UiT The Arctic University of Norway

Faculty of Science and Technology.

Master's thesis paper:

"Arctic region as a new hydrocarbon production area. Technology needs and equipment availability for the development of the Russian Arctic"

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Abstract

The Arctic area is a relatively new and challenging arena for national and international interests. For many years it was just a cold region, basically, just for meeting of scientific and exploration intentions. But recently, it turned to be a resource base for world leading states, as well as for civil and military interest. One of the main players in the region is the Russian Federation - the largest country in terms of land, Arctic coastline and significant state resources, both financial and technological. Although, Russia is a very versatile state, it combines different advantages of the modern and highly-educated society with an old 'imperial' approach to economic development, foreign political influence and its sovereign independent sight for the Arctic region. Decisions are often made by considering a number of very different factors; sometimes with a lack of strategic approach and at the same time - strong demand for self-identity with a reliance on local capabilities.

As one of the richest fossil fuel lands, Russia has a long, almost 150-year history of oil production, broad experience, which, however, is largely inclined to traditional easy-reachable reserves. Top modern technologies, effective 'western' management of oil production and cost-efficiency ratio of infrastructural and transport projects are still demanding for the Russian oil and gas industry, especially when it comes to the High North.

Secondary factors, such as political uncertainty, access of only state-owned entities to the strategic arctic and sub-arctic offshore areas, enormous geographical distances and military provisions also contribute to creation of Russia's unique approach and future possible actions in inhospitable Arctic region.

In this thesis, a number of questions, concerning the present and the future of Russian hydrocarbon policy in the Arctic area are covered, with a description of necessary technologies and main projects that constitute Russian plans for the nearest decade up to 2030 in presence of western technological and financial sanctions, available equipment and potential for localization.

The main contribution of the thesis are comprehensive technological, climatic and geographical and legal review of Arctic oil and gas industry and discussion of different possible scenarios for Russian Arctic towards 2030.

The project consists of 109 pages, 39 figures and 3 tables.

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PART I

Chapter 1. Topic description and general statements

1.1 Research questions and motivation for study

The Arctic offshore region recently became an area for extensive development of the oil and gas resources. Increased competition and cooperation between the main players – the Arctic states, creates both opportunities and tensions. This thesis will be focusing on the Russian Federation as the main country - the biggest and most active 'stakeholder' of the Arctic territory, with rich experience of operations in the High North in the research and production fields. Technologies behind efficient and safe development of shelf and deep-sea explorations will be discussed.

The main objective of the present work is to define several possible scenarios for the period of next decade (years 2020-2030), to conduct a research of the available and required technologies for the Arctic offshore hydrocarbon development and to provide recommendations for future actions.

Sub-objectives of the thesis are the following:

1) to provide the reader with a general overview of the Arctic region in terms of location, climate, history, nature and environment.

2) to describe the present hydrocarbon resource base, state of international laws, regulations and claims of the involved countries.

3) to conduct an overview of available technologies and economical effectiveness of developing new sites above the Polar Circle in the nearest future. Estimation of production needs, costs and market possibilities.

5) to study Russia's previous and present Arctic activities.

6) to give an overview of Russian offshore infrastructure – the oil ice-class rig 'Prirazlomdaya', Yamal peninsula LNG plants, Murmansk city hub, 'Sevmash' and SSK 'Zvezda' as the main construction shipyards.

7) to develop five possible 10-year scenarios on the basis of the conditions after 2014 - Western countries general sanctions and specific restrictions for supply of technologies and services for the Arctic shelf. Research of available ways to avoid sanctions and establish local production.

1.2 Methods

This Master thesis paper contains data from available open sources, collected and systemically ordered by the author, as well as data about most modern technologies and personal experience during work in the Russian arctic oil and gas industry. Survey of the effect of sanctions and cluster comparative analysis with prior-sanction development of country's hydrocarbon sector with implications for different areas.

Qualitative analysis of literature and related company's reports, specific industry societies and organizations, conference protocols is performed. Conclusions are based on theoretical analysis and lacks practical field studies due to limitations of 2020-21. Approximations and surveys are conducted where it is possible. References to original sources are provided.

1.3 Conclusions and practical implications

The result of the present study indicates that the Russia's future activities in the Arctic will be influenced by both internal and external factors. Of importance are the demand of the oil and gas sector's development, substitution of old depleting resource base, global and regional investments, political willpower from one side and binding effect of western sanctions from another. Possible cooperation and various ways to continue activities are suggested. Recommendations are made regarding how to take into account the future direction of relevant global and regional trends by evaluation of available technology solutions, increasing share of local R&D sector and other ways to overcome restrictions.

Chapter 2. Introduction and general information of the region

2.1 Definitions and general description

A simple, though still very popular definition of the Arctic region is determined as a territory North of Polar Circle, which is located at 66° 33’ N; the approximate boundary of Polar night/ Midnight sun presence. It is a cold and challenging area rich in fish resources, fresh water, fossil fuels and scientific exploration. The region is making up about 6% of the Earth’s total surface or about 21 million km^2 of which almost 8 million is onshore and more than 7 million km^2 is on the continental shelves under less than 500 metres of water depth. Its extensive continental shelf constitutes the geographically largest unexplored prospective area for petroleum remaining on Earth.

The alternative, more scientific ‘climatic’ definition of the region is shown below (fig. 1). It is a significantly bigger area, where the isotherm temperature in July is below or equal 10 °C.

Figure 1. Arctic climatic definition– red line shows the border. Source: arctic-council.com

Today we are still extremely dependent on crude oil and natural gas - the global economy is strongly based on these kinds of fuel, especially in rapidly developing countries in Asia and Africa and emerging economies like China and India. Almost all industrial facilities, transport, heating of the cities and chemistry are connected to daily oil or natural gas consumption. It has a constant growth in recent decades and there is no evidence of retreat. As a simple example – it is estimated that around 1,1 billion road vessels exist nowadays, and only 5,6 million (less than 0,5%) of them are electric. Global forecast of OPEC also predicts further growth of oil and gas production till 2040. The most important reason for the interest in the development of the Arctic territories is primarily due to economic factors, enormous reserves of natural resources, mainly hydrocarbons, but some kinds of ore as well. For example, only the reserves of the Arctic oil are capable of meeting world demand for three years. Having become more accessible with the use of new technologies, resources led to the emergence of claims to the Arctic territories from non-Arctic states and state unions - The European Union, India, China, South Korea, Brazil, and Japan as well. By their claim, non-Arctic countries of the European Union call on treating the Arctic Ocean as the part of a "Common heritage of mankind".

However, the more relevant Arctic states, such as the USA and Canada, Norway and, particularly, the Russian Federation, contentiously develop their own future oil production strategies with respect to the region, previously too expensive and technologically demanding. These challenges provide a limiting effect on sustainable development. But with increased demands and opportunities, the situation starts to change.

Chapter 3. Historical and geographical information

3.1 Key dates of Arctic exploration

Since the beginning of the 20th century, the Arctic got its modern description and became a part of human knowledge of Earth both in geological, scientific and utility sides. It was reached by numerous ships, submarines, airplanes, trucks and even by zeppelins and snowmobiles – by almost all existing transport means. Temporary and later on – permanent settlements were founded on the way to the North Pole, archipelagos Franz Josef Land and Svalbard became inhabited. Marine exploration of the sea shelf as well as the Northern Sea Route and the Northwest Passage were executed by Russia, Canada and Norway. Drifting ice research stations, airfields and supply bases were constructed as an evidence of every country plans for obtaining a part of this region.

During the Cold War, a number of military bases were established by both Soviet Union and NATO countries, so for now, such regions as Alaska, Finnmark and even Greenland preserves these specific facilities.

Below is the brief overview of most remarkable events in the Arctic for the past 500 years.

- 1472: Didrik Pining and Hans Pothorst mark the first of the cartographic expeditions to Greenland.
- 1596 -1597: Third Willem Barentsz expedition, discovery of the Spitsbergen, the Bear Island and the Novaya Zemlya (fig.2).
- 1607: Henry Hudson explores Spitsbergen.
- 1633 -1648: Russian explorers Popov, Rebrov, Zaryan open mouth of Lena, Yenisey, Indigirka, Kolyma – the main rivers of present Russian High North.
- 1760 -1763: S.F. Loshkin explores Novaya Zemlya and put rRussian claim on it.
- 1809 -1811: Yakov Sannikov and Matvei Gedenschtrom explore the New Siberian Islands.
- 1827: First Norwegian expedition to the Arctic, led by Baltazar Mathias Keilhau. It reaches Spitsbergen by 82°45’N.
- 1918 - 1925: Roald Amundsen traversed the Northeast Passage with Maud
- 1926: The airship - ‘Norge’ (Roald Amundsen, Umberto Nobile and Lincoln Ellsworth) – reached the North Pole – first successful attempt.
- 1933: Russian steamship ‘SS Chelyuskin’ managed to get through most of the Northern Route before it was caught in the ice in September.
- 1958: USS Nautilus passes under the Arctic ice.
- 1977: ‘Arktika’, nuclear-powered icebreaker, reaches the North Pole – the first ship to reach North Pole.

- 2007: “Arktika expedition-2007”, Russian submersible descends to the ocean floor below the North Pole from the Icebreaker Akademik Fyodorov – as a result Russia claims for Lomonosov ridge.
- 1962 - 1967: First oil fields discovered in Arctic: Tazovskoye Field in USSR and the Prudhoe Bay Field in Alaska.

Figure 2. Barentz third expedition original map Source:
https://upload.wikimedia.org/wikipedia/commons/a/a8/Barentsz_Full_Map.jpg

3.2 Period of oil and gas explorations

Since the year 1957, the Arctic region becomes the aim for resource exploration and production. From the middle of 1960s, both Soviet and US satellites scanned area surface and discoveries of underwater ocean ridges and plate tectonics were made. Soon after, the Soviet Union began the extraction of non-ferrous metal ores on the Taimyr and Kola peninsulas. In the North Sea, Norway began hydrocarbon activities in 1969 and the United Kingdom started oil production in 1975. In 1977 - the first developments the North America, Prudhoe Bay oil region in Alaska. At present, the major activities in the Arctic are located in the most easy-accessible areas - the Southwest of Barents Sea, the Kara Sea and the Russian onshore - Western and Eastern parts of Siberia. (fig.3)

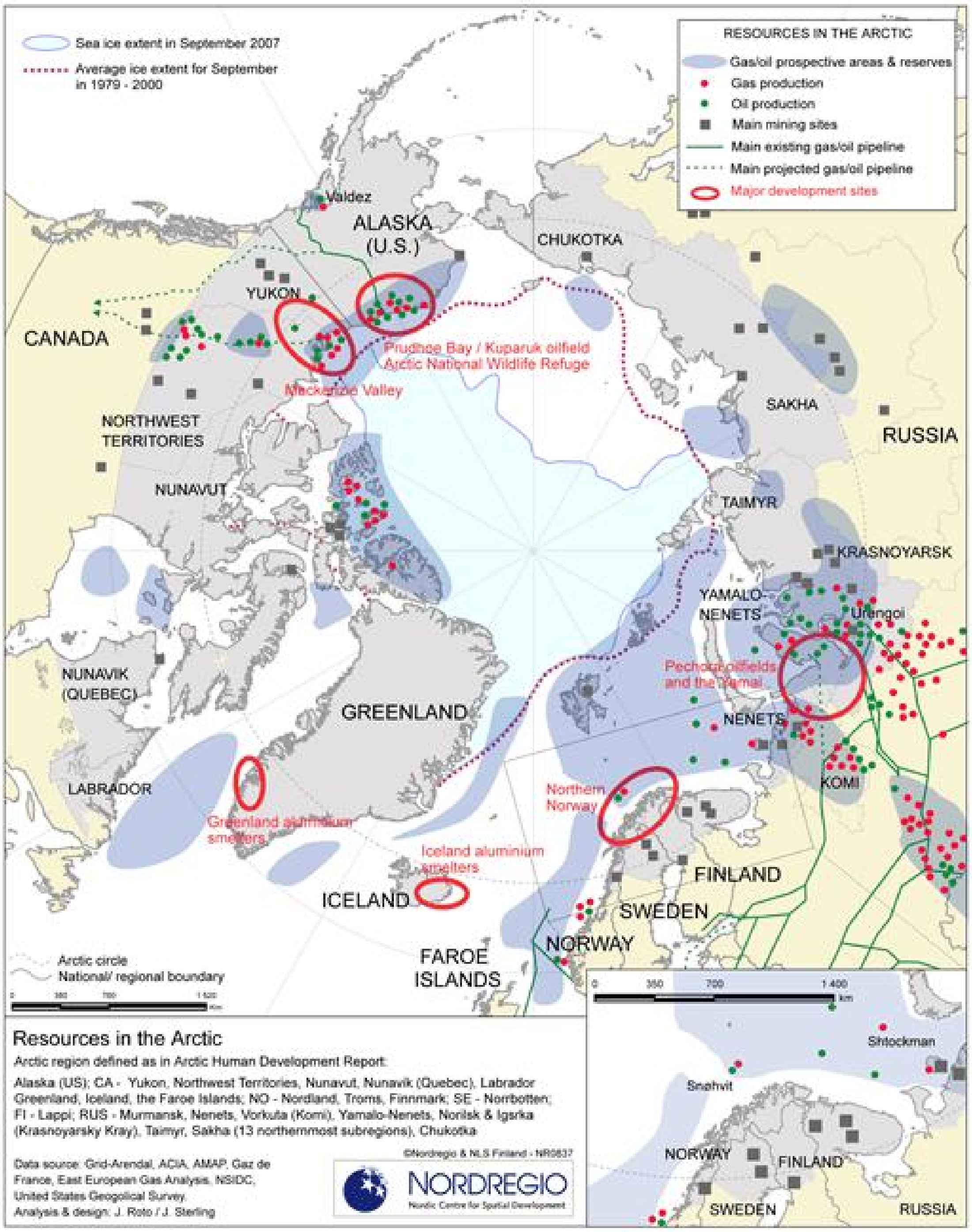


Figure 3. Arctic resource base and regions of the main activities. Source: https://www.thearcticinstitute.org/arctic-oil-and-gas-role-regions/.

3.3 Geographical and geological division of Arctic region

Although the international status of the Arctic is agreed world-over, there are still certain difficulties around it. Initially, the region was divided into five sectors of responsibility between the countries, bordering the area - namely Russia, the USA, Norway, Canada and Denmark. However, the exact borders of the Arctic are still unclear. When the agreement process has been started in period of 1925-1927, a sectoral approach prevailed, according to which the Arctic was divided between adjacent circumpolar states, with the North Pole being the border of all interested states. In the year 1909, Canada declared sovereignty over all territories between the North Pole and its Northern coast. In May 1925, Canada officially secured its right to its Arctic sector. Following that, the Soviet Union in 1926 declared its territory the entire all the way from the North Pole to the mainland limited by meridians. Nevertheless, the sectoral approach contains certain legal gaps, since it determined the legal status of islands and lands, but not the water areas of these sectors. Therefore, in 1982, the Convention on the Law of the Sea was adopted, according to which the state's water area extends only to the Arctic shelf, while the outer zone is declared international. Under the new convention, 12 miles of coastal waters were declared territorial, and a 200-nautical mile zone near the coast as economic territory. So, the question - where the sea shelf ends – became essential for each particular participant.

Today – the five countries claimed the Arctic offshore as their sovereign territory, but there are also three more involved countries – Iceland, Finland and Sweden that are the constant members of the Arctic Council, though it relates only to the matters of indigenous population and the environmental protection.

Chapter 4. Current state by country

Below is the brief characteristics of each country involved.

4.1 Canada

In terms of the total area, Canada is the second largest country in the world, after Russia. Along with its mainland in the upper regions of the North America, Canada claims sovereignty over the related continental shelf and so-called the Canadian Arctic Archipelago. It considers the waters between the islands of the Archipelago to be Canadian Internal Waters. The United States among others considers those to be international waters.

Canada has more Arctic land mass than any other country but one of the smallest Arctic populations. Canada's Arctic land is included within the administrative regions of the Northwest Territories, Nunavut, and Yukon, although geographically and in some cases legally, parts of Newfoundland and Labrador and Northern Quebec are included as well. As of 2015, approximately 107.000 Canadians live in the Arctic **[Census of population – Statistics Canada, 2016]**. The world's northernmost settlement, Canadian Forces Station Alert, on the northern tip of Ellesmere Island – latitude 82.5°N – which lies only 817 km from the North Pole. Much of the Canadian Arctic is covered by ice and permafrost. By considering all the islands, Canada has the longest total coastline in the world, with a total length of 243.042 km. Three of Canada's arctic islands, Baffin Island, Victoria Island and Ellesmere Island, are among the ten largest in the world. **[National Atlas of Canada, 2017]**

Canada’s oil and gas natural reserves consist of more than 90 considerably large oil and natural gas sites, explorations were made after 1964. Today, most Canadian petroleum companies are active in both crude oil and natural gas development and the level of capital investments in exploration and development has increased significantly in recent years. Capital investment in the conventional oil and gas industry has grown steadily from an average of CAN$ 5 billion in the early 1990s to CAN$ 10 billion per year in 2006. Overview of Canada’s seven major sedimentary basins compose major petroleum-producing fields of conventional natural gas, crude oil and oil sands with established pipeline network.

According to the 2007 Arctic Monitoring and Assessment Programme Assessment Report “Oil and Gas in the Arctic: Effects and Potential Effects”, Canada issued most licenses for the Arctic land in the late 1960s and early 1970s, late 1980s and again in the early 2000s. Seismic data acquisition in Canada peaked in the early 1980s and then fell to very low levels in the 1990s. More recently small amounts of seismic activity have taken place. Exploration and discovery wells drilling peaked in Canada in the mid-1970s and then dropped to low levels in the early 1990s followed by a slight increase.

Estimated Canadian Arctic Oil and Gas Reserves.

The US Geological Survey estimates that the Amerasia Basin, which is shared by Canada and the US, holds the second biggest undiscovered oil local share in the Arctic, which amounts to ca. 10 billion barrels of oil equivalent (BBOE) . Counting all the estimated oil reserves together that belong to Canadian provinces or shared provinces with Canada involved, the total oil share is 18.52 BBOE, which is approximately 20.6% of the total undiscovered Arctic oil estimate.

In terms of natural gas, Canadian provinces and provinces shared with the U.S. contain an estimated 124.78 BBOE, which amounts to approximately 7.5% of the total undiscovered gas estimate. The share of undiscovered natural gas liquids is 2.09 BBOE, which corresponds to approx. 4.7% of the total estimate. While the natural gas and natural gas liquids (NGL) estimates are not overwhelming for Canada, the oil estimate – after all one fifth of the total – is large enough to justify at least an exploration interest.

Securing access to these oil resources also explains why Canada has listed securing international recognition of the Canadian continental shelf as one the priorities in its 2010 Arctic Foreign Policy statement. **[1]**

4.2 The United States of America

The USA became an Arctic nation upon the purchase of Alaska from the Russin Empire in 1867. Although it was the pioneer state in exploration of oil and gas resources in Alaska – its Arctic territories, the present-day situation is far from any rush. Previously banned drilling in accordance with indigenous Inuit community agreements, the first real licenses were granted to Oil company Shell only in 2007. Since that, it spent more than 7 billion USD for survey, but didn’t reach any significant success. The oil prices dropped and it became economically inefficient to continue activities. Since now, One of the six planned wells was drilled by Shell to a depth of 1,505 feet. Low price of oil and gas, and opposition by Greenpeace and the Inuit population led to the project being abandoned. Followed by a new legislation banning drilling by March 2017, new Senate started debates for opening up new coastal waters for oil and gas drilling.

Alaska, so-called National Petroleum Reserve, lacks similar to Golf Stream hot waters, therefore most of the basin is covered by ice. It also contributes to the cost of exploration, environment issues and potential for vast oil production. A 2002 assessment concluded that it contains between 6.7 and 15.0 BBOE, with a mean (expected) value of 10.6 BBOE. Most oil accumulations are expected to be of moderate size, on the order of 30 to 250 million BOE each. Large accumulations like the first discovered Prudhoe Bay oil field (whose ultimate recovery is approximately 13 BBOE are not expected to occur **[2]**

Both Canadian and US Arctic shares lack warm current waters like the Gulf stream provides to Europe. It creates huge amount of iced area, that prevents from expanded exploration. (fig. 4)

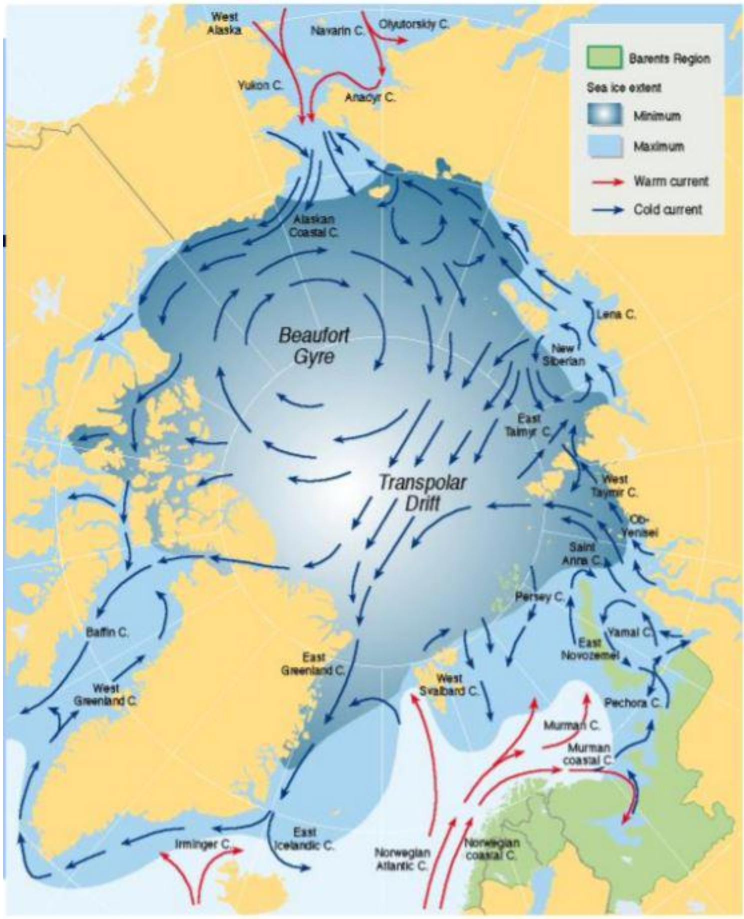


Figure 4. Cold and warm currents in Arctic. Source: https://en.wikipedia.org/wiki/Arctic_resources

4.3 Denmark – Greenland

Greenland is the world's largest island. It covers an area of approximately 2.2 million square kilometres and has over 44,000 kilometres of coastline. Despite its huge size, only 14 oil wells have been drilled offshore Greenland in the last 40 years. Despite Greenland's considerable potential hydrocarbon resources and supportive political environment, Greenland continues to struggle to sustain a thriving oil and gas industry. **[3]**

In 2008 the US Geological Survey conducted the Circum-Arctic Resource Appraisal focusing on all areas north of the Arctic Circle. Based on the estimates from this appraisal, the three major basins around Greenland are believed to hold up to 52 BBOE of potential oil and gas resources. Although these figures are estimates, they clearly demonstrate the enormous oil and gas resource potential of Greenland. The Arctic as a whole is estimated to contain about 415 barrel equivalent, so Greenland's part is 1/8.

