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Prospects of energy cooperation between the Russian Federation and the Republic of Korea in the context of establishing of the Asian Super Grid*

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The article presents the results of comparative analysis of energy sector reforms undertaken in Russia and South Korea in the 2000s that are aimed at decentralizing their energy sectors, previously dominated by one state-owned energy company. The article demonstrates that although the energy sector reforms in both nations took place simultaneously and with similar aims, Russia completed its reform, while Korea abandoned decentralization midway. Research behind this article compares the outcomes of the energy sector reforms from two perspectives. First, it compares the outcomes of the reforms from the viewpoint of their contribution to an increase in the share of electricity produced from renewable energy sources in national energy balances. Second, it compares the outcomes of the reforms from the viewpoint of their compatibility with integration of the energy systems into wider networks, using the Asian Super Grid and Inter-Korean Connector as examples. It appeared that despite Russia having completed its reform, while Korea abandoned it halfway, both countries made significant progress in terms of increasing energy production from renewable sources. At the same time, Russia, thanks to its ability to complete the reform, is better prepared to integrate its energy system into wider networks. The article concludes that Korea's unpreparedness to incorporate its energy system into wider networks creates an obstacle to the country's further progress towards a greater share of electricity produced from renewable energy sources in the nation's energy balance.

Keywords: renewables, energy, integration, East Asia, Russia, Korea, Asian Super Grid, power system interconnection, international cooperation.

Many nations, including the Russian Federation and the Republic of Korea, have recently made a significant progress towards increase in the share of electricity produced from renewable energy sources in their national energy balances. Further progress can be achieved, if nations manage to integrate generation facilities located across wide areas, as well as to connect integrated generation facilities with consumers dispersed across similarly wide areas. Existing models of optimal connections of solar parks across time zones for minimizing intermittency [1] demonstrate how large integrated energy

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systems help increase cost efficiency of electricity production from renewable energy sources. Various scholars have already called for regional integration of energy systems. In particular, Grossmann et al. have called for a Pan-American energy system [2]. Battaglini et al. have found the way for Europe to combine what had before been perceived as two exclusive alternatives: wide area power generation and decentralized power generation [3].

Concerning Asia in particular, Taggart et al. have called for consideration of a Pan-Asian energy infrastructure [4]. For the relations between Russia and Korea, it means consideration of two alternative but not exclusive projects. First, it is the project of building an on-land interconnector between Russia and South Korea through the territory of North Korea, which has been under discussion among Russian, South Korean and North Korean officials for almost a decade. Despite those discussions set an ambitious aim of establishing of a Eurasian energy grid [5], they have not significantly progressed so far. Second, it is the project of connecting both Russia and South Korea to an Asian Super Grid, which has been negotiated among China, South Korea, Japan and Russia, again, for almost a decade, and again, without substantial progress. Stimulating progress in the field is impossible without analysis of obstacles to integration in energy sphere in Northeast Asia, including also Russia.

Integration in energy sphere in Northeast Asia, including Russia, faces four types of obstacles. Those are geopolitical, economic, technological and legislative obstacles. This article focuses on the latter type of obstacles, and on Russia and South Korea in particular. This article asks if the legislations regulating energy sectors in Russia and South Korea, including its implementation, favours integration of the nations' energy systems into a greater network, be it Inter-Korean Connector (IKC) or Asian Super Grid (ASG) or both. To do so, the article will, first, evaluate on the connection between increase in the share of electricity produced from renewable energy sources in global energy balance and international integration of energy systems; an analysis of projects aimed at formation of integrated energy systems in different regions of the world will be provided. Second, the article will evaluate on the progress achieved so far in the motion towards establishment of ASG; an analysis of obstacles facing the motion will be provided.

