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## Territorialisation, Urbanisation, and Economic Development in the Russian Arctic: Energy Issues

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### Abstract

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For the past ten years, energy issues—alongside the policies implemented to address them—have once again been at the heart of development issues in the Arctic and circumpolar regions. The reasons for this situation are based on the intensification of the exploitation of natural resources, for which the impacts of climate change (warming) are perceived as opportunities, thereby accelerating economic development and the reterritorialisation of the Arctic space. The policies linked to the energy transition are driven by both ecology and the need to have autonomous production unit grids reinforcing the interrelations between territorial development and energy. Energy production units—whether wind, solar, gas, coal, nuclear, or sometimes hydroelectric—are key drivers of economic development in the Arctic and circumpolar space, determining the exploitation of future natural resources and human security. Without energy planning, there can be no economic growth, no human development, and no territorial development. Energy safety is fundamental for the territorial development of the Russian Arctic. The analysis of the Russian Arctic space by remote sensing shows intense urbanisation processes accompanying the exploitation of natural resources.

### Keywords

Urbanisation  
Energy  
Territorial Development  
Arctic  
Russian Federation

The development of the Arctic, and in particular of the Arctic Zone of the Russian Federation, is intrinsically correlated to energy, its implementation, and efficiency. The exploitation of natural resources, the implementation of mining and port cities, and especially those territories undergoing metropolisation (such as Yakutsk) or urban areas (such as Murmansk) are dependent on energy capacity. **AQ1** This is based on a multiplicity of energy production methods: fuel, gas, and coal-fired power plants, nuclear power, wind power farms, or solar power plants (as in Batagaï in the Republic of Sakha Yakutia). These types of energy production are complementary and depend on the forms of territorialisation: micro coal-fired power plants in villages, gas-fired power plants, or even nuclear power plants for Arctic cities, etc.

Since the 2010s, the complementarity between renewable energy and coal or gas-fired power plants appears as a new energy pattern for urban centres in the making or the process of deployment in some territories. The mono-energy model of the Soviet period is gradually being replaced by a mixed energy production model combining renewable energy and fuel, coal, gas, or nuclear power plants (Overland, 2010). Overland, I. (2010). Russia's Arctic energy policy. *International Journal*, 65(4), 865–878. This energy mix is due to the economic needs and issues related to the exploitation of natural resources, as well as a strategy with the need to territorialise the Siberian Arctic regions and the search for autonomous energy production systems (Péné-Annette et al., 2017). Péné-Annette, A., Gadal, S., & Kamicaityte, J. (2017). Pioneering cities of mining: Comparison of the Eastern Venezuela and Eastern Siberia. In *Digital cities and spatial justice* (pp. 135–145).

Renewable energy is an option under testing and implementation. However, there are many disparities between the European and Asian parts of the Russian Arctic: these differences are due to geographic inequalities in terms of territorial structures, to urbanisation, and to demographics, which occur due to the very exploitation of the Arctic Zone of the Russian Federation.

Energy plants are the fundamental infrastructure for human establishment (bases, ports, mines, urban centres) in the Arctic Zone. This raises not only the question of their integration into the territory in terms of location, energy efficiency for Arctic urban centres such as Tiksi, or mobile and modular city projects, but also the spatial modelling of their inclusion in the territory: optimal location, integration into the energy grid, responses to energy needs, environmental and landscape visual impacts, etc. The choice of spatial configuration and their territorial integration is often forgotten, yet is a fundamental aspect in the Arctic environment. It is crucial for the implementation of mobile urban blocks and the rehabilitation of Arctic urban centres, which will relate economic and territorial development policies with the future Northern Sea Route and the exploitation of natural resources.

## 23.2. The Exploitation of Natural Resources: The Main Driver of the Arctic Territorial Development

The question of the development of the Russian Arctic, with the processes of territorialisation and urbanisation as geographical corollaries of the dynamics of anthropisation, is closely intertwined to and dependent on energy issues: availability, power, technological choices linked to the energy transition, and the needs of urban and industrial centres and natural resource extraction areas. This was, and is, the driving force behind the processes of territorialisation and urbanisation in the Arctic and sub-Arctic. Without energy and the exploitation of fossil resources, there is no territorial and economic development and urbanisation dynamics (Anisimov and Kokorev, 2016). Anisimov, O. A., & Kokorev, V. (2016). Cities of the Russian North in the context of climate change. In R. W. Orttung (Ed.), *Sustaining Russia's Arctic cities: Resource politics, migration and climate change* (pp. 141–174). Berghahn Books.

