will be still operational. The natural gas-fired capacities include both new highly efficient and flexible units and retrofitted ones, considering the age of the current natural gas-fired plants, estimating that the decrease due to decommissioning will exceed the increase foreseen through the new capacities.

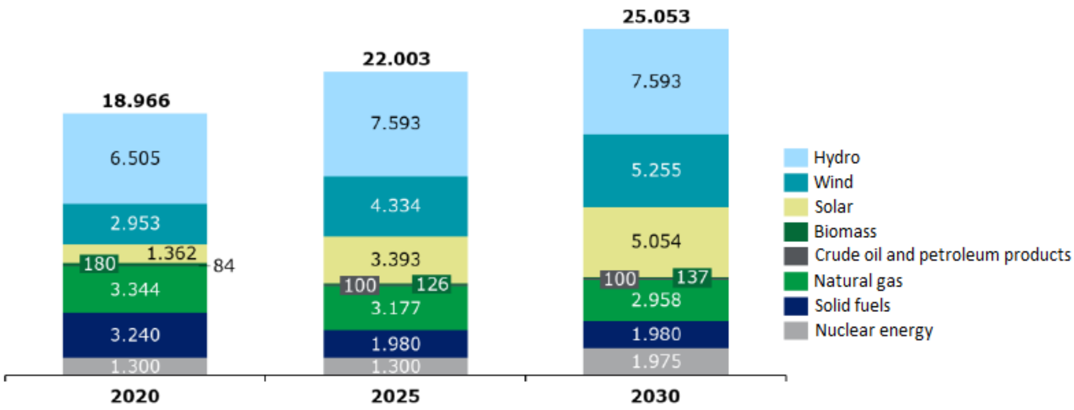


Figure 7.2: Net installed capacities - mix at national level (MW)

Source: MEEMA, 2020

Also, there is the Report on projections of GHG emission - Draft version 2020 (MMAP, 2020), forecasting the structure of the electricity generation until 2040. According to Figure 7.2, in both WEM “existing with measures” and WAM “with additional measures” scenarios, it is underlined that, in Romania, solid fossil fuels will no longer be used in the energy sector starting from 2030, and liquid fossil fuels from 2025.

Figure 7.2: Total electricity production projection by type of fuels, at national level (GWh)

Source: MMAP, 2020

Unfortunately, in none of these reference documents no specific mentions were found related to Jiu Valley transition from coal, in terms of the future structure of the electricity generation by type of fuels. Thus, the forecast for Jiu Valley, for the other energy generation technologies than hard-coal will consider the analysis performed in TRACER D3.2 Report (TRACER, 2020), mainly the draft technical energy transition concept updated and improved, observing in the same time the approach at national level in both documents mentioned above.

7.2.1 Other fossil fuels powered energy generation technologies

Natural gas is used in reduced quantities (10-15% of the total natural gas consumption in Jiu Valley) in cogeneration at Paroșeni CHPP as combustion support and for the start-up TP boilers. As mentioned before, another sector where fossil fuels, other than coal, are still significantly used in Jiu Valley micro-region is thermal energy generation for heating purposes targeting public, residential and commercial/industrial buildings and small industries processes (wood processing, textiles, etc.).

Due to lack of field data, mainly related to thermal energy demand or fuels consumption for heating and hot water, estimations for projections were made based on statistical data related to household stock, population decline, natural gas distribution (INS, 2019) and the heating technologies used (see Section 7.1.2), as: natural gas based individual thermal installations (95%-99% efficiency) and stoves (low efficiency 40%) for around 75% of the building stock; in less than 5%, fossil liquid fuels stoves with low efficiency; and for the rest 20%, individual thermal installations (90% efficiency) and stoves (very low efficiency 20%-30%) based mainly on firewood.

It is recommended that until 2035-2040, population supply with firewood for heating purposes to be switched to pellets and wheat/straw briquettes, through the development of an integrated collecting and processing mechanism of wood wastes, resulting from wood industrial processing, and agricultural wastes, for the entire Jiu Valley.

Knowing that high-efficient cogeneration is the greener way to generate both electricity and heat, solutions must be identified to meet heating needs mainly for household use, based on new technologies and the use of local and sustainable energy resources.

To this aim, it is recommended that in terms of technical solutions, a comparative FS and ESIA analysis between the following two options, are a “MUST” for Jiu Valley micro-region:

A. resumption of at least 1/3 of the existing DHS, with an adequate retrofitting and upgrading program, vs.
B. transition to a semi-decentralized DHS, by implementing a retrofitting and upgrading program, including the transformation of TS into micro-CHP or TP for different insulated areas (groups of buildings - public, commercial and residential/collective dwellings), using:
   - natural gas and/or syngas recovered from UCG implemented technology and/or mine methane captured with MMC technology;
   - RES - heat pumps systems (heat recovery of the groundwater or/and mine water thermal potential) and/or biomass-based technology (wood wastes resulting from wood industrial processing and agricultural wastes).

Both proposed technical solutions for covering heating demand are strongly conditioned by the reconnection of about 6,000 – 10,000 former consumers (public, residential and commercial buildings) to the retrofitted and upgraded DHS. Having in view the recent Law no. 214/2020, all measures related to the National Program for connecting the population and non-household customers to the smart natural gas distribution system will start to be implemented. To this aim, in Romania the natural gas use for both electricity and heat generation will be maintained also after 2040, being gradually replaced by hydrogen once the National Strategy on Hydrogen will be approved.

7.2.2 Renewable energy and other new energy generation technologies

Starting from the analyses performed in TRACER Report D3.2 (TRACER, 2020), the proposed policies and measures to be implemented in analysed scenarios (A, B) described in Section 7.1, and considering also the updated data provided by the electricity DSO and AFM (AFM, 2020), Jiu Valley micro-region renewable energy generation forecast, in terms of installed capacities and energy production, is presented in Table 7.5 and Figure 7.3.

Table 7.25: Renewable energy generation sector's projections, Jiu Valley micro-region

RES categories		2016	2017	2018	2019	2020	2025	2030	2040	2050
							SCENARIO A / SCENARIO B			
Total installed capacity (in MW), from which	**electric**	4.91	4.91	4.91	5.29	5.96	6.30 / 6.30	33.60 / 64.60	33.60 / 89.60	33.60 / 89.60
	thermal	0	0	N/A	0.44	0.44	1.94 / 1.94	3.44 / 53.44	3.44 / 53.44	3.44 / 53.44
MHC		4.91	4.91	4.91	4.91	4.91	4.91 / 4.91	6.91 / 6.91	6.91 / 6.91	6.91 / 6.91
PV		0	0	0	0	0.67	1.01 / 1.01	26.31 / 26.31	26.31 / 51.31	26.31 / 51.31
Wind		0	0	0	0	0	0 / 0	0 / 6	0 / 6	0 / 6
Biogas	electric	0	0	0	0.38	0.38	0.38 / 0.38	0.38 / 0.38	0.38 / 0.38	0.38 / 0.38
	thermal	0	0	N/A	0.44	0.44	0.44 / 0.44	0.44 / 0.44	0.44 / 0.44	0.44 / 0.44
Solar thermal / Biomass / HPs	electric	0	0	N/A	N/A	N/A	0 / 0	0 / 25	0 / 25	0 / 25
	thermal	0	0	N/A	N/A	N/A	1.5 / 1.5	3 / 53	3 / 53	3 / 53
Total energy production (in GWh), from which		1.68	1.64	1.70	1.66	1.29	6.43 / 6.43	32.20 / 259.82	32.20 / 282.32	32.20 / 282.32
Electric energy		1.68	1.64	1.70	1.66	1.29	2.77 / 2.77	25.54 / 108.16	25.54 / 130.66	25.54 / 130.66
Thermal energy		N/A	N/A	N/A	0.66	0.66	3.66 / 3.66	6.66 / 151.66	6.66 / 151.66	6.66 / 151.66

Source: TRACER data collecting and ISPE data estimation and processing, February 2021

Without being based on a Renewable Potential Assessment Study for Jiu Valley micro-region, RES capacities proposed to be installed are purely indicative. Thus, it was estimated that the evolution of RES use will be slow until 2025, with an increase only in PV of about 50% compared to 2020. The growth rate becomes more pronounced after 2025 and until 2040, stagnating after that. Baleia MHPP (2 MW) will be the only new small hydro project knowing the environmental protection issues, Jiu Valley being also surrounded by NATURA 2000 sites.

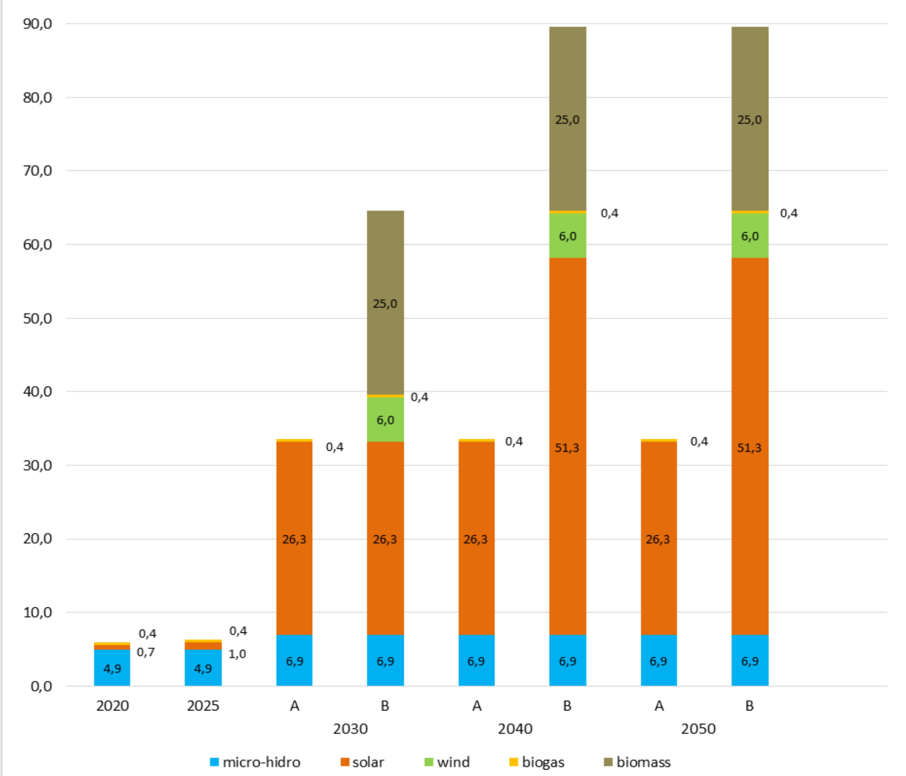


Figure 7.23: Projection of RES installed capacities - mix in Jiu Valley (MW)

Source: TRACER data collecting and ISPE data estimation and processing, February 2021

In scenario B, the evolution is more visible, taking into account the possible development of a WPP (2 x 3 MW) and a greenfield project for a new CHP biomass-based unit (25 MW_e and 50 MW_{th}).

Regarding the alternative resources, Jiu Valley has the opportunity to become a Hydrogen HUB, by developing the factory for producing green hydrogen for different purposes as electricity storage, public transport, and household heating, through gradual injection into the natural gas network with replacement rates of about 5%, then 10%, with the perspective of using the existing retrofitted and upgraded infrastructure with the transition to 100% hydrogen.

