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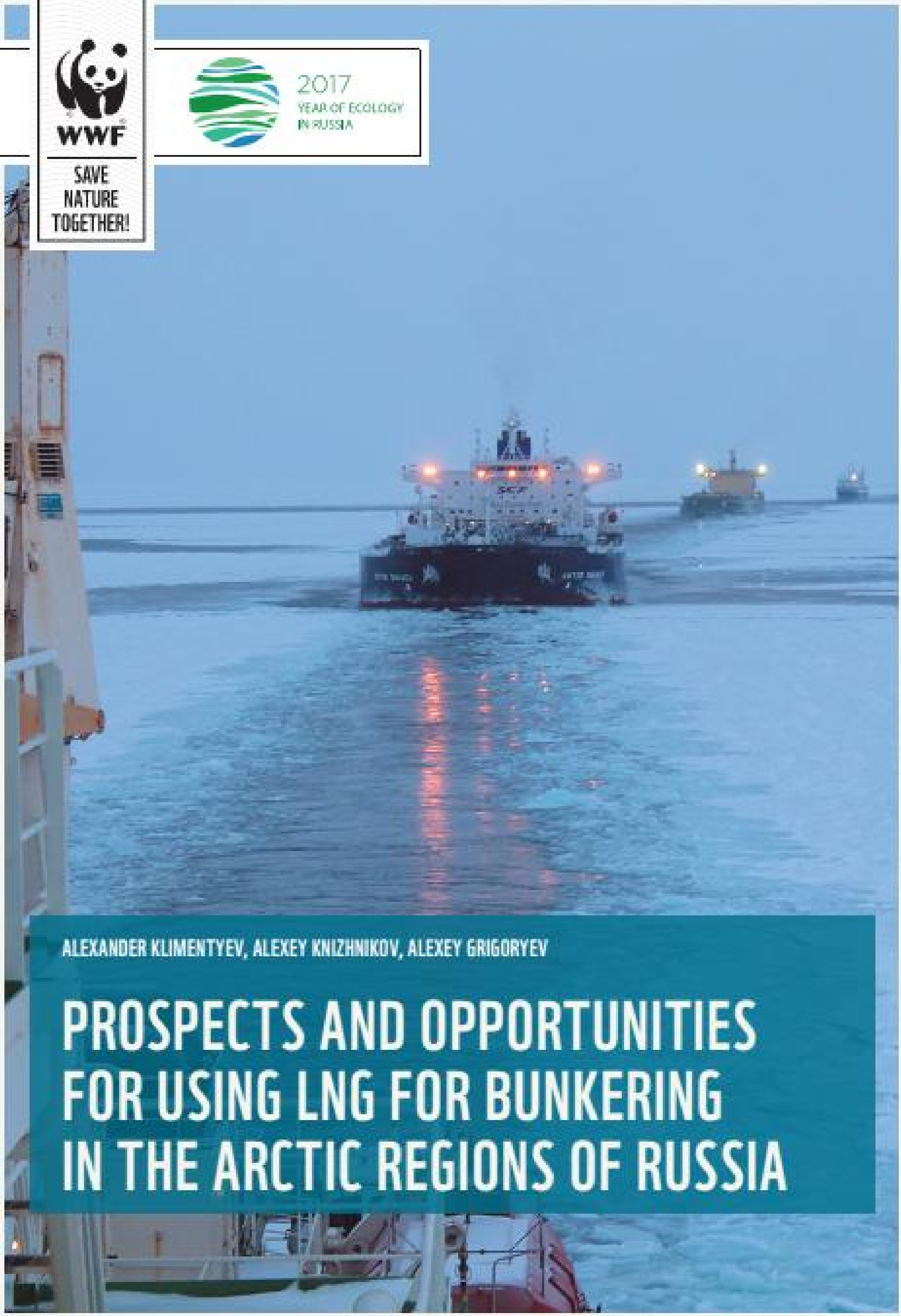

ALEXANDER KLIMENTYEV, ALEXEY KNIZHNIKOV, ALEXEY GRIGORYEV

PROSPECTS AND OPPORTUNITIES FOR USING LNG FOR BUNKERING IN THE ARCTIC REGIONS OF RUSSIA

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PROSPECTS AND OPPORTUNITIES FOR USING LNG FOR BUNKERING IN THE ARCTIC REGIONS OF RUSSIA

Moscow, 2017

The report “Prospects and opportunities for using LNG for bunkering in the Arctic regions of Russia”

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“Prospects and opportunities for using LNG for bunkering in the Arctic regions of Russia”/ A. Klimentyev, A. Knizhnikov, A. Grigoryev, WWF. – M., 2017. – 60 pages

This study evaluates the prospects and opportunities for using liquefied natural gas as marine fuel in passenger and cargo shipping in the Arctic region of the Russian Federation.

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Symbols and abbreviations

BC	black carbon
DM (MGO)	distillate marine grade (marine gas oil)
ECA	emission control area
FLNG	floating LNG Facility
HFO	heavy fuel oil
IMO	International Maritime Organization - an international intergovernmental organization, a specialized agency of the United Nations
MARPOL	International Convention for the Prevention of Pollution from Ships
OC	organic carbon
PM	particulate matter
RM (HFO)	residual marine grade (heavy fuel oil)
LNG	liquefied natural gas
NSR	Northern Sea Route

A conversion table of the frequently used values:

into / from	bl. cub. m	bl. cub. ft.	ml. t LNG	tn. Btu
1 bl. cub. m	1	35.3	0.73	38.8
1 bl. cub. ft	0.028	1	0.021	1.1
1 ml. t LNG	1.38	48.7	1	51.9
1 bl. Btu	0.028	0.98	0.02	1

Source: "The Global Liquefied Natural Gas Market: Status and Outlook", December 2003, Energy Information Administration

The following ratios were used for the calculations:

RUB/$	65
knot/ km/h	1.852
nautical mile/km	1.852

PROSPECTS AND OPPORTUNITIES FOR USING LNG IN ARCTIC REGIONS OF RUSSIA: WWF RUSSIA OVERVIEW

The implementation of the decisions of the International Maritime Organization (IMO) to impose strict limits on the emissions of polluting sulfur and nitrogen oxides for marine fuels used in North America, part of Europe's water area, and Baltic and North Seas, can be made possible with transition to low-sulfur, higher-quality oil fuels, the installation of cleaning systems, or with a switch to liquefied natural gas (LNG). Low-sulfur fuels are significantly more costly than the traditionally used types of residual marine fuels. The installation and operation of cleaning facilities will also require substantial investment. Transition to LNG will require the construction of new types of vessels or profound reconstruction of existing vessels.

Nevertheless, companies across the globe have for many years (up to 10 years) been designing, building and operating LNG fueled ferries including passenger ferries, patrol, support and replenishment ships, and dry-cargo ships, tankers, cruisers, dredgers, and towing vessels. In 2016, Finland constructed and launched the first powerful Polar Class 4 Icebreaker fueled by LNG.

The world's largest ports such as Rotterdam and Singapore are actively building LNG bunkering facilities. The EU is planning to create an LNG bunkering system in marine ports as well as inland waterways to 2020.

The interest in LNG increased in 2016, after the IMO had confirmed the earlier decision to introduce global limits on sulfur content in marine fuels in 2020. The switch to LNG is one of the more efficient ways to prepare for the anticipated additional limitations on the emissions of sulfur and nitrogen oxides, black carbon (soot), etc.

Russia possesses extensive experience in converting land vehicles to natural gas propulsion, and work is in progress to start using LNG for water transport. Switching from oil to gas has already been proven to have considerable environmental effects in terms of reducing atmospheric emissions. Russian LNG produced by a plant located in Pskov is used to power a large Estonian ferry that started to operate in 2016 between Tallinn and Helsinki. Two LNG bunkering projects are being actively implemented in the Russian part of the Gulf of Finland. Gas tankers built for a Yamal LNG project will be powered by the natural gas they transport.

One of the largest LNG production facilities is already functioning in Sakhalin, Russia. Yamal LNG will start production within the 2017 and Russian LNG production will rise on 150 %. Gazprom, Shell and Total, companies participating in these projects, are actively working not only on LNG production and export, but also on its use in water transport. With the extensive LNG production capacities available, there exist all the necessary conditions to expand its use to fuel both water and land vehicles in the Arctic, and to supply gas to coastal settlements and local communities, plants and industrial customers, like is already happening in the Kaliningrad region.

The use of LNG will require a significant upgrade of vessels navigating the Arctic, but this will have to be done with consideration given to the mature status of the Russian Arctic fleet. LNG will mitigate the risk of residual fuel oil spills and reduce the emissions of pollutants into the atmosphere. Efforts in this direction will strengthen the position of Russian LNG producers in the rapidly expanding global LNG fuel market, and allow the development of advanced shipbuilding technologies.

The switch to LNG as bunkering fuel will also solve another crucial environmental problem – emergency spills of residual marine fuel oil, especially in ice-covered areas. At present, the world has no proven technologies and solutions to clean up large amounts (hundreds of tons and more) of crude oil and residual fuel oil spills in the ice cover areas. This is a challenging issue for the Baltic Sea, the Sea of Azov, the northern Caspian Sea, the Sea of Okhotsk and the Bering Sea.

This issue becomes particularly pressing in polar waters, where it is complicated due to the thick ice cover, but also polar night conditions, low temperatures, strong winds, and a lack of infrastructure. In view of this, the International Maritime Organization (IMO) decided in 2011 to ban the use and transportation of heavy oil products and crude oil (with the density of more than 900 kg/m^3), as well as resins and bitumen in the Antarctic region.

A group of environmental protection organizations united under the Clean Arctic Alliance, which includes the World Wildlife Fund (WWF), have come forward with an initiative to execute a similar agreement for the Arctic region, and a corresponding proposal has been brought to the attention of the IMO's Marine Environment Protection Committee (MEPC) twice in 2016. The proposal suggests that the use of Heavy Fuel Oil (HFO) in the Arctic needs to stop by 2020. The discussion of the possibility to sign such an international agreement will continue in 2017. In 2016, the USA and Canadian government have already made a joint statement on the intention to support this agreement.

