BEYOND 2020 - GEOLOGY EXPLORATIONS AND OPEN PIT ACTIVITIES AFFECTATION IN RECLAMATION DESIGNING IN KOLUBARA COAL MINES (KCM) SERBIA, NEW CONSIDERATIONS

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ABSTRACT

Geology explorations in KCM[3] runs from 1936. year up to these days and still ongoing. Results in >7,200 drill holes with ≈600,000 m of core drilling and gave lignite ore resources of > 4,1Bt, which 1,15Bt are excavated since 1986. of XIX up to early years of XXI century. For further mining operations in open pits stay 1,5Bt of lignite. Under waste heaps are ≈80 km², additional 85 km² should be filled. All of that masses/areas were, are and should be under mining and biology reclamation.

INTRODUCTION:

GEOLOGY IN KCM

All 85 years of geological research have passed. It started with buckshot drilling, various technological types of drilling rigs were in use. At the beginning of the III millennium, the 3rd and somewhere the 4th World technological revolution is underway, the most modern drilling rigs are in use in explorations. In the past 30,000 geological days, 1,1Bt of coal were excavated in KCM, 7,200 exploration holes were drilled and every 4 days one new well was added to the total fund of geological material of the KCM Basin. A total of 600,000 meters of drilling were drilled in this period (Figure 1).

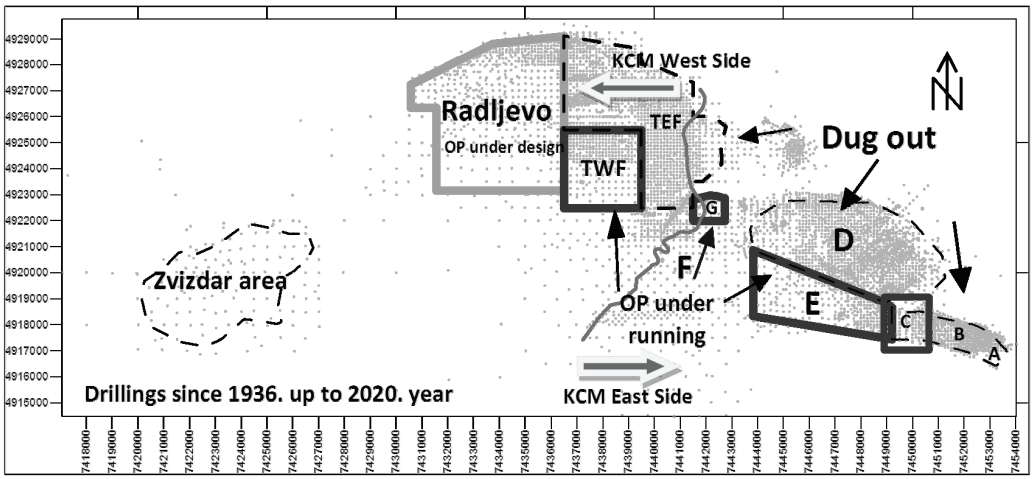

Figure 1. KCM operational area, drill-holes since 1936. year; total >7,200 holes, e.g. 600,000 m of core drilling; curved line – river Kolubara divide area on East and West side

Whole period of geological surveys from 1936. up to 2020. in the geological and mining aspects is very successful. As a result, about 4,1Bt of geological lignite reserves and resources were explored, as well as additional few hundred million m3 resources of non-metallic mineral raw materials. Coal exploration and exploitation began in the eatern part of the basin, where it is still ongoing, but is slowly moving to the western part of the basin, where it is becoming more important.

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KCM – Kolubara Coal Mines; Serbian most important Lignite Mine Enterprise, under running since II WW

The KCM basin is represented by Paleozoic, Mesozoic and Cenozoic rocks. The surrounding hilly terrain and floor area are made up of Paleozoic metamorphites and Mesozoic sediments. The central part of the coal basin is built of Cenozoic and Quaternary sediments (Figure 2).

