Smart strategies for the transition in coal intensive regions

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Blueprint on Kolubara region energy transition

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Executive summary

Kolubara region, as the largest coal mining and energy generation complex in Serbia, is responsible for over 75 % of total coal production and more than 50 % of total electricity generation in Serbia. Actually, it is the major single employer in the country, with about 12,000 employees working in coal mining and power generation. In order to preserve security of electricity supply and avoid risk of raising dependence on foreign markets, energy resources in Serbia in the next decade will still be based on fossil fuels. However, in line with the contemporary trends in sustainable energy development domain, transition process in the coal regions is timely planned, considering gradual coal phase out. Kolubara coal basin shall lead the way, since some of the opencast mines there shall be closed in the nearest future.

Transition process will be extremely challenging one, since serious economic and social transformations will be a consequence of the replacement of coal by other primary energy sources for electricity generation in the country. Along with the activities related to reclamation of ex-mines areas, the possibilities related to energy generation from renewable and other sources would be examined and prepared for development in the near time span. The legal framework for an optimal planning of these actions was recently adopted in the fields of energy and mining, but the most important of them are still pending, namely the Integrated National Energy and Climate Plan (INECP) by the year 2030, and the Energy Development Strategy by the year 2040, both with a vision by the year 2050.

Strategic directions for the future energy development of the Kolubara region should ensure security of energy supply, alongside with the energy efficiency improvement, the two major issues of concern for a smooth energy transition from coal to renewable and other carbon-free energy sources. The drafts of both above mentioned strategic documents are based upon governmental commitment towards providing carbon neutrality by the year 2050.

The transition period in Kolubara coal region practically starts in the next year. According to the National Emission Reduction Plan, the oldest coal fired power generation plant Kolubara A is planned to be shut down by the end of 2023, to mark first practical steps in the Kolubara region's transition. As the major thermal power plants "Nikola Tesla A" and "Nikola Tesla B" in the Kolubara region remain operational, the coal exploitation will continue, but gradually decreasing at a rate determined by the scheduled closure of the units on these power plants.

It is possible that not all coal fired units will be decommissioned after closure: some of them may remain in stand-by regime for the case of emergency, while some may be adapted to switch to natural gas combustion and continue to operate either as combined cycle cogeneration units or as open cycle backup units to support intermittent electricity generation from wind and solar power plants. As mentioned in TRACER-D4.4 report on Matchmaking, certain PV generation capacities might be constructed on the existing ash or overburden deposits, after the reclamation process is carried out. There is also a possibility to use parts of the existing infrastructure for potential construction of small modular nuclear reactors, as mentioned in the draft of INECP.

High priority measures in the transition from coal in the Kolubara target region are proposed based on the current knowledge of the local situation as well as of the best available practice in the world when solving the problems encountered in fighting against climate change. These high priority measures should include the following actions:

- Intensify the transition from electricity generation in the Kolubara region from local coal to renewable energy and other carbon free energy sources;
- Ensure a reasonable amount of back up and base load generation from natural gas, local biomass and eventually from nuclear fuel;
- Increase public and private investments and governmental subsidies in raising energy efficiency and implementation of renewable energy sources;
- Plan the reskilling/retraining process for the current employees leaving the energy sector and start its implementation in due time.

1. Kolubara region common vision statement

Serbia today is not a member country of the EU, but as a candidate for the EU membership and signatory of the Treaty Establishing Energy Community, is obliged to closely follow the EU energy and climate policy. This specifically applies to the Kolubara target region as the country's major coal mining and electricity generation area. It is therefore well understood by the major stakeholders that the transition away from coal is a vital issue for the Region, as well as for the country as a whole. It is their common vision that Kolubara region is of prime importance to keep the country's energy supply secure and import dependency low, so that the energy transition from coal to RES should be a *Just* one and slow, rather than fast, process.

Having in mind that huge investments are needed for enormous changes to take place during the transition process, the common vision of the transition in Kolubara region is expected to be based on *Smart Specialisation* and *Research and Innovation.* The Kolubara region as part of the Green Agenda for the Western Balkans can greatly benefit from Smart Specialisation Strategies, which are conceived as place-based, innovation-led transformation agendas for sustainability and create the opportunity to engage regions in transformation, contributing to the European Green Deal, providing an overall framework and directionality for innovation investments. The Western Balkans are already participating in Horizon 2020 – the EU's Framework Programme for Research and Innovation, of which the TRACER project is an important part. It is expected to support and facilitate energy transition being based on the utilization of specific, measurable, achievable, realistic, and timely (SMART) strategies aimed at actions towards successful implementation of sustainable energy policy in nine coal reach regions of Europe.

