Technological Revolution 4.0 for the Arctic

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Abstract. The article presents the author's opinion on the development of Arctic territories in the circumstances of the 4th industrial revolution. The main tools of the new technological structure being introduced in the northern territories are reviewed. The leading role of oil and gas companies in the promotion of technologies and tools of the new industrial paradigm in a number of Arctic regions of the Russian Federation is remarked. The inevitability of changing the Arctic development perception from an ecological catastrophe to the careful and sustainable development of Arctic spaces using the modern achievements of the Technological Revolution 4.0 is indicated.

1. Introduction
The Arctic is a key region of the planet, providing climate management processes, preserving the planet's biodiversity and playing a significant role in global natural processes. At the same time, there is an increased interest of various states and transnational companies towards the Arctic as a source of mineral and biological resources, as a cross-point of international transport routes of intra- and transcontinental scale in recent decades [1-12].

Thus, the Arctic simultaneously represents a complex ecosystem of a planetary importance and a unique international interaction platform for states, international organizations, society and business.

Arctic development issues bring the unique task of preserving the fragile Arctic ecosystem to the forefront in the face of the increasing pace of technological progress and fundamental changes that the Fourth Industrial Revolution brings to bear.

2. Review of approaches to Arctic territories development concept
Within the above-mentioned task, it should be noted that the attitude of the world community towards the development of the Arctic has not yet fully formed. There are at least two main viewpoints on this issue. The first point of view leads to keeping the entire territory of the Arctic as a kind of planetary reserve with almost all economic activities to be banned and suspended in this region. This concept is supported mainly by international environmental organizations and is partially included in the development strategies of some countries and international collaborations resolutions [13-17]. Thus, the Finnish government approved the Arctic Strategy in 2013, where the idea of assigning the status of the protected territory to the sea areas around the North Pole is expressed [1]. In 2014 the European Parliament adopted a resolution to preserve the water area around the North Pole in order to protect it from industrial fishing and mineral resources exploration [20], whereas in 2017 the European Parliament appealed for a ban on drilling oil wells in icy Arctic waters [21]. The weakness of this
approach is the absence of the internationally enshrined concept of "Arctic territories" and, as a result, a different interpretation of the area not to be covered by economic activities. Hence there occur the contradictions related to the need to cease existing economic activities carried out by the countries of the Arctic G8 within their national territories, including those closely related to the well-being of the population that is not indigenous but has been living in this territory for at least a century, having formed a stable society.

The second one is related to ensuring reasonable environmental management in the development of the Arctic territories, the development of non-resource segments of the Arctic economy, the Arctic region development based on a sustainable development model [22-25]. It is obvious that the formation of this approach is a difficult task for a number of reasons. The main risks are related to the Arctic ecosystem fragility, harsh climatic conditions (oppressive polar night, long winter, annoying polar day, strong winds, negative ultraviolet and radiation balance, etc.), poor territories development, lack of infrastructure and communications in high latitudes, as well as consumer mindset towards the nature by individual transnational and national corporations and businesses operating in the Arctic.

Concerns about Arctic development risks are not groundless. Climate change is irreversibly changing the appearance and potential of Arctic territories, leading not only to ocean and soil warming, and air temperatures rising; melting permafrost, decreasing the perennial sea ice area and ice cover as a whole, changes in vegetation and animal abundance and species diversity, in Arctic cyclone characteristics, sea currents, etc. [26-29]. Indirect influence is manifested in disruption of the engineering infrastructure of settlements and industrial facilities in permafrost degradation zones, roads deterioration, population living conditions decline, in particular, in the destruction of houses as a result of the coastal territory erosion, lack of adequate drinking water quality, increased air pollution in industrial cities and many other consequences [30-34].

The increasing strategic importance of the Arctic as a new source of resources also leads to a change in the seemingly formed consensus on conservation areas in the circumpolar space. Thus, official conservation areas currently under the state protection account for more than 17% of the Arctic land. These territories have recently drawn serious attention from industry, including the oil, gas, mining, forestry and transport sectors. It might result, for the purpose of industrial development of the existing protected areas, in a certain pressure or influence on population, local communities and executive authorities on the part of industrial enterprises, including promises of generating employment, investments in socially significant infrastructure, and great monetary benefits to municipalities in order to open up existing protected areas for alternative use. However, environmental damage and reduction or disappearance of protected areas will be an integral part of economic activity [35].

The manmade disaster in Norilsk in 2020, which resulted in at least 20,000 tons of petroleum products leakage, is also indicative. This leakage became one of the largest disasters in the Arctic of all time, and the largest in recent decades. The catastrophe was caused by the enterprise negligent attitude to the industrial safety examination and oil storage tanks control in specific Arctic conditions [36].