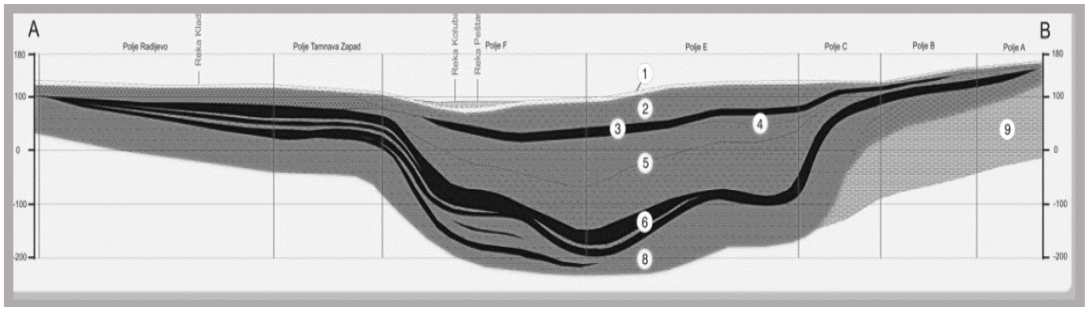

Figure 2. KCM regional geology profile, No.9 – Paleozoic metamorophites and Mezozoic sediments; No.1,2,4,5,7,8 – Cenozoic sediments; No.3,6 – coal beds

The main coal seam is developed in a large part of the KCM basin and covers an area of about 200 km^2. The morphology of the hanging and laying wall of the Main Coal Bed (Figs. 2, 3, 4 and 5) indicates a clearly pronounced synclinal form with the eastern (fields A, B, C and D) and western (Zvizdar) elevated part, opposite the lowered central one (fields Tamnava, Radljevo) and especially southern part of the deposit (fields F, E). The height difference between the highest elevation of the coal floor of +160 m (on north and east side) and the lowest of -280 m above sea level (south part) is 440 m.

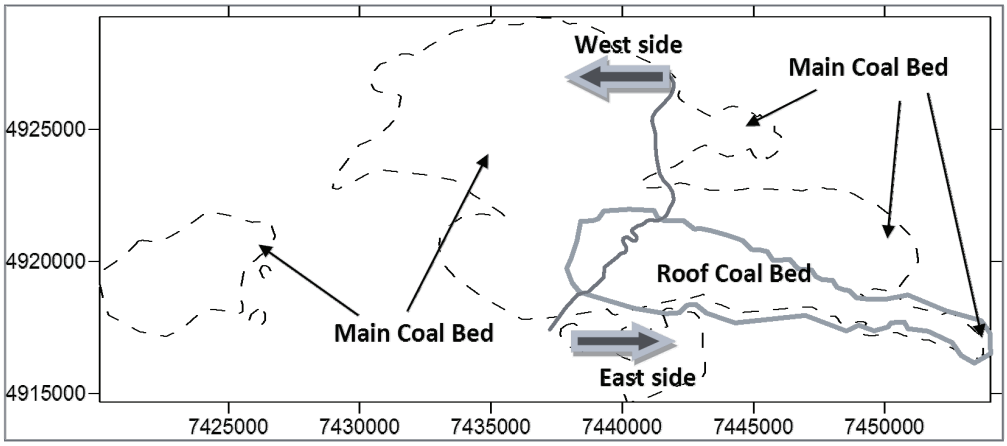

Figure 3. KCM coal bearing area, position of Main and Roof Coal Bed; curved line – river Kolubara divide area on East and West side

Roof Coal Bed is developed in the southern part of the basin (Figure 3) and cover the area of about 36 km^2. The longer axis of the general direction of the SE-NW extension is about 7.5 km long and sinks from east to west. Considering the previously mentioned, it can be stated that the basic and only overburden rocks during excavation are clays, sands and gravel. As such, they do not contain increased concentrations of heavy metals or other harmful substances, which has been proven by numerous laboratories analyzes. From the beginning of open pit excavation, since 1952, it was dug out 1,1Bt of coal and up to 3Bm^3 of overburden.

MINING IN KCM

UNDERGROUND MINING

First underground exploitation in this area noted at 1896; next 75 years' underground coal mining was performed in a medium scale. At the end, in 1974 when last pit was closed, amounts of dug out coal reach 12,6Mt (figure 4).