This agreement presents a step in the right direction, despite the fact that it will not yet deal with the problem of heavy fuel oil shipping, or crude oil production and transportation in the Arctic. In 2015, WWF Russia collected 80 000 signatures of Russian citizens to a petition to introduce a 10-year moratorium on oil production on the Arctic shelf. Natural gas can be an alternative to oil in order to ensure the compliance with present-day environmental safety requirements; it is also able to replace residual marine fuel oil.

The year 2017, which has been declared the Year of Ecology in Russia, is seen as a favourable opportunity to attract public attention and take practical steps towards expanding the LNG use as marine fuel.

Furthermore, it should be taken into account that, in May 2017, Finland, one of Russia’s neighbours, had to take over the two-year chairmanship of the Arctic Council, and intends to play quite an active part in its operation. The results of Russia-Finland cooperation – the first of its kind and the most powerful in Finland LNG-powered icebreaker “Polaris” – must become an example of technological solutions that promote environmental safety of Arctic navigation and development of the Arctic region. Arc7 LNG tankers for Yamal-LNG project are pioneers in LNG transportation in Arctic for all seasons. Implementation of LNG as fuel will shrink both gas losses for transportation period and pollution of the environment.

Discussions of the opportunities in using LNG as fuel for transportation, including the Northern Sea Route, and implementation of large-scale infrastructure projects both in the Arctic and the Far East (especially on the Sakhalin island) need to be accelerated.

A whole range of LNG production projects in the Baltic, Pechora-LNG, and Arctic-LNG will not only change the role of Russia in the global LNG market, but also create a functioning transport corridor between Europe and Asia, where only LNG is available for bunkering.

The expected growth of Arctic traffic at present is mainly connected with the development of natural resources in Timan-Pechora, Yamal and Taymyr regions. The transportation of equipment and cargo for Arctic industrial projects and further shipments of harvested natural resources will require either the creation of extensive infrastructure for oil fuel supply and storage, or the integration of Arctic LNG projects into the transportation and energy framework of regional development projects and programs.

This report was prepared by the team led by A. Klimentyev and presents data, facts and arguments for wide LNG implementation in Russian Arctic.

INTRODUCTION

The Arctic has played a significant role in the history of Russia. And currently the Russian Arctic is turning into a thriving industrial region, where in the next 10 years large mining and industrial hubs are set to appear, with the continues dynamic of the Norilsk industrial district. The largest organizations interested in the industrial and transport development of the Arctic include Roscosmos, Rosatom, Russian Railways (RZhD), ALROSA, Gazprom, NOVATEK, and Rosneft. According to the Russian Ministry of Economic Development, 152 projects are scheduled to be implemented here with a total of 5 tn. RUB in investment.[1]

The Arctic region of Russia is considered to be one of the key economic areas and can open up a crucial transit route, connecting Europe and Asia. A unique feature of this route is that there is a possibility to set up LNG bunkering facilities along almost the entire length of it, using natural gas from on- and offshore deposits.

A part of these deposits is under development, and construction projects of LNG facilities are ongoing, while other deposits are already in operation providing gas to settlements, cities and industrial hubs. Without doubt, a large part of the natural gas resource potential in the Arctic still needs to be estimated and unlocked.

In order to protect the environment from emissions caused by shipping, the quality requirements on marine fuels are becoming stricter, and new environmental standards are introduced. The most stringent of these requirements are reserved for specific areas around the globe, called ECAs (Emission Control Areas), which are created in accordance with MARPOL regulations.

In Europe such areas cover the Baltic and the North Seas, and in North America – Pacific and Atlantic coasts.

In 2019 China will introduce its own ECAs.[2]

In addition, there are areas where the use of certain types of fuels is prohibited and stricter ecological requirements apply. For example, south of 60 degrees South an Antarctic Special Area is designated, not an ECA, however, in which the use of heavy fuel is prohibited. Some countries, such as South Korea, do not introduce their own ECAs but support the construction and use of vessels that meet the ECA requirements and use of LNG.

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1 «International cooperation in Arctic: new challenges and vectors of the development" conference, a report by D.Fishkin «Approaches of social-economical development of Russian Arctic», Moscow, 12–13 October 2016.

2 https://www.dnvgl.com/news/china-introduces-sulphur-requirements-for-marine-fuels-50359

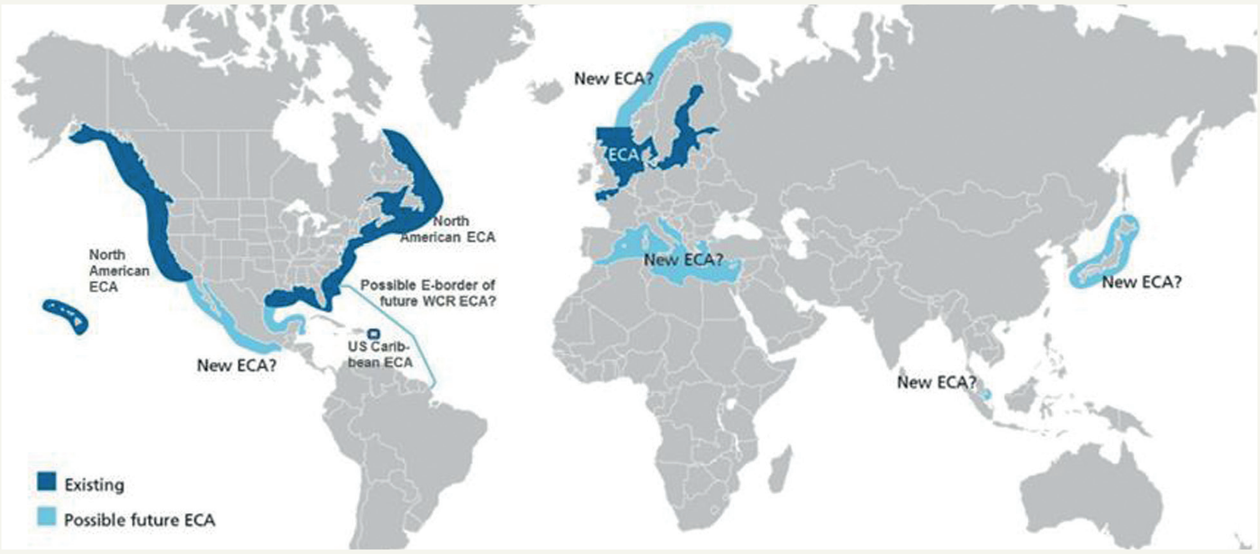


Figure 1. Existing and planned ECAs around the world

No such ECA is planned to be introduced in the Arctic.

The use of gas as bunkering fuel appears to be one of the most promising ways to observe the international shipping regulations with regards to reducing atmospheric emissions from shipping. As a rule, vessels that use gas as their engine fuel fully meet the existing and planned environmental requirements.

The Scope of the Study

As part of this study, an evaluation of the fleet operating in the Russian Arctic waters was conducted, and the possibility of using LNG for bunkering was evaluated. The environmental impacts of the use of LNG for bunkering were also considered. There are currently a range of sustainable options available to the shipping industry around the world:

- methanol;
- DME;
- hydrogen;
- electricity;
- bio-LNG;
- biodiesel etc.

In this study the use of these fuels is not considered due to the absence of necessary facilities in the region, as well as the absence of plans, strategies, frameworks, or programs that could lead to the construction of such facilities.

The Geographic Scope of the Study

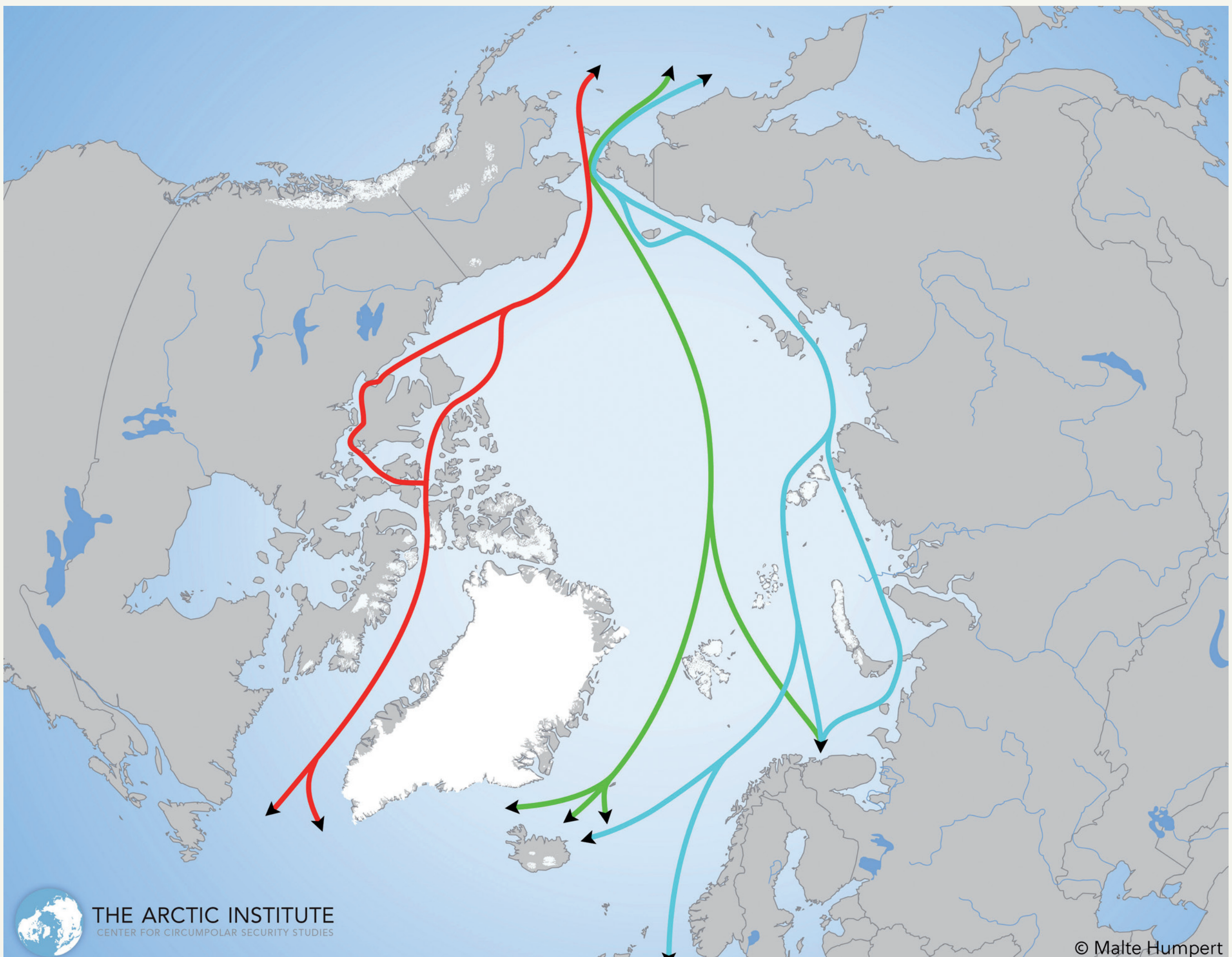
The part of Arctic region of the Russian Federation, including the Northern Sea Route area and the adjacent Barents Sea.