The development of the Arctic in the dual approach context described above is a complicated task, possible to be solved on the basis of the sustainable development concept and new technological tools. The strategy for the mankind existence, its productive environment development and, as a result, the development of territories cannot be formulated without new approaches that not only correspond to modern realities, but also to the proposed development prospects of a new human-nature interaction model. The intellectual and technological potential capacity accumulated by humanity allows us to take a fresh look at the Arctic development objective, not only to carry out this process without damaging future generations (in accordance with sustainable development principle), but also to create a strategically new interaction format with the natural environment.

3. Industry 4.0 innovative tools
The necessary balance between meeting the needs of society, the economy and ensuring the sustainability of natural ecosystems can be ensured through processes that are commonly called the 4th technological revolution.

The most important and innovative tools of the new technological structure have already found their place in the strategy and technology for the Arctic area development.

Digitalization is a long-term fundamental trend of a new technological structure that will improve the region's population quality of life, ensure the regional economy growth, safe and sustainable Arctic transport routes development, open up new non-resource opportunities for the Arctic, etc.

The Far East Development Fund announced the single statistical and information-analytical system establishment in 2021 to monitor the Russian Arctic development. An inventory of artificial intelligence technologies projects, developed in Russia for the harsh Arctic conditions, has been created in order to allow their practical use in the economic activities. It is planned to create digital twins in various industries, thus, so-called digital underwater fields in offshore oil and gas production, the digital twin of the Northern Sea Route (including the twins of ships), and the digital twins of 18 northern ports, energy supply facilities, settlements, road and railways, pipelines [48].

The digital model will allow to elaborate scenarios for both the Arctic development in general and individual territories, will enable to anticipate financial and technological risks at the stage of construction planning, to solve the issue of targeted expenditures at the time of obligations formed. The digital twin will connect all project participants in a single digital environment with the same set of rules, allow to clearly correlate design documentation and estimates, monitor contractors’ activities, and interact with authorities.

A notable example of the digitalization trend is Arctic Connect [46], an information and communication technologies development project based on modern ultra-fast communication lines, which is meant to become the basis for the digital breakthrough of the region and new technologies development. With high-speed Internet, including 5G technology, introduced in remote Arctic settlements it will be possible to launch telemedicine, educational, transport and several other initiatives changing the region’s capabilities. Telecommunication infrastructure that meets modern requirements will create a network of Russian ultra-fast data processing and storage centers, similar to those already created in other Arctic states [47].

Another promising tendency for the development of Arctic territories may be the idea of creating digital twins of large systems. Models of various systems types have been done before but only in recent years it has become possible to carry out real-time calculations and constantly update models with data from objects through devices connected to the network and exchanging data online ("internet of things"). Mathematically accurate description covering all processes in a large system is an extremely complicated task, but with big data on system operation over the past period of time at hand, its work patterns can be identified with a neuronet.

Oil and gas companies operating on the Arctic shelf are already actively using digital twins. The pilot use of digital twins at PAO “Gazprom Neft” began back in 2014 [49]. In 2017 the Production Management Center was created, where the core system is a digital twin of the liquid lifting process from wells. It allows to select the best operating modes, identify non-standard situations in advance, and conduct a preventive assessment of the system in case of a change in its configuration. Over time the Production Management Center will be widened with other digital twins – for reservoir pressure maintenance, energy supply, associated gas treatment and utilization systems.

Monitoring of Arctic territories inevitably leads to the accumulation of large volumes of data (ice situation, meteorological data, wave parameters, sea current data, state of the atmosphere, geomagnetic field, etc.). Accumulated information is a very important information asset. So, it seems inevitable to develop analysis, systematization, and structuring information methods using large databases and artificial intelligence.

Impressive data volumes have been collected by oil and gas companies operating in the Arctic. Big data analysis allows today to avoid errors in management decisions, predict emergency situations, optimize resources and manage risks, calculate hydrocarbon production volumes and choose the right
operating modes for oil and gas equipment. As a result, the production volume can be increased by 35%, while the prime cost of these works can be reduced by 25% [50].

A gas hydrates formation preventing system based on artificial intelligence developed and implemented at OOO “Gazprom Dobycha Yamburg” can be an example. The system makes it possible to increase safety and economic efficiency of production due to intelligent control of introduction of hydrate formation inhibitors [51].

Artificial intelligence technologies are already improving the quality of Arctic medicine. Botkin.AI platform based on artificial intelligence technology for severe and oncological diseases detection in early stages has been introduced in a number of health institutions of northern territories [52].

Artificial intelligence will improve the quality of life of the population of the North. The use of smart systems in the heat supply of the settlements in Yakutia and the Republic of Komi already allows us to save at least 30% of the heat consumption [53].

Successful examples of artificial intelligence technologies launch will contribute to the sustainable development of technologies of natural resources extraction and processing, in logistics, life support systems, data transfer and processing, improving the population life quality, facilitating the emergence of a new paradigm for the Arctic development.

Unmanned vehicles are one of the key drivers of the changes we witness at present. Unmanned piloting and transport management technologies are as appropriate as possible to ensure transport accessibility and infrastructure support in the vast desert spaces of the Arctic region. Unmanned technologies are already a part of the daily life in the Russian Arctic territories.

