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Current State and Future Prospects of Hydro Energy in Russia

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ABSTRACT

The authors argue that the contemporary scholarship on hydro energy in Russia lacks a comprehensive overview of development trends, global and regional challenges, and future prospects in connection with the ongoing processes in other sectors of the national economy. Consequently, this paper addresses the gap existing in the scholarship by providing a holistic view of the current state of Russia's hydro energy. It also identifies and discusses the key developmental constraints, including the general economic and political situation developing both in Russia and in the world, negative trends in the country's wholesale electricity market and the long-term capacity market, the Russian Government's focus on development of nuclear power stations and not hydroelectric power stations, as well problems of ensuring the technical and environmental safety of hydropower facilities. Finally, the paper outlines prospects of hydro energy in Russia, taking into account global, regional, and national trends in energy development

Keywords: Hydro Energy, Strategy, Development, Constrains, Siberia, Russian Far East
JEL Classifications: Q25, Q48

1. INTRODUCTION

The Russian Federation is often perceived as an "energy superpower," both with abundant energy and fuel resources and its impact on world energy markets (Sagers, 2006; Milov et al., 2006; Bouzarovski and Bassin, 2011; Wang and Liu, 2015; Bradshaw et al., 2019; Goldthau and Boersma, 2014).

Consequently, it drives the interest of scholars and practitioners around the globe and stimulates research on the Russian energy and fuel complex. For instance, there are well established and continuously developing groups of scientific knowledge devoted to Russia's traditional energy resources: (a) Oil (Kryukov and Moe, 2018; Vatansever, 2017; Kapustin and Grushevenko, 2018; Tuzova and Qayum, 2016; Depellegrin and Pereira, 2016; Locatelli and Rossiaud, 2011; Locatelli, 2006; Reynolds and Kolodziej, 2007); (b) natural gas (Pierk and Tysiachniouk, 2016; Orazalin and Mahmood, 2018; Shvarts et al., 2016; Talipova et al., 2019; Visenescu, 2018; Mitrova et al., 2016; Korppoo, 2018); and (c) coal (Gorbacheva and Sovacool, 2015; Grammelis et al., 2006; Das, 2001; Alekseenko et al., 2018; Krasil'nikova, 2001; Artobolevskiy, 2003; Sperkach, 2010; Tumanovskii, 2017; Lakhno, 2015).

Despite such a close and extensive coverage of Russia's traditional energy sources, there is a growing research into renewable energy sources in Russia and former Soviet countries (Belokrylova, 2018; Pathak and Shah, 2019; Gaynanov et al., 2018; Boyarinov, 2018; Lanshina and Kulakov, 2017; Daus et al., 2016; Ratner and Nizhegorodtsev, 2017; Bayar and Gavriletea, 2019; Pristupa and Mol, 2015).

Hydro energy is one of the most promising clean, renewable energy sources that regularly receives much attention in the contemporary scholarship (Solarin and Ozturk, 2015; Lin and Omoju, 2017; Javed et al., 2020; Fu et al., 2017; Solarin et al., 2017; Yah et al., 2017; Ma et al., 2014; Neto et al., 2017; Yang et al., 2016; Guezgouz et al., 2019). Russia's hydropower resources and potentials are also carefully researched. One could identify the following groups of scholarly research on the topic: (a) Hydro energy as part of alternative energy sources in Russia (Proskuryakova et al., 2018; Boute and Willems, 2012); (b) engineering issues of Russia' hydropower (Denisov and Denisova, 2017; Sadovskii, 1997; Rumyantcev, 2008); (c) electricity generation and markets (Belyayev, et al., 2016); (d) ecology and climate with respect to hydro energy (Vinokurov et al., 2011; Akentyeva et al., 2014; Saifutdinova et al., 2015); (e) federal and local hydropower policies (Bogush et al., 2016; Lubimova, 2006; Saveliev and Chudinova, 2009).

Despite such extensive coverage, the contemporary scholarship on hydro energy in Russia certainly lacks a comprehensive overview of development trends, global and regional challenges, and future prospects in connection with ongoing processes in other sectors of the national economy. Consequently, this repaper addresses the gap existing in the scholarship. In particular, it provides a holistic view of the current state of Russia's hydro energy. Then, we identify and discuss several developmental constraints. Finally, the paper outlines prospects of hydro energy in Russia, taking into account global, regional, and national trends in energy development.