It is a key element in the development and territorialisation of Arctic areas.

Because of the economic and political stakes for the Russian Federation, the energy issue is at the core of development strategies (Fedorova et al., 2021). Fedorova, V., Kadzhaeva, E., & Vovkodav, K. (2021). Transformation of the energy sector in the Arctic in the context of sustainable development of the region. *IOP Conference Series Materials Science and Engineering*, 1201(1), 012069.

The exploitation of natural resources—minerals, oil, gas, etc.—of the Russian Arctic regions is fundamental for the federal state, in an economy that moreover depends (directly and indirectly) on the public and para-public sectors for 85 per cent. The Yamal Peninsula provides 9.3 per cent of the consolidated revenues dedicated to the federal budget in 2021. The significant role of the Arctic territories and the exploitation of natural resources is increasingly marked and will become more pronounced, particularly with the exploitation of new—admittedly still confidential—deposits in the Far East, such as in Yakutia (Fig. 23.1).

**Fig. 23.1**

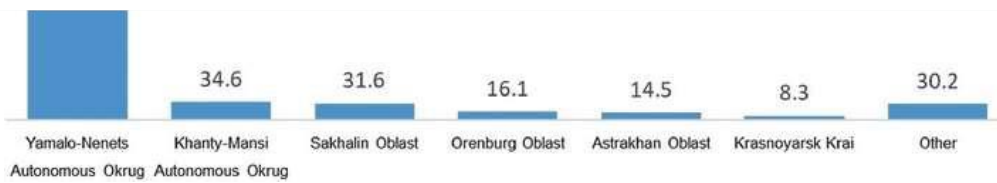
Regional structure of the gas production in Russia in 2019, billion cubic metres

(Source adapted by the authors from Analytical Center under the government of the Russian Federation [2020]. *Fuel and Energy Complex of Russia*. URL: [https://ac.gov.ru/uploads/2Publications/TEK\\_annual/TEK.2019.pdf](https://ac.gov.ru/uploads/2Publications/TEK_annual/TEK.2019.pdf) [in Russian])

A bar graph illustrates the regional structure of gas production in Russia in 2019. The data in billion cubic meters are as follows: Yamalo-Nenets Autonomous Okrug, 603. Kanty-Mansi Autonomous Okrug, 34.6. Sakhalin Oblast, 31.6. Orenburg Oblast, 16.1. Astrakhan Oblast, 14.5. Krasnoyarsk Krai, 8.3. Other, 30.2.



Regional structure of gas production in Russia, billion cubic meters



The intensification of the exploitation of natural resources on the Russian Arctic continental shelf—minerals, fossil fuels such as coal, gas, and oil, and fish in the Arctic Sea—is certainly driven by extraction opportunities related to the impact of global warming, as is often emphasised, but it is essentially linked to the need to compensate for the loss of yields from European and Siberian oil and gas fields, while at the same time increasing revenues for the federal-state budget (Statistica, 2020). Statistica. (2020). The Russian oil industry. <https://www.statista.com/study/65069/oil-industry-in-russia/>

The latter's dependence on the exploitation of natural resources is growing to represent 60 per cent of the Russian GDP (Knight et al., 2021). Knight, D., Emelyanova, O., Rostovtseva, I., Freije-Rodriguez, S., Kolchin, V., Nagle, P., Wheeler, C. M., Ruch, F. U., Levitanskaya, K., Wuester L. J., Aviomoh, H., Mbowe, A., & Prokhorova, A. (2021). Russian economic report 46. World Bank. <https://documents1.worldbank.org/curated/en/099050011302118976/pdf/P17756206d40310aa0a5e109d6fa60bc55a.pdf>

This is even more important as the Russian economy is directly or indirectly linked to the public sector. The development of new deposits in the Arctic and circumpolar regions is essential for the economic survival and financing of federal-state policy (Fig. 23.2).

**Fig. 23.2**

Contribution of the region in the Russian GDP in 2019

(Source Adapted by the authors from Analytical Center under the government of the Russian Federation [2020]. *Fuel and Energy Complex of Russia*. [https://ac.gov.ru/uploads/2Publications/TEK\\_annual/TEK.2019.pdf](https://ac.gov.ru/uploads/2Publications/TEK_annual/TEK.2019.pdf) [in Russian])

A map of Russia marks out the contribution of specific regions in the Russian GDP in 2019. Saint Petersburg, 4.9 percent. Moscow, 21 percent. Moscow oblast, 4.9 percent. Samara oblast, 1.8 percent. Yamalo-Nenets Autonomous Okrug, 3.6 percent. Khanty-Mansi Autonomous Okrug, 5.2 percent. Krasnoyarsk Krai, 2.7 percent.