7.3 Projections for the energy mix of the region for 2050

Considering all the above analyses and observing at the same time the approach at national level, 2050 forecast for the energy mix in Jiu Valley micro-region has the following structure, presented in Table 7.6 and Figure 7.4 for both analysed scenarios (see Section 7.1):

Table 7.36: Energy mix forecast 2020-2050, installed capacities in Jiu Valley micro-region

Installed capacities (in MW)	2020	2025	2030	2040	2050	2025	2030	2040	2050
		SCENARIO A				SCENARIO B			
Total, from which	**156.0**	**156.3**	**73.6**	**73.6**	**73.6**	**156.3**	**64.6**	**89.6**	**89.6**
coal	150.0	150.0	0.0	0.0	0.0	150.0	0.0	0.0	0.0
hidrocarbons	0.0	0.0	40.0	40.0	40.0	0.0	0.0	0.0	0.0
micro-hidro	4.9	4.9	6.9	6.9	6.9	4.9	6.9	6.9	6.9
solar	0.7	1.0	26.3	26.3	26.3	1.0	26.3	51.3	51.3
wind	0.0	0.0	0.0	0.0	0.0	0.0	6.0	6.0	6.0
biogas	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
biomass	0.0	0.0	0.0	0.0	0.0	0.0	25.0	25.0	25.0

Source: TRACER data collecting and ISPE data processing, February 2021

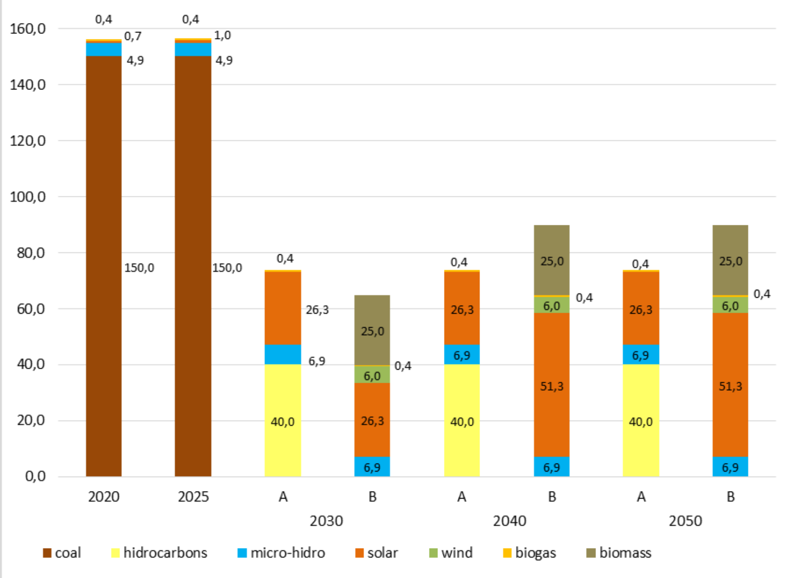


Figure 7.34: Forecast for the energy mix - installed capacities in Jiu Valley (MW)

Source: TRACER data collecting and ISPE data estimation and processing, February 2021

The contribution of the forecasted energy mix in Jiu Valley electricity production, in both analysed scenarios A and B, is presented in Table 7.7 and Figure 7.5:

Table 7.37: Electricity production forecast 2020-2050, in Jiu Valley micro-region

Electricity production (in GWh)	2020	2025	2030	2040	2050	2025	2030	2040	2050
		SCENARIO A				SCENARIO B			
Total, from which	**95**	**96**	**143**	**143**	**143**	**96**	**108**	**131**	**131**
coal	93	93	0	0	0	93	0	0	0
hidrocarbons	0	0	116	116	116	0	0	0	0
micro-hidro	1	1	2	2	2	1	2	2	2
solar	0	1	24	24	24	1	24	46	46
wind	0	0	0	0	0	0	9	9	9
biogas	1	1	1	1	1	1	1	1	1
biomass	0	0	0	0	0	0	73	73	73

Source: TRACER data collecting and ISPE data processing, February 2021

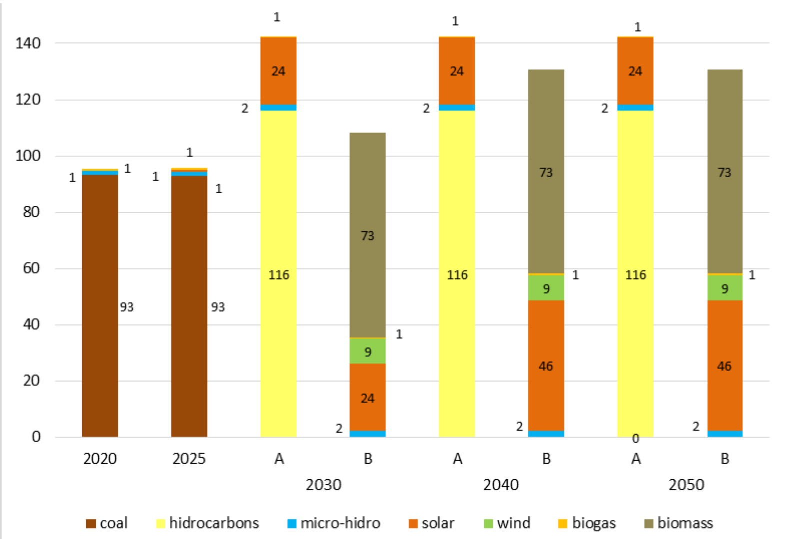


Figure 7.35: Electricity production forecast 2020-2050 in Jiu Valley (GWh)

Source: TRACER data collecting and ISPE data estimation and processing, February 2021

Based on the total electricity consumption historical data and projections, as shown in Table 7.4, and considering 6% electricity distribution network losses, the degree of the electricity demand covering by the proposed future energy production mix in Jiu Valley micro-region can be observed in Figure 7.6. As is obvious, the electricity produced by the installed capacities in Jiu Valley micro-region might not reach the level of the local electricity needs, the additional electricity supply being covered via NPS through 220/110 kV Paroşeni electrical station, which will be upgraded in 2022 according to Transelectrica – Romanian TSO (Transelectrica, 2020).

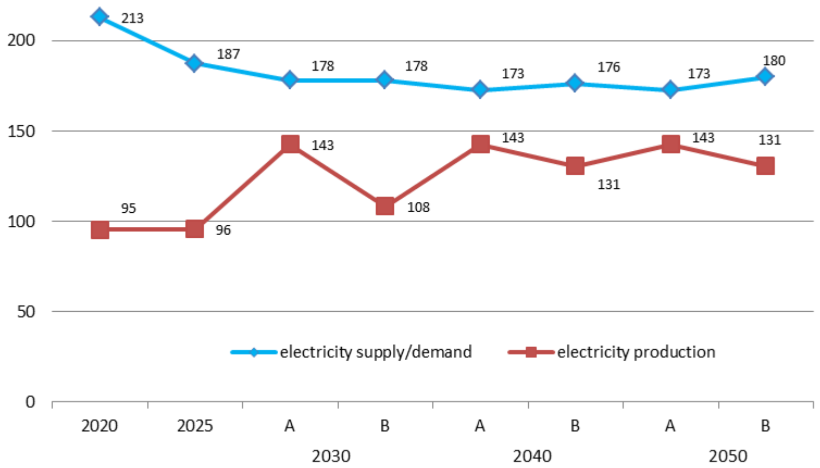


Figure 7.36: Electricity production and demand forecast for 2020-2050 in Jiu Valley (GWh)

Source: TRACER data collecting and ISPE data estimation and processing, February 2021

Related to the thermal energy, even if at the national level natural gas use for heat generation will be maintained also after 2040, in the Jiu Valley it is recommended the preservation of the cogeneration source in Paroşeni CHPP and the rehabilitation of the DHS in a semi-decentralised structure. The lack of field data at local level regarding the heating demand, natural gas consumption and other types of fossil fuels used in individual heating installations, did not make possible a comparison of Jiu Valley carbon footprint in the options with and without cogeneration in Paroşeni CHPP.

From both analysed scenarios, Scenario B is recommended based on the fact that the integrated waste management at county level can easily ensure the necessary biomass from municipal waste, given the estimated annual capacity of about 100,000 tons/year. In order to support Scenario B, and prove its techno-economic feasibility, it is extremely necessary to carry out pro-active awareness campaigns for household consumers (up to 10,000 households) to re-connect to the semi-decentralized DHS.

7.4 References

AFM (2020). *Sisteme Fotovoltaice, Sisteme Fotovoltaice pentru gospodarii izolate si Casa Verde*. Bucharest: Administratia Fondului de Mediu. Retrieved from https://www.afm.ro/sisteme_fotovoltaice.php, https://www.afm.ro/casa_verde.php, https://www.afm.ro/fotovoltaice_izolate_cereri_aprobate.php

GUVERNUL ROMANIEI. (2020). *Planul National de Investitii si Redresare Economica, iulie 2020.* Bucharest: Romanian Government. Retrieved from https://gov.ro/fisiere/programe_fisiere/Planul_Na%C8%9Bional_de_Investi%C8%9Bii_%C8%99i_Relansare_Economic%C4%83.pdf

INS (2019). *Baze de date statistice*. Bucharest: Institutul National de Statistica. Retrieved from http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table

ME (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/

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

MIPE (2021). *Strategia pentru dezvoltarea economică, socială și de mediu a Văii Jiului (2021-2030).* Bucharest: Romanian Government. Retrieved from http://mfe.gov.ro/initiativa-valea-jiului/

MLPDA (2019). *2020-2050 Long Term Renovation Strategy.* Bucharest: Romanian Government. Retrieved from https://www.mlpda.ro/pages/proiecthgaprobaresnrtlrenovareparcnationalcladirirezidentiale

MMAP (2020). *Report on projections of GHG emission in accordance with article 14 of Regulation (EU) no. 525/2013 (Draft version).* Bucharest: Ministry of Environment, Water and Forests, Romania.

ROMGAZ (2020). *Mediu*. Medias: ROMGAZ. Retrieved from https://www.romgaz.ro/ro/content/mediu

TRACER (2020) *D3.2 Report "Technical concepts for the transition of the energy system into a smart, sustainable and renewable energy system in the TRACER target regions".* Bruxelles: TRACER Project. Retrieved from https://tracer-h2020.eu/wp-content/uploads/2020/08/TRACER-D3.2-Technical-Concepts.pdf

TRANSELECTRICA (2020). *New power plants with technical permits for grid connection.* Bucuresti: Transelectrica. Retrieved from http://www.transelectrica.ro/avize-contracte

TRANSELECTRICA (2020). *Planul de Dezvoltare a RET perioada 2020-2029.* Bucharest: Transelectrica. Retrieved from https://www.transelectrica.ro/ro/web/tel/planului-de-dezvoltare-ret-2020-2029;jsessionid=DB171A860F808E220FBC533E43E6F4B0

TRANSGAZ (2017). *Planul de dezvoltare a sistemului national de transport gaze naturale 2018 -2027.* Medias: SN Transgaz SA, Romania.

UN-ECE (2010). *Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines.* New York and Geneva: UN Publication.

8 Serbia, Kolubara region

8.1 Projections for the energy generation technologies using coal for 2030

8.1.1 Coal driven thermal power (TP) and CHP plants

Coal-driven power plants in the Kolubara region include pulverized coal firing boiler technology with steam cycle of both condensing and cogeneration (CHP) types, with subcritical steam parameters. The major power plants (‘Nikola Tesla’ A with six units and ‘Nikola Tesla’ B with two units) are located on the banks of Sava river and use the once-through cooling system, while the mine-mouth located Kolubara A power plant with five smaller units use the recirculation cooling with mechanical draft cooling towers.

The life span of the existing plants is defined by the obligations of the Republic of Serbia under the Energy Community Treaty and associated Decisions regarding compliance with EU Industrial Emissions Directive. In line with this, the National Emissions Reduction Plan (NERP) has been adopted in February 2020, defining power plants that will be opted-out by the end of 2023 and those that will remain in operation under the condition to implement environmental protection measures and system by the end of 2027. In the Kolubara target region, the oldest small power units (TPP Kolubara A and TPP Morava) are scheduled for shut down by the end of 2023, while the remaining units (TPP Nikola Tesla A and B) will continue operation until 2038/40, all under the strict requirements regarding environmental protection measures.

Coal supply for the power plants in the forthcoming period will be from the existing open pit mine “Tamnava West” and the new open pit mine “Field E”. Besides the existing power plants, in an aim to utilize the remaining coal resources in the region, a new 350 MW plant Kolubara

B will be completed at the mine-mouth and supplied from the new “Radljevo” coal mine. This unit is designed with pulverized coal fired steam boiler with sub-critical steam parameters, all in line with the EU regulation regarding design and construction requirements for this kind of facilities, including environmental limit values for the new plants. Carbon capture, utilization and storage (CCUS) technologies have not been considered in the design of this new power plant.

The age of the existing units of power plants fired by lignite from the Kolubara coal mines is within the range between 35 and 50 years, as presented in Table 8.1. The older units that have been planned for closure by the end of 2023 are not included.

Table 8.1: Age of the existing units fired by coal from Kolubara mines

Plant name and site	“Nikola Tesla” A Obrenovac	“Nikola Tesla” B Vorbis	Kolubara B Kalenic
Start-up year of particular units	A1: 1970 A2: 1970 A3: 1976 A4: 1978 A5: 1979 A6: 1979	B1: 1983 B2: 1985	2025

Source: Annual Technical Report, Electric Power Utility of Serbia, 2006

Being constructed a few decades ago, and bearing in mind coal quality parameters, original net efficiency of the existing units is rather low. It should also be noted that existing power units refurbishment included their re-powering, provided without coal consumption increase and based on turbine island reconstruction, in that way also ensuring higher gross efficiency. In the same time, turbine reconstruction enabled greater gross energy production of the units.

On the other hand, installation of new environmental protection facilities (such as FGD systems, waste water treatment plants, hybrid filters, etc.) increased self-consumption of the power plants. In summary, it can be concluded that environmental compliance did not reduce overall net plant’s gross efficiencies. According to already done technical documentation, the expected net efficiency values of the considered units will fulfil both national and EU regulation requirements.

According to national Rulebook on Minimal Energy Efficiency Requirements for Energy Generation Facilities (Official Gazette RS No. 112/2017), requirements for the existing plants are as follows: units A1 and A2 are required to keep originally designed energy efficiency value minus 1.5% (for FGD Plant introduction), while the greater units (A3-A6 and B1/B2) shall reach energy efficiency of (35-1.5 %), after reconstruction. According to the new Large Combustion Plants Best Available Techniques Reference Document (LCP BREF), minimal net energy efficiency for the existing TPPs “Nikola Tesla” A and B shall be 31.5%. The net efficiency of the new “Kolubara B” unit will be 35.7%.

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 (realized in the early stage of their exploitation), 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. This project is currently in progress, and be completed in the next few years.

