doi: 10.46793/EEE21-3.73L

Stručni rad

UDK 620.92:622.33]:502/504

Pametna i socijalno odgovorna energetska tranzicija u regionima sa intenzivnom eksploatacijom uglja

Smart and Socially Responsible Energy Transition in Coal Intensive Regions

Jasmina Mandić Lukić, Đorđina Milovanović, Maja Stipić, Sanja Petrović Bećirović, Radoslav Raković, Brankica Popović Zdravković, Miodrag Životić

Energoprojekt Entel, Belgrade

Rezime - Suočena sa preuzetim međunarodnim obavezama koje se odnose na aktivnosti usmerenim ka ublažavanju posledica klimatskih promena, a koje će se i zvanično reflektovati kroz regulatorna dokumenta koja su u procesu definisanja i usvajanja (Strategija i Akcioni plan niskougljeničnog razvoja i Zakon o klimatskim promenama), u Srbiji se sve jasnije sagledava neophodnost da se eksploatacija i korišćenje domaćeg uglja zameni ekološki prihvatljivijim gorivima ranije nego što je to inicijalno planirano. Poznata činjenica da sektor energetike u Srbiji generiše 80% ukupnih GHG emisija na nacionalnom nivou, a da su pomenute emisije dominantnim delom posledica sagorevanja domaćeg lignita, jasno ukazuje na zaključak da se najveći uticaj na usporavanje daljih klimatskih promena na lokalnom nivou prvenstveno može ostvariti kroz korišćenje alternativnih izvora energije.

Ipak, imajući u vidu da pomenuti proces energetske tranzicije sa sobom nosi niz značajnih tehnoloških, ekoloških, ekonomskih, socijalnih i drugih poteškoća, EU je kroz program Horizont 2020 pokrenula više projekata, a jedan od njih je TRACER koji ima za cilj da prikaže primere najboljih istraživačko-inovacionih strategija usmerenih ka lakšem prelasku na niskougljeničnu, održivu energetsku praksu. Projekat analizira devet evropskih regiona sa intenzivnom eksploatacijom uglja, među kojima je i Kolubarski region u Srbiji. U radu su prikazani tehnološki, ekološki i socijalni izazovi u procesu tranzicije, sa akcentom na Kolubarski region, i predlogom za energetsku tranziciju u Srbiji, uvažavajući Istraživačko-inovacione strategije i Pametnu specijalizaciju.

Ključne reči - Energetska tranzicija, Istraživačko-inovacione strategije (I&I), Zelena energija, Pametna specijalizacija

Abstract - Faced with forthcoming international obligations related to climate change mitigation measures, primarily planned to be reflected through the Law and Action Plan on Low Carbon Development Strategy, as well as the Law on Climate Change, all of which are currently being defined and adopted, Serbia is increasingly facing a need to switch its coal-fired facilities to alternative, environmentally more acceptable options. The related measures will have to be implemented much sooner than initially planned. Knowing that 80% of national GHG emissions originate from the energy sector, as well as that the dominant portion of those emissions results from the use of locally available coal, it is clear that the most efficient climate change mitigation measure would be a switch to alternative fuel options.

However, having in mind that such an energy transition process is coupled with significant technological, environmental, economic, social, and other difficulties, the EU has initiated several projects, and one of them is TRACER, launched under the Horizon 2020 program, that strives to shed light on the best research and innovation strategies facilitating easier transition to the sustainable, low carbon energy system. The project addresses actions across nine coal-intensive European regions, including Kolubara Region in Serbia. The paper presents technological, environmental, and social challenges in the transition process, with an emphasis on the Kolubara region, and a proposal for the energy transition in Serbia respecting R&I strategies and Smart Specialization.

