Can Russian Arctic Regions Benefit from Collaborating with Northeastern China? Current Challenges to the Low-Carbon Agenda

Gao Tianming, Vasilii Erokhin, Zhu Dianyong & Zhu Gexun

The need to boost economic growth and develop high-tech energy-intensive industries requires an all-out effort to increase power generation. On the other hand, the human-induced carbon footprint has become so evident that radical actions are needed to reduce emissions and decarbonize the energy sector. Russia's attitude to the international carbon neutrality agenda is essential since the bulk of hydrocarbons and coal comes from the Russian Arctic, Siberia, and the Far East, where climate change is rapidly advancing. At the same time, Russia is facing a growing territorial imbalance between the demand for energy in the European part of the country and the extraction of fossil fuels which is shifting further to the northeast to the Arctic. Due to the abundance of local energy resources, most Russian Arctic regions prioritize further exploitation of oil, gas, and coal fields. Nevertheless, some territories have started turning to renewable energy in an attempt to overcome infrastructure gaps and to make local energy mixes more resilient to energy supply disruptions. Since the mid-2010s (the first international sanctions against Russia), part of Russia's energy supplies has been redirected to China (the Turn to the East policy), while Chinese companies have increased their share in Russia's energy sector. China is interested in expanding transboundary energy supply for domestic needs in the northern and northeastern provinces, making Russia's Far East and the Arctic zone particularly attractive to Chinese investors. However, the heated conflict in Ukraine has disrupted conventional collaboration formats with Russian energy companies, cut Russia from Western technologies and equipment, and forced the EU countries to embargo Russian oil. The chapter attempts to feel around for the new reality mechanisms of Russia-China collaboration which could contribute to bridging the spatial development gaps in the energy sector and address the contemporary challenges posed to the low-carbon transition in the Russian Arctic.

Introduction

One of the United Nations Sustainable Development Goals (SDGs) states that "all people and businesses worldwide should get universal access to affordable, reliable, sustainable, and modern energy and related energy services" (United Nations, 2022a). In recent decades, however, the increase in production and consumption of energy both for industrial and personal needs has significantly exacerbated global environmental and climate issues. As estimated by the United

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Nations (2022a), the energy sector is the source of 73% of all greenhouse gases of anthropogenic origin. Many studies indicate that the carbon footprint of the energy sector is increasing (United Nations Framework Convention on Climate Change, 2018; Panait et al., 2019; Andrey et al., 2021), while the average annual concentration of carbon dioxide in the atmosphere is breaking new records every year (not even every decade) (Klimenko et al., 2021). There is a growing sentiment (see, for example, Bansal et al. (2005), Khambalkar et al. (2010), Lundy (2019), and Sayigh (2021), among others) that the only way for humanity to avoid a climate catastrophe is to decarbonize all spheres of energy production and consumption. Decarbonization is a wide concept that involves not only reducing emissions of pollutants from traditional energy sources and increasing the energy efficiency of oil, gas, and coal, but also a systematic transition from conventional fossil fuels to renewable energy. Integrating the climate and environmental agenda into national and international energy development programs to ensure an accelerated green transition is one of the fundamental conditions for achieving the United Nations SDGs by 2030 and beyond (United Nations, 2022b, 2022c). In most developed countries and in many developing economies, the strategy of green growth through the decarbonization of the energy sector and by increasing the share of renewable energy sources in the national energy mix is becoming the dominant trend of long-term sustainable spatial development and for smoothing the imbalances between energy-abundant and energy-scarce territories (Van, 2014; Sadiku et al., 2019; Kokorin, 2017; Nosko, 2017). In light of the increasing environmental and economic sustainability of spatial development, renewable energy based on local energy sources is turning into an important element in ensuring the energy security of individual territories (United Nations Development Program, 2012; Somani & Koenig, 2018; Avramenko & Baiguskarova, 2018) and an effective tool for stimulating green growth and reducing emissions of carbon dioxide and other pollutants into the atmosphere, soil, and water areas (Dincer, 2000; Xu et al., 2018).

Commitment to decarbonization and low-carbon development of the energy sector implies a fundamental transformation of the entire chain from the extraction of natural energy resources to the final consumption of goods and services. According to the United Nations Development Program (2022), achieving the global goal of curbing the pace of climate change within 1.5°C requires a radical reduction of carbon dioxide emissions globally by almost half by 2030 and the subsequent complete abandonment of carbon-emitting energy solutions in the second half of the 21st century. It is natural that each country should make its individual contribution to achieving this global goal. Nevertheless, a reasonable chance of overall success can be achieved only in the case of concerted actions and coordinated low-carbon policies of the largest producers and consumers of energy. Among these trendsetters are Russia, one of the world's largest suppliers of oil, natural gas, and coal, and China, one of the world's largest consumers of energy. The role of Russia is all the more important because a significant part of fossil fuels produced in the country falls on the Russian Arctic – about 80% of all Russia's natural gas and 17% of its oil. Russia's section of the continental shelf contains more than 85.1 trillion m^3 of natural gas and 17.3 billion tons of oil (including gas condensate) (Erokhin et al., 2019). Energy resources extracted in the Russian Arctic are supplied to China as part of both joint investment endeavors (Yamal LNG and Arctic LNG 2) and long-term infrastructure projects (Power of Siberia pipeline) (Erokhin et al., 2022). The main entry points of Russian energy resources into China are the northeastern provinces of the country, namely, Heilongjiang Province and Jilin Province (Power of Siberia and oil and natural gas plants in Sakhalin), Liaoning Province (maritime supplies from Yamal, Novy Port, and Prirazlomnaya offshore oil platform), and Inner Mongolia Province (Power of Siberia 2 under construction) (Figure 1).

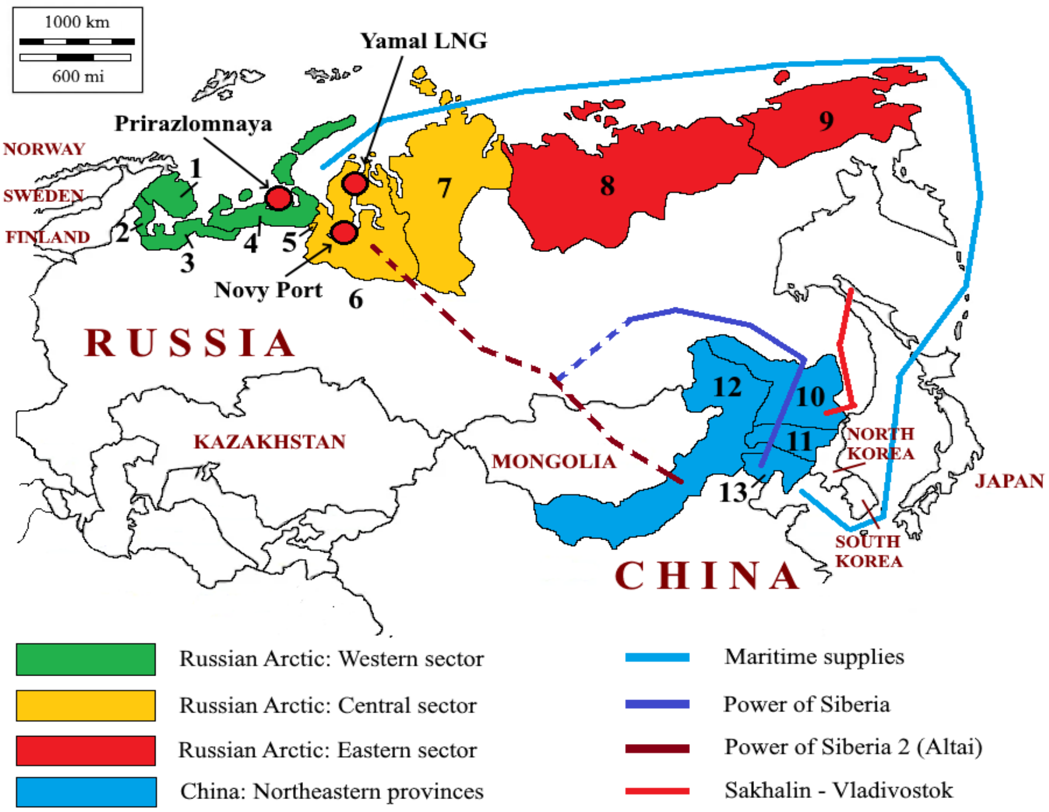

Figure 1. Russia's Arctic Zone and China's Northeast: supplies of oil and natural gas

Note: 1 = Murmansk Oblast; 2 = Republic of Karelia; 3 = Arkhangelsk Oblast; 4 = Nenets Autonomous District; 5 = Komi Republic; 6 = Yamal-Nenets Autonomous District; 7 = Krasnoyarsk Krai; 8 = Republic of Sakha (Yakutia); 9 = Chukotka Autonomous District; 10 = Heilongjiang Province; 11 = Jilin Province; 12 = Inner Mongolia Province; 13 = Liaoning Province

Source: Authors' development

However, there are both strategic and tactical challenges to the existing spatial format of energy cooperation between Russia and China. The former ones center around the sustainable development dilemma: the need to maintain a certain relationship between the goals of economic and spatial development and the impact of such development on the environment and climate. Oil, gas, coal, and other natural resources are the core pillars of the economic and social development of Russia's circumpolar territories (Gao et al., 2021). Energy consumption and massive imports of all types of energy are the fundamentals of China's industrial development and economic growth. However, oil and gas fields being explored in Russia's High North are being depleted. Exploration and development of new hard-to-recover fields further to the north and the east of relatively densely populated territories in Central Russia incur not only substantial production and transportation costs, but also increasingly negative effects on the climate and the fragile Arctic ecosystems (Winzer, 2012; Lucas et al., 2016). Most recent studies, such as Luoto et al. (2019), Polvani et al. (2020), Cai et al. (2021), and McCrystall et al. (2021), show that the climate change in the Arctic outpaces the global average. Although it is hardly possible to quantify the individual contribution of the energy sector in the Russian Arctic to the acceleration of climate change in the

High North as a whole, the existence of such an influence is to be admitted (Southcott et al., 2018; Nuttall & Callaghan, 2019; Gao & Erokhin, 2020b; Morgunova & Kovalenko, 2021).