The increase in the exploitation of natural resources in the Russian Arctic space is related to the growing international demand for raw materials and energy in the traditional markets of the European Union—especially Germany—and the emerging markets of China and Turkey. For example, the Yamal Peninsula contributed 9.3 per cent of the Russian state-federal budget in 2021. 20 per cent of the gas consumed in France came from the Yamal Peninsula in 2020. Germany's energy transition is based on the exploitation of Russian gas, most of which comes from the Arctic and the Yamal Peninsula.

If the exploitation of mineral and fossil resources is highlighted, this must not be done at the expense of the equally important exploitation of fisheries resources and their role in food security. More than 25 per cent of the fish consumed in North America comes from the waters of the icy Arctic Ocean.

The importance of the processes of the re-territorialisation of the Arctic and sub-Arctic spaces is not only linked to the exploitation of natural resources, as was the case during the various periods of the Soviet regime (Potravny, 2021). Potravny, I. (2021). Cities and towns of the Russian Arctic: Approaches to sustainable development. *Systems Analysis and Modelling of Economic and Environmental Systems*, 338(2), 237–242 (in Russian).

If they were one of the pillars of the policy of territorial control subject to the exploitation of natural resources during the USSR, the 1990s were characterised by massive anthropic and urban abandonment, particularly with the closure of mines, transport infrastructures, etc. Tiksi, a major port centre, designed to accommodate 50,000 inhabitants, now in 2021 has 4745 inhabitants, where it had 11,649 inhabitants in 1989. However, some territories, such as Yakutsk, have been experiencing a continuous metropolisation process since the



1990s, with more than 330,615 inhabitants in 2021, compared to 193,000 people in 1991. The processes of territorialisation of the Arctic space are not new.

### 23.3. Urbanisation, Hydrocarbon Exploitation Areas, and the Emergence of Territorial Structures

Spatial analysis of changes in territorial structures—based on the evolution of urban structures and areas of exploitation of fossil and mineral resources between 1992 (blue), 2005 (green), and 2013 (red) identified from DMSP (Defence Meteorological Satellite Program) (Sun et al., 2020) satellite Sun, C., Liu, Y., Zhao, S., & Jin, S. (2020). Estimating offshore oil production Using DMSP-OLS annual composites. *ISPRS Journal of Photogrammetry and Remote Sensing*, 165, 152–171. images taken in the visible near-infrared (VNIR)—highlights an intensification of the exploitation of the Russian European Arctic space and western Siberia (Yamal Peninsula) that has been ongoing since the break-up of the USSR (Fig. 23.3).

**Fig. 23.3**

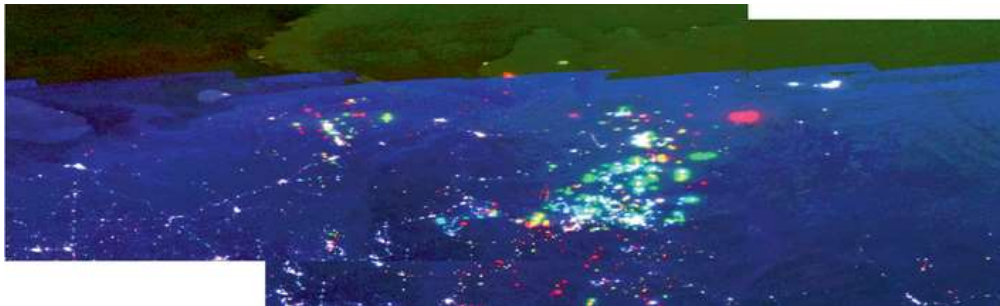
Urban, oil and gas extraction area change in the European and West Siberia Arctic zones (1992–2013)

(Source Gadai, S., November 2017–September 2021, NOAA-USAF DMSP F10, F15, and F18 satellites, VNIR OPL-PS sensor, mean annual spectral measurement, Urban and exploitation areas land change modelling by Ensemble' algorithm with linear model-data fusion (Li and Zhou, 2017; Ma et al., 2020) . Li, X., & Zhou, Y. (2017). Urban mapping using DMSP/OLS stable night-time light: A review. *International Journal of Remote Sensing*, 38(21), 6030–6046.

Ma, J., Guo, J., Ahmad, S., Li, Z., & Hong, J. (2020). Constructing a new inter-calibration method for DMSP-OLS and NPP-VIIRS nighttime light. *Remote Sensing*, 12(6), 937.