Kolubara region is the largest coal mining and energy generation region in Serbia, which ensures about three quarters of total coal production and more than a half of total electricity generation in the country. The proven coal reserves in the basin could allow coal exploitation till the middle of this century. However, in line with the contemporary trends in sustainable energy development domain, promoted worldwide, the Region and Serbia as a whole face a serious and challenging task to shift from its former energy supply strategy, based on fossil fuels, to the carbon neutral energy sources, primarily PV solar, wind and biomass.

Considering economic and social effects that may arise as the consequence of Kolubara mines closure for the Region and country as a whole, it is obvious that the transition process should be gradual and that in the forthcoming period (of about the next 15-20 years), energy resources used in Serbia should still include fossil fuels, in order to preserve security of energy supply and avoid risk of imports dependence. Besides, a significant number of the existing Kolubara's 12,000 employees, currently working in the Kolubara coal basin, both in coal mining and associated industries, will be gradually left without jobs and in need for another employment, often after re-skilling, to ensure adequate income for their families.

In the active remaining mine exploitations, sustainable mine operations should be supported by R&I work to use modern mining machinery, providing better lignite extraction efficiency while minimizing environmental impacts. Mine exploitation technology should be improved to provide the possibility of coal quality control in the defined range of parameter values. In addition, coal quality parameters should be monitored continuously to ensure level of required quality, before delivering to the final consumers.

In the next decades, the resources in Kolubara open cast mines will completely be exhausted, so that these areas would require a lot of reclamation works and adequate adjustment for repurposing. It is obvious that such works should include a comprehensive environmental rehabilitation in order to make these sites safe for future use by people who will be living and working there.

Along with the activities related to reclamation of post-mining areas, the possibilities related to employment in energy production from renewable sources should be prepared for development in due time. Such possibility will particularly be convenient for employment of those currently working in the electricity generation plants in the Kolubara region.

As a candidate country for EU membership, Serbia is in need to harmonise its legislation with the directives of the EU. Serbia has shown its commitment to European energy policy by accepting and ratifying some important documents in the field of energy transition and green energy development, such as: the Paris Agreement, in 2015, EC Green Deal, in 2019, Podgorica - Joint statement on the transition to clean energy, in 2019, Sofia Declaration on the Green Agenda of the Western Balkans, in 2020. The latest adjustment of the local regulations includes implementation of the Third Energy Package of the EU and certain provisions of the EU Clean Energy Package for all Europeans. The legal framework for an adequate planning of all these actions will consist of the following four laws in the field of energy (3) and mining (1), adopted by the Serbian parliament in April 2021, with an aim of providing better conditions for a faster and smooth energy transition:

- Amendments to the Law on Energy,
- Law on Energy Efficiency and Rational Use of Energy,
- Law on the Use of Renewable Energy Sources,
- Amendments to the Law on Mining and Geological Research.

In addition, the Law on Climate Change has also been adopted to serve as a legal framework for the Low-carbon development strategy of Serbia by 2050, which has already been drafted. On this basis, the new Energy sector development strategy by 2050 is currently in its final stage of preparation. To complete the set of legal and strategic documents for the energy transition, Serbia has also drafted its Integrated National Energy and Climate Plan (INECP), with concrete targets and measures for reducing greenhouse gas emissions, for RES share and energy efficiency by the year 2030, with projections until the year 2050.

2. Kolubara region projection of the energy mix

2.1. Review of the installed capacities in Kolubara region

Actual major energy production sources in the Kolubara region are coal-fired thermal power plants (TPPs) based on pulverized coal firing boiler technology with steam cycle of both condensing and cogeneration (CHP) types with subcritical steam parameters. The total installed capacities of the TPPs in Kolubara region of initial 3,148 MW have been upgraded (to 3,405.6 MW), of which 3,144.6 MW will remain operational beyond 2023, when all 5 units at the old Kolubara A TPP with total installed capacity of 261 MW will be shut down, under obligations of the Republic of Serbia according to: the Energy Community Treaty and associated Decisions regarding compliance with EU Industrial Emission Directive and, in line with the National Emission Reduction Plan (NERP) adopted in February 2020.

Table 2-1 below presents the installed capacities at TPPs “Nikola Tesla” A and “Nikola Tesla” B**.**

Table 2-1: Nominal capacities of thermal power plants in Kolubara region [1]

Power plant	**“Nikola Tesla” A**	**“Nikola Tesla” B**
Nominal installed capacity per units, before/after their modernization (MWe)	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

From TPP „Nikola Tesla “units A1 and A2 over 90 MWt is extracted for the district heating system of the Obrenovac city, while extraction of 600 MWt from the units A3 to A6 is designated for the base load in the district heating system of the capital city of Belgrade.