Greenland has historically been – and still is – a territory of the Kingdom of Denmark. During the 20th and 21st centuries however, Greenland has become increasingly independent with additional autonomy to oversee certain policy areas. The latest major development was the passing of the Act of Greenland Self-Government (Act no. 473) by the Danish Parliament on 12 June 2009 (the "Act"). **[4]**

The Act allows the Government of Greenland to assume certain legislative, executive and judicial powers from the Danish authorities provided that those responsibilities are financed by the Government from the date of assumption. As part of this power transfer, the Government has assumed authority in respect of the mineral resource activities. (fig.5)

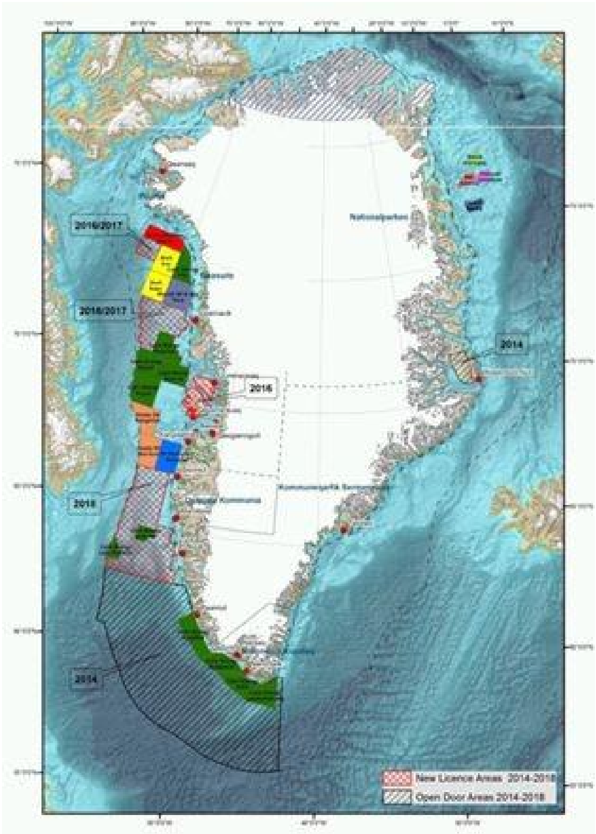


Figure 5. Greenland top view with promoted basins. Source: [*https://www.mondaq.com/oil-gas-electricity/366832/oil-and-gas-in-greenland-still-on-ice.*](https://www.mondaq.com/oil-gas-electricity/366832/oil-and-gas-in-greenland-still-on-ice.)

One of the most recent manifestations of the Government of Greenland's authority over mineral resources has been the publishing of Greenland's Oil and Mineral Strategy 2014-18. The stated goal of the 2014-2018 Strategy is to 'promote prosperity and welfare by creating new income and employment opportunities in the area of mineral resources activities'. In respect of oil and gas, the 2014-2018 Strategy attempts to maintain the current levels of exploration activity over the next five years and extend those activities into different regions of Greenland in the hope that they result in a commercially viable oil discovery, ensuring exploration and related production activities generate jobs for the local population, an increasing focus on mitigating the environmental impact of oil and gas exploration and production in Greenland, with the introduction of new strategic environmental impact assessments and the expansion of Greenland's oil spill response capabilities. It also proclaims establishing educational and scientific institutions to provide sufficient knowledge to local supervisors.

It is necessary to mention about the recent attempt to 'acquire' Greenland by US. In 2018 such proposal was made on an official level. The answer from Danish government was a refusal, but it is still unclear about the future of such demands, since Greenland has obtained broader independence from mother authorities.

4.4 Norway

Norway's Arctic territory consists of the three counties - Nordland, Troms and Finnmark on the mainland, and the Svalbard archipelago and the island of Jan Mayen. Together, these areas make up almost half the Norwegian land mass and they are home to around 470000 people or a tenth of the Norwegian population. Norway's maritime areas in the Arctic come to approximately 1.500.000 km^2, which corresponds to the combined area of France, Germany and Spain.

Due to the warming effect of the Gulf Stream, the Northern Norway is much more hospitable than other parts of the world at this latitude. Tromsø is the largest city in the Northern Norway and is commonly referred to as the "Gateway to the Arctic". Other important towns in the Northern Norway are Bodø, Harstad, Narvik, Alta, Hammerfest and Kirkenes. Today, Norway is the world's 7th largest exporter of oil and the 2nd largest exporter of gas. Norway possesses and utilize the most recent offshore technologies since the beginning of 70th was the first platform Ekofisk established. It also has a more than 30-year history of petroleum activity above the Polar Circle. **[5]**

Figure 5. Goliat offshore petroleum field located in the southern part of the Barents Sea at approximately 370m sea depth, 85 km from shore. Source: https://thebarentsobserver.com/en/industry/.

Petroleum activities on the Norwegian continental shelf both in Vestland and the Arctic are based on the highest standards of health, safety and environment. The resource base is also significant.

According to Oil Directorate article dated 27 august 2017, studies of the northern part of the Norwegian Barents Sea shows twice the resource potential per square km as the southern Barents Sea. After signing the agreement with Russia in 2010, marking the boundaries in the Barents Sea, a process of mapping and licensing of oil sites started. **[6]**

Another big issue for Norway is a recent dispute and news are connected to Lofoten resource area. In 2019 the government announced a radical decision – complete ban of any oil drilling operations in Lofoten, Vesterålen and Senja areas. It is believed that these regions contain more than 35 billion barrels, which will contribute to the national production about 7.6 billion USD in first 5 years in current oil prices.

Though the potential of old oil fields still exists on certain level, the depletion and forthcoming drop of oil production will affect future management of Arctic resource base. To sustain the present level of the oil production companies like Shell, Conoco Philips and Equinor – the main operators of the Norwegian industry will focus on these new mapped and licensed oil sites, proceeding with exploration and drilling operations in the nearest future (figs. 7 and 8).

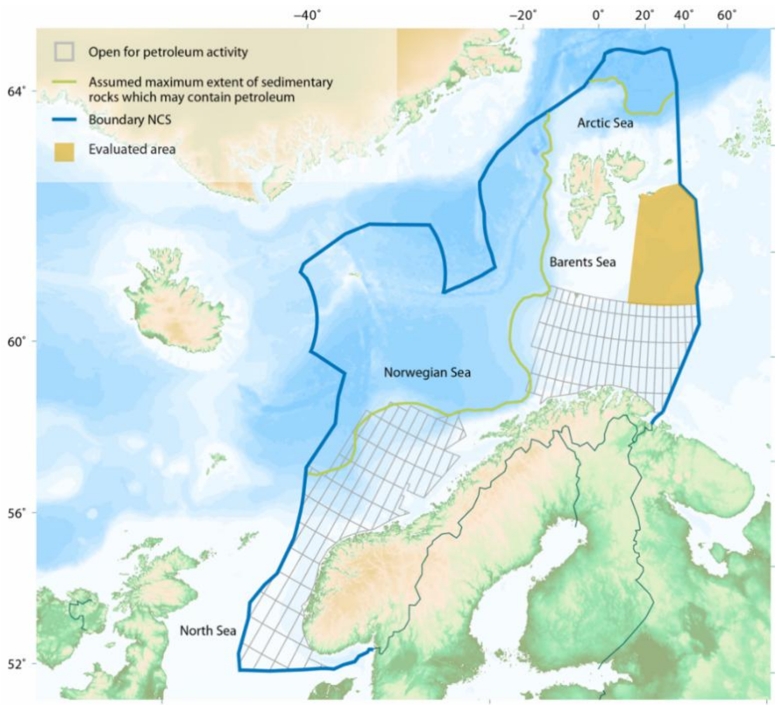


Figure 7. Norwegian oil and gas exploration area, including icing conditions. Source: The Norwegian Petroleum Directorate.

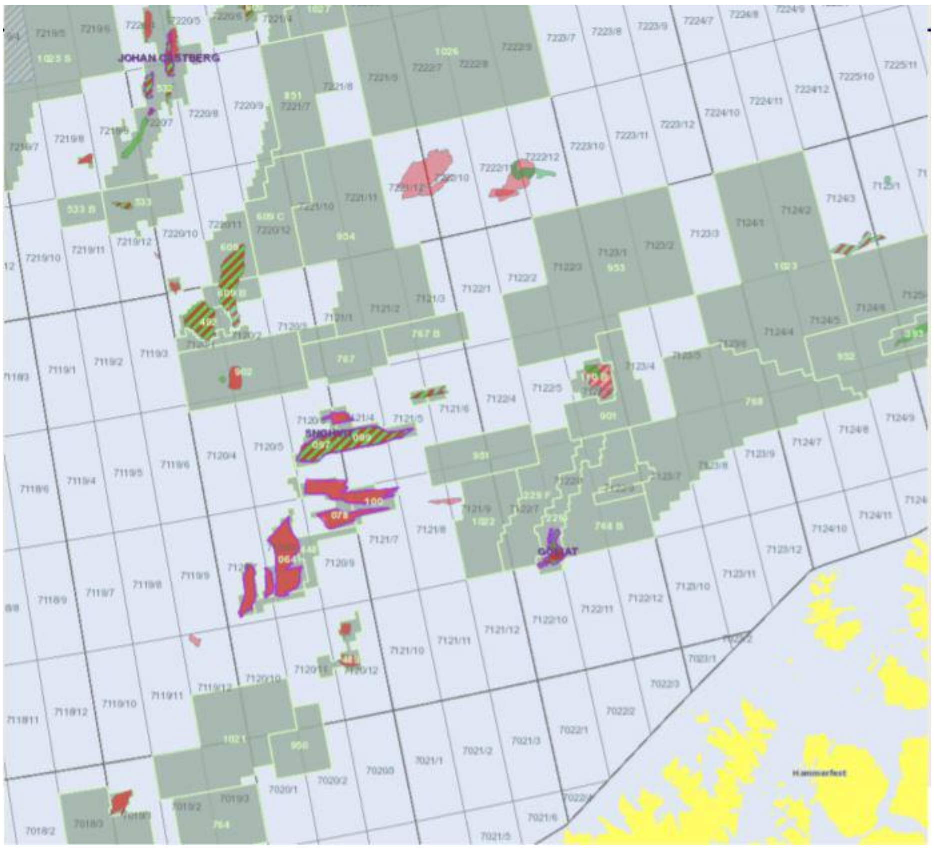


Figure 8. Petroleum fields on the Norwegian Continental Shelf in the Barents Sea. Source: The Norwegian Petroleum Directorate

4.5 The Russian Federation.

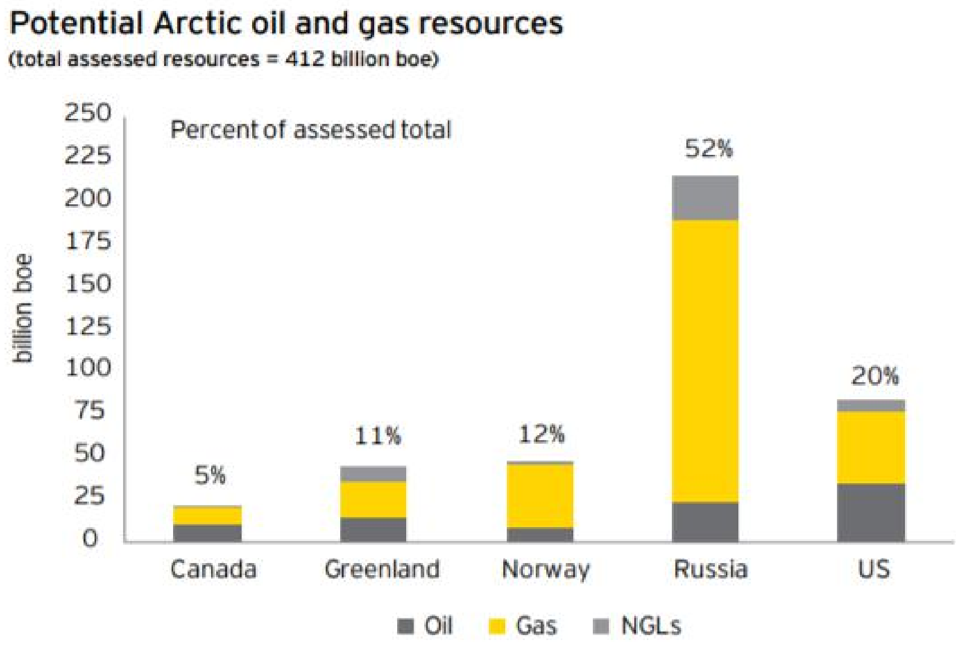
Russia's crude oil and natural gas reserves are enormous. But as the most of other so-called 'raw resource-supplying' states, it strongly connected with the political and strategic decisions, influenced by a large number of reasons, both domestic and international. The state priority is based on the constant oil production, any drops and decreases are critical. By the year 2019 Russia was the second largest oil exporter (after Saudi Arabia) with approximately 11.4 million barrels per day and primary markets – Central Europe and China. Natural gas is the second largest export resource for the country. Clearly, Russia has ample reserves that could still be tapped, and it is anticipated to see the start-up of its new major LNG export terminals – Yamal LNG and Arctic LNG-2 (see chapter 9) – in the course of the next few years. However, it is assumed that the major frontier areas in the Arctic largely remain prohibitively expensive and difficult to develop. The recent expansion of US sanctions on Russia has the potential to make the involvement of US energy companies, in particular, more challenging, thus theoretically curbing access to experience and the technology relevant to developing the country's High North.

Despite owning around half of the total oil and gas resources tucked under the Arctic shelf, as well as a bulk of explored reserves, Russia has so far failed to significantly develop these holdings. Even the ‘Prirazlomnaya’ oil platform (fig. 9), which will be described later (see chapter 8), has produced only insignificant amount of very costly crude oil. **[7]**
Other oil and gas projects in the Arctic haven’t gotten even that far. The Shtokman field in the Barents sea, once a signature project for Gazprom, Russia’s natural gas monopoly, was shelved in 2012 thanks to growing expenses.

Although, the potential can still exist. Compared to Russia’s previously mentioned discovered 52% of all resources of the Arctic shelf, the United States, which holds only 18-20 %, followed by Canada, Denmark, Greenland and Norway, which divide the remaining 28-30 percent among them. Russia’s estimated explored offshore oil reserves add up to 5 billion tons (each ton contains approximately 6-7 barrels depending on liquid density). Norway is a distant second with 1 billion tons of proven reserves. (see table below). However, for a number of reasons, both economic and environmental, those resources may go nonrecoverable. **[8]**

Figure 9. Gazprom's ‘Prirazlomnaya’ Rig, (Photo: Gazprom, https://www.gazprom.com/*)*

The table 1 below summarizes present potential overall Arctic resource base.



Source: Ernst & Young calculations from US DOE and US GS data

Table 1. Potential Arctic resource base.

Chapter 5. International regulations and interstate agreements.

In this chapter I would like to cover several important international agreements, its values and general statements, as well as the attitude of involved countries to the Arctic - geopolitical, climatic and environmental, resource and transport opportunities.

5.1 The Arctic Council

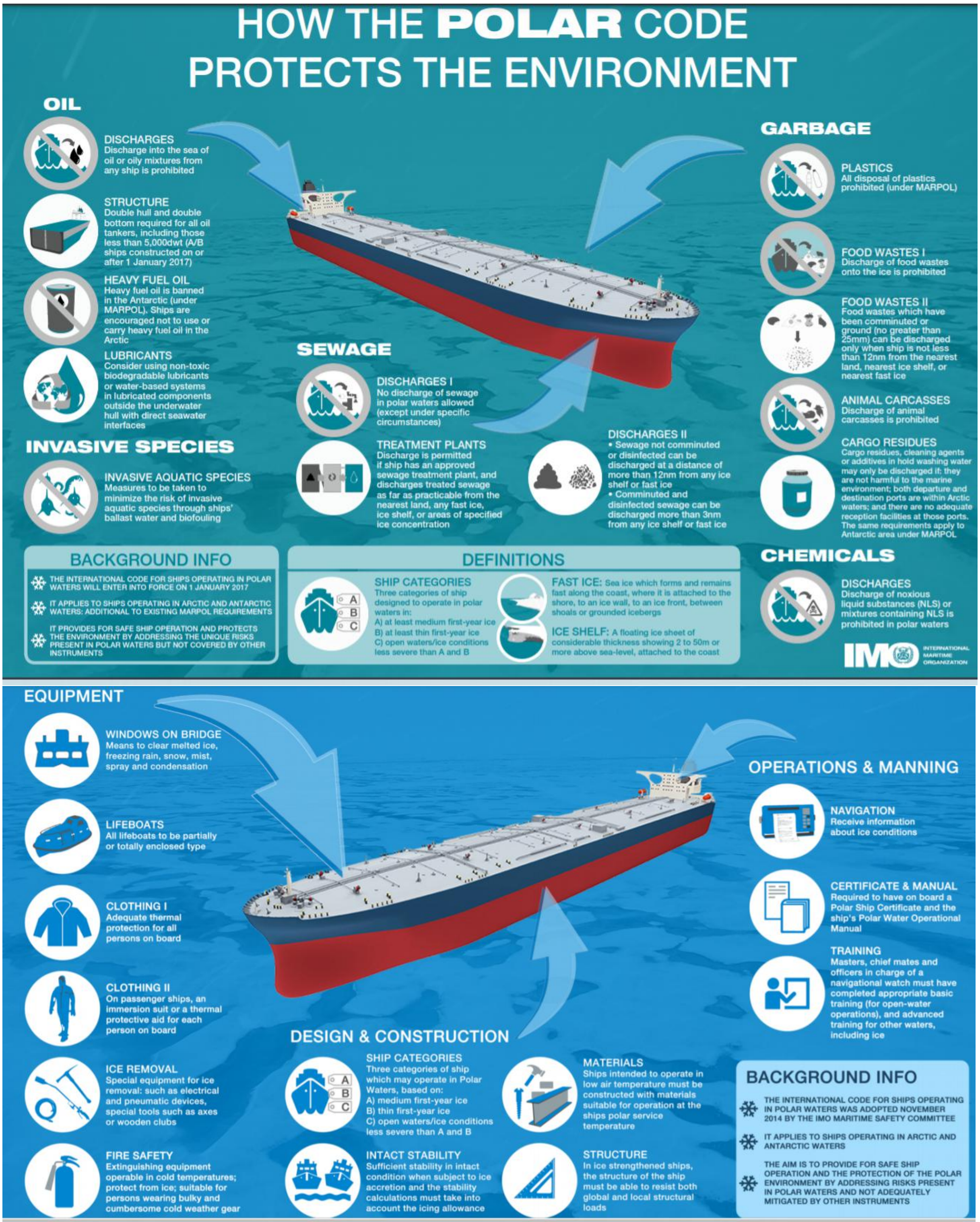
The main and most recognized authority, regulating activities in the Arctic is an Arctic Council - organization of eight member states and a number of observing participants, that was established in 1996. **[9]**
The initial aim of establishing this forum was to promote cooperation, coordination, and interaction among the Arctic states, with the involvement of the Arctic Indigenous communities and other Arctic inhabitants on issues such as sustainable development and environmental protection. The Arctic Council has conducted studies on climate change, oil and gas, and Arctic shipping. Today there are eight members - the USA, Norway, Kingdom of Denmark, Sweden, Finland, the Russian Federation, Iceland and Canada. The number of observing states, non-profit organizations, funds and international authorities (such as Aleut International Association, Inuit and Saami Councils) also participate in debates.

As the main function of the Arctic Council is being a forum - providing a place for discussion and cooperation, it has no real legislative power. The Arctic Council does not and cannot implement or enforce its guidelines, assessments or recommendations. That responsibility belongs to individual Arctic States or international bodies.

5.2 The Polar Code

The other significant achievement of international cooperation in the North is a recently established Polar Code - a special framework, developed by International Maritime Organization (IMO) which covers design, construction, equipment, operating, training, search and rescue and environmental protection matters relevant to the ships and infrastructure in waters of both Arctic and Antarctic, in the inhospitable waters surrounding the two poles. But it is applied only for large vessels - fishing boats are out of its jurisdiction. It is also should be mentioned that today many environmental protection measures are already effective in Antarctica and not yet in effect in the Arctic. It is in effect since Jan. 1, 2017.

The summarizing issues of the Polar Code can be seen on two infographics below (figs 9 and 10):



Figures 9 and 10. Polar Code main inquiries. Source: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Polar-default.aspx

There are also two important sub-articles related to Arctic activities.

Ship reporting in the Arctic region

The Maritime Safety Committee (the MSC), at its 91st session in November 2012, adopted a new mandatory Ship Reporting System (SRS) Barents Area SRS (proposed by Norway and the Russian Federation). The new mandatory ship reporting system entered into force on 1 June 2013. The following categories of ships passing through or proceeding to and from ports and anchorages in the Barents SRS area are required to participate in the Ship Reporting System, by reporting to either Vardø Vessel Traffic Service (VTS) centre or Murmansk VTS centre: all ships with a gross tonnage of 5,000 and above; all tankers; all ships carrying hazardous cargoes; a vessel towing when the length of the tow exceeds 200 meters; and any ship not under command, restricted in their ability to maneuver or having defective navigational aids.

S**hip routing in the Arctic**

The MSC, at its 99th session in May 2018, adopted new and amended ships' routing measures in the Bering Sea and Bering Strait, aimed at reducing the risks of incidents - the first measures adopted by IMO for the Arctic region where the Polar Code applies.

The measures include six two-way routes and six precautionary areas, to be voluntary for or all ships of 400 gross tonnage and above, in the Bering Sea and Bering Strait off the coast of the Chukotskiy Peninsula and Alaska, proposed by the Russian Federation and the United States. These waters are expected to see increased traffic due to rising economic activity in the Arctic.

In addition, the MSC established three areas to be avoided in the Bering Sea, proposed by the United States, to improve safety of navigation and protect the fragile and unique environment. These measures entered into force on 1 December 2018. **[11]**

5.3 Other international acts and agreements

The necessity for further interstate agreements appeared soon after the year 2000. The potential opening of the Arctic and its resources and the anticipated increasing accessibility of the region to shipping, due to the global warming, coincided with these global anxieties with regards to future oil supplies. As a result, the Arctic was considered to hold the key to meeting future energy needs. The region’s potential was published with promising numbers in the Arctic in 2008. It estimated that 13 % of the world’s undiscovered, technically recoverable oil, 30 % of natural gas and 20 % of natural gas condensate could be found in the Arctic. As many have pointed out since, most of these sources were expected on land and within the Arctic Ocean coastal state's 200-nautical-mile Exclusive Economic Zones (EEZ), which means that these states have the exclusive right to explore and exploit resources in the water column (fish) as well as in the seabed and subsoil (oil, gas, minerals). There is no international 'race for the Arctic' to claim these resources, as oil and gas drilling in the region is extremely capital-intensive and needs political stability and security of investment. This may be one of the reasons why Russia and Norway were able to delimit their maritime boundary in 2010.

In general, oil companies are hesitant to bid for licenses in areas that are disputed. In this particular case, Norway was interested in opening up new areas for oil and gas drilling, as its oil production had been in decline ever since it peaked in 2004. At the same time, Canada and the United States had not yet been able to delineate their international maritime boundary between Yukon and Alaska in the Beaufort Sea, despite the fact that the area is rich in fossil fuels. It is estimated that the potential oil and gas reserves are not equally spread all over the Arctic, but primarily expected to be located in the Beaufort (Canada, United States) and Chukchi seas (United States, Russia), as well as in the Barents (Norway, Russia) and Kara seas (Russia). According to these estimates, half (52 %) of the assessed total will be located within Russian jurisdiction and EEZ, 20 % within the US, 12 % in Norway, 11 % in Greenland and 5 % in Canada. The study estimates that the Arctic as a whole holds three times more gas than oil resources and that 84 % of these are located offshore. However, these are only provided probabilities and estimates of undiscovered hydrocarbon resources, which were based on geological prediction models and not actual exploratory drilling. So now it is considered to be 'the Arctic is an area of high petroleum resource potential, low data density, high geologic uncertainty and sensitive environmental conditions'. **[12]**

Mentioning other agreements, it is important to say about involvement of the EU. It doesn't deal with resource shares, but with intellectual, educational and cultural cooperation. Initiated in 1999 and renewed in 2006, the joint policy between the EU, Russia, Norway and Iceland successfully promoted dialogue and concrete cooperation along four sectoral issue areas, namely environment, public health and social well-being, transport and logistics and culture. Through its Working Groups the Barents-Euro Arctic Council (BEAC), addresses economic and environmental issues, transport, as well as social issues such as health, education and youth exchange. Its members are Denmark, Finland, Iceland, Norway, Russia, Sweden and the European Commission. The joint EU and BEAC cross-border programs had been very successful in building trust and establishing extremely cooperative relations for two decades until the 2014 Russian annexation of Crimea.