Blue: 1992 [no change]; Green: 2005 [emergence of urban/natural resources spots]; Red: 2013 [emergence of urban/natural resources spots]; Yellow: between 2005 and 2013 [change recognition]; White: between 1992 and 2013 [no change]

A satellite image of spatial analysis of changes in the European and West Siberia Arctic zones, which is based on the evolution of urban structures and areas of exploitation of fossil and mineral resources between 1992 and 2013.



The European part of the Russian Arctic Zone, which is highly structured (white) with its communications networks linking urban centres and natural resource exploitation built during the Soviet period, is characterised by transformation (pink) and peri-urbanisation dynamics between 2005 and 2013, notably with the exploitation of new deposits (green and red spots). The Yamal Peninsula is experiencing unprecedented economic development with the exploitation of gas reserves (green and red spots). This massive territorial and economic dynamic is accompanied by the emergence of new urban centres or the extension of those built during the USSR, such as Nadym located in the southeast of the peninsula. The region further to the east between the Ob and Yenisey rivers is characterised by an intense hydrocarbon exploitation activity associated with the accompanying urbanisation dynamics (Fig. 23.4).

**Fig. 23.4**

Urban, mineral, oil and gas extraction area change in the Eastern Siberia Arctic zones (1992–2013)

(Source Gadai, S., November 2017–September 2021, NOAA-USAF DMSP F10, F15, and F18 satellites, VNIR OPL-PS sensor, mean annual spectral measurement, Urban and exploitation areas land change modelling by Ensemble' algorithm with linear model-data fusion (Jeswani et al., 2019) . Jeswani, R., Kulshrestha, A., Gupta, P. K., & Srivastav, S. K. (2019). Evaluation of the consistency of DMSP-OLS and SNPP-VIIRS night-time light datasets. *Journal of Geomatics*, 13(1), 98–105.

Blue: 1992 [no change]; Green: 2005 [emergence of urban/natural resources spots]; Red: 2013 [emergence of urban/natural resources spots]; Yellow: between 2005 and 2013 [change recognition]; White: between 1992 and 2013 [no change]

A satellite image of urban, mineral, oil and gas extraction changes in the area of Eastern Siberia Arctic zones between 1992 and 2013.





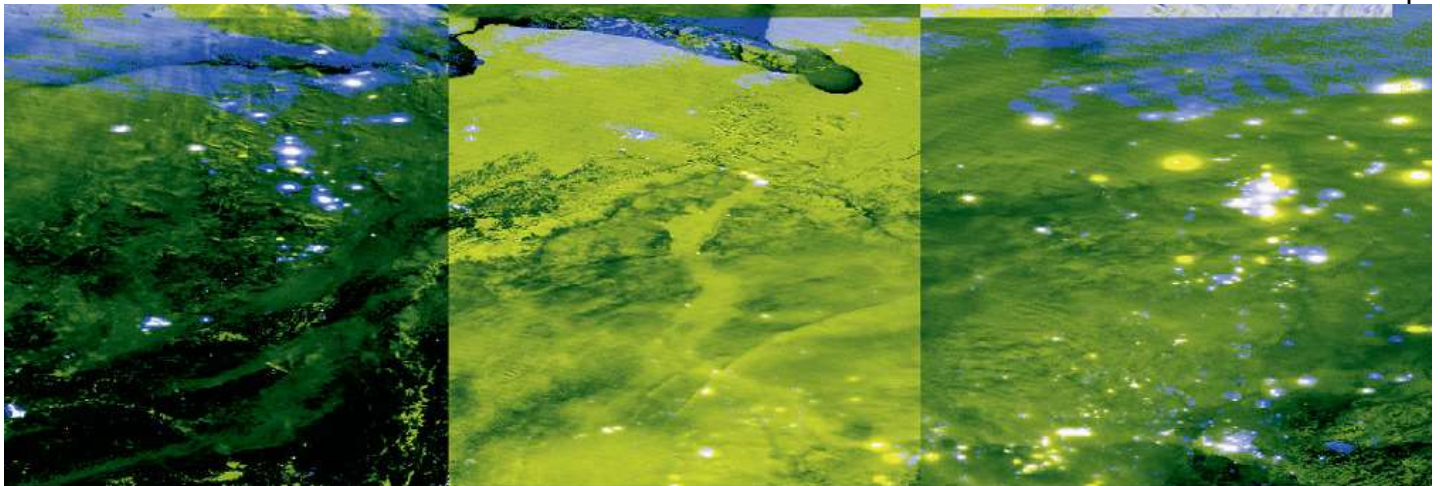
The Arctic and sub-Arctic regions of the Siberian Far East are characterised by urbanisation and metropolisation dynamics unique to Yakutia, which does not depend on the dynamics of urban pioneer fronts generated by the exploitation of natural resources. The Yakutsk region, a sub-Arctic territory characterised by an Arctic climate, has experienced sustained urban growth since the 1990s, with the emergence of a vast suburban territory that stretches along the Lena River for more than 100 km from the north to the south of the metropolis (between Pokrovsk in the south and Namtsy in the north), and in the east in central Yakutia with a demographic growth affecting villages and urban centres (spots in red). These urbanisation dynamics based on the demographic growth of villages also concerns the regions of Tommot, Aldan, and Nerioungri in the south of the Republic of Sakha Yakutia. The urban centres (in blue) located in the Oyimyakonsky district have disappeared or experienced a sharp decrease in population with the cessation of mining activities. Only Oyimyakon (a cold city linked to tourism) has not been affected by the urban decline (Fig. 23.5).

