THE FUTURE OF COAL AS A NEW GENERATION OF ENERGY AND POTENTIAL RISKS

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Abstract: Until now, coal as a resource has been the most reliable energy source on the world market. The great world crisis caused by a sudden pandemic almost confirmed this fact. The year 2023 records larger certain shifts in coal consumption that are diametrically opposed. While coal consumption is increasing in some countries, some of the world's countries/a smaller number are experiencing a slight stagnation to a decrease in consumption. All previous efforts to significantly limit the use of coal as an energy resource did not yield satisfactory results. The year 2024 brings new strategic projections and orientation towards other energy sources to the detriment of coal, and special importance is given to investments in energy from nuclear power plants of various configurations, but according to the needs of users. And this could mark the current and next decades in all parts of the world, including in Serbia. Drastically growing energy needs open up new formats of energy configurations in the world as well as their transversal to users/consumers. It is difficult to predict whether such transformations will take place quickly and how long it will take. This is because this kind of transformation is the biggest/never recorded and it is decomposed into individual levels, according to the size of the countries, their economy, the achieved level of energy technologies and development. Risk potentials in the newly created energy turbulent configurations in the world energy redistribution seem to have never been higher and with the synergy of influence, they become very complex for detection and positioning from the aspect of their gradual reduction or minimization. The paper analyzes the newly created energy circumstances and the place of coal as an energy resource with the mapping of potential risks.

Keywords: Coal, mining, energy, energy transition, risk.

1. INTRODUCTION

Coal as a world resource energy potential can be analyzed in conditions of rapid growth of energy needs in the world on the one hand and efforts to limit its use with trends in the status of constant reduction and decline in consumption. The question arises whether this is first of all realistic, given the fact that rapid energy transformations in the world are extremely demanding and expensive, and the energy transition in this context necessarily defines a longer period of
time? Based on past experiences, the reduction of coal consumption in the world is not going exactly as everyone would expect. Especially in conditions of global polarization and disruptive transition flows, which is due to the nature of reserves and economic projections that are not the same for everyone and which diametrically affect the redistribution of global coal reserves.

The latest determinations in the world are to reduce the consumption of coal on a global level, but at the same time, everyone is aware of the fact that such an energy strategy is impossible to implement quickly, even for a somewhat slower achievement in a longer period of time. At the same time, the facts show that even when such rigorous energy strategies are adopted, the discipline of their application is quite unstable with a lot of oscillations in different groups and at different levels. The world is simply not so perfect that even a strategy conceived in this way would be solved quickly. The big ones still remain big and the small ones remain small, so the will of the big ones largely influences all world trends, including the aforementioned strategic determinations.

Therefore, it is an indisputable fact that energy strategies are not carried out in ways, exactly as outlined in many national, regional, continental and finally generally defined agendas in the world. Everyone in their own way, according to their personal positions and needs for energy, interprets their own energy priorities, and demands for changes in their own levels, while the world ones often remain either on the sidelines or almost archived in the long term.

This state of affairs leads to a justified fear that the world will not collapse due to energy needs, and that the damages that would result from this could exceed all known economic crises that occurred due to various influences.

A very important question is how to ensure the energy stability, energy independence and energy security of the country in the newly created circumstances, where are the smaller countries identified in this, and how much should it cost overall, viewed through economic parameters? There is also the special question of the large number of risks that are inevitable for such world changes and events, how to detect the greatest number of them at different levels and destinations and how to manage them?

2. WHY COAL IS NOT THE ENERGY OF THE FUTURE

The large imbalance between the production and consumption of electricity points to the conclusion that the world is in the stages of a major energy crisis and that everyone is trying to solve the new situation according to their own preferences, possibilities and needs. Until just a year ago, it seemed that coal as an energy resource potential was coming back into use with the pretensions to once again be the leader in the world's balance configuration formats.

The situation is changing very quickly, although these areas are specific and not as flexible for expected rapid changes, more precisely, these processes require more time for overall consolidation and changes. What is clear is that these are only short-term measures and that the intensive use of coal only overcomes the current energy situation.

There is also the fact that fossil fuels, and coal in particular, cannot or may not be part of a long-term sustainable energy strategy, whether it is economic or especially the aspect of climate perspectives.

Therefore, it remains to follow the new world energy scenario through new configurative forms and system content, which means building a new sustainable energy infrastructure for renewable energy sources, increasing energy efficiency and saving energy.