5.4 Russia - Norway delimination treaty agreement in the Barents Sea

The treaty between the Russian Federation and Kingdom of Norway on delimitation of the sea areas and cooperation in the Barents Sea and the Arctic Ocean was sighed on 15 September 2010 as a result of long-term mutual negotiations and willingness to determine rich and easy-accessible hydrocarbon reserve area. 844 nautical miles created by demarcation line.

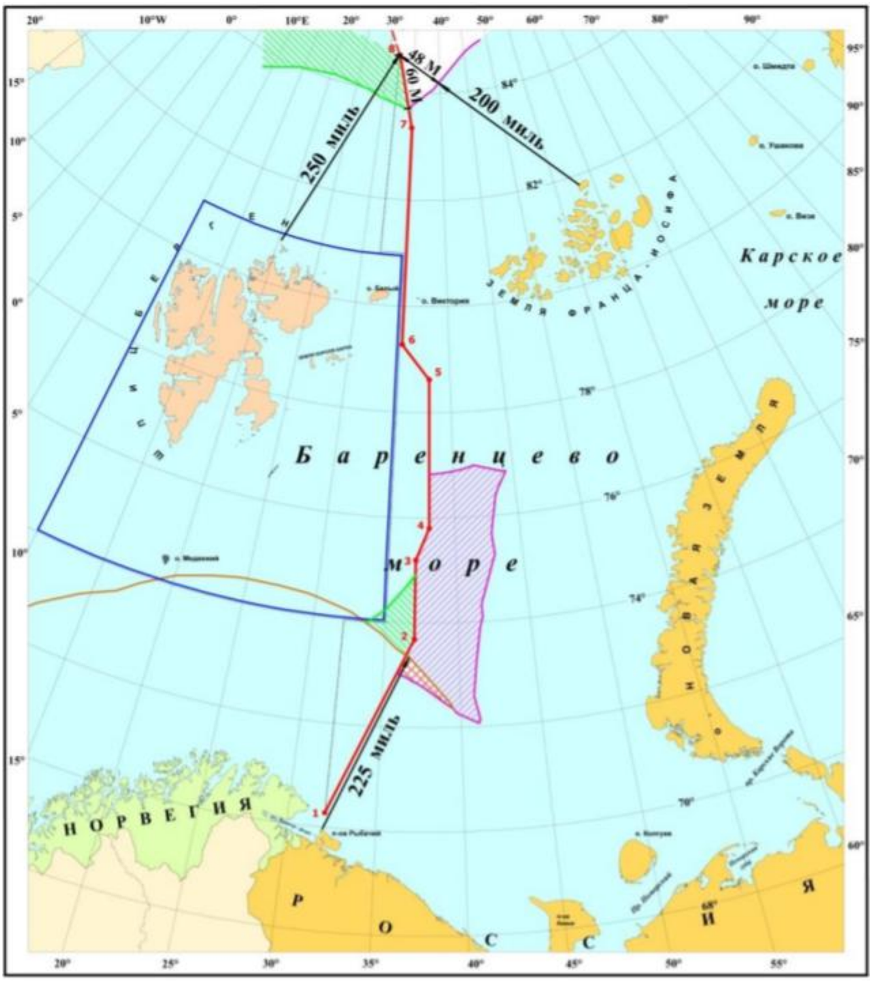


Figure 11: Delimination of the Barents Sea upon Russian-Norwegian Treaty. Source: Arctic and North. magazine 2017. No. 29. *Signs as follows:*
Black line means Russian Polar territories; Red line is the demarcation line according to the Treaty 2010; Blue line is borders of the Spitsbergen Treaty 1920; Green Line is the 200 miles line from Spitsbergen; Orange stripes is the special area according to the Treaty 2010; Violet stripped area is the Russian Exclusive economic zone; Brown line limits the Norwegian Exclusive economic zone. Continental shelf outside the 200-miles zone: Norway (green field), Russia (violet field). All distances measured in miles.

Besides the importance of hydrocarbon area division and complex fishery agreement, this treaty gives a significant improvement in common safety actions, emergency prevention and environmental protection. It also provides a positive basement for the further cooperation between two states and business for development of transport, tourist, service and civil infrastructure in the North.

PART II

As it was mentioned previously in Part I, the Arctic region consists of two main areas that require quite different approach to each other - onshore tundra land and offshore shelf - cold water seas bordering the Arctic Ocean. Both areas are considerably large and rich in mineral resources, but its development difficulties are incomparable.

In my opinion, it is important to analyze both parts - Russian deep offshore, coastal shelf - border sea-land area and Arctic inland. Each area presents its own challenges, current level of development, existing and planned activities as well as long-term future perspectives.

Chapter 6. Natural and environmental challenges of Arctic development

In general, Arctic land is characterized by extra-long distances, harsh climate conditions, sensitive areas of natural habitat zone and traditional living areas of indigenous people. It is also very cost-demanding and technology-dens to develop region. Each failure becomes critical both for budget and environment.

The development of some of the promising Arctic areas for oil and gas exploration can easily become not only non-profitable, followed by highly surpluses and consecutive dangers. Underrated nature effects, poor pollution prevention and the lack of conditional monitoring is likely to bury any ambitious project.

6.1 Climate of the Arctic region

The Russian part of Arctic climate differs a lot - mild sub-arctic in the Barents Sea region, strong continental further East and extreme cold in Asian part. The country crosses eight time zones, stretching over 9000 km between 30° and 170° meridians. According to World resource institute, the length of Russian coastal line is more than 25 000 km, though the exact number depends on calculating methodology.

Although, the region is generally cold, the weather fluctuations across such distances are a challenge itself. The lack of permanent meteorology forcasting stations, minor historical weather data, difficulties with conducting meteorological research - all these factors create general complexity and climate related issues. Unpredictable weather can impact in completely different strategy when it comes to any activity - exploration, drilling, extraction, transportation and infrastructure construction. So, mandatory consideration of ice cover, permafrost, polar lows (Barents Sea) and simply enormous distances from the main production and repair facilities increase the basic cost and risk of failure of any project by times. This also follows to exceptionally long lead times and added complexity of project planning.

Other factors that have direct influence on the activity in the region are the following:

- ice cover. Land area, namely Arctic tundra, is covered by ice most time of the year. Cold waters of Barents and Kara seas have both drifting and packed ice. Eastern seas, such as Ohotsk and Laptev seas regularly freeze and require ice-resistant technologies for any structures there;

- cold temperatures. A big part of available instruments and equipment, used in exploration and production operations is not designed for such extremely low temperatures. Special insulation, external heating and anti-ice measures are required. Rubber materials, such as seals, gaskets, manifolds change their quality drastically under severe North conditions. Liquids normally require special anti-freezing injectors to be used on a permanent basis;

- winds and pressure changes. This factor often leads to wind chill effect and results in ice covers of outer structures that exposure cold winds and humidity. Stop of performance, difficult and time-consuming ice cleaning works affect planned production and lead to delays and unplanned expenses;

- polar nights. Several winter months the Sun does not rise above the horizon and it creates a well-known effect of endless dark time. From the technological side, it requires a significant amount of artificial light sources to be added on constructions. It also affects human behavior and additional personal equipment;

- icebergs. By definition - it is a is a piece of ice that has become detached from its parent glacier by a process known as calving. They can reach up to 250 meters in thickness, though the majority will be underwater. According to Canadian Encyclopaedia **[13]**, icebergs in the Arctic Ocean are generally pieces of floating shelf ice that form principally on the north coast of Ellesmere Island. These thin, tabular icebergs are typically 30 m thick, often up to 100 km^2 in area, and 2–6 m above water. Irregular formations could be met further North. These types are the most dangerous for any equipment on the sea - in rare cases they can have irregular spires reaching up to 100 meters above sea surface. US Geological Survey posts iceberg forecasts. Oil and gas operations in the Beaufort Sea and between the Queen Elizabeth Islands are threatened by collisions between even small ice islands and drill platforms or pipelines. The threat to shipping in the North Atlantic is now minimal, as a result of the establishment of the International Ice Patrol after the sinking of the Titanic in April 1912.

So, we can conclude that it is obvious - large-scale activities in the Arctic contribute to high level of risks and create additional challenging conditions for people and technology, require special design, manufacture and testing. Start-up operations, maintenance, condition monitoring - all this will differ a lot from its analogues in more traditional areas.

6.2 Communication

When it comes to extremely long distances across sparsely populated areas, the quality and stable connection becomes crucial. Communication is closely related to transport, but on the other hand, contributes much when no transport is available in practice.

Highlighted below are the main features of the Arctic communications system that clearly shows its significance for the development of both parts of the region:

- remoteness of the Arctic region from developed industrial and financial centers;
- harsh climatic conditions for doing any activities;
- low density of distribution of business entities and their autonomic location;
- discontinuous uneven settlements;
- significant extent of territories. The analysis showed that the communication system in the Arctic as a whole is poorly developed, and the degree of development of infrastructure is strongly differentiated. High level of accessibility characterizes only the territory of the Murmansk region (with the exception of the partial limited timing of the Lovozersky and Tersky districts). For the rest of the continental Arctic region only airplanes and helicopters can provide connection to the mainland.

6.3 Transport

Railway transportation historically plays the main role for delivering cargo to huge construction sites to remote regions of Russia. A broad net of railroads was constructed up to the High North to build settlements, channels and develop first oil and gas field in Western Siberia. So, for today, this tradition remains. For large-scale projects, such as on Yamal Peninsula, JSC "Gazprom" – operator of this area and PAO 'RZD' - Russian National Railways have cooperated to build its unique railway route to support infrastructure development. Obskaya – Bovanenkovo railroad. It created an all-year round delivery independent from ordinary summer season of sea navigation. The railroad stretches for 572 kilometers from the Obskaya station to the

Karskaya station and 525 kilometers to the Bovanenkovo station (fig. 12). It includes 5 stops, 12 passing loops, and 70 bridges with a total length of more than 12 kilometers. The entire railroad was opened for traffic in 2011. **[14]**

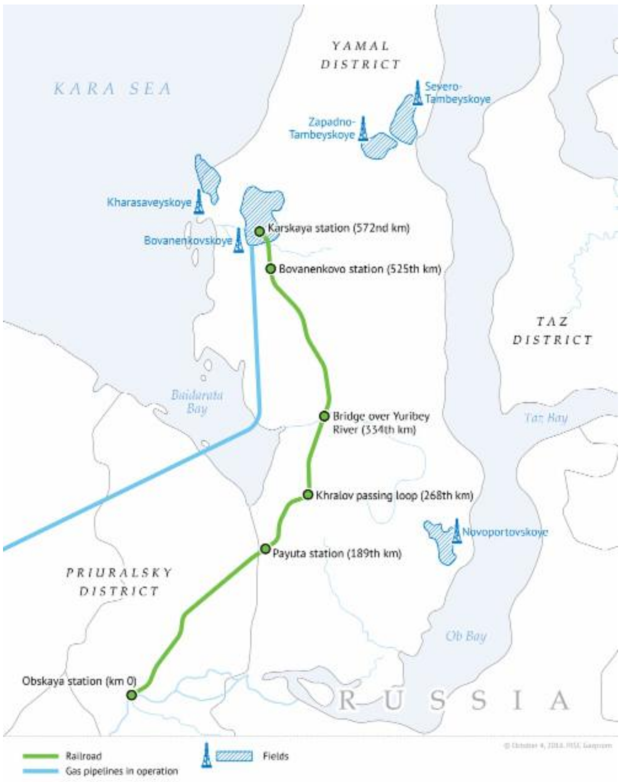


Figure 12. Yamal peninsula railroad to Bovanenkovo. Source: www.gazprom.com/projects/obskaya-bovanenkovo/

Figure 13. Bridge over Yuribey River. At 3.9 kilometers in length, it is the world's longest bridge beyond the Arctic Circle. Its life span is 100 years. Source: www.gazprom.com/projects/obskaya-bovanenkovo/

In general, the major challenge for Arctic sea, river and road transport becomes a seasoning division. Every operator has limited time in a year when ice-free routes are available.

Most of onshore Arctic sites have no railroad connection and require summer river transportation and winter route caravan supplies. Personnel are delivered by helicopters, which operate year round, but are highly dependent from everyday weather conditions. The river transportation and delivery of goods by means of river transport is functioning few warm months - the exact period is defined by location.

‘Greenfield’ onshore sites of Eastern Siberia (Vankhor cluster and Timano-Petchora oil fields) face the above-mentioned challenges.

The problem could be partially solved by shipping via the Northern Sea Route (NSR), and as far as the future of the gigantic Vostok (‘East’) Oil project is clarified, the investments in NSR transport will be amplified.

6.4 Pipeline transportation of produced hydrocarbons

Pipelines are the most common and still - the cheapest way to deliver crude oil and oil products by land.

Figure 14. Project ‘Nord Stream- II’ gas pipeline running from Russia to Northern Europe on the bottom of Baltic Sea. Source: http://www.gazprom.ru

Thousands of kilometers, which normally separate main production areas from refineries and end users forced producing countries to develop their own broad network of pipelines (fig. 14). It remains the most efficient way to transport large quantities of oil, refined oil products or natural gas over land. Average costs of pipeline transport of crude oil are about USD 5/barrel.

Railway onshore transportation is at least 2-3 times higher with average up to USD 18/barrel depending on location. Tank trucks have even higher costs due to the additional labour required. **[16]**

However, today underwater oil pipelines loose in cost (about two times more expensive) to ocean tanker fleet, mainly because of significant capital costs, complex technologies and higher risks related hazards and environment protection.

The largest crude oil supertankers can store and transport up to 2 million barrels. The cruise speed is 15 knots and cost of transportation. Average construction and operational expenses of a tanker gives an approximate barrel transportation cost of less than USD 2.5/barrel.

Pipelines have a very diverse flow rate depending on diameter and pumping force. The average speed of oil moving in 1200 mm diameter pipe is 5.5 km/hour, which is nearly four times less comparing to tankers. But for land transportation, as it was mentioned before, it remains the cheapest and most effective way.

In contradictory, for natural gas transport pipelines is the cheapest and usually the only way both onshore and offshore. LPG plants and vessels are way more complicated and expensive in use. For the Arctic projects ice-class ships are required, movement in convoys during ice season and planning routes with consideration of long distances between supply bases.

The World's Arctic pipeline development finds its starting point in 1977, when the design and construction of first large-scale Trans Alaska Pipeline System (TAPS) was implemented. There were many know-hows and engineer practical solutions for technical, logistical and environmental challenges in the difficult, isolated terrain.

Still in operation, TAPS has provided experience in operating long-distance (1287 km), large-diameter (48 inches) crude oil transport lines in the unique arctic environment, was led by other similar projects, for example the Mackenzie Gas Pipeline. These initial projects also shown disadvantages of Arctic pipeline transportation - huge financial investments, extra-long market distances and environmental risks made such projects possible only for major large-scale hydrocarbon sites, but still require extreme reliability and high-cost rare materials, extra-long construction and repair times.

The first subsea arctic oil production pipeline in the North American Arctic was installed only in the beginning of 21st century by British Petroleum and it was a shale pipe (the depth is only 11 m) connecting the Northstar production facilities on Seal Island, about 10 km offshore Alaska in the Beaufort Sea. Two threads, 10 inch each diameter steel pipelines comprise the heart of the Northstar system, which was buried 7-to-10 ft below the sea floor to avoid ice scour and is equipped with three leak-detection systems.

The other important North America subsea arctic production pipelines were installed at the Ooguruk field, also 10 km offshore Alaska in 2007 and at the Nikaitchuq flowline bundle at 2011. Both these pipelines are rather short and requires constant monitoring and commissioning.

Below are two examples of existing extra-long pipelines from the Russian onshore Arctic:

1. Yamal - Europe gas pipeline, 4196 km.
Yamal peninsula in Western Siberia is a treasury of Russian both oil and gas reserves. High above Polar Circle with yearly temperatures around zero, it became a high-tech construction just from the design phase. With a diameter of 1420mm (the largest available pipe diameter), Yamal - Europe is considered the world's widest pipeline, able to carry 33 billion m^3 of natural gas through 14 compressor stations. This pipeline connects Russia to Austria, stretching across North-West of the country and then to Belarus, the Ukraine, and Slovakia. Yamal-II thread redirects from Belarus through Poland to Austria. Owned by a national state company Gazprom and its European subsidiaries. Reported construction cost is 5 billion USD.

2. Eastern Siberia-Pacific Ocean Oil Pipeline,4 857 km.
The Eastern Siberia-Pacific Ocean Oil Pipeline (ESPOOP) is a 4,857 km project operated by Russian oil transport company PJSC 'Transneft'. It is a recently constructed pipeline which connects Taishet in the Irkutsk region (Central Siberia with loading terminal Koz'mino on the Far East and export metering station Skovorodino on Chinese border. It collects produced oil from Arctic Eastern Siberian oilfields directly to China - among the biggest consumers of hydrocarbons in the world.
The capacity is up to 300,000 barrels per day, which is relatively humble volume, but the cost of construction is huge, was increased several times and now is around 8,9 billion USD. Main contributors to the volume of oil are Vankhor and Timano-Pechora oil clusters and connected by a additional 550 km long OJSC 'Rosneft' owned pipeline 'Vankhor-Purpe'.

There is a number of other ambitious projects which are under construction for now:
- The Bovanenkovo-Ukhta-2 gas pipe (Gazprom owned);
- Zapolyarye-Purpe gas and oil pipeline (Rosneft owned);
- Kuyumba-Taishet - (Transneft);
- 'Sila Sibiri' ('The Power of Siberia') new large gas pipeline to China (Gazprom).

As we can see, due to its territory, scales and resource field location diversity, Russia historically had to build the broadest and effective pipeline network, both for internal and export evaluation.

6.5 Requirements for pipeline construction

Every comprehensive pipeline facility should be designed, produced, protected, checked and maintained according to international standards, such as ISO (International Standards Organization), ASME (The American Society of Mechanical Engineers), API (American Petroleum Institute) and others.

Below I would like to emphasize the most general requirements of every stage of production.

6.5.1 Design, production and maintenance

It is obvious, that different technical requirements, process parameters, environment and landscape contribute to the design and production, using of materials and instruments, construction and support vessels and many other factors that have to be considered during engineering phase. Certain safety margins according to standards are required.

It can be sea bed, permafrost region, hilly land, tundra or populated urban area. Developers must consider nature protection, the interest of indigenous people and necessity to lead pipeline threads distanced, even by the increased costs. A couple of examples are: the pipeline from Siberia to China was redesigned and relocated further North to avoid close contact with Baikal area - a natural water reservoir that possess the deepest fresh water lake on Earth. The concern of local population about pipeline safety led to prohibit of any construction in the Canada Northern Territories and the whole island of Greenland. Seasonal issues such as soils, permafrost and temperature changes are among challenges for designers.

The current engineering and material design level allows to develop pipe bodies with wide range specific parameters according both to process and environment. Multi-layered steel, corrosion resistant materials and isolation provide defense from outer factors. Automated welding and non-destructive control of pipe quality are essential for initial construction.

Regarding maintenance and life cycle, most modern pipelines are designed for 35-50 years of failure-free work with regular service, but different requirements lead to individual approach. When it comes to field work, construction regulations - both local and international rises, the acceptability of special construction vehicles (in a example with Eastern Siberia pipeline construction a number of cranes were lost because of swampy areas) and vessels, access to certain materials and personnel - in some areas it is very hard to get highly-qualified specialists on site for managing the work and logistics issues become a problem.

One of the examples of modern technology in this field is the ‘Nord Stream’ gas pipeline from Russian High North to Germany (fig. 17), covering the distance 1224 km (and two threads are 2448 km of large-diameter pipes) is solely laid down on the bottom of the Baltic Sea, with using of subsea technologies, underwater robotics and precise dynamic positioning pipe-layer vessels (PSV), such as ship ‘Akademik Chersky’ (figs. 15 and 16).

Figure 15. ‘Akademik Cherskiy’ - a ship involved into the construction of underwater gas pipeline Nord Stream II. *Source: www.marinetraffic.com/ru/ais/details/ships/shipid:899194/*

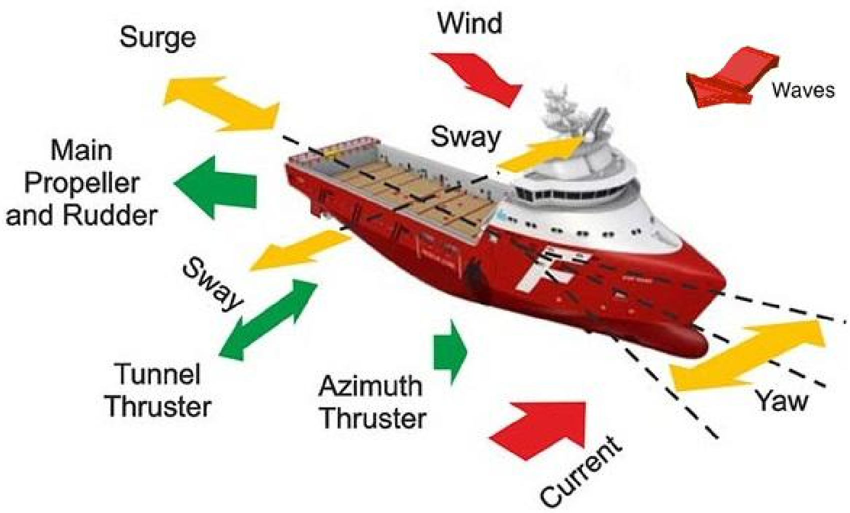


Figure 16. Dynamic control of stability of a ship during pipe layer process in open sea. Source: https://www.kongsberg.com/ru/maritime/support/themes/dynamic-positioning-basic-principles/

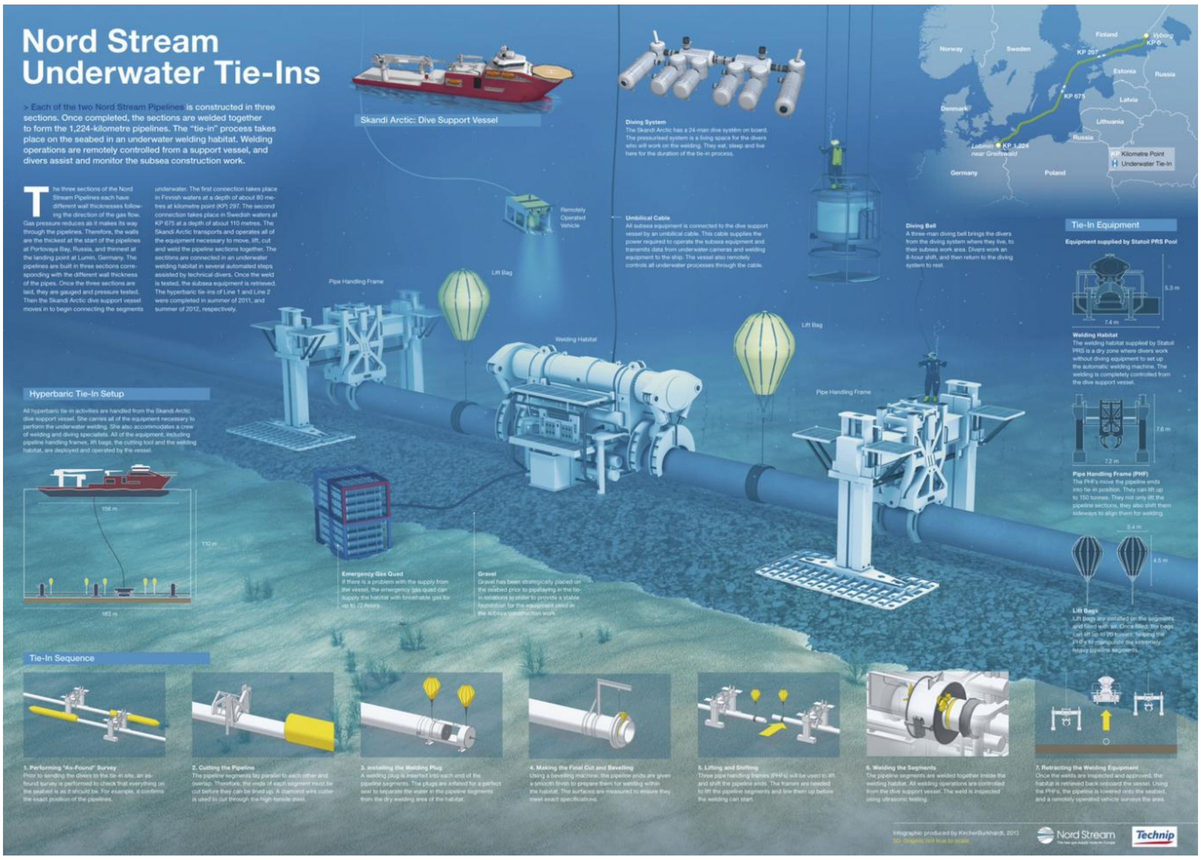


Figure 17. Nord Stream underwater Tie-Ins. Each of the two Nord Stream Pipelines is built in three sections. Once completed, the sections must be welded together to form the 1,224 kilometer pipelines. This "tie-in" process takes place on the seabed in an underwater welding habitat. Welding operations are remotely controlled from a support vessel, and divers assist and monitor the subsea construction work Source: https://www.nord-stream.com/en

6.5.2 Damage of pipelines in the Arctic

The development pipeline system in the Arctic regions results in increased probability of damage by drifting ice. As the largest part of iceberg is below sea surface, and occasionally can reach the sea bottom with pipe trenches. That's why it is important to develop 3D-maps and design pipelines according to the level of hazard in the particular area (fig. 18).