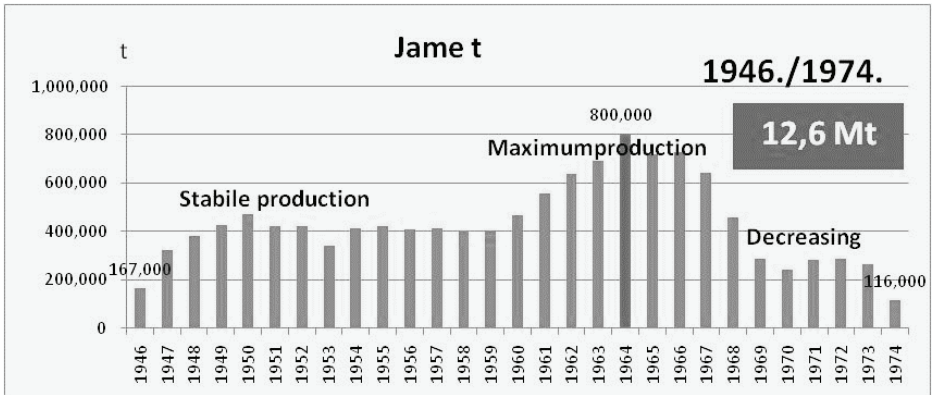

Figure 4. KCM underground mining; from 1946 up to 1974 year

SURFACE MINING - OPEN PITS

Mining coal in Kolubara opencast mines dating back to the early 50-ies of XX century (figure 5). In the first years it was mined on a modest scale, and later the acceleration of mining activities began. Miles and miles of fertile farmland have been excavated and replaced by open pit overburden. Coal is sold, the money was spent, the original arable land no more exists. At the end of 2020. the exploitation of coal has been completed on six open pits since 1974 on ''A'' up to "D" in 2019. year. Since 1994, the surface mine "Tamnava–West field" is in operation, northern and central part has been excavated, and the southern part of the deposit has remained for exploitation. After the closure of the above mines, replacement capacities were opened, i.e. new surface coal mines were successively opened: fields ''E" in 2015, ''C" in 2016 and "G" in early 2018. In the following years, after the closure of the surface mine "Tamnava–West field", the opening of the surface mine "Radljevo" is planned. At the end of 2020, geological surveys are no longer running in the "A", "B", "D" and "Tamnava-East Field'' areas.

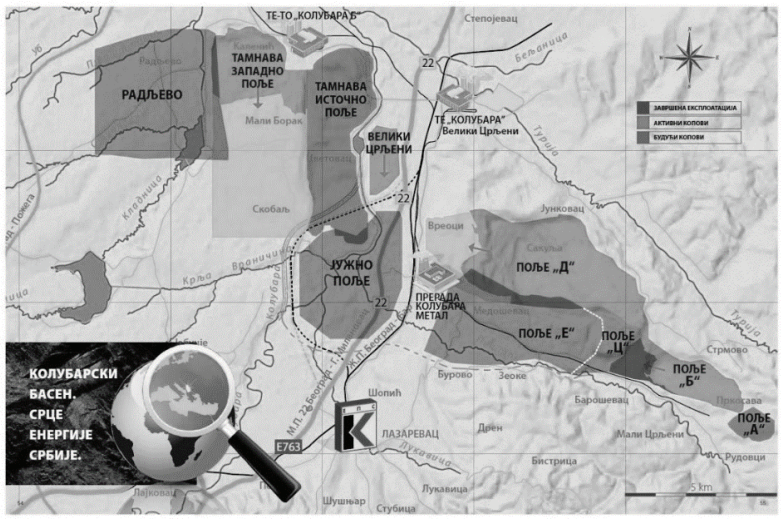

Figure 5. Overview map of mining activities in KCM, end of 2019; (www.RB Kolubara)

After the first years of operation, production of coal in surface mines "Kolubara" is uprising from year to year, coal mining capacity increases, so now the annual output is about 30 million tons of coal. Graphic representation of the amount of ore obtained from surface exploitation, for the period 1952-2019. year is given in the following diagram (Figure 6).