**Fig. 23.5**

Urban, oil and gas extraction area change in the European and West Siberia Arctic zones (2015–2021)

(Source Gadal, S., Zakharov, M., 23 December 2021, NOAA-Suomi National Polar-orbiting Partnership, VIIRS sensor, Urban and exploitation areas land change modelling by Ensemble algorithm with histogram equalisation model-data fusion. Blue: 2015 [decline]; Red: 2013 [emergence of urban/natural resources spots]; Yellow: between 2015 and 2021 [change recognition]; White: between 2015 and 2021 [no change])

A satellite image shows area changes in the urban centers of European and West Siberia Arctic zones due to oil and gas extraction.



**Fig. 23.6**

Novy Urengoy and the areas of gas exploitation captured at night

(Source photos taken by Gadal, S., 02 December 2021, Novy Urengoy, Yamal, Russia)

Two photographs captured through satellite at night show the Novy Urengoy and the gas exploitation areas.



The use of VIIRS (Visible Infrared Imaging Radiometer Suite) data from the NOAA-Suomi NPP (Suomi, 2021) sensor (Suomi NPP VIIRS S ensor. (2021). VIIRS-NRT. NASA. <https://earthdata.nasa.gov/earth-observation-data/near-real-time/download-nrt-data/viirs-nrt>



commissioning of new gas fields can be observed (yellow spots), several gas extraction sites have not changed over the last 6 years, and several urban centres have declined (blue spots). The European part of the Russian Arctic is characterised by stagnation, even a decline in the intensity of hydrocarbon production between 2015 and 2021 (Figs. 23.6 and 23.7).

**Fig. 23.7**

Urban, mineral, oil and gas extraction area change in the Eastern Siberia Arctic zones (2015–2021)

(Source Gadai, S., Zakharov, M., 23 December 2021, NOAA-Suomi National Polar-orbiting Partnership, VIIRS sensor, Urban and exploitation areas land change modelling by Ensemble' algorithm with histogram equalisation model-data fusion (Kimijima et al., 2021). Kimijima, S., Sakakibara, M., & Nagai, M. (2021). Detection of artisanal and small-scale gold mining activities and their transformation using earth observation, nighttime light, and precipitation data. *International Journal of Environmental Research and Public Health*, 18 (20), 10954.

Blue: 2015 [decline]; Red: 2013 [emergence of urban/natural resources spots]; Yellow: between 2015 and 2021 [change recognition]; White: between 2015 and 2021 [no change]

A satellite image of urban, mineral, oil and gas extraction changes in the area of Eastern Siberia Arctic zones between 2015 and 2021.



The territorial dynamics observed during the last 6 years in central Yakutia are significantly different from the period 1992–2013. While the urban region of Yakutsk is experiencing a significant process of growth and intensification of urbanisation, as well as certain urban centres in central Yakutia, there are processes of decline in certain villages and urban centres (blue spots).

## 23.4. Energy Security and Economic Development

The question of energy is integral to the economic development of the Russian Arctic territories, as well as for regional and global sustainability (Ilinova et al., 2020). Ilinova, A., Solovyova, V., & Yudin, S. (2020). Scenario-based forecasting of Russian Arctic energy shell development. *Energy Reports*, 6, 1349–1355.

Energy security is a major issue in the Russian Arctic, due to the strong regional isolation factor, which has been the fundamental roadblock to stimulating regional growth (Ghani et al., 2019). Ghani, R., Kangash, A., Shakeel Virk, M., Maryandyshev, P., & Mustafa, M. (2019). Wind energy at remote islands in the Arctic region: A case study of Solovetsky Islands. *Journal of Renewable and Sustainable Energy*, 11, 053304.