The following cases of damage of pipeline system by icebergs are known in international practice:

- In the years 1967 - 71 gas pipeline on the bottom the lake Erie (USA, Canada) were a large number of severe exposure ridges on the bottom
- Underwater pipeline lay on the bottom of the Great Slave Lake (Canada) was moved at a distance of two kilometres and destroyed in several places over a length of about 250 m, as a result of exposure of drifting ice. The depth of the breach of the bottom surface piece was up to 2,5 m.
- In the period between 1960 - 1970 registered 25 rushes of different functional pipelines in the area of Labrador Sea related with impact of icebergs .

Both historical and analytical data can contribute to the understanding of real hazards from icebergs during pipeline design. Computer models of ice conditions are developed to simulate seasonal ice drifts. Figures 19 and 20 represent the mechanism of moving ice ridge, affecting underwater pipeline. So we can conclude, that icebergs are main risk factors for underwater pipelines and any significant underestimation of this hazard leads to pipe damage, economic losses and pollution of sensitive marine area.

Regarding the Russian North, there were a number of serious disasters that occurred throughout the history of Soviet/Russian Arctic pipeline construction. Due to closed archives, it is difficult to get any info about 20th century cases. Although, recent events are available. One of examples is what had happened with Gazprom's underwater pipeline passing through the Baydaratskaya Bay in Yamal - two threads have erupted to the surface. This had happened twice - in 2018 and in 2019. However, the company has disclosed information about the violation of the gas pipeline's design only half year later.

To mitigate the consequences, Gazprom announced repair works for over 54 mill USD and are scheduled for 2022-2023. It is assumed that during the repair work, the gas pipeline will be laid back in a trench up to 4.5-5 meters deep from the bottom surface. But according to ecologists, this will negatively affect the state of aquatic biological resources in the Kara Sea - Baydaratskaya Bay.

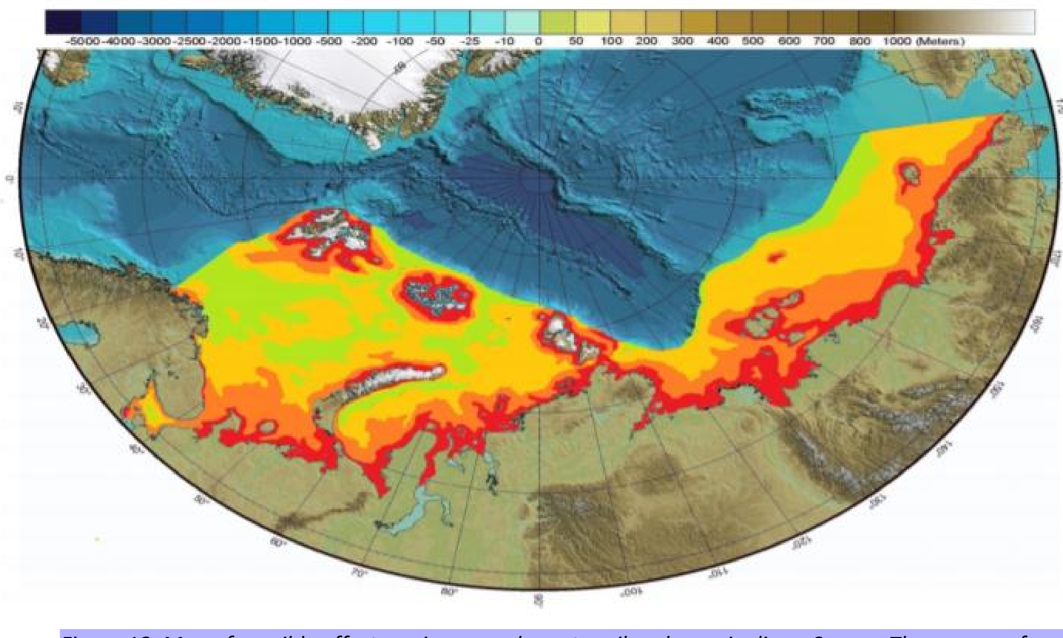


Figure 18. Map of possible effects on ice on underwater oil and gas pipelines. Source: The resource foundation of oil and gas of the Arctic shelf of Russia. Institute of Oil and Gas Institute.
Red *- the highest treat, yellow - treat exists, green - treat is minimal.*

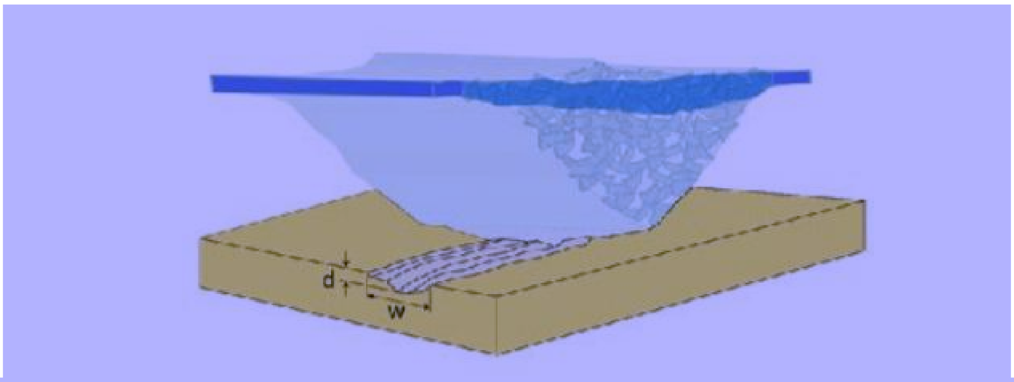


Figure 19. Track of iceberg ridge. Source: Stability and Strength of the Subsea Pipeline Under Iceberg Load in Arctic. A. Papusha, D. Gorntaev, MSTU, 2013.

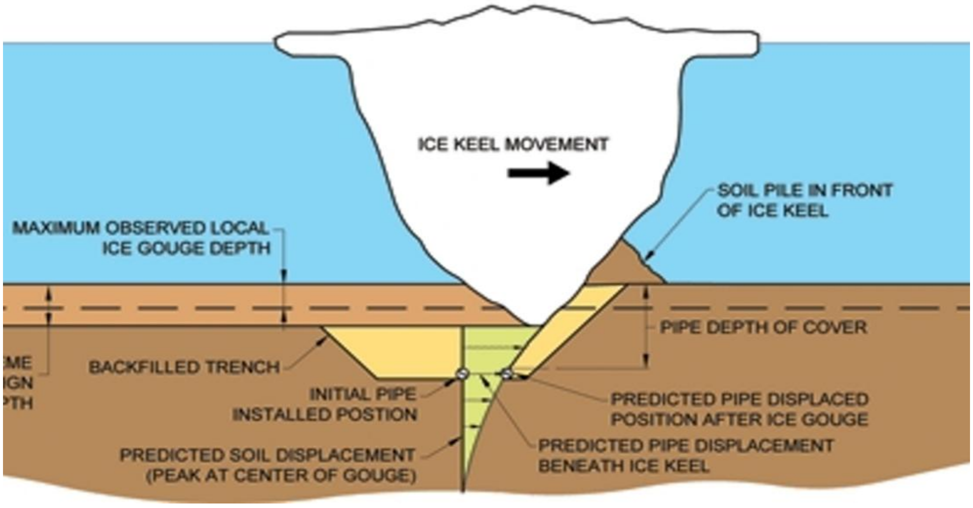


Figure 20. Seabed gouging due to moving ice ridge. The ridges could represent a hazard to pipelines trenched into the seafloor.

Chapter 7. Oil and gas offshore technologies. Subsea and topside. Deep sea drilling.

As it was mentioned before, the exploration and production operations of oil and gas reserves in a variety of water depths have become a challenge to the offshore industry. Arctic shelf and natural hazards vary significantly comparing to traditional offshore areas like Mexican Gulf and Caspian Sea. Recent years technology goes underwater - development of robotics, remote control units, fiber optics communication and studies of new composite materials contributed to possibilities of development in extreme conditions. Increased demand of deep-water drilling and cut of costs for establishing huge oil rigs led to significant increase of subsea equipment, also in the Arctic.

The depth of the offshore part varies from several dozens of meters on coastal shelf up to three kilometers in deep waters. I would like to focus on both parts and cover the possibility of activities in each of them.

Since these subsea developments are moving further offshore and into deeper waters, the technical challenges of such projects are continuously increasing. In 2010 a new technical standard was published - 'ISO 19906, Petroleum and natural gas industries — Arctic offshore structures' **[17]** - the latest edition to the series of ISO standards 1990x dealing with offshore industry worldwide.

The approximate list of necessary equipment for offshore installation is given in ANNEX 1.

Since Arctic oil production is still relatively new and technology demanding area, it lacks so-called 'Best Practices' - the list of recommendations, developed by oil and service companies that usually works good for self-regulation and establishing high and safe standards of activities. Although, some general technical provisions and guidelines could be found:

- well drilling be confined to periods of time when open water is available, meaning July through early October (106 days), due to the difficulty or even impossibility of cleaning possible oil spills underneath ice.

- increased number of polar class vessels to support drilling operations.

- audit of sub-contractors, independent inspection, remote control of main parameters and redundancy for well construction, blowout prevention measures.

- the best material and thickness standards for pipelines, as well as manufacturing inspection and leak detection measures.

- requirement for a reasonable time to withdraw assets near the end of a drilling season.

- requirements for staff expertise, high qualifications and multi-year experience of involved personnel.

- strong prohibition of discharge of cuttings, water, waste, mud, and other materials that can be reasonably collected and recycled or utilized.

7.1 Subsea production systems and arrangements.

7.1.1 Subsea technology overview

For deep water developments, a wide range of subsea complex layouts and production systems are utilized.

The latest achievements in subsea technologies are usually gathered into a subsea engineering system definition - the subsea production system (SPS). It is associated with the overall process, instrumentation and equipment involved in drilling, field development and operational control.

A subsea production system consists of a subsea completed well, subsea 'Christmas- trees' and wellhead systems, subsea tie-in to flow line system, jumpers, umbilical and riser system and subsea equipment to operate the well. Moreover, existing depleting oil sites can get a second life through using of subsea approaches (the recent example - 'Thor II' field in the Norwegian sector). The single or clustered well can be connected through the flow line to a fixed platform, FPSO (Floating Production, Storage and Offloading) or onshore facilities (figs. 21 and 22).

Figure 21. FSPO 'Baracca' - one of the most innovative vessels in industry. Estimated cost of the construction is over 830 million USD. Source: https:/vesselfinder.com

Figure 22.'Terra Nova' is another FSPO, used in the Canadian Arctic region. 350 kilometres southeast of Newfoundland and Labrador, Canada, is one of the largest FPSO vessels ever built, at a length of 292.2 metres, a width of 45.5 metres and it stands more than 18 storeys high. The FPSO can store 960,000 barrels of oil and accommodate up to 120 personnel. Source: https:/petro-canada.com/en-en/knowledge-centre/casestudy/terra-nova

Due to the high pressures, potentially large temperature gradients and harsh environment in deep-water, subsea systems and equipment are subjected to complex and critical load cases. But on the other hand, they allow to minimize surface factors, such as ice and iceberg dangers, to be more tolerant to the changing weather. In harsh conditions of the Arctic region accidents lead not only to unpredictable environmental disasters, but also enormous economic losses - any reactive service operation will be times more expensive than a traditional one. Therefore in all offshore pipeline systems the transportation of fluids including the flow of oil, gas, water and mixtures should be analyzed at the design and factory production stages to optimize performance and minimize the operational risks. International regulations promoting oil pollution preparedness, prevention, and response should be developed prior to start of any major activity.

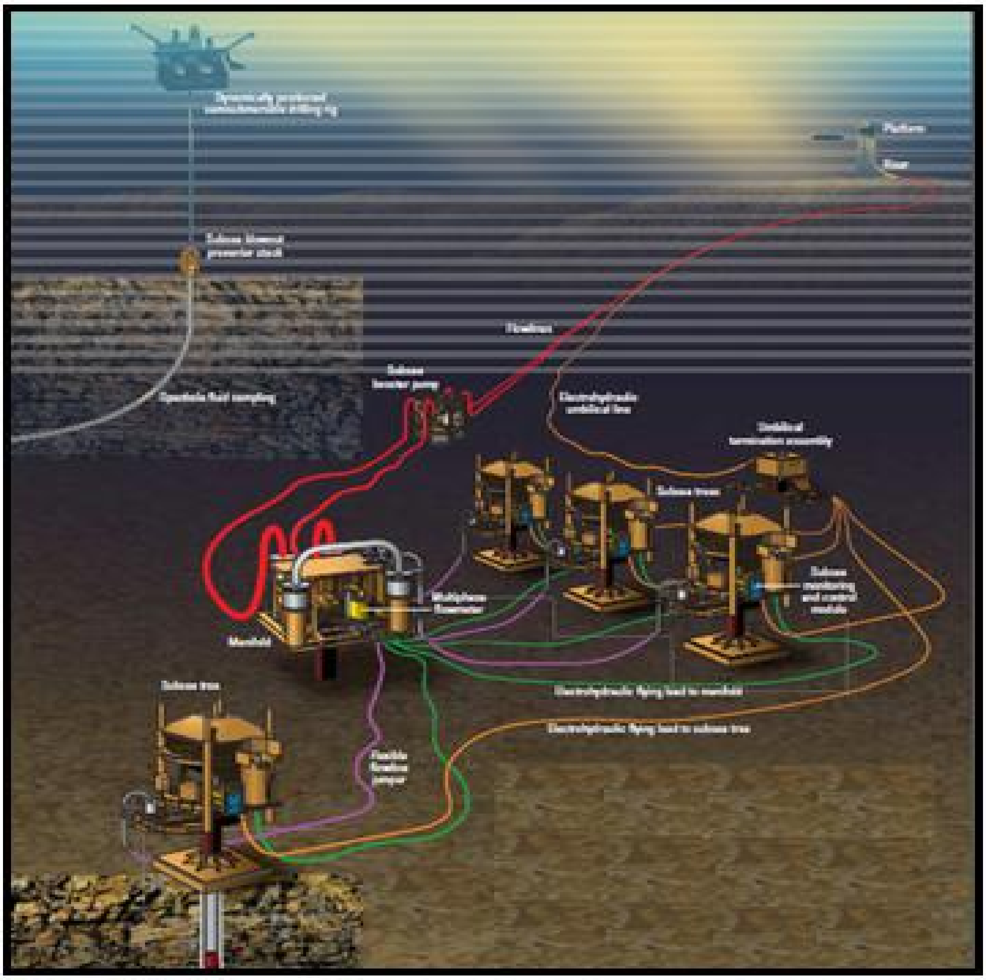


Figure 23. Schematic of a typical subsea layout. Source: Schlumberger Oilfield Review – 2006

In subsea field development, the following issues should be considered (fig. 23):

- Deepwater or shallow - water development - the depth of sea in this area
- Dry tree or wet tree
- Stand alone or tie-back development
- Hydraulic and chemical units
- Subsea processing in ice-laden areas
- Artificial lift methods
- Facility configurations (i.e., template. well cluster, satellite wells, manifolds)
- Ice protection
- Low temperature design
- Additional safety systems with redundancy.

The typical operation of subsea production system can be briefly explained as follows: flowline, before finally reaching a riser that pipes it to surface for processing. Pressurized reservoir fluid samples collected in an open hole wellbore may be analyzed at surface to characterize the physical properties of the fluids. An electrical submersible pump in a completed well propels reservoir fluids thousands of feet up to the wellhead and beyond. Subsea trees, positioned at top of each completed well, contain pressure control valves and chemical injection ports and a flow line jumper carries produced fluids from each subsea tree to the manifold, which commingles production from the wells before sending through a flow line to a platform.

A subsea booster pump, located downstream of the manifold, pumps produced fluids along the length of the flow line and up the riser to the platform's production deck.

Umbilical lines from the platform run back to a subsea umbilical termination assembly before branching off to each wellhead and then to the manifold. The umbilicals supply electric and hydraulic power for wellhead or manifold control functions, and chemicals to suppress the formation of scale and hydrates in the production stream. The umbilical lines also carry bidirectional communications and control instructions between the platform, wellhead and downhole devices. **[18]**

7.1.2 Subsea Architecture

The goal of subsea field development is to safely maximize economic gain using the most reliable, safe, and cost-effective solution available at the time.

Offshore architecture encompasses the hardware, systems, and equipment used to drill for, produce, and transport oil and natural gas from offshore locations.

This includes surface facilities, subsea equipment, and pipelines, as well as the tools and systems used to operate and maintain them.

Subsea production systems architectures are generally arranged as shown in the figure below, but others are considered, based on several and different issue to be considered.

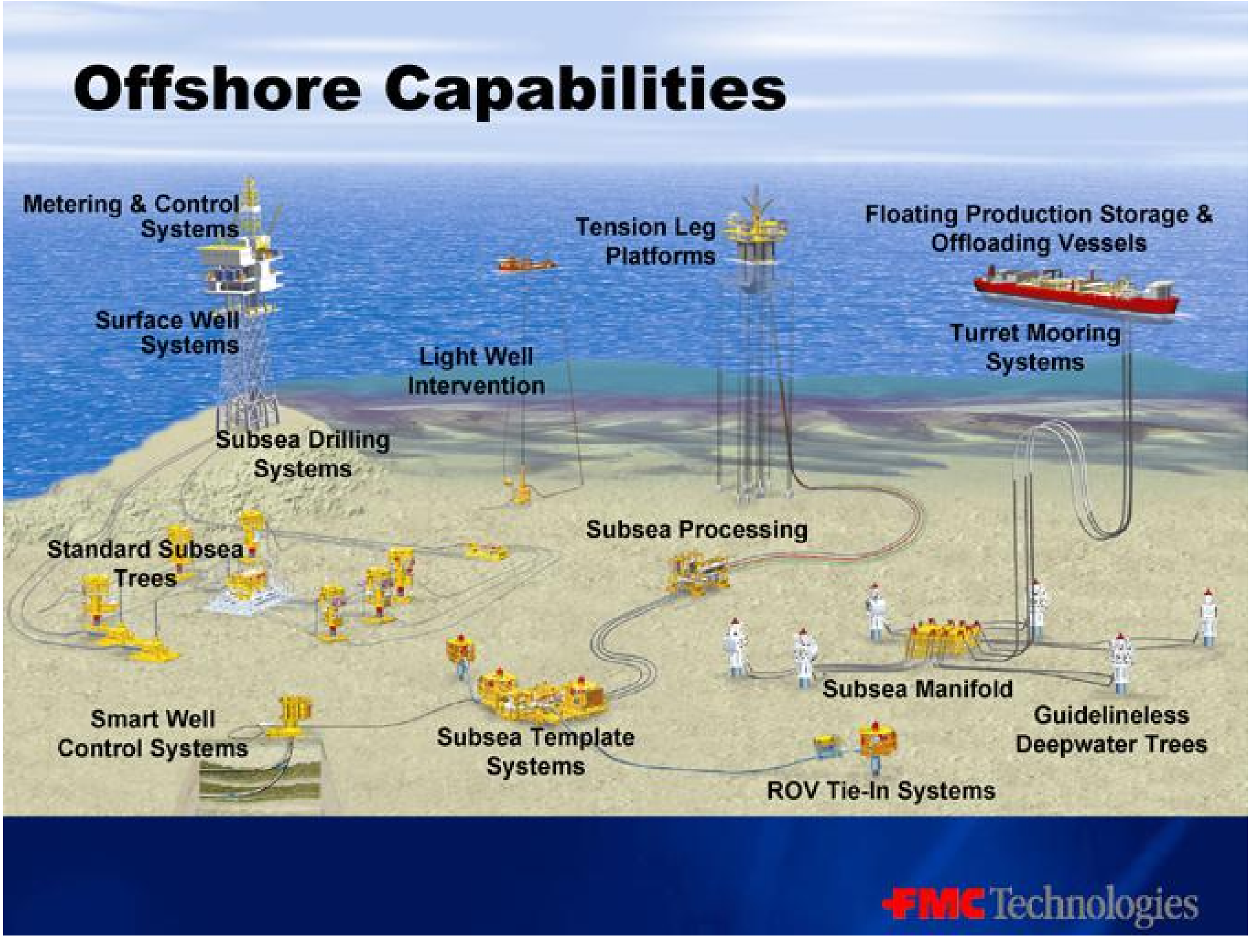


Figure 24. Different subsea arrangements. Source: www. technipfmc.com

Some subsea production systems are used to extend existing platforms. Example - the geometry and depth of a reservoir may be such that a section cannot be reached easily from the platform using conventional directional drilling techniques or horizontal wells.

Based on the location of the tree installation, a subsea system can be categorized as a dry tree production system or a wet tree production system and the water depth can also impact subsea field development. For the shallower water depths, limitations on subsea development can result from the height of the subsea structures. Even though wet well systems are still relatively expensive, their attraction in reducing overall capital expenditures has already been made clear.

The Norwegian Continental Platform (NCS) is a region where subsea developments have been adopted and represents an area of pioneering subsea technology application.

A typical subsea field development is based on the subsea equipment being located in template structures (fig. 24).