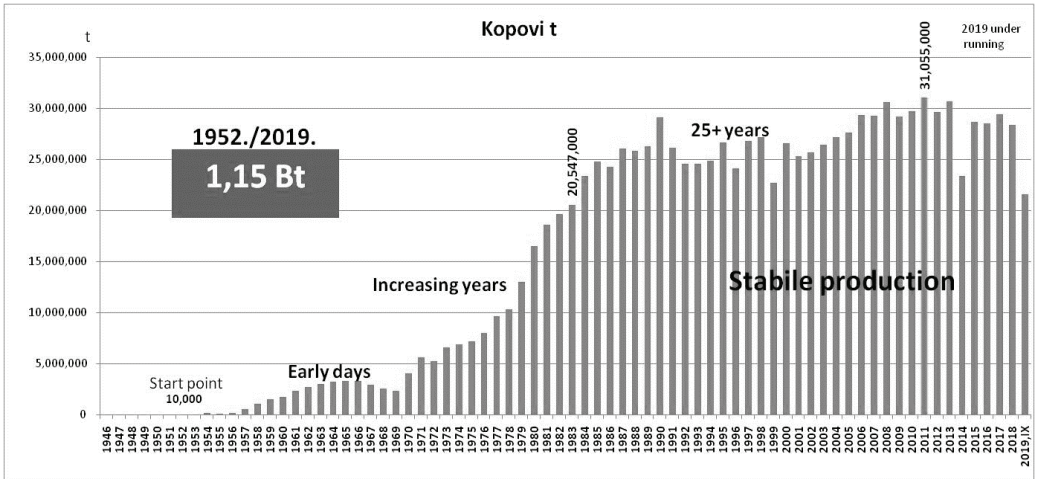

Figure 6. KCM opencast mining; from 1952 up to 2019 year

Strippnig ratio on open pits was 1:1 in early years, then it was 2:1 in late XX century; in early XXI century reach 3:1. In the next decades of operation of surface mines, the strippnig ratio of overburden will be 3.5 and even more than 4:1. All of that produce enormous quantities of waste, which were deposited inside the open pits or outside in them nearest vicinity.

RECLAMATION IN KCM
CURRENT

Numerous attempts to land reclamation brought positive effects, but always in a small scale on a small experimental parcel. By the end of 2020, more than 70 km^2, or about 7,000 ha, is unused. Such land, which is not ecologically contaminated and which is not completely sterile, is a topic for serious scientific-expert considerations regarding the game of large numbers. This paper discusses possible forms of remediation and reclamation of this land, in the form of sustainable development, giving considerations and suggestions for further activities. Currently, the Kolubara mine has a reclaimed area of 8 km^2, devastated waste zones with auto vegetative processes on 62 km^2 and zones of active mining works on 10 km^2. The picture 7 shows that in three green areas we have 800 ha of professionally reclaimed space.

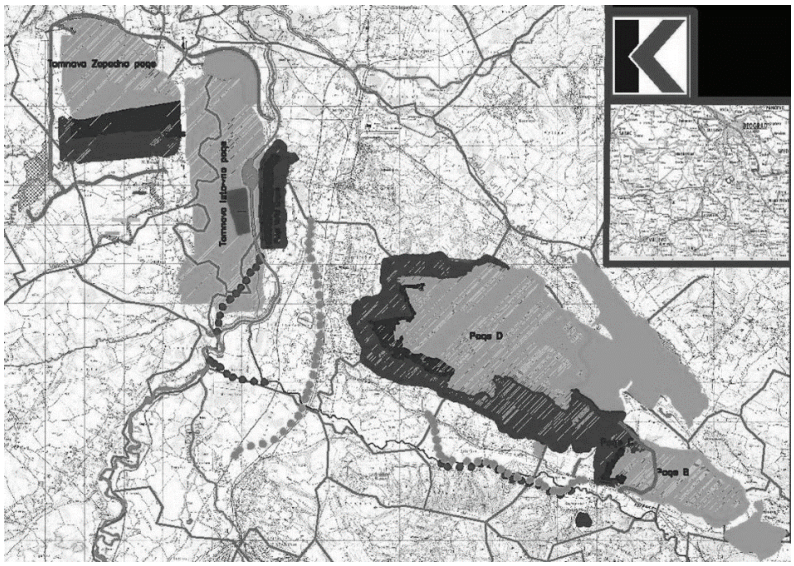

Figure 7. KCM overview map of mining and reclamation activities, solid gray - recultivated areas; light dashed gray- devastated zone of overburden with autovegetative processes, dark dashed gray- areas of active mining works (www.RB Kolubara)

The first reclamation works began in 1957 with the planting of 110 ha of acacias in fields A and B. In the first years of operation, pure crops of deciduous and coniferous tree species were raised on the degraded areas of surface mines in Kolubara, and later mixed crops were introduced. Of the deciduous species planted: maple, ash, linden, alder, acacia and oak. Of the coniferous species, the following were planted: black, white and Weymouth pine, larch, spruce, Douglas fir. Better results were achieved by planting coniferous tree species whose acceptance and growth does not lag behind in comparison with the normal plantings on forest land. Cultivation of field crops is done on about 100 ha by sowing corn, wheat and other field crops. An apple orchard was planted on an additional 7 ha. All of the above is at the disposal of the professional service of the Kolubara mine - Sector for Environmental Protection.