2. CURRENT STATE OF HYDRO ENERGY IN RUSSIA

The primary branch of the contemporary economy, which determines the location, development, economic efficiency, and stability of all its other branches and social sphere, is the electric power industry. Hydropower ranks third among other generations of this system in terms of power generation (Kapustin and Grushevenko, 2018). Russia has a vibrant hydropower potential. About 9% of the world's hydropower reserves are concentrated on its territory. It ranks second in the world after China in terms of hydropower resources, ahead of the United States, Brazil, and Canada (Proskuryakova et al., 2018), which clearly shows the potential for the development of domestic hydropower.

What is the role of hydropower in the economy of the Russian Federation? First of all, hydropower provides the system reliability of the country's power system. Hydropower forms 95% of the reserve of adjusting power in it. Hydropower is a critical element of the power systems of the Russian Federation and neighboring countries (Zakharov and Kozlov, 2018. p. 3).

In 2016, hydropower participation in the provision of domestic power consumption is characterized by the following data: 8% in the European part, 49.5% in Siberia, and 55% in the Far East (Novozhenin, 2017. pp. 3-4). Hydraulic power plants are crucial in the fight against floods to protect the population and industrial facilities from flooding. Hydroelectric power stations (HPSs) ensure the functioning and development of such infrastructure facilities as shipping, industrial and municipal water supply, agriculture, recreation, and others. Hydropower generation of 170 billion kWh/year saves up to 55 million tons of standard fuel annually (Ministry of Energy, 2018). Hydropower has the lowest specific carbon dioxide emissions, creating the potential for decarbonization of the Russian economy. Finally, the use of plant stations allows accumulating electricity in the volumes necessary for regulating the operation of the power system, including creating conditions for the operation of renewable energy sources with unstable generation.

The contemporary hydropower complex of Russia consists of 46 HPSs with a capacity of over 100 MW and 54 HPSs with a capacity of <100 MW. Russia's largest HPSs are the Sayano-Shushenskaya HPS (6,400 MW), Krasnoyarskaya (6000 MW), Bratsk (4,500 MW), and Ust-Ilimskaya HPSs (3,840 MW) (Ministry of Energy, 2018). All of them were commissioned in Soviet times in a centrally planned economy. In 2000–2010, the Boguchanskaya HPS (3,000 MW), the Bureyskaya HPS (2010 MW), and the Zagorsk PSPS (840 MW) were commissioned (Ministry of Energy, 2013. p. 4).

Currently, construction projects and other HPSs are being implemented, but the volumes are far less massive than before. The total installed capacity of hydro units at HPSs in Russia is approximately 45 million kW (5th place in the world). However, the distribution of economic hydro-resources in the territory of the Russian Federation is highly uneven. Approximately 80% of the hydro-resources are in the eastern regions (Siberia, the Far East), and only 20% of them are in the European regions of the country (Bellendir et al., 2016. p. 52). In the total volume of electricity production in Russia, the share of HPSs did not exceed 21% in 2017. More precisely, it was 17% in installed capacity (Zakharov and Kozlov, 2018. p. 2).

Despite the continuing important role of hydropower in the fuel and energy complex of Russia, its current state cannot be called prosperous, in our opinion. The results of the last decade indicate the growing danger of hydropower losses of its strategic importance at the national level. The hydropower potential of the European part of Russia involved in the operation is approximately 50% of the technical level, 20% in Siberia, and only 5% in the Far East (Zakharov and Kozlov, 2018). Consequently, most of the undeveloped hydropower resources are concentrated in the Siberian (Eastern Siberia) and Far Eastern Federal Districts.

3. DEVELOPMENTAL CONSTRAINTS

Despite the rather wide opportunities for hydropower engineering, at the present stage, the hydropower development in Russia in the near future is evaluated by many experts as unfavorable (Alekseenko et al., 2018; Bouzarovski and Bassin, 2011; Denisov and Denisova, 2017; Kapustin and Grushevenko, 2018). There are many serious problems faced by the domestic hydropower industry. First of all, they are related to the general economic and political situation developing both in Russia and in the world, in our opinion. The pace of development of the Russian economy has slowed due to several reasons: (a) The global and domestic economic crisis, (b) the introduction of economic sanctions against Russia since 2014, (c) the decline in oil prices on the global energy market. Therefore, we may conclude that there are not enough reliable economic factors that could be used as a basis for reassessing the country's economic hydro potential.