Emissions to air from the thermal power units considered in operation after 2023, shall be estimated assuming that planned emission reduction measures are designed to meet the requirements set up in the new LCP BREF (2017) for existing, lignite fired PC boilers, put in operation no later than 2014. The Best Available Techniques (BAT) - **a**ssociated **e**mission **l**evels (BAT-AELs) for the regulated pollutants are as presented in the Table 8.2.

Table 8.2: BAT-associated emission limits of power plants in the Kolubara region

Pollutant	BAT-AELs, mg/m³	
	Existing plant	New plant
Sulphur dioxide (SO_2), mg/Nm³	130	75
Nitrogen oxides (NO_2), mg/Nm³	175	85
Dust (PM), mg/Nm³	8/12*	5
Hydrogenchloride (HCl), mg/Nm³	5	3
Hydrogenfluoride (HF), mg/Nm³	3	2
Mercury (Hg), µg/Nm³	7	4
Ammonia (NH_3), mg/Nm³		3**

** Depending on the boiler thermal power input*

*** In case that SCR is applied*

The emission reduction technologies planned to be installed in the existing plants include wet limestone/gypsum technology for sulphur-dioxide, chloride, fluoride and mercury emission reduction, low NOx burners and phased oxygen injection in the furnace followed by selective non-catalytic reduction (SNCR) for nitrogen oxides emission reduction, as well as the hybrid (electrostatic + fabric) filters for particles and mercury emission reduction. Pollutant emissions to air from the power plants burning lignite from Kolubara coal region, based on the adopted emission limit values and mean effective operating hours in the period up to 2030, are presented in the Table 8.3.

Table 8.3: Pollutant emissions to air from power plants in Kolubara region

Pollutant/TPP Unit	TPP A1 A2	TPP A3-A6	TPP B1 B2	TPP Kolubara B
Sulphur dioxide (SO_2), t/a	598	1,044	2,411	611
Nitrogen oxides (NO_2), t/a	805	1,406	3,246	692
Dust (PM), t/a	55	96	223	41
Hydrogen-chloride (HCl), t/a	23	40	93	24
Hydrogen-fluoride (HF), t/a	14	24	56	16
Mercury (Hg), t/a	0,032	0,056	0,130	0,033
Carbon dioxide (CO_2), t/a	1,203,519	2,096,873	4,725,000	2,124,000

Source: Techno-economic analyses for the completion of construction of the new TPP Kolubara B Unit, 350 MW, in Kolubara coal region, Energoprojekt Entel, Belgrade, 2020

As mentioned above, the nominal (nameplate) capacities of all TPP „Nikola Tesla“ A and B units have been increased, as a part of reconstruction and life extension activities. The nominal capacities before and after refurbishment and upgrades (where applicable) are presented in the Table 8.4. From TPP „Nikola Tesla“ units A1 and A2 above 90 MW_{th} is extracted for the district heating system of Obrenovac city, and extraction of 600 MW_{th} from the units A3 to A6 is destined for the baseload in the district heating system of the capital city of Belgrade.

Table 8.4: Nominal capacities of thermal power plants in Kolubara region

Power plant	“Nikola Tesla” A	“Nikola Tesla” B	Kolubara B
Nominal installed capacity of units before/after their modernization, MW_e	Unit A1: 210/221,8 Unit A2: 210/221,8 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	354

Source: Annual Technical Report, Electric Power Utility of Serbia / Thermal Power Plants Branch, 2016, and Technical documentation for TPP Nikola Tesla A and TPP Nikola Tesla B reconstruction and repowering, prepared in period 2006-2017, Energoprojekt Entel, Belgrade

Based on the forecasted electricity demands, the net mean values of the power generation by lignite fired units in Kolubara region in the period up to 2030 is presented in Table 8.5.

Table 8.5: Electricity production by power plants in the Kolubara region

Power plant	"Nikola Tesla" A	"Nikola Tesla" B	"Kolubara" B
Net electricity production per unit, GWh/year	Units A1/A2: 1,000 Units A3-A6: 1,900	Units B1/B2: 4,000	Unit 1 1,700

Source: Techno-economic analyses for the completion of construction of the new TPP Kolubara B Unit 350 MW, in Kolubara coal region, Energoprojekt Entel, Belgrade, 2020

In the forthcoming period, the main investments in coal power plants will be devoted to fulfilment of the adopted obligations related to environmental protection and modernization standards, as well as to modernization of coal exploitation and uniform coal quality provision from the newly opened mines ("Field E" and "Radljevo" mines). Some of the projects are already finished or in progress (like FGD Plant construction in TPP Nikola Tesla A, waste water treatment plant at TPP Nikola Tesla A, opening of the mine "Field E"), but some will start in the near future (such as construction of the flue gas desulphurisation-FGD plant in TPP Nikola Tesla B, reconstruction of electrostatic precipitators-ESP to hybrid filters, implementation of the SNCR technology, extension of solid waste disposal sites, etc.). All these investments will result in an increase of electricity production cost to over 40 EUR/MWh, which is considerably higher than the current cost of about 30 EUR/MWh thanks to low cost of coal from local mines.

Apart from the direct investments in production sector, Electric Power Industry of Serbia will have to improve living conditions in the settlements close to the open pit mines, as there are many complaints from the people living there. The main activities should be to reduce noise and vibration and air pollution and provide reliable and safe potable water supply. Coal exploitation from the new open-pit mine "Radljevo"requires resettlement of some villages. Also, as some old open-pit mines will be closed in the next period ("Field C" and "Field D"), land reclamation activities will be necessary to mitigate harmful impacts on the environment in the surrounding areas, as well as to restore the ex-mining space for another use.

8.1.2 Other coal-fired energy generation applications

Other coal-fired facilities that use about 10% of coal from Kolubara mines include the heat-only boilers (HOBs) used to produce either steam or hot water for technological and mining purposes, as well as a variety of devices for space heating.

A large HOB with two units plant in Vreoci delivers process steam, while numerous smaller HOB units are distributed over the "B", "D" and "Tamnava" surface mining fields. Another large HOB plant has recently (in 2019) been commissioned in Barosevac, comprising two 5 MW boilers. This plant provides heat and steam for the facilities within the new open pit mine „Field E"(~40% of nominal power), as well as heat for central heating in Barosevac (~60% of nominal power). The plant is fired by dried coal from a nearby coal-drying facility. It is designed and constructed and operated according to the EU environmental protection standards.

The small coal-fired facilities are used for space heating end/or cooking purposes. They include single boilers, furnaces, stoves, etc. distributed in suburban and rural settlements of the target region. In fact, these facilities are alternatively fired with wood. Also, in the past few years, smaller space heating facilities are reconstructed to burn wood pellets as a substitute for coal.

The steam boiler plant in Vreoci is in operation since 1979. In 1978, nine smaller boiler units have been commissioned in the mining field "D" and a couple of years before three boilers begun operation in the mining field "B". Two boiler units have been commissioned in the field "Tamnava" during 1980, followed by five boiler units commissioned during 1987. All of the boiler units are nearing to the end of their useful operational life, except one in Barosevac operated since 2019.

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 the oldest small coal fired facilities. However, although several decades old, the larger ones still remain for space heating in individual houses, stores or elsewhere.

Generally, the technologies for small applications, particularly those that are rather obsolete, have considerably lower efficiencies 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 by 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.

In relation to capacities, the main source of pollution among the considered applications is the boiler plant in Vreoci. The new boiler plant in Barosevac, as most of the other boiler plants in Kolubara region, is fired with dried coal, with small content of ash and sulphur. Flue gases are discharged through a 30 m high chimney. Emissions from the existing boiler plants in Kolubara region is expected to remain the same in the future.

Small coal fired facilities for space heating have much higher specific emissions of each of the pollutants, including carbon-monoxide and the particles of unburnt coal, fly ashes and dust. In the majority of cases no filters or any protection devices are installed. Unfortunately, emissions from the 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, emissions from such sources result in air pollution well above the regulated limits and are harmful for human health. 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 of existing boiler plants in Kolubara coal mines range from 0.3 to 2.5 MW, while the new boiler plant in Baroševac has a capacity of 10 MW. These boiler plants are used in support to the mining process dynamics and burn dried coal from the nearby drying plant.

Capacities of various facilities used for space heating based on lignite from Kolubara coal basin are quite different, depending on how and where that 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). For the small coal facilities their usage is expected to decrease with time, in line with the trend of fuel conversion to renewable sources (wood, pellets, solar panels), as well as some villages become connected to the district heating systems (as in the settlements Vreoci, Obrenovac and Barosevac).

Typical heating devices are stoves. A large stove would cost about € 2,500 to € 3,500, including the stovepipe and installation. Smaller stoves for households are almost an order of magnitude less costly. The estimated annual cost of coal used for space heating is comparable with the natural gas and lower than the costs of other energy sources such as biomass (wood chips or pellets), fuel oil or electricity. Calculated with actual prices of coal on the Serbian market (65 €/ton for raw lignite and 100 €/ton for dried lignite), the mean annual energy consumption per dwelling (~60 m^2), would cost from 350 €/year to 420 €/year per household.

8.2 Projections for the other energy generation technologies for 2030

8.2.1 Other fossil fuels powered energy generation technologies

Natural gas fired heat-only boiler technology is used in the district heating system of the capital city of Belgrade. It is also used for cooking and heating in urban households reached so far by the gas distribution network. In rural households of the target region, however, natural gas network has not been developed so far, and firewoods and coal remain the main fuels for heating and cooking. Use of electricity in households is rather high, due to its relatively low price. Being the source of pollution, as the coal fired boilers, facilities based on fuel oil are currently being replaced by natural gas in the remaining oil-fired heating plants in urban areas.

However, as the natural gas is becoming available at a large scale from the new ‘TurkStream’ gas pipeline, it is expected that the distribution gas network will reach rural areas as well. Of course, the main expectation of the natural gas in the future is to gradually replace the coal for power generation in Serbia. Thanks to its well-developed power infrastructure, tradition and skilled workforce, Kolubara target region is expected to lead this transition process.

As the thermal power plant Kolubara A will be closed by the end of 2023, the heat for neighbouring settlements district heating system, as well as the steam for industrial needs will be provided from a new boiler plant fired by natural gas as the main fuel and gas fuel oil as the stand-by fuel. As natural gas will not be available during first several years of plant’s operation, gas fuel oil will be used instead. The new boiler plant shall be constructed according the latest environmental protection standards.

It is expected that similar projects will be realized in the region, as a result of shifting from coal to more environmentally friendly energy sources, including renewable energies like biomass, wind and solar PV. However, these changes will be gradual, depending on the availability/ reliability of other fuels (primarily natural gas as the most suitable), as well as the price of produced energy compared to one, originally produced from coal.

Capacities of the facilities are present in a wide range, from utility sizes to individual household sizes. Natural gas applications depend on the pace of development of the gas network in the region. When natural gas will be made available, it is expected that will mostly be used for heating, but also for cooking, particularly so as the price of electricity is getting higher. However, this will be possible in larger settlements and newly built buildings, while for the existing ones, the possibility to use natural gas is mainly in district heating plants, after boiler reconstructions.

The efficiency of natural gas applications is significantly higher than when coal or oil are used. Therefore, considerable benefits are expected both for the local environment, and for human health in the region when consumption of coal would be replaced by natural gas.

Thus, one of the priority investments foreseen in the Republic of Serbia Investment Plan in Air Pollution Mitigation up to 2030 is devoted to the replacement of coal and heavy fuel oil boilers with natural gas boilers for heat production in the region. In parallel with the investments in the environmental protection measures, the new Law on efficient use of energy provides different subsidies for the investment in energy efficiency, particularly in the building sector.

8.2.2 Renewable energy and other new energy generation technologies

Most of renewable energy and other new energy generating technologies have potential to develop in the region as a substitute for coal when the mines will be closed up (either the generation by coal becomes suspended. or the coal reserves become exhausted). The 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), while the average solar energy that may be harvested annually is about 1.4 MWh/m^2.

Wind power in the target region was not found to be significant, as the mean wind speed is low (3-4 m/s) and the average wind power is 100-200 W/m^2, with a potential average annual generation between 900 and 1600 kWh/m^2. Given that, wind is considered as a moderate potential energy source in the region. There is also potential for biomass production and use, but there is currently a lack of organization for collecting agricultural biomass. The wood biomass could be used as fuel in local individual small boilers (in public institutions such as schools, etc.) for heating energy production. Furthermore, the Kolubara target region lacks the potential for hydro-energy production.

The increase of the share of RES in energy production/consumption in Serbia in the forthcoming period is driven by the need to reduce harmful emissions from coal under the obligations of Serbia as an Energy Community Contracting Party and the EU candidate country. Under the Treaty establishing Energy Community, Serbia is committed to monitor and report in the areas of renewables, energy efficiency and greenhouse gas emissions, as well as to provide any other information relevant to climate change. Moreover, through its first Nationally Determined Contribution (NDC) submitted on 30th June 2015, under the Paris Agreement, Serbia has a commitment to reduce GHG emissions by 9.8% until 2030, compared to 1990 emissions. The new Strategy for a low-carbon economy is aimed to accelerate the reduction in emission of greenhouse gases, which would put a strong a pressure on increased use of renewables in order to reduce emissions from burning lignite.