Third and most importantly, the article will present results of comparative analysis of the energy sector reforms that Russia and South Korea undertook in 2000s. The reforms will be analysed from two viewpoints: their compatibility with the aim to increase the share of electricity produced from renewable energy sources in national energy balances, and their compatibility with the aim to connect national energy system to a wider energy system, be it IKC or ASG. Below, I will demonstrate that Russia and South Korea launched their energy sector reforms almost simultaneously and with similar aim at decentralization of originally one state-owned company-dominated energy sector. In Russia, the energy sector was effectively decentralized, while in South Korea, the reform was dropped halfway. This did not prevent either country from making a significant progress towards increase in the share of electricity produced from renewable energy sources in their national energy balances. However, Russia, which has completed its energy sector reform, is now better prepared for integration of its energy system into a greater network, be it ASG or IKC or any other project of the kind.

Renewable Power and Integrated Energy Systems

Since mid-19th century, global energy sector has grown 35 times. The growth was not linear, but it went through three stages of development. Each stage of development was shorter than the previous one. On each stage, growth of energy consumption was smaller than on the previous stage. Energy consumption grew 4,8 times through the first stage, 4,2 times through the second stage, and 1,6 times through the third stage. Energy demand fell sharply at the end of each stage. The first stage took place between mid-19th century and the beginning of WWI; coal came to dominate over other primary energy sources by the end of the stage, its share in global energy balance grew from 5 % in mid-19th century to over 50 % by the threshold of the 20th century. The second stage took place between the end of WWI and the beginning of the Western oil crisis of 1970s; oil came to challenge the role of coal among primary energy sources by the end of the stage, its share in global energy balance grew from 3 % in 1915 to over 50 % in 1975. The third stage has been taking place since the end of the Western oil crisis of 1970s; across this stage, natural gas has become third most important source of primary energy, together with coal and oil; its share in global energy balance grew from 3 % in 1930 to 23 % in 2017 [6].

Current decline in global energy consumption might signify that global energy sector is approaching another transition period. One might predict that the global energy sector will be soon entering a new stage of development; growing role of hydropower combined with other renewable energy sources will be characteristic of this stage. One might expect that rapid growth of renewable energy sources will help this segment to occupy 35 % to 50 % of global electricity production and 20 % to 25 % of global energy consumption by 2040 [7]. In connection to that, one might also expect that international cooperation in the field of production, transportation and distribution of electricity will significantly develop within next twenty years, not only on company-to-company, but also on inter-state level.

Russia is one of the leaders in world energy and a great player on international energy market. Fuel and energy sector, including exports of its products, play a special role in Russian economy. According to the draft Energy Strategy of Russia till 2035 (as of April 2020), the country will transit from resource-based to resource-innovative development of the fuel and energy sector in the next fifteen years [8]. The country’s fuel and energy sector is expected to become a “stimulating infrastructure”, capable to create the conditions for development of the Russian economy, including its diversification, its technological development and minimization of infrastructure restrictions. Adoption of international experience in the country’s electricity production, transportation, distribution and consumption is also expected to play a key role in the development of the country’s fuel and energy sector as a whole [9].

Unlike thermal and nuclear power plants, which can be built close to consumers, production of renewable energy is place specific. Hydropower cannot be produced far from rivers or seashores (in case of tidal power), solar power production is more efficient in places, where solar activity is strong, etc. Thus, production of electricity from renewable energy sources in many cases requires transportation of energy to large distances. Also, production of renewable energy is more dependent on natural cycles, be them daily cycles for solar power, moon cycles for tidal power, seasonal cycles for hydropower, etc. Integrating renewable-energy power plants into a system, for example, connecting solar power plants located in different time zones, decreases the dependence of electricity production on natural cycles and allows for saving on storage capacities. Thus, more effective production of electricity from renewable energy sources in many cases, again, requires transportation of energy to large distances between different production facilities belonging to the same integrated energy system.