The economic crisis in the country and the subsequent stagnation significantly limit the investment opportunities of the state. It becomes difficult to fulfill their commitments to create energy, transport, construction, and household infrastructure for new HPS in areas of new industrial development, including in the areas of priority development (Belyayev et al., 2016. p. 34). The features of the country's wholesale electricity market and the long-term capacity market have a negative effect.

Due to the fall in economic growth, the demand for electricity and new generating capacity has decreased markedly within the country. Moreover, an excess of these capacities has arisen in the country. The question of putting a dozen gigawatts of electricity into a long-term cold reserve is even raised because of this (Saveliev and Chudinova, 2009). At the same time, despite the massive potential of energy resources in 2015, Siberia itself is experiencing a shortage of electricity. In total, 2.3 billion kWh electricity was transferred to this region, including from Kazakhstan (Novozhenin, 2017. p. 8).

Changes in Russia's Energy Strategy and the reassessment of the role of the power industry in the Russian economy for the period up to 2035 affected the development prospects of the domestic hydropower industry (Belyayev et al., 2016. p. 34). In our perspective, shifted priorities led to a significant reduction in the volume of hydropower construction.

The Strategy of the Energy Development of Russia for the period up to 2035 (Ministry of Energy, 2019) practically retains the existing structure of power generation with some "advanced development of non-thermal power plants," focusing on only nuclear power stations and not HPSs. With the expected increase in electricity production by 2035 in 1.27/1.43 times (from 1062 to 1352/1514 billion kWh), the growth of electricity production at nuclear power stations is expected to be in a range of 1.4/1.8 times, and it is 1.2/1.3 times with respect to HPSs, with an increase in production based on renewable energy sources in dozens. Consequently, these state energy strategies are planning to slow down the development of large hydropower in the future. As a result, the total output of "fuel-free" electricity will decrease from the current 18% to 13-14% by 2035 (Novozhenin, 2017. p. 3).

Unfortunately, there is no proper crystallization of approaches to the development of domestic hydropower in government circles, federal and regional authorities. This is also reflected in the documents of the strategic planning in the electric power industry, which are not synchronized so far with regard to the pace of development of this industry and the timing of the implementation of projects for the construction of new HPSs (Zakharov and Kozlov, 2018. p. 4). For example, in the draft Energy Strategy of the Russian Federation for the period up to 2035, in the optimistic version, the power input of the HPS-PSPS should reach 11,400 MW (in the conservative version - 7300 MW) by 2030. In the General Layout of Electric Power Industry Objects for the Period up to 2035 (approved in 2017), the input of HPS-PSPS should reach 3552 MW (according to the basic version) and 2470 MW (according to the minimum version) by 2030 (Ministry of Energy, 2019; Government of Russia, 2019).

The most severe problem of ensuring the technical and environmental safety of hydropower facilities is the condition of their fixed assets. To date, almost 70% of available capacity has been in operation over the regulatory period (Bogush et al., 2016. p. 14). A necessary condition for the operation of old equipment at hydropower plants is timely and fully completed repair and restoration work.

At the same time, due to insufficient volumes of electricity consumption and carrying capacity of the electrical network in the IPS of the East, restrictions on the minimum capacity of thermal power plants and the inability to export electricity to China, for various reasons, the energy output of new commissioned hydraulic units is often not fully utilized. Part of the water has to be dumped idly.

In the most promising (in terms of hydro-construction) areas for various reasons (socio-economic, environmental, water management), the construction of high-capacity hydropower plants on the main channels of the largest river basins (Yenisei, Lena, and Amur) has become almost impossible. As a result, the technical potential of their hydropower resources decreases from 849 and 1009 billion kWh/year to 574 and 357 billion kWh/h/year, respectively (Saveliev and Chudinova, 2009).