The template is the foundation that carries the weight and loads of the structure, and supports the wellhead and drilling activities, manifold and control system as well as the protection structure.

7.1.3 Subsea installations and vessels

The development of subsea production systems requires specialized subsea equipment.

The deployment of such equipment requires specialized and expensive vessels, which need to be equipped with diving equipment for relatively shallow equipment work, and robotic equipment for deeper water depths (see 7.2)

Subsea installation refers to the installation of subsea equipment and structures in an offshore environment for the subsea production system.

Installation in an offshore environment is a dangerous activity, and heavy lifting is avoided as much as possible.

This is achieved fully by subsea equipment and structures that are transmitted to the installation site by installation vessels.

7.1.4 Flow assurance

The buildup of wax, scale and hydrate deposits in wells, subsea flowlines, wellheads, risers and surface equipment is a special problem for subsea production where temperatures are quite low and the pressurized fluids are an un-processed well-stream. Flow assurance is the new term referred to the study of the complex phenomena involved with steam of produced fluids in order to guarantee the maximum flow. These fluids are comprised of a combination of gas, crude/condensate and water together with organic and inorganic solids: hydrate, scale, wax / paraphine, sand, asphalts.

For an effective subsea production, it is necessary to identify the potential for and quantify the magnitude of all of these solid depositions in the production system.

Changing pressures, temperatures and production flow profiles over the field life also complicates the posed difficulties.

It is also necessary to control and predict rushes during transient flow regime, which means that the system should be able to shut-down and restart in a controlled manner.

There are many considerations that go into designing an effective flow assurance program for a field and these include considering the requirements for all parts of the system for the entire production life.

Some of the considerations for an effective flow assurance program are listed below:

- production profile optimization;

- chemical inhibitors (injection & storage);

- produced fluids properties versus pressure and temperature;

- host facility (pigging, fluid storage, tubing & flowline ID's & handling, intervention capability);

-insulation (tubing, wellhead, etc.).

Capital and operating costs for different flow assurance solutions varies a lot.

Engineers have developed distributed sensors and other devices that can warn the operators of impending flow blockages in the process line remotely.

Thermal insulation and protective coating can be applied to components subjected to deep or/and cold-water immersion.

7.2 Offshore support vessels

Huge offshore expansion of offshore industry influenced many other resulted also in increasing demand for offshore support vessels (OSVs) to carry out different operations necessary for floating drilling rigs, as well as moored or fixed production platforms. In order to encompass a more varied and multifunctional role, the facilities installed on board OSVs vessels have been revolutionized, so that they are now among the most technically sophisticated vessels.

The OSVs can be divided into a number of types according to the operations they perform: seismic survey ships, platform supply vessels (PSV), offshore construction vessels (OCV), dive support vessels, inspection, maintenance and repair vessels (IMR) and variety of combinations of these. **[19]**

- **Seismic Survey Ship** – A vessel mapping out geological structures in the seabed by firing air guns transmitting sound waves into the bottom of the sea. The echo of the shot is captured by listening devices/hydrophones being towed behind the vessel. Dedicated seismic survey vessels are highly specialised ships. The working decks are enclosed but typically are open at the stern and at a lower level, have the air gun handling system and storage, and at a higher level, they have winches and storage reels for streamers. The ship itself must be capable of accurate track and station keeping and the propulsion system must have low radiated noise and minimal propeller induced noise to avoid interference with the survey equipment.

- Platform Supply Vessel (PSV) – The PSV is designed for supplying offshore drilling rigs and production platforms with necessary equipment, stores and drilling consumables. These are typically cement, baryte and bentonite transported as dry powders; drill water; oil or water-based liquid mud, methanol and chemicals for specialized operations.

The PSV loads at a shore base. Liquid cargo is carried in double bottom tanks, dry bulk cargoes in special pneumatic pressure tanks, equipment and drill pipes on the aft open deck. At the rig or platform, the liquid and powder cargoes are pumped up or transferred pneumatically while deck cargo is handled by the rig crane (fig. 25).

- **Construction Support Vessels** – Dynamically-positioned Class 3 vessels with large unobstructed deck areas, substantial accommodation capacity and significant surface and subsea heavy lift crane capability, able to support surface and subsea construction and installation projects, as well as inspection, repair and maintenance (IRM) programs. Construction Support Vessels are designed to provide tailored solutions and facilitate larger projects that often require such vessels to remain on location for long periods of time.

- **Diving Support Vessel (DSV)** – A vessel provided with diving equipment and used for underwater work such as the maintenance and inspection of mobile platforms, pipelines and their connections, well-heads, etc.

- **Inspection Maintenance and Repair (IMR) Vessel** – A dynamically positioned ship-shaped offshore unit provided with equipment for well stimulation or maintenance (e.g., coil tubing).

Figure 25. 'Skandi Vega' PSV in Tromso harbor. Source: author's photo

7.3 Subsea protection methods against icebergs and ridges

Offshore operations in the North meet one more hazard that is necessary to consider during design of any northern offshore production site. In icy waters of the Barents, Beaufort or Pechora Seas, subsea structures are at high risk of being damaged by natural northern waters objects - icebergs or sea ice ridges. This generally occurs when an ice object drifts into shallower areas and its keel starts ploughing the seabed over considerable distances. So, adequate protection against these events can be achieved in several ways. Below is a brief description of the general solutions, most commonly used for this matter.

Trenching. For long and narrow pieces of equipment, such as cables, production pipelines and manifolds, burying them under the sea bed is the still the best approach. It is simple and can provide protection against general threats. The main disadvantage is that it is very expensive with increased burial depths. If the keel of an iceberg can reach a trench up to several meters underneath the sea floor, this type of protection is very hard to perform. This is partly because the current trenching technology normally handles depths not exceeding about 2 m.

For complex-shaped subsea modules it is hard to build a proper trench and predict its efficiency. One of the solutions is to provide a solid concrete protection cover. Concrete thick covers are put above subsea structures, providing protection and additional anti-buoyancy effect.

Shielding. It refers to the construction of a protective structure able to withstand a direct impact when met with an ice feature. Submarine silos and barriers made from rocks, and steel are normally used for local equipment protection. such as wellheads and Christmas trees. However, here again, these methods would not be cost-effective if applied to lengthy segments.

Ice conditions modeling using Monte Carlo equations and ice surveillance management can also provide some sort of preliminary protection, but on a long run there are no real working simulation models that accurately predict iceberg movements. Radars and satellite photos provide limited information and can just add to design data.

A very good theoretical and analytical work in this area was done by three Russian authors - Vershinin, S.A., P.A. Truskov, P.A. Liferov (2007): “Ice features action on seabed.” (In Russian). IPK “Russkaya kniga”, Moscow, Russia. (Вершинин С.А., Трусков П.А., Лиферов П.А. Воздействие ледовых образований на подводные объекты). Present discoveries and historical data of interaction ice features with subsea equipment is collected and precisely described.

PART III

Chapter 8. Russian Arctic projects - present and future

Unlike many other countries, which try to diversify their energy sources and export goods, Russia is still focused on fossil fuel production, domestic consuming and export sells.

The main Russian Arctic projects currently under development are the following:

- Vankhor cluster (Eastern Siberia) - onshore;
- Sakhalin cluster (Far East) - offshore;
- Yamal peninsula gas oil field - Novatek Yamal and Arctic LNG Plants - shelf;
- Shtokman gas condensate field - (Barents Sea) - offshore;
- ‘Prirazlomnaya’ oil production site (Pechora Sea) - offshore.

Initial experience in offshore cold climate resource production the country gained only in late 90-s in the Far East with Sakhalin island projects, under strong cooperation with the international oil and service companies (primarily EXXON, Royal Dutch Shell and Mitsubishi Inc.). This is a sub-arctic area with the very inhospitable climate similar to the High North. A part of technologies and production facilities that were used and proved its efficiency for Sakhalin offshore, are now utilized in the Arctic region.

8.1 Large angle-directed drillings rigs; ‘Yastreb’ and ‘Krechet’

One of the examples is an onshore oil-drilling rig ‘Yastreb’, which allows angle-directed drilling of shelf oil wells from the shore (fig. 26). It was primarily built for Sakhalin-1 project, but from that time used at diverse projects where it is applicable.

Figure 26. ‘Yastreb’ oil rig with support vessel. Source: https://www.sakhalin-1.com/en-RU

It is known as one of the most powerful land rigs in the industry. It is designed to drill extended reach wells to offshore targets from land-based locations.

Extended reach drilling (ERD) technology reduces the high capital and operating costs of large offshore structures while minimizing environmental impact to sensitive near shore areas.

The initial drilling program at Chayvo site was completed in 2008 with a total of 20 wells drilled, setting world records in depth, horizontal reach and drilling speed.

The 'Yastreb' was then dismantled, modified and transported to the Odoptu field where it was utilized in yet another world record setting drilling program from May 2009 to February 2011. Total five angled drilling operations were conducted, with each well the length of 10-11 kilometres.

Since 2018, the similar to the 'Yastreb' drilling platform 'Krechet', which possesses modified characteristics of mobility continues to develop Odoptu field. The overall reserves are estimated around 2,3 billion barrels of low-sulfur quality crude oil and over 285 billion m^3 of natural gas.

8.2 SSK 'Zvezda'; https://sskzvezda.ru/index.php/en/

The other huge entity for heavy industry, aimed to support Eastern Arctic projects in Russia is a newly established (in 2016) Shipyard Complex 'Zvezda' - a deep renovation of existed in Soviet times 'Center of ship maintenance and repair of the Far East'. It is planned that the factory will focus on ice-class supply ships for offshore rigs , tankers for delivery of produced oil from site to the shore receiving terminal, structural elements of oil platforms.

For instance, the construction of first four ships - tankers of the reinforced ice-class ARC7 are designed for operation in ice up to 1.8 m thick at atmospheric temperatures up to minus 48° C, started in 2017 with the finish of 2020 and there will be 6 more of such class in a row.

Although, sanctions, aimed to limit access to the offshore equipment, were introduced in 2014, PJSC 'Rosneft' could sign a priority agreement with the French gas company "GDF Suez" to provide technologies for LNG tankers. The intention is to build up to ten vessels for future shelf projects and delivering gas via Northern Sea Route. These tankers will have a special class 'Suezmax' - which means that they will combine innovative western solutions with the capabilities to operate in the Arctic environment.

Figure 27. SSK 'Zvezda' aerial view. Source: https://sskzvezda.ru/index.php/en/project/9-news-en/532-a-batch-of-new-crane-equipment-has-been-delivered-to-the-zvezda-ssk

While the installation of the factory production equipment is still in process, but with long-term intentions to provide local manufacturing for the Arctic, it will soon play one of the major roles in Russian strategy in the region.

8.3 Production wharf 'SevMash', www.sevmash.ru/eng/

Another very important production facility that Russia possesses and that directly can be used to establish infrastructure and supply equipment to the national Arctic projects is a 'SevMash' military production factory. Specialized in warfare production during Soviet era, the JSC PO 'Sevmash' (Russian: ОАО ПО „Севмаш") is a now part of United Shipbuilding Corporation (state-owned).
The formerly top-secret Arctic production plant in the city of Severodvinsk on a shore of White Sea, now it is a unique heavy industry facility of such kind in the High North.

Figure 27. 'Sevmash' production facilities. Source: Google maps.

Initially established as a crucial military production entity during the Cold War - production of nuclear submarines and missile carriers, its present orientation are the growing demands of Arctic Barents and Kara sea projects. The plant is already responsible for several key projects, among which are famous oil rig 'Prirazlomnaya', support vessels, oil exploring platforms 'Arkticheskaya' and 'MOSS CS-50'.

8.4 'Prirazlomnaya' oil ice-class rig

Figure 28. 'Prirazlomnaya' oil rig construction site. Source: www.sevmash.ru

I would like to particularly emphasize the first one, as it is a first project of such kind and scale. Though it is more an image-creative project rather than economically beneficial, it stands to show the ability to develop a very demanding and difficult region with local produced modern heavy equipment, despite of international restrictions.

The 'Prirazlomnoye' oil field, in the Pechora Sea, was initially discovered in 1977 and made ready for deep-hole prospecting (deep drilling) over the following 10 years. In 1989 the presence of economically recoverable oil reserves, geological model was put 2 years later.

Special ice-resistant offshore stationary platform (rig) that would allow the field to be developed, which was delivered to the Pechora Sea in 2011 for installation 60 meters from the shore. Oil production at 'Prirazlomnoye' commenced in December 2013 through PJSC 'Gazprom-Neft' subsidiary - 'Gazprom-Neft Shelf', and the first consignment of "ARCO" - a new Arctic oil brand was on its way to European consumers within five months, in April 2014.

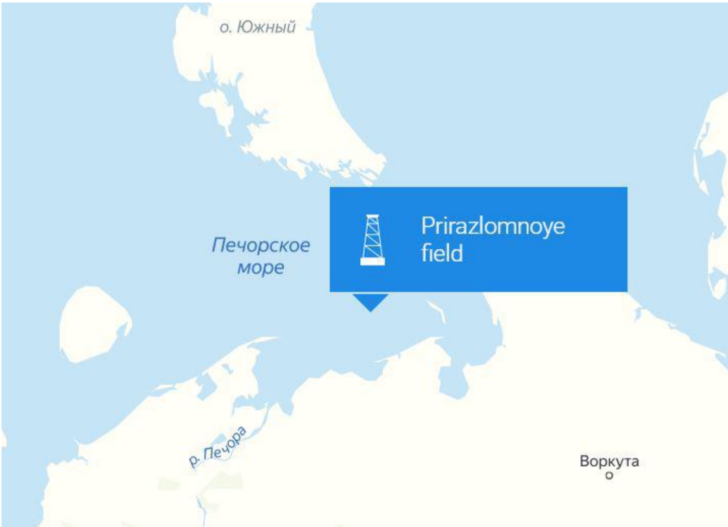
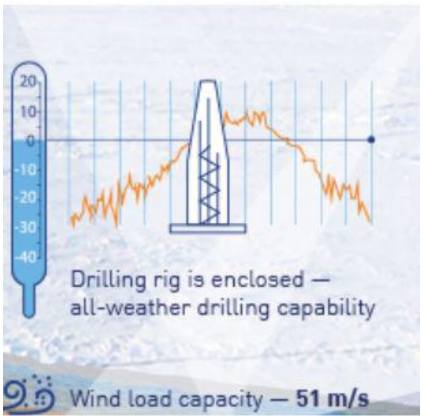


Figure 29. Prirazlomnoye oil field location. Source: https://www.gazprom-neft.com/company/major-projects/prirazlomnoe/



Main parameters:

- All-year 24/7 oil drilling and production
- Well depth – up to 8.1 km. Total 32 wells drilled (horizontal drilling). Sea depth – 20 m.
- 60 km from land. Nearest port – Varandey.
- Projected life cycle – up to 36 years.
- Climate: Arctic. 9 months – below zero-degree C.
- Wave height up to 11 m

- PSV ships are necessary for crude oil unloading from rig to oil tanker (one week to full load). PSV presence gives opportunity to exclude accidents during storms.
- Safety supply ship 'Alyeut'. Full-time presence of ice-breaker class ship. 3-month shifts.

Figure 30. Platform with ice-class support vessel. Source: https://www.gazprom-neft.com/company/major-projects/prirazlomnoe/

The platform was designed for operations in harsh natural and climatic conditions, meets the strictest safety requirements and can sustain maximum ice pressure.

The platform is 126 meters long and wide and 141 meters high. It is reliably stationed on the seabed due to its gravitational weight, which exceeds 500 thousand tons, and actually developed into an artificial island. Its gravitational stability and ground anti-washing protection are ensured by a rock-and-stone berm (with a volume of over 45 thousand cubic meters) around the perimeter of the platform bed. Structurally the platform comprises several parts: the caisson with oil storage, an intermediate deck, auxiliary module, the superstructure, a residential module and two oil-loading facilities. 200 people daily operate on the platform and the shifts change every 30 days. **[20]**

A special system of over 60 sensors, which immediately reacts to any operational changes, monitors the 'Prirazlomnaya' round-the-clock:

Inclinator to monitor caisson inclination; deformation sensor to measure ice pressure, ground dynamometer to measure pressure on the ground; accelerometer to monitor seismic activity around the platform; piezometer to measure pressure in the ground from dynamic horizontal load.

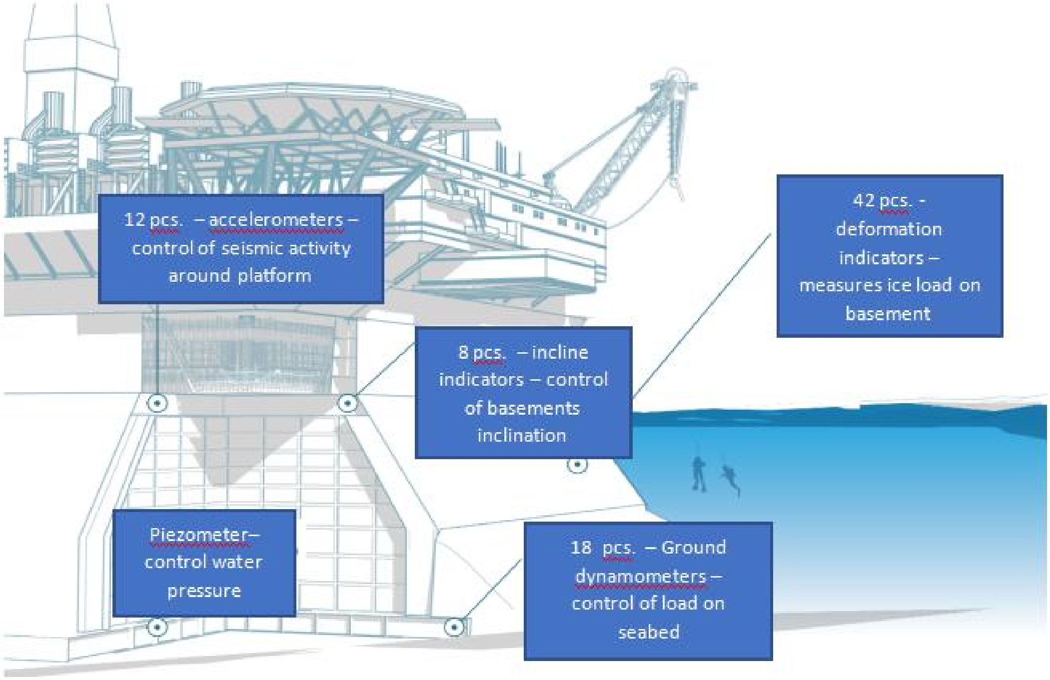


Figure 31. Arctic platform sensors. Source: https://www.gazprom-neft.com/company/major-projects/prirazlomnoe/

As a huge initial investment, the owner Gazprom Neft considers the Priazlomnaya platform as the hub for processing of oil from many smaller fields in the area. Estimated life cycle of this project is around 25-28 years, starting from 2014. Overall proved reserves are estimated around 70 million tons of oil.

In the years 2019-2020 it produced 3,14 million tons oil yearly with maximum potential up to 5,5 million tons.

8.5 Varandey Arctic terminal

https://trans.lukoil.ru/ru/About/Structure/VarandeyTerminal

Figure 32. Varandey terminal aerial photo. Source: www.lukoil.com

The Varandey oil export terminal was finalized in 2008, but commission and start-up works prolonged operation till 2010. The main task of this installation is the year-round loading of oil, which is produced in the Timano-Pechora hydrocarbon region. The design capacity of the terminal is 12 million tons oil per year. Located high above the Polar Circle, in the village of Varandey, on the shores of the Eastern Barents Sea. Unique feature of this installation is a stationary offshore ice-resistant offloading berth.

The design of the Varandey terminal is prescribed by its location in the harsh natural conditions. The Eastern part of the Barents Sea is covered with ice on average 247 days a year, while the ice thickness reaches 1.25-1.8 m. The shallow coastal zone does not allow building a loading terminal on the coast. Therefore, to load large-capacity tankers with a deadweight of up to 70.000 tons, a stationary offshore ice-resistant loading berth was built at a distance of 22 km from the coast.

The height of the construction is 52 m with a total weight of over 11.000 tons. It consists of two parts - a support base with a living module for 12 people and technological systems, as well as a rotary mooring and cargo device with a helipad. Oil is loaded into the bow of the tanker by using a flexible hose. The Varandey terminal is listed in the Guinness Book of Records as the northernmost year-round operating oil terminal in the world.

In addition to the berth, the Varandey terminal complex includes an onshore tank farm and two strings of an underwater oil pipeline with a diameter of 820 mm and a length of 22 km. The total capacity of the onshore tank farm is 325.000 m^3. The terminal is built on permafrost. All tanks have double-walled glass-in-a-glass to avoid oil spills.

Chapter 9. Perspectives of Russian projects in the Arctic

9.1 Russian Arctic activities in 20th century

Historically, all industry experience of Russian natural resources is gained on land - since the discovery of enormous oil and gas reserves in the Western Siberia region in 60-es, Soviet Union established large infrastructure, communications, transport network and pipelines to utilize explored hydrocarbons. It was enough for several decades of extensive, but low-efficient ratio resource extraction and led to the state, that most old fields are highly depleted, the production sinking and the volume of water fraction steadily increases. Although, there are certain technologies on the market that allow to re-use such depleting oil wells, extend their lifespan, but they all require western hi-tech technologies, which are limited for delivery nowadays.

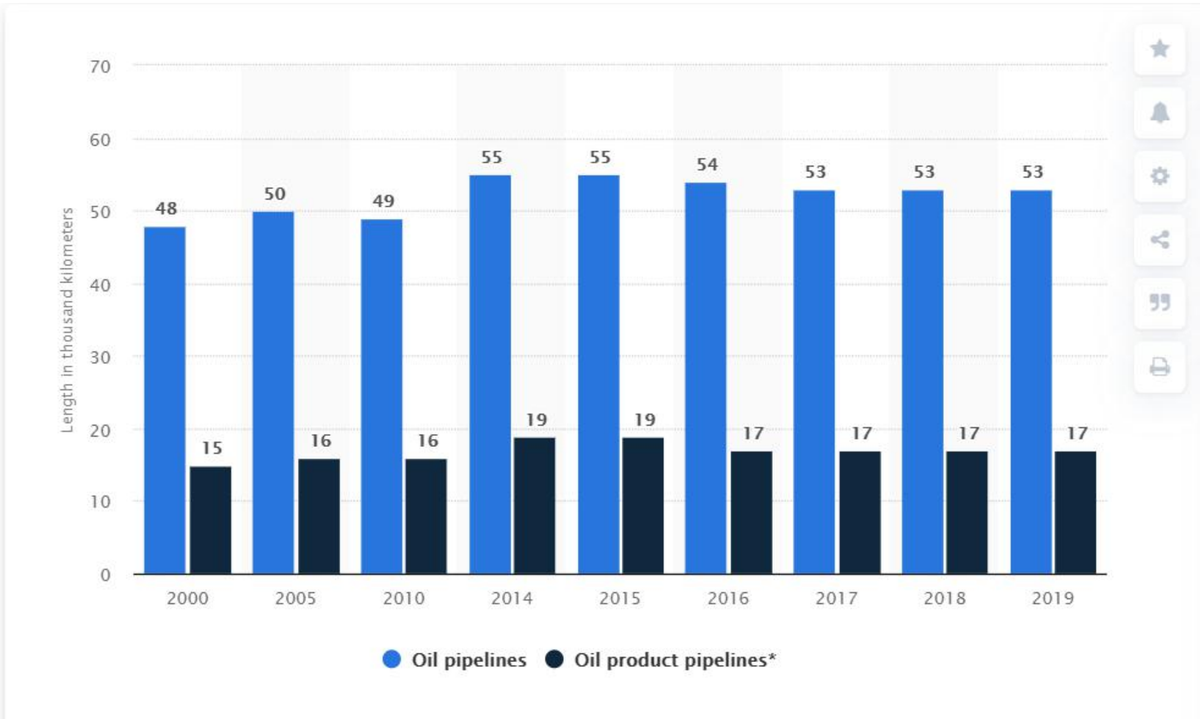
Just one of examples is a hydraulic fracking. The world leaders of providing services for fracking - companies Schlumberger and Halliburton, have decided to switch their cooperation with Russian state oil companies under threatening of sanctions. Only existing activities such as supply of spare parts and aftermarket support of old projects are allowed. A priority for former governmental authorities was to start as many production sites as possible - intensification of resource export with the aim to quick revenue led to a very low income from each site, costly infrastructure, roads and settlements. As a benefit we can notice the biggest land-based pipeline network in the world - more than 70.000 km of oil and liquid product pipelines (almost solely owned by state company PJSC 'Transneft'), and more than 170.000 km of gas pipelines, primarily owned by PJSC 'Gazprom'. Below are tables 2 and 3, showing the development of pipeline network on the territory of Russia.