The second group of tactical challenges (which are actually intrinsic to such countries as Russia and China, which significantly depend on the supply or consumption of a homogeneous range of resources) includes the desire to protect the energy sector from external force majeure events. These include fluctuations in prices on the global energy market (Galinis et al., 2020), disruptions of supply chains due to trade, economic, or political disagreements between counterparts (for example, trade tensions between China and the USA or between Russia and the EU), and, most recently, a sharply intensified international sanctions regime against Russia in connection with the military conflict in Ukraine. The sixth package of sanctions against Russia announced in June 2022, among other measures, included a partial embargo on oil supplies from Russia (European Council, 2022). It is planned that the EU will abandon purchasing oil from Russia before the end of 2022 and petroleum products and oil derivatives during the first quarter of 2023. The ban on the insurance of transportation of oil from Russia by sea may hurt oil transportation to China from oil sites in Yamal and the Prirazlomnaya offshore platform in the Pechora Sea via the Northern Sea Route (NSR). China has not yet declared joining international sanctions (most probably, such a thing would never be declared openly). It adheres to continuing cooperation with Russian companies under previously concluded contracts and agreements reached. Nevertheless, from an operational angle, maintaining everyday ties would become difficult – mind at least restrictions on international settlements, sanctions against major Russian companies, banks, and energy tycoons, and the refusal of international insurers to service Russian vessels. In such a situation of extreme uncertainty, the natural desire of any consumer is to diversify not only the sources of supply, but also the means of generating energy to ensure its own energy security (Esfahani et al., 2021).

Such a two-dimension strategic and tactical vision of the energy-related issues currently shapes the spatial patterns of the Russia-China energy agenda. Considering both the strategic focus on combating climate change by decarbonizing the energy sector, and current uncertainties in the formats of work with Russian companies against the background of sanctions and a partial embargo on Russian oil imports, one of the options for energy cooperation between Russia and China in the Arctic and cross-border cooperation between Russia's Far East and China's Northeast may be renewable energy. In China, this sector is growing rapidly. The country is making a radical transition from the dominance of coal in the national energy mix to lower-polluting sources of energy (Salygin et al., 2015). Many studies (Zheng et al., 2020; Turnbull et al., 2016) unequivocally link China's current environmental problems with the rapid growth of coal-based energy generation during the early industrialization period in the 1980-1990s. As Mastepanov (2020) demonstrates, in the northern provinces, atmospheric pollution triggers more frequent droughts and other extreme climate events. As part of the green growth and decarbonization agenda, China has doubled the share of renewable energy sources in the total energy mix over the past two decades. Since 2014, the share of renewable energy in China's energy balance exceeds the global average.

In Russia's energy sector, renewable energy is of minor importance. In the Russian Arctic, the role of renewable energy in establishing territorial energy balances is even smaller. Nevertheless, the development of small decentralized energy solutions based on local renewable sources is of critical importance for ensuring sustainable spatial development of remote Arctic territories and settlements. Such an infrastructure would make it possible to establish an energy reserve in case of supply disruption, reduce energy supply costs, and strengthen the overall energy security of circumpolar territories. In the Far East, trans-border cooperation with China in generating and transmitting energy from renewable sources could diversify the energy balances of both sides. Despite the fact that until recently, the Russia-China energy cooperation in the Arctic has been focused on mega-projects in the conventional energy sector without due consideration of the specifics of sustainable spatial development, this study aims to explore the possibilities of diversifying such cooperation and triggering decarbonization processes in the Russian Arctic through renewable energy.

The Low-Carbon Agenda in Russia and China

Along with the different dynamics of the development of the renewable energy sector in Russia and China, the national specifics of the green transition policies and the low-carbon agenda also differ. Russia focuses on the climate and environmental effects of renewable energy development, while China also priorities the need to diversify energy sources and gradually move away from the dominance of fossil fuels in the energy mix (along with stressing the crucial importance of climate change mitigation and sustainable development of ecosystems) (Erokhin & Gao, 2022).

In Russia, the main directions of renewable energy development are determined by a document entitled "State Policy in the Field of Improving the Energy Efficiency of the Energy Sector Based on the Use of Renewable Energy" (Government of the Russian Federation, 2009). Being first adopted in 2009, the policy was substantially updated in 2021. The document defines the development goals in the renewable energy sector for the period up to 2035 and the fundamental principles of this development. It is assumed that by that time, the share of renewable sources in the country's energy mix will reach 6% (currently about 1%). Russia wants to achieve such a significant breakthrough in the renewable energy sector through the implementation of a triple set of measures for the development of energy generation and transmission, economic incentives for the construction of new power generation and storage facilities, and improving the efficiency of government support and public regulation of the renewable energy sector (Table 1).

Table 1. Development measures in Russia's renewable energy sector

Spheres	Development measures
Infrastructure for power generation, transmission, and storage	Scientific and technological services for the development of renewable energy
	Rational use of the potential of the domestic renewable energy sector
	Information support and introduction of advanced information technologies
	Training programs and dissemination of knowledge
	Documentation for the construction and operation of power generation facilities
	Stimulation of consumption of renewable energy and good produced thereof
Market environment and institutions	Price regulation in the wholesale renewable energy market
	Obligation to purchase a given amount of renewable energy
	Improvement of the legal regime for the use of natural resources
	State support for the renewable energy sector from the government budget
Public governance in the renewable energy sector	Improvement of the system of target indicators
	Monitoring the achievement of targets in the renewable energy sector
	Improvement of state statistical reporting in the renewable energy sector
	Updating the allocation scheme of renewable energy facilities
	Attraction of investment in the establishment of power generation assets
	Support of small businesses in the renewable energy sector

Source: Authors' development based on Government of the Russian Federation (2009)

Russia mainly focuses on developing the infrastructure for producing and transmitting hydropower, solar, wind, and other kinds of renewable energy. In this sphere, the following measures are implemented (Government of the Russian Federation, 2009):

- increase in the efficiency of research and innovations for the development of the renewable energy sector and maintenance of power generating facilities;
- rational use of the potential of domestic industry for promoting renewable power solutions, including through providing state support for the export of basic and (or) auxiliary power generating equipment;
- establishment of the information environment, including assistance in the creation and development of an expert and consulting network of engineering and information support for developing the renewable power sector and introducing advanced information technologies to management;
- development and implementation of programs for the dissemination of knowledge about the use of renewable power and the training of specialists in the spheres of design and operation of power generation facilities;
- stimulation of economic entities and households to consistently increase consumption of energy derived from renewable sources and consume related goods and services.

The improvement of the governance system includes six kinds of measures (Government of the Russian Federation, 2009):

- elaboration and revision of target indicators in the renewable power sector;
- monitoring the achievement of established targets, including their periodic clarification based on Russia's priorities in the economic, energy, and environmental spheres;
- better data collection, analysis, and state statistical reporting related to the use of renewable power facilities;
- development and regular updating of the allocation scheme of power generation facilities across Russia, taking into account the location of productive forces, economic development of individual territories, and available renewable energy resources, including a list of projects for the construction of new and reconstruction of existing power generation facilities;
- development and implementation of measures to attract non-budget (private, foreign, etc.) investments in the construction of new and reconstruction of existing power generation facilities in the renewable energy sector to achieve target thresholds of capacity growth (including the attraction of venture capital);
- elaboration of a set of measures to promote the growth of small and medium-sized power generating facilities in the renewable energy market.

In regards to market regulation of generation, transportation, storage, and use of energy obtained from renewable sources, the policy aims at creating a fair market environment and equal conditions for competition between producers and suppliers of energy (Government of the Russian

Federation, 2009). Some of the public regulation measures include the obligation of energy market actors to purchase a certain amount of renewable energy, the establishment of rules for the use of natural resources for the construction and operation of power generation facilities, as well as various mechanisms of direct and indirect public support for the renewable energy sector.

Similar to Russia and the international community, China aims to increase in every possible way the contribution of renewable energy sources to the country's energy mix as one of the green transition measures and climate change mitigation efforts (Khazova, 2019). In particular, the development of renewable energy as part of the energy strategy and the quality growth trajectory of the power sector with Chinese characteristics in the new era (State Council Information Office of the People's Republic of China, 2020) corresponds to the general principles of China's development, which prioritizes "resource conservation and environmental protection" (Xi, 2017: 45). In 2017, President Xi Jinping underscored the commitment of the country to promoting low-carbon development, preventing and controlling pollution of air, water, and soils, restoring ecosystems, and developing biodiversity protection networks (Xi, 2017: 45-46). The green development model is recognized to be an essential requirement of China's new development concepts (Xi, 2017: 428). China "embraces the vision of a global community of shared future and accelerates its transformation towards green and low-carbon development in economy and society" (State Council Information Office of the People's Republic of China, 2020) and aims to "speed up the building of … an industrial system for green, circular, and low-carbon development" (Xi, 2017: 429). In the international arena, China is one of the most active and action-oriented global actors in terms of both achieving the UN Sustainable Development Goals and implementing the international climate agenda. In 2020, President Xi Jinping pledged that China would scale up its Intended Nationally Determined Contributions by "adopting more vigorous policies and measures, striving to have carbon dioxide emissions peak before 2030 and to achieve carbon neutrality before 2060" (State Council Information Office of the People's Republic of China, 2020). Such a vision of China's role in building an "ecological civilization" (Xi, 2017: 47) is enshrined in China's Arctic Policy 2018, which states that "the Arctic situation now goes beyond its … regional nature, having a vital bearing on … the survival, the development, and the shared future for mankind" (State Council of the People's Republic of China, 2018: Foreword).

China's commitment to the low-carbon development agenda is the unifying thread in a set of documents on energy policy, such as the White Paper on Energy 2007 (State Council Information Office of the People's Republic of China, 2007), Energy Policy 2012 (State Council Information Office of the People's Republic of China, 2012), and Energy Development Strategies Notice of Action Plan 2014-2020 (State Council Information Office of the People's Republic of China, 2014). The latter articulates five tasks of the energy policy:

- improving energy security based on the effective use of "clean" coal, further growth of oil and gas sectors, promotion of renewable power, and establishment of an emergency reserve of power generation capacities and strategic reserves of oil;
- transformations in energy consumption – strict control over the use of energy, implementation of energy efficiency improvement plans, and changes in electricity consumption;

- optimization of the power consumption portfolio (less coal, more natural gas, nuclear energy, and renewables);
- expansion and deepening of international collaboration, establishment of a regional energy market, and participation in the global governance of the energy-related issues;
- development of energy-related technologies and innovative energy systems.