BEYOND 2020, SUSTAINABLE OUTSIDE OFFICIAL DEVELOPMENT PLANS

This paper discusses outside the standard framework, recommending a modern approach to reclamation and use of space in accordance with the principles of sustainable development.

GEOTHERMAL ENERGY POSSIBILITIES

Geothermal energy is energy generated and stored in the earth's crust. It is located at depths of 100 up to several thousand meters. Thermal energy can be accumulated in underground rocks, gases or most often in underground thermal or thermo-mineral waters. The temperature is provided by the presence of magma or radioactive decay of certain chemical elements. Depending on the depth at which it is located and the heating source, temperatures can reach hundreds of degrees ^{0}C. The potential of geothermal energy in a certain area can be described as the flow density of geothermal heat (in the amount of geothermal heat that comes from the interior of the Earth to its surface every second through the area of 1m^2). The average values in Europe are around 60mW / m^2, while in Serbia these values are significantly higher, in the central part of Serbia and over 100mW / m^2 (Figure 8).

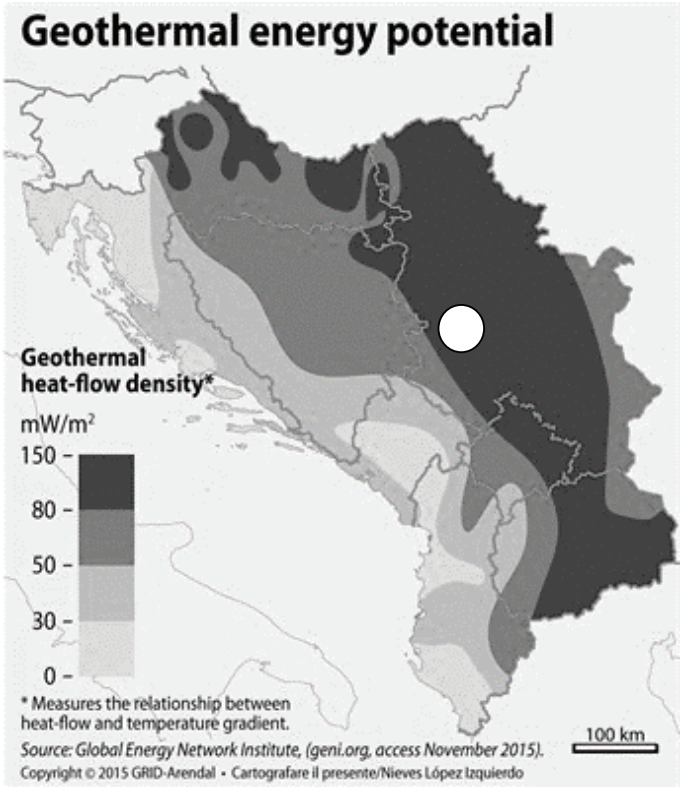

Figure 8. The potential of geothermal energy in mW/m^2, the central part with the greatest potential in Serbia (Global Network Energy Institute, 2015) Note: the white dot represents the region from the KCM

In general, the Earth's geothermal energy can be used from shallow or greater depths. Of course, the greater the depth of intervention, the higher the temperature and the amount of energy. The above indicates a very significant potential of geothermal energy in Serbia. Given that Kolubara coal covers an area of 600 km^2 and that wells could use geothermal energy from greater depths without degrading the terrain surface, we conclude that there is a significant energy potential deep below the lowest levels of Kolubara coal. The following considerations are of a theoretical nature, based on general data on geothermal energy for Serbia and represent a game of large numbers. More detailed geological research and numerous technical-technological considerations are necessary for more detailed considerations. Economic parameters were not considered. Given the above, we can conclude that the potential of the surface and subsoil of this area is huge.