The Serbian government adopted the National Renewable Energy Action Plan (NREAP) in 2013, as the document setting up the target of 27% of renewables in gross final energy consumption until 2020, but failed to achieve it. The new Law on renewable energy, in line with other laws related to energy efficiency in Serbia provides subsidies to accelerate the penetration of renewables. This law introduces the concept of 'prosumers' that enables energy consumers to become energy produces as well. They are given the right to sell surplus electricity on the market, either directly to the network or indirectly through an association that becomes a market player as a virtual power plant.

All those measures are expected to increase the share of renewables in parallel with the most needed improvement of energy efficiency, so that the construction of new facilities and refurbishment of the existing ones always meet requirements regarding the increase of both energy efficiency and the share of renewables in the energy mix in the region. This should include energy-related rehabilitation of buildings and introduction of renewables in the building sector (mainly in the public sector), replacement of heating oil, coal and natural gas used for heating with biomass and solar, introduction of district heating systems based on renewables and combined heat and power production, replacement of the use of electricity for the production of sanitary hot water with solar energy and biomass, etc.

The main use of solar energy would be in electricity generation both in large utility size power plants located on the abandoned mines or overburdened deposits and in small roof-top PV installations. Solar heating in households or local public institutions could provide hot water in roof-mounted solar panels or as small/medium heating facilities. So far, there are no plans for such project's development, but it may be expected that in the future period such energy sources will be more favourable, bearing in mind both electricity price raises as well as the overall rise of awareness about the necessity of environmental protection and climate change mitigation. In line with this, the Energy Utility of Serbia (EPS) is preparing a comprehensive study with the main objective to evaluate the possibilities of solar energy used to generate electricity and heat within its facilities, both as mounted on the existing structures (buildings, etc.) and put on the open space properties (closed mines areas, ash and overburden disposal areas, etc.).

On the other hand, biomass is primarily used now in rural households for cooking and space heating. Also, considerable consumption of wood as fuel could be in local individual small boilers for heating energy production (such as schools, public institutions etc.). Wood could also be used for co-firing with coal to produce heat (hot water or steam) in the existing boilers either for residential or industrial purposes in the Kolubara region. The wood pellets have also been experimentally used in large gas-fired boilers of the district heating system in Belgrade.

The efficiency of conversion of solar radiation to electricity in the Kolubara region spans over a wide range, depending on both technology (fixed or moving panels) and the age of solar cells. On an annual basis, the energy efficiency of fixed PV panels is slightly above 11% for a number of older installations such as the one on the roof of Energoprojekt's head office building in Belgrade. Several experimental PV solar installations built in the Kolubara region with the moving panels technology have demonstrated about twice higher efficiency. As the utility size solar power plants are supposed to increase in efficiency alongside flexible generation from natural gas and energy storage, they are expected to play an important role in the post-mining energy transition and thus benefit from the relatively high solar radiation in the region.

The efficiency of appliances based on burning fuel wood and other forms of biomass mainly depends on the capacity and age of the facility. The newly constructed stoves and boilers found on the current market are more efficient than the existing ones in the region, which convert less than a half of the primary energy into usable heat.

A wide range of capacities may be found when renewable energy and new energy technologies in the Kolubara region are considered. While the existing roof-top PV installations are of the order of several tens of kilowatts, the expected utility-size PV solar power plants may reach several hundred megawatts and, if associated with adequate energy storage capacities, may play an important role in the power generation mix in the region.

Biomass-based cogeneration of heat and electricity is subsidized in Serbia, but so far its capacity sizes are generally small, particularly if biomass is burned in stoves of individual households. Larger size units may be found in the central heating installations either of the commercial buildings or in the multiple flats' buildings. Such buildings may sometimes use electrical heating by the use of the ground (or underground water) based heat pumps.

Whichever the case, the application of small size renewable energy and other new energy technologies in the Kolubara region is mainly for individual production of heat, steam or electricity, and their economic feasibility is highly dependent on the prices of commodities supplied by the national power utility and/or district heating system. Currently, the electricity prices for the so called 'tariff consumers' such as households are very low and many households in the Kolubara region use electricity for heating.

On the other hand, the price paid for heat from the district heating system reflects the high cost of the imported natural gas, while the price of heat from a few district heating systems based on lignite from the Kolubara mines is relatively low. However, the economics are expected to completely change as the transition away from coal progresses. Economic benefits from the use of renewable and other energy technologies may come from the current effort of Serbia to reduce emissions of greenhouse gases in line with the new Law on climate change and increase the use of RES by subsidies provided by the new Law on renewable energy.

8.3 Projections for the energy mix of the region for 2050

Serbian energy transition is strongly influenced by the obligations set by the accession process towards EU membership and a series of ratified international agreements, in particular the 'Stabilization and Association Agreement' and 'Energy Community Treaty'. Serbian authorities have already aligned national legislation with the EU directives on energy, environment, and competition fields. So far, the Serbian energy transition has been legally driven by the Energy Law and Energy Strategy to 2030, but recently a series of legal documents have been adopted by the Parliament in line with the obligations accepted in the meantime. Also, according to the Energy Community Recommendation 2018I1IMC-EnG on preparing for the development of integrated national energy and climate plans by the Contracting Parties of the Energy Community, Serbia is currently developing its Integrated NECP for the 2021-2030 period.

With regards to energy supplies, Serbia is currently self-sufficient only in electricity thanks to its lignite reserves and hydro potential, while for liquid and gaseous fuels it is about 90% dependent on imports (the overall import dependence is slightly above 30%). Domestic lignite keeps the major share in the Serbian primary energy balance. In the final energy consumption, oil derivatives dominate, followed by electricity, heat energy, firewood, coal and natural gas. Households in Serbia consume more than a third of energy (almost half of electricity), followed by industry and transport.

One of the strategic priorities for Serbia is to increase its security of energy supply. While power generation currently matches electricity demand, this is not the case with natural gas and liquid fuels. Almost all natural-gas is imported from Russia via Ukraine and Hungary, and recently via Turkey and Bulgaria. The new gas pipeline connection to the "TurkStream" via Bulgaria is built under obligation to implement the EC Regulation on conditions for access to the natural gas transmission networks in Europe.

According to the actual plans, although the share of lignite in the primary energy consumption would decline, it will remain dominant in the period up to 2030. The share of oil would also decline, while the share of natural gas, biomass, hydropower and other renewables would rise. According to the newly drafted Strategy for the low-carbon economy of Serbia by the year 2050, with a vision until the year 2070, the use of coal should end around 2040 and be replaced by natural gas and renewable sources of energy. Such a transition process should be enforced by adequate environmental and climate policies that still need to be carefully defined, adopted and dully implemented.

One focus in the energy field that may develop improvement of energy mix towards larger extent of renewables use should be the modernization of district heating plants, including fuel switching from fossil to renewable energy sources, especially to wood biomass. The main condition in achieving this goal is to organize the collection of available wood and agricultural biomass. On the other hand, the current huge deforestation without reforestation, which causes huge harms to the land, makes the use of wood biomass for energy questionable.

The energy transition process in the Kolubara target region shall be in line with the new national energy strategy that is to be initiated soon, according to the new Energy Law. Obviously, the transition in the region would take into account local needs and possibilities, but above all the major national interest to ensure supply of more than a half of total electricity consumption in Serbia, which is currently being generated from the coal mined and burnt within the Kolubara region alone.

While still waiting for the new longer term energy strategy, as well as for the Integrated NECP up to the year 2030, a vision of the energy transition in the Kolubara target region by the year 2050 could hardly be clearly given. Bearing in mind the current negotiations between Serbia and the European Union, it is reasonable to assume that Serbia will become a member country of the European Union and will be obliged to strictly follow the Union's energy and climate policy at the national level. With this in mind, the region's transition away from coal will to a large extent be that of Serbia as a whole, but with due care of the consequences that the local population will be exposed to.

Of course, all the EU Member States will have the same development goals, but different pathways adjusted to their local conditions. This may mean that the transitional dynamics might be different. Power outages in the USA and Europe in mid-February this year (2021) have already shown that some pathways in the energy field overlooked certain important issues such as weather emergency augmented by climate change.

8.4 References

ELECTRIC POWER UTILITY OF SERBIA (2018-2020) Annual Technical Reports. Electric Power Utility of Serbia, Belgrade

ENERGOPROJEKT ENTEL (2020) Techno-economic analyses for the completion of construction of the new TPP Kolubara B Unit, 350 MW, in "Kolubara" coal region. Energoprojekt Entel, Belgrade

ENERGOPROJEKT ENTEL (2006-2017) Technical documentation for TPP Nikola Tesla A and TPP Nikola Tesla B reconstruction and repowering. Energoprojekt Entel, Belgrade

EUROPEAN COUNCIL OF ACADEMIES OF APPLIED SCIENCES TECHNOLOGIES AND ENGINEERING - EURO CASE (2017) Energy Transitions in Europe - Common Goals but Different Paths. Euro-CASE Energy Platform

FISCAL COUNCIL OF THE REPUBLIC OF SERBIA (2018) Investments in Environmental Protection – Social and Fiscal Priorities. Ministry of Finance of the Republic of Serbia, Jun 2018

LECOMTE T., FERRERÍA DE LA FUENTE J.F., NEUWAHL F., CANOVA M, PINASSEAU A., JANKOV I., BRINKMANN T., ROUDIER S., SANCHO L.D. (2017) Best Available Techniques (BAT) Reference Document for Large Combustion Plants. European Commission, European IPPC Bureau

MINISTRY OF THE CONSTRUCTION, TRANSPORT AND INFRASTRUCTURE (2017) Rulebook on Minimal Energy Efficiency Requirements for Energy Generation Facilities. Official Gazette RS No. 112/2017

MINISTRY OF THE ENVIRONMENTAL PROTECTION (2020) National Emission Reduction Plan of the Republic of Serbia. Official Gazette RS No. 10/2020

9 Ukraine, Donetsk region

9.1 Projections for the energy generation technologies using coal for 2030

9.1.1 Coal driven thermal power (TP) and CHP plants

Coal is the only energy source in Ukraine, with own production volumes that are potentially sufficient to almost fully meet the needs of the national economy.

The development of supply proposals to the electricity market by existing TPPs will be determined by the presence, levels and mechanisms for supporting the implementation of the National Emissions Reduction Plan from large combustion plants, the expediency of supporting power plants with a low coefficient of use of installed capacity, as well as by the state energy policy, in particular, by greenhouse gas emissions restricting Mechanisms and their stiffness.

The energy strategy of Ukraine until 2035 is aimed at the innovative development of the energy sector and construction of or investment in new generation capacity to replace decommissioning one. The choice of the type of generation will depend on the forecast price situation for fuels and the intensity of development of each type of generation, which will increase the level of competition between them, as well as 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, NOx 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.

The coal sector must achieve competitive and transparent operating conditions by extending the life of coal-fired power plants, putting into conservation and /or replacement by modern high-shunting capacities of additional 2 - 6 GW of TPP capacities, transferring a number of coal-fired power units from anthracite to bituminous coal, under the conditions of technical and economic feasibility.

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 (involving large-scale international assistance) should take into account the world's best practice in social mitigation, which includes severance pay, advice to redundant staff, professional training and retraining.

However, taking into account the state of the economy in the Donetsk region and in Ukraine as a whole, no significant changes are expected till 2030 in coal combustion technologies at power plants. The total electrical capacity of coal TPPs in the Donetsk region will be up to 6000 MW. The main steam generators that are working on coal were installed in 1960-1970s and work on supercritical steam parameters (545°C, 24 MPa). At present, no systems of purification of flue gases from sulfur dioxides and nitrogen oxides are applied in the Donetsk region. In addition, the installation of carbon capture, utilization and storage (CCUS) is not scheduled.

The possibility of maintaining existing capacities at coal-fired TPPs was accepted in accordance with the proposals for the adjustment of the National Emissions Reduction Plan formed by the working group under the Ministry of Energy of Ukraine.

Modeling of energy development was performed by Ukrenergo. The analysis was carried out in two scenarios. The “Neutral climate economy” scenario (SCNE), which provides for timely implementation of legislation, as well as additional climatic policies, and the reference scenario (RS), which was created to obtain a model assessment of timely and full implementation of the entire current legislation adopted until 01.09.2019, as well as draft normative legal acts developed and presented as of this date. With the reference energy development scenario, the average capacity of coal power units in Ukraine will decrease from 18.4 GW in 2021 to 16.1 GW in 2030, including 9.53 GW of new maneuvering capacities (2 GW high-maneuvering capacities with a fast start). When implementing the SCNE scenario, the average capacity of coal power units in Ukraine will decrease from 18.4 GW in 2021 to 2.5 GW in 2030, without commissioning of new coal power units.

These scenarios can be transferred to the Donetsk region in the corresponding shares of coal capacities. At this time, the total number of coal-fired TPPs that are located in the Donetsk region is 6 (Kurakhivska – installed electric capacity of 1470 MW, Slovianska – 880 MW, Vuhlehirska – 1200 MW, Starobeshivska – 2010 MW, Zuivska – 1200 MW, and Myronivska – 115 MW) and 1 CHP plant (Kramatorska). Starobeshivska and Zuivska TPPs are located in the occupied now 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 / hr, as well as boilers with a nominal steam capacity of 230 t / hr, one 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 in the village of Myronivske will not be 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: 880 MW. Design fuel is anthracite with a net calorific value of 23.45 MJ/kg or 5600 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/hr. 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 power unit was converted to co-firing of coal and fuel oil. At this time, after re-marking, the capacity of the units was 1 x 80 MW, 1 x 800 MW.