Index Terms - Energy transition, Research and Innovation (R&I) strategies, Green Energy, Smart Specialization

I Introduction

Energy is the driver and key factor of economic change; in some way, it is the backbone of the country's economic development. Having in mind the importance of energy for one country, each country sets its long-term goals in this regard. Today the biggest challenge is the fight against climate change and related to that the EU has set long-term reduction greenhouse gas emissions by 80-95% compared to 1990 levels by 2050 [1]. There are specific targets for 2030:

- a 40% cut in greenhouse gas emissions,
- at least a 27% share of renewable energy consumption,
- at least 27% energy savings compared to the business-as-usual scenario.

As the main source of greenhouse emission represents fossil fuel combustion, the main goal of a sustainable energy future is seen in the fuel switch to renewables. Such energy transition is very complex and financially demanding, and also time-consuming.

Energy transition must be supported by the entire global community. Although Europe represents only a small portion of

the worldwide energy society, it plays an important role in this transition, having in mind that it is in many respects at the forefront of this change: it has a very high energy consumption per capita, and hence GHG emissions per capita. Also, there is a fact that global resources are limited and that environment needs to be protected. Although energy transition is seen as a necessity in the modern world, one should also keep in mind that each European country has access to different energy resources and thus different approaches to the energy transition. In order to achieve the goal set, many projects have been launched in the EU to support and facilitate energy transition especially those based on the utilization of the so-called smart strategies aimed at specific, measurable, achievable, realistic, and timely (SMART) actions towards successful implementation of sustainable energy policy.

One such project is the EU-funded TRACER (HORIZON 2020 - 836819) project which aims to support the energy transition of a number of coal-intensive regions around Europe by shaping their R&I strategies so as to define roadmaps for their transition into sustainable energy systems. These roadmaps will lead to the diversification of local economies in order to take care of social challenges and reskilling needs of the local workforce currently engaged in coal-related activities.

In the TRACER project, nine European coal intensive regions are considered, where six of them belong to EU Member States (Bulgaria, Czech Republic, Germany, Greece, Poland, Romania) and three of them are in countries outside the EU (UK, Serbia, Ukraine). In the next section, these regions are presented briefly.

In the third section Serbian coal intensive region Kolubara is presented and the factors influencing its transition; then in section four the path of EU countries towards energy transition is described, noting that each country has its own specific path. Serbian transition path is considered, having in mind targets and objectives.

II TRACER PROJECT

TRACER project [7] supports the transition of coal-intensive regions around Europe towards a low carbon economy. The focus is on some of the most coal-dependent regions (Figure 1):

1. Bulgaria, Yugoiztochen Region
2. Czech Republic, North-West Bohemia
3. Germany, Lusatian Lignite District/Economic Region Lusatia
4. Greece, Western Macedonia Region
5. Poland, Upper Silesia Region
6. Romania, West Region / Jiu Valley
7. Serbia, Kolubara region
8. Ukraine, Donetsk region
9. United Kingdom, Wales

Coal mining and utilization in heat and electricity production in target regions are characterized by different intensities. Table 1 presents coal production, installed power generation capacities, and production of electricity according to the latest available data.

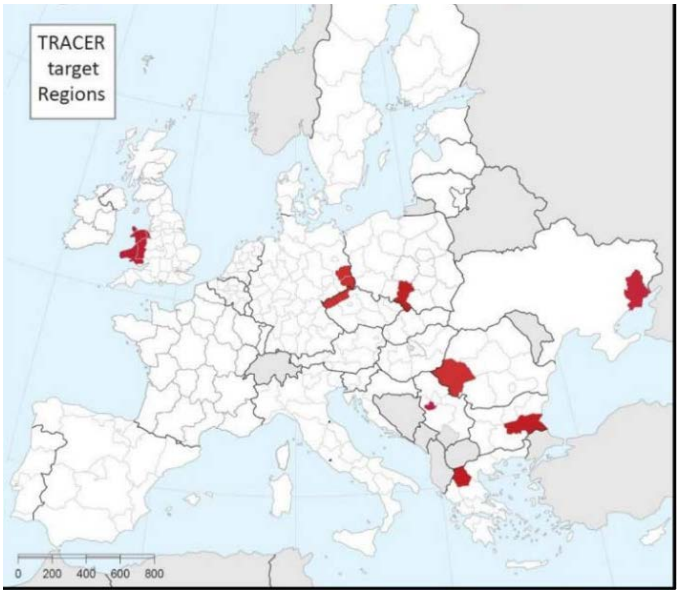

Figure 1. TRACER target regions

Table 1. Coal production, installed electrical capacity & electricity generation across regions [7]