SHIPPING AND TRANSPORTATION IN THE ARCTIC

Shipping activity is unevenly distributed throughout the Arctic. The highest traffic areas are registered in the ice-free seas of Norway and Iceland. Considerable traffic is also present along the Northern Sea Route.

Climate change causes the ice caps of the Arctic Ocean to melt, which increases the role of the Arctic as a shipping area. Regular bulk shipping routes can be mapped in three main directions:

1. Northern Sea Route – Russia
2. Transpolar Sea Route – international waters
3. Northwest Passage – Canada and USA



	Northern Sea Route	4740 nautical miles*	6 weeks of open water
	Transpolar Sea Route	4170 nautical miles	2 weeks of open water
	Northwest Passage	5225 nautical miles	periodically ice-free

* distance between Bering strait to Rotterdam

Figure 2. Shipping routes in Arctic Ocean

Source: The Arctic Institute

Arctic shipping also includes the territories of large rivers that enter the Arctic Ocean, as well as the White Sea-Baltic Canal.

According to the Russian Maritime Register of Shipping (RMRS)[3], there are a total of 439 vessels registered in the Arctic ports of Russia.

Table 1. Classes of ships, assigned to the Arctic ports and their ice categories

Vessel Class \ Ice category	Arc7	Arc6	Arc5	Arc4	Ice3	Ice2	Ice1	0+other	Total of each category
Container Ships and General Cargo	6	–	15	27	3	13	14	2	80
Oil Tankers and Carriers	1	–	3	4	8	11	1	3	31
Bulk Carriers	–	–	1	11	–	–	–	–	12
Tugs	–	–	11	12	1	10	1	11	46
Rescue and Service Ships	–	–	10	3	–	–	–	1	14
Passenger Ships	–	–	–	2	–	3	–	–	5
Scientific and Research Ships	–	–	11	4	6	1	3	6	31
Fishing Vessels	–	–	–	16	34	84	37	16	187
Offshore Platforms	–	–	–	–	–	–	–	2	2
Crane Vessels	–	–	–	–	–	2	–	2	4
Sailing Boats	–	–	–	–	–	–	–	1	1
Dredgers	–	–	–	–	1	5	1	–	7
Refrigerating Ships	–	–	–	–	–	–	3	–	3
Fireboats and Diving Support Vessels	–	–	–	–	–	3	1	–	4
Total of each class	7	–	51	79	53	132	61	44	
Icebreakers	12	–	–	–	–	–	–	–	12
TOTAL									439

Source: Author's estimates based on the RMRS data

[3] established December, 31st, 1918. Since 1969 RMRS is a member of the International Association of Classification Societies (IACS). http://www.rs-class.org/ru/

The fleet in the Arctic region is fairly old, 36% of vessels operating in the Arctic are over 30 years, and 46% of the ships are aged between 20 and 30 years. Only 4% of the fleet is under 5 years old, another 4% is aged between 5-10 years, and 10% of the ships were launched 10-20 years ago.

The age composition of the fleet makes it easier to transition some of the ships to LNG. There is also an opportunity to use LNG as part of the expansive project of modernization the current fleet.

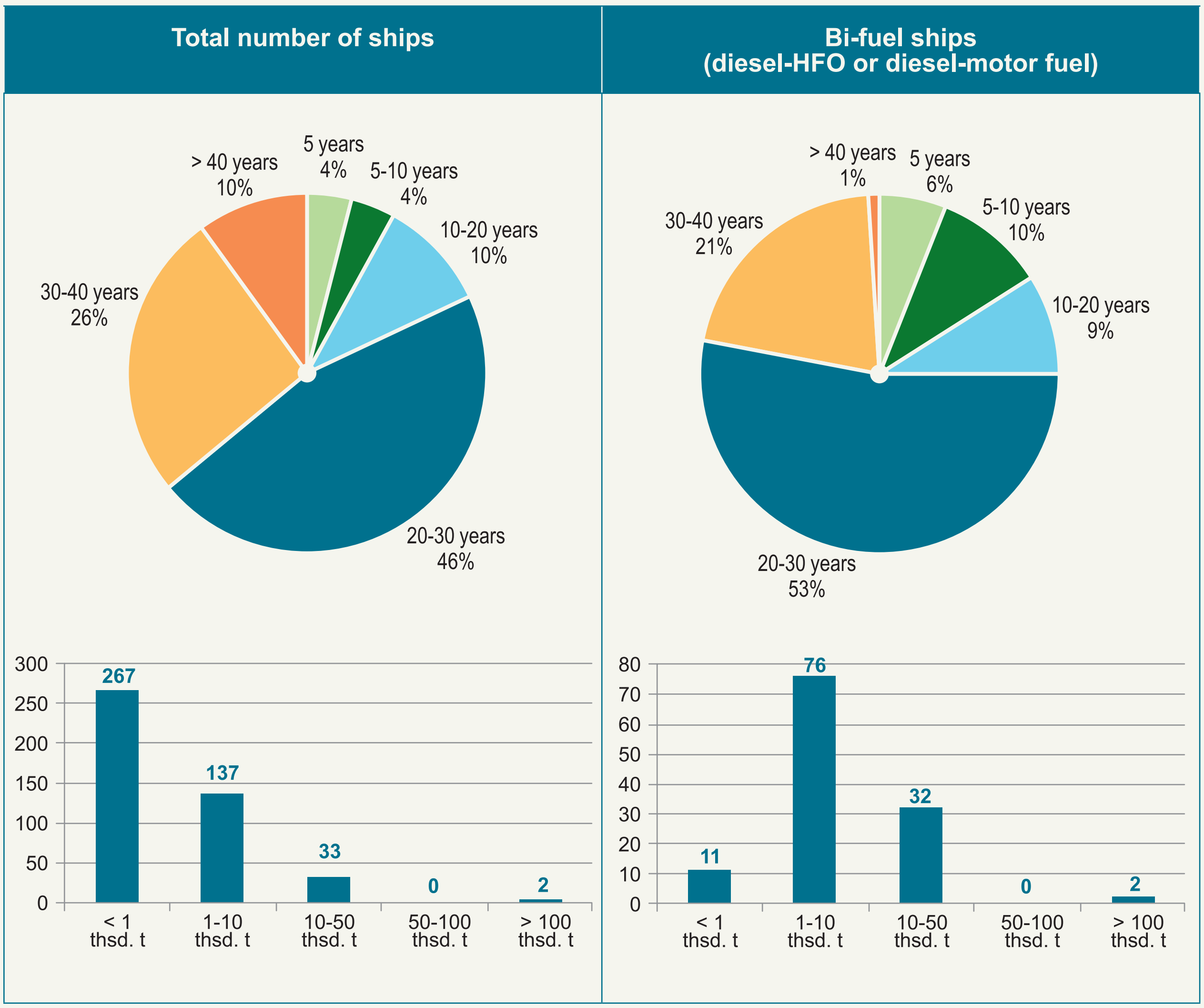


Figure 3. Distribution of the Arctic fleet vessels according to age, deadweight and using type of fuel

Source: Author's estimates based on the RMRS data

The graph of deadweight distribution demonstrates that the majority of the ships carry up to 1000 t of cargo. Only two vessels carry over 100 000 t: floating oil storage "Umba" – more than 300 000 t, and tanker "Nataly" – more than 140 000 t.

The vast majority of the ships in the Arctic region of Russia use diesel as marine fuel.

Table 2. Distribution of vessels according to the type of marine fuel used

Diesel	Motor Diesel	Nuclear	Heavy Fuel	Motor
312	46	6	5	63

Source: Author's estimates based on the RMRS data

There are 5 vessels in the registry that use HFO as marine fuel. 109 vessels use marine motor oil and motor diesel oil. This, in effect, signifies that a transition to using low-sulfur types of fuel should be fairly simple since it won't require a significant overhaul of the vessels' fuel injection system.

In addition to the ships registered in the RMRS, ships registered in other ports, such as "Shturman Malygin" and "Shturman Albanov" from the port of Saint Petersburg, can also be found traversing the NSR. These are new tanker models of ice class Arc7 with 42 000 t deadweight that perform shuttle oil shipments from Novoport oil field.