Vuhlehirska TPP

Installed Capacity is 3600 MW. Number of power units: 7. Design fuel for the four (4) power units of 300 MW is bituminous coal, with LHV of 20.93 MJ/kg or 5000 kcal/kg. Design fuel for the three (3) power units of 800 MW is natural gas.

The power plant was built in two stages: the first stage with a capacity of 1200 MW consists of four power units of 300 MW each with single-case pulverized-coal boilers with steam capacity of 950 t/hr 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 2650 t/hr and turbine units with a capacity of 800 MW. Each turbine unit has a heating installation with a capacity of 15 Gcal/hr. The units are designed to provide thermal energy to the satellite city of Svitlodarsk and the industrial site.

Now, the 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 Kurakhove, in the Mariinsky district of Donetsk region. Electric power is 1527 MW. Design fuel is Donetsk bituminous coal with high ash content. 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 raised 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. 7), expanded the range of maneuverability from 80 to 120 MW, increased the efficiency of power units by 12%, and significantly improved the environmental performance.

Kramatorska CHP plant 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 plant, the founders of which were 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).

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

- steam boiler of the TP-170-110 type (1955) - in 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 extractions of steam - in operation.

9.1.2 Other coal-fired energy generation applications

At this time, coal in 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 2550 tons per hour. Much less coal is used at district CHP plants 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. These technologies will be mainly used till 2030 for central district heating.

Low-power boilers that burn coal are represented by:

- BKZ-75-39 FB single-drum, pulverized coal combustion with natural circulation, steam capacity of 90 tons per hour, in an amount of 3 pieces,
- PK-19-2 vertical water-pipe, single-drum boiler unit with natural circulation, steam capacity of 110 tons per hour, in an amount of 4 pieces,
- NZL-80-34M with steam productivity of 80 tons per hour, in an amount of 2 pieces, and
- TP-120 with a steam capacity of 120 tons per hour, in only one piece.

In the Donetsk region, these boilers are installed in district CHP plants and most of them now operate in hot water mode. CHP boilers that were designed for coal combustion (for example, the NIISTU boilers with a capacity of 0.3-0.6 Gcal per hour) were converted to natural gas combustion for environmental reasons.

Most of the boilers installed at the Ukrainian CHP plants have been 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 the boilers during coal combustion, with O_2=6%, dry gas, are: solid particles – 1500-4000 mg/m^3, SOx – 800-9000 mg/m^3 and NOx – 500-1600 mg/m^3.

In the Donetsk region coal is used to heat individual rooms or households. Non-modern stoves are sometimes 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.

Table 9.1 shows the distribution of coal quantities for household needs in 2017. Since 2030 it is planned to close unprofitable mines (about half of the existing), then it should be expected the population and communal services of the Donetsk region to consume about 200 thousand tons of coal per year.

Table 9.1 Non-industrial coal consumption In Donetsk region in 2017

Purpose of coal	Quantity of coal, tons
Social sphere, including:	43 413
Medical institutions	3 952
Entertainment education	36 203
Other activities	3 258
Boiler rooms	156 616
Population	201 229
Total:	401 258

9.2 Projections for the other energy generation technologies for 2030

9.2.1 Other fossil fuels powered energy generation technologies

The consumption of energy resources in residential and non-residential buildings in Ukraine is about 40% of all the energy consumed in the country, and the amount of energy consumed by 1 m^2 exceeds several times the corresponding indicator in the EU countries with similar climatic conditions.

Natural gas and fuel oil are at the moment the auxiliary fuels on coal power plants. As a basic fuel, natural gas is used for generation of electricity in Ukraine in 3 CHP plants (Kharkiv CHP-5 with installed capacity of 540 MW, Kyiv CHP-5 with installed capacity of 700 MW, Kyiv CHP-6 with installed capacity of 500 MW). None of them is located in the Donetsk region. At the moment, there are no plans to build electric power stations that will operate on natural gas or fuel oil.

At the moment, approximately 230 million cubic meters of natural gas are used in the Donetsk region per month in private households. The share of heating boilers that will work on natural gas is expected to increase until 2030. This will reduce the emissions of ash, nitrogen oxides and sulfur dioxide into the atmosphere, as well as carbon dioxide emissions.

9.2.2 Renewable energy and other new energy generation technologies

For 2019, in Ukraine and the EU generation with renewable energy sources was 3.6% and 23.8% respectively, without taking into account HPPs and Hydro-accumulating power systems (HAPs), and 8.7% and 34.6% respectively, taking into account hydropower capacity.

In the first nationally determined contribution (NDC) submitted in 2016, Ukraine defined independently its goal of limiting GHG emissions – in 2030 it will not exceed 60% of the 1990 level. This level of GHG emissions reduction is not ambitious in the context of the Paris Agreement, as it envisages an increase in national GHG emissions by 75% by 2030 relative to 2017. In 2018, Ukraine announced a review of the NDC in order to significantly increase its ambition, which was expected to be approved in the spring of 2020. The main current legislation on state policy and management in the field of climate change is the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the period up to 2030, the Concept for the implementation of state policy in the field of climate change for the period up to 2030 and the relevant action plan for it.

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 (biofuel 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 and solar power plants together 0.3%. The total share of RES was less than 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 energies in Ukraine is projected to increase to 12% of primary energy and to at least 25% by 2035 (including all hydropower and thermal energy).

The generated electricity is used by the household consumers for their own needs and its "balance" is sold to the universal service provider at a "green" tariff. As of April 2019, there were about 70 such household consumers in the Donetsk region, and their number is constantly increasing. The amount of electricity sold at the "green" tariff is (depending on the season) about 100-200 thousand kWh, which is 0.1-0.2% of the electricity consumption in the Donetsk region.

The calculations of new power generation capacities and frequency regulation systems for low-carbon development scenarios according to Ukrenergo are shown in the Tables 9.2 and 9.3 below.

Table 9.2: Reference scenario, 2030

Technology	Production of electric energy (in % of produced energy)	Production of electric energy (in billion kWh)	Capacity factor* (in % of installed capacity)	Minimum installed capacity (in GW)
NPP	46	91.1	85	13.8
Bio TPP / CHP	5	9.9	50	2.3
Wind PP	11	21.8	36	7.0
Solar PP	7	13.9	13.5	12.0

Table 9.3: "Neutral climate economy" scenario, 2030

Technology	Production of electric energy (in % of produced energy)	Production of electric energy (in billion kWh)	Capacity factor* (in % of installed capacity)	Minimum installed capacity (in GW)
NPP	46	95.2	85	13.8
Bio TPP / CHP	5	10.4	50	2.4
Wind PP	11	22.8	36	8.0
Solar PP	11	22.8	13.5	12.0

** The capacity factor (as indicated here) is equal to the average arithmetic actual (real) capacity divided by the installed capacity of electrical equipment for a certain period of time.*

9.3 Projections for the energy mix of the region for 2050

The state policy should be aimed at mobilizing investments to ensure a "green" transition through the creation of favourable conditions for private investors and the introduction of appropriate state support mechanisms, in compliance with the requirements and standards of such support introduced in the EU countries without violating the rules of state aid. The state contribution will require the revision of existing budget programs in the field of energy and climate, as well as developing new financial instruments (for example, to implement a fair transition, innovation support, investment promotion in the priority areas of the green economy), including state and municipal co-financing Projects.

In the electric power, parallel processes of modernization, greenhouse gas emission reductions and gradual reduction of coal generation should be taken. This should take place through the development of the latest technologies that involves compulsion and / or incentives for the introduction of advanced technologies for TPPs that use non-renewable energy sources (primarily coal). Compulsion assumes that all or a certain part of power plants on coal will use a certain technology, in particular IGCC, CCS. Incentives include direct subsidies and / or assistance in attracting funding to implement the latest technologies and / or long-term procurement of TPP products or services.

According to Ukrenergo, which is an operator of the transfer system of Ukraine with the functions of operational and technological management of the united power system of Ukraine, with an optimistic energy development scenario, the average used capacity of coal power units in Ukraine will decrease from 18.4 GW in 2021 to 14.0 GW in 2050, including 12 GW of new maneuvering capacities, from which 2 GW high-maneuvering capacities with a fast start. When implementing a pessimistic scenario without commissioning of new coal power units, coal generation will cease to operate in Ukraine. These scenarios can be transferred to the Donetsk region in the corresponding portions of coal capacities.

Complete substitution of coal thermal power plants (TPP) by 2050 will be due to the development of solar and wind generation, and biomass power plants in combination with new high-level generating power plants on natural gas (in a more remote perspective on synthetic gases produced by RES), accumulation and storage technologies, electricity for balancing in the power system and, possibly, new nuclear energy technologies.

According to the Low Carbon Development Strategy under the baseline scenario, total CO_2 emissions in Ukraine will increase from 347 million tons of CO_2 in 2020 to 592 million tons of CO_2 - in 2050. When implementing an energy-efficient scenario, this growth can be reduced to 448 million tons of CO_2, and with the active implementation of RES will decrease to 278 million tons of CO_2. This could be possible by implementing the following measures:

- Introduction on new and existing power generating enterprises of highly efficient cogeneration units in order to utilize waste heat, which is formed in the production of electricity, and its supply to consumers.
- Creation of competitive conditions for free selection by consumers of suppliers of different types of energy or fuel for the purpose of saving energy resources and / or reducing financial expenses.
- Introduction of incentives for communal enterprises to increase the efficiency of natural gas use in existing and / or upgraded boiler installations.

Stimulating the use of RES should include:

- Implementation of the green certificate system in order to stimulate production and supply of clean energy.
- Encouraging implementation of practices and equipment, which will contribute to reducing GHG emissions in the production of agricultural products and food due to increasing production and use of RES, such as the installation of solar or wind power devices, the use of hydroelectric generators, in particular for irrigation, etc.
- Increasing of the use at enterprises of own biomass and biofuels and expansion of the energy audit programs.
- Increasing of bioethanol production, biodiesel and / or other types of liquid or gaseous biofuels from raw materials of rural and forestry for replacing fossil fuels used in stationary and mobile installations.

It is planned to increase also the share of cogeneration, and, where it will be economically feasible, carbon capture and storage technologies can be used in combustion installations.

The “Low-carbon development strategy” shows that the share of nuclear power generation in the electricity balance of Ukraine will decrease to a level of 20-25%, and hydropower will remain at the current level. New nuclear power can be built on the basis of small modular nuclear reactors technology. At the same time, the import of electricity should not play a significant role in the electricity sector of the economy, which however, along with the export of electricity, will play a significant role for balancing the united energy system of Ukraine.

Ukraine has a significant natural potential for the implementation of "green" transition in all sectors of the economy. Taking into account the possibilities and availability of modern renewable energy technologies, as well as their rapid development, Ukraine is entirely powerful and economically capable to reach 70% of the share of electricity by RES in the electricity production. Moreover, a significant part (up to 15%) could come from the production of electricity from the solar power plants in the roofs of households and businesses.

The calculations of new power generation capacities and frequency regulation systems for low-carbon development scenarios till 2050 according to Ukrenergo shown in the Tables 9.4 and 9.5 below.

Table 9.4: Reference scenario, 2050 year

Technology	Production of electric energy (in % of produced energy)	Production of electric energy (in billion kWh)	Capacity factor* (in % of installed capacity)	Minimum installed capacity (in GW)
NPP	40	122.6	87	16.1
Bio TPP / CHP	8	23.9	50	5.4
Wind PP	20	59.8	36	19.0
Solar PP	14	41.9	13.5	36.0

Table 9.5: "Neutral climate economy" scenario, 2050 year

Technology	Production of electric energy (in % of produced energy)	Production of electric energy (in billion kWh)	Capacity factor* (in % of installed capacity)	Minimum installed capacity (in GW)
NPP	41	154.0	90	19.5
Bio TPP / CHP	9	34.7	50	7.9
Wind PP	26	100.1	36	32.0
Solar PP	18	69.3	13.5	58.6

** As above (in Tables 9.2 and 9.3)*

9.4 References

KRUTSYAK, M. (2019). Forecasting demand on the Ukrainian electricity market using socio-economic variables. - Economics, Management and Sustainability, 4(1).

MINISTRY OF ECOLOGY AND NATURAL RESOURCES OF UKRAINE (2018) Low-carbon development strategy. URL: https://menr.gov.ua/files/docs/Proekt/LEDS_ua_last.pdf.