Another "negative factor" for hydropower development is the long duration of construction. The term for the construction of such objects in world practice is 5-6 years. The average duration of the construction of such facilities is 4-5 years (Novozhenin, 2017. p. 6). Nevertheless, it is possible to build even longer. For instance, it took or 30 years to build the Boguchanskaya and Ust-Srednekanskaya HPSs. This indicator determines the attitude of the investor to the effectiveness of their investments.

The tightening of environmental requirements is also not conducive to clarity in the assessments of the medium and long-term prospects for the economic development of the country and the market for fuel and energy resources (Bogush et al., 2016. p. 7). The long-term water in the basins of the country's largest rivers has a significant impact on the functioning of existing HPS and the efficiency of the implementation of hydropower projects (Saveliev and Chudinova, 2009).

Another set of developmental constraints for the Russian hydropower industry is related to environmental and climate issues. In particular, the imperfection of the mechanism for determining the amount of compensation for damage to aquatic bioresources during the construction and operation of hydropower plants is striking. Thus, the calculation of the amount of damage to aquatic bioresources is carried out based on methods that do not take into account, according to some experts, the peculiarities of the operation of hydroelectric power plants.

Namely, one discusses the absence of non-returnable water intake and the availability of positive effects from reservoirs. When assigning compensation, the regulator selects the costliest measures, as a rule. For example, the lowest rate of return is set for the restoration of valuable fish species. The harm assessment model, developed in the 1960s, is used in methods. According to some specialists (Zakharov and Kozlov, 2018; Bogush et al., 2016), the Russian legislation requires changes to improve the system of compensation for damage to aquatic biological resources and taking into account the existing system of payments deducted by the owners of HPSs to the budget.

4. FUTURE PROSPECTS

The factors contributing to the development of the domestic hydropower industry in the coming years include not only the expected increase in the demand for electricity and, as a result, in new generating capacities. In our perspective, when considering future prospects of hydro energy in Russia, one should immediately note the following: (a) Significantly outdated hydropower equipment and its negative impact on technological safety and the environment; (b) hydro energy is still not sufficiently evaluated in terms of its infrastructural role in the development of natural resources and remote areas; (c) there is a growing demand for relatively cheap and environmentally friendly energy (and hydro energy is highly attractive in economic terms); (d) the need to support the construction of small HPSs.

In the economic evaluation of different generations, we should bear in mind another circumstance. If the cost of electricity from HPSs is final for the entire unlimited period of operation, the cost of electricity from a TPS has a constant upward trend due to the rising cost of fuel, especially gas, as well as potential environmental benefits (Novozhenin, 2017. p. 5). Despite the fact that electricity tariffs for consumers exceed any of its prime cost by order of magnitude or more, this indicator is of great importance for the economy of the power industry and its facilities, especially for the period of their operation after the return on investment.

Taking into account the factors listed above and in order to diversify the country's fuel and energy balance, the Energy Strategy of Russia for the period until 2030 provides for the advanced development of nuclear, coal, and renewable energy (including hydropower). The Institute of Energy Strategy, together with a number of specialized research institutes and design organizations, have developed the Program for the Development of Hydropower Industry in Russia until 2030 and for the Prospect until 2050 (Bogush et al., 2016. p. 5), which became an integral part of the Energy Strategy of the Russian Federation until 2030. In this document, as well as in the draft Energy Strategy of the Russian Federation until 2035, one of the main directions for the development of Russia's hydropower industry in the next 20-30 years is the expansion of hydropower engineering in Eastern Siberia and the Far East, which have the wealthiest hydropower resources (Barinov et al., 2013, Government of Russia, 2019; Ministry of Energy, 2019).

The most critical condition for the successful development and development of the eastern regions of Russia is the priority development of the energy infrastructure, ensuring their guaranteed power supply. Practice shows that there is a close interdependence in the implementation of industrial investment projects in clusters, and hydropower projects. The demand for electricity is growing particularly rapidly in such clusters.