PORT INFRASTRUCTURE

There are 17 ports operating in the Russian Arctic. Those in the Barents and White Seas (Murmansk, Arkhangelsk and Kandalaksha) are year-round ports with the highest cargo turnover in the region. The turnover of the ports further east is significantly smaller.

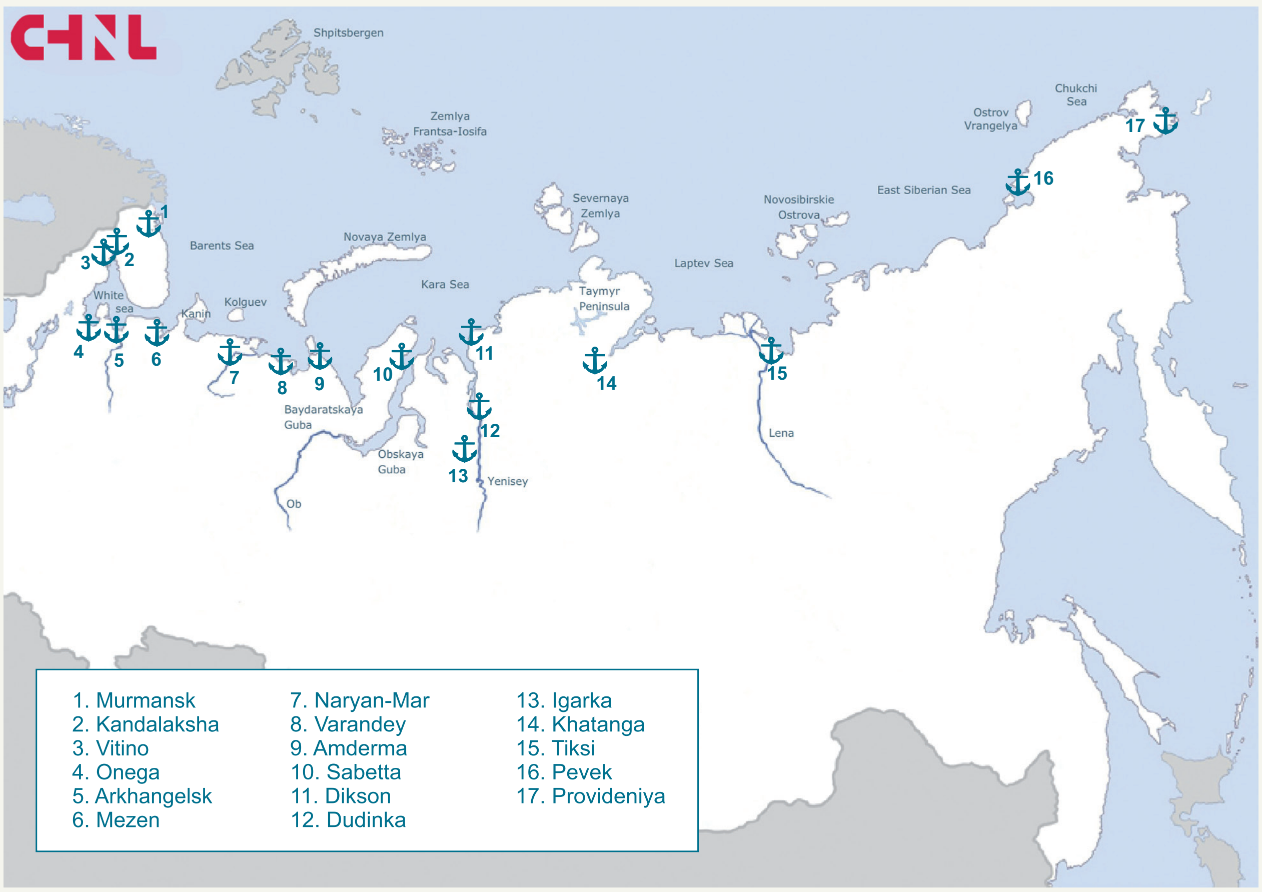
The primary cargo turnover volumes[4] of these ports come largely from foreign and domestic cargo trade. Domestic cargo amounts to 21.9% of the total turnover (according to 2012 data).

Large port development projects are expected on the Yamal and Taymyr Peninsulas.

Most of the year, all ports in the Arctic Basin (except for the ice-free port of Murmansk) operate in below zero conditions and in frozen water. And, in order to operate normally, they require port icebreakers. Cargo is deliv-

Figure 4. Location of ports in the Arctic region of Russia

Source: Center for high north logistic



[4] "The Strategy of Russian Port Infrastructure Development until 2030", Moscow, 2013. Approved by the members of the Maritime Board, affiliated to the government of Russian Federation on September, 12th, 2013.

ered to these ports under escort of ice-breaking vessels, including those powered by nuclear energy. Arctic ports facilitate the delivery of goods, essential to the livelihoods of Northern indigenous people and are necessary for the mineral extraction operations of the vast Northern Territories.

Another feature of the Arctic ports is the role they play in the maintenance of the Northern Sea Route, which is bound to become more crucial as the volume of international transit cargo grows along the NSR, as it becomes an international trade route. The ports will have to expand their vessel maintenance services (bunkering, support, emergency repair, etc.) The transshipment volume of fuel and energy resources (crude oil, oil products, coal, and liquefied gas) has been growing in the past 10 years. Additionally, oil and gas are delivered from shelf oil drilling installations and offshore hydrocarbon deposits. The ports of Varandey, Harasavey (port station), Arctic Gate, Prirazlomnaya platform, Dudinka are built for their transshipping.

Port Sabetta is under construction for load operation of LNG from the gas of South-Tambeiskoye gas-condensate field. LNG and condensate will be supplied from Yamal to the energy markets of Europe, North and South America and Asia-Pacific region in accordance with Decree of the Government of Russian Federation #129-p form 13.07.2012. There are two stages of port construction. Preliminary stage consists of port for bulk cargo, modular equipment and construction materials for Yamal-LNG project. The first cargo was arrived in 2013. Port Sabetta has all year round operations. The turnover of the port was reached of 6 mln.tons in 2016 (twice more comparing with 2015) delivered and 259 sea vessels and 304 river vessels. The main stage includes LNG and gas condensate loading facilities and piers. Sabetta port is ready to execute LNG loading operation in 2017. 17 international routes from NSR to Sabetta were in 1st quarter of 2017.

NORTHERN SEA ROUTE

The Northern Sea Route is the shortest marine passage between Europe and Asia. It was created in USSR in the mid of 1930 and historically operated as a transport route that supplied goods to the Russian North and for export in Europe, Japan and China.

The main turnover for the NSR were from several industrial hubs where precious, REM and hydrocarbons were produced.

The Northern Sea Route extends through the seas of the Arctic Ocean (Kara Sea, Laptev Sea, East Siberian Sea, Chukchi Sea), and its length, measured from Kara Strait to Cape Dezhnev, amounts to around 2,500 nautical miles.

Figure 5. The Northern Sea Route
Source:
http://www.tassgraphics.ru/item?id=34471&utm_source=twitterfeed&utm_medium =twitter;
http://img1.liveinternet.ru/images/attach/c/5/85/491/85491547_53803.jpg;
http://stranniknk.narod.ru/images/p4_severnyiymorskoyput-.jpg;
http://www.rudata.ru/w/images/5/5f/Северный_Морской_Путь_и_его_значение_ во_внешнем_товарообмене_Сибири_книга.jpg.

The Central Research Institute of the Navy has developed several options for strategic development of the Northern Sea Route.[5] They are guided by the provision of large-scale transportation of hydrocarbons from the Timan-Pechora province, from the Ob basin, from the Yamal Peninsula to the European part of the country, Northern Europe and Asia-Pacific region. The concept of development of the Northern Sea Route route presupposes the construction of new nuclear and diesel icebreakers, the modernization of existing ones and the construction of new ports. And, of course, that the development of the NSR should be sustainable and safe for the shipping. For the last decade infrastructure of the NSR became outdated. Almost all along the NSR is not normal infrastructure for support, bunkering and repairment facilities. There is the need to upgrade fleets both on sea and on northern rivers, modernization of ports facilities and maintaining the required level of navigation and meteorological and aviation services and communications.[6]

The Northern Sea Route is a part of the Northern Maritime Corridor, which stretches from the port of Murmansk to Cape Dezhnev.

Until recently the main purpose of the NSR was to provide the indigenous people of the Arctic with sustenance and supplies, as well as to transport raw minerals, extracted from the Arctic deposits. After the launch of icebreaker "Arctic" (1975), year-round navigation in the west Arctic became possible. Atomic icebreaker "Siberia" and icebreaker "Captain Sorokin" had provided support to a caravan of two diesel-electric vessels to Dudinka in May 1978.

As a result of climate change and the subsequent melting of the polar ice caps, the NSR now offers new navigational opportunities along the northern coast of Russia. The average time it took to traverse the NSR in 2015 was 10.6 days.

However, such developments have not only positive effects.

At the first, some Russian experts have opinion that, in the foreseeable future, shipping in the Arctic will be possible only during the warm period, but the support of icebreakers will be still required f.e. between Wrangel island and the Novaya Zemlya archipelago (over 3 thousand km), it will be

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5 U. Morozov The Northern Sea Route – the Euro-Asian maritime transport corridor URL: http://helion-ltd.ru/euro-asian-tr-corr/

6 M. Nikilaev Challenges of the Arctic. - M.: Periodical of Federal Council of Russian Federation. 2009, 303 p.

impossible to completely abandon the ice transaction. Ice-class of the vessel should be that reduce the speed of the vessel. Thus, the ice protection retrofit reduces the speed by 10-15%, floating ice — 2 times, shipping in caravan regime – 3 times, which is seriously decrease the advance in distance of the NSR compared to the southern routes. It is necessary to take into account the possibility of icing of ships, reducing the weight of the received cargo, increasing fuel consumption, increasing rates insurance because of higher risk, pay for the services of icebreakers and other factors. All this makes the use of the Northern sea route as an international transport corridor is not economically and attractive as it seems at first sight.