According to the State Council Information Office of the People's Republic of China (2020), the country prioritizes further promotion and use of renewable power as a principal element of its transition to carbon neutrality. However, as we have already noted above, along with a purely climatic and environmental agenda, the role of renewable energy in China is considered more broadly. Renewable energy is one of the factors of diversification of the energy mix, reduction of dependence on fossil fuels, as well as the development of the economy and welfare of individual territories based on local energy sources. To increase its energy security, China emphasizes not only the diversification of the energy mix, but also the diversification of energy sources (local or foreign, conventional and alternative) and the localization of the engineering of appropriate equipment for the generation, storage, and transportation of energy obtained from renewable sources. In light of this vision of the energy agenda, measures to develop China's energy sector can be divided into inward-directed measures and outward-directed measures (Table 2). The approach is somewhat different from that we observe in Russia, where the emphasis is on domestic measures, while exogenous factors are considered as threats rather than development opportunities.

Table 2. Development measures in China's energy sector

Directions	Development measures
Inward-directed measures	Development of gas and nuclear energy to diversify renewable energy sources
	Energy saving and improving the efficiency of fuel and energy use
	Establishment of the strategic oil reserve
	Development of clean coal technologies for optimal use of domestic reserves of coal
	Development of infrastructure for generation, storage, and transmission of energy
	Market reforms in the energy sector
Outward-directed measures	Diversification of energy cooperation and search for new markets
	Safety of transportation of imported energy resources
	Collaboration in the sphere of advanced energy technologies
	Diversification of types of energy imported from abroad

Source: Authors' development based on Wu and Storey (2007), Fang (2010), and Mastepanov (2019).

Inward-directed measures aim at (1) increasing the efficiency of using available energy sources and energy resources; (2) reducing dependence on energy imports through the development of domestic power generation capacities and the introduction of energy-saving technologies in industrial production and household consumption; (3) attracting foreign investment and technologies to develop the competencies of Chinese companies in exploration and development of hard-to-recover deposits; (4) reducing the carbon footprint of conventional industries; and (5) increasing energy efficiency of renewable sources. Like Russia, China pays much attention to government regulation of competition, pricing, and market relations in the renewable energy sector (Energy Research Institute, 2015) and the establishment of rules and standards for the generation and consumption of energy from renewable sources (Zeng et al., 2018).

Outward-directed measures focus on the diversification of energy suppliers (countries and companies), types of energy resources supplied (conventional coal, oil, and natural gas, electricity, and other types of energy carriers), as well as delivery formats (oil and gas pipelines, railway tanks (oil) and carriages (coal), cross-border power lines, oil and liquefied natural gas supplies by sea tankers). Chinese companies are strongly encouraged to enter into joint projects for the exploration of oil, gas, and coal deposits, as well as investment projects in the renewable energy sector outside of China. One of the priorities for the development of the energy sector is the establishment of long-term partnerships with major suppliers of energy resources.

Renewable Energy in the Russian Arctic

Russia's energy complex comprises the oil, gas, coal, and peat industries, nuclear power, electric power, and heat supply. Russia ranks among the world's top countries in hydrocarbon reserves and production and export of energy (in various forms) and energy-related technologies (particularly in the oil, gas, and nuclear sectors). Despite the abundance of fossil fuels, the country's energy mix is one of the lowest carbon-emitting among the world's major energy producers. More than 30% of electric power generation is accounted for by nuclear power and hydropower and about 50% by natural gas. The share of hydroelectric power plants, including pumped storage power plants, in the power generation portfolio is 20%. Hydropower dominates in the renewable energy mix (Table 3). As of 2021, the installed capacity of solar power plants and wind power plants was 0.834 GW and 0.184 GW, respectively. The total capacity of small-scale hydroelectric power plants exceeds 1.2 GW. The use of local fuels (peat, forestry industry residues, agricultural products, and household solid waste) plays a minor role in territorial energy mixes.

Table 3. Major parameters of the renewable energy sector in Russia in 2000-2020

Sectors / parameters	2000	2005	2010	2015	2020
Hydropower					
Share in the renewable energy mix, %	98.41	98.24	98.04	97.78	96.89
Total generation, TWh	162.44	170.95	164.82	166.31	196.00
Electricity generation per capita, KWh	1,109.00	1,190.00	1,149.00	1,147.00	1,436.00
Primary energy consumption, TWh	456.00	464.00	434.00	425.00	524.00
Energy consumption per capita, KWh	3,113.00	3,232.00	3,025.00	2,931.00	3,591.00
Wind power					
Share in the renewable energy mix, %	0.01	0.01	0.01	0.09	0.62
Total generation, TWh	0.01	0.01	0.01	0.15	1.14
Electricity generation per capita, KWh	1.00	1.00	1.00	1.00	9.00
Primary energy consumption, TWh	0.01	0.02	0.01	0.37	2.81
Energy consumption per capita, KWh	0.00	0.00	0.00	3.00	19.00
Solar power					
Share in the renewable energy mix, %	0.00	0.00	0.00	0.20	0.77
Total generation, TWh	0.00	0.00	0.00	0.34	1.86
Electricity generation per capita, KWh	0.00	0.00	0.00	2.00	11.00
Primary energy consumption, TWh	0.00	0.00	0.00	0.85	4.59
Energy consumption per capita, KWh	0.00	0.00	0.00	6.00	31.00

Source: Authors' development based on Our World in Data (2022)

By 2024, Russia aims to increase the installed capacity in the solar energy sector and the wind energy sector to 2.24 GW and 3.42 GW, respectively (Table 4). The volume of technically available renewable energy sources in Russia is equivalent to 4.6 billion tons of reference fuel.

Table 4. Targets for commissioning of generating capacities in the renewable energy sector in Russia by 2024, MW

Years	Wind power	Solar power	Small-scale hydropower	Total
2020	500.0	270.0	16.0	786.0
2021	500.0	162.6	24.9	687.5
2022	500.0	162.6	33.0	695.6
2023	500.0	240.0	23.8	763.8
2024	214.7	238.6	41.8	495.1
Total	3,415.7	2,238.0	210.0	5,863.7

Source: Authors' development based on Government of the Russian Federation (2009)

According to the updated Renewable Energy Strategy 2035 (Government of the Russian Federation, 2009), Russia aims at localizing at least 70% of solar energy equipment and technologies and 65% of those in the spheres of wind energy and small-scale hydropower by 2024. International sanctions would probably enforce Russia's attempts to substitute critical equipment and technologies across the energy sector. However, given the state of technology in the renewable energy sector, the exploitation of renewable sources of energy is cost-inefficient without government support (with the exception of hydropower). Major reasons for the underdevelopment of the sector include the following:

- low competitiveness of renewable energy projects compared to fossil fuels (abundance of fossil fuels in Russia, focus on oil, gas, and coal in the Arctic, volatile oil and gas prices on world markets, sanctions and embargo on oil, but still at least a breakeven profit for largest oil and gas tycoons – for example, Novatek in its LNG endeavors in Yamal);
- undeveloped renewable energy infrastructure, including (1) insufficient level and quality of research on renewable energy sources; (2) inadequate information environment, including information on potential energy resources and data on the parameters of ongoing projects and individual power plants; (3) weak regulatory framework and software tools in the design and operation of renewable energy facilities.

The power grid system (electricity, heating, and delivery of fuel to remote territories) is overcentralized. It primarily focuses on using fossil fuels to generate energy from conventional sources. Hydropower is part of the unified energy system, but the integration of other renewables into the power grid system remains weak. It requires the construction of power and heat supply lines, power accumulation facilities, and other kinds of renewables-related infrastructure.

The most promising sectors of renewable energy in the Russian Arctic are hydropower, wind and solar energy, biofuels, and ocean energy (Gao & Erokhin, 2022). Long winters (up to 300 days a year) with temperatures down to -50°C produce strong and steady winds. Along the coastline of the White and Barents seas and the Novaya Zemlya and Franz Josef Land archipelagos, the wind speed reaches 5-8 meters per second. With climate change, the strength and frequency of winds are increasing. The higher density of cold air compared to warm air results in the higher energy efficiency of wind farms in the Arctic compared to mid-latitude zones. Scattered wind turbines within a territory can be integrated into a single network and then into the country's united grid system (Gao & Erokhin, 2022), which significantly increases the spatial stability of wind energy development in remote Arctic territories. Several wind farms are operating in the Arctic: an experimental four-turbine wind farm in Labytnangi (Yamal-Nenets Autonomous District), a ten-turbine wind farm in Anadyr (Chukotka Autonomous District), and a three-turbine wind farm in Tiksi (Republic of Sakha (Yakutia)). In 2019, Enel Russia launched the construction of the largest wind farm in the Russian Arctic (201 MW, 57 turbines) on the Kola Peninsula (Murmansk Oblast). The Kola wind farm is projected to generate about 750 kWh of electricity per year, while reducing emissions by 600 thousand tons of carbon dioxide. Currently, the total capacity of all wind power plants in the Russian Arctic is 210 MW. They are operated either separately or in combination with solar panels and diesel generators.

Solar power plants can be installed in Eastern Yakutia. In cold climates, the potential for solar energy production increases. The lower the temperature, the more efficient solar cells work. Thus, at 0°C, the efficiency of solar cells increases by 10% compared to a moderate temperature of 20°C. As a result, the average annual intake of solar energy in the Arctic during the daytime can reach 2-5 kWh (up to 6 kWh in some territories). Solar power plants operate in the Republic of Sakha (Yakutia) (Batagai, Betenkes, Batamai, and other localities) and the Yamal-Nenets Autonomous District.