This would be a long-term world strategy that should be respected and implemented by everyone in the world. Whether it will be like that remains to be verified in time, if it will be possible at all. At the same time, many believe that this is the only way out of the great world economic energy crisis that is on the threshold or, as others believe, is already underway.
On the other hand, there is also the fact that in some EU countries, coal-fired thermal power plants have been restarted with the intensification of their use in order to compensate for the lack of electricity. It seems to be a forced situation for a short time until the existing situation is overcome. But no one gives more precise information, when it should happen or what are the time limits for this kind of situation.

The current circumstances are such that the coal mines of the world operate with high profits, thanks to the high prices of coal. Therefore, coal is still at a price and widely used by everyone of electrical energy systems and is dominant in all electrical energy balances of countries.

What is important is that, at the same time, despite the difficult energy situation when it comes to the EU, new and large investments in energy infrastructure for renewable energy sources are recorded, unlike in the coal mining sector, where investments tend to decrease.

Redirecting to energy from nuclear power plants, which are announced as a long-term salvation for the world, was especially emphasized as a way out of this situation. These are really large and financially demanding projects, and the dilemma remains as to who will be able to participate in such investments, when and how much.

Global flows of energy changes in the world are really demanding in all aspects, so it is uncertain who can follow it all and whether a large number of countries will be more or less late, when it comes to respecting the implementation configuration forms at the time of implementation?

This is because the world's energy turbulences are so great that they begin to drastically affect all processes of life and work. Even the price of energy products is not so important for some world energy powers like USA, China, India, Russia and others.

Qualitative energy mix modeling, even with the most developed, is difficult to interpret/understand and often does not lead to optimal goals and results.

For the less developed, it becomes only a dream or a distant chance in the future (https://www.energypolicy.columbia.edu/, 2023).

The most pessimistic scenarios predict that if these energy trends continue, there could be an almost collapse of the world economy, which would bring the world to the brink with catastrophic consequences for everyone. Of course, in that scenario, not everyone would bear the consequences equally, which is somewhat understandable (Henderson et al., 2020).

One of the conclusions is emerging that energy solidarity is slowly ceasing to exist in the world, and that energy relations are drastically tightening in relation to the /most developed-medium developed-under developed/countries in the world.

These are just some of the observations that are not in favor of coal as a renewable energy source, and it is not regarded as an energy source for the future. The world's large coal reserves could probably be left for use by future generations with completely new strategic approaches and new safer, cleaner technologies that will not be so harsh on the climate security of the world and the country on a planetary level.

3. COAL EXPLOITATION STRATEGIES IN THE WORLD AND IN THE REPUBLIC OF SERBIA

Today, the exploitation of coal in the world is seen as a short-term measure, and its long-term use is not an option at all. However, coal reserves in the world are large. According to the US Energy Information Administration (EIA), the ten countries with the largest coal reserves in the world are: USA, Russia, Australia, China, India, Germany, Ukraine, South Africa, Poland and Kazakhstan. However, the largest concentrations of coal reserves in the world are in five
countries. The USA has 22.3% of world supplies, Russia 15.5%, Australia with 14%, China 13.1%, and India 9.5%, so a total of 74.4% of total world reserves (https://www.iea.org/, 2024).

Indonesia, Turkey, New Zealand, Serbia, Brazil, Canada, Colombia, Czech Republic, Vietnam and Pakistan were also on the list of the top 20 countries in terms of coal reserves.

At the same time, the largest coal reserves do not mean that the countries that mine them exploit them the most, so the USA is in third place and Russia in sixth place in terms of coal production in the world.

The three largest producers of coal in the world are: China, India and Indonesia. So Indonesia shares the third place with the USA.

That it is not so easy to give up coal as a resource energy source is shown by the year 2023, when the demand for coal reached 8.53 billion tons, which is the historical maximum.

The places with the highest demand for coal in the world are Asia and its countries.

Only in China in 2023 coal consumption jumped by 220 million tons or 4.9% compared to 2022, in India by 98 million tons or 8% and in Indonesia by 23 million tons or 11%.

In contrast, in the EU, lower coal consumption is recorded in the form of a sudden drop of even 107 million tons or 23%. In the USA, a drop in coal consumption by 95 million tons or 21% was registered for the year 2023.