Region	Coal production (Mt/ year)	Coal based TPPs	
		Installed capacity (MW)	Electricity generation (TWh/year)
BG: Yugoiztochen	28	3,214	14
CZ: Norh-West Bohemia	38	> 2,850	36
DE: Lusatian Lignite District	171	6,717	49
GR: Western Macedonia	29	4,438 (3,755 since 2011)	25 (in 2014)
PL: Upper Silesia	53	31,300	79
RO: West Region / Jiu Valley	2	1,225	1
RS: Kolubara	29	3,411	18
UA: Donetsk	11	6,875	55
UK: Wales	1	2	No data

Through different reports, the current role of coal and related policy in the target region were analysed. Additionally, were considered technological challenges and the opportunities for the transition of the energy system into a smart, sustainable, and renewable energy system, the necessary social transition, not forgetting opportunities for environmental protection and post-mining landing reclamation. It is planned to meet possibilities and engage forces for financing transitions in the region through one work package. Different activities are planned to develop smart strategies for the transition in coal intensive regions. The best practice examples of successful and ambitious transition processes in coal-intensive regions were analysed, and they can serve as guidelines for TRACER target regions. It is planned that regional actors assist in developing R&I strategies for an easier transition to sustainable energy systems. As a key task, roadmaps from coal towards transition strategies and new technologies will be developed.

III KOLUBARA TARGET REGION

Kolubara target region or Kolubara open-pit coal mine spreads across two NUTS2 regions – Belgrade City region (3,234 m^2 of surface area and a population of 1,687,132) and Sumadija and Western Serbia region (26,493 km^2 of surface area and a population of 1,941,130). The mine is mostly located inside the boundaries of the City of Belgrade, the capital of Serbia, and with one minor portion located in Kolubara District (2,474 km^2 of surface area and a population of 165,273) which belongs to Sumadija and Western Serbia region. The coal excavation area covers about 130 km^2 and is organized in the municipalities Lazaravec, Ub, Lajkovac, Obrenovac, and Arandjelovac. Kolubara River divides the open mine area into two parts – larger western and smaller eastern parts.

A Social Situation

More than half of the population of the Kolubara region are economically inactive (children under the age of 15, students, retired, unemployed persons, etc.). For the employed population, average net salaries in Lazarevac and Lajkovac are above both national and capital city averages, while in Obrenovac net salaries are above national levels. The unemployment rate in the region is lower than the state's average.

Activities in the field of culture take place mainly in municipal areas. Most rural settlements have Homes of Culture, which are mostly multifunctional purpose buildings, so they are used to accommodate diverse sports activities, trade, health services, as well as administrative work. At the same time, these facilities (buildings) are mostly unconditional, inadequately equipped, and of poor quality.

Educational structure is disadvantageous, due to the predominantly rural population, having a low formal education level. The majority share of the population has completed secondary education (39.5÷56.1%). The population with higher education levels is concentrated in towns (Lazarevac, Obrenovac) and economic centres (Kolubara mine, power plants, associated companies).

B Economic Development

The Kolubara region is more developed than other regions of similar size in Serbia, due to two main reasons: it is located within the boundaries of the Belgrade city region (which itself has above-average economic development), and it represents a highly important area for the mining sector.

The infrastructure is very well developed in this region, quite a lot of kilometres of public roads in the Belgrade City region, as well as in Sumadija and Western Serbia region. Belgrade (Serbia) – Bar (Montenegro) railway runs through the region and comprises several rail stations. In addition, the international airport "Nikola Tesla' is also not far from the Kolubara target region.

There is a gas network in the region, as well as several long-distance power lines.