There are no wind power generators installed so far, while data on small solar applications are not available.

Coal supply for the power plants in the forthcoming period will be from the existing open pit mines “Tamnava West” and the new open pit mine “Field E”. Opening of a new open pit mine “Radljevo” was planned primarily in connection with a decade’s long project of new TPP Kolubara B with two units 350 MW each. The construction of TPP Kolubara B begun in 1986, but postponed and the final decision taken under strict intention of the Serbian government to follow EU coal phase-out strategy to terminate construction is still under reconsideration.

Several minor energy production sources in the Kolubara region include steam boiler plant in Vreoci, constructed for the needs of coal processing facilities in “Kolubara Prerada” works and other related facilities in the area, as well as boiler plants operated in the scope of mines fields. There are also numerous small coal/wood fired facilities for space heating in the households.

2.2. Projection of the energy mix in Kolubara region

Projection of the energy mix in Kolubara region is in a close relation with the energy transition policy in Serbia, aimed to reach carbon neutrality by the middle of this century. The transition in Serbia is guided by the legal and strategic documents prepared in line with the country’s determination to become EU member and comply with the EU energy and climate policy, including all related regulatory documents. Based on its new regulatory framework adopted in 2021, Serbia is currently finishing its bylaws and two major strategic documents: the Energy sector development strategy by the year 2040 with a vision by the year 2050, accompanied by a separate Hydrogen development strategy, and the Integrated national energy and climate plan (INECP) by the year 2030 with a vision by the year 2050. As the mainstay of the Serbian energy supply, Kolubara region remains in the greatest focus of those documents, and the projected energy mix for the future.

Kolubara region is currently Serbia’s major energy supplier. 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 below 40%). Domestic lignite keeps the major share in the Serbian primary energy balance. In the final energy consumption, oil derivatives dominate, followed by electricity, heat, firewood, coal and natural gas. Households consume more than a third of final energy (almost a half of electricity), followed by industry and transport

One of the strategic priorities for Serbia is to increase security of energy supply, which currently depends on coal from Kolubara region to a great extent. While electricity generation currently matches 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 from recently is available via Turkey and Bulgaria as well. The new built gas pipeline connection to the “Turkish Stream” via Bulgaria is built under obligation to implement the EC Regulation on conditions for access to the natural gas transmission networks in Europe. A third gas pipeline connection is currently under construction jointly with Bulgaria to ensure an additional way of natural gas supply from the LNG platform in Aleksandropulos, Greece. Nevertheless, the coal mined in Kolubara region, alongside with hydro and new built solar and wind capacities, will continue to be the key enabler of a secure energy supply at least for the medium term.

Both, the Energy sector development strategy and INECP will drive energy transition in Serbia with its major impact on the energy mix timeline in the Kolubara region. The initial steps of the planned transition in the Region have been determined by the Serbian National Emission Reduction Plan (NERP) which provides that all 5 units at the TPP Kolubara A with the total installed capacity of 261 MW should be shut down by the end of 2023, followed by the potential closure of 2 units (A1 and A2, 221.8 MW each) of the TPP “Nikola Tesla” A by the end of 2027, if not equipped by adequate environmental protection technologies (FGD and DeNO_X), such as are currently being installed at the rest of 4 units (A3 to A6, with total 1,361

MW installed capacity) of the TPP “Nikola Tesla” A and at both units (B1 and B2, with the installed capacity of 670 MW each) of the “Nikola Tesla” B, all being fired by the lignite from Kolubara mines. The coal mining beyond 2027 will mainly be determined by the needs of the TPPs in the Region that will remain operational according to the provisions of the INECP and the Energy sector development strategy by the year 2050.

It is obvious that the Serbian INECP by the year 2030 refers mainly to the Kolubara region, when coal mining and electricity generation are considered. With above mentioned capacities in operation beyond the year 2023 and optional completion of the Kolubara B TPP with a capacity reduced to one 350 MW unit based on fluidized-bed combustion (FBC) technology, the Region will continue to dominate in the coal fired share of the Serbian energy mix, as presented in Table 2-2.

Table 2-2: Gross installed capacities (GW) by 2030, at national level [8]

Year	**Coal fired**	Natural Gas	Industrial CHP	Bioenergy and EfW	Hydro power	Pump storage	Wind onshore	Solar PV
2019	**4.42**	0.44	0.28	0.02	2.44	0.61	0.35	0.02
2025	**4.40**	0.63	0.21	0.11	2.48	0.61	0.75	0.59
2030	**3.34**	0.62	0.13	0.16	2.52	1.89	3.51	1.54

Bearing in mind that the units A1 and A2 of TPP “Nikola Tesla” A are currently used for district heating system of Obrenovac city, it would be necessary to solve heating with different technologies, prior to the closing year 2027. Also, the implementation of the Belgrade district heating project with heat extraction from the units A3 to A6 of TPP “Nikola Tesla” A would mean that these units will remain in operation well after 2030 (taking into account the value of the investment in plants and equipment for implementation of the Project, it requires a pay-off period of 20 to 25 years).