Hydropower plays a significant role in the energy mix of all nine territories of the Russian Arctic, especially the Western sector (Murmansk Oblast, Archangelsk Oblast, and the Republic of Karelia). There are seventeen hydroelectric power plants in Murmansk Oblast (including the Kislogubskaya tidal power plant in Ura-Guba (1.7 MW)), two plants in the Republic of Sakha (Yakutia), and one plant in Arkhangelsk Oblast. Severny power plant is being built in the Dolgaya-Vostochnaya Bay of the Kola Peninsula (12 MW, annual electricity generation – 23.8 million kWh). The station will become the first tidal power plant in Russia to reach the industrial level of energy generation. Another tidal power plant will be launched in the Mezen Bay (the White Sea) (8 GW, annual electricity generation – 38.9 billion kWh). However, the parameters of tides for stable energy production (intensity, frequency, constancy, water height, ice conditions, wind inertial currents, etc.) are poorly studied (Baumann et al., 2020). Due to technical issues, the production of both tidal and wave energy is geographically limited to ice-free areas or offshore waters in open water (mainly the Western sector of the Russian Arctic).

Geothermal energy can be produced in the eastern territories bordering China (the Far East, the Eastern sector of the Russian Arctic, Sakhalin Island, and the Kuril Islands) (Butuzov, 2019). Approximately, the heat reserves in the artesian basin of Western Siberia amount to 200 million Gcal per year. In Kamchatka and the Kuril Islands, the generation capacity of geothermal sources and the thermal capacity exceed 2,000 MW and 3,000 MW, respectively. In Kamchatka, geothermal resources can generate from 250 MW (eastern part of the peninsula) to 550 MW (central and northern parts). On the Kunashir and Paramushir islands, the potentials of geothermal reservoirs are 52 MW and 100 MW, respectively. In regards to thermal energy, the potential resources are thermal waters (about 1 km below the land surface). Geothermal stations may supply energy to remote settlements. When there remain unused oil or gas wells, then installing power plants incurs no substantial capital expenditures.

Spatial Patterns of the Renewable Energy Development

Studying spatial patterns of renewable energy development in the Russian Arctic, we should emphasize the increasing territorial imbalance between the demand for energy and its production

(Kudryashova et al., 2019). This applies to the entire energy sector, not specifically renewables. There is an increasing concentration of energy consumption in the European part of the country (60% of the country's total energy consumption) amid shifting the extraction and production of energy resources further to the northeast (over 80% of the total extraction of energy resources in the Russian Arctic). From the point of view of the sustainability of the energy complex, the main challenges are the instability of energy supply (cut off from the unified energy infrastructure and gas supply system) and local electricity generation based on the use of inefficient (economically) and dirty (environmentally) diesel fuel (Zaykov et al., 2017). Energy resources extracted in the Russian Arctic are exported out of the region, processed, and returned to the Arctic in the form of motor fuel. The use of natural gas is limited to areas around oil and gas fields or small deposits developed specifically for supplying power to large industrial clusters, such as the Norilsk mining and metallurgical industrial district. There are plans to supply liquified natural gas from Yamal to settlements along the Arctic Ocean coast, but such an initiative requires the construction of regasification terminals and gas distribution networks throughout the Arctic zone.

The comparative study of local development programs demonstrates that due to the abundance of local energy resources, most of the Russian Arctic territories prioritize further exploitation of oil, gas, and coal deposits. However, we see that the Western sector territories (not that rich in oil and natural gas) emphasize the need for developing renewable energy (Table 5).

Table 5. Regional priorities for the development of the energy sector in the Russian Arctic

Energy sectors	**Western sector**				**Central sector**			**Eastern sector**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Coal					X		X	X	X
Oil				X	X	X	X	X	
Natural gas	X			X	X	X			
Offshore energy projects	X		X			X			
Renewable energy		X	X						
Power generation and transmission	X	X				X		X	X

Note: 1 = Murmansk Oblast; 2 = Republic of Karelia; 3 = Arkhangelsk Oblast; 4 = Nenets Autonomous District; 5 = Komi Republic; 6 = Yamal-Nenets Autonomous District; 7 = Krasnoyarsk Krai; 8 = Republic of Sakha (Yakutia); 9 = Chukotka Autonomous District.

Source: Authors' development based on President of the Russian Federation (2020a, 2020b), Governor of Murmansk Oblast (2014), Government of Murmansk Oblast (2013), Assembly of Deputies of Nenets Autonomous District (2019), Government of Chukotka Autonomous District (2014), Legislative Assembly of Yamal-Nenets Autonomous District (2011), Governor of Yamal-Nenets Autonomous District (2018), Government of the Republic of Karelia (2018), Government of the Russian Federation (2020a, 2020b, 2021), Assembly of Deputies of Arkhangelsk Oblast (2019), Government of the Komi Republic (2019), Government of Krasnoyarsk Krai (2020), Head of the Republic of Sakha (Yakutia) (2020)

Western Sector of the Russian Arctic

The Western sector of the Russian Arctic includes Murmansk Oblast, Republic of Karelia, Arkhangelsk Oblast, and Nenets Autonomous District. Due to the combination of natural resources, landscapes, and climate, the Western sector territories enjoy the most favorable conditions in the Russian Arctic for the development of renewable energy. The relative density of population (compared to the Central and Eastern sectors) along with the high density of energy infrastructure make it possible to integrate renewable energy facilities into a centralized energy supply system. The development of renewable energy is mentioned among the development priorities in the Strategy of Social and Economic Development of the Republic of Karelia till 2030 (Government of the Republic of Karelia, 2018) and the Strategy of Social and Economic Development of Arkhangelsk Oblast till 2035 (Assembly of Deputies of Arkhangelsk Oblast, 2019). In Karelia, the flagship project in the renewable energy sector is the construction of cascades of small hydropower plants in rivers and lakes (Government of the Republic of Karelia, 2018; Government of the Russian Federation, 2020a).

Due to its specialization in the processing of timber, Arkhangelsk Oblast develops a project for the production of biofuels from timber industry residuals within the framework of closed-cycle waste-free production technology (Assembly of Deputies of Arkhangelsk Oblast, 2019). Another specialization of Arkhangelsk Oblast is the engineering and construction of marine equipment for various purposes, including equipment and sea platform blocks for exploring offshore oil and gas fields (Gao & Erokhin, 2020a). Together with the neighboring Murmansk Oblast, the two territories establish the largest technological and engineering cluster in the Western sector of the Russian Arctic in the spheres of building cargo vessels and icebreakers and the production of large marine engineering structures.

Murmansk Oblast establishes a center for constructing large-capacity offshore structures for the production, storage, and shipment of LNG. The local government also supports enterprises engaged in the repair and maintenance of marine machinery and equipment used to develop offshore deposits (Governor of Murmansk Oblast, 2014). Another promising venue is the enrichment of minerals and other natural resources on the Kola Peninsula. The Strategy of Social and Economic Development of Murmansk Oblast till 2020 and for the Period until 2025 (Government of Murmansk Oblast, 2013) involves the transfer of local production clusters to more environmentally friendly sources of energy, the reduction of the carbon footprint by updating coal and fuel oil boilers, and the increase in the share of renewable energy sources in local electricity generation.

Nenets Autonomous District stands somewhat out of the Western sector's low-carbon and renewable energy agenda. The territory is much richer in natural gas and oil compared to neighbor Arkhangelsk Oblast. Among the energy sector priorities, the Strategy of Social and Economic Development of Nenets Autonomous District till 2030 (Assembly of Deputies of Nenets Autonomous District, 2019) emphasizes the development of gas-condensate mineral resource centers (Korovinsky and Kumzhinsky gas-condensate fields and Vaneyvissky and Layavozhsky oil and gas-condensate fields) and oil and mineral resource centers (Varandeysky, Kolguyevsky, Kharyago-Usinsky, and Khasyreysky).

Central Sector of the Russian Arctic

The Central sector of the Russian Arctic is the largest source of hydrocarbons in the Arctic zone and the entire country. Yamal-Nenets Autonomous District alone produces 81% of Russia's natural gas (1/5 of the world's total output), 77% of gas condensate, and 6% of oil. The district ranks first in Russia in terms of reserves and volumes of natural gas production and second in terms of proven reserves of liquid hydrocarbons (oil and condensate). In total, 93 oil and gas fields out of 234 are being developed in Yamal-Nenets Autonomous District. Obviously, natural gas is the top priority for the local energy sector. The Strategy of Social and Economic Development of Yamal-Nenets Autonomous District until 2020 (Legislative Assembly of Yamal-Nenets

Autonomous District, 2011) underlines the development of natural gas fields in the Ob basin and the Ob Bay and the development of pipeline infrastructure (including the new Power of Siberia 2 pipeline that will connect the district with Russian South Siberia and then direct to Mongolia and China's Northeast). Yamal LNG is currently the most successful joint investment project in the Russian Arctic with the involvement of Chinese and other foreign investments. Arctic LNG 2 has been partially commissioned. Other promising endeavors include the development of Novoportovsk oil and gas condensate mineral resource center, Bovanenkovo gas-condensate mineral resource center, and Tambey group of fields (Governor of Yamal-Nenets Autonomous District, 2018). However, now it appears to be questionable whether the new LNG projects in the Russian Arctic could be launched due to the sanctions. In April 2022, as part of the fifth package of sanctions, the EU imposed direct sanctions against the Russian gas industry and banned the supply of LNG-related equipment to Russia. There is a ban on the sale, supply, transfer, or export to Russia, directly or indirectly, of goods and technologies used for gas liquefaction, regardless of whether such goods or technologies originate from the EU or not. The stop list includes installations for the separation of hydrocarbons during gas liquefaction, cryogenic heat exchangers and pumps, and other kinds of equipment for cooling and liquefaction of natural gas. Before the outbreak of the Ukraine conflict and the introduction of the sweeping sanctions against Russia, the share of foreign equipment in the Russian oil and gas sector averaged more than 50%, in particular, 48% in geological exploration, 49% in oil refining, 61% in increasing oil recovery, and 68% in LNG and offshore endeavors. The most painful is the ban on the supply of heat exchangers for large-capacity gas liquefaction. Before 2014, Russian companies used to employ spiral heat exchangers by Air Products (USA). First Crimea-related sanctions forced them to switch to using installations by Linde (Germany). Since then, the technology has not been localized (Gao & Erokhin, 2021). The first line of Arctic LNG-2 is 98% completed, but the launch is postponed until 2024. The second line (40% ready) can hardly be launched in the coming years, while the construction of the third line has not even started.