Thus, KAMAZ unmanned trucks (Kama Automobile Plant, Russia) were successfully tested in the Russian Arctic, which confirmed the effectiveness of the use of unmanned vehicles that allow to improve cargo transportation safety and optimize the remote areas supply [37]. Zala Aero Group tested the Zala Arctic unmanned aerial system (drone). The device is designed for year-round environmental monitoring [38].

Oil and gas companies are also successfully testing and introducing unmanned technologies. So, in 2020 PAO “Gazprom Neft” conducted a number of successful tests of UAVs with an increased flight range for geophysical works [39]. The same company is testing UAVs to respond to emergency situations when drilling exploratory and prospecting wells in the Kara Sea [40]. Another Russian oil company Rosneft began using UAVs for a comprehensive study of the ice situation [42] and aeromonitoring of pipelines in vast areas [43].

At the X International Forum "Arctic: Present and Future" Russian unmanned aerial vehicles for the Arctic were presented with record numbers of flight duration and length as well as with their own data processing and 3D imaging software [44].

To ensure the integrated safety of coastal and marine economic activities, the Northern Sea Route development and offshore operations performance in the Arctic area of the Russian Federation, the Ministry of Emergency Situations is deploying ten Arctic emergency rescue centers equipped with unmanned aerial vehicles modules [45].

A promising track for digital technologies in the Arctic is marine robotics, including the use of underwater unmanned vehicles capable of conducting integrated monitoring and research of Arctic waters, which is especially relevant for assessing deep-sea, inaccessible areas and emergency situations activities. Robotic complexes are already actively used to study the condition and do repair works of Northern Basin naval vessels hulls.

The development of naval vessels equipment, autonomous systems based on the unmanned control principles is worth to be highlighted. It will make navigation possible in difficult conditions without a team on board the ship.

A bright national robotic development, the CRAB complex used by PAO “Gazprom Neft”, should also be mentioned. This is a mobile hardware and software marine complex designed to study the transit zones and the shelf for seismic exploration of offshore hydrocarbon deposits. The project is a set of autonomous bottom stations for recording seismic signals for four components, as well as a software and hardware laboratory for sensing and processing information. Each station can be
autonomous for over 45 days. The CRAB complex allows to create a detailed geological seabed record.

An important technological trend for the Arctic is also the large-scale introduction of carbon-free, renewable and alternative energy technology (wind energy, sun energy, earth heat energy, hydrogen, and tidal energy etc.), which can ensure the ecological balance in the Arctic in its economic development. For example, the coasts of the Barents and Kara Seas, characterized by constant winds with up to 9 m/s average monthly speed, are attractive in terms of wind energy development. In 2021 the launch of the largest wind power plant in the Arctic with a capacity of 200 MW is planned in the Murmansk region [54].

The Republic of Sakha (Yakutia) demonstrates a high potential for the development of solar energy. At present 16 solar stations are operating, the largest among them has a capacity of about 1 MW. The construction of four major wind energy plants in coastal areas is currently planned [55].

The Arctic regions with a developed woodworking industry (Arkhangelsk region, Komi Republic), have experience in biofuel production from chips, briquette, firewood waste. Energy plants operating on biofuels can supply small settlements. Thus, more than fifty heating stations operate on biofuels in the Arkhangelsk region municipalities [56]. 20 hydroelectric power plants are already successfully operating in the Arctic (17 of them are in the Murmansk region, 2 – in Yakutia, 1 – in the Arkhangelsk region), which can be classified as small hydropower facilities.

In the newly created green Arctic energy, new solutions will be based on predictive control technologies, the use of digital platforms and equipment management technologies for electrical networks of all voltage classes. These are dispatching, network operation modes optimization, minimization of power losses, remote control and regulation, small distributed generation control, virtual power plant technologies, smart consumers and neural networks [57-58].

4. Conclusion

The presented review of the applied tools of the new technological structure for the development of the northern territories is far from complete and, no doubt, will be in the near future expanded with promising solutions that are at the stage of development and industrial implementation. The adopted Arctic strategies of foreign countries indicate a consolidated opinion on the need to develop the Arctic taking into account balanced, sustainable environmental management, alternative energy development, wide “green” technologies introduction, the use of carbon-free fuel, advanced environmental standards and management.

The use of the tools of the 4th industrial revolution will contribute to economic activities in the Arctic on the basis of digital, intelligent production technologies, robotic systems and artificial intelligence; new materials, design and construction methods, intelligent transport and telecommunication systems will create a new infrastructure framework, ensure the excellent quality of life for the population in the High North.

The technologies and tools of the new industrial paradigm considered in the article can change the perception of Arctic development as an inevitable environmental disaster, ecosystems resilience reduction and climate challenge radicalization. On the contrary, these achievements of human thought are able to turn the development of Arctic spaces into a new stage and format of economic activity of the mankind.

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