Therefore, the formation and development of large territorial production clusters in the areas of construction of HPSs is economically viable. So, according to experts, in Eastern Siberia, the Nizhne-Priangarsky, Lensko-Bodaibinsky, and Northeast clusters are considered very promising. They unite a complex of industries, including the production of hydropower, natural gas, oil, as well as gas processing and gas chemistry, mining and processing of metal ores, logging, and wood processing (Bogush et al., 2016. p. 8). In the coming years, the construction of the Angarsk cascade of hydropower stations with an additional energy output of about 12 billion kWh is to be completed (Ministry of Energy, 2018). Moreover, the development of hydropower resources of the Upper Yenisei should begin, where already the first objects of average power can give up to 15 billion kWh of energy (Novozhenin, 2017. p. 8).

The Evenki HPS on the Nizhnyaya Tunguska River should become the leading, first-priority facility in Eastern Siberia. The power generation of this HPS is 50 billion kWh/year, with a capacity of 10-12 million kW. This pearl of the national hydropower industry and its reservoir are located almost in a deserted region of the country, ensuring minimal damage to the economy, social sphere, and the environment. In terms of power generation, it is equivalent to a nuclear power station with a total capacity of 7 million kW (Kursk and Smolensk NPSs taken together), or a thermal power station with a capacity of 9 million kW (Novozhenin, 2017. p. 8).

Particular attention in the "Development Program ." is drawn to the construction of small, micro, and mini HPS needed for local power supply of isolated territories. Their technical potential is 128 billion kWh/year in Eastern Siberia and 146 billion kWh in the Far East (Saveliev and Chudinova, 2009). HPSs can be constructed both in conjunction with other HPSs and separately on a territory that has not yet been developed.

In general, the construction of HPSs, especially in remote areas of little-developed, gives an excellent impetus to their further economic development and landscaping.

The direct socioeconomic effect of the implementation of hydroelectric projects is to expand employment in the construction and operation of HPSs, as well as in enterprises of growing local industry and transport infrastructure, to increase tax revenues from new enterprises to the local budget. This will help to create comfortable socio-cultural living conditions for the population. Besides, HPSs are environmentally friendly sources of electricity, contributing to reducing the anthropogenic impact on the environment. More than that, the creation of reservoirs allows reducing damage from catastrophic flooding of farmland, from flooding of settlements, roads, and communication lines. The most significant anti-flood effect of waterworks is expected in the territories of the Primorsky, Khabarovsk, and Amur Regions.

Thus, the construction of new hydropower facilities will help to overcome the adverse crisis phenomena in the economy, reduce social tensions and should ensure the attractiveness of hydropower projects for investors. It is expected that the implementation of the "Russian Hydropower Development Program ..." will lead to an increase in the economic hydro potential of the Far East from 8% to 25%, and from 33 to 61% by 2050 in Eastern Siberia (Bogush et al., 2016. pp. 7-8). It is assumed that the share of HPS and PSPS in the Russian power industry will remain at 5.5% throughout the period under review in the conservative scenario and it will increase to 6% in the target scenario of the total production of primary fuel and energy resources by 2050 (Bogush et al., 2016. p. 9).

HPSs in the eastern regions are designed to promote not only the rapid development of their natural resources, but also the development of interstate electrical links with the Asia-Pacific countries (Saveliev and Chudinova, 2009. p. 1). In addition to the export of primary energy resources, the exchange of electricity and power between neighboring countries for the implementation of systemic integration effects, including regime, power, environmental, it seems appropriate (Solovyov, 2014). The continuing competitive advantage of the cost of domestic electricity produced at Russian HPSs, compared with the cost of foreign electricity, should contribute to this. First of all, the competitive advantage of the cost of domestic electricity is due to the weakening of the ruble in the foreign exchange market. The current economic conditions will contribute to the integration of large Russian HPSs into global electricity markets with the ability to compete with other sources of energy.

At the present stage, the further expansion of the Unified Electric System (UES) of Russia will occur through the construction of new power plants, including new HPSs and the construction of long high and extra-high voltage AC and DC lines as part of the Unified National Electric Grid. The main role of these power lines will be to create East-West electric transit in several directions (north, center, and south) (Barinov et al., 2016. p. 23). Consequently, the construction of powerful clusters of power stations (hydro and thermal) in Eastern Siberia and the Far East will allow using electricity transmission lines of direct current of ultrahigh voltage to export electricity, primarily in the direction of Southeast Asia.