To achieve its goal of carbon neutrality by the middle of this century, Serbia is planning to focus its energy policy towards an ever-increasing share of renewable energy from wind, solar and bioenergy including energy from waste (EfW), as well as from natural gas, while drastically reducing the share of coal (Table 2-3). Due to the current crisis in gas supply, Serbia considers as optional use the nuclear energy, for baseload generation, provided that the current legal embargo on nuclear fuels will be removed. However, this option does not imply a reduction of baseload generating capacity from coal, but rather doubling the prevention from wind-based intermittent generation (Table 2-4).

Table 2-3: Gross installed capacities (GW) by 2050, at national level [8]

Year	**Coal fired**	Natural Gas	Industrial CHP	Bioenergy and EfW	Hydro power	Pump storage	Wind onshore	Solar PV
2030	**3.34**	0.62	0.13	0.16	2.52	1.89	3.51	1.54
2035	**3.35**	0.22	0.06	0.24	2.85	1.89	6.28	2.41
2040	**2.59**	1.04	0.04	0.32	3.17	1.89	6.42	3.28
2045	**1.99**	1.03	0.04	0.44	3.42	1.89	6.86	4.14
2050	**1.91**	1.02	0.04	0.53	3.42	3.69	10.51	19.06

The projected rate of reduction of coal in the Serbian electricity generation is mainly reflected in gradual closing down of coal mining in the Kolubara region. This appears to be in line with the exhaustion of the lignite reserves of the Region. However, even if/when carbon neutrality will be achieved in 2050, there is a belief that some of the current generating units in the Kolubara region will not undergo complete decommissioning and will remain in stand-by mode, ready to operate in the case of emergencies. This particularly refers to the potentially new built Kolubara B unit based on CFB technology, capable to operate on low-quality lignite

that currently cannot be used in the existing TPPs, that operate with pulverized coal with heating value above 5,300 kJ/kg.

Table 2-4: Gross installed capacities (GW) with nuclear option by 2050, at national level [8]

Year	Nuclear	**Coal**	Natural Gas	Industrial CHP	Bioenergy and EfW	Hydro Plants	Pump Storage	Wind	Solar
2030	0	**3.34**	0.62	0.13	0.16	2.52	1.89	3.51	1.54
2035	0.80	**3.39**	0.22	0.06	0.24	2.85	1.89	6.08	2.41
2040	1.20	**3.15**	0.23	0.04	0.32	3.29	1.89	6.71	3.28
2045	1.60	**1.99**	0.22	0.03	0.40	3.42	1.89	6.86	4.14
2050	1.60	**1.96**	0.22	0.02	0.48	3.42	3.69	10.75	20.50

The geographical position of the Kolubara region is not suitable for development of wind-based electricity generation [9], however, it is suitable for solar based generation, both PV and solar thermal, as well as for biomass-based generation either with direct firing of biomass or upon its gasification. As presented in TRACER-D4.4 report on Matchmaking, there is a good possibility in the Region to provide a considerable surface area for short rotation plantations such as short rotation forestry (SRF) as well as for utility scale solar power plants. For example, on the 55 ha large landfill area that will become available after the closure of the TPP Kolubara A in 2023, there is a possibility to build a land-based PV solar plant of about 30 MW installed capacity. The overall landfill area of the TPPs “Nikola Tesla” A and B combined is about 20 times larger, and can accommodate considerable solar capacity there, for which an adequate electricity network connection infrastructure already exists. Also, the final closure of coal mines in the Region leaves large surface area after mining and overburden deposits for such purposes. These opportunities will ensure Kolubara region to remain equally important for the Serbian energy supply in the future as well, but with a quite different energy mix.

Energy mix in the Kolubara region is, thus, expected to change over time, following the adopted transition process dynamics. It shall mainly be in line with the overall dynamics of reaching the national goals defined by the new energy strategy of Serbia. Obviously, the transition in the Kolubara target region should take into account local needs and possibilities, and above all, keep up the major national interest to ensure continuous supply of electricity in Serbia, while keeping the desired level of employment of the local population.