The export of Russian coal to the countries of the Asia-Pacific region has surprisingly increased by 23% at the end of 2023. Otherwise, the Russian coal industry covers 15% of the world market with this energy source. Coal exports have increased by 70% in the last two years. Russian expectations are that the demand for coal in these markets will reach an increase of at least 15% compared to the previous period, and their goal is to increase coal exports by at least a third by 2030, or about 30% compared to exports in 2023.

There are also some data that coal production in Russia at the end of 2023 decreased by 1.1% to 438.7 million tons compared to 443.6 million tons of coal in 2022.

So it follows that practically there is still a constantly growing demand for coal in the world, and it records after records.

It is difficult for any country in the world to stop consuming this energy so quickly. This is precisely the problem why no electric energy strategy balanced with the reduction of coal consumption has been achieved so far, and how difficult it will be in the future (https://www.mining-technology.com/, 2022).

More precisely, all the nominated strategies for reducing coal consumption in Serbia were delayed in their adoption and verification. So, for example, the last strategy proposed in 2018, and the deadline for its adoption was 5 years, was not adopted. Such a strategy can now be considered in a certain sense outdated considering the large shifts and oscillations caused by events in the world in several directions of the electric energy sector. In 2022, an identical strategy was adopted, which means that it is practically outdated, and its implementation is limited to the end of 2050 years (Zang et al., 2024).

There are some interpretations that it is not a strategic projection, but a version of an analytical projection that is already being commented on as unrealistic and unachievable. Serbia can hardly give up coal until 2050 years. The time of 26 years as a transformational period is long. No one can predict what events will happen and what scenarios will be realized for that period, when it comes to electrical energy combinatorics. If the strategy from 2018 years is outdated and as such the exact same one is re-nominated in 2022 years, it means that the events and changes in the previous five years were not considered, and there were some that were almost drastic to extremely paradoxical. This points to the fact in the previously defined determinations, how, at least in some visions and directions, energetic events will be directed and realized (Saadia, 2024).
It follows that strategies should be understood as projections or scenarios, which need to be reviewed every five years, and perhaps even for shorter periods. According to these findings, the scenario for Serbia according to (INEKP) is defined as follows:

- By 2030: The share of electricity production from coal should be reduced below 50% of the total production in Serbia for the first time.
- By 2035: The share of production from coal is already drastically lower than the share of renewable sources: 14.7 TWh per year against 25.5 TWh from solar, wind and hydropower combined.
- By 2040: Production from wind and solar alone (17.85 TWh) exceeds the production of electricity from coal, which by then will decrease to only about 10 TWh per year.
- By 2045: Wind, solar and hydropower individually produce more than twice as much electricity in Serbia as coal, whose production decreases to around 6 TWh per year.
- By 2050: Electricity production from coal in Serbia drops to zero, and only some natural gas capacity remains from fossil fuels, with the aim of maintaining grid stability (https://www.mre.gov.rs/, 2023).

The balanced electrical energy mix in the Republic of Serbia is based on coal in the largest percentage (about 65%). If we look at coal reserves, most of which is lignite, only in the Kolubara and Kostolac basins, and according to data (there is a total of about 2,400,000,000 tons (Kolubara 1,700,000,000 and Kostolac 700,000,000).

These two basins have coal of fairly uniform quality. In the Kolubara basin, for the poorer quality of coal from some surface mines, there is technology for coal homogenization/unification of quality (https://rgf.bg.ac.rs/, 2023).

The average annual production of coal in Serbia ranges from 37 to 40 million tons. Taking into account the above-mentioned strategies and the fact that 65% of the share of coal in the energy mix of the Republic of Serbia, coal reserves with current production would be at the level of 50-70 years.

If the participation of coal in the energy mix were to be gradually reduced, then that time can be extended for another 30-40 years.

Observed multi-dimensionally, the situation with the use of coal in the world is quite complicated. Besides England, there is almost no other country in the world that does not have coal in its energy balance.

Countries that do not have it as their own resource, import it from countries that are the largest exporters in the world (Singh et al., 2019).

When positioning the world's energy strategies, there is no solidary consensus that they should be realized for a previously defined period. It is usual that the most objections and resistance to the application come from the world's most developed coal producers.

On the one hand, the profits made from coal seem to be a big barrier, and hardly anyone will give up so easily in that context.

If there is agreement on anything when it comes to coal, it is that the world needs a new flexible strategy of the previous energy mixes, and in their creation, they have the greatest influence.