C Energy Generation Using Coal

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

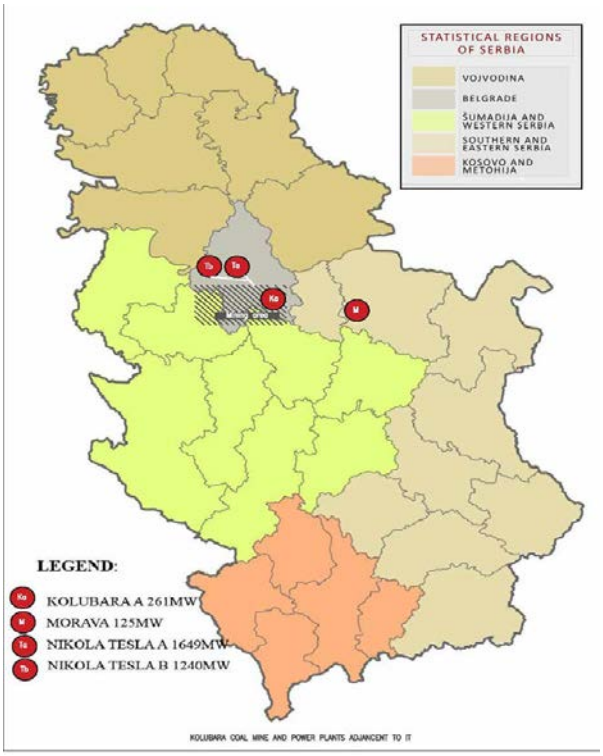

Figure 2. Location of Kolubara target region

Table 2. Age of the existing units fired by coal from Kolubara mines

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

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

At the time when these power plants have been built, the existing environmental legislation was applied to limit the emissions of particulate matter from the flue gasses. For the purpose of additional air quality protection, the plants have been equipped with high chimneys in aim to dissipate flue gasses away from the

site. Currently, the EU standards on emission control have been implemented into the Serbian legislation, and the modern electrostatic precipitators, flue gas desulphurization and denitrification facilities are being introduced into the power plants that are planned to operate beyond the year 2023.

By then, 6 smaller old units (Kolubara A and Morava) will be shut down as their modernization to satisfy new environmental standards is not considered feasible.

In the past decade, nominal capacities of major power plants fired by lignite from the Kolubara coal basin (TPP's Nikola Tesla A&B) have been changed following an effort of Electric Power Industry of Serbia to extend the life and increase their rated power, Table 3.

Table 3. Nominal capacities of thermal power plants fired by lignite from Kolubara basin [15].

Power plant	"Nikola Tesla" A	"Nikola Tesla" B	Kolubara A	Morava
Nominal installed capacity of units before/after their modernization, MW	Unit A1: 210/225 Unit A2: 210/225 Unit A3: 305.5/329 Unit A4: 308.5/345 Unit A5: 308.5/340 Unit A6: 308.5/347	Unit B1: 618/670 Unit B2: 618/670	Unit A1: 32 Unit A2: 32 Unit A3: 65 Unit A4: 32 Unit A5: 110	Unit 1: 125

D Environmental Situation

Environmental impact issues recorded in the region are mainly related to the operation of mining and energy sectors, and associated industries and industrial activities. The main air, soil, and water polluters are open-pit mine Kolubara, coal dumps, power plants, and ash and slag dumps (Spatial plan of Kolubara, 2016). The mining process affects soil degradation, while emissions of particulate matter Sox, Nox, and volatile organic compounds negatively affect ambient air quality. Wastewaters from coal in some cases, run to the Kolubara River without sedimentation and filtration. All activities carried out during coal excavations also emit noise.