Oil and oil product pipelines, USSR and Russia		**1940**	**1960**	**1990**	**2000**	**2010**	**2016**
Length, x1000 km	USSR	4,1	17,3	86	-	-	-
	Russia	1,7	15	68	63	65	71

Volume of transportation, x10⁶ tonnes	USSR	7,9	130	611	-	-	-
	Russia	5	123	558	318	524	579
Turnover, tonnes x km	USSR	3,8	51,2	1310	-	-	-
	Russia	1,5	49	1240	745	1123	1308

Gas pipelines, Russia	**1990**	**2000**	**2010**	**2016**
Length, x1000 km	144	152	168	179
Volume of transportation, $x10^6$ tonnes	543	511	537	509
Turnover, m^3 x km	1335	1171	1259	1181

Table 2. Oil and gas pipeline length, volume, turnover. USSR and Russia. Source: www.transneft.ru/en/history



* - including Russia-owned export oil product pipelines on the territory of other countries.

Table 3. Oil and oil product pipeline length, 2000-2019 in Russia. Source: https://www.statista.com/

An old Soviet approach in onshore Arctic production was to establish permanent settlements, ‘workers villages (Russian: ‘рабочие посёлки’), that intended to provide all-year-round activity in the region. It is now obvious that such settlements can only exist on a shift-worker basis (like newly established oil town Vankhor for 3500 workers). Towns like Dikson, Tiksi, Vorkuta and Igarka are now suffering from emigration of majority of their population to the 'Mainland' - although they are still mainland themselves, but with literally no connection to other country except for rare transport. These almost abandoned towns could be soon completely demolished because of total loss of their purpose. Environmental risks are high and a costly program for relocating people, deassembling remaining buildings and infrastructure is required. The rest should be safely utilized.

Figure 33. Nearly abandoned town Dikson on Taymir peninsula. The population change in the period of 1959-2019 is 3800 up to 5600 and now to just 250 citizens. Source: finvalcenter.net.

When moving further towards the North Pole, Russian specialists have even less experience of underwater pipeline construction, ice protection and pollution-free geological and exploration activities. Gas activities, such as cooling and LNG production are also out of their field of knowledge.

So, as a general summary of the past and present hydrocarbon country's production activities, the following should be listed:

- broad experience of Arctic land resource extraction. Developed basic infrastructure - transport (roads, river ports, airfields, railways), permanent living facilities, pipeline network;

- good level, locally available technologies for land-based sites and almost absence of own modern technologies for offshore drilling and production (subsea, support vessels);

- manufacturing of heavy machinery for the Arctic on former military factories - very high level of quality;

- engineering and scientific approach due to specific industry educational entities. Experienced staff - large amount of local qualified personnel;

- the largest and most effective ice-breaker fleet, including several nuclear class vessels;

- very little development of offshore infrastructure - almost all facilities must be constructed as new with huge capital investments;

- insufficient environmental regulations due to intensified production in the past, a large area of the Arctic was utilized in an improper way; pollution

- Arctic resource nationalism - very limited access of the private and foreign companies to work in the Arctic. Cooperation is allowed only on a minor partner basis, key technology supplier and unclear benefits for long-term investments for these third parties;

- strong dependence from market gas and oil prices - as the unit price goes down - any activities in the Arctic become not profitable and postponed for future (Stockman gas condensate field example);

- intentions to develop Arctic region using transport capabilities of the North Sea Route and permafrost railroads, construction of LNG plants, shipyards, support infrastructure.

9.2 Present prerequisites for Arctic offshore activities

Although, Russia's Arctic performance is strongly influenced by political decisions, it can't be independent from world trends and international market demands.

A vast activity in the Russian offshore industry had started soon after the significant world hydrocarbon market changed. The main global reasons for such rise were the following:

- increased demand of natural gas in Western Europe due to closing of environmentally harmful coal heating stations and nuclear power plants in Germany. Natural gas is a clean energy in this sense and it gives opportunity to be an in-between source in a process of transition to sustainable 'green' economy (wind, solar, hydrogen energy);

- increased oil prices - in the period 2001-2011 the average price for one barrel BRENT was USD 96,46, with the highest price was above USD 150 in June 2008; **[22]**

- unpredictable early stage impacts of shale and tight oil production. It is a 'game changer' but with both pros and cons;

- increased energy resource requirements of China due to a strong steady growing economy;

- overall growth of energy consumption, still slow and ineffective growth of renewable energy in emerging economics;

- general technology development and modern offshore solutions;

- climate change gives access to previously unreachable areas.

Soon after 2014 a situation has changed drastically.

- Several European warm winters decreases consumption of natural gas in Europe. New suppliers of LNG appeared on world market, such as the USA and Qatar.

- Tensions with the Ukraine after the local elections resulted in difficulties and frequent interruptions in pipeline transit through the Ukrainian territory. At a certain time period of few weeks pipeline transport was completely stopped, which decreased the reliability of Russia as a reliable gas supplier.

- Technological breakthroughs in shale oil production primarily in the USA resulted in a significant additional amount of oil on the world market. According to Baker Hughes report (GE, 2017), the cost/efficiency ratio for US oil shale well is USD 54/barrel and continues to fall. So, since 2014 to 2017 the amount of oil wells increased by 1.3 times each year (+182/year). The release of surplus oil reserves by the United States to the world market resulted in a decline in barrel price.

The above-mentioned fact of shale and tight oil production intensification soon after the oil price becomes favourable, means that there are no real expectations of a 3-digit oil price in future as it was in 1970th and 2009 (around USD 155/ barrel). That means decreased income and limited ability of capital investments In the Arctic development.

- After Crimea case, Western countries introduced a sanction package towards Russia to prohibit access to hi-tech technologies in the hydrocarbon industry. Not only for offshore drilling and production, but in many areas of advanced level - custody metering technology, laboratory precise quality metering equipment, diagnostics and telemetry and other.

- The Northern Sea Route (NSR) is still very expensive to use, and represents a high risk means of goods transportation. It is intended to be used by Arctic offshore suppliers and developers, but seasonal risk issues and high initial capital costs, the lack of infrastructure along the way, prevents from using the route on a constant basis.

According to Russian Ministry of transport, in 2018, 8 million tons of cargo were transported along the NSR. The main advantage is that it is almost half the length of the traditional routes to deliver hydrocarbons to Asia market (at average of 11.000 miles instead of 18.000 along traditional route via Suez channel). It was planned a significant increase of cargo traffic up to year 2028 - it should be more than 80 million tons per year, mainly hydrocarbons. To solve this issue, two state oil companies - PJSC 'Rosneft' and PJSC 'Neftegasholding', proposed to create an infrastructure for oil supplies via the NSR from their northern fields- namely an oil pipeline from the Vankor cluster of Rosneft through the Payakhskaya group of oil and gas fields in Taimyr to the North Bay, where an oil terminal will be built.

After the implementation of the first stage of this project, it is assumed, that it will create a new oil and gas province in the Arctic (Vostok Oil), simultaneously loading NSR and developing a number of related industrial sectors. According to KRMG auditor's estimates, the multiplier effect will amount to 90 billion by 2038, experts believe it is realistic to increase jobs up to 30 thousand within 10 years. The logistics analysis, made by Russian Higher School of Economics and Rosneft experts, shows that when using ice-class tankers, transporting hydrocarbons via the NSR is half the price of the current solution - by the Vankor-Purpe pipeline and further along Eastern Siberia pipeline to China. The oil will be transported by ice-class tankers with partial convoys of icebreakers. However, without special tax regime (namely zero taxation for the next 10-20 years of initial investments), the project of NSR as a main route to Asia can't be properly fulfilled.

- Russia intensified sovereign development of technology for Arctic, primarily in the areas of already existing technologies, such as year-round airports, nuclear-powered ice-breakers and ice-class tanker fleet, pipeline and railroad construction on permafrost.

- By the decision of top state authorities, deep sea exploration drilling was started in April 2017, despite of enormous costs of each survey well. Tsentralnaya-Olginskya-1 is among such examples - located in Laptev sea (Khatanga region), it is considered to be the northernmost point of oil activities in the country. **[24]**

- Absence of western and limiting of local private companies decrease competition advantages in Arctic offshore development. Literally, only two state-owned companies have access to this region, the licenses are distributed among them - PJSC 'Gazprom' and PJSC 'Rosneft'. And formally private companies like NOVATEK, LukOil and OJSC 'Surgutneftegas' are strongly affiliated with the state.

- Overall economic dependence from crude oil and gas export. More than 56% of country's total export revenue received from hydrocarbon resource export deliveries.

Despite all above-mentioned aspects, in 2018 Russia has published its updated Arctic policy, which deals with increased industrial development in the Arctic, offering massive state investments in the region.

There are two major Russian Arctic projects that are crucial for the whole scale of activities in the region. One of them - the world largest Shtokman gas condensate field in the Eastern part of the Barents Sea is already postponed with unclear future and another one - Yamal Peninsula - is now at its main construction stage.

I will focus on both as they represent the nearest possible scenarios of Russian Arctic hydrocarbon policy.

Common features of these projects are the following:

- both are gigantic gas fields situated far North beyond existing infrastructure.

- both are aimed to supply gas to the Northern European market in nearest future, but with perspective to use Northern Sea Route for LNG tankers to deliver products to Eastern Hemisphere (primarily to China).

- each of them requires innovative technologies which are not available in the country locally. Strong cooperation with top service companies and sharing of risks for investments are mandatory. Russia can't execute any of these projects on its own.

- delivery of gas to the European markets from both sources is intended to be via the Nord Stream-2 underwater gas pipeline, which by today can't be finished because of the existing US sanctions towards implementation of this transport means. Many western service companies and technology providers have already quit or minimized their participation in 'Nord Stream-2' pipeline (information April 2021). Even project certification of Norwegian DNV GL was stopped for the period.

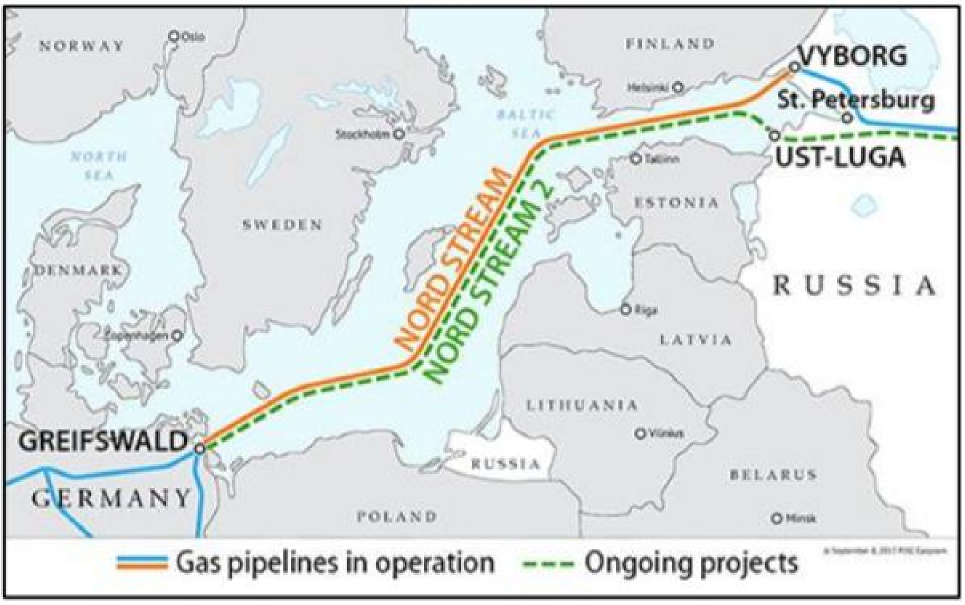


Figure 34. Nord Stream general layout. As per year 2020, it is the longest underwater sea pipeline in the world. Source: https://www.nord-stream.com/press-info/press-releases/next-step-in-the-potential-extension-of-nord-stream-426/

9.3 Shtokman gas condensate field

Initially, in 2007, Stockman was planned to be developed by the joint venture of three major gas companies - Russian Gazprom, Norwegian Statoil (now Equinor) and

French Total. Gasprom controlled the project with 51% of shares (through its European subsidiary company Gazprom Shtokman AG, Zug, Switzerland), TOTAL and Equinor were granted 25% and 24%, respectively. Both companies have a huge experience in cold climate operations. **[25]**

So why is the project so crucial for the Russian gas industry? In fact, it is a unique gas area in terms of contained reserves. The first explorations were made in 1981 and now the proven reserves are considered to be more than 3.7 trillion m^3 of gas and 31 million tonnes of gas condensate. It is known to be the largest gas field in the world of proved conventional reserves with a scale of twice as big as all gas reserves of Canada. It can fully satisfy European Union needs for the next 7 years, and with more than 20 years at the present Russia's EU gas market share of 25-30%. It is also a strong trigger for development of infrastructure of High North - not only locally, but internationally - northern parts of Finland, Sweden and Norway will be affected.

But since the time of discovery, the major obstacle for start of the project is its remote location far in the High North. Shtokman is located 550 km northeast of Murmansk, and the closest land is the western coast of the Novaya Zemlya archipelago, from which the field is 300 km away. It is a harsh Arctic offshore region, much colder and ice covered than any Norwegian site in the Barents Sea, including the Svalbard Area.

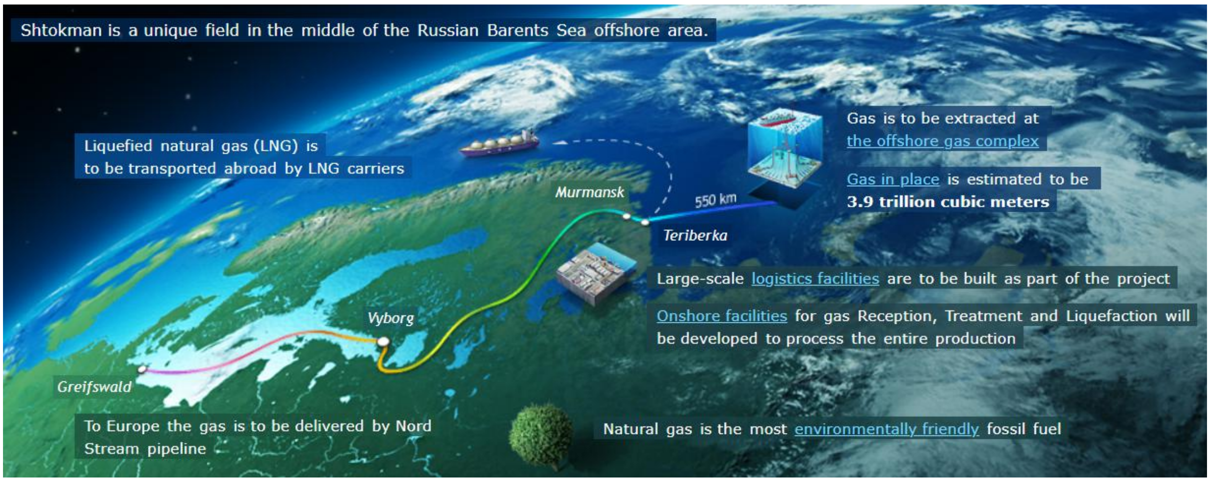


Figure 30. Shtokman project general information. Source: www.shtokman.ru

The main competitor factor for the Russia's Arctic gas in Europe is an intensification of shale and unconventional gas resources in North America. It affects the selling market prices, creating possibility to deliver liquid natural gas across the Atlantic Ocean. With the growing LNG offers, and a decreasing demand in large volumes due to warm winters and green energy expansion, it is still doubtful that Shtokman could be implemented someday. The present stand-by mode can probably become permanent.

So, recently Russia has focused on another huge project - Yamal Peninsula - Bovanenkovo gas field with construction of two innovative LNG plants.

9.4 The Yamal LNG Plant

The overall natural gas reserves of the Yamal Peninsula is around 16 trillion m^3, which makes it one of the biggest gas depots on the Earth along with Qatar-Iranian gas basin. Calculated estimated investments are around USD 150 billion and it will require up to 40 years to build infrastructure. On the other hand, Yamal is relatively conveniently located in relation to Russia's existing pipelines from Nadym Pur-Taz to domestic and foreign markets. Ice melting in the region will also allow to use Arctic class LNG tankers for Eastern direction, but for now the western market is in the priority. It is also estimated that developing Yamal will require relocation of 50.000 shift workers for civil construction works.

As Shtokman project is frozen, Yamal peninsula sites will carry out gas extraction and liquefied natural gas production solely, even so the production capabilities of Yamal LNG plant were designed to serve both projects. **[26]**

A plant with a capacity of 17.4 millions of m^3/year of LNG production is being built right at the South-Tambeyskoye field on the western coast of the Ob Bay. Due to logistics issues, its construction was made in modules - so called trains or lines. The LNG plant will consist of four such trains. The first one was launched in December 2017.

Figure 31. Loading of two tankers at Yamal LNG terminal. Source: www.novatek.ru

Among other infrastructure, it is important to mention a newly established airport and sea port. The Sabetta airport was built in 2014 and already serves flights from several Russian cities. The sea port was initially constructed to receive cargo ships with equipment and materials for the plant construction purposes, and later on had been transformed into LNG loading peers, which are now the integral parts of the project and are managed by Yamal LNG.

The Sabetta village, located on the western coast of the Yamal peninsula, seven kilometres from plant, is the base for whole Yamal LNG project in terms of providing residential and support facilities. Most of the temporary modular buildings will exist only during the construction phase.

Due to the successful implementation of a Risk Based Inspection (RBI) maintenance system at the Yamal LNG, the first scheduled maintenance is postponed by one year from August 2021 to 2022. The RBI methodology allows to maintain reliable operations of the LNG plant while reducing the total number of service hours.

9.4.1 Technical requirements, design and technologies, used for this project

By the year 2010, the Yamal LNG plant was a truly unique project for Russia. As it was mentioned above, before it's start, all produced gas was delivered by wide-diameter gas pipelines with a number of pump stations to maintain proper pressure level. The decision to establish the LNG plant was made because of remoteness from main pipeline network and a favourable production's cold climate conditions, which allow to liquify natural gas at lower cost.

Construction area is characterized by constant low temperatures, with averages less than (-5° C) during the period of 8-10 months a year. The designed lowest temperature is (-50° C). Wind speed average is 6,5 m/s with gusts up to 40 m/s. A total designed number of days with snow cover is 256, with a maximum thickness of 72 cm.

The plant is located in the zone of permafrost up to a depth of 500 m. Buildings, structures and open outdoor units are planned to be placed on pile foundations. To protect permafrost soils from thermal effects, all modules are built at a certain height above the ground surface, due to which:

- in winter, cold air circulation is provided under the modules;
- in summer - cooling the soil and preventing possible heat flow from the modules into the ground.

The location area is distinguished by the lack of production infrastructure, and in these terms all works are planned to minimize construction and installation operations on site, but with wide use of factory pre-assembled modules in which all technological equipment, pipelines, interconnections etc. are pre-installed, combined by the process installation in the process plants/complete technical devices.

Due to harsh weather conditions, it is planned to build two loading terminals for different types of LNG tankers and a tank park up to 160 000 m^3 for storage of produced gas when it is unable to load ships. Interruption and stand-by mode of technological process due to long-lasting bad weather is also taken into consideration as an extreme preventive measure.

Electrical power supply will be provided with a local power plant, specially constructed for these purposes.

Since it is the first project for the country, there are no regulation documents that could cover construction and evaluation of such plant. So new standards, specially designed for these purposes were required. By the year 2021, only general amendments to building principles were existed. 'СТУ' - special technical requirements for modules, equipment and safety measures are still developing and require technical approval.

9.5 Arctic LNG -2 project

Figure 35. Future Arctic LNG-2 Terminal. Rendered picture. Source: www.novatek.ru

Arctic LNG-2 is another LNG production-related project of NOVATEK. The project includes construction of three LNG trains, with a capacity of 6.6 million tons of LNG each, and 1.6 millions of tons of stable gas condensate. The total LNG capacity of the three trains will be 19.8 millions of tons. The project employs an innovative construction concept using a gravity-based structures (GBS). 'Arctic LNG-2 Ltd' is the operator and owner of all the assets. 60% belongs to NOVATEK, 10% TOTAL, 30% are a group of Chinese investors. **[27]**

A resource base for Arctic LNG-2 is the 'Utrenneye' field. The field is located in the Gydan Peninsula in YNAO approximately 70 km across the river Ob Bay from Yamal LNG.

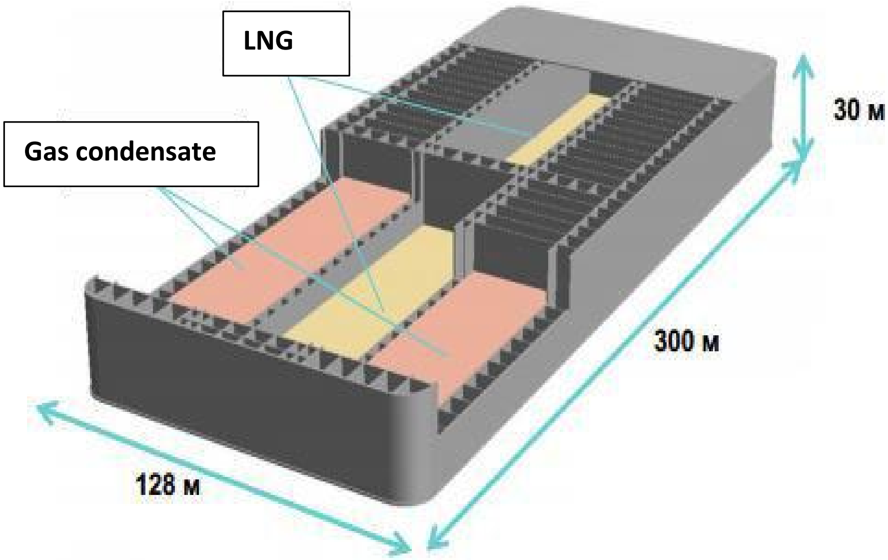
In 2019, front-end engineering design was finalized and site preparation started, including construction of early phase power supply facilities, production wells drilling, and construction of peers. Capital expenditures to launch the project at full capacity is estimated at USD 21.3 billion.