Krasnoyarsk Krai and Komi Republic also build their energy strategies on the exploration and exploitation of abundant mineral deposits, not only oil and natural gas, but also coal (Government of Krasnoyarsk Krai, 2020; Government of the Komi Republic, 2019). In the Komi Republic, the local government promotes deep processing of coal raw materials and coal chemistry in coal mineral resource centers in the Pechora coal basin (Government of the Komi Republic, 2019). In Krasnoyarsk Krai, eleven energy-isolated territories have no access to central power supply networks. Local power generation facilities use fuel oil and diesel fuel imported from neighboring territories and regions. Fuel supply chains are vulnerable due to short supply windows (several weeks a year) and undeveloped transport infrastructure (mainly small-scale deliveries by low-water rivers). Imported fuel is expensive both in terms of delivery and its storage on site. The depreciation of power generation facilities in the energy-isolated territories is about 70%. Therefore, the modernization of local power generation systems, including through the development of renewable energy sources, is a matter of time. It is hardly possible to abandon fuel oil and other fossils, but the pioneer hybrid solar power plants (Evenki district) show that diesel fuel consumption can be reduced by 15-20%. Taimyr has one of the highest potentials in the Arctic zone for the development of wind generation. Wind and wind-diesel facilities can be effective across the peninsula. Wind generation on Taimyr may become one of the ways to ensure energy supply to the NSR infrastructure (ports and support on-land facilities) and the Yenisey Siberia investment project. However, alternative energy is not considered the main type of power generation, but only one of the elements of the energy mix to increase the stability of energy supply in remote northern territories and compensate for failures in centralized energy supply or fuel delivery.

Eastern Sector of the Russian Arctic

Territories in the Eastern sector of the Arctic zone (Republic of Sakha (Yakutia) and Chukotka Autonomous District) face the most severe challenges to the sustainability of the spatial development of energy supply due to the weak territorial interconnectedness and a low level of energy infrastructure development. Therefore, both the Strategy of Social and Economic Development of the Arctic Zone of the Republic of Sakha (Yakutia) till 2035 (Head of the Republic of Sakha (Yakutia), 2020) and the Strategy of Social and Economic Development of Chukotka Autonomous District till 2030 (Government of Chukotka Autonomous District, 2014) prioritize spatial development by forming networks of interconnected industrial and energy clusters is a key sustainable development goal.

Two-thirds of the territory of Yakutia belongs to a decentralized energy supply zone (the Northern Energy District, an extremely sparsely populated area with less than 100,000 people). The main source of electricity in these territories is isolated local diesel power plants. The situation is similar in Chukotka, where three power networks (Anadyrsky, Egvekinotsky, and Chain-Bilibinsky) are disconnected from each other. A characteristic feature of the Chukotka power system is no market for unclaimed power, except for the supply of about 16 million kWh of electricity per year to neighboring Yakutia. The Chukotka Autonomous District is an energy-surplus region, but given the isolation of the territory, electricity cannot be exported or even redistributed within the district. Local power plants operate at low loads, which results in premature equipment wear and excessive fuel consumption. In general, for the Eastern sector of the Russian Arctic, the core issues of sustainable spatial development are the energy supply of remote territories and the development of local power generation facilities and power transmission networks.

Republic of Sakha (Yakutia) became the first region in Russia to adopt the regional law on renewable energy (Head of the Republic of Sakha (Yakutia), 2014). The regional program for the development of local energy facilities provides for the replacement of aging power generation facilities with cost-effective modern equipment, including an increase in the share of lower-cost renewable energy solutions in the energy mix. Examples of successful projects in the renewable energy sector are a wind-diesel complex in Tiksi and a power supply to isolated settlements through the construction of autonomous hybrid solar power plants (Verkhoyansky district). The Far East territories develop local small-scale renewable energy facilities in collaboration with Chinese firms (for example, agricultural and forestry biofuels, production of pellets and briquettes from wood and agricultural waste, and the conversion of boilers to biofuels). The development of small-scale nuclear power is considered an option for localizing energy supply for extremely remote areas of the Arctic (floating nuclear power plant in Chukotka). But such projects are both expensive and excessive for individual settlements. They make economic sense only when a power grid network unites residential and industrial objects across territories.

Russia-China Collaboration in the Energy Sector

The Room for China's Northeast

Russia-China collaboration in the sphere of renewable energy in the Arctic is still scarce. Solar Systems LLC has built solar power installations across central and southern Russia, but not yet in the Arctic zone, where construction, accumulation, and distribution costs are substantially higher, while the demand for energy across sparsely inhabited territories is lower. Russian Rosnano Group together with Chinese Zhongrong Trust International have created a Russia-China joint investment fund to promote joint projects related to the development of intelligent electric networks, improvement of the adaptability and efficiency of local and regional power systems, optimization of the allocation and distribution of power generation facilities, and stimulation of renewable energy consumption at the local level (wind farms in the coastal areas in the Russian Arctic and the Far East). RusHydro collaborates with Power China in the Far East and China's Northeast. The estimated capacity of renewable energy sources in the region is 500 MW. The two companies have launched wind complexes in Kamchatka and Sakhalin. In total, RusHydro plans to build 139 solar power plants and 35 wind farms. RAO Energy Systems of the East (affiliated with RusHydro Group) signed an agreement with Dongfang Electric International Corporation on cooperation in the energy sector in the Far East. In June 2022, Zhongyu Xinxing Energy Industry Corporation announced establishing an LNG terminal in Primorsky Krai (about 7 million tons per year). A low–tonnage LNG plant along with a logistics complex for the transshipment of liquid hydrocarbons will be built near the border (Khabarovsk Krai, Jewish Autonomous Oblast) to supply power generation plants and industrial enterprises in Heilongjiang Province.

Technological solutions that Russia needs to facilitate the low-carbon transition in the Arctic (and potentially carbon-neutral growth) include hydrogen energy technologies. There is a need for low-carbon hydrogen production technologies (conversion, methane pyrolysis, and electrolysis). In its Energy Strategy (Government of the Russian Federation, 2020b), Russia admits that most critical technologies could be borrowed from abroad (despite the overall trend of every possible substitution of all kinds of equipment and technologies fueled by international sanctions). Among the priorities in the hydrogen energy sector is the development of fuel cells based on hydrogen and natural gas for transporting and using hydrogen and hydrogen-based mixtures as accumulators and converters to increase the stability of centralized energy supply systems. A new promising source of energy is gas hydrates. Chinese research institutions and engineering companies lead the pack in this field. The Russian Arctic is abundant in near-the-surface gas hydrates. The exploration and exploitation of methane hydrates in permafrost zones across the Arctic require less sophisticated technologies than those Chinese engineers are testing in marine bottom gas hydrate deposits. There are no such technologies and equipment in Russia.

Chinese developers can compensate for the lack of digital technologies in the Russian energy market, including the Internet of Things, 3D modeling, modeling and forecasting based on big data analysis, neural networks, cloud computing, virtual and augmented reality, machine learning, computer simulation based on digital twins, intelligent sensors, production robotics, and additive technologies (Erokhin et al., 2018; Gao & Erokhin, 2020a).

In February 2022, Russia's President Vladimir Putin issued instructions following a meeting with the Government of the Russian Federation on developing alternatives to natural gas in those remote territories where connecting residential and industrial facilities to a unified gas supply system is economically inviable (President of the Russian Federation, 2022). Most of the circumpolar territories with no connection to the centralized natural gas grid fall under this category. Local authorities were expected to submit proposals for the development of alternative sources of energy by September 2022. However, the autumn escalation of the Russia-Ukraine conflict along with the start of the mobilization campaign in Russia on September 21, 2022, would delay many of the civil initiatives. Territories were requested to create targeted fuel and energy balances and monitor and forecast demand for all types of energy by various types of consumers (industrial, residential, municipal). It can be expected that when drawing up fuel and energy balances, local authorities will look for opportunities to use equipment and technical solutions offered by their Chinese counterparts. According to the Minister of Energy of the Russian Federation, remote territories in the Arctic, Siberia, and the Far East must promote using renewable energy sources, small nuclear generation, clean coal technologies, liquefied natural gas, and electric boilers and heaters. Current Russia's needs for equipment and technologies in the energy sector can be divided into three groups according to the dominant types of energy carriers: oil and gas (including LNG), coal (emission reduction and clean coal energy technologies), and power generation from renewable sources. Table 6 demonstrates the differentiation of needs per territory and sector.

Table 6. Russia's needs for energy-related technologies and equipment in the Arctic

Technologies and equipment	**Western sector**				**Central sector**			**Eastern sector**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Analysis of rock and reservoir fluid, data telemetry				X	X	X			
Automated control and monitoring, intelligent power networks, digital information transmission devices	X	X	X			X		X	X
Automated mining complexes and units		X			X			X	X
Automated transport vehicles, hydraulic transportation of coal					X		X	X	X
Autonomous power generators on gaseous and hydrogen fuel designed for continuous power generation	X	X				X		X	X
Coal chemistry, including liquid fuels					X		X	X	X
Coal cleaning equipment and technologies					X			X	X
Control systems for hydraulic supports for coal mining							X	X	X
Design of large-capacity modules for energy facilities	X		X						
Development of hard-to-recover reserves, directional drilling							X	X	X
Digital twins, including means of conducting comprehensive digital tests of equipment and confirming reliability parameters	X	X	X						
Dust suppression and dust-explosion safety systems integrated into tunneling and cleaning equipment	X	X			X		X	X	
Electrical energy accumulation systems, batteries and fuel cells	X	X	X			X			
Equipment and technologies for natural gas liquefaction						X			
Gas-insulated electrical equipment		X	X	X		X			
Geoinformation systems				X	X	X	X	X	
High-capacity wind turbines	X		X	X					
High-performance miner-bolters	X	X			X			X	X
High-performance photovoltaic modules	X	X	X						
High-voltage and generator circuit breakers	X	X				X		X	X
Higher performance of turbines through changes in their parameters and the use of new working fluids, including CO_2	X	X	X						
Hydraulic excavators	X				X		X	X	
Ice-class drilling complexes	X		X	X		X			
In-situ conversion, kerogen conversion technologies				X		X	X		
Monitoring and control of parameters of rock massifs		X						X	X
Offshore and onshore seismic surveys, wireless data acquisition	X		X	X	X	X			
Power gas turbines (65 MW and higher)	X	X	X						

Prevention of combustion of coal in rock massifs and storages					X		X	X	X
Processing hydrocarbons, additives and catalysts for oil refining				X	X	X			
Reservoir stimulation, including hydraulic fracturing	X			X	X	X			
Rock properties analysis, boundary effects, phase transformations				X	X	X	X	X	
Shearers for high coal deposits							X	X	X
Smart field equipment, pumps, flowmeters for multiphase flow				X		X			
Static reactive power compensators, inverters, rectifiers		X	X						
Stripping equipment and coal mining and quarry transport	X				X		X	X	X
Subsea production units	X		X	X					
Tunneling combines					X		X	X	

Note: 1 = Murmansk Oblast; 2 = Republic of Karelia; 3 = Arkhangelsk Oblast; 4 = Nenets Autonomous District; 5 = Komi Republic; 6 = Yamal-Nenets Autonomous District; 7 = Krasnoyarsk Krai; 8 = Republic of Sakha (Yakutia); 9 = Chukotka Autonomous District.