Integrated energy systems can emerge on national level, like in Russia, or even on international level. Cooperation in this field has been carried out for years in Europe and in North America. In Europe, 43 systemic energy operators from 26 European countries are parts of the European Network of Transmission System Operators for Electricity, ENTSO-E [10]. Energy companies from Belarus, Russia, Estonia, Latvia and Lithuania participate in the BRELL Energy Ring [11], despite energy companies from the Baltic States have many times declared that they would quit the network for political reasons. There are no unified energy systems in neither the United States nor Canada or Mexico, but energy companies from the three North American countries have to choose between four networks: Western Interconnection, Eastern Interconnection, ERCOT Interconnection centred around Texas, and Quebec Interconnection [12]. Such structure of the energy sector in North America, on one hand, prevents transportation of energy between different times zones, for example, between the Western Interconnection and the Eastern Interconnection, but it facilitates energy transportation among certain parts of the three North American nations.

Other regions of the world follow the experience of Europe and North America, through their efforts aimed at establishment of integrated energy systems are rather projects than functioning power grids. There are working interconnections in Southern Africa and in East Africa, and there are projects to build similar interconnections in other parts of Africa, such as the Nigeria-Niger-Benin-Burkina Faso Power Interconnection Project, Projet d'interconnexion électrique Cameroun-Tchad, and the Guinea-Mali Electricity Interconnection Project [13–15]. Saudi Arabia, Kuwait, Qatar, United Arab Emirates, Bahrain and Oman have established the Gulf Cooperation Council's Interconnection Authority with a mandate to coordinate electricity producers from those countries [16]. The Initiative for the Integration of the Regional Infrastructure of South America includes its "energy aspects" [17], though the initiative has not yet come out with concrete plans in the field. Finally, the Asian Super Grid to be discussed below remains rather a project than a functioning power grid, despite it was proposed more than a decade ago.

Asian Super Grid: Ten Years Was Not Enough

Russia and South Korea proposed unification of energy systems in Northeast Asia as early as in 2000s. Thanks to Soviet practice, Russia has important experience with the use of long-distance power grids. Thanks to collapse of the Soviet Union, Russia also has important experience with international cooperation in the field. In 2002, the Korea Electrotechnology Research Institute, KERI, and the Institute of Energy Systems of the Russian Academy of Sciences proposed a project aimed at integration of energy systems in Northeast Asia [18]. Their plan involved connecting power grids of Russian Far East and of South Korea through the territory of North Korea. Russian and Korean experts were not the only ones to propose plans of integration of energy systems in Northeast Asia. For example, in 2008, the Hannes Seidel Stiftung proposed the Gobitech initiative aimed at providing electricity to the coastal regions of China, North Korea and South Korea produced at solar energy facilities in the desert regions of Mongolia and China [19].

However, the concept of the ASG, which aimed at creation and development of interstate energy associations of the countries of East Asia, was finally formed in 2011. The accident at the Fukushima Daiichi Nuclear Power Plant in Japan gave a shift to formation of the plan. The accident did not only result in serious environmental consequences at both regional and global levels, but it also forced Japan itself and its neighbouring states to rethink their energy policies. Masayoshi Son, a Korean Japanese entrepreneur famous for investments in production of solar energy, initiated the project. The ASG aimed at unification of electric grids of Japan, South and North Koreas, China, Mongolia and Russia for mutual benefit by means of exchanging energy produced from renewable sources, such as wind and solar power, as well as hydroelectricity [20].

Proponents of the ASG expect Japan and South Korea to play the roles of consumers rather than producers of energy, North Korea will play the role of a consumer and a transit country, China and Mongolia will play the role of energy producers and transit countries, while Russia will play the role of important energy producer. The innovative component of the ASG is its focus on hydroelectricity and renewable energy sources. Despite the ASG today is far from being completed, international power grids that might become vital elements of future ASG have been constructed throughout 2010s. In particular, separate cross-border power lines with a voltage of mainly 110–220 KV and with a capacity of 100–150 MW are now connecting territories of Russia and Mongolia, China and Mongolia, Russia and China, and trade in electricity is underway between these countries. Mongolia imports electricity from Russia through interconnection in order to compensate for the shortfall of electricity supply in the northern central area during winter peak.