At the second, global climate change will open and alternatives maritime route North-West passage (NWP) – way from the Atlantic to the Pacific ocean via the Beaufort sea and Baffin Bay along the coast of Alaska, Canada and Greenland. During 2007-2008 the ice in the NWP is completely melted, and for a few weeks, the passage was open for shipping – for the first time in history. In the future this route can completely turn the situation in global trade, reducing trade route to the East for several thousand kilometers.

Thirdly, global climate change can generate international tension in Arctic for energy resources and for the use of sea transport routes, biological resources, food resources.

Very important and the other consequences of global warming and change – change of the coastline, as well as the depths of the sea, associated with the raising of the water level in the ocean and flooding of land.

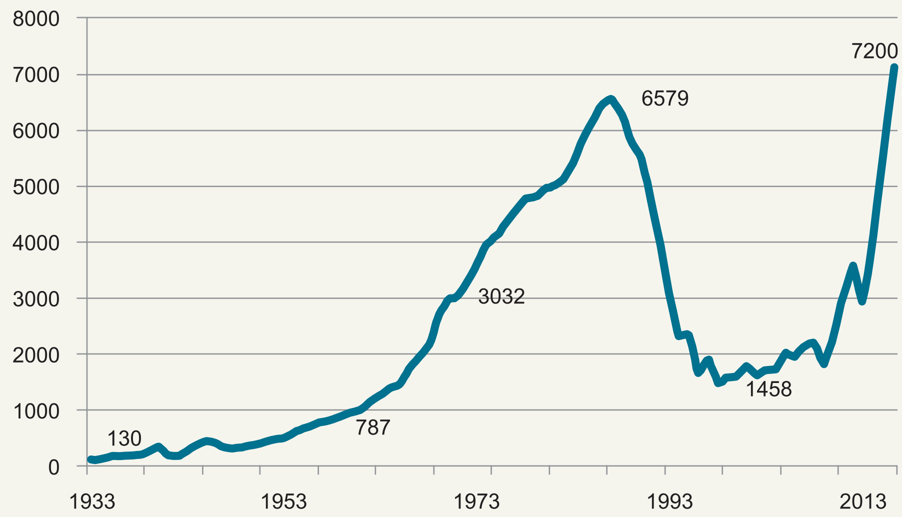
After an extended period of decline in shipments along the NSR until 2010, when the Norilsk industrial district remained its primary user, a noticeable increase in shipping can now be observed, due to the new industrial development in the Arctic and to a new way of looking at the NSR as an alternative passage between Europe and Asia.

In the past 3 years, the NSR has begun to support shipping of equipment for development projects for the large Arctic oil, gas and coal deposits. These deposits, in turn, are likely to ensure an enormous spike in cargo traffic along the NSR for the decades to come.

Developing the NSR can give significant impetus to industrial projects along the Arctic rivers, particularly the Ob and the Yenisei. As eastward

Figure 6.
Turnover along the NSR, 1933-2016, in thous.t

Source:
Soyuzmorniiproekt (1933-2009), Goskomstat (2014-2015), public domain sources (2010-2013, 2016)



shipments along the NSR increase, similar projects will appear in the basin of the Lena.

Dozens of millions of tons of oil have been transported across the Arctic waters since 2008. For instance, more than 52 ml. t of oil were shipped out of Varandey since 2008.[7] Oil is shipped by three shuttle tankers of Sovcomflot "Vasiliy Dinkov", "Captain Gotskiy" and "Timofey Guzhenko".

More than 4 ml.t was uploaded from oil platform Prirazlomnaya from 2014 till March of 2017. Arctic class shuttle tankers "Mikhail Ulyanov" and "Kirill Lavrov" were built on "Admiraltiyskiye shipyards" in Saint-Petersburg.

Oil shipment from the year round terminal "Arctic Gate" in gulf of Ob river in Kamenny Cape on the Yamal Peninsula began in May 2016. Five new Arc7 oil tankers with deadweight of 42 thousand tons each were built for oil shipment from "Arctic Gate" through ice up to 1,8 m thick. The tankers are equipped with 22 MW powerful Azipod type engine. More than 200 trips took place in the last year and nearly 4,5 ml. t of oil was transported. CEO of "Gazprom neft-Yamal" A. Ovechkin make a statement that up to 6,3 ml. t of oil will be uploaded in 2018 from the "Arctic Gate" terminal. To ensure the transportation of oil, the construction of two support vessels – "Alexander Sannikov" and "Andrey Vikitsky" will be completed at the Vyborg shipyard.

[7] https://www.youtube.com/watch?v=TPXkld69jfU

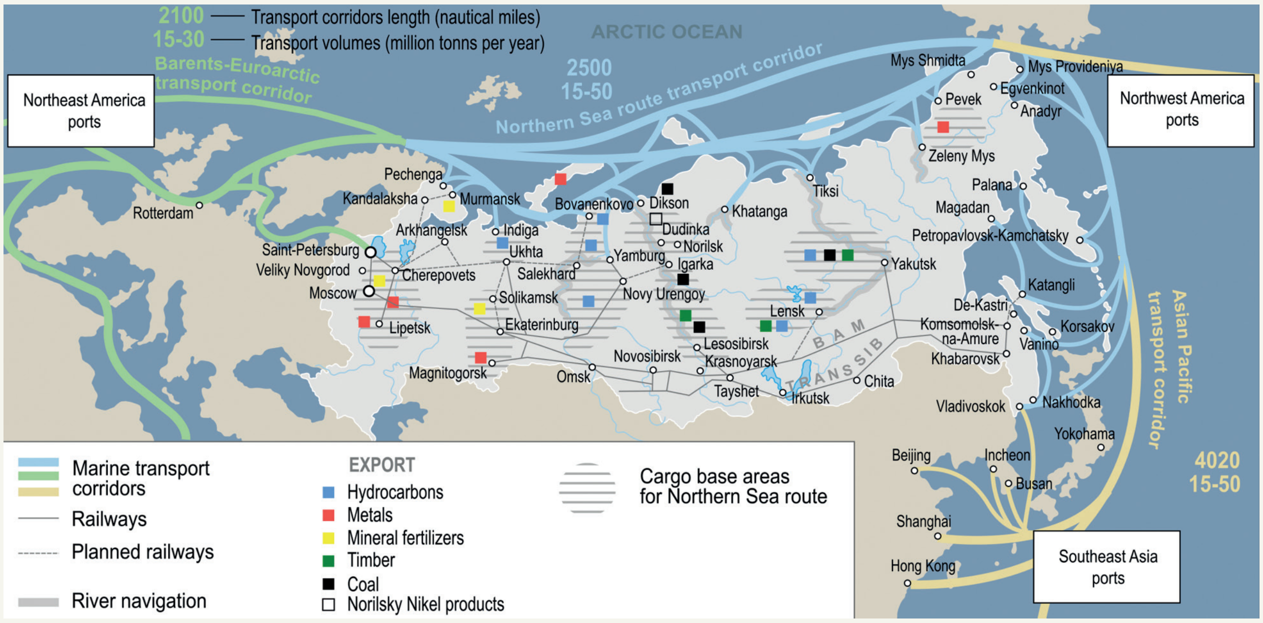


Figure 7. The Northern Sea Route transportation corridor and developing economic regions of Siberia

In the next 20 years the primary cargo shipped along the NSR will be LNG, condensate, crude oil and coal.

There are no official estimates that demonstrate the long-term composition of cargo traffic along the NSR.

In order to create such an estimate the following sources and materials were taken into account:

1) an evaluation based on the declared volume of shipments required for the largest mineral extraction projects in the Arctic region, including the Varandey terminal and the Prirazlomnaya platform.
2) an evaluation by M. Grigoryev, CEO of Gekon Ltd.[8];
3) findings of "The Strategy of Russian Port Infrastructure Development until 2030", except the forecast of cargo traffic for the ports of Murmansk and Arkhangelsk;
4) Federal State Unitary Enterprise "Atomflot" findings, based on contracts signed and requests for icebreaker escorts received.[9]

In general the planned cargo traffic volume is expected to increase to 55-65 ml. t in 2025 and to 65-75 ml. t in 2030. The values in the column "Estimate based on the projects scheduled" differ significantly from the rest. The

8 http://neftianka.ru/dlya-vsyakoj-bochki-degtya-najdetsya-lozhka-meda/
9 https://www.youtube.com/watch?v=xBItojl_Ypg

Table 3. Cargo traffic estimates along the Northern Sea Route up to 2030 (forecast), in ml. t

Estimate Year / Cargo traffic estimate	Estimates based on the projects scheduled				Estimate of Gekon Ltd.	The strategy of port infrastructure development		FSUE "Atomflot"		
	2016	2020	2025	2030	2025	2020	2030	2020	2025	2030
Total	**12.4**	**47.7**	**75.0**	**104.4**	54.97	38.7	67.5	36	64.5	65.3
Petroleum Products	**9.6**	**36.2**	**50.8**	**69.4**	40	33.9	57.6	33.5	50	50
Oil and Condensate	**9.6**	**19.7**	**31.7**	**36.7**		5.9	6.2	17	17	17
Prirazlomnaya	1.0	4.8	4.8	3.0						
Varandey	6.6	8.0	12.0	12.0						
Novoport	2.0	5.5	8.5	8.5				8.5	8.5	8.5
Payyach			5.0	5.0				7.3	7.3	7.3
Yamal-LNG		1.2	1.0	0.8				1.2	1.2	1.2
Dolginskoye			0.0	7.0						
Others	0.1	0.2	0.4	0.4						
LNG	**0.0**	**16.5**	**19.1**	**32.7**		28	51.4	16.5	33	33
Yamal-LNG	0.0	16.5	16.5	16.5				16.5	16.5	16.5
Arctic LNG 2	0.0	0.0	0.0	11.0					16.5	16.5
Pechora LNG	0.0	0.0	2.6	5.2						
Concentrates and Ores	0.7	1.0	1.0	1.0	0.97	0.5	0.5	0	1.3	1.3
Norilsk Nickel	0.7	0.7	0.7	0.7	0.6				1.3	1.3
Pavlovsk Deposit	0.0	0.3	0.3	0.3	0.27					
Mayskoye Mine	0.0	0.1	0.1	0.1	0.1					
Coal	1.0	8.0	20.0	30.0	10	1.8	5.4	0	10	10
Taibass	1.0	8.0	20.0	30.0	10				10	10
Severny Zavoz	1.0	1.5	2.0	2.0	2	1.5	2	1.5	2	2
Transit	0.0	1.0	1.2	2.0	2	1	2	1	1.2	2

Source: Author's estimates, companies' data primary reason for that is the coal shipping estimates of the Taibass mine, which, according to “Vostokugol”, the company owning the project, will see its production output increase to 30 ml. t in 2030, while other sources put its production output at 10 ml. t.