Source: Authors' development

At the national level, Russia has adopted a procedure for supporting renewable energy in retail markets and in remote and energy-isolated territories (the Russian Arctic and the Far East). There is practiced long-term tariff regulation of renewable energy in retail markets. Regional authorities establish the procedure and requirements for the competitive selection of investment projects and their further inclusion in the development plans in certain territories. Therefore, the adopted regulations allow local authorities in the Arctic and the Far East to make decisions on supporting joint projects with China. In 2020, Russia's Government approved the following mechanisms to stimulate the generation of renewable energy:

- competitive selection of investment projects in the renewable energy sector for the inclusion of such projects in regional development programs, including detailed regulation of tenders;
- price (tariff) ceiling based on tenders for energy produced from renewable sources, instead of direct price regulation;
- elaboration and unification of rules and procedures for qualification of power generating facilities;
- development of the procedure for concluding contracts for the purchase and sale of electric energy with grid organizations, standardization of contract terms, simplification of determining the volume of sales of electric energy under contracts;
- improvement of the rules for maintaining the register of certificates confirming the volume of energy generation from renewable sources.

New rules and principles for the implementation of investment projects in the renewable energy sector should be considered when concluding investment agreements between Russian and Chinese counterparts. The most significant change is that investment projects are now selected based on the principle of the overall effect of the project, rather than the costs principle. The government sets the highest possible amount of support and gradually reduces the bar when making its choice between projects. The government also established the criteria for determining the capacity of renewable energy facilities supplied to the market and payable by consumers. The support measures are conditioned by the need for investors to comply with the requirements for the localization of energy equipment components (forcing Chinese manufacturers to localize part of production and technology in Russia) and the requirements for mandatory export volumes (stimulating the entry of Russian companies into China's energy market or the entry of joint Russia-China enterprises into the world market where sanctions against Russian energy companies allow that).

Permanent Impediments and New Uncertainties

The following technical, spatial, economic, and political issues hinder or could potentially hinder the Russia-China joint low-carbon agenda and the collaboration in the renewable sector in the Arctic.

Technical issues center around the fact that the specific climatic conditions of the Arctic require significant adaptation of existing Chinese equipment and technologies. During the first deliveries and installations, the risks of equipment failure or a noticeable decrease in design capacity are particularly high. Most probably, equipment failures will force the Russian side to abandon transactions and put technical risks and related expenditures into contracts. Pre-testing of the equipment at low temperatures is required to avoid icing of blades and moving parts of wind turbines and snow and icing of solar panels and increase the performance of solar panels and saving of energy during polar nights. Among the technical obstacles is the requirement to localize foreign technologies and equipment production in Russia. From 2025, localization requirements across the renewable energy sectors will almost double – up to 90% in solar energy for the period 2028-2035, up to 85% in wind energy for the period 2031-2035, and up to 80% in small hydropower for the period 2031-2035. Starting from 2028, the permissible share of net imports in the solar energy sector is set at 5% (now 30%), in the wind energy sector – 10% (now 35%), and in small hydropower – 15% (now 35%).

The specifics of the spatial development of the energy sector in the Russian Arctic degrades the economies of scale from investments (Gubina & Provorova, 2018). Isolated markets are narrow and energy grid systems are poorly interconnected. Power generation facilities serve local needs, while the substantial increase in generation makes no economic sense due to spatial constraints to demand (Plisetskii & Plisetskii, 2019). Transportation of excess energy over extremely long distances between dense settlements and industrial sites is unprofitable, and the accumulation of energy in the Arctic climate is technically challenging. The implementation of large investment projects is possible only near cities or industrial facilities, but such large consumers need a stable centralized energy supply ensured by the use of conventional energy sources (Galtseva et al., 2015). For the foreseeable future, we can hardly expect a mass transition of large consumers to renewable energy sources.

A critical economic issue is that in the Russian Arctic, the profitability of renewable energy is extremely low. In one form or another, all of the current projects in the renewable energy sector have gained government support. Low profitability is due to high construction costs (climatic conditions, permafrost) and logistics in narrow isolated markets. Thus, investors could hope for returns if their projects are included in the government subsidy program. To approve joint investment projects in terms of localization, Russia's Ministry of Industry and Trade uses a point rating system of compliance. Investors need to establish a project in such a way that it gains the qualifying number of points. Chinese companies which want to escape full localization of their production in Russia may involve more Russian partners so that the overall localization score for a project meets the requirements. From 2025, all renewable energy endeavors will have to export at least part of their output (4% of exports from capital expenditures in 2025-2030 and 8% in 2030-2035). To meet this condition, Chinese investors will either have to import energy or goods to China or enter the international market through Russian projects (again, if sanctions allow doing that), while creating competition with purely Chinese enterprises. Localization requirements do not take into account the narrow market for renewable energy in the Arctic. Deepening localization will result in the underutilization of the capacities of manufacturers of energy-related equipment and components and an increase in the overall production costs. With the current low return on investment in the renewable energy sector, it may become unviable without substantial government support after the 2030s.

Finally, political or rather geopolitical issues. We finalized this text in early June 2022 and then revised in September 2022, so we cannot keep track of events around the Russia-Ukraine conflict beyond that time. A sharp change in the geopolitical situation both in Russia itself and in Russia's political and economic relations with the USA and other Western countries has largely contributed to the expansion of the energy crisis. While the very focus on the green agenda is being discredited in Russia in a burst of political infighting with the West, in many countries (in particular, in Europe), renewable energy is becoming one of the few options to replace the missing supplies of conventional fossil fuels from Russia. In the conditions of external pressure and the rupture of economic and political cooperation with the West in many spheres, the low-carbon energy agenda is losing its relevance for Russian authorities. Sanctions against Russia have remained and will remain the main political issue in recent years, which actually penetrates into all sectors of the economy, production, finance, technological development, and everyday life. The sanctions introduced after the 2014 events in Crimea and Eastern Ukraine have not specifically affected the renewable energy sector, but created a general background of uncertainty about the future of the energy sector. They have gradually forced Western energy companies out of the Russian Arctic and suspended Russian companies from accessing Western equipment, technologies, and competencies. In September 2022, Equinor withdrew from joint energy projects with Russia in the Arctic. After six months of negotiations, the company got rid of its Russian assets of about €1.2 billion and withdrew from all its joint ventures in Russia, including the Haryaga agreement (joint oil venture in the Nenets Autonomous District). The last portion of Equinor's assets and investment obligations were sold to Rosneft for €1. Since March 2022, the sanctions regime has sharply tightened against the background of the Russia-Ukraine conflict. It directly affects not only the cooperation on energy projects (including the flagship Yamal LNG and the about-to-launch Arctic LNG 2 projects), but also the export of energy resources from Russia in general. Russia, for its part, also resorts to translating the political confrontation with the West into the energy sphere most sensitive for European countries. In the run-up to the 2022-2023 heating season in Europe, Gazprom stopped gas supplies via the Nord Stream, citing a malfunction of the last operating turbine at the Portovaya compressor station. It is unlikely that supplies can be resumed in the foreseeable future. After the shutdown of the Nord Stream, Russia supplies gas to Western Europe through Sudzha gas station in Ukraine (limited to 40 million m^3 per day). In light of the ongoing firefights in the region and the new escalation of the conflict in the fall of 2022, such a route is extremely unreliable. Greece, Hungary, and Serbia are now supplied through the Turkish Stream. Supplies via the Nord Stream can resume only if sanctions are lifted, which definitely requires reaching a general political settlement between Russia, Ukraine, the EU, and the USA. It can be expected that the surplus of domestic production of conventional fossil fuels due to the partial embargo on purchasing Russian oil and petroleum products will hurt the economic prospects of Russia's renewable energy sector. In the heat of confrontation with the West, Russia may withdraw from its international obligations to reduce emissions and decarbonize the economy, which will destroy the prospects for renewable energy in the Arctic.

Conclusion

It is a fair assumption to say that conventional fossil fuels dominate and will be dominating the energy balances of such large energy producers and consumers as Russia and China, respectively. However, in accordance with the global trend toward mitigating climate change and protecting the environment, both countries are making efforts to decarbonize their economies. China has advanced much further than Russia on this path through the accelerated development of all types of renewable energy. Russia's achievements are modest, which comes natural to energy-abundant countries that build their economies and their foreign trade on the production and export of energy resources. For energy companies in such markets, economic incentives for green transformation and transition from conventional energy to alternative solutions are rather weak. For certain territories, however, it is renewable energy that can become the key to stabilizing energy supply, improving the efficiency of local energy and economic resources, and eliminating spatial development imbalances. Sparsely populated, remote, and energy-isolated territories of the Russian Arctic are one of the most demonstrative examples of areas for the development of renewable energy. China's competence and expertise in renewable energy technologies can spur the cooperation between the two countries, including interregional ties between the Russian Arctic, the Far East, and China's Northeast.