Also, Mongolia imports electricity from the Inner Mongolia Autonomous Region in China due to electricity demand of the Oyu Tolgoi copper mine in the south. Through the interconnection across the Amur river electricity is exported from Amurskaya Oblast in the Russian Far East to Heilongjiang Province in Northeast China [21]. Since 2011, an export power transmission line with a voltage of 500 kV began to operate, connecting the Amurskaya substation (Russia) and the Heihe substation (China) with a capacity of 750 MW, and with a DC insert. The new line allows for exportation of electricity without ensuring the synchronous operation of the energy systems of the two states. Previously, the amount of electricity exported from Russia was 1,000 GWh or less per year. However, since completion of this high-voltage transmission line, the export grew to more than 3,000 GWh in recent years [22]. Since 2012, studies have been underway aimed at creation of solar and wind power complexes in the Gobi Desert in Mongolia with the prospect of including them in a single energy ring [19].

Scholars and entrepreneurs discuss projects of international power grids. For example, in 2014, Korea Electric Power Corporation (KEPCO) proposed the concept of a Smart Energy Belt that connects Japan, South Korea, China, Russia, and Mongolia with a highly efficient electricity supply-demand system combining power storage technologies and smart grid. In 2016 KEPCO offered a Northeast Asia Interconnection Vision as an approach for power grid connecting Northeast Asian countries. In 2015, the State Grid Corporation of China (SGCC) announced its Global Energy Interconnection (GEI) vision. Their vision is based on utilization of ultra-high-voltage transmission systems [21]. In 2016 SoftBank Group of Japan, State Grid Corporation of China, KEPCO and Rosseti of Russia signed a memorandum of understanding on research and planning for the promotion of the international power grid in Northeast Asia. Since 2017, a study has been underway aimed at interconnecting power grids of China, the Republic of Korea, and Japan; recently, the study has entered the stage of technical feasibility test and cost-benefit assessment [23].

Studies aimed at connecting Russia to ASG are also underway. In Russia, Skoltech and the Institute of Energy Systems of the Russian Academic of Sciences participate in the studies. In the Republic of Korea, the participating agency is the Korean Electrotechnology Research Institute (KERI) and Korea Energy Economics Institute (KEEI). In Japan, it is the Renewable Energy Institute. Russian researchers' group concluded that the annual economic effect from the formation of the energy super grid will exceed $24 billion. China and japan will be main beneficiaries of the project, although Russia will also earn as much as $2 billion annually [24, 25]. The ASG is a large project, which is impossible to coordinate from a single centre. Instead, one can distinguish multiple sub-systems within the future super grid. One of the sub-systems involves cooperation between the Russian Federation and the Republic of Korea in the field of electricity production and transportation.

The ASG is of great importance for both Russia and South Korea. In 2017, Moon Jae-in, the President of the Republic of Korea, included energy cooperation into his "Nine Bridges" Initiative, which outlines nine most important aspects of bilateral cooperation between South Korea and Russia [26]. Creation of a power interconnector between Russia, China, Japan and South Korea, according to Moon Jae-in, will significantly strengthen relations between Russia and South Korea. In 2018, Russian Energy Minister Aleksandr Novak declared Russia's willingness to participate in the project when addressing the Eastern Economic Forum [27]. Russia has also declared the "Eastern Vector" of development of its fuel and energy sector a priority. Such Russian strategic documents as Energy Strategy of Russia till 2035 (still a draft as of early 2020), the Development Strategy for Siberia, and the Strategy of Socio-Economic Development of the Far East and the Baikal Region include basic provisions for the development of that part of the country and of the country as a whole [8; 28; 29].