In any case, an exponential increase in cargo shipping traffic, and the resulting environmental impacts from ships transporting equipment and products, can be expected as these industrial and mining projects are being implemented.

For a long time the main prospect for the NSR was its transit role for the ports of Europe and Asia. It has also been suggested that in time shipping along the NSR could compete with the Suez Canal.

Advantages	Drawbacks
The shortest distance between European and Asian ports is 7300 nautical miles/ The Suez Canal is 11 200 nautical miles.	Need for icebreaker assistance
No threat of piracy	Crew requires special training to work in the Arctic
The possibility for LNG bunkering all along the NSR	Short navigation season

The main advantage of the NSR is its shorter length, which allows ships to save fuel and shipping time. New technological advances open up the necessary navigational opportunities, and growing demand for mineral and petroleum products ensures the economic viability of shipping along the NSR.

In 2010 a ship with 41 000 t deadweight would save more than $300 000 using the NSR, and transporting 147 000 cub. m of LNG from Melkøya to Yokohama along the NSR in 2013 took 21.4 days less than the route using the Suez Canal, and saved $6.854 ml.

After reaching its peak in 2013 the volume of transit cargo fell dramatically. One of the primary reasons for that was a drop in oil and marine fuel prices after 2013. As a result, fuel costs of shipping using the traditional route have decreased, and so has the economic attractiveness of the NSR. Other reasons for the decrease in transit were start-up of the gas condensate terminal in Ust Luga, and a decrease in price of iron ore concentrate.

Table 4. The effectiveness of shipping along the NSR, compared to the Suez Canal, for different types of vessels[10]

Distance, nautical miles	Kirkenes – Shanghai Route for a Bulk Carrier of Panamax Class		Kirkenes – Lianyungang Route for a Bulk Carrier Nordic Barents		Melkøya – Yokohama Route for a Gas Carrier	
	HFO	LNG	HFO	LNG	2013	2016
Deadweight, tons	75 000		41 000		65 000[11]	
Reduction of Time, days	21		17.50		21.40 * 2	
Fuel Saved, tons (600 $/t HFO and 400 $/t LNG)	1 260	1 031.53	500	409.34	2 782	
Emissions Reduced, t						
NO_x	128.00	184.72	50.00	72.51	64.01	
SO_x	89.00	144.70	35.00	57.10	–	
CO_2	3 980.00	4 370.85	1 560.00	1 715.10	7 653.56	
Cost Reduction, $	820 000	1 060 000	300 000	528 000	6 854 000	5 741 200

Source: Center for High North Logistic

Table 5. Transit shipping along the NSR

Year	Number of Vessels	Volume of Transit, in thous. t	Volume of Domestic Shipping, in thous. t
2010	4	110	
2011	34	834.9	
2012	46	1 261	
2013	71	1 356	2 800
2014	23	274	3 707
2015	18	40	5 392
2016	19	214	7 200

Source: Goskomstat, public domain sources, http://www.arctic-lio.com/

[10] http://www.chnl.no/publish_files/Future_of_Arctic_Shipping_Routes.pdf
[11] 147.000 m^3 LNG

On the other hand, tighter environmental regulations calling for a transition away from cheap heavy fuels and towards more expensive low-sulfur types also require installation of additional pollution prevention equipment. With that in mind the possibility of bunkering using cheap LNG all along the NSR can make this route more attractive for international shipping. The development of LNG storages and bunkering facilities in the most important ports in Arctic (with distance 2000-3000 km between bunkering points) is required. LNG storages could be used as source of LNG for local settlements and for other customers. New markets for LNG in the Arctic will play significant role in cost management and to support the low price of LNG.

As the shipping industry along the NSR develops, insurance and infrastructure costs will go down, which will increase the route's economic viability.

The NSR should not be expected to revolutionize international shipping, but it can fill in a specific demand for certain types of cargo and destinations.

LNG PRODUCTION PROJECTS IN THE ARCTIC

At the moment there is no infrastructure to use of LNG in the Russian Arctic region.

However, elements of it are being built by the "Yamal LNG" corporation, as it pursues its own project on the Yamal peninsula.

One such element is the Sabetta port infrastructure, as well as the LNG carrier fleet, and the planned use of LNG-fueled icebreakers for port assistance in Sabetta.

Three large LNG production projects can be identified within the Arctic Ocean waters. At one point the possibility of producing LNG in the Norilsk district was also considered but at the moment it's not clear if that project is going to happen. There is also a possibility of delivering LNG from sites in

Table 6. Existing and planned LNG projects for bunkering

Name	Project Owner	Region	Type of infrastructure	Status	Output, thous. t/year	Technology
Arctic Projects						
Pechora LNG	Alltech Rosneft	Indiga Port Barents Sea	land-based/ floating LNG facility (FLNG) marine terminal (FLSO)	Feasibility Study	2 x 2600	Air Products
Yamal LNG	NOVATEK	Sabetta Port Yamal Peninsula Kara Sea	land-based LNG facility sea port	construction	3 x 5500	Air Products
Arctic LNG 2	NOVATEK	Gydan Peninsula Kara Sea	submersible platform	conception	3 x 5500	Linde
Baltic Projects						
Baltic LNG	Gazprom	Gulf of Finnland Baltic Sea	land-based LNG facility	conception	10 000 (up to 15 000)	Shell
GCS Portovaya	Gazprom		land-based LNG facility	conception	1000	OMZ
Port Vysotsk	Gazprom-bank		land-based LNG facility	design	660 (up to 1000)	Air Liquide
LNG Gorskaya	LNG Gorskaya		floating LNG facility (FLNG)	design commissioning of bunker barges	440 (up to 1260)	proprietary
Potential Future Projects						
Norilsk LNG	Norilskgaz-prom	Dudinka Yenisei river		potentiality	2000	
Yakutsk LNG		Yakutsk Lena river		potentiality	1000	
Anadyr LNG		Andyr Bering sea		potentiality	100	
Arkhangelsk LNG	Sozvezdie Association	Arkhangelsk White sea		preFEED	150	

Source: Author's estimates

the Baltic Sea through the White Sea-Baltic Canal, as well as along the Lena River from the Western and Central Yakutia deposits. The small LNG production output can be achieved in Anadyr as it already has an existing local gas production and transportation system.

LNG Production Projects

Yamal LNG

Yamal LNG is a large-scale LNG production project currently being developed. Six months a year LNG shipments will be delivered along the NSR towards the Pacific, and the other six months LNG carriers will deliver LNG in the direction to Murmansk. This project involves the construction of an LNG facility that would produce 16.5 ml. t/year, using the mineral resources of the South Tambey gas field on the Yamal Peninsula. The facility will include three production lines, with an output of 5.5 ml. t/year per each. The first line is scheduled to start-up in 2017, the second one in 2018, and the third in 2019. Gas will be shipped out using ice-class LNG carriers. For that to happen, a tanker fleet needs to be built, as well as a sea port near Sabetta, a village on the east coast of Yamal, next to the Gulf of Ob and the Kara Sea.

Figure 8. Loading procedure of a Yamal LNG carrier

Source: Author's estimates

Special tankers of ice class Arc7 (according to the Russian classification) have been designed and are being built for the Yamal LNG project. These tankers don't require icebreaker assistance and enable year-round westward navigation, and during the summer navigation months – eastward, along the Northern Sea Route.

Key features of the Arc7 tanker[12]:

- Cargo capacity around 172 000 cub. m of LNG;
- Engine output 45MW;
- Speed in open water 19.5 knots;
- Speed when moving through 1.5 m of ice coverage 5.0 knots;
- Main fuel type – LNG;
- Diesel-electric propulsion system of three “Azipod” units.

[12] http://yamallng.ru/bitrix/templates/.default/ajax/video.php?path=L3VwbG9hZC9tb3ZpZXMvWWFtYWxfTE5HQy1EU01FX2ZpbG0uZmx2

Figure 9. The first Ice-class LNG carriers of the Yamal LNG project (Yamalmax)
Source: Sovcomflot

LNG carriers of the Yamal LNG project will use LNG as main fuel.

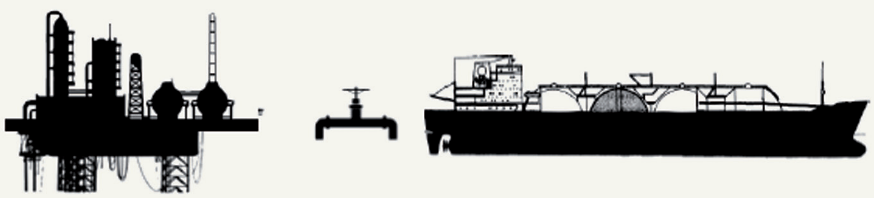
Arctic LNG 2

Another Arctic project by "Novatek" – "Arctic LNG 2" – is in its early development stages. Arctic LNG 2 owns the license for the Salmanovskoye (Utrenneye) gas field that contains 235 bl. cub. m of gas and 9 ml. t of liquid hydrocarbon of proven reserves. Based on these resources a second regional LNG facility is scheduled to be built in the northern part of the Gydan Peninsula.