Table 4. Dust emission factors depending on the type of activity and equipment, according National Pollutant Inventory (Study on the Long Term, 2015)

Activity/equipment	Unit	Dust emission factor	
		Total suspended particles	Particular matter
Dragline excavator	kg/m^3	0.06	0.026
Excavator on overburden	kg/t	0.025	0.012
Excavator on coal	kg/t	0.029	0.014
Belt conveyors	kg/t	0.005	0.002
Loading from the pile	kg/t	0.004	0.0017
Movement of the vehicle	kg/km	4.08	1.24
Unloading from the truck	kg/t	0.012	0.0043
Bulldozer	kg/t	17.0	4.1
Erosion by the wind	kg/ha/h	0.4	0.2

Table 4 shows data on the intensity of segregation (emissions) of dust under the influence of primary and secondary sources in mining facilities according to the natural and technological conditions on surface mines in the area of the Kolubara region.

Thermal power plants in the Kolubara region represent sources of SOx, NOx and particulate matter emissions which negatively affect air quality (presented in table 3). As equipment for flue gas desulphurization is not yet installed in all power generation units, pollution levels with respect to SOx multiple times exceed the limit values.

Table 5. Emissions of pollutants to the air from thermal power units burning lignite from Kolubara coal basin (2016 data)*

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

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

IV Smart Energy Transition

The starting point for the energy transition consideration is the greenhouse emissions. It is envisaged that the origin of the man-made recent climate change is manifested through the greenhouse effect. In order to mitigate the impact of climate change, greenhouse gas emissions have hence to be reduced.

In November 2010 the European Commission announced the first major EU energy strategy, the so-called "2020 Energy Strategy". In practice, each EU Member State was obliged to draft an integrated National Energy and Climate Plan (NECP) by 1 January 2019 covering the period 2021 – 2030 [14]. From 2021, each country has to produce a progress report every two years (first due by end of 2022), which will complement the Commission's evaluation of the implementation of the national plans.

In addition to this, it should keep in mind that the main problem is European diversity, i.e., the present energy mix in the member states is extremely different, and then also objectives and instruments of energy transitions. EU countries started with their own energy transition, so the speed and success on that path will be different.

A Targets and Objectives for Serbian Energy Transition

Bearing in mind that the Republic of Serbia is a candidate country for EU membership so that the Serbian energy transition is strongly influenced by obligations set by the EU Accession process and related agreements signed by Serbia. This particularly refers to the Stabilization and Association Agreement and the Energy Community Treaty. Serbian authorities have aligned national legislation with the EU Acquis, while the Energy Community Treaty obligations enforce the implementation of the EU legislation in the fields of energy, environment, and market competition. In addition, Serbia has also climate change-related obligations resulting from the Paris agreement, which the country has signed.

It can be stated that the Serbian energy transition has started and is mainly driven by the Energy law (2014, 2018, 2021) and Energy Strategy to 2030 (2015). Also, the Government of Serbia has passed the updated National Plan for the reduction of main air pollutants from old combustion plants. The adopted document is Serbia's NERP (National Emission Reduction Plan) [13]. As per this document, all units at sites of TPP Kolubara A and TPP Morava are scheduled to be closed by the year 2023. The rest of the large coal combustion plants is planned to continue operation after being thoroughly refurbished (with both the life extension and capacity increase measures) and equipped with modern facilities for environmental protection equipment. NERP is prepared fully in accordance with European Energy Community guidelines and considers the contribution of these plants to maximal pollutant emissions and defines mechanisms for monitoring and reporting implementation of the Plan in force.

B Energy Transition Concept

In order to define the technical transitional concept, both documents:

a) The Energy development strategy of the Republic of Serbia;
b) The Low Carbon Development Strategy, with Action plan,

must be respected. In addition, the positions of various stakeholders must equally be taken into account. The stakeholders have been consulted on different occasions, and their positions carefully studied. It appears that their positions may roughly be grouped in two groups, one, larger, in favour of coal use in the target region by the end of the exploitation (about 2050) and/or by the end of the operational lifetime of the power generating equipment, and another supporting the EU climate policy calling for an urgent transition away from coal towards natural gas and renewables.

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

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

Strategy proposes gradual replacement of coal in energy generation by natural gas and renewable energy sources. The expected adoption and implementation of the Low carbon strategy could strongly hit the energy sector and the future use of coal in Serbia, which would strongly affect the Kolubara target regions in many aspects.