Russia's policy aimed at providing energy security in the country's Asian part has two priorities. First, Russia expects new energy centres in its Asian part to emerge with the aim at providing greater energy security for the whole country, including restoration and enhancement of energy connections between Russia's different parts. Second, it expects the decline in the cost of energy, including both electricity and fuels, and greater stability of energy supplies. Finally, Russia expects greater environmental safety of energy supplies in its Asian part, thanks to development of energy infrastructure connecting Russia's Far East and Northeast Asia, including building of international oil and gas pipelines and power grids. Russia aims at building of energy and transport infrastructure in its Asian part ready for integration into a common Asian energy space. However, development of the energy sector in the Asian part of Russia requires big capital investments. The cost of implementation of the strategy is estimated at U.S. $200–250 billion for the construction of new fuel and energy facilities alone.

New oil and gas pipelines and power grids will require additional U.S. $80–85 billion of capital investments [9, p. 37]. Therefore, it will be extremely difficult for Russia to develop the energy sector in its Asian part without bringing foreign direct investments into the field, which implies close international energy cooperation between Russia and the countries of Northeast Asia. Connecting Russia's Asian part to the ASG is a less costly venture. KEPCO estimates that interconnection of Russia, China, South Korea and Japan into an Asian Super Grid would require investing 7,2 to 8,6 trillion won, i.e. U.S. $6 to 7 billion [30]. Also, according to KEPCO, interconnection of Russia and South Korea through the territory of North Korea would require investing up to 3 trillion won, i.e. U.S. $3 billion [21]. However, according to the Ministry for the Development of the Russian Far East and Arctic, interconnection of the four nations would require up to U.S. $30 billion [31].

Besides the infrastructure cost, one should also consider differences in currency exchange rates and tariffs. In Russia, corporate consumers are subjects to higher electricity tariffs, while electricity tariffs for households are subsidised by the state. To the contrary, in South Korea, corporate consumers are subjects to lower electricity tariffs that are introduced with the aim to support domestic producers of industrial goods. In late 2016, after Russia revised its Energy Law, the government introduced a series of measures aimed at decreasing average consumer price on electricity in the Far East to average consumer price on electricity in the whole country. Emergence of a common market of electricity between Russia, China, South Korea and Japan could result in the growth of average consumer price on electricity not only in the Russian Far East, but also in Russia as a whole. To conclude, the ASG is a costly venture, but economic obstacles to its construction are only one type of obstacles that prevent fast implementation of the project. Other types of obstacles are technological obstacles, geopolitical obstacles and legislative obstacles.

Under technological obstacles, it is meant the difference in parameters of power grids in Russia, China and Mongolia, on one hand, and in South Korea and Japan, on the other. In Russia, China and Mongolia electricity networks operate at 220 V and 50 Hz. In South Korea, it operates at 220 V and 60 Hz. In Eastern Japan, in operates at 100 V and 50 Hz, while in Western Japan in operates at 100 V and 60 Hz [32]. Northeast Asia is the place where the European standard (220–240 V and 50 Hz) meets the American standard (100–127 V and 60 Hz), thus providing grounds for multiple variations as results of attempts to bridge the differences between the two standards.

Under geopolitical obstacles, it is meant the role of North Korea, which is not at all times positive, especially in the case of IKC in the form of an on-land high-voltage DC power line. High voltage power lines are more economical when transferring large volumes of energy over long distances. A DC power line allows transferring electricity between unsynchronized AC power systems; it also allows transferring electricity between AC power systems operating at different frequencies, in this case, 50 Hz and 60 Hz. The shortest route passes from Russian Far East through the territory of North Korea into South Korean province of North Gyeonggi, north of Seoul; the length of the route is around 1000 kilometers. At present, however, thanks to severe international sanctions imposed on North Korea, any trilateral cooperation in the energy sector seems unlikely. Other routes of unification of the power systems of Russia and South Korea, which involve laying submarine cables, are technically possible, but costs of such projects are much higher than the cost of an on-land high voltage line through the territory of North Korea.