SURFACE

On the surface of the terrain we have 7,000 ha, or 70 km^2, an area suitable for further consideration. Surface area is not fully defined purpose. The surface area is completely devastated and covered with thick layers of tailings from surface mines. Tail, by itself, does not have elevated concentrations of heavy metals or other chemical compounds dangerous to the environment, it is suitable for all types of biological reclamation. Decades ago, the "standard" method of biological reclamation was approached. Alternative solutions are needed.

UNDERGROUND

The energy potential of the underground is huge and is absolutely not used. The level of geological research is low. Realization of works on geothermal energy from great depths does not endanger the environment on the surface of the terrain. It is possible to get geothermal energy in large quantities. It is an inexhaustible and completely free input raw material. Substitution of energy from coal by another energy is achieved. The development of new technologies and the employment of a large number of workers will be achieved. Environmentally it is absolutely acceptable and recommended. ultimately it is sustainable development in mining in practice.

ONE GEOTHERMAL DAY OF NON-CULTIVATED AREA

For an area of 70 km^2, the amount of completely unused geothermal energy is 6,000,000,000 mW in just 1 second. That is, it is 60 MW/sec, or 60,500 MW/day, or 60.5 GW/day. Which is equivalent to the energy contained in 8,400 t of Kolubara lignite.

ONE GEOTHERMAL YEAR OF NON-CULTIVATED AREA

The following could be calculated as 1 year/70 km^2 = 220,500 GJ/year. Which is equivalent to the energy contained in 3,100,000 t of Kolubara lignite. The amount of geothermal energy from this area can be used for several types of purposes, but still primarily for direct use by heating. Residential and business premises, hotel-tourist complexes, sports facilities, agricultural goods (stables, greenhouses, processing facilities, warehouses, garages, services, etc.), fishponds, industrial facilities, road infrastructure, etc. can be heated. This amount of energy viewed as energy for direct use (heating) can supply up to 210,000 family households or less if the use is for multiple types of heating. In any case, this amount of geothermal energy far exceeds the needs of the city of Lazarevac and its surroundings. In every respect, the installations of geothermal plants do not occupy large areas and do not pollute or degrade the surface of the terrain at all. In that case, the terrain area remains for additional complementary activities.

BIOLOGICAL RECLAMATION

Previously, about the complete ecological acceptability of surface mine tailings in terms of establishing agricultural and forest crops, very positive and encouraging results of afforestation and agricultural production, decades of experience in these jobs and huge free areas allow us to play the game of large numbers. Namely,

the non-standard approach implies a departure from "classic" types of afforestation, and the emphasis is on planting acacia seedlings in the entire area. There is a great justification for this and great favorable opportunities. Acacia is a type of tree that is very easy to receive when planting, and it is almost equally good on all types of terrain and substrate. It is a very resistant species to plant diseases and weather conditions. Acacia seedlings are by far the cheapest on the Serbian market and are easily available. They are honey-bearing during the flowering period and the quality of the wood mass is excellent. The calorific value of wood mass is excellent, while the growth of wood mass is lower than with other types of trees. Multipurpose use is also possible.

Conceived in this way, this can be achieved by simple planting in the appropriate spacing, successively by plots and years. Shortly after planting, in 3-5 years, acacia blooms in significant quantities and represents a honey-bearing agricultural crop. After 10 years it reaches a significant size and bloom, the lifespan is over 50 years. Along with the planting of acacia, locally on smaller plots and with planted linden, beekeeping sections (plots) with a large number of hives will be established. Geothermal energy is produced from underground, agricultural and economic activity is performed on the surface, tailings are cultivated, afforestation is performed, honey is produced. Also, the value of produced honey is significant and represents a saving on the extraction and combustion of lignite, of about 3Mt per year.

CONCLUSION

This paper presents natural indicators of energy production and / or possible types of energy production and compares the average calculated calorific value of lignite that is still unearthed in the form of deposits in the districts of the Kolubara Mining Basin, with other selected types of energy production. Special attention is given to the possibility of using geothermal energy as a source of energy production. This type of energy is renewable and actually inexhaustible. This process of energy exchange takes place every day, before our eyes, every second or day, or year, completely unnoticed and absolutely unused. A complete understanding of the geothermal capacity of the Kolubara basin is possible only if extensive geological research is performed, followed by numerous multidisciplinary studies of technical and technological feasibility, all the way to the final financial parameters. If in the next period the possibilities of using at least 10% of this presented energy potential are shown, the ecological and other profit would reach exceptional proportions.