Most of the Russian Arctic is either connected to small independent power grids or is served by decentralised generation systems using mostly petroleum-derived products.

The reliance of many of these communities on external deliveries for their energy supply limits the number of hours that the population has access to electricity: in some cases down to only several hours a day. Wind energy—and renewables in general—can help provide the isolated settlements with uninterrupted power (increasing electricity/heat consumption up to 24 hours a day) and significantly reduce the cost of delivering hydrocarbon fuel (by roughly 30 per cent). At the same time, the low carbon footprint of these plants will help significantly reduce the human impact on the environment and improve the living conditions for the local population, both in terms of quality of life and health in extreme conditions (Fig. 23.8).

**Fig. 23.8**

Carbon power plant, Verkhoyansk, Republic of Sakha Yakutia

(Source photo taken by Gadai, S., Zakharov, M., 17 July 2017, Verkhoyansk, Republic of Sakha Yakutia, Russia)

An aerial photograph of a carbon power plant in Verkhoyansk, Republic of Sakha Yakutia.





Access to reliable energy sources is imperative for revitalising Arctic settlements (including three new mobile military modular cities) and supporting regional economic activity (gas, oil, mines, fisheries, tourism, etc.). Furthermore, considering the vital role that the development of the Northern Sea Route will play not only for Russia but for the entire global community, the economic development and the energy security of these regions become essential factors in turning these Arctic waters into the new major trade artery (Gadal and Ignatyeva, 2020). Gadal, S., & Ignatyeva, V. (2020). Alternative energy sources as part of sustainable development in the Arctic regions. In *Public administration and development in Russia: National goals. Russia's Arctic regions. The role of national projects in shaping sustainable development*, 1 (pp. 732–742). Scientific Library Publishing House (in Russian).

Alternative green energy—such as wind and solar—has already been implemented in several regions of the Russian Arctic—for example, Batagai in the Republic of Sakha Yakutia—to test the operating capacity of these systems, as well as to see if these solutions can help alleviate some of the carbon and fuel dependence of the regions. The identification of the benefits and challenges of such installations in the region and can help build a roadmap for more successful and effective integration of such systems throughout the region (Fig. 23.9).

**Fig. 23.9**

**Solar power plant of Batagai, Republic of Sakha Yakutia**

(Source photo taken by Gadal, S., Zakharov, M., 16 July 2017, Batagai, Republic of Sakha Yakutia, Russia)

An aerial photograph of the solar power plant of Batagai, Republic of Sakha Yakutia.



## 23.5. The Paradigm of Autonomous Cities

The political, technological, and societal paradigm of the energy transition driven by “green” energies has a triple interest: economic, in terms of reducing the cost of infrastructure aimed at bringing electricity, gas, coal, and fuel oil to Arctic towns and urban centres; environmental, in terms of the impact on the health of the population (coal and fuel oil power stations); and through the implementation of autonomous production units (Suter et al., 2019). Suter, L., Streletskiy, D., & Shiklomanov, N. (2019). Assessment of the cost of climate change impacts on critical infrastructure in the circumpolar Arctic. *Polar Geography*, 42(12), 267–286.

The establishment of autonomous energy units based on green energy, and the implementation of nuclear micro-power stations, make it possible to meet the growing energy needs related to the renovation of port infrastructures (and other such infrastructures) in the Arctic, and to meet the energy deficits of certain urban centres, as well as to support the development of mining, gas, and oil activities, particularly in territories not covered by any energy grid. The economies of scale in terms of the costs of implementing new areas of natural resource exploitation in the Arctic and sub-Arctic regions are theoretically particularly interesting. The “green” energies promoted by the energy transition are one of the vectors of this. The autonomous structure of the “green” energy grids makes it possible to open new areas for the production and extraction of natural resources.

While several Arctic villages and small towns have developed autonomous energy grids since the 1960s based mainly on the use of coal and/or oil-fired power stations, others are connected to the gas network. Coal and oil-fired power plants tend to be replaced by dual-energy plants if they cannot be connected to the gas grid. Their addition to the gas network is linked to the presence of gas pipelines. The construction of the gas pipeline between the Yamal Peninsula and the People’s Republic of China has made it possible to connect several villages to the pipeline (Meynkhart, 2020). Meynkhart, A. (2020). Priorities of Russian energy policy in Russian-Chinese relations. *International Journal of Energy Economics and Policy*, 10(1), 65–71.