Finally, under legislative obstacles, it is meant the difference in legislation among countries of Northeast Asia themselves, including South Korea, and the difference between those countries and Russia. For example, Japanese legislation bans imports of electricity entirely. At the moment, the Japanese Parliament is debating amendments to the country's national legislation necessary to adopt in light of possible unification with the ASG [21]. In China, in Russia and in South Korea national legislations allow imports of energy; however, there are other significant differences between corresponding legislations in Russia and China, in China and South Korea, and in Russia and South Korea. For example, as noted above, Russia has introduced higher electricity tariffs for commercial consumers to support households, while South Korea has introduced lower electricity tariffs for commercial consumers to support businesses. Legislation regulating energy sectors in Russia and South Korea do not differ in the aspect of the tariffs alone. A more detailed comparison of the legislations in the energy sector in Russia and in South Korea will be presented below.

Energy Sector Reforms in Russia and in South Korea

Russia inherited its energy sector from the Soviet Union, while democratic South Korea inherited its energy sector from the Cold War-era South Korea, which was one of the closest allies of the United States in East Asia. One could have expected great differences between legislations regulating energy sectors in Russia and South Korea in 1990s. However, in fact, the differences were not as great. In both countries, one large state-owned company dominated the energy sector: Korea Electric Power Corporation (KEPCO) and Unified Energy Systems (UES) of Russia. In 2000s both countries undertook reforms aiming at decentralization and privatization of their energy sectors. Below I will demonstrate that Russia completed the reform, while South Korea left it halfway. As a result, more differences between legislations regulating energy sector in Russia and South Korea emerged as outcomes of the energy reforms. Below, I will compare the outcomes of the reforms from two viewpoints, namely their contribution to increase in the share of electricity produced from renewable energy sources in national energy balances, and their compatibility with integration of the energy systems into wider networks.

The Republic of Korea took the path towards development of green economy under President Lee Myung-bak. On August 2008, Korea announced a new Low-Carbon, Green Growth vision aimed at shifting the traditional development model of fossil fuel-dependent growth to an environmentally friendly model [33]. To realise this vision, the Presidential Commission on Green Growth was established in February 2009. The Basic Act on Low Carbon and Green Growth was subsequently submitted and took effect in April 2010 [34].

Incumbent Moon Jae-in declared his support to the trend towards reduction of the share of nuclear energy in global energy balance a month after being elected President. He declared that construction of new nuclear power plants would cease, and the activities of reactors that had exhausted their resources would not be extended [35]. Also, as part of South Korea's policy aimed at reducing carbon dioxide emissions into the atmosphere, it was decided to stop the construction of new coal-fired power plants in exchange for obsolete ones. Third general plan for the development of the country's energy sector adopted in June 2019 set the goal to increase the share of renewable energy sources in the country's energy production to 30–35 % by 2040 [36]. One should remember that according to KEPCO, South Korean state-owned energy giant, in 2017 production of 1 kW/h of electricity at a nuclear power plants cost U.S. $0.057, it cost U.S. $0.062 if produced from coal, it cost U.S. $0.085 if produced from liquefied natural gas, and it cost U.S. $0.092 if produced from renewable sources [37]. Transition of South Korea to energy balance, in which renewable energy sources would play a greater role, but the cost of electricity did not rise dramatically, would require enhanced economic cooperation, including integration into the ASG.

Structural features of the electric power industries and markets of the participating countries will play an important role when creating an international energy system, such as the ASG. Russian reform aiming at decentralization of the country's electric power industry undertaken in 2004–2008 determined the current state of the industry, its structure and its organizational and management system. After the collapse of the Soviet Union, state-owned company with minor private investors, including foreign investors, RAO UES of Russia, established in 1992, owned 72 % of the installed capacity of electric power generation and 96 % of the length of power lines of all voltage classes. The company's activities covered all areas of the industry: production, transportation, distribution and marketing of electricity. The company split as a result of the reform undertaken in 2004–2008. Dividing lines went between naturally monopolist sectors of the industry, such as transportation of electricity and dispatch control of its transmission, and potentially competitive sectors, such as electric power generation, distribution and marketing, maintenance and services [38].