On this occasion, the specific coefficients of energy conversion into electricity, technical-technological solutions of production, environmental conditions and / or problems, production cost prices, economics of electricity production, etc. Only some selected examples with the idea are given. to be considered in the following period from the energy aspect as relative indicators in technical design and strategic planning. Also, with additional activities on the surface of the terrain, it is necessary to perform reclamation by afforestation with honey acacia seedlings, during which an exceptional combined profit is achieved. The proposals given in this paper are an example of sustainable development in action in the areas where mining has been completed and which are looking for the appropriate most favorable purpose for the next decade.

REFERENCES

1. Jankovic V., 2009 : Geothermal Energy : How to Take Advantage of Hidden Potential of Serbia - Jefferson Institute, USA, 2009.,
2. Milivojevic M., Martinovic M., 2003 : Utilization of Geothermal Energy in Serbia – International Geothermal Conference, Reykjavik, Iceland, 2008.,
3. Martinovic M., Milivojevic M., 2008 : Geothermal Energy Utilization in Serbia – New Aproach - United Nations University, Geothermal Training Programme, 30th Aniversary Workshop, Reykjavik, Iceland, 2008.,
4. Oudech S., Djokic V., 2015 : Geothermal Energy Use, Country Update for Serbia – World Geothermal Congress, Melburne, Australia, 2015.,
5. Vuckovic B., Nesic D., Bogdanovic V., Ilic Z., 2011 : Sustainable Development in Kolubara Coal Mines, Serbia – Non Metallic Resources as a Significant Additional Coal Open Pit's Income (Possible $

Scenario) – VII International Brown Coal Mining Congress, 13-17 April, Belchatow, Poland, 2011., p. 727-734.,
6. Vuckovic B., Nesic D., 2011. : Beyond 2010, Sustainable Development in Kolubara Coal Mines, Serbia - SGEM 11th International Multidisciplinary Scientific GeoConference, 20-25 June, Albena, Bulgaria, 2011., p. 727-734.,
7. Vuckovic B., Nesic D., Andjelkovic N., 2012 : Geological Exploration Investments – What Does it Worth? (Review of Kolubara Coal Mines, Serbia) - SGEM 12th International Multidisciplinary Scientific GeoConference, 17-23 June, Albena, Bulgaria, 2012., p. 593-602,
8. Vuckovic B., Radosavljevic S., Ignjatovic M., Bakic V., 2015 : Investments in Geology Explorations – Results (Review of the Kolubara Coal Mines, Serbia) - 47th IOC, International October Conference on Mining and Metallurgy, 04-06 October, Bor Lake, Bor, Serbia, 2015., p. 41-44,
9. Vučković B., Radovanović B., Petrović N., 2015 : Kolubara Lignite Combustible Sulfur Environmental Impact – Natural and Atificial Sources Comparison – V Međunarodni simpozijum "Rudarstvo i zaštita životne sredine, MEP 2015", 10-23 jun 2015, Vrdnik, Srbija, str 120-129,
10. Vučković B., Stojković H., Ignjatović M., Šubaranović T., 2016 - Comparison of kolubara lignite value (with selected natural and artificial materials) - natural indicators — XXXII Međunarodno savetovanje "Energetika 2016", 22-25. mart. 2016., Zlatibor, Srbija, str. 459-466,
11. Vuckovic B., Stojkovic H., Ignjatovic M., Subaranovic T., Rakijas M., 2016 - Comparison of kolubara lignite value (with selected natural and artificial materials) - natural indicators – 13th International Symposium Continuous Surface Mining ''ISCSM 2016'', 11-14. Sept. 2016, Belgrade, Serbia, p. 657-673. ISBN: 978-86-83497-23-2,
12. Vučković B., Ignjatović M., Rakijaš M., Vučković J., Rakijaš S., 2017 - Kolubarski lignit, Vol. IV – energetska vrednost i poređenje sa potencijalom geotermalne energije u kolubarskom ugljonosnom basenu - VIII. Simpozijum sa Međunarodnim učešćem "RUDARSTVO 17", 16-18. maj 2017., Palić, Srbija, str. 51-65, ISBN: 978-86-80420-13-4,
13. Vuckovic B., Rakijas M., Stojkovic H., Vuckovic J., 2017 - Comparison of geothermal energy potential in Kolubara Coal Basin with lignite, Vol. 5 – Energy value and previous geological considerations - VI. International Symposium ''Mining and Environmental Protection, MEP 2017'', 21-24. june 2017., Vrdnik, Serbia, p. 223-229, ISBN: 978-86-7352-298-2,
14. Vučković B., Rakijaš M., Vučković J., Rakijaš S, 2017 - Potencijal geotermalne energije u kolubarskom ugljonosnom basenu (prethodna razmatranja), Vol. V – 2nd International Symposium Investements and New Technologies in Energy and Mining, 18-19. September 2017., Borsko Jezereo, Srbija, p. 77-86, ISBN: 978-86-80464-07-7,
15. Vučković B., Rakijaš M., Vučković J., Rakijaš S., 2017 - Geothermal potential of kolubara coal basin (previous review), Vol. V 2nd International Symposium Investements and New Technologies in Energy and Mining, 18-19. September 2017., Borsko Jezereo, Srbija, p. 77-86, ISBN: 978-86-80464-07-7,
16. Vučković B., Ignjatović M., Stojković H., T. Šubaranović, Rakijaš M., G. Đikić - Non-standard approach to land reclamation of excavated areas open pit mines of kolubara mining basin - serbia, sustainable development and possible financial aspects - VI. Counseling with International Participation of Environmental Protection and Sustainable Development "ENERGY AND MINING 2018", 28-30. March 2018, Sremski Karlovci, Serbia, p. 10-20, ISBN: 978-86-80420-16-5,
17. Vuckovic B., **Dimitrijevic B**.: *Unvestments in Geological Exploration and Afectation on Mining Operating Cash Costs at Lignite Open Pits Kolubara (Lazarevac), Serbia,* Book of Abstracts, 14th International Symposium of Continous Surface Mining ISCSM 2018, pages: 66, Greece, Thessaloniki 23-26 September 2018, Aristotel University Research Dissemination Center,
18. Geological Explorations and Open Pit Activites Affectation in Reclamation Designing in Kolubara Coal Mines (KCM), Serbia, B. Vučkovic, D. Životic, **B. Dimitrijevic**, Proceedings of the IX INTERNATIONAL Geomechanics CONFERENCE, ISNN: 1314-6467, pages: 315-322, 7-11 September 2020, Varna, Bulgaria,