MINISTRY OF ENERGY AND COAL INDUSTRY OF UKRAINE (2017) Ukraine 2050 green energy transition concept. URL: https://mepr.gov.ua/news/34424.html

MINISTRY OF ENERGY AND COAL INDUSTRY OF UKRAINE (2017). Energy Strategy of Ukraine till 2035. URL: http://mpe.kmu.gov.ua/minugol/doccatalog/document?id=245239554

MINISTRY OF ENERGY AND COAL INDUSTRY OF UKRAINE (2017) National Plan for Reducing Emissions from Large Combustion Plants. URL: http://mpe.kmu.gov.ua/minugol/control/publish/article?art_id=245255506

NATIONAL ENERGY COMPANY "UKRENERGO" (2020) Principal materials on the formation of demand scenarios and offers. URL: https://ua.energy/wp-content/uploads/2020/12/Obgruntovuyuchi-materialy-shhodo-formuvannya-stsenariyiv-popytu-ta-propozytsiyi.pdf

ZAVGORODNYA SP (2020) Improving energy efficiency as a means of overcoming energy poverty. URL: https://niss.gov.ua/sites/default/files/2020-04/energoefectyvnist-1-4.pdf

10 United Kingdom, Wales

Wales is one of four nations in the United Kingdom (UK). Under the UK devolution settlement and the Wales Act 2017, the Welsh Parliament (Senedd Cymru) can make laws on matters that are not reserved to the UK Parliament. Therefore, energy policy for electricity, oil and gas, coal, nuclear energy and energy efficiency includes large areas of responsibility reserved to the UK Government. The majority of activities related to LNG importing and transmission are controlled by the UK Government. The powers to provide financial incentives to invest in energy generation through mechanisms such as Contracts for Difference (CfD), Feed in Tariff (FIT) and Renewable Heat Incentive (RHI) are the responsibility of the UK Government under the Energy Act.

The Wales Act devolved powers to Welsh Ministers on energy consenting for onshore and offshore generation up to 350 MW. Policy for heat, and onshore oil and gas licensing is also devolved. 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 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. The decarbonisation measures are summarised in the 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, and is also motivated by economic and equality-related reasons. It includes a vision for a future energy system in Wales (see Figure 10.1).

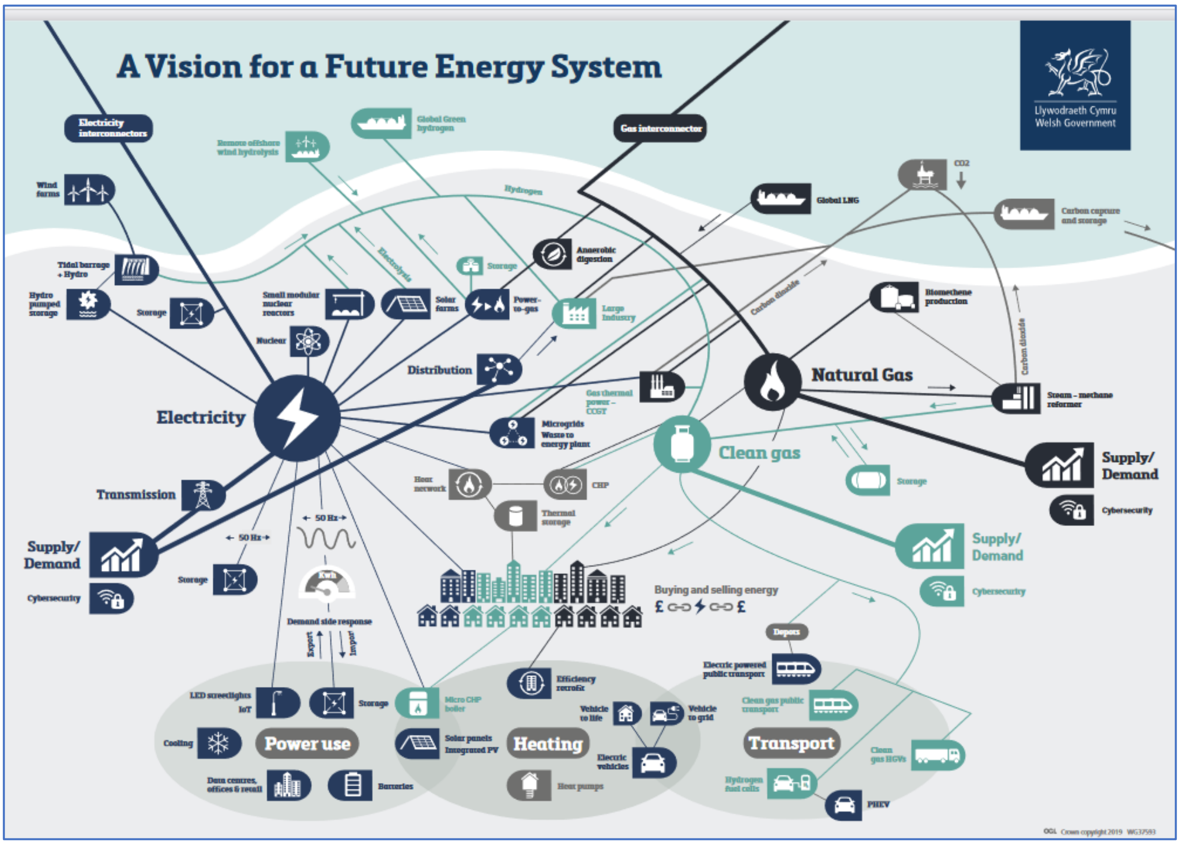


Figure 10.1: Vision for a future energy system in Wales

Source: Welsh Government (2020) A Vision for a Future Energy System; https://gov.wales/low-carbon-energy-scheme-infographic

Current energy generation capacity in Wales and an analysis of how it has changed over time is set out in the Energy Generation in Wales 2019 report.[3] The aim of the report is to support the Welsh Government with the development of energy policy, helping to evidence the economic, community and environmental benefits from the development of Welsh energy projects.

Wales is a net exporter of electricity, generating approximately 27.9 TWh of electricity in 2019, while consuming around 14.7 TWh. Approximately 27% of electricity generation in Wales was from renewables in 2019, with much of the rest generated by gas-fuelled power stations (Welsh Government 2020a). How energy is currently used in Wales and how this has changed over time is set out in the Energy Use in Wales 2018 report,[4] which provides a potential scenario for energy use across Wales, presented by sector, end use, fuel and geographical area.

10.1 Projections for the energy generation technologies using coal for 2030

10.1.1 Coal driven thermal power (TP) and CHP plants

The UK Government has committed to removing coal from the electricity mix by 2025, and is currently consulting on bringing this forward to 2024 (HM Government 2020). It will not provide new direct support for UK thermal coal mining or coal-fired power plants. In Wales, the last coal-fired power plant for commercial energy generation closed in March 2020. The Aberthaw Power Station had a long-term output capacity of 1,560 MW. One of the two power stations on the site had co-fired biomass at 55 MW_e capacity between 2004 and 2017. The station was also the location of a carbon capture trial, however no published results confirmed the feasibility for scaling up after the trial.

Another former coal-fired power station (now called Uskmouth Power) is seeking permission for conversion to fire on biomass and refuse derived fuel. The station was built in 1959 and has a generating capacity of 363 MW. It was earmarked for closure in 2014, but plans were announced in 2015 to convert it to run fully on biomass pellets and waste plastic (waste-derived fuel pellets consisting of 50% waste biomass materials, with the remaining fuel pellet content made up of plastic wastes unsuitable for recycling). SIMEC Atlantis Energy initially planned to convert two of the three units, producing a net output of 220 MW.[5] However, these plans have been adjusted due to COVID-19, and the project will now be developed in two phases. The initial phase will comprise conversion of the first 110 MW generation unit, starting in 2021.

Coal fired electricity generation is therefore not expected to contribute to Wales' energy mix in the future (Welsh Government 2020a). Further, Welsh planning permissions on new coal mining sites are effectively halted, on the grounds of stricter and legally-binding emissions reductions targets that came into force in the first half of 2019. Planning Policy Wales, which sets out the land use planning policies of the Welsh Government states: "*Proposals for opencast, deep-mine development or colliery spoil disposal should not be permitted. Should, in wholly exceptional circumstances, proposals be put forward they would clearly need to demonstrate why they are needed in the context of climate change emissions reductions targets and for reasons of national energy security*."

Welsh Government made a commitment to providing a policy on the extraction of coal for energy in *Prosperity for All: A Low Carbon Wales*.[6] The 'Coal in Wales' consultation ran between July and September 2020 and included the proposed policy to avoid the continued extraction and consumption of fossil fuels. The coal policy was published in March 2021[7] .

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[3] https://gov.wales/sites/default/files/publications/2021-01/energy-generation-in-wales-2019.pdf
[4] https://gov.wales/energy-use-wales-2018-report
[5] https://simecatlantis.com/2020/07/16/uskmouth-power-station-conversion-project-update/ .
[6] https://gov.wales/sites/default/files/publications/2019-06/power-sector-emission-pathway-factsheet.pdf
[7] https://gov.wales/coal-policy-statement

10.1.2 Other coal-fired energy generation applications

A number of people in Wales rely on solid fuels as a primary means to heat their home, particularly in rural areas that are off the gas grid (Welsh Government 2020b). Around 22% of Welsh properties are off the gas grid (Welsh Government 2020a). An estimated 2% of the 1.35 million homes in Wales use solid fuel (coal, wood or biomass) as the main heating fuel.[8] The UK Government plans to consult in early 2021 over new regulations to phase out fossil fuels in off-grid homes, businesses and public buildings, including a backstop date for the use of any remaining fossil fuel heating systems. The proposed Clean Air Bill would ban the indoor burning of solid fuels (traditional house coal and wet wood) after 2023 (Welsh Government 2020b). Decarbonisation of these homes would require use of options such as heat pumps and smart storage heating (UKCCC 2020). As already noted, coal-fired energy generation is not expected to contribute to Wales' energy mix in the future (Welsh Government 2020a).

10.2 Projections for the other energy generation technologies for 2030

10.2.1 Other fossil fuels powered energy generation technologies

In the UK as a whole, gas currently represents almost 30% of final energy consumption and 40% of electricity generation (it is particularly prominent in fuelling gas boilers in households and other buildings). UK Government accepts that the country will continue to rely on natural gas for 'some years' (HM Government 2020). It plans to consult with network operators, suppliers and consumer groups in 2021 on the future of gas, including on whether it is appropriate to end gas grid connections to new homes from 2025 in favour of clean energy alternatives. The UK and Welsh Government's independent advisor on decarbonisation, the Climate Change Committee (UKCCC), has recommended no new unabated gas power plants to be built after 2030 and unabated gas-fired electricity generation to end by 2035 (UKCCC 2020). A gradual move away from fossil fuel boilers is planned through a combination of energy efficiency measures and lower carbon replacement boilers.

In Wales, gas fuelled power stations accounted for almost 70% of electricity generated in 2019, with four gas plants making up 85% of total gas power capacity (Welsh Government 2020a). However, gas generation is increasingly changing from providing a steady, baseload supply to a more flexible peaking and backup role.

UKCCC recommend that Welsh Government work with the UK Government to deliver a phase-out of the burning of unabated gas for electricity generation by 2035, ensuring that existing gas plants in Wales are given opportunities to switch to low-carbon hydrogen or fit CCS within their economic lifetime (UKCCC 2020). In their 'Balanced Pathway Scenario' for Wales, the UKCCC recommends the phase out of the sale of gas boilers by 2033 in residential homes, and by 2030-33 in commercial properties.

In their recommended Balanced Net Zero Pathway scenario, the UKCCC envisages hydrogen playing an important role in the switch from gas at UK level, with:

- hydrogen grid conversion trials in the 2020s;
- patchwork large-scale conversions starting from 2030 near industrial clusters;
- some buildings in these areas switching to hydrogen; and
- conversion continuing until 2050.

Wales also has approximately 814 MW of small-scale (<100 MW) fossil fuel electrical capacity, which includes diesel generators, CHP projects, open cycle gas turbines and gas reciprocating engine sites. Although the Medium Combustion Plant Directive has prevented unabated large-scale diesel generators from being developed and operated, small-scale diesel plants may still have a role for backup generation to critical infrastructure in Wales (Welsh Government 2020a).

[8] Data from the Welsh Housing Conditions Survey 2017.

However, as one of the Welsh Government's policy objectives is to avoid the continued extraction and consumption of fossil fuels, these may be unlikely to play a significant role in the energy mix by 2030. UKCCC's 'Balanced Pathway Scenario' for Wales recommends the phase out of sales of oil boilers by 2028 in residential homes and by 2025-26 in commercial properties. The UK Government has also announced the end of the sale of new petrol and diesel cars in the UK by 2030.

10.2.2 Renewable energy and other new energy generation technologies

Renewable sources with a substantial share in Welsh electricity generation are currently wind, solar PV and biomass. Nuclear energy generation entirely disappeared in Wales after 2016, due to the closure of the nuclear plant on Ynys Môn/Anglesey, North West Wales.

UKCCC's 2020 'Balanced Net Zero Pathway for Wales' outlines a scenario where the low carbon share of generation in Wales increases to 100% by 2035. UKCCC is not prescriptive about the precise mix of generation that is used (e.g., new renewables, nuclear or BECCS capacity) [BECCS = Bio-energy with carbon capture and storage]. The UKCCC recommends that Welsh Government prepares an updated assessment of how much renewable and dispatchable low-carbon electricity generation will be required to meet Net Zero in Wales and contribute cost-effectively to Net Zero in the UK, with a clear trajectory to 2050 (UKCCC 2020).