Unlike with the Yamal LNG project, gas liquefaction facilities will not be situated on land but rather on an offshore platform or an artificial island, which should protect the facilities from permafrost degradation and allow for LNG carriers' loading without mooring areas. Production output is expected to reach 16.5 ml. t using three production lines of 5.5 ml. t/year each.

Figure 10. Loading procedure for an LNG carrier of the Arctic LNG 2 project

Source: Author's estimates



Pechora LNG

The gas liquefaction plant Pechora LNG will be situated on a plot of land near the village of Indiga, in the ice-free area of the Barents Sea coast, 230 km away from the administrative center of the region, Naryan-Mar. PJSC "NK Rosneft" and Alltech company are stakeholders of the Arctic project "Pechora LNG". 50.1% of shares belong to Rosneft, the rest – to Alltech.

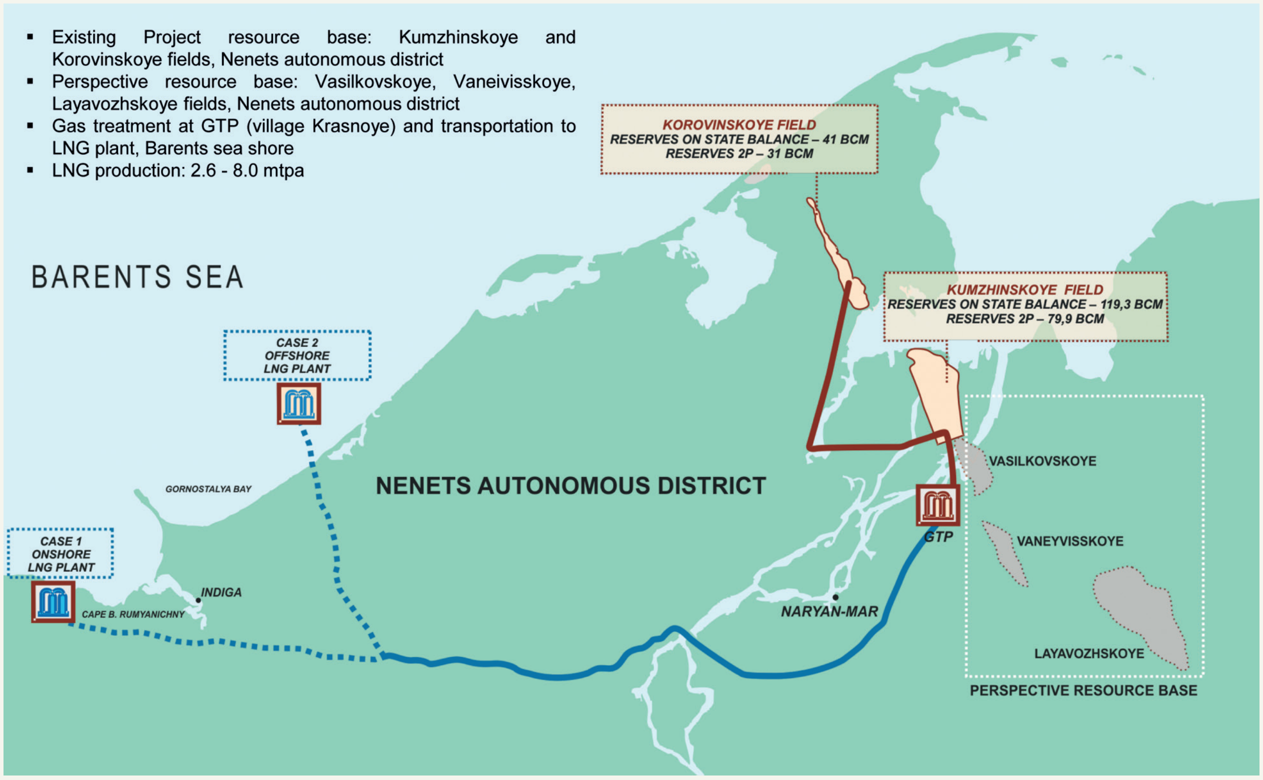


Figure 11. LNG allocation plan of the Pechora LNG plant

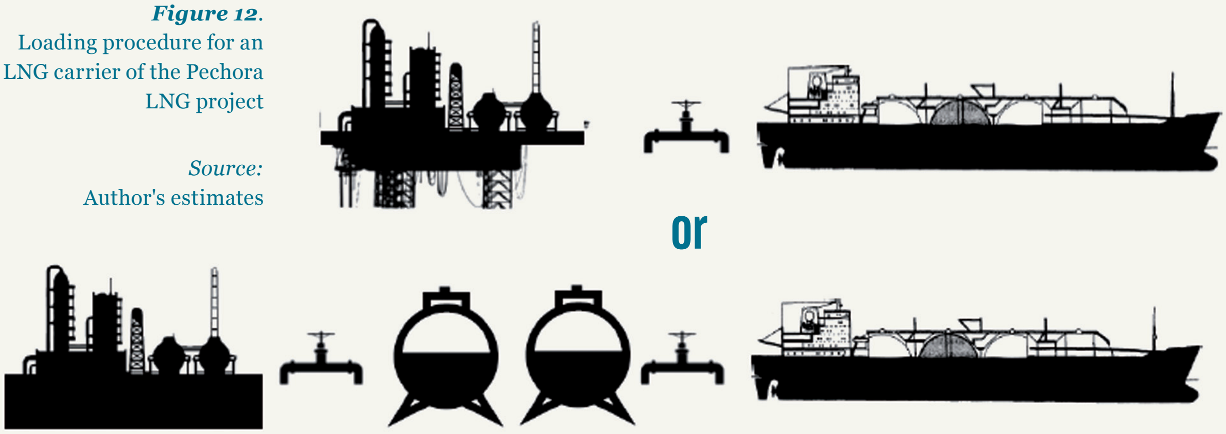
Source: Pechora LNG

Pechora LNG involves the Kumzhinskoye and Korovinskoye gas fields development in the Nenets Autonomous Region (deliveries from Layavozhskoye gas field are also possible), gas pipeline and LNG plant construction, complex gas treatment unit (CGTU) and offshore shipment terminal installation. The first stage of the project will ensure the production of 4 bl. cub. m of "dry gas" per year and 2.6 ml. t of LNG. The project design also includes a possibility of expanding the gas processing plant to 8 bl. cub. m and increasing LNG production to 5.2 ml. t. There is no data so far regarding the development progress for this project.

The possibility of using Floating LNG (FLNG) technology that ensures extraction, processing, liquefaction, storage and offshore dispatching, is considered as an option.

Figure 12.
Loading procedure for an LNG carrier of the Pechora LNG project

Source:
Author's estimates



In order to supply LNG on market , several Arctic LNG carrier-tankers of Arc4 ice-class with 180 000 cub. m cargo capacity each will be built. As mentioned several years ago the construction contract has been signed with the “Far East Shipbuilding and Maintenance Center”, a member of the United Shipbuilding Corporation.

The Baltic Projects

There are four known LNG production projects in the Baltic region that can provide LNG fuel for bunkeringin Arctic region:

1. Baltic LNG – 10 ml. t/year
2. GCS Portovaya – 1 (or 1.5 according to some sources) ml. t/year
3. Port Vysotsk – 660 000 t/year
4. LNG Gorskaya – 440 000 t/year

A large, Gazprom-funded project in Western Russia – Baltic LNG – involves the construction of a gas liquefaction plant with the output of 10 ml. t/year and a possibility of increased output of 15 ml. t/year in the area of the Ust-Luga Port in the Leningrad Region. The plant was first expected to launch in 2018 but the completion continues to be delayed. According to the 2016 presentation for Gazprom investors, the launch is now expected to take place after 2021. There is a chance that Shell will also participate in the Baltic LNG project.

The LNG production, storage and dispatching plant in the Leningrad Region is expected to be built not far from a compressor station (CS) “Portovaya” that feeds gas to the Nord Stream pipeline. It is expected that this LNG production facility at the site of the “Portovaya” CS will ensure 1 ml. t/year of LNG output.

The primary market for the LNG production and transshipment terminal on the premises of Port Vysotsk of the Leningrad Region is bunkering of marine vessels. The amount of investment is estimated to be 50 bl. RUB, and the main investor is Gazprombank. The terminal's output will be 660 000 t of LNG per year, with a possibility to expand to 1 ml. t/year by 2020.

There is also an independent LNG production project in the Leningrad Region – LNG Gorskaya that aims to work independently from Gazprom's liquid gas production facilities. A floating LNG facility is scheduled for construction with the output of 1.26 ml. t of LNG per year, as well as a fleet of bunkering barges, a dock, a loading bay, a gas pipeline, and several gas terminals abroad: in Finland, Germany, and Sweden.

Potential Future LNG Production Projects

It is possible to build LNG plant in the Norilsk industrial hub (2 ml. t/year), shipments to Tiksi from Yakutsk (up to 1 ml. t/year), LNG production on the Chukotka Peninsula (100 000 t/year).

A small LNG production plant could be started in Arkhangelsk (150 000 t/year) if there are leftover gas capacities after the gas infrastructure development project in Arkhangelsk Region is finished.

LNG shipments for bunkering of the ships along the Northern Sea Route and in East-Siberian and Chukcha seas are acceptable from Sakhalin-2 LNG project.

TECHNOLOGICAL CHARACTERISTICS OF USING LNG

Liquefied natural gas is one of the new types of fuel that can be used for bunkering.

The total number of vessels that use LNG around the world today is estimated to exceed 400 units, including LNG carriers.

Due to the strengthening of the emission regulations for oil-based marine engines and the advantageous prices of LNG, LNG can be expected to become the marine fuel market leader.