Batagai’s energy grid combines a coal-fired power plant with a solar panel farm providing more than 30 per cent of the urban centre’s electricity needs; it is now the largest solar panel farm in the Arctic.

If the implementation of new green and autonomous energy grids makes it possible to substitute totally or partially oil and coal-powered power plants and to support the energy needs for the exploitation of natural resources, then the development of infrastructures and urban centres (for which 11 micro nuclear power plants on barges [or ships] are one of the flagship elements) would



become possible. The question of their implementation is a technical issue, which sometimes becomes critical due to the extreme conditions (temperatures, wind, etc.) and land movements linked to the permafrost dynamics and its thawing in certain places. This is an upcoming problem faced by energy power plants such as the nuclear plant of Bilibino localised at the Chukotka Autonomous Okrug in Eastern Siberia. Accelerated melting of permafrost is an emerging problem for both power plants and mining, gas, and oil extraction areas, as well as buildings and infrastructure (Streletskiy et al., 2015). Streletskiy, D., Shiklomanov, N., Kokorev, V., & Anisimov, O. (2015). Arctic cities, permafrost and changing climatic conditions. In 68th Canadian geotechnical conference—GEOQuébec 2015, Quebec, Canada. Although the consequences regarding the destruction of buildings, infrastructure, etc. are known, the magnitude of the consequences and impacts are not well known yet.

## 23.6. The Example of the Wind Farm Experiment in Tiksi

Starting from 2017, the construction of new modern wind farms is ongoing in the Russian Federation (in the Ulyanovsk Region, the Republic of Adygea, the Republic of Sakha, in the Stavropol Territory, in the Rostov and Murmansk Regions). In November 2018, 3 Japanese wind turbines with a capacity of 0.3 megawatts each were put into operation in the Arctic city of Tiksi, an important transport hub for the Northern Sea Route. The successful operation of 3 wind turbines together with a diesel generator in the winter season of 2019 showed the efficiency of electricity generation in difficult weather conditions and the feasibility of further development of this area. In 2020, in the Bulunsky district, the wind farm of alternative energy sources will be replenished with three new Japanese wind generators.

The wind turbines provide great savings to Sakhaenergo. The founders of the wind farm—the companies Yakutskenergo and RusHydro—have become pioneers in attracting investments to the remote Arctic region, particularly the village of Tiksi, in which wind loads allow the power plants to operate.

The organisation of the urban Tiksi settlement is spatially dispersed and divided into three micro districts: Tiksi-1, Tiksi-2, and Tiksi-3. In total, about 4600 people live in the village. Tiksi is one of the strategically important transport hubs of the Russian North: there is a seaport, the main hub of the infrastructure of the Northern Sea Route, and an airport of federal significance. The transport and economic significance of the territory makes it necessary to develop innovative approaches to rational nature management and the issue of energy supply in the Arctic.

Despite the equipment's high stability to climate change, to ensure the safe operation of wind turbines and to increase the efficiency of their work, a crucial factor is the availability of a monitoring and forecasting system for meteorological conditions in the Tiksi wind farm (Strijhak et al., 2021). Strijhak, S., Gergel, V., Ivanov, A., Gadal, S. (2021). On the problem of choosing the optimal parameters for the wind farm in the Arctic town of Tiksi. In D. Balandin, K. Barkalov, V. Gergel, I. Meyerov (Eds.), *Mathematical modeling and supercomputer technologies*. Springer.

In addition, the issues of reliable operation of wind turbines and assessing the impact of a wind farm operating in difficult climatic conditions on the local microclimate have not been studied. There are currently no scientific publications on this wind farm or this topic in general.

While the diverse landscape of the Russian Arctic provides many opportunities for the integration of various renewable energy systems, wind energy has emerged as one of the primary candidates for implementation in the Arctic (Tabachkova et al., 2020). Tabachkova, X., Prosekov, S., & Sokolinskaya, N. (2020). Energy system structure in the Russian Arctic: Coal production forecast. *International Journal of Energy Economics and Policy*, 10(3), 476–481.

The constant and intense winds along the northern coast of Russia, on average sustaining 5–7 metres per second, provide good conditions for wind power generation.

The first regional implementation of wind turbines in Tiksi (designed by the Japanese company NEDO and RusHydro under the supervision of Sakha Energy) and the proposed future extension of the park (to 16 turbines) could be analysed as the example of green renewable energy utilisation in the extreme Arctic climate. Such an analysis would allow a better understanding of the potential for the renewable energy system integration in the Russian Arctic, and the role it can play in helping to improve energy access and security while reducing the environmental impact of energy and economic related activity (Ivanov et al., 2019). Ivanov, A. V., Strijhak, S. V., & Zakhharov, M.