In 2017, the Welsh Government announced a target of meeting the equivalent of 70% of Wales' electricity demand from Welsh renewable electricity sources by 2030. The Welsh Government also set a target for at least 1 GW of renewable energy capacity to be locally owned by 2030 and there is an expectation for all new energy projects in Wales to have at least an element of local Welsh ownership from 2020. The *Low Carbon Delivery Plan 2* will be laid in regulation in the Welsh Parliament in the autumn of 2021 and will outline the path to decarbonisation.

Following publication of the UK White Paper, decisions on specific pathways for several of the relevant technologies are expected to be published during the course of 2021.

Offshore and onshore wind are likely to continue to play an important role in renewable energy generation in Wales; they accounted for 29% and 38% of renewable generation respectively in 2019. Wales currently has three offshore and six onshore wind farms. Identified onshore expansion opportunities have included former mining sites. 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. It has a 4 MW capacity generating c. 8 GWh/year.[9] The Maesgwyn wind farm in the area of Neath Port Talbot (South West Wales) was commissioned in 2011 and has a nominal power of c. 32 MW (17 turbines ranging between 1.7 and 2.5 MW each).[10]

Wales already has the fifth-largest offshore wind farm worldwide in Gwynt y Môr (Sea Wind). Doubling of the current capacity (576 MW) and the leasing of three new sites are currently under consideration.[11] The offshore wind opportunities are summarised in Table 10.1.

Table 10.1: Offshore 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.

[9] https://www.theguardian.com/environment/2014/jun/05/windfarm-opens-on-former-welsh-coal-mine-site
[10] https://www.thewindpower.net/windfarm_en_16295_maesgwyn.php
[11] https://www.thecrownestate.co.uk/en-gb/media-and-insights/news/2021-offshore-wind-leasing-round-4-signals-major-vote-of-confidence-in-the-uk-s-green-economy/

Solar accounted for 12% of all renewable electricity generation in Wales in 2019. A high number of solar thermal projects were deployed in the past decade and small installations (e.g. on buildings) led to total thermal energy generation of 13 MW. However, the initial momentum faded 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). However, a study undertaken in preparation of the National Development Framework 2020-2040, now Future Wales, did identify a number of zones as priority areas for large-scale solar energy developments (Welsh Government 2019c).

There are no large-scale hydroelectric schemes currently planned in the UK, with small projects[12] developed by Battery Quarry in the planning phase, and pumped storage will play an increasingly important role in the UK electricity grid in future years as more intermittent sources of electricity generation come on line.

Turning to hydrogen, the UK is aiming for a 5 GW low-carbon hydrogen production by 2030, equating to 42 TWh annual low-carbon production (HM Government 2020). Work is being done to enable up to 20% hydrogen blending on the gas network by 2023, subject to the success of testing and trial.[13] A UK Hydrogen Strategy is to be published in spring 2021. UKCCC's recommended pathway would see low carbon hydrogen scaling up to 90 TWh by 2035 at UK level, produced using electricity or from natural gas or biomass with CCS.

The Welsh Government is currently consulting on developing the hydrogen sector. The report which accompanies the consultation presents a pathway and next steps for developing the hydrogen energy sector in Wales (Element Energy 2020). The hydrogen pathway outlined is intended to inform activity up to 2025, although the overall role of hydrogen in the energy mix is acknowledged to depend on wider national and international developments. The pathway presents ten key actions to help generate momentum in the Welsh hydrogen sector, preparing for scale-up and commercial deployment from 2030 (see Figure 10.2). Welsh hydrogen projects include a demonstrator at Hanson Cement.[14]

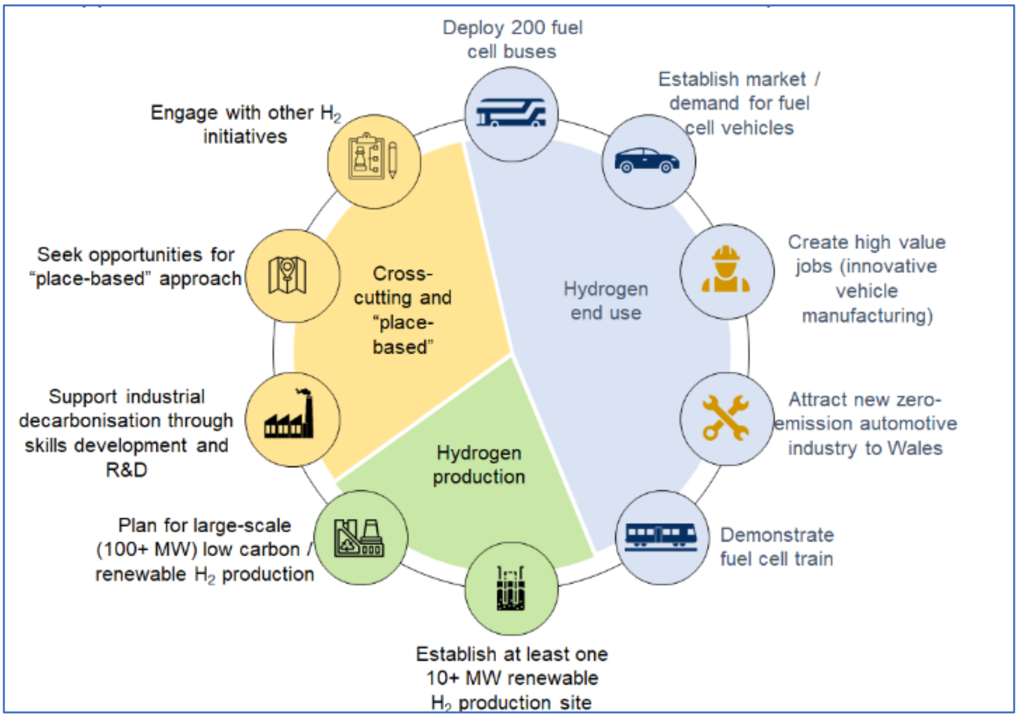

Figure 10.2: Proposed near-term objectives to develop the hydrogen sector in Wales

Source: Element Energy (2020).

12 https://www.snowdoniapumpedhydro.com/project-status
13 https://www.keele.ac.uk/discover/news/2020/january/hydeploy-goes-live/at-keele-university.php
14 https://www.rice.cymru/en/news.htm?id=127

On marine and tidal energy, two demonstration zones[15] have been assigned in Wales to test wave and tidal stream technologies. Using EU funding, these projects make the technology more cost-competitive; however, further investment is required to generate revenue as a sector. An earlier impact study revealed that, in the longer term, wave and tidal stream energy could account for 1 GW of marine energy capacity (Regeneris Consulting 2013). The UK Government intends to "*consider the role of wave and tidal energy, following further evaluation of the commercial and technical evidence*" (House of Commons 2021). According to recent evidence given to the Welsh Affairs Committee, marine energy has the "*potential to be enormously successful if it replicates the sort of success of onshore wind in pricing support*" (House of Commons 2021).

There are no nuclear power stations currently operating in Wales. Plans for a new nuclear plant at Wylfa Newydd on Anglesey were suspended in January 2019 and Hitachi confirmed in September 2020 its intention to exit all nuclear activity in the UK by the end of March 2021. The Wylfa Newydd site is still regarded as the best in the UK for large new nuclear and work continues to find a solution that will enable a new project to come forward. The former Trawsfynydd site in Gwynedd, North-West Wales, is owned by the Nuclear Decommissioning Authority and Welsh Government is in the process of creating a site development company - Cwmni Egino - to help unlock the site's potential (Welsh Government 2020a). Possible projects include the deployment of SMR technology and a medical radioisotopes and research reactor. The UK Government aims to bring at least one new large-scale nuclear project to the point of Final Investment Decision (FID) by the end of this UK Parliament term, and also aims to build a commercially viable fusion power plant by 2040. Investment (up to £385m) has also been promised to develop Small Modular Reactor (SMR) design and Advanced Modular Reactor (AMR) demonstration, and to develop the regulatory frameworks and the UK's supply chain (HM Government 2020).

The 2030 energy mix is also projected to include installation of increasing numbers of heat pumps. UKCCC's Balanced Pathway for Wales recommends 52,000 heat pump installations per year in Wales by 2030, rising to 75,000 by 2050 (UKCCC 2020). In addition, the UK White Paper also outlines plans to support the deployment of Carbon Capture and Storage in four not yet specified industrial clusters to be operational by 2030. Wales has relevant experience in this technology, as the South Wales Industry - A Plan for Clean Growth was one of six projects across the UK receiving a share of UK government funding as part of a drive to create the world's first net zero emissions industrial zone by 2040.[16]

10.3 Projections for the energy mix of the region for 2050

The plan for reducing emissions and developing a decarbonisation pathway in Wales are summarised in the policy paper *Prosperity for All: A Low Carbon Wales. Wales' commitment to tackling climate change* (Welsh Government 2019a). The Environment (Wales) Act 2016 set a 2050 target for reducing emissions and put in place a statutory process establishing interim targets for 2020, 2030 and 2040, as well as carbon budgets. Welsh Ministers must set five yearly carbon budgets, with associated delivery Plans. Pathways are set out for power, buildings, transport, industry, land use, agriculture, waste and F-gases. The second statutory decarbonisation plan, *Low Carbon Delivery Plan 2* (LDCP2) will be laid in regulation in the Welsh Parliament in the autumn of 2021. An engagement plan has been published setting out Welsh Government's plans for communication and engagement with stakeholders in the development of LDCP2.[17]

The December 2020 UK Climate Change Committee report outlines the path to Net Zero and progress on reducing emissions in Wales (UKCCC 2020). The Welsh *Prosperity for All* plan is

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[15] https://www.morlaisenergy.com/
[16] https://www.gov.uk/government/news/green-boost-for-regions-to-cut-industry-carbon-emissions
[17] https://gov.wales/sites/default/files/publications/2020-07/engagement-approach-for-low-carbon-delivery-plan-2.pdf

also an important indicator of the future direction of policy (Welsh Government 2019a). At regional and local levels within Wales, the new regional energy strategies and local area energy planning process will be key in setting out pathways to Net Zero. However, use of policy levers at both UK Government and Welsh Government levels will be required.[18] At UK level, the UK Government is reluctant to target or forecast a particular energy generation mix by 2050. As stated in December 2020's Energy White Paper, *"We are not targeting a particular generation mix for 2050, nor would it be advisable to do so. [...] The electricity market should determine the best solutions for very low emissions and reliable supply, at a low cost to consumers"* (HM Government, 2020).

The UKCCC report provides multiple scenarios for Wales in order to reduce Welsh and UK emissions to Net Zero by 2050. Based on these scenarios, a recommended Balanced Net Zero Pathway has been developed, which "makes moderate assumptions on behavioural change and innovation, and takes actions in the coming decade to develop multiple options for later roll-out (e.g., use of hydrogen and/or electrification for heavy goods vehicles and buildings)".

In line with *Prosperity for All: A Low Carbon Wales*, there is an emphasis on the importance of reducing demand, a whole-system approach to decarbonisation, and alignment with the goals of the Well-being of Future Generations Act (Wales) 2015. In the Balanced Net Zero pathway:

- Fossil fuels in Wales would largely be phased out. Demand would fall significantly for oil (-95%) and natural gas (-60%). Petroleum use would be mainly restricted to the aviation sector, with natural gas use limited to combustion with CCS for power generation and industrial processes and phased out of use in buildings. Opportunities for high-efficiency electrification (e.g., moving to EVs and heat pumps) would mean that demand for oil and gas falls more rapidly than the increase in electricity demand.
- Low-carbon electricity would become the dominant energy source, with output increasing to more than double current levels by 2050.
- A hydrogen economy would develop from the 2030s onwards, to a scale that is comparable to existing electricity use by 2050.
- Bioenergy and waste use would grow modestly by 30% to 2050 at UK level.
- Carbon capture and storage would play an important role in the manufacturing and construction sectors, and in the production of hydrogen and electricity generation in Wales.
- There are important implications for land use in Wales, such as the shifting agricultural land to carbon sequestration uses, including tree planting and peatland restoration.

Industrial sites in Wales (and specifically the South Wales industrial cluster) are mentioned in terms of the need to either switch away from fossil fuels to low-carbon alternatives and/or install carbon capture and storage at scale from the mid-2030s.

The Net Zero South Wales project[19] outlines three possible scenarios specifically for South Wales: high electrification, core hydrogen and high hydrogen (see Figure 10.). In all three scenarios, energy consumption reduces due to energy efficiency and the relative efficiency of new technologies, and electricity consumption increases. The analysis states that although the decarbonisation pathway is becoming more consistent and certain in some areas, such as the electrification of electric vehicles and the optimisation of renewable energy (wind and solar) capacity in South Wales, in other sectors, such as heat, "there remains significant uncertainty about future technology routes" (Regen 2020).

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[18] The pathways and policy framework of *Prosperity for All* are explained in more detail in the TRACER report *Technical concepts for the transition of the energy system into a smart, sustainable and renewable energy system in the TRACER target regions* (Section 11, Figure 37): https://tracer-h2020.eu/wp-content/uploads/2020/08/TRACER-D3.2-Technical-Concepts.pdf.