As part of the energy transition strategy, the construction of gas plants (emitting 3-4 times less CO2 than coal fired plant) at locations owned by EPS is considered, such as TPP Morava, TPP Kolubara A and TPP Kostolac A.

The national energy policy is also putting an emphasis on transition towards an increased use of the renewable energy sources and provides subsidies to attract the investment in their development to gradually replace lignite-based generation.

The bulk of new renewable electricity will come from wind (planned capacity is 500MW by 2020, realized 374 MW). Current solar potential remains under-utilized (10 MW only), but new Law on the Use of Renewable Energy Sources will contribute to the change and is expected to draw investments in solar power. Construction of new large hydro capacities is behind schedule: no new large hydropower plants have been built, although the plans exist. There are large number of small hydro power plants (SHPP) in operation: 15 owned by Electric Power Industry of Serbia (20 MW in total), 154 built by private investors (107.61 MW in total). New Law on the Use of RES has prohibited further construction of SHPP. The construction of first waste-to-energy cogeneration facility near Belgrade has started and is expected that new waste project will be developed as well. Biomass facilities have not yet gained broader attention, although some biomass heating plants have been constructed.

As it is evident that electricity consumption is constantly growing, Serbia cannot conduct energy transition without introduction of new power plant. So far, Serbian energy strategy development for the period up to 2050 is not yet defined, but some projects will be launched to examine possible paths. One possibility is to introduce power plants based on fuels with lower carbon footprint, such as gas, as well as biomass and waste. The other possibility is implementation of new technologies, when commercially available (such as hydrogen), as well as

participation in the investment for construction of a nuclear power plant in one of the neighbouring countries (like Hungary or Bulgaria) is increasingly mentioned.

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

Besides these arguments, Serbia is struggling to improve its low energy efficiency, both in generation and consumption. To promote the use of efficient cogeneration of heat and electricity, subsidies were provided. With the newly adopted law on RES, auctions are introduced instead of feed in tariffs and bylaws are currently being prepared. Also, a particular objective is to reduce the consumption of electricity for space heating.

C Smart Specialization Strategy

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

When considering the economic potential of importance for further activities in the Kolubara region, statistical data from two statistical regions in Serbia are of importance to be considered. In Belgrade statistical region [RS11] a strong development potential is identified in the areas of information and communication technology (ICT), scientific research and innovation (R&I), education, as well as in some areas of the manufacturing industry. The Sumadija and Western Serbia statistical region [RS21] is characterized by agricultural activities (including food production), the automotive industry, a strong science base in the fields of mechanical engineering and pharmacy, as well as the production of general-purpose machinery. Based on the EC methodology for developing national smart specialization strategy and the entrepreneurial discovery process (EDP), the Smart Specialization Strategy of the Republic of Serbia has identified national priority areas for Serbia, for which a strong development potential is available in the Kolubara target region. These priority areas include the following key development technologies:

- Food for the future,
- Information and communication technology,
- Machines and manufacturing processes of the future (manufacture of machinery and electronic devices),
- The creative industries, as well as
- Environmental protection and energy efficiency.

V CONCLUSION

The inevitable transitional process of the energy sector in Serbia would result in a significant shift of the current energy development strategy of Serbia towards the low-carbon development strategy. This would imply a shift towards climate adaptable economy in the Kolubara target region. However, the required dynamics of the transition, needed to accomplish much talked about net-zero GHG, emission reduction by 2050 - could hardly be achieved. Rather a slower, stepwise energy transition towards an efficient carbon-free energy sector should be provided in the Kolubara target region. According to the current position of the stakeholders in the region, this may be the only way to meet the required goal, while maintaining the security of energy supply and social welfare.

The Low Carbon Development Strategy of Serbia defines several scenarios to achieve a carbon-neutral economy and society, including gradual replacement of coal in energy generation by natural gas and renewable energy sources. The expected adoption and implementation of the Low carbon strategy could strongly hit the energy sector and the future use of coal in Serbia, which would strongly affect the Kolubara target region in many aspects.