This is a harsh but also extremely realistic position of today's situation when it comes to the exploitation of coal in the near future (Svobodova et al., 2021).
Figure 1. Hunter valley, New South Wales, an aerial view of an open pit coal mine, Australia (https://www.shutterstock.com, 2024)

Figure 1 shows a surface coal mine of the Hunter Valley, New South Wales, Australia (https://www.shutterstock.com, 2024).

Figure 2. The Tagebau Garzweiler surface mine in the German state of North Rhine-Westphalia. It is operated by RWE and used for mining lignite, Germany, (https://theworld.org/, 2023)

Figure 2 shows the surface mine Tagebau Garzweiler in the German province of North Rhine-Westphalia. It is operated by RVE and used for lignite mining, according to Germany (https://theworld.org/, 2023).

Figure 3. Pereyaslovskiy surface coal mine in Russia (https://www.ruscoal.com/, 2023)
Figure 3 shows the Pereyaslovskiy surface coal mine in Russia, according to (https://www.ruscoal.com/, 2023).

Despite all the contradictions that appear when the participation of coal in the energy mix of countries is evident, there are different scientific views on the further exploitation of coal. The problem here is that the part of coal that is categorized as low-calorie with a lot of moisture and sulfur, such as lignite, is the first to be hit for exclusion from use.

There is a group of scientists who believe that it is necessary to continue using coal as an energy potential, so that energy production from ecologically clean coal (Green Coal Solutions/GCS) is realized in phases and in the long term, in highly efficient smart thermal power plants.

This implies the phased realization of the use of coal from the initial stages of mining, processing to burning in thermal power plants or other combustion facilities.

Figure 4 shows a picture of a rotary excavator/technical system for the surface mining of coal at the Polje "C" and Radljevo surface mines in RB "Kolubara", EPS, Republic of Serbia, according to: (www.eps.rs. 2024) and (https://www.ekapija.com/, 2023).

Therefore, in the long term, clean coal energy should be realized in three phases.
- In the first phase, revitalization of existing and construction of new smart thermal power plants with increased efficiency, reduced emissions of SO\(_2\), NO\(_x\) and ash is carried out.
- In the second phase, smart thermal power plants are being built with the highest utilization rate, even over 60%.
- In the third phase, modern smart technologies for extracting and depositing CO\(_2\), or turning coal into gas (IGCC technology) are used.

With the constant modernization of thermal power plants, much greater utilization and extraction and deposition of CO\(_2\), coal is becoming a leader in environmental protection and security of energy supply.

According to Japanese experts, low-caloric coal as a prospective energy source using modern (IGCC) technologies, due to minimal carbon dioxide emissions, has a great chance of becoming a new generation fuel.

In the USA, new smart technologies are going in a completely different direction, namely smart technologies that are primarily adaptable for use in existing thermal power plants or thermal power plants that are about to be shut down/closed (http://www.nakoso-igcc.co.jp/, 2022).
The development of smart technologies can certainly even in the near future completely change today's paradigm when it comes to the use of coal, through changes to a new energy paradigm in which coal becomes the green fuel of the new generation. This situation would certainly change the world energy mix and turn it in completely different directions towards the generation of a new global consumer agenda (https://energetskiportal.rs/, 2023).

The Republic of Serbia must definitely follow the latest trends in the world in the use of coal and gradually implement new smart technologies in its own energy processes, in order to ensure the continued existence of coal in its energy balance mix. Research shows that trends in the further development in all aspects of R. Serbia will generate at least 3-4 times greater need and consumption of electricity by 2050 years, which additionally implies new thoughts, questions and suggestions for additional energy provision of the country.

4. **USE OF COAL AND POTENTIAL RISKS**

Observing the use of coal in the structure of energy mixes as a potential energy resource can be analyzed in at least two context frames.

The first analytical approach of observation would be the continuation of the use of coal at this threshold of technological applications and the very technologies of application. Here, one should position himself on all valid existing strategic projections as well as the circumstances in which they are realized, partially realized or not realized at all. It is about realistic perceptual frameworks in today's very turbulent world energy practice.

Another analytical approach of observation would be in the direction that coal can be the fuel of the future if the technological frameworks of use were changed, especially in combustion processes in thermal power plants or other thermal energy facilities. This implies a total technological contextual transformation, more precisely a different approach to coal as an energy source, new smart technologies at all levels and in all technological processes, in which this energy source is treated to the final outcome of being a green energy source and ultimately a potential energy resource of the new generation (Radosavljević et al, 2009).