Based on the comparative study of regional development strategies and specific needs of individual territories, promising avenues of Russia-China collaboration in the energy sector in the Russian Arctic, Russia's Far East, and China's Northeast include the following:

- As part of the development of regional target fuel and energy balances in accordance with President Putin's instructions, Chinese business development circles and officials should submit proposals to local authorities in nine Russian Arctic territories to replace natural gas and conventional energy with Chinese technologies and equipment.
- Establishment of joint industrial parks and solar energy parks. Russia's Ministry of Energy and the State Grid Corporation of China are working on the development of wind generation in the northern Far East. The wind farm project provides for the transmission of electricity to China.
- Joint demonstration sites for testing equipment and technologies for generating electricity from the energy of sea waves and tides.
- The use of advanced Chinese technologies for the exploration of hydrohydrates and hydrogen energy in permafrost zones across the Russian Arctic.
- Processing of agricultural waste into biogas in Primorye, Khabarovsk Krai, and other territories and cross-border transfer of energy to China.
- Digitalization of the energy sector by using Chinese equipment and technologies. One of the options is cooperation within the framework of the Russian National

Technology Initiative EnergyNet. Potential areas: intelligent technologies and means of monitoring and diagnostics of energy systems equipment; intelligent energy systems (digital substation, virtual power plant, intelligent electricity metering systems, highly sensitive equipment, power electronics, relay protection and automation devices, fast switching equipment); intelligent real-time energy management based on the integration of electrical and information networks (energy Internet); and cost-effective large-scale energy storage solutions.

The current geopolitical realities alter the accustomed collaboration formats. Many of them are either unavailable or significantly restricted by international sanctions against Russia. There are fears that in a heat of fierce confrontation with the West, Russia may withdraw from international climate agreements. Such a move would significantly undermine international climate change mitigation efforts and challenge the global low-carbon transition. China has not declared support for sanctions against Russia and has consistently advocated every possible agreement and cooperation between all involved parties on global issues such as the sustainable development of the Arctic. However, it can be expected that sanctions will inevitably distort existing Russia-China ties. In order to prevent the negative effects of immediate geopolitical confrontations on the long-term sustainable development of the Arctic territories, it is necessary to study the needs of individual territories and look for opportunities for interregional cooperation in the renewable energy sector.

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References

Aliev, R., & Zakharcheva, K. (2017). Changes in the Ratio of Generating Capacities in Different Countries: From Fossil Fuels to Alternative Energy. *Bulletin of the Moscow Region State University, 2*, 8-17.

Andrei, J.V., Avram, S., Băncescu, I., Gâf Deac, I.I., & Gheorghe, C. (2021). Evolution of Romania's Economic Structure and Environment Degradation – An Assessment Through LMDI Decomposition Approach. *Risk Management and Healthcare Policy, 14*, 3505-3521.

Assembly of Deputies of Arkhangelsk Oblast. (2019). *Decree #57-5-OZ from February 18, 2019, "On the Approval of the Strategy of Social and Economic Development of Arkhangelsk Oblast till 2035".* Retrieved from: https://docs.cntd.ru/document/462642024.

Assembly of Deputies of Nenets Autonomous District. (2019). *Decree #256-sd from November 7, 2019, "On the Approval of the Strategy of Social and Economic Development of Nenets Autonomous District till 2030".* Retrieved from: https://docs.cntd.ru/document/561620008.

Avramenko, A., & Baiguskarova, A. (2018). Collaboration between China and Russia in the Sphere of Use of Renewable Sources of Energy. *Eurasian Union of Scientists, 49*(4), 4-6.

Bansal, R.C., Zobaa, A.F., & Saket, R.K. (2005). Some Issues Related to Power Generation Using Wind Energy Conversion Systems: An Overview. *International Journal of Emerging Electric Power Systems, 3*(2), 1070.

Baumann, T., Polyakov, I., Padman, L., Danielson, S., Fer, I., Janout, M., Williams, W., & Pnyushkov, A. (2020). Arctic Tidal Current Atlas. *Scientific Data, 7*(1), 275.

Butuzov, V. (2019). Russian Geothermal Energy: Analysis of Hundred Development of Scientific and Engineering Concepts. *Journal of Environmental Earth and Energy Study, 3*, 4-21.

Cai, Q., Wang, J., Beletsky, D., Overland, J., Ikeda, M., & Wan, L. (2021). Accelerated Decline of Summer Arctic Sea Ice During 1850-2017 and the Amplified Arctic Warming During the Recent Decades. *Environmental Research Letters, 16*(3), 034015.

Dincer, I. (2000). Renewable Energy and Sustainable Development: A Crucial Review. *Renewable and Sustainable Energy Reviews, 4*(2), 157-175.

Energy Research Institute. (2015). *China 2050 High Renewable Energy Penetration Scenario and Roadmap Study*. Beijing: Energy Research Institute.

Erokhin, V., & Gao, T. (2022). Renewable Energy as a Promising Venue for China-Russia Collaboration. In S. A. R. Khan, M. Panait, F. Puime Guillen, & L. Raimi (Eds.), *Energy Transition. Industrial Ecology* (pp. 73-101). Singapore: Springer.

Erokhin, V., Gao, T., & Zhang, X. (2018). Arctic Blue Economic Corridor: China's Role in the Development of a New Connectivity Paradigm in the North. In L. Heininen & H. Exner-Pirot (Eds.), *Arctic Yearbook 2018* (pp. 456-474). Akureyri: Northern Research Forum.

Erokhin, V., Gao, T., & Zhang, X. (Eds.). (2019). *Handbook of Research on International Collaboration, Economic Development, and Sustainability in the Arctic*. Hershey, PA: IGI Global.

Erokhin, V., Konyshev, V., Sergunin, A., & Gao, T. (2022). The Northern Sea Route Development: The Russian Perspective. In I. Ilin, T. Devezas, & C. Jahn (Eds.), *Arctic Maritime Logistics: The Potentials and Challenges of the Northern Sea Route* (pp. 283-303). Cham: Springer.

Esfahani, A.N., Moghaddam, N.B., Maleki, A., & Nazemi, A. (2021). The Knowledge Map of Energy Security. *Energy Reports, 7*, 3570-3589.

European Council. (2022). *Russia's Aggression Against Ukraine: EU Adopts Sixth Package of Sanctions*. Retrieved from: https://www.consilium.europa.eu/en/press/press-releases/2022/06/03/russia-s-aggression-against-ukraine-eu-adopts-sixth-package-of-sanctions/.

Fang, T. (2010). Current State of China's Energy Policy. *Moscow University Bulletin of World Politics, 4*, 124-134.

Galinis, A., Martišauskas, L., Jääskeläinen, J., Olkkonen, V., Syri, S., Avgerinopoulos, G., & Lekavičius, V. (2020). Implications of Carbon Price Paths on Energy Security in Four Baltic Region Countries. *Energy Strategy Reviews, 30*, 100509.

Galtseva, N., Favstritskaya, O., & Sharypova, O. (2015). Monostructural Development of Economy at the Arctic Territories: Russian and Foreign Experience. *Bulletin of the North-East Scientific Center, Russia Academy of Sciences Far East Branch, 3*, 109-118.

Gao, T., Bobylev, N., Gadal, S., Lagutina, M., Sergunin, A., & Erokhin, V. (2021). Planning for Sustainability: An Emerging Blue Economy in Russia's Coastal Arctic? *Sustainability*, *13*(9), 4957.

Gao, T., & Erokhin, V. (2020a). China-Russia Collaboration in Arctic Shipping and Maritime Engineering. *The Polar Journal, 10*(2), 353-374.

Gao, T., & Erokhin, V. (2020b). Widening the Scope of Responses to Environmental Concerns in the High North: Arctic Countries' Policies and the Role of China. In L. Heininen, H. Exner-Pirot, & J. Barnes (Eds.), *Climate Change and the Arctic: Global Origins, Regional Responsibilities? Arctic Yearbook 2020* (pp. 357-397). Akureyri: Arctic Portal.

Gao, T., & Erokhin, V. (2021). How Russia's New Vision of Territorial Development in the Arctic Can Boost China-Russia Economic Collaboration. In L. Heininen, H. Exner-Pirot, & J. Barnes (Eds.), *Defining and Mapping the Arctic: Sovereignties, Policies, and Perceptions. Arctic Yearbook 2021* (pp. 249-278). Akureyri: Arctic Portal.

Gao, T., & Erokhin, V. (2022). Blue Economy of the Arctic: China's Involvement in Establishing the International Agenda. In L. Raimi, & J. Kah (Ed.), *Implications for Entrepreneurship and Enterprise Development in the Blue Economy* (pp. 104-130). Hershey, PA: IGI Global.

Government of Chukotka Autonomous District. (2014). *Decree #290-rp from July 16, 2014, "Strategy of Social and Economic Development of Chukotka Autonomous District till 2030".* Retrieved from: https://docs.cntd.ru/document/446123709.

Government of Krasnoyarsk Krai. (2020). *Decree #122-r from February 26, 2020, "On the Approval of the Strategy of Social and Economic Development of Northern and Arctic Territories and Support of Indigenous People in Krasnoyarsk Krai till 2030".* Retrieved from: https://docs.cntd.ru/document/570728130.

Government of Murmansk Oblast. (2013). *Decree #768-PP/20 from December 25, 2013, "Strategy of Social and Economic Development of Murmansk Oblast till 2020 and for the Period until 2025".* Retrieved from: https://minec.gov-murman.ru/activities/strat_plan/sub02/.

Government of the Komi Republic. (2019). *Decree #185 from April 11, 2019, "On the Strategy of Social and Economic Development of the Komi Republic till 2035".* Retrieved from: https://docs.cntd.ru/document/553237768.

Government of the Republic of Karelia. (2018). *Decree #899r-P from December 29, 2018, "On the Approval of the Strategy of Social and Economic Development of the Republic of Karelia till 2030".* Retrieved from: https://docs.cntd.ru/document/465420565.

Government of the Russian Federation. (2009). *Decree #1-p from January 8, 2009, (updated on June 1, 2021) "On the Approval of the Main Directions of the State Policy in the Field of Improving the Energy Efficiency of the Energy Sector Based on the Use of Renewable Energy for the Period Until 2035".* Retrieved from: http://government.ru/docs/all/66930/.

Government of the Russian Federation. (2020a). *Decree #973-r from April 10, 2020, "On the Approval of the Individual Program of Social and Economic Development of the Republic of Karelia for 2020-2024".* Retrieved from: https://docs.cntd.ru/document/564652911?marker=65A0IQ.

Government of the Russian Federation. (2020b). *Decree #1523-r from June 9, 2020, "Energy Strategy of the Russian Federation for the Period until 2035".* Retrieved from: https://minenergo.gov.ru/node/1026.