Two types of companies were built in the electric power generation sector: wholesale power generation companies (WGCs) and territorial power generation companies (TGCs). WGCs were organized in accordance with extraterritorial principle. Six thermal WGCs with similar starting conditions, such as installed capacity, asset value and average equipment, were established. Each of the thermal WGC owned assets located in different parts of Russia to prevent potential rise of any of them to the position of a monopolist in a certain part of the country. RosHydro, the company operating 53 Russia's biggest hydropower plants became the seventh WGC. Rosenergoatom, the company operating Russia's nuclear power plants, had been excluded from the RAO UES of Russia system even before the reform [39].

Unlike WGCs, 14 TGCs were organized in accordance with territorial principle: they operate smaller generation facilities, including thermal and hydropower plants as well as facilities generating electricity from alternative sources, in certain parts of Russia, from TGK-1 operating in Northwest Russia to TGK-14 operating in Russia's Far East. The reform created conditions for private investors to enter potentially competitive areas, foreign companies also entered the industry. German E. On took control of WGC-4 with 83.7 % of shares, and Italian Enel took control of WGC-5 with 56.4 % of shares. In 2008 Finnish Fortum came to control TGK-10, a power generation company of Western Siberia, which now officially bears the name of AO Fortum. Companies of various forms of ownership appeared also in the sector of distribution of electricity. To conclude, the reform introduced a competitive model, which gave a shift for the development of Russia's electric power industry [39].

Electricity transportation system of Russia consists of the unified energy system of Russia and territorially isolated energy systems. The unified energy system of Russia consists of seven regional energy systems, such as the energy systems of Central Russia, Middle Volga, Southern Russia, the Urals, the Northwest Russia, Siberia and the Far East, united in one. The Far Eastern regional system covers five regions of the Russian Federation, namely Primorsky Kray, Khabarovsky Kray, Amurskaya Region, Jewish Autonomous Region and southern part of the Republic of Sakha Yakutia. Three high-voltage power lines of 220 kV connect it to Siberian energy system. The Far Eastern regional system borders the energy system of China. Isolated energy systems are located in the north-eastern part of the country, they operate in Kamchatka and Chukotka, in Sakhalin Region, including the Kuril Island, and in Magadan Region, in the Energy District of Norilsk and Taymyr, in the Nikolaevsky Energy District, and in northern part of the Republic of Sakha Yakutia. Isolation of those energy systems is grounded in their geographic distance from most inhibited parts of Russia, as well as with technological difficulties of constructing high-voltage power lines across permafrost territories [40].

As of January 1, 2019, total capacity of all Russian power plants was more than 1000 TWt/h, of them 68 % accounted for thermal power plants, 20 % for hydropower plants, and 12 % for nuclear power plants. Almost 64 % of electricity generated in Russia in 2018 was generated at thermal power plants, 19 % at nuclear power plants, and 17 % at hydropower plants. Electricity generation out of alternative sources accounted for less than 1 % of total electric power production [40].

South Korea's energy sector has been restructuring since the late 1990s. This industry has traditionally been a state monopoly. The main objective of the reform was to introduce principles of free competition. In January 1999 the government announced the Basic Plan for Restructuring the Electricity Industry. The plan included the unbundling and privatization of Korea's state-owned electricity monopoly, KEPCO. The power generation part of KEPCO was split into six wholly owned companies — five thermal generation companies and the Korea Hydro & Nuclear Power Company Limited. The five thermal generation companies were to be privatized in stages. However, in July 2008, the government announced there would be no further privatization of KEPCO and its five subsidiaries. At the end of 2015, 51 % of KEPCO, a holding company, was owned by the Korean Government [41]. KEPCO is still a dominant player in the electricity sector, controlling 79 % of total power generation and 100 % of transmission and distribution in the Republic of Korea. South Korea's electricity generation in 2016 was 558 terawatt-hours (TWh). Generation of thermal energy, including coal, oil and natural gas, accounted for 64 % of the total electricity generated, followed by nuclear energy at 29 % and hydropower and renewables at 3.6 % [41].