19. Vučković B., Životić D., 2022 - Geological exploration of lignite in the kolubara coal basine, 85 years of geological operations –- 8th Balkan Mining Congress, 28-30. September 2022, Beograd, p. 226-231, ISBN: 978-86-82673-21-7, DOI: 10.25075/BMC.2022.00,
20. **Bojan S. Dimitrijević**, Optimization of the Land Reclamation management Process at Coal Open Pit Mines,, Doctoral Dissertation, University of Belgrade, Faculty of Mining and Geology,, Belgrade 2014,
21. **B. Dimitrijević**, SELECTION OF THE LAND RECLAMATION OPTION FOR THE TAMNAVA ZAPADNO POLjE OPEN PIT MINE BY MULTI-ATTRIBUTE ANALYSIS, Proceedings of VII Inrernational Conference COAL 2013, page 37-42, Yugoslav Opencast Mining Cpmmittee of Association of mining and Geological and Engineers of Serbia, Zlatibor, Hotel Palisad, 02-05. October 2013, Serbia,

JOURNALS, WWW, DOCUMENTATION CENTER :
Alternative Energy Magazine, 2015
EPS, Kolubara Coal Mines, Technical & Designing Documents
European Environmental Agency, Annual Report 2012
EU, South East Europe, Transnational Cooperation Programme, Geo SEE, 2014 : Serbia – State of the Art of Country and Local Situation, 2014
Global Wind Electricity Council (GWEC) : Annual report 2014
Renewables Global Status Report, 2012
Republika Srbija, Ministarstvo Energetike, Razvoja i Zaštite Životne Sredine, 2013 : Construction of Plants and Electricity/Heat Generation frpm Hydro-Geothermal Sources in the Republic of Serbia, 2013
Stanford University Magazine, 2012
The International Geothermal Association (IGA), Annual Report 2011.
www. EPS.co.rs