Government of the Russian Federation. (2021). *Decree #484 from March 30, 2021, "On the Approval of the State Program of Social and Economic Development of the Arctic Zone of the Russian Federation".* Retrieved from: https://docs.cntd.ru/document/603154509?marker=6540IN.

Governor of Murmansk Oblast. (2014). *Decree #126-PG from August 27, 2014, "On Approval of the Regional Program of Social and Economic Development "Murmansk Oblast – Strategic Center of the Arctic Zone of the Russian Federation"".* Retrieved from: https://docs.cntd.ru/document/412386353.

Governor of Yamal-Nenets Autonomous District. (2018). *Draft Strategy of Social and Economic Development of Yamal-Nenets Autonomous District till 2030.* Retrieved from: https://www.yanao.ru/documents/all/57256/.

Gubina, O., & Provorova, A. (2018). Modern Approaches to Economic Exploitation of Russian Federation Arctic Territories in the Aspect of Perspective Spatial Development. *Fundamental Research, 11-1*, 46-51.

Head of the Republic of Sakha (Yakutia). (2014). Law *#1380-3 from November 27, 2014, "On the Renewable Energy Sources in the Republic of Sakha (Yakutia)".* Retrieved from: https://base.garant.ru/26765678/.

Head of the Republic of Sakha (Yakutia). (2020). *Decree #1377 from August 14, 2020, "On the Strategy of Social and Economic Development of the Arctic Zone of the Republic of Sakha (Yakutia) till 2035".* Retrieved from: https://www.sakha.gov.ru/news/front/view/id/3204989.

Khambalkar, V.P., Katkhede, S.S., Dahatonde, S., Korpe, N.D., & Nage, S.M. (2010). Renewable Energy: An Assessment of Public Awareness. *International Journal of Ambient Energy, 31*(3), 133-142.

Khazova, V. (2019). Prospects for the Development of Renewable Energy in China. *Moscow Economic Journal, 7*, 430-441.

Klimenko, V., Klimenko, A., Tereshin, A., & Mikushina, O. (2021). Energy and Natural Climate Factors: If There Is a Chance to Stop Global Warming? *Energy Policy, 158(*4), 12-29.

Kokorin, A. (2017). Climate Change as Basis of the Paris Agreement. *Energy Policy, 3*, 34-37.

Kudryashova, E., Lipina, S., Zaikov, K., Bocharova, L., Lipina, A., Kuprikov, M., & Kuprikov, N. (2019). Arctic Zone of the Russian Federation: Development Problems and New Management Philosophy. *The Polar Journal, 9*(2), 445-458.

Legislative Assembly of Yamal-Nenets Autonomous District. (2011). *Decree #839 from December 14, 2011, "On the Strategy of Social and Economic Development of Yamal-Nenets Autonomous District till 2020".* Retrieved from: https://docs.cntd.ru/document/424064239.

Lucas, J.N.V., Francés, G.E., & González, E.S.M. (2016). Energy Security and Renewable Energy Deployment in the EU: Liaisons Dangereuses or Virtuous Circle? *Renewable and Sustainable Energy Reviews, 62*, 1032-1046.

Lundy, M. (2019). Renewable Energy Goals in the Face of Climate Change. *Berkeley Scientific Journal, 23*(2), 18-21.

Luoto, T., Ojala, A., & Zajaczkowski, M. (2019). Proxy-Based 300-Year High Arctic Climate Warming Record from Svalbard. *Polar Record, 55*(3), 132-141.

Mastepanov, A. (2019). State Policy of China on the Development of Low-Carbon Energy. *Environmental Bulletin of Russia, 1*, 32-37.

Mastepanov, A. (2020). Prospects for the Development of Renewable Energy in China. *Energy Policy, 146*(4), 52-67.

McCrystall, M., Stroeve, J., Serreze, M., Forbes, B., & Screen, J. (2021). New Climate Models Reveal Faster and Larger Increases in Arctic Precipitation than Previously Projected. *Nature Communications, 12*(1), 6765.

Morgunova, M., & Kovalenko, A. (2021). Energy Innovation in the Arctic. *Energy Policy, 158*(4), 30-43.

Nosko, P. (2017). The Paris Climate Agreement as a Determinant of the Future Global Economy and Its Implications for Russia. *Bulletin of the Financial University, 1*, 145-150.

Nuttall, M., & Callaghan, T. (Eds.). (2019). *The Arctic: Environment, People, Policy*. London: Routledge.

Our World in Data. (2022). *Charts on Renewable Energy*. Retrieved from: https://ourworldindata.org/grapher/hydropower-consumption.

Panait, M., Voica, M.C., & Radulescu, I.G. (2019). Approaches Regarding Environmental Kuznets Curve in the European Union from the Perspective of Sustainable Development. *Applied Ecology and Environmental Research, 17*(3), 6801-6820.

Plisetskii, E.E., & Plisetskii, E.L. (2019). Features of the Current Phase and Problems of Spatial Development of the Arctic Regions of Russia. *Management Sciences in Russia, 9*, 32-43.

Polvani, L., Previdi, M., England, M., Chiodo, G., & Smith, K. (2020). Substantial Twentieth-Century Arctic Warming Caused by Ozone-Depleting Substances. *Nature Climate Change, 10*(2), 130-133.

President of the Russian Federation. (2020a). *Decree #164 from March 5, 2020, "On the Foundations of the State Policy of the Russian Federation in the Arctic till 2035"*. Retrieved from: http://www.kremlin.ru/acts/news/62947.

President of the Russian Federation. (2020b). *Decree #645 from October 26, 2020, "On the Strategy for the Development of the Arctic Zone of the Russian Federation and Ensurance of National Security till 2035"*. Retrieved from: https://docs.cntd.ru/document/566091182.

President of the Russian Federation. (2022). *List of Instructions of the President of the Russian Federation Following the Meeting with Members of the Government of the Russian Federation on February 7, 2022г.* Retrieved from: http://kremlin.ru/acts/assignments/orders/67738.

Sadiku, M., Alam, S., & Musa, S. (2019). Green Growth. *SSRG International Journal of Economics and Management Studies, 6*(2), 82-84.

Salygin, V., Guliyev, I., & Ryabova, M. (2015). Renewable Energy in China. *MGIMO Review of International Relation, 43*(4), 36-45.

Sayigh, A. (2021). Up-Date: Renewable Energy and Climate Change. *Renewable Energy and Environmental Sustainability, 6*, 13.

Somani, S., & Koenig, H. (2018). *Global Trends in Renewable Energy*. Singapore: KMPG.

Southcott, C., Abele, F., Natcher, D., & Parlee, B. (2018). *Resources and Sustainable Development in the Arctic*. London: Routledge.

State Council Information Office of the People's Republic of China. (2007). *White Paper on Energy. China's Energy Conditions and Policies*. Beijing: The State Council of the People's Republic of China.

State Council Information Office of the People's Republic of China. (2012). *China's Energy Policy 2012*. Beijing: The State Council of the People's Republic of China.

State Council Information Office of the People's Republic of China. (2014). *Energy Development Strategies Notice of Action Plan (2014-2020).* Retrieved from: http://www.gov.cn/zhengce/content/2014-11/19/content_9222.htm.

State Council Information Office of the People's Republic of China. (2020). *Energy in China's New Era*. Beijing: The State Council of the People's Republic of China.

State Council of the People's Republic of China. (2018). *China's Arctic Policy. The State Council Information Office of the People's Republic of China*. Beijing: The State Council of the People's Republic of China.

Turnbull, J., Keller, E., Norris, M., & Wiltshire, R. (2016). Independent Evaluation of Point Source Fossil Fuel CO2 Emissions to Better than 10%. *Proceedings of the National Academy of Sciences of the United States of America, 113*(37), 10287-10291.

United Nations. (2022a). *Goal 7: Ensure Access to Affordable, Reliable, Sustainable and Modern Energy for All*. Retrieved from: https://sdgs.un.org/goals/goal7.

United Nations. (2022b). *Goal 13: Take Urgent Action to Combat Climate Change and Its Impacts*. Retrieved from: https://sdgs.un.org/goals/goal13.

United Nations. (2022c). *The 17 Goals*. Retrieved from: https://sdgs.un.org/goals.

United Nations Development Programme. (2012). *Transforming On-Grid Renewable Energy Markets*. New York, NY: United Nations Development Programme.

United Nations Development Programme. (2022). *The SDGs in Action*. Retrieved from: https://www.undp.org/sustainable-development-goals.

United Nations Framework Convention on Climate Change. (2018). *UN Climate Change Annual Report 2018*. Bonn: United Nations Framework Convention on Climate Change.

Van, L. (2014). Green Growth: The Sustainable Economic Growth Model. *Science and Technology Development Journal, 17*(3), 6-13.

Winzer, C. (2012). Conceptualizing Energy Security. *Energy Policy, 46*, 36-48.

Wu, K., & Storey, I. (2007). Energy Security in China's Capitalist Transition: Import Dependence, Oil Diplomacy, and Security Imperatives. In C. McNally (Ed.), *China's Emergent Political Economy: Capitalism in the Dragon's Lair* (pp. 190-208). New York, NY: Routledge.

Xi, J. (2017). *The Governance of China II*. Beijing: Foreign Languages Press.

Xu, J., Assenova, A., & Erokhin, V. (2018). Renewable Energy and Sustainable Development in a Resource-Abundant Country: Challenges of Wind Power Generation in Kazakhstan. *Sustainability, 10*, 3315.

Zaykov, K., Kalinina, M., Kondratov, N., & Tamitskii, A. (2017). Innovation Course of Economic Development in the Northern and Arctic Territories in Russia and in the Nordic Countries. *Economic and Social Changes: Facts, Trends, Forecast, 10*(3), 59-77.

Zeng, Y., Weishaar, S., & Vedder, H. (2018). Electricity Regulation in the Chinese National Emissions Trading Scheme (ETS): Lessons for Carbon Leakage and Linkage with the EU ETS. *Climate Policy, 18*, 1246-1259.

Zheng, X., Lu, Y., Yuan, J., Baninla, Y., Zhang, S., Stenseth, N., Hessen, D., Tian, H., Obersteiner, M., & Chen, D. (2020). Drivers of Change in China's Energy-Related CO2 Emissions. *Proceedings of the National Academy of Sciences of the United States of America, 117*(1), 29-36.