(2019). Modeling weather conditions in the port area and coastal zone of Tiksi Bay. In *Proceedings of the Institute for System Programming of the RAS (Proceedings of ISP RAS)*, 31(6), 163–176 (in Russian).

At the same time, the study should also consider the existing barriers for the widespread deployment of such systems, including the technical challenges, such as the need for adaptation of materials to the harsh local climate, the lack of sufficient infrastructure, and the absence of specialised human capital in the prospective regions.

The physical modelling of the energy efficiency of the wind power farms, their microclimatic and environmental impacts, and the benefits and challenges of the implantation of this type of renewable energy system would allow a better understanding of the possibilities and limitations of such systems implementation. The model for energy efficiency of wind power systems should consider not only effective electricity generation but also the local environmental impacts. It should integrate different geographic data from the metrological station, microclimatic exposure and evolutions, high-resolution (centimetres) terrain relief models generated from drones, digital elevation model (DEM) (2 × 2 metres covering large areas), high-resolution mapping of the land covers and land use, landscape permafrost, and their change dynamics at different seasons modelled by high and medium spatial satellite remote sensing Sentinel 2A (Fig. 23.10).

### 3D map of the Tiksi area with the location of the 3 wind turbines

(Sources compiled by Zakharov, M., 23 December 2021, Arctic Digital Elevation Model, Colour composite from Sentinel 2A satellite MSI data)

A three-dimensional map of the Tiksi area along with the location of the following wind turbines: Wind power farm, Tiksi-1, and Tiksi 3.



## 23.7. Conclusions

The question of energy is integral to the economic development of the Russian Arctic territories, as well as for regional and global sustainability. With its abundant supply of hydrocarbons, Russia has never placed a strong emphasis on renewable energy development; however, some recent efforts have been made to keep on top of global trends and to start integrating the renewable energy system into national energy strategies and to develop the necessary mechanisms to stimulate this energy transition. The rapidly growing strategic importance of the Arctic territories for the Russian government provides the perfect opportunity to study how the integration of these renewable energy systems can help address several economic, social, and environmental challenges that exist in the region.

Energy security is a major issue in the Russian Arctic, due to the strong regional isolation factor, which has been the fundamental roadblock to stimulating regional growth. Most of the Russian Arctic is either connected to small independent power grids or is served by decentralised generation systems using mostly petroleum-derived products. The reliance of many of these communities on external deliveries for their energy supply limits the number of hours that the population has access to electricity, in some cases down to only several hours a day.

Access to reliable energy sources is imperative for revitalising Arctic settlements (including three new mobile military cities planned by the Russian Army) and supporting regional economic activity (gas, oil, mines, fisheries, tourism, etc.). Furthermore, considering the vital role that the development of the Northern Sea Route will play—not only for Russia but also for the entire global community—economic development and energy security of these regions become essential factors in turning these Arctic waters into the new major trade artery.

Wind energy—and renewables in general—can help provide the isolated settlements with uninterrupted power (increasing electricity/heat consumption up to 24 hours a day) and significantly reduce the cost of delivering hydrocarbon fuel (by roughly 30 per cent). At the same time, the low carbon footprint of these plants will help significantly reduce the human impact on the environment and improve the living conditions for the local population, both in terms of quality of life and health.

The implementation of green energy has an internal contradiction, even a controversial dimension: on the one hand, the green energy grids are the vectors of the acceleration of the processes of exploitation of natural resources in the Russian Arctic and of territorialisation; on the other hand, they provide a key element contributing to human security: the comfort of life with access to gas and electricity, as well as the reduction of the health and environmental impacts of oil and coal power plants. Perhaps this could be considered as the “ecology policy as a support of the economic development as well as the protection of Arctic natural resources and territorialisation with the implementation of the green energy power plans”. The development of the green energy policy contributes one form of support to the Arctic territorial development and the exploitation of the natural resources, as well as providing for human security (health, living environment). The green energy power plans deployment is contributing to the global warming policy agenda; this is possible because of the autonomous energy grids of the green energies for the human settlements, mines, etc. The generalisation of the autonomous energy grids accelerates the emergence of new urban and rural settlement models characterised by self-development and self-urban dynamics, especially in the Siberian Arctic Zone. The distances, the extreme climate and environment, and the absence of transportations infrastructures (excepting the airports) connecting the “arctic urban islands” (including mobile settlement bases) are one key-face of the Arctic geography. Autonomous energy grids provided by the energy transition reinforce this territorial organisation.

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