Bearing in mind the current negotiations of Serbia with the EU for future membership, it is reasonable to assume that it will be able, alone and with the assistance of the EU, to follow the Union’s transition dynamics while adjusting its own energy mix, so to reach the goal of carbon neutrality energy by the middle of this century. The Region’s transition from coal will, to a large extent, be the same as that of Serbia as a whole. Of course, Serbia and the EU member countries have the same development goals, but different pathways adjusted to their local conditions, meaning that the transitional dynamics of Serbia, including Kolubara region, might be slightly slower than that of the EU.

3. Kolubara region available options for meeting the planned energy transition

3.1. Energy generation technologies

The existing pulverized coal-fired thermal power units in the Kolubara region have been commissioned from mid-fifties (oldest units at Kolubara A) to mid-eighties (the second unit at “Nikola Tesla” B). With their age in mind, it is obvious that, even the youngest units with

originally applied technologies from mid-1980s, are inefficient, thus causing high specific fuel consumption. In addition, due to a low calorific value of lignite from Kolubara mines, a considerable amount of liquid fuel is added to coal to support burning process in the boilers. The overall efficiency increases to some extent when the combined heat and power generation is enabled for supplying thermal energy to the district heating systems (DHSs) in Obrenovac and Belgrade cities, but with the obsolete technology it does not mean much.

To keep the fuel economy at the reasonable level, the TPPs have been upgraded over time. Table 3-1 presents in certain details the technologies originally applied to all TPPs in the Region and the improvements included in the scope of reconstruction and repowering of the TPPs “Nikola Tesla” A and B, except TPP Kolubara A that will be closed by the end of 2023.

Table 3-1 The main characteristics of the applied TPP technologies

Description	TENT A	TENT B	TE Kolubara A
1. In original project			
Combustion technology	Pulverized coal combustion	Pulverized coal combustion	Pulverized coal combustion
NOx emission reduction	No	No	
Steam conditions	Sub-critical	Sub-critical	Sub-critical
Heat recovery by cogeneration (CHP)	Yes, Units A1 and A2	No	Yes
Fly ash collection	ESP (Eff = 98% for A1&A2) (Eff = 99,5% for A3-A6)	ESP (Eff. = 99.8%)	ESP (Eff. = 98%)
Flue gas desulphurization	No	No	No
Fly and bottom ash disposal	Landfill disposal site, Hydraulic transport in poor slurry	Landfill disposal site, Hydraulic transport in poor slurry	Landfill disposal site, Hydraulic transport in poor slurry
Cooling system	Once through - hot water discharged in the river	Once through - hot water discharged in the river	Wet, mechanical draught cooling tower – blowdown waste water discharged in the river
Flue gas discharge	Stack 1 for Units A1-A3 Stack 2 for Units A3-A6	Stack 1 for Units B1-B2 (separate flues in the common stack)	Stack 1 for Units A1-A3 Stack 2 for Units A3-A6
Boiler make-up water treatment	Raw water demineralization (groundwater from wells) in ion exchange units	Raw water demineralization (groundwater from wells) in ion exchange units	Raw water decarbonization and demineralization (raw water from the river Kolubara) in ion exchange units
2. After modernization			
NOx emission reduction	Yes, primary measures + SNCR	Yes, primary measures + SNCR	TPP shall be shut down till end of 2023. (Opt-out operation)
Generator cooling	Air for Units A1/A2		
Fly ash collection	1st step: ESP (ELVs = 20 mg/m^3) 2nd step: Hybrid filter (ELVs = 8 mg/m^3)	ESP (Eff. = 99.8%) (ELVs = 30 mg/m^3)	-
Flue gas desulphurization	Yes, wet limestone/gypsum technology (project in progress)	Yes, wet limestone/gypsum technology (project in progress)	-
Fly and bottom ash disposal	Landfill disposal site, Hydraulic transport in	Landfill disposal site, Hydraulic transport in	-

Description	TENT A	TENT B	TE Kolubara A
	dense slurry	dense slurry	
Flue gas discharge	Wet stacks	Wet stacks	-

Apart from the technologies listed in table above, no other technologies for environmental protection are deemed necessary, nor the carbon capture and storage (CCS) technology has been envisaged for the TPPs in the Kolubara region. Also, apart from the pulverized coal fired technology, no other electricity generation technologies are presently used in the Region. However, if/when the TPP Kolubara B project would have been completed, the FBC technology might also become implemented in coal fired plants, that has already been applied for burning the municipal waste in a new combined heat and electricity generating plant (CHP) in the capital city of Belgrade. The CHP technology with gas turbines has been operated within the DHS of Belgrade, but stays shut down for decades. Currently, the CHP technology is applied in two units of the TPP “Nikola Tesla” A to supply heat to the DHS of Obrenovac, while the rest four units will also start to operate in the CHP mode when the heat transport pipeline between the plant’s site in Obrenovac and the connection point in DHS of Beldrade be completed. There are ideas to construct a combined cycle gas turbine (CCGT) power plant at the site of the TPP Kolubara A, but it still remains uncertain.