In fact, the UES of Russia acts as a kind of bridge connecting electric power systems and associations of European and Asian countries. Russian hydropower resources can play an important role in the Eurasian ISEA. Expansion of electrical ties with the neighboring countries of Eurasia will become a serious stimulus in the development of domestic hydropower in the visible future: The construction of new hydropower plants with a total capacity in Siberia of 8.4 and in the Far East - 14.2 GW is forecasted until 2050 (Belyayev et al., 2016. p. 36).

In our opinion, the Russian HPSs will act not only as exporters of clean electricity, but also as facilities providing system effects from the construction of an ISER that promotes the formation of interstate electrical associations. The implementation of integration effects, especially the equalization of the energy efficiency of renewable energy sources at the expense of reservoirs of HPSs of Siberia and the Far East, will significantly affect the ISEA regimes. The electricity integration into the Eurasian space and the Global ISEA will provide significant energy and economic effects for Russia. Thus, the expansion of the export energy potential of Russia in the East Asian direction will occur mainly due to the Russian HPSs.

One of the promising projects for the integration of hydropower resources of Russia into the global electric power markets is the creation of the "Asian Super Energy Ring," a global project to integrate individual national energy systems. In the next 20 years, large-scale work on the creation of the Eurasian part of the global electric power system (GEPS) will unfold, which implies the unification of the national energy systems of Russia, Kazakhstan, Belarus, and European countries (Bellendir et al., 2016. p. 55).

In addition to the construction of new HPSs and the creation of transnational relations based on high-voltage direct-current lines, the formation of common energy markets of all Eurasian countries is important to ensure for the successful integration of Russia's hydropower resources into the global electricity markets of Eurasia. It will also require the development of an efficient energy transport infrastructure.

So, according to the "Program for the Development of the Hydropower Industry of Russia ...," the growth of the installed capacity of HPS (including PSPS) is forecasted in the UES of Russia by 8.2%, i.e., from 46 GW in 2012 to 49.8 GW in 2017-2019 years. The share of hydroelectric power plants in the structure of installed capacity in the UES of Russia should increase from 20.6% in 2012 to 20.9% in 2019. In the projected structure of electricity production in the UES of Russia, the share of HPSs will increase from 15.1% in 2012 to 15.8% in 2019 (Ministry of Energy, 2013. pp. 2-3).

5. CONCLUSION

Assessing the current level of use of hydropower resources, as the most efficient and stable, environmentally friendly renewable energy source in Russia in comparison with similar indicators of other countries, we should recognize it as extremely low. In European countries, in the large countries of North and South America, China, and Japan, the hydropower potential is used as efficiently as possible. And this is not only characteristic of countries with low reserves of fuel resources.

On the basis of our review, we would like to identify several restraining factors of hydropower development in the eastern regions and Russia as a whole. First of all, the already used material, monetary, and labor resources are not sufficient for faster development of hydro energy in Russia. Consequently, it is hard to find potential investors for newly built HPSs, because such projects are capital-intensive and require a longer period of refunding. Third, Russia's eastern regions experience demographic problems and the associated with them lack of qualified personnel for all spheres of hydropower engineering.

Consequently, both national and regional state bodies should pay special attention to the infrastructure of hydropower engineering its crucial role in the development of new territories. Promising areas of hydropower development should take into account reasoned assessments of the possible risks of implementing the intended ways of functioning and development of the industry based on a comprehensive analysis.

Domestic and international practice of hydropower engineering shows its significant multiplicative effect, in which the satisfaction of energy needs with cheap electricity along with the creation of industrial, transport, and social infrastructure contributes to the integrated industrial and social development of regions, to the development of new territories, the creation of large energy-intensive industrial complexes, increasing the level of occupancy and the quality of life of the population, reducing the negative economic impact on the environment, ensuring economic and energy security. The organization of inter-regional energy relations as an integrating factor and method for leveling natural and economic disparities, development, and diversification of long-term and efficient energy exports also should be considered.

These features of hydropower construction again become relevant for real, rather than declarative, integrated and stable development, especially in the regions of Siberia and the Far East. This does not mean that hydropower is able to replace all other generations, but state priorities should be given to its development in strategic assessments and practical actions.

Also, our review clearly demonstrates that a significant change in the current unfavorable situation in Russia's hydropower construction is possible only with the general stabilization of the country's economic development.

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