Such an approach would imply new strategic forms and system configurations that would be completely opposite to all the ones valid until now and continuously related to the first approach. At the same time, this understanding of coal as an eco-energy source and energy-generating new fuel generation would generate a new energy paradigm, the world would be additionally relaxed and relieved of the previously negative effects of coal in the energy mix, primarily due to the large balance reserves of all types of coal in the world (Radosavljević et al, 2017).

The projection of a world with ten billion inhabitants by 2050 implies an increase in the need for energy of all kinds by at least 50%. Such a demand with constant annual increase is almost unbearable for the world. If they were to give up coal as an energy source, this seems like an unachievable balance sheet projection. That is why the world is also interested in coal remaining in the energy mix of all countries, provided that the aforementioned conditions are met (Radosavljević et al, 2009).

The risk analysis of the use of coal in the energy mix of countries and energy balancing can be observed in at least the aforementioned contexts. Both analytical contexts are many times different, precisely for the reasons stated in the previously mentioned observations.

This implies new risk configuration forms through new smart models and analytical methods for the second option to the creation of a completely new smart risk integration platform that would be adaptable, operable, functional and realistically applicable to all organizational system configurations and all system users in the world.
These are the modeling of completely new smart risk tools and methods, for the new smart time, completely new smart generations, based on operating smart machine learning, artificial intelligence and new multi-functional smart integration formats that have not been generated so far (Radosavljević et al, 2013).

One of the useful tools for risk analysis and assessment is the software tool Design Safe 9.0. It is a tool that was first designed in 1995 and has undergone significant evolution and practical confirmation in the world of risk analysis. This software tool was first practically applied by the group of authors of this paper in the Republic of Serbia in 2005 in the field of mining and surface exploitation and coal processing. The tool is configured to evaluate the possibility of product design improvement, as a systematic method for implementation and risk assessment based on a specific task, as a technique for minimizing or eliminating hazards, as a safety design tool that is incorporated into the analyzed process (https://www.designsafe.net, 2024).

Design Safe 9.0 gives designers a quick and easy tool to assess hazards and risks throughout design. It helps companies to identify potential dangers and, through methods, delegate adequate responses to them. It helps risk engineers to complete a risk assessment for their own products and processes. It prevents the realization of bad and unsafe scenarios, improves productivity and reduces liability. Assists the Risk Analyst with all risk related project activities. It helps the risk analyst to identify the greatest number of potential hazards that could be overlooked. It helps in emergency situations when it is necessary to reduce/minimize the risk of existing hazards. It can be continuously updated and provides a transparent overview of detected risks as well as newly emerging potential risks. Minimizes risk assessment time and reduces overall risk assessment costs. It is adaptable and can be used for a wide range of different processes and process activities (https://www.designsafe.net, 2024).

It is a very simple method for documenting and assessing risks in processes and decomposed process activities.

5. CONCLUSION

It is indisputable that coal, as an important energy resource in the world, will still occupy a high usage position in almost all countries. Some countries simply use coal at all costs and do not want to eliminate it from their balance energy mix. For now, the situation is similar in the Republic of Serbia. There is a hunger for energy and energy resources in the world. In a short time, thoughts became focused on the long-term level, but also on the achievement of mostly short-term goals for now.

The energy crisis that has determined new transit energy routes in the world, which are often variable even in those circumstances, countries simply cannot follow either in time or economically, so they withdraw from the market and rely on their own carbon balance reserves. So the future of coal is still not in doubt. Especially if we take into account the fact that, along with new technologies and modified ways of use, it can also become a resource of a new generation of energy sources. With all the technological progress that the world is experiencing and new configurative evolutionary forms, methods and models, this kind of setting is apparently possible and achievable. The variant where coal will be completely replaced by new energy sources by 2050, on the other hand, is questionable in its exclusivity, as well as positive that large amounts of coal will be left as a legacy and available for use by the next generations in the future.

Risk analysis will certainly experience new, special and important transitional configuration forms, both tools and models and methods, so that they can follow all new changes and in the case of various destructive potentials, they can be detected in time,
structurally recognized, analytically processed according to priorities, especially in the area of hidden risks, to minimize them until possible complete elimination.

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