Other technologies considered to be applied in the Kolubara region for electricity generation in the future are those mainly based on renewables, in particular biomass and solar energy. While the utility scale ground based solar generation is still pending in the Region, the roof-top PV generation is already a well-established technology, but still in small scale. There are also projects of the façade-based building integrated PVs (BIPVs), but no wind turbines are envisaged yet. The hydrogen technology has already been considered by the Draft Hydrogen Strategy of Serbia, almost exclusively based on renewable (solar) energy.

The nuclear option has already been considered by the INECP after the year 2030. The Small Modular Nuclear Reactors (SMRs) have been envisaged, which makes it possible for the Kolubara region to integrate this technology, either on the existing TPPs former-sites, after decommissioning to make use of the existing infrastructure, or on the newly developed sites within the Region. This option is still questionable because the construction of nuclear power plants in Serbia is currently banned by law. For large size nuclear power plants there is less chance to be located in the Kolubara region due to a limited nuclear wastes management possibility.

Apart from its use in thermal power plants in Kolubara region, coal is used to generate industrial heat or steam, as well as for households heating where it competes with many other energy sources. The most frequently used for space heating in households in the Region is the firewood, while the share of other fuels such as oil and gas are not significant. Also, only a small percentage of residential consumers has individual gas installations. In some municipalities a good share of consumers is connected to the DHSs. Also, a number of households still uses electricity for space heating.

Obviously, the technology choice for heating and cooling is mostly influenced by the location of the household (urban-rural), by the age and composition of the family, as well as by fuel and heating devices availability and price. Apart from the old-fashioned stoves, fired by wood and coal in rural households, consumption of wood pellets in becoming attractive and modern one, but there are no precise data on wood pellets consumption. It is also becoming modern to install solar collectors for water heating instead of commonly used electrical heaters.

The draft INECP projects the share of renewables used for heating and cooling to almost double by the middle of this century, but still less than is the projected share of renewables in electricity generation that grows 3 times (Table 3-2). This fact implies that the Heat Pumps (HPs) technology may be applied to make the use electricity for heating and cooling much more efficient than conventional ohmic technology.

Table 3-2: Share of renewables in electricity and heating & cooling sectors (%), at national level [8]

Year		2019	2025	2030	2035	2040	2045	2050
Electricity generation	Without nuclear	30.1	33.9	49.1	63.8	67.6	80.5	91.4
	With nuclear	30.1	33.9	49.1	56.9	62.1	68.3	86.3
Heating and cooling		26.7	39.7	50.9	51.7	48.7	50.5	51.1

3.2. Environmental remediation/reclamation works

Environmental impact issues recorded in the region are primarily related to mines and power plants, but also to the associate industries and industrial activities (for example coal preparation facilities in the company “Kolubara Prerada”, as well as “Kolubara Metal”). The mining process accelerates soil degradation, while emissions of particulate matters – PM, SOx, NOx, and volatile organic compounds (VOC) have harmful impacts on air quality. Wastewaters from coal mines are discharged to the Kolubara River and its tributaries without proper treatment. All activities carried out during coal excavations also produces noise that affect life in the neighbouring settlements.

Existing TPPs in the Kolubara region are significant sources of SOx, NOx and PMs emissions which negatively affect air quality. As these power plants are in operation for several decades, in the past years they are all faced with challenges to comply with new, more severe, requirements regarding reduction of environmental impacts. New national regulation, in line with EU guidelines and directives, imposes numerous actions to be performed to comply with the required emission limit values and other environmental protection measures to provide operation in a more sustainable way. So far, new environmental protection installations for PMs and NOx emissions reduction have been installed, and new flue gas desulphurization (FGD) plants are under construction. According to the National Emissions Reduction Plan (NERP), deadline for introduction of all environmental protection measures in compliance with the EU Industrial Emission Directive is 1st January 2028.

Other environmental projects, currently implemented in power generation and coal mining include waste waters treatment plants and drastic reduction of water for ash and slag removal (1:1 instead of 10:1). These measures will reduce negative impacts on surface and ground waters and on land in the vicinity of ash dumps. Special attention is paid to the gradual recultivation of the soil after the mining of the lignite. Out of 37.4 km2 land area taken by mining about 20% has already been reclaimed and re-used primarily for forestry and to a lesser extent to agriculture. Apart from agriculture/forestry and other uses, the future works on remediation and reclamation of the mining wastes dumps will try prepare soil for energy crops as well. Also, a part of the area left after mining is over as well as about 1000 ha of the closed ash & slag dumps will also be repurposed for installation of the utility size ground PV power plants.