In both the Russian Federation and the Republic of Korea energy sectors are open to private companies, including foreign investors. In both countries' energy production is separated from energy transportation and energy distribution, and in both countries state-owned companies control energy transportation. Both countries have established their national wholesale markets of electricity aiming at market liberalisation of electricity sales. International trade in electricity in Russia is in the hands of the state-owned Inter RAO Company, in South Korea international trade in electricity is in the hands of KEPCO.

Russia and South Korea also significantly differ in terms of the structures of demand and supply of electricity in the two respective countries. Demand of electricity in South Korea reaches its seasonal peak twice a year, in summer and in winter, while in Russia it reaches its seasonal peak only once during the year, in winter. In summer, Russia is capable of producing more electricity than the demand is; thus, Russia can export part of it to neighbouring countries, such as South Korea, where another seasonal peak of electricity consumption occurs in summer. Structures of energy demand in Russia and in South Korea in wintertime are also different: while in Russia demand of electricity quickly grows already in October, in South Korea, it starts slowly growing in November only [21] Daily peaks of electricity consumption in Russia and in South Korea differ, too. In winter, demand of electricity in South Korea during the day usually reaches its peak in the morning, while in Russia it happens in the evening. In addition, due to time difference, demand of electricity in Russia reaches its peak daily with a one- or two-hour delay compared to South Korea [21].

Conclusions

Nine years since the accident at Fukushima Nuclear Power Plant in Japan, which gave a shift to plans aimed at construction of the Asian Super Grid, have not been enough to complete the project. Seven years since South Korea's President Park Geun-hye proposed to connect her country to an emerging Eurasian power network through the Inter-Korean Connector were not enough for that project either. A set of obstacles, including geopolitical, economic, technological and legislative factors, this article focusing on the latter group, have been preventing the two projects from being implemented. To answer the questions, to what extent the energy systems of Russia and South Korea are prepared to integration into a greater regional network, this article has undertaken a comparative analysis of the energy sectors reforms that the two countries undertook in 2000s. The two energy reforms took place almost simultaneously, and the content of the reforms was also similar in Russia and in Korea: they aimed at decentralization of the energy sector.

Originally, large state-owned companies dominated energy sectors of the two countries: KEPCO of Korea and UES of Russia. In Russia, the reform was implemented as planned, which resulted in decentralization and privatization, also to foreign investors, of energy production, while transportation of energy to large distances remained in the hands of the state through state-owned company System Operator of the UES of Russia. That created competition among energy producers, including in the field of electricity production from renewable sources, which resulted in significant increase in production of hydropower (including from small-capacity hydropower plants), wind power, solar power, and tidal power.

In South Korea, the reform stuck in late 2000s, thus leaving over half of energy production in the hands of KEPCO. On one hand, that did not prevent the country from increasing the share of electricity produced from renewable sources in its energy balance. Given the country's size and geography (Korea is located on a peninsula characterized by vast mountainous areas and high density of population in lower-altitude areas), Korea placed increase of capacity of floating solar and wind power facilities into the core of its strategy aiming at increase of the share of electricity produced from renewable sources in the country's energy balance. Korea's success in adding floating capacities is remarkable. On the other hand, the uncompleted energy reform remains an obstacle to international collaboration, including formation of the Asian Super Grid and building of an interconnector with Russia through the territory of North Korea, as well as to increase in the share of foreign direct investments in the energy sector. That sets a natural limit to increase of the share of electricity produced from renewable sources. In the future, when South Korea reaches the limit, it will face the necessity to revisit the issue of reforming its energy sector. That will reopen the way towards formation of the Asian Super Grid and of an interconnector between South Korea and Russia through the territory of North Korea.

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