ZAHVALNICA/ACKNOWLEDGMENT

The authors would like to thank the TRACER partners for their contributions, cooperation and exchange of experience in the project. The authors would like to thank the European Commission and the INEA for the support of the TRACER project. TRACER has received funding from the European Union`s Horizon 2020 research and innovation programme under grant agreement No. 836819.

The authors thank Dr Miodrag Mesarović, the member of the World Energy Council and Serbian Academy of Engineering Science, for all suggestions and advices in preparing the paper.

Disclaimer: The sole responsibility for the content of this paper lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the INEA nor the European Commission are responsible for any use that may be made of the information contained therein.

LITERATURA/REFERENCES

[1] Energy transitions in Europe: Common Goals but Different Paths, Euro-CASE Energy Platform, 2017. https://www.euro-case.org/wp-content/uploads/2019/10/Eurocase/Publications/PDF/platform_energie2019.pdf [pristupljeno 30.03.2021]

[2] Spatial plan of Kolubara Mining Region – 2016.

[3] SORS (Statistical Office of the Republic of Serbia), 2018a. Statistical Yearbook 2018.

[4] SORS (Statistical Office of the Republic of Serbia), 2018b. Statistical Yearbook 2018. Municipalities and Regions in the Republic of Serbia, 2018.

[5] Electric Power Industry of Serbia 2018, 2019. Environmental Report. http://www.eps.rs/eng/Documents/energyEfficiency/The%20PE%20EPS%20Environmental%20Report%202018.pdf [pristupljeno 30.03.2021]

[6] Study on the Long Term Exploatation of Coal in Kolubara Mining Region, 2015.

[7] TRACER project, https://tracer-h2020.eu [pristupljeno 30.03.2021]

[8] Mergner, R., et al., Smart strategies for the transition in coal intensive regions, in Proc. *28th European Biomass Conference & Exhibition (EUBCE 2020)*, Marseille, France, 6-9 July 2020. https://eurec.be/smart-strategies-for-the-transition-in-coal-intensive-regions/ [pristupljeno 30.03.2021]

[9] Radulov, L., Nikolaev, A., Genadieva V. (Eds.) Report on the current role of coal mining and related policies in the TRACER target regions, D3.1, September 2019, Project No: 836819, Smart strategies for the transition in coal intensive regions.

[10] Doczekal, C., et al., Technical concepts for the transition of the energy system into a smart, sustainable and renewable energy system in the TRACER target regions, D3.2, page 101-114, July 2020, Project No: 836819, Smart strategies for the transition in coal intensive regions.

[11] Strategy on development of Energy Industry in Serbia up to 2025, with projection up to 2030 (Official Gazette of Republic of Serbia 101/2015).

[12] Program of implementation of Strategy on Development of Energy Industry in Serbia up to 2025, with projections up to 2030 (Official Gazette of Republic of Serbia 104/2017)

[13] National Plan for Reduction of Main pollutants from old large combustion Plants (Official Gazette of Republic of Serbia 10/2020).

[14] National energy and climate plans (NECPs), https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en [pristupljeno 30.03.2021]

[15] Annual Technical Report, Electric Power Utility of Serbia/ Thermal Power Plants Branch, 2016.

AUTORI/AUTHORS

Dr Jasmina Mandić-Lukić, Energoprojekt Entel p.l.c., jmlukic@ep-entel.com
MSc Đorđina Milovanović, Energoprojekt Entel p.l.c., djmilovanovic@ep-entel.com
Maja Stipić, Energoprojekt Entel p.l.c., mstipic@ep-entel.com
Dr Sanja Petrović Bećirović, Energoprojekt Entel p.l.c., spetrovic@ep-entel.com
Dr Radoslav Raković, Energoprojekt Entel p.l.c., rrakovic@ep-entel.com
Brankica Popović Zdravković, Energoprojekt Entel p.l.c., bpopovic@ep-entel.com
Dr Miodrag Životić, Energoprojekt Entel p.l.c., mzivotic@ep-entel.com