Besides the implementation of the environmental regulations and standards and investments in technical and technological systems that reduce harmful impacts on the environment, special focus is also given to the climate change issues. Of particular importance for the energy transition is the reduction of CO_2 emissions per kWh generated by increasing efficiency of the thermodynamic cycle of the TPPs by other measures. It is clear that the decarbonisation is the key word in the process of energy transition. However, bearing in mind the economic and social situation in Serbia, the energy transition process should be conducted carefully and slowly, over the next few decades, requiring broad consensus on the modalities of its implementation.

As in the next 15-20 years coal will remain the main electricity generation source, improvement of the existing power plants operation is the main issue. One of the first steps in this regard is increase of the power plants’ efficiencies (Table 2-1). On the other side, current European energy development insights strongly suggest introduction of renewable energy sources (solar, wind, hydro and green biomass) in the country’s energy mix.

Given all the above, the main actions in the field of technology development, including R&I for environment, shall include:

- Implementing measures to improve energy efficiency in technologies applied in the existing power plants, aiming to reduce self-energy consumption and increase specific heat rate (kJ/kWh);
- Finalising planned and already started projects for environmental protection measures implementation (such as FGD and NOx emission reduction measures, mainly secondary measures, based on SNCR technology, waste waters treatment systems, fly and bottom ash and gypsum disposal system improvement), designed to comply with the latest EU guidelines and regulation (LCP BREF 2017);
- Researching for possibilities to continue operation at the locations of the oldest coal power plants (TPP Morava and Kolubara A) by switching from coal to natural gas or domestic municipal wastes;
- Researching for possibilities to implement the newest technologies, based on hydrogen utilization, together with natural gas;
- Construction of solar power plants on the former ash disposal sites (TPP Morava and Kolubara A).

3.3. The work-force structure

The occupations and skills of the employees in the mining and energy industries and the ones needed in the renewable energy industry differ in many aspects. In the transition process planning and development, an important aspect is to consider which of the existing occupations and skills are common to both sectors, which occupations require additional training and how much time does it take to implement such training.

The experience from the similar coal intensive regions have shown that current coal mining workers occupations have good base for the employments in the field of renewable energy facilities operation, so that the foreseen retraining duration is one to six months, the longest for machine operators (six months) and the shortest for the maintenance and repair workers (one month). For the electricians the estimated reskilling period is three months.

Apart from the new power plants, decarbonisation process will provide opportunities for the development of agricultural production, forestry, wood industry, sports, tourism and trade. The development of these activities will increase or create the need for the following occupations: agricultural technician, forestry technician, hunting and fishing technician, agricultural machinery operator, food and beverage processor, biotechnology technician, food technician, food technologist, agricultural engineer, expert organic food production, tourism specialist, forestry engineer, wood processing engineer, etc.

4. Kolubara region high priority measures and concrete actions

Following the strategic directions in the Serbian energy sector, the future energy development of the Kolubara region is expected to be in the forefront of the country's energy transition. The Region should ensure energy security, while undergoing energy efficiency improvement and supporting energy transition to renewable energy sources, providing carbon neutrality by 2050.

The transition in the Kolubara region practically starts at the end of the next year (2023), when its oldest TPP Kolubara A is due to be shut down, initiating a gradual change of the overall energy mix in Serbia towards carbon neutrality. Following the country's energy transition dynamics, the Kolubara region will continue to supply coal to the remaining TPPs in the Region and provide electricity for base load for the power system following a continuous

increase of intermittent generation from wind and solar plants primarily in other parts of the country.

The prioritization of the proposed measures in the Kolubara region is primarily devoted to creation of adequate conditions for supporting the overall transition process in the country. As the key reference documents related to the national energy strategy (Energy sector development strategy by the year 2050, and Integrated National Energy and Climate Plan by the year 2030) are not yet officially adopted, the Kolubara region high priority measures and concrete actions are proposed herewith on the basis of current understanding and knowledge and according to TRACER-D6.4 report.

High priority measures are recommended to include the following actions:

- Intensify the transition from electricity generation in the Kolubara region from local coal to renewable energy and other carbon free energy sources;
- Ensure a reasonable amount of back up and base load generation from natural gas, local biomass and eventually from nuclear fuel;
- Increase public and private investments and governmental subsidies in raising energy efficiency and implementation of renewable energy sources;
- Plan the reskilling/retraining process for the current employees that will be going out of the energy sector and start its implementation in due time.