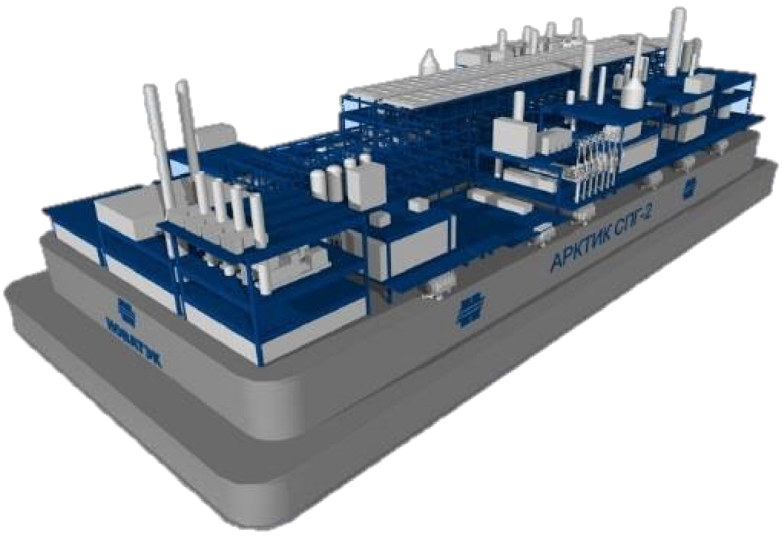
Figure 36. Natural gas reserves of the Yamal peninsula. Source: www.novatek.ru

Its design concept with the focus on local manufacturing of equipment and materials available inside the country allow to decrease capital costs and minimize dependence from international suppliers. For this reason, a special offshore super-facility construction center is built in Belokamenka near Murmansk.

As planned, it will provide fabrication of the gravity-based structures (GBS), assembly and installation of topside modules, production of semi-floating cranes. The Centre will comprise two dry docks for GBS, manufacturing large-scale facilities and heavy metal works.

At the end 2021, the overall progress for Arctic LNG-2 is estimated at 30%, with the first train is roughly 40% completed.





Figures 38-39. Arctic LNG-2 production line concept - platform rendering. Each platform is 300x128x30 m, weight 440 000 tons. Project includes three such modules. Source: LNG forum 21.06.2017 - TechnipFMC presentation.

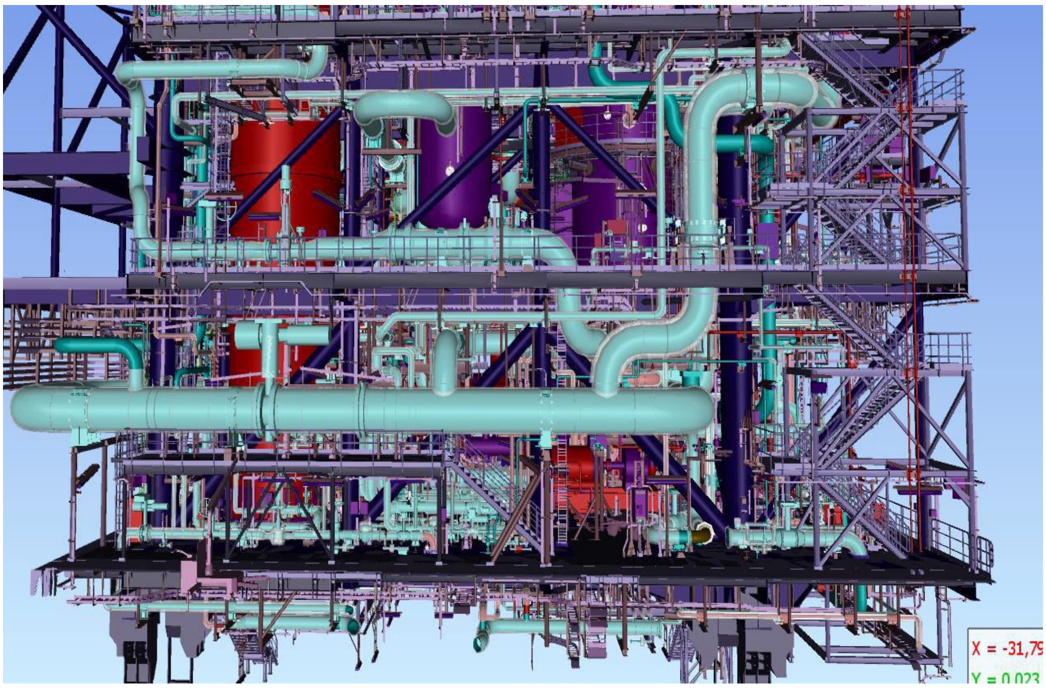


Figure 40. Arctic LNG-2 module design. Modules are pre-constructed and can't be modified after manufacturing. Source: LNG forum 21.06.2017 - TechnipFMC presentation.

One production line will consist of 25 modules (45m x 50m) mounted on one platform. The total mass of modules on one platform is approx. 120.000 tons, of which equipment is 23.000 tons, metal structures - 57.000 tons, pipelines and connection routes - 17.000 tons.

The Centre for the construction of large-capacity offshore structures is the Kola shipyard. Commissioning of the 1st stage - end of 2021. Overall dimensions of one platform 324m x 152m x 30m (LxWxH)

The License for the technological process of natural gas liquification is obtained from Linde AG (Munich, Germany). Saipem (Montingy, Italy) will provide a technological audit and scaling of existing design for future projects.

SBS Consulting (Russia) will provide report on localization possibilities of equipment, included in design with aim to reduce costs and contribute to Russian manufacturers.

EPC contract signed with TechnipFMC (London, UK)

United Shipbuilding Corporation (Murmansk, Russia) - strategic partnership for support vessel construction.

Research and development (R&D) will be conducted by NIPIgas (scientific research institute, Krasnodar, Russia) and Skoltech (research university, Moscow region, Russia).

Equipment, designed to be used in project is listed in Annex 2.

It is important to mention that both Yamal and Arctic-2 LNG projects are out of existing sanction lists (March 2021) so if no new restrictions are introduced, both projects will be fully completed and start operating as scheduled.

9.6 Vostok Oil

The most ambitious inland project, that by plans, will drive whole Arctic development in the nearest decade or two is the 'Vostok Oil' – a giant 'greenfield' oil development conducted by OJSC 'Rosneft'. This is a new project - implementation phase has been started only in 2021. But in terms of overall investments, it is considered to be one of the biggest oil projects in world history.

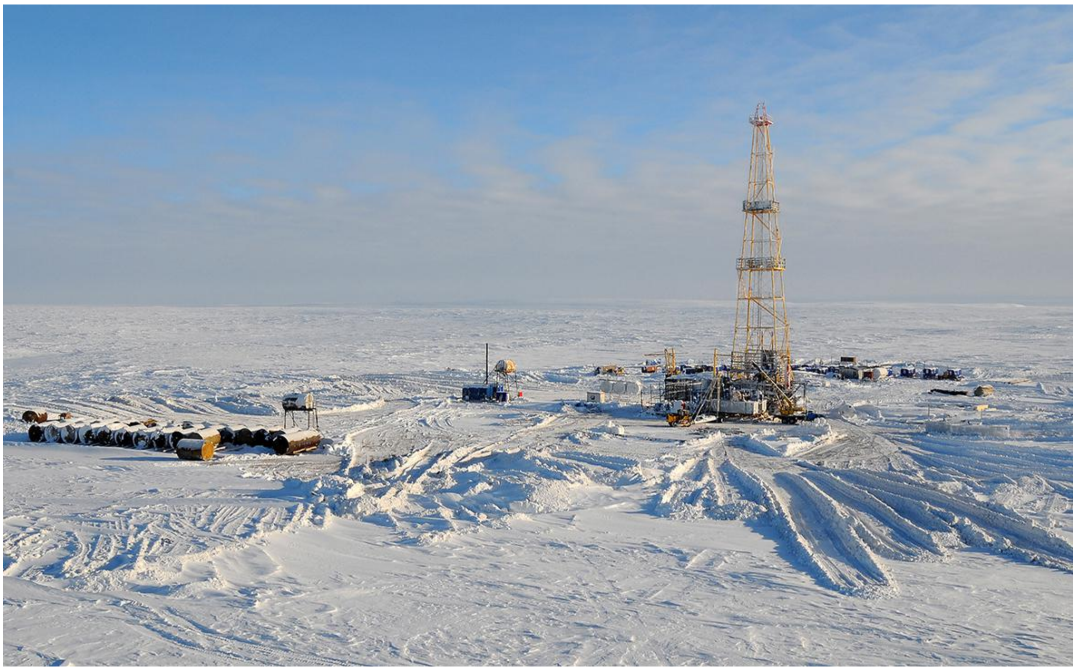


Figure 37. Vostok Oil exploration site - drilling rig. Source: tass.ru

This project still lacks details, existing data is gathered from several sources.

The first exploration drilling was started only in March 2020. After 10 months the first oil was obtained. Laboratory analysis shows it is a very high quality, comparing it to Middle Eastern brand. It contains very low level of sulfur and phosphorus. The aim now is to sell this oil as an independent 'ARCO' brand, not mixing it with usual URALS brand from Western Siberia.

The general funding will be obtained directly from the Wealth Fund, which has, despite the pandemic circumstances of 2020-2021, reached the amount of USD 200 billion. It is estimated that nearly 1,5% of the Fund will be used for support of infrastructure, while Rosneft will establish production facilities. **[28]**

This project is one of a number of previously discovered, but not developed oil fields with significant volume of deposits. Location - in the remote Arctic region, Taimyr peninsula, it is the largest in Russia and at northernmost continental point of Eurasia, and with an extremely low temperatures up to (-62° C).

The project requires massive investments in civil infrastructure and initial production. OJSC 'Rosneft' has already received tax break for the 'Vostok Oil' work for the next 10 years.

Several advantages of this project are the following:

1) It possesses huge oil deposits that comprise several considerable oil fields, the main are Eastern Vankhor and Payakta. Proved deposits for 2021 are around 44 billion barrels.

2) This project is solely onshore - only terminals for tankers will be built on the shelf - so present sanctions (as per year 2021) can be avoided.

3) Existing time-tested technologies allow to implement this project without using any new and risky approaches.

4) Strong interest from foreign investors, primarily from India and China with intentions to get a large share in this perspective.

5) High quality oil that in future could lead to creation of profitable local market in the Far East.

6) The Taymir peninsula is also a unique location for establishing huge wind farm infrastructure. The natural environment is comparable to what is now in Denmark. 'Rosneft' hopes and promises that in future the whole project will be powered by renewable energy sources.

7) It is designed to have a very low impact on the environment - in average 4 times less than traditional oil production. This will be achieved by both wind power and use of modern technologies in infrastructure, which is intended to be constructed from the very beginning. Most present oil fields were established 50-70 years ago and followed very poor environmental protection and ecological standards.

PART IV

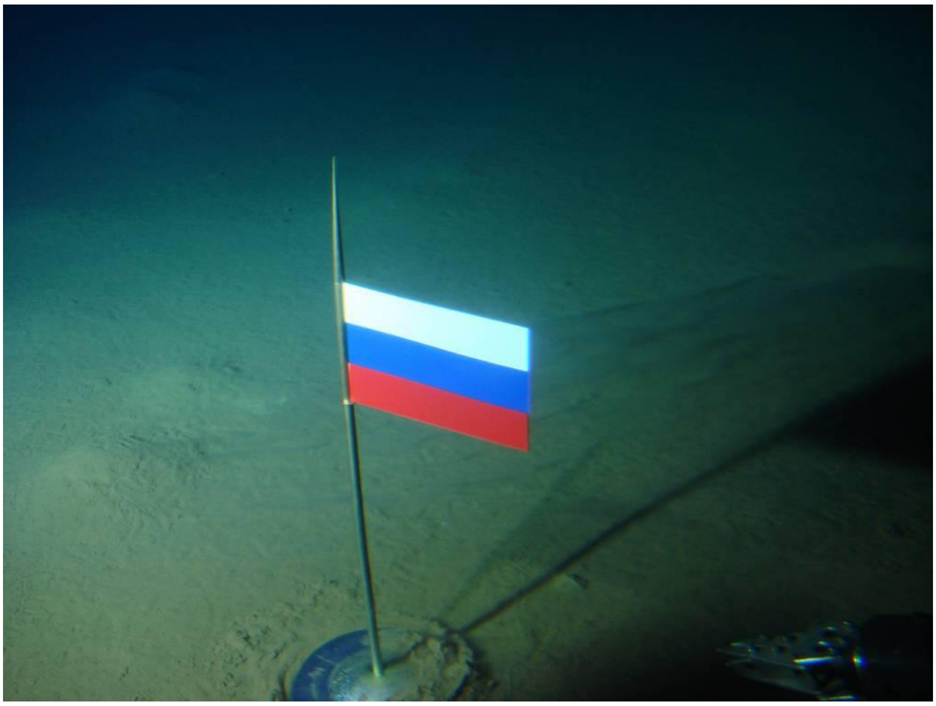
Chapter 10. Russian state strategy in the Arctic

Many experts are inclined to think that in the present geopolitical status and current oil prices are not in favorable conditions, the development of Arctic should be postponed until later, focusing on increasing the efficiency of production in traditional regions and extraction of tight shale oil.

In contradictory, Russia's attitude to the Arctic is quite different. It is not about economic benefits, but primarily, a means of showing its power and capabilities. In this sense, technologies and investments in Arctic projects are a part of state top-priority strategy along with state space program and foreign world policy influence.

Before developing possible scenarios for Russia in the Arctic region, I would like to give a background overview of recent changes in attitude to the Arctic, what stands behind the increased interest and activities, right in the 21st century. Soon after the presidential elections in May, 2000, the current leader Vladimir Putin proclaimed Russian oil and gas resources as the key geopolitical instrument to return to the 'superpower state' status in the world. Russia still possesses a significant volume of hydrocarbons in more traditional regions, such as Caucasus (Dagestan, Chechnya), Volga river region (Samara, Tatar and Bashkir oil basins) and, of course, in the Western Siberia - a vast and very rich inland region above the Polar Circle, which allowed the country to become one of the leading oil export countries since 1960th. Soon after 2000, Russia proclaimed a huge territory of the Lomonosov and Mendeleev ridges as a sovereign territory and shelf extension. A scientific expedition ruled by professor Artur Chelingarov in 2007 explored depths of the Arctic Ocean and put a Russian flag on the sea bottom (figs. 38 and 39). **[29]**

The claim was put to the international society for consideration. Russia actively prepared in details all the findings, acquired on the Arctic shelf, which were finally submitted in 2016. It reported that Russia is growing along the Lomonosov Ridge to include large parts of the Arctic shelf. After that, the UN Commission on the Law of the Sea will decide regarding the claim. It is estimated to take 3-5 years, and in a success scenario, Russia will receive international rights to the Arctic by 2020-2023, which is 1.2 million square kilometers.



Figures 38-39. Russian Flag on the bottom of the Arctic Ocean. Up - Deepwater vessel 'Mir' (up to 650 bar designed pressure). Source: tass.ru

In western discourse one could see a description of this event as an underwater land-grab demonstrating Russia's expensive 'colonial' approach to the Arctic. However, it is common in centuries for explorers to put their national flags when they reach any crucial destination - Mount Everest is a good example, at the Moon, at South Pole, at famous land discoveries. And going through all legal framework may allow Russia to convert its claims into an approved case, regardless of other players' opinions.

However, the real benefits of such acquisition are still unclear. The lack of technologies for exploration and production in the Arctic, unstable economic situation, the effect of sanctions and overall 'imperial' non-competitive approach create more imaginary activities than real perspectives.

I will mainly focus on the effect of sanctions and global world framework in the region, which both influence on Russia's policy.

First of all, let us compare two execution models - Western and Russian, as they are both are implemented in the region. Western states, such as the USA and Norway have set up clearly defined domestic and interstate laws, regulations, open access to private companies and international investors on a free competative basis. Governments of the Nordic countries, for instance, work closely together to gain benefits from environmental changes and technological development in the Arctic. Participants agree, that only common approach, firm and simple rules, openness would only be useful at present stance, where risks are high and initial investments are huge. A combination of valuable international experience, honest competition in tenders, wide cooperation, independent reliable forecast of trends and perspectives will bring positive results.

Contrariwise, Russia's future plans for the development of its Arctic part is strongly politically influenced, lack proven analysis, fair protection of business, absence of tenders and preferences to few state-owned companies binding all other players. Considering the rapid change in the global environment at the transnational level, the growing technological vulnerability and isolation of Russia after the 2014-sanction package creates even a bigger gap between intentions and real action, dependence from additional sources of technology and risky investments.

EU, the USA and the Nordic countries have implemented a modern technological and accurate approach, primarily increased investments in R&D of the Arctic. The introduction of artificial intelligence, secure broad communications with remote sensors, satellite survey technologies, revision of oil leakage and oil spill detection systems, flexible management of permits for exploration and drilling - just a part of today's activities. All this is based on state-private sector cooperation, with attention to environmental protection and indigenous people's needs. Transparency and public negotiations of plans give opportunity for audit of all significant steps in the development.

Talking about Russia, as it was mentioned before, it is more of showing intentions, to gain reputational achievements rather than economic and scientific values. Below are some facts:

Less than 1% of the total population of Russia lives in the Russian Arctic, of which about 140.000 people are representatives of 16 small native communities of the North. The country proclaims support of global carbon balance and preserving ethnic and cultural diversity on paper, but indigenous people gain very little from new resource projects. In the Russian Federation, only 5% of the Arctic territory is stated as protected zone, which is substantially less than in other Arctic countries. The intense onshore resource development in the 20th century (the efficiency of most Western Siberian oil wells is 30-50% less than similar in Canada), and using of outdated technology and infrastructure of Soviet heritage should be of concern. The carbon-intensive energy infrastructure (power plants, production and transport enterprises), along with ignoring environmental-friendly technologies, hinders the economic development of the Arctic.

The strategy of the Russian Federation is based on the document paper "Fundamentals of the state policy of the Russian Federation in the Arctic for the period 2020 and beyond", providing for the implementation of projects totaling more than 15.3 billion USD. Within the framework of the program, cooperation with the Arctic Council and its working groups, administrations of polar districts and cities is being intensified. An important feature of this program is the dependence and reliance on few state and ‘defacto-state’ oil and gas companies: Gazprom, Rosneft, LUKOil and NOVATEK. **[30]**

Chapter 11. Five scenarios for the development of the Russian Arctic

In this chapter five different possible scenarios are developed and described. Each of them is based on current state plans and assumptions for future projects. Also, proclaimed political, economic and technological directives for development are taken into consideration. The scenarios are the following:

- “Seized fortress”;
- “Raw resource supplier”;
- “Western turn”;
- “Eastern turn”;
- “Black swan scenario”.

11.1 “Seized fortress”

Key aspects for this scenario are the impaired relations with the Western states, huge focus on local production and extensive ‘aggressive’ resource development. China helps little because of fear of US sanctions.

In this scenario two main factors will play crucial roles: overall decrease of traditional reserves and obtaining technologies to substitute this fall in the Arctic.

Since 1960, when huge fossil fuel reserves were discovered in Siberia, primarily in its Arctic territories, Soviet authorities tried to develop as much new oil fields as possible. This fast and extensive activity followed to serious implications afterwards - both in environmental and production areas. As a result, many oil wells are almost depleted and now produce raw well liquid with more than 90% of water. This problem has several solutions, but none of them is real without modern technology using. Large-scale angled drilling, hydraulic fracking, rapid increase of well pressure are among them.

The other solution is to develop unconventional Arctic inland reserves. According to scientists, it will provide the main increase in hydrocarbon reserves in the long term. From the ‘Rosnedra’ state authority report, the degree of exploration of all proven reserves in Russia reaches 55%, the degree of exploration of the initial total resources is 46%. Moreover, the share of unconventional fuels is steadily growing due to the predominant development of easily recoverable reserves. Of the total balance reserves of proved oil reserves, which in Russia exceeds 18 billion tons, about 12 billion tons (66%) are in the unconventional category. Without involvement of its production, it will be practically impossible to maintain the achieved level of profitability in the period after 2020. **[31]**

Development of easy-accessible, conventional but tiny in terms of its reserves oil fields is another possible strategy, but it requires large involvement of small business - local and regional private oil companies, which operational costs are much less comparing to majors. We can observe such strategy in light of the tight oil revolution in the United States. Such companies, with tax support from the government, can establish production relatively fast, involve local work power and provide more effective solutions when it comes to transportation and temporary infrastructure.

Prerequisites for a favorable entrance of small private oil companies into such activities include being able to obtain rights to drill on free lease competitions, the availability of get financing and bank credits, and rules for using of hydraulic fracking technology.

A least probable and doubtfully effective means to sustain present oil production in this scenario is an exploitation of Arctic offshore resources. It requires both time and huge investments because of initial lack of technologies and modern infrastructure. Under western sanctions, proclaimed in 2014, it becomes nearly impossible to get high-tech equipment for the Russian Arctic. Subsea solutions and special vessels are prohibited from delivery. Forwarding state investments for local research, design and manufacturing of required equipment seems to be unlikely.

Anyway, at time of unfavorable market opportunities (with oil barrel price less than 80 USD/unit), such investments will overlap possible economic effect and will lead to enormous spending with unclear return.

High environmental and pollution risks due to reliable equipment inaccessibility will create new ecological threats and public pressure from neighboring countries (as it already happened throughout Russia’s Soviet period).

The Northern Sea Route still will not play a significant role and most infrastructure onshore projects will be covered by means of land transportation with focus on existing and planned railways. Commercial international exploitation of the route will be deferred because of mutual threat, and unwillingness to promote Arctic free cooperation. China will play an independent transport role with its newly established Great Silk Route to Europe (which does not go through Russian territory at all).

Moreover, establishing new and reconstruction of old Cold War military bases will also prevent other countries to seek partnership with Russia, increased geo-political tensions will require sole acting and will probably lead to a state where any high-risk projects will be set on pause or even frozen.

11.2 “Raw resource supplier”

The main points of this scenario are the development of easily accessible oil and gas fields and absence of a sustainable Arctic strategy. There will be limited investments in renovation of existing Arctic onshore fields. Short-term economic benefits are prioritized with relatively little technology improvements.

In this scenario, reliance on local production capabilities will still dominate. Two main state companies - namely PJSC ‘Gazprom’ and PJSC ‘Rosneft’ are monopolists in obtaining offshore licenses and exploration permits. As per year 2020, according to the Russian Ministry of Natural Resources, licenses to exploit subsurface resources in the Arctic and Far East seas are split solely between these two companies, with about 41 licenses belonging to ‘Rosneft’ and 32 - to ‘Gazprom’. The main targets for ‘Rosneft’ are the Barents shelf (including its southeastern part, named the Pechora Sea) and the Okhotsk seas, while Gazprom is expected to concentrate on Kara Sea projects (21 licenses).

Overall across the country, ‘Rosneft’ owns 4 of 10 largest oil deposit sites in Russia, and ‘Gazprom’ operates in 87% of gas fields.

Existing gas contracts also suffer from market uncertainties - in February 2021 China's gas purchase prices from Russia fell as risks rise. So, only a year after Russia opened its giant strategic ‘Sila SIbiri’ (‘The Power of Siberia’) pipeline to China, natural gas prices for the Chinese market have fallen below European rates.

Moreover, due to landscape and natural issues, construction works for pipeline connections between its Chayanda and Kovykta gas fields in Siberia are almost tripled, which require more spending for ‘Gazprom’ (from USD 722 million up to USD, 2,1 billion only in 2020) with decreased Eastern direction benefits. **[32]**

Due to the complexities and lack of public information between two state-owned companies, Chinese CNPC and Russian ‘Gazprom’, it is hard to predict its economic effect. Right now, revenue and the profit of the ‘Power of Siberia’ project have not been determined and few experts have given comments on commercial attractiveness of this 30-year gas deal. However, ’The Power of Siberia’ story does reveal the inherent risks in such deals. They take a long time to negotiate, finance and complete; capital costs and operational risks are high, market conditions can change; and political decisions make deals easier to conclude, but does not guarantee commercial success.

‘The Power of Siberia’ project is followed by the relative success of Russia's first oil pipeline to Asia - the Eastern Siberia-Pacific Ocean (ESPO) project, which opened direct deliveries in 2011, paving the way for massive investments in pipeline transportation.