[19] A partnership between Regen, Western Power Distribution (WPD) and Wales and West Utilities, as part of the Zero2050 South Wales initiative led by the National Grid. National Grid ESO, the electricity system operator for Great Britain, develops and publishes Future Energy Scenarios. https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

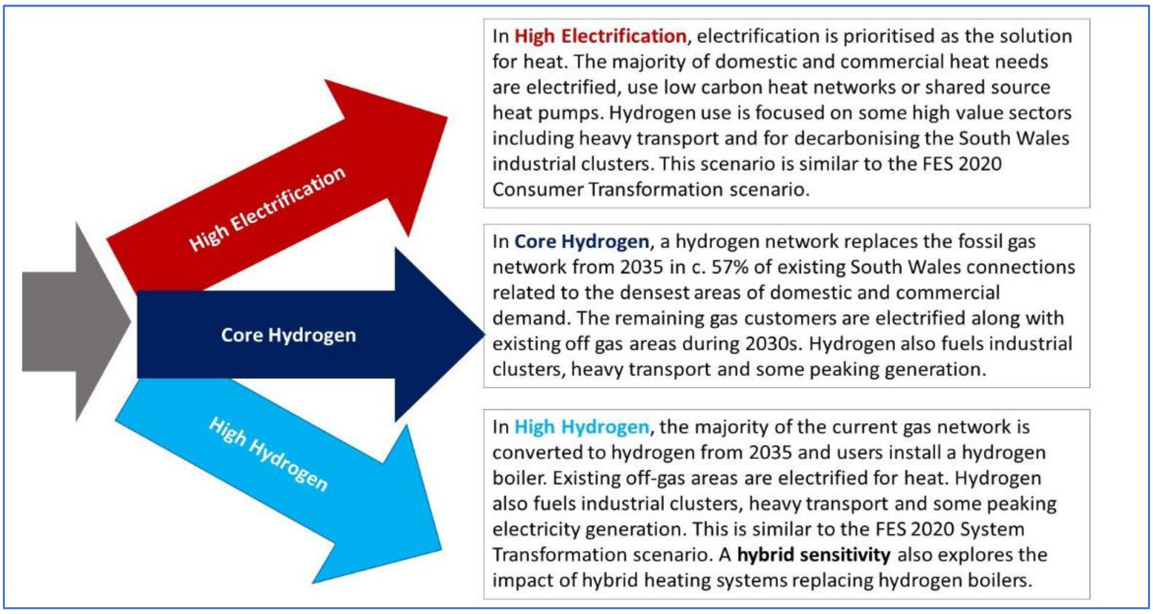

Figure 10.3: Three possible joint electricity and gas Net Zero 2050 scenarios for South Wales

Source: *Regen, Wales & West Utilities, Western Power Distribution (2020) Net Zero South Wales. A combined gas and electricity distribution network future energy scenarios (DFES) assessment for South Wales to 2050, Learning webinar 17 June 2020.*

Looking ahead, the four new regional energy strategies in Wales set out the scale of change needed by 2035 for a path consistent with Net Zero, and explore the related economic opportunities (see Figure 10. for a summary of the Energy Strategy for Cardiff Capital Region). The Welsh Government has co-developed the energy strategies with each region of Wales to understand the increase in renewable energy capacity required to meet Wales legal targets for Net Zero. The Comprehensive Energy Vision for Mid Wales is the latest regional strategy.[20] These will play a key role in creating an effective electricity grid network to fulfil the Welsh Government's renewable and low carbon ambitions.

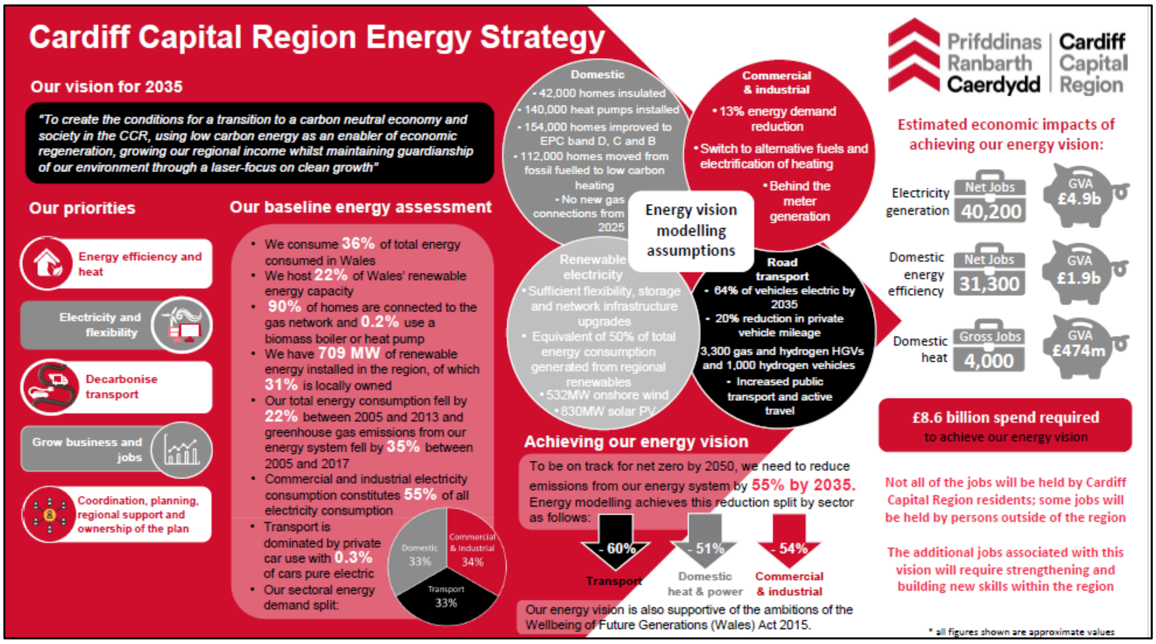

Figure 10.4: Cardiff Capital Region Energy Strategy

Source: Welsh Government Energy Service

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[20] https://www.ceredigion.gov.uk/resident/news/comprehensive-energy-vision-for-mid-wales-developed/

The next step is Local Area Energy Planning, to be developed during 2021. The Welsh Government is working with local authorities to consider how both can together achieve detailed street by street level thinking at the level of detail needed for network operators to design and build grid at the pace required. Currently, Welsh Government are working with Conwy County Borough Council and Newport City Council to run a Local Area Energy Planning pilot study.

10.4 References

BEIS (2020a) *Modelling 2050: Electricity System Analysis*, Department for Business, Energy & Industrial Strategy, London, UK, December 2020. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943714/Modelling-2050-Electricity-System-Analysis.pdf

BEIS (2020b), *Energy Trends UK*, July to September 2020, Statistical Release, 22 December 2020. Department for Business, Energy & Industrial Strategy, London, UK. https://www.gov.uk/government/statistics/total-energy-section-1-energy-trends

BEIS (2019) *The UK's Draft Integrated National Energy and Climate Change Plan (NECP)*, Department for Business, Energy & Industrial Strategy, London, UK.

ECPK (UNDATED), *Aberthaw Power Station*, Engineering Timelines: http://www.engineering-timelines.com/scripts/engineeringItem.asp?id=971

ELEMENT ENERGY (2020) *Hydrogen in Wales. A pathway and next steps for developing the hydrogen energy sector in Wales*, Report to Welsh Government, https://gov.wales/sites/default/files/consultations/2021-01/hydrogen-in-wales-consultation.pdf

HM GOVERNMENT (2020) *Energy White Paper. Powering Our Net Zero Future*, CP 337. December 2020. https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future

HOUSE OF COMMONS (2021) *Welsh Affairs Committee Oral Evidence: Responsibilities of the Secretary of State for Wales*, HC96, 14 January 2021.

REGEN (2020) *Net Zero South Wales. A combined gas and electricity distribution network future energy scenarios (DFES) assessment for South Wales to 2050*. Learning report. Report for Western Power Distribution and Wales and West Utilities, 17 June 2020. https://www.regen.co.uk/publications/net-zero-south-wales/

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 (2020) *Advice Report: A Path to Net Zero Wales.* London: UK Committee on Climate Change, December 2020: https://www.theccc.org.uk/publication/the-path-to-net-zero-and-progress-reducing-emissions-in-wales/

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/

UKCCC (2017a) *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 (2017b) *Building a low-carbon economy in Wales: Setting Welsh carbon targets*. Technical Annex. London: UK Committee on Climate Change, December 2017: https://www.theccc.org.uk/wp-content/uploads/2018/03/CCC-Welsh-carbon-targets-Technical-Annex.pdf

WELSH GOVERNMENT (2020a) Energy Generation in Wales 2019. Regen for Welsh Government, Exeter, United Kingdom: https://gov.wales/sites/default/files/publications/2021-01/energy-generation-in-wales-2019.pdf

WELSH GOVERNMENT (2020b) Clean Air Plan for Wales, Healthy Air, Healthy Wales: https://gov.wales/clean-air-plan-wales-healthy-air-healthy-wales

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.

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

11 Conclusions

The European coal regions can play an active role in the European energy transition while, at the same time, do not have to stay behind in the frame of a continued economic and social evolution. While the transition is already happening, the clean energy potential in coal regions can enable them to be active participants in the energy transition and move, in many cases, from a single- to a multi-industry model.

There are two misleading arguments used against coal phase out: maintaining energy supply and replacing jobs that will be lost when coal mines and power plants will be shut down. Tackling both requires structural changes in energy technologies as well as in the energy economy. Close cooperation in the European, national and regional/local levels between companies, regulators, investors, land-use planners and local communities is essential to identify the most sustainable options, exploit regional potential and maximize social and economic development.

In taking policy decisions, it is very important to reconcile the key factors driving the transition. Each region needs to be analysed considering their comparative decarbonizing employment potential that takes into account the technical potential available per clean energy resource as well as their competitiveness and their contribution to the optimal achievement of the current and future policy targets.

This was the main concept behind the work made in the frame of this task of TRACER project, and more specifically in the process of developing the Research & Innovation strategies for the target regions, but also the main conclusion derived from the analysis made by the partners regarding the TRACER target regions. From the projections for the transition to 2030/2050 presented, it became more than obvious that the targeted coal intensive regions are in different stages of planning for the “next day”, as is also the case with the corresponding countries as a whole.

In the TRACER project there are countries that have already committed to phase out coal from their energy mix either before 2030 (e.g. Greece, UK) or slightly after this benchmark-year (e.g. Germany), countries in which the phase out of coal is under consideration but without setting strict time frames (Czech Republic, Poland), as well as countries – respectively, full regions of these countries – in which no phase out has been planned (at least not included in their NECPs), like Bulgaria and Romania. In the rest two countries of the TRACER consortium, i.e. Serbia and Ukraine, not being EU Member States yet, their policies are under development but no phase out of coal is foreseen neither for 2030, nor for 2050 (in the longer term).

The TRACER target coal intensive regions have exploitable energy infrastructure as well as land available to implement renewable energy – or, more generally, 'clean' energy - projects. As coal extraction is a land-intensive activity, both in terms of area size required and the physical strain that mining puts on the land, after decommissioning coal-mining areas, especially open cast lignite areas, cannot easily be reused for agriculture or settlements. However, those areas can effectively be converted to be used for developing renewable energy sources like solar, biomass and wind. The practical experience with energy cropping, special crops on reclaimed land is very low, with only a few promising examples, especially regarding SRC (poplar and black locust). Also, the processing chains are underdeveloped. Therefore, it is important to activate biomass production and make use of the regional cropping experience to ensure sustainable land management.

This repurposing can help accelerate mine rehabilitation which provides immediate jobs for former miners and a safe, healthy local environment. Building up a strong renewable energy sector also prevents coal regions from falling into the trap of so-called transition fuels, e.g. natural gas, which is however expected to be the case in the end (this option is justified by the existence of centralized heating supply systems for local communities, which have DH systems based on coal fired CHPPs and their smooth operation must be ensured). By investing in solar, wind energy and biomass technologies, which also contribute to the decentralization of energy production, coal regions can leapfrog fossil natural gas, which, as its combustion still produces emissions, would only add another painful transition in the years to come.

When considering the re-use of coal power plants, the integration of energy storage systems within existing power plants should be taken into consideration, as it presents some major advantages:

- The re-use of coal-power plants stops the facilities from becoming stranded assets.
- Using the existing infrastructure reduces the cost of plant closures, while also reducing the investment costs for setting up the new energy storage systems.
- Reskilling can help former workers keep their jobs.
- The region's identity as a power producer will remain, which can help with the public acceptance.

Energy storage technologies (thermal energy storage, pumped hydro energy storage, or even chemical battery storage systems) can play a key role as a supplement for intermittent renewable sources like solar and wind. Thus, in many cases, a combination of renewables (including solar heating, deep geothermal energy) and energy storage will be beneficial. Former coal-fired power plant sites might develop into clean energy hubs combining energy production, and processing (e.g. hydrogen) with demand.

With these in mind, and based on the projections for the transition to 2030/2050 regarding the energy mix in the targeted coal intensive regions, which are other existing (i.e. made in the frame of the general energy planning process of the country/region) or prepared for the case of the work needed to be done in this Task of TRACER (see e.g. the Romanian case), or even extracted from the scientific literature, it was possible to detect the energy technologies that are expected to be used in the targeted regions, during and after their decarbonization process. And as far as these energy technologies will form the back-bone of the transition process, in these technologies should focus the corresponding R&I capacity should be oriented in the near future (always in consistency with the SET Plan).