The strategic document NECP is setting Serbia pathway to becoming climate neutral by 2050, alongside ambitious goals for the current decade. To this aim, the provisional targets for 2030 are:

- Cut greenhouse gas emissions from 1990 levels by 40.3%,
- Reach a 41% share of renewable sources in gross final energy consumption,
- Reach a 49.1% share of renewable sources in electricity production,
- Reach a 50.9% share of renewable energy sources in heating and cooling,
- Reach a 6.1% share of renewable sources in transportation,
- Boost energy efficiency to lower primary energy consumption to 14,750 megatons of oil equivalent (MTOE),
- Boost energy efficiency to lower final energy consumption to 9,528 MTOE,
- Add 1.54 GW in solar power capacity or 100 more than the current level, and
- Add 3.51 GW in wind power or ten times more than what is now installed in Serbia.

The correlation between Kolubara region's high priority measures and concrete actions recommended to be put in practice and scheduled on a proposed time-line (2020-2050), is presented in the Blueprint Benchmark Annex to this current report.

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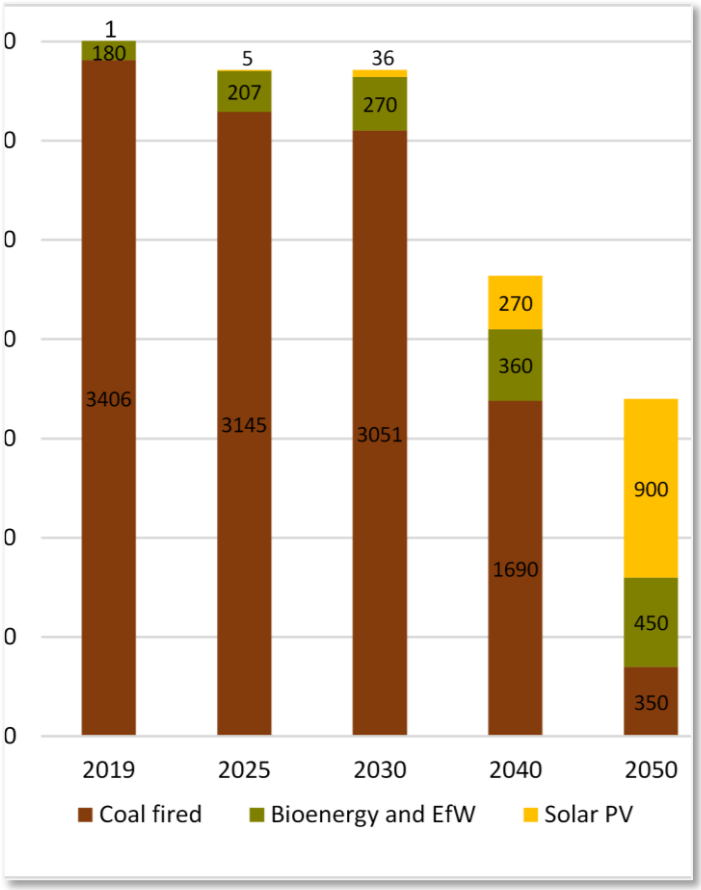
ANNEX
Kolubara Region Blueprint Benchmark

SERBIA
RS11 & RS21
KOLUBARA

	2020
SURFACE (km^2)	2,474
POPULATION (inhabitants)	212,373
GDP PER CAPITA (EUR)	8,100

	2020
DIRECT EMPLOYMENT IN THE COAL INDUSTRY (power and/or heat generation, mining) (pers.)	11,600 (mining) 2,270 (power and/or heat generation)
UNEMPLOYMENT RATE (%)	5.1



TIME LINE OF KOLUBARA'S ENERGY MIX FORECASTING (MW)

JOB CREATION POTENTIAL DURING THE DECARBONISATION PROCESS

TOTAL ESTIMATED LABOUR YEARS 2040/2050	HYDRO	SOLAR PV	WIND	BIOMASS	ENERGY EFFICIENCY
25476/36349	0	9576/16999	0	5400/6750	10500/12600

KOLUBARA ENERGY TRANSITION TIMELINE

YEARS	PRIORITY MEASURES / AREAS	CONCRETE KEY ACTIONS	TECHNOLOGIES / SYSTEMS / SERVICES	MILESTONES
2025		Kolubara A shut down	Coal homogenization system operational	Connection to DHS of Belgrade
2030	Work force reskilling plan	Kolubara B on the grid		
2040		Nikola Tesla A shut down	Utility size solar PV on the grid	
2050	Carbon neutrality	Nikola Tesla B shut down	Nuclear on the grid	Coal phase out