But unlike the investment in ESPO, Russia failed to secure any Chinese financing for 'The Power of Siberia' project, leaving 'Gazprom' to bear the risks on its own.

It did not stop state gas company to increase export to China with an upgrade of the existing project - the so-called "Power of Siberia-2" - pipeline crossing Mongolia to deliver another 50 billion m^3 of natural gas per year.

It is proclaimed as technically feasible and a cost-effective project, but extra-long distances and requirement for establishing brand new and complex infrastructure, such as powerful pumping stations and living quarters for service workers in previously unpopulated areas will add to the cost.

Generally speaking, this scenario will allow Russia to be a stable, reliable partner both for East and West, though without any real development of Arctic offshore and unconventional Arctic reserves. Existing pipelines and future LNG plants will support export of crude oil and natural gas for another decade up to 2030.

In contrast to it, orientation on 'green' economy in Northern Europe, Chinese turn to electric transport and renewable energy sources, new environmental regulations and increase of global LNG supplies will affect even the traditional Russia's export positions. The solution seems to be found in filling of domestic market demands, by intensification via modern technologies, renovating of existing refiners and switching to export of secondary oil products with added value, rather then of crude oil and gas.

11.3 "Western turn"

This scenario describes a complete change of political situation - openness and vast involvement of western companies, cooperation and using of modern high-reliable technologies.

Russia continues to play its role as a major supplier of oil and gas to the EU, industry still depends from fossil fuel for the nearest future. Commitment to renewables and lowering carbon emissions makes effect, but present needs will grant Russia with long-term contracts and wide cooperation in technology-dense production areas.

In the next 10-15 years EU will receive oil and gas primarily from the top two suppliers - Norway and Russia. Natural gas, in particular, will retain its significance in the medium-term, as it is considered a bridging energy carrier until the shift toward 'pure clean' energy is completed. In 2018, 50% of natural gas imports came from Russia and 35 % from Norway. It is also a sort of energy that has no contradiction to EU present environmental policy. The respective numbers for oil are 27% and 11%.

Countries like Germany, Hungary and most Eastern and Central European states are particularly dependent on oil and natural gas deliveries from Russia, both for heating and industrial purposes.

In this scenario we can assume a mutually beneficial Europe - Russian cooperation - governments will agree on lowering, freezing or cancellation of technological sanctions, a fruitful climate for the Western investments will be introduced.

In the nearest 5-10 years this can result in new explorations, cost reduction by means of western methods in management and fair local audit.

Friendly attitude to the private business activity in country's strategic Arctic basin region will result in significant growth of innovative technologies, modern and effective solutions for offshore and onshore unconventional reserves. One of the most probable impacts of such cooperation can be a re-start of the famous Shtokhman project, its development by means of joint ventures. As it was mentioned previously, it will affect whole High North area, involving Northern territories of several countries into a deal.

The Russian government approves a package of 'tax holidays' for companies planning to implement new high-cost and technology-dense projects in the Arctic to stimulate bringing best practices and standards, sustainable and safe services. Western participants will secure their investments with clear perspectives of long-term projects, assurance for friendly cooperation and revenue.

'Gazprom' and 'Rosneft' could be divided into several smaller companies with further privatization. It will help to ease private business integration to the Arctic, by getting ownership shares of Arctic licensed reserves and obtaining technologies through newly established subsidiaries.

These activities will push the trigger to a peaceful and innovative approach to the Arctic development - it will become a field of new level of Russia-West relations, and provide a rich soil for establishing both a common research base and an environmentally safe modern production partnership (the previous similar successful example was in space industry - International Space Station).

A most fortunate version of this scenario will provide top-level interstate governmental supervision, increase of university and scientific contacts, coastal safety activities, civil infrastructure construction following the highest ecological and human standards, as well as people's attention to this matter.

Hedging of risks related to unstable oil and gas prices, unpredictable climate conditions and high initial costs of exploration drilling between major domestic and international companies will provide a contiguous growth of prosperity both for the state, Western partners and local indigenous communities, which will benefit from overall region development.

Common running of the Northern Sea Route under convoying of existing and future nuclear ice-breakers will result in supply of resources to the Northern China, Korea and Japan, as well as founding of number ports, supply and repair bases along the NSR way.

11.4 “Eastern turn” - focus on Asia-Pacific region

This scenario has been already partly implemented in 2017, when Russia looked for financial and technology partners for its cooperation in the Arctic, by inviting Chinese companies in its most prestigious energy projects, LNG plants on the Yamal peninsula. It is started soon after proclaiming the first package of the Western sanctions and combines possible ways to overcome them by interaction with Eastern companies for obtaining necessary technologies, manufactured equipment and financial support. This is implemented in the following ways:

- A shareholder in cooperation from the Russian side is a private Russian gas company, such as NOVATEK in Yamal LNG, but with strong informal state control. Other examples of such companies are oil majors OJSC ‘SurgutNefteGas’ and LUKOil. The main advantage of such approach is that they are well-known world production companies, financially independent, act in the public domain and have a share of Western owners. So, they are usually excluded from any state sanction lists.

- Chinese companies often ignore Western sanctions towards third parties and act only according to their sole interests. This already happens in Iran, where many ways to overcome US sanctions were presented. Copies and close analogs of western technologies are delivered despite of any restrictions.

- The most modern shipyard for tanker and oil rig construction is located in South Korea, which also avoids introduction of sanctions against Russia, get more and more construction orders for Arctic projects.

- Russia has proclaimed that it will try to sign future trade agreements avoiding financial schemes in US dollars or Euro, but using local currency (Russian rubles and Chinese renminbi).

- Local assembling is a priority - on a basis of existing production sites (‘Sevmash’) and newly established (‘Zvezda’). Assembling of complex units by buying essential components abroad and manufacturing basic parts locally and structure elements is a winning strategy.

- The main liquid oil projects on which the government will rely on are located in the Eastern onshore part of the country. Vostok oil fields of ‘Rosneft’, in particular the actively developing Vankhor cluster, and Neftegasholding in the North of the Krasnoyarsk district. It will require investments and time in restoration of the Arctic infrastructure (such as nearly abandoned Soviet-time towns Tiksi and Dikson).

The scenario will depend on creating a fertile ground for companies to invest, depending on government policy, finding local technological solutions and equipment suppliers and those who will be ready to provide with the appropriate technologies under the western sanction regime.

Concerning onshore natural gas and condensate, Russia still will be a supplier for both main markets - European and Asian, though the approaches and outcomes differ a lot. Europe’s political decision to use natural gas as a ‘bridge’ towards a full implementation of renewable energy in the future and in China to reduce coal consumption to 58 % by 2030 will still provide Russia with markets for its natural gas in the nearest future.

Natural gas from the Bovanenkovo field destined for the EU market will also be transported via existing gas pipelines - ‘Nord Stream’, ‘Turkish Stream’ and ‘Soyuz’. But recent US sanctions against 'Nord Stream-2' construction of the pipeline will cause the finalization of the pipeline to be postponed or frozen.

It also highlights the interconnections between geoeconomics and geopolitics, which pose a challenge to Russia’s energy production plans and explains the collaboration with Chinese companies. **[33]**

11.5 “Black swan” scenario

The term “Black swan” determines a number of unexpected events in a row that create a big impact. It could be major industrial accident, unpredictably rapid development of renewable energy, severe drop in oil and gas prices, natural disasters in the Arctic region, technological breakthroughs, sudden geopolitical issues, etc.

Some trends and prerequisites of this scenario we can observed today, though on a very early stage:

- the impact of the pandemic - airline industry world oil consumption in 2019 was 8% of total hydrocarbon needs, but in 2020 its drop was up to 80%. In the future, it is likely that fewer people will choose air travel and more companies will switch to digital events when its applicable. It means a very low chance that aircraft industry will reach its previous oil consumption values.

- ‘green’ energy - even during the national economic falls in 2020, Western countries confirmed to follow Paris agreements towards lowering CO_2 and to increase the share of renewable energy sources. Some experts admit that even in the Arctic cold climate region it is more profitable to use renewable energy such as wind farms and solar power. Countries like Norway have already limited selling of fossil consumption vehicles, more and more people choose electro-powered automobiles for everyday life. Rapid interstate railroads contribute to this trend.

- The shale revolution, primarily in the United States, has substituted costly and technically difficult drilling in the Arctic. For the same reason, oil sands in Canada remain more profitable than oil and gas drilling in the Arctic. Greenland’s early explorations have also shown dry wells and decreased interest of oil companies for further works. In general, this means that Russia becomes a sole player in terms of Arctic offshore development, but with actual absence of technology and sufficient funding.

- as we can see from the present Arctic offshore projects, namely ‘Prirazlomnaya’ and ‘Shtokman’, the time period between exploration, start of development and investments return are decades of years. Both these sites were discovered in 1988-1990 and since that time only one is in operation, far from providing profit. During the next 20–30-year period, the grade of uncertainty is high and it will affect any further actions in such projects.

National interests and decisions of market participants can also affect Russian perspectives. For example, in early 2021, the Rolls-Royce company had intention to sell an innovative ship engine manufacturer, the Norwegian ‘Bergen Engines’ to the Russian holding company ‘Transneftemash’. It was necessary for Russia to obtain complete solution for production of ice-class tankers Arc4 and Arc7. The deal was blocked by the Norwegian government and it will probably lead to a considerable throwback in local construction and postponed plans for Northern Sea Route navigation. In contradictory, the blockage of Suez Channel by the container mega-vessel ‘Ever Given’ on March 24, 2021 has led to seek for alternative ways of oil delivery from Asia - building another transit pipeline through Russian territory or to pay attention to NSR perspectives. These two events are rather small and unpredictable (so-called ‘Novel risks’), but show how vulnerable any plans could be.

We can assume many different ‘black swans’ with different probabilities - but the main idea is that neither risks nor consequences could be assessed and mitigated. It also concerns time period - some events can happen simultaneously, other - only by trigging of other circumstances.

Another big issue are sanctions. As per 2021, some technological and investing restrictions are in action, but with relatively little effect on Russian plans for the

Arctic. It may change, if more serious Western sanctions take place. Embargo on purchasing of Russian crude oil is among them (similar to Iran). It probably will result in increase of costs due to necessity of seeking alternative markets. A possible expansion of list of technologies and equipment, that are prohibited to deliver, in theory can result in significant throwback of the Arctic program, putting even existing projects into a stand-by mode.

Sanction's expansion decisions are usually influenced by changes in international relations and cannot be predicted beforehand. This will also work as a 'black swan' for domestic assembly industry, still dependent from service and spare parts from abroad.

Chapter 12. Conclusions and recommendations.

It is likely to think that further Russian Arctic strategy is seriously affected by the current geopolitical situation, absence of offshore experience and technologies under sanction regime. In terms of time saving and gaining of revenue it is often inclined to increase the efficiency of production in traditional regions and developing unconventional hydrocarbon sources, rather than establishing long-term and costly projects in the Arctic region.

It is also clear, that nowadays Arctic plays more perspective role. It can boost the overall state technological and industrial development – a similar example can be observed in the Space and military sectors during the Cold War. But the number of investments and related risks with unclear outcomes create uncertainty towards active actions even for the state oil majors. Negotiations around Arctic offshore perspectives continue. State authorities and oil company's management evaluating and comparing risks doubt whether developments are feasible and beneficial.

Just one opinion of the deputy director of the Russian Center for Analysis of Strategies and Technologies, Konstantin Makienko:

"The Arctic is one of the most important undeveloped, untouched reservoirs of hydrocarbons and it is clear that this region is very difficult for the extraction and transportation of hydrocarbons. And it requires even more resources than the time of the development of oil and gas in Western Siberia - that region was also considered extremely difficult, required colossal investments, but, nevertheless, was developed.

And, frankly, the country (Russia) still lives on the investments, that were made in the sixties and seventies during the development of Western Siberia.

Arctic development will become essential in a long perspective - perhaps fifty-sixty, or even a hundred years ahead. The oil and gas fields in the Arctic zone are gigantic, and this is an asset that is necessary not only for Russia - it is clear that Russia is, first of all, - but hopefully, it is an asset that will be in demand all over the world."

Countries like Canada and Denmark have frozen their Arctic offshore activities, when other states - Norway, the USA and even China show increased interest. Norway intends to develop the previously deliminated border zone in the Barents Sea, the USA allowed their companies to explore Alaska offshore zone and China builds its own nuclear Ice-breaker fleet.

However, it is estimated that present-day technologies will allow economically beneficial hydrocarbon production and transport in the Arctic offshore zone at the market oil prices above USD 100/barrel, which is quite unlikely to happen, as many experts admit.

The other conclusion is based on statement that real Arctic resource players in the next decade will probably be major state companies, whether they will act with or without foreign cooperation. Building of Arctic infrastructure for establishing new oil and gas sites, particularly offshore, use of Northern Sea Route and mitigating environmental risks, harsh terrain and connection to distanced autonomous settlements will require investments that only state and fully supported oil companies can withstand. They will require special tax regulations, special credit possibilities and accommodate huge research, production and service powers. Many of former Soviet research and experimental institutions became parts of oil majors' companies and carry out R&D studies to boost the technology level.

But it is obvious, that investments in fundamental scientific research, particularly which require long time to complete and resources to carry out, will likely to be rejected.

The most efficient way to proceed with Arctic hydrocarbon production for Russia, is to combine its own existing advantages - profound experience, large research potential, relatively cheap work costs with the international management, common investments and added value of western knowledge and modern technologies.

Most of the mentioned here perspective Arctic projects are also influenced by outer factors, such as oil and gas market prices, the strength of sanctions, scale and ability to cooperate with China.

Based on the discussion in this thesis, it is clear that sole acting and reliance only on local technologies will lead to further interruptions and difficulties in development with possible complete withdrawal from the region.

Some scientists are even more are skeptical with the risk level associated with oil and gas developing in the Russian offshore Arctic. They stress that the existing governance regime in the Arctic is inadequate - with limited resources available to respond to a loss of well control combined with pristine and highly diverse ecosystems would make a 'Deepwater Horizon'-type incident have far more dire consequences in the Arctic than it did in the Gulf of Mexico. As for similar global disasters, it will surely affect many other lands. Furthermore, critics argue that existing Russian technology standards are not Arctic tested for operations in ice-covered waters, and that there is no equipment and infrastructure in the region to respond to an oil spill.

12.1 Recommendations and author's opinion

The Arctic region is a unique area with extremely sensitive environment. It is very challenging to develop, difficult to exclude risks and mitigate significant disasters. This area should be out of any political games and technological competitions. It should be preserved by the whole global society. International world organizations, such as the UN and the Arctic Council should continue to develop internationally recognized laws and rules to act in the Arctic area. Intentions to militarize Arctic, extract resources in a dangerous way, lacks of prior planning and risk assessment are not allowed and can lead to a global catastrophe.

In this way, the best solution for Russia as a main holder of hydrocarbon reserves is to slow down independent plans and to develop a long-term comprehensive strategy, involve Western companies with their best practices. Broad cooperation is possible only by means of state-private partnership, clear market rules and tax reduction. Introduction of innovative technologies, continuous research activities and audit of existing infrastructure with its possible upgrade to the modern standards can result in both sustainable and effective growth of the Russian Arctic hydrocarbon industry. This also requires a shift from viewing the Arctic primarily as a security threat in a strictly military and geopolitical sense, to focus on a safety threat in the context of climate change, sustainability of wildlife and native indigenous communities, pollution protection and conservation for the future generations.

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ANNEX 1

Equipment, required for Arctic offshore development. Developed by state oil company OJSC 'Rosneft'
https://www.rosneft.ru/business/Upstream/shelf_equipment/

Ships and Vessels

Seismic vessels
Floating drilling rigs for exploration drilling
Subsea equipment for exploration and well completion
Survey vessels
Pipeline construction vessels
Icebreakers
Transport ships
Tugs
OSR vessels
Personnel transport vessels
Underwater technical support works vessels
Floating supply barges
Floating cranes
Rescue ships
Oil transport tankers
LNG tankers
Floating storage barges
Stationary Marine Platforms

Marine equipment

Ice class and cold-resistant equipment - anchors, rescue boats, steering gear.
Mooring and towing, handrail and awning devices.
Heated windlass.
Cold condition materials - oils, rubbers, hydraulic systems, fittings.
Boat devices, equipment and supplies.
Ship supply.
Products and fittings for ship hydraulics systems.
Marine boilers, auxiliary mechanisms, shafting, propulsion devices, electrical equipment, on-board communications.
Marine filters for zero-class emission.
Satellite communication devices (Thuraya, Iridium)
Satellite positioning systems with full area coverage (GPS (USA), GloNass (Russia), Galileo (EU))

Marine power equipment and connecting devices.
Ship lighting equipment.
Marine electric heating equipment.
Actuators, devices and details of ship systems and pipelines
Manual ship fittings.
Remotely controlled ship fittings.
Automatic ship fittings.

Aircrafts

Marine helicopters
Cargo aircrafts
Passenger transport aircrafts
Drones - unmanned aerial vehicles for ice monitoring
Flight support facilities

Drilling equipment and tools

Technical equipment for drilling offshore side-direction wells (incl. telemetric observation)
Equipment of casing columns for offshore wells with a depth of 6500 m

Exploration equipment

Exploration drilling rigs and assemblies
Drilling pumps for exploration drilling and assemblies

Production drilling rigs, installation and support equipment

Erection cranes
Rotor assemblies
Diesel hydraulic equipment
Actuators, high-pressure manifolds, block valves
Heated shelters
Drilling rigs units and secondary equipment
Installations for powering engines with fuel and dispensing oil

Electric equipment

High voltage switchgear
Power and converter transformers
Electric motors
Electronic control devices for electric drives of drilling rigs

Process equipment

Circulation system equipment (CC) for cleaning and preparation of drilling fluids
Blocks for preparation of drilling mud from powder materials
Circulation mill systems
Hydrocyclone plants, sand and mechanical particles separators
Primary reservoirs
Rig heating systems
Cleaning and regeneration assemblies
Mixers

Equipment for transportation and storage of bulk materials
Warehouse equipment
Railway tank cars-cement carriers
Cement trucks

Blowout prevention equipment

Preventers
Blowout Equipment (BOP) Manifolds
Equipment used in environments with a high content of toxic gases
Well shutting-down equipment
Drill string assembly equipment and tools
Locks and connecting conestsy
Bottom layout
Drilling locks
Drill pipes
Centralizers
Drill-string valves
Column heads
Ejectors
Column shoe
Downhole hydraulic motors
Downhole turbine motors
Downhole drilling motors
Rotary-turbine and jet-turbine drills
Non-standard equipment for equipping workshops for the repair of hydraulic downhole motors
Rock cutting tool
Chisels
Drilling diamond heads
Coring equipment

Equipment for preventing and eliminating complications during drilling and well casing

Impact-impulse devices and auxiliary mechanisms for eliminating stuck columns
Equipment for increasing the durability of casing pipes
Technological casing rigging (except packers)
Equipment for repair and isolation works in wells
Technical devices to combat absorption
Packers and anchors
Assistive devices and tools
Vane calibrators
Downhole motor centralizers
Stabilizers
Extenders
Shock absorbers

Oilfield equipment

Equipment for the operation of offshore wells
Equipment for flowing wells
Equipment for sucker rod pumping operation
Equipment for rodless deep pumping operation
Equipment for the simultaneous separate operation of several layers in one well
Lifting units
Aggregates
Towers
Swivels
Elevators

Equipment for maintaining reservoir pressure

Centrifugal pumps
Reservoir pressure maintenance pumping stations
Wellhead fittings for injection wells
Installations of submersible centrifugal electric pumps for maintaining reservoir pressure

Equipment for active stimulation

Plants and pumps for pumping water and other liquids into plunger pumps for them
Steam generating units for steam injection into the reservoir
Equipment for creating and maintaining the in-situ combustion front

Equipment for water preparation, preparation of solutions of various chemical reagents and dosage
Equipment for gas injection into reservoirs
Wellhead equipment for injection of various agents into reservoirs
Downhole equipment for injecting various agents into formations
Discharge control equipment
Equipment for active stimulation of oil reservoirs
Gas screw compressors

Equipment for collection and preparation of oil and gas

Metering installations
Mass measuring units for wells
Separation block plants
Block oil pumping stations
Pressure sedimentation tanks for waste water treatment
Block pipeline heaters
Tube furnaces
Block settling tanks for oil treatment
Sedimentation tanks for oilfield wastewater treatment

Complexes and installations for oil and gas treatment

Flare installations
Equipment and tools for cementing offshore wells and other technological processes
Mixing plants
Manifold block
Stage Cementing Couplings
Cementing plugs, valves, heads
Compressor stations

Downhole installations

Well acidizing devices
Well dewaxing equipment
Electric borehole induction heaters
Stage cementing devices

Pumping, ventilation and compressor equipment

Mud pumps for exploration drilling
Installations of submersible centrifugal pumps for oil production
Installations of submersible screw electric pumps for oil production

Installations of submersible diaphragm electric pumps for oil production
Installations of hydraulic piston pumps for oil production
Centrifugal pumps for maintaining reservoir pressure
Pumping units for washing works
Well acidizing pumping units
Pumping units for well cementing and other technological processes
Sucker rod pumps
Pumping units, pumping units
Oil main pumps
Units and parts of pumps are replaceable
Compressors
Machines for casing pipes and sectional turbodrills
Spare parts

Other essential equipment
Research and laboratory equipment
Equipment for non-destructive testing
Prefabricated and mobile buildings
Rescue equipment
Safety equipment
Fire-fighting equipment
Environmental protection equipment
Cleaning equipment
Welding equipment
Heat exchange equipment
Anti-corrosion equipment
Repair tools
Special equipment, non-standard
Gas distribution stations

Raw materials and supplies

Reagents
Chemicals and materials for preparation and regulation of properties of drilling fluids
Filtration reducers
Viscosity regulators
Clay Swelling Inhibitors
Silicone defoamers and antifoam agents
Lubricating additives
Surfactant additives
PH control reagents
Hydrogen sulfide neutralization reagents
Materials for filling drilling fluids

Reagents for stimulating oil production
Corrosion inhibitors
Corrosion inhibitors - bactericides
Paraffin wax inhibitors and removers
Grouting compounds and reagents for repair and insulation works
Enhanced oil recovery products
Oil preparation products
Reagents used in oil transportation
Anti-turbulent additives
Reagents for water purification
Soil cleaning agents
Reagents for air purification
Well cementing materials
Backfill cement
Additives to oil well cement
Cement compositions
Slag cement

Insulation materials
Electrical insulation
Fiberglass, glass fibre
Products made of foam diamite, diamite, trefoil
Perlite products
Asbestos-containing products
Basalt fibre products
Inorganic loose materials
Waterproofing mastic
Powder waterproofing
Sealants, putties

Other

Personal protection equipment
First aid kits

ANNEX 2

Types of equipment and material for Arctic LNG project implementation

[Consolidated presentation. LNG Forum 21.06 2017. TechnipFMC proposal] *

Note: equipment listed below is prohibited to be delivered for offshore purposes and on the territory of Crimea according to EU and US sanction list:

- Compressors - process compressor units, unit aux. systems
- Power generation Gas turbines -pressure vessels.
- Columns, tanks, shell and tube heat exchanges
- Flare system with column
- Safety equipment, fire and gas detection, lightning systems.
- Pumps - centrifugal pumps sealed pumps, lift pumps, electric motors.
- Electrical and Instrumentation, communication networks, switch gear transformers, UPS systems.
- Unloading arms, standers - technologically complete units
- Filters, pipelines -seamless and welded pipes, fittings and flanges, supports.
- Valves; ball valves for cryogenic and non-cryogenic liquid, butterfly valves for cryogenic and non-cryogenic liquid, gate valves, check valves, double block and bleed valves, emergency preventers.