Bunkering Scheme

Several operational procedures can be used to organize LNG bunkering:

1. TTS – truck-to-ship
2. TPS – intermediate terminal-to-ship
3. STS – ship-to-ship

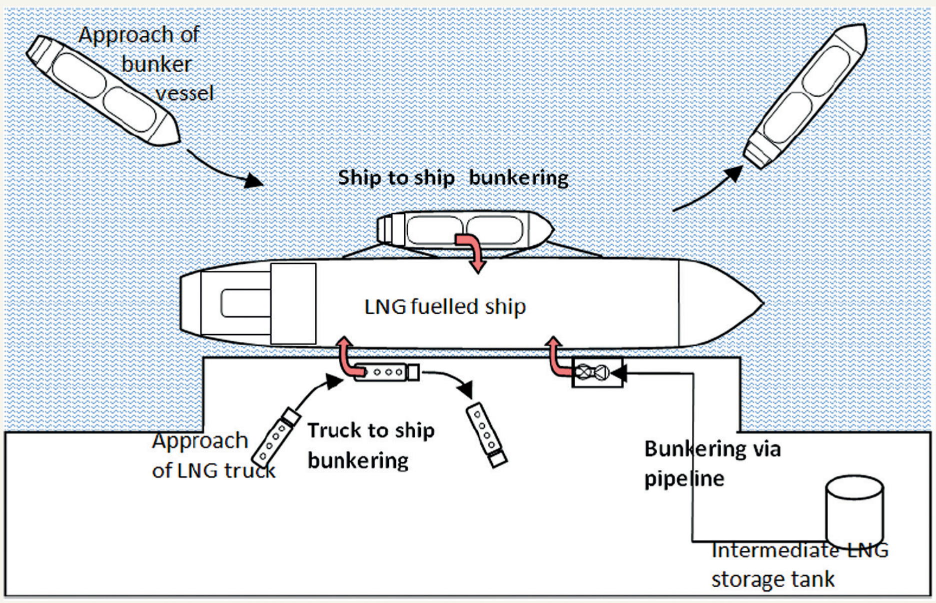


Figure 13. Type of LNG bunkering operation in a port

Source: Feasibility Study on LNG Fuelles Short Sea and Coastal Shipping in the Wider Caribbean Region SSPA Report 2012

The TTS refueling scheme is possible if there is a large capacity storage available to the onshore users. A well-developed reliable highway network is required for this refueling method.

This scheme can be set up both in even small ports, such as Onega and Tiksi, and large ports, such as Murmansk or Arkhangelsk.

Considering the limited capacity of the truck tank (up to 20 t), it is most realistic to use this refueling method for vessels operating inside the harbors – towing vessels, crane ships.

The TPS refueling scheme is possible if the LNG storage terminal is situated directly in the port. With this method, LNG from the storage terminal can be shipped for bunkering, as well as to the local users of the port and the surrounding area.

If there are mooring berths of sufficient depth available, it should be possible to refuel harbor vessels, as well as large marine vessels. The TPS refueling scheme can be set up in the ports with LNG production plants, like Sabetta and Igarka, or in the ports with sufficient mooring berth depths, like Vitino, Arkhangelsk and Murmansk.

Most likely, the STS refueling method will be the most prevalent one in the Arctic region.

The direct ship-to-ship refueling procedure ensures bunkering for any vessel in any quantities, in the port waters, off the harbor, and all along the NSR.

LNG should be uses as a utility product for industrial projects and other customers in the Arctic region, this could allow for the joint construction and use of the LNG storage terminals.

If LNG infrastructure is shared with power plants, local energy networks, etc., the costs will become less for everyone. As a result, the construction of LNG plants and infrastructure is crucial for a proper evaluation of certain aspects of the use of LNG for bunkering.

The use of LNG as a utility product is already intended within the development of the Pavlovsk lead-zinc deposit on the Novaya Zemlya archipelago.

LNG as fuel can be used in Taymyr Peninsula coal-mining projects, particularly as engine fuel for heavy quarry equipment.

Opportunities for Using LNG as Bunkering Fuel

There are examples from around the world of all the types of vessels used in the Arctic region operating on LNG:

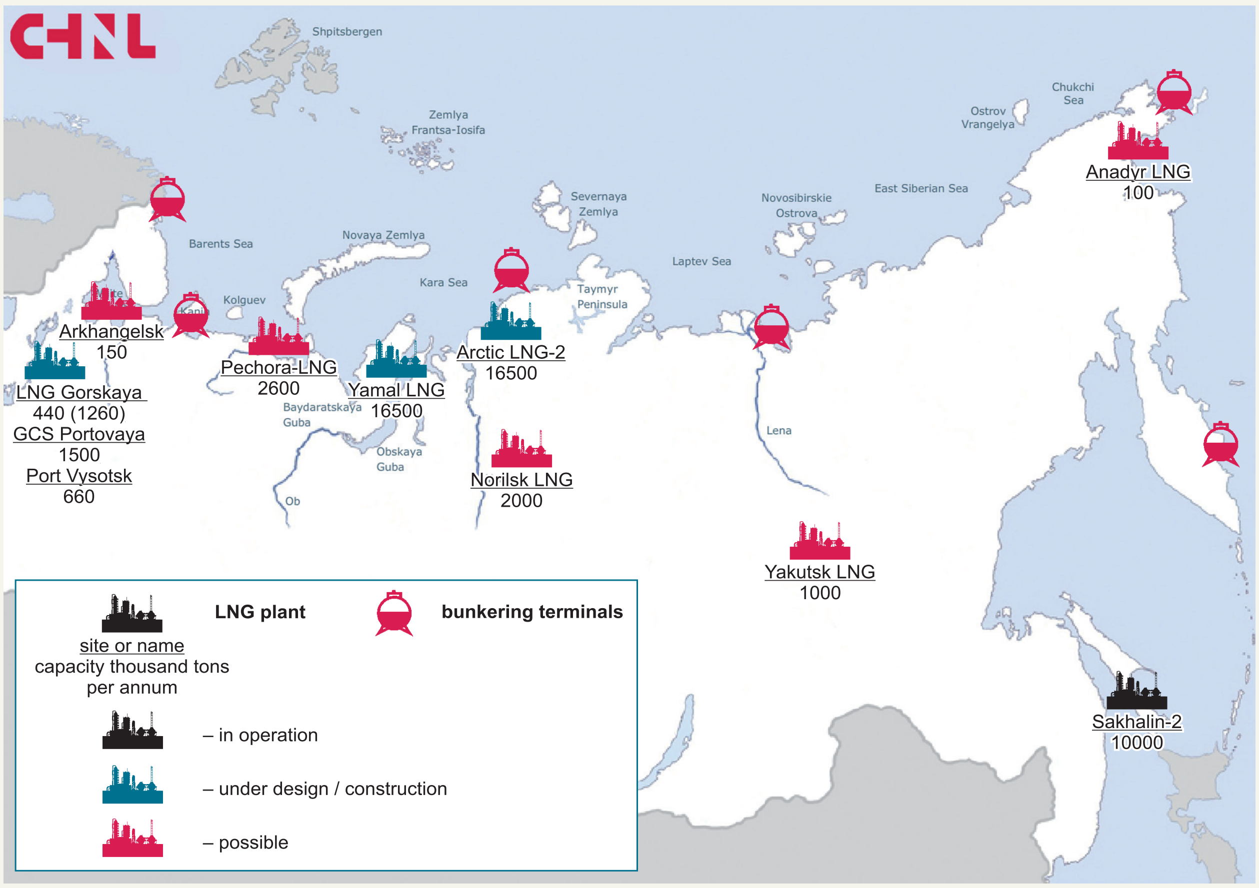
- towing vessels;
- passenger ships;
- bulk carriers;
- tankers;
- LNG carriers;
- service vessels;
- icebreakers;
- dredgers.

The perspectives and opportunities of using LNG for bunkering greatly depend on the expected geography of where LNG vessels will be used. This is because it is impossible to build reliable LNG bunkering infrastructure all along the NSR in a very short time.

Most importantly, bunkering centers are inseparable from LNG production plants. And, in addition, in order to set up port operations in the Arc-

Figure 14. Map of possible LNG production plants along the NSR

Source: Author's estimates, map by Center for high north logistics



tic region and along the NSR, LNG storage and bunkering terminals are needed in the harbors of:

- Murmansk and Arkhangelsk using LNG shipments from the Baltic and Yamal LNG. Arkhangelsk bunkering terminal could use own LNG from possible LNG project in Arkhangelsk;
- Dikson using shipments from Yamal LNG, Arctic LNG 2 and the Norilsk LNG project;
- Tiksi using shipments from Yamal LNG and from Central Yakutia along the Lena River during summer time;
- Anadyr using own LNG production plants or Sakhalin-2 shipments.

Additionally, for ships moving westward LNG bunkering is possible in Norway and will soon become widely available in the Baltic ECA.

The first vessels using LNG in the Russian Arctic will be the LNG carriers of the Yamal LNG project.

Oil Spills and Environmental Impacts in the Arctic

Oil and chemical spills are highly hazardous for the Arctic environment[13]. They cause both immediate and long-term damage. Some Arctic animal species are particularly sensitive to oil spills, since their skin, fur and feathers lose their heat-insulating qualities when contaminated by oil.

This is true for sea birds, polar bears, and other marine mammals. Even minimal oil spills lead to severe consequences, if they happen around wildlife breeding grounds, or bird nesting places, for instance. The consequences of spills and their environmental impacts depend on the physio-chemical characteristics of the spilled substances and the natural factors – temperature, light, wave disturbance, and ice cover.

Oil spills response measures are hindered by weather conditions and the need to mobilize and transport people and equipment over large distances. For instance, during the sinking of the 'Selendang Ayu' bulk carrier, more than 1 100 tons of fuel and other substances were spilled. The cleanup works took 18 months and cost more than $100 ml.[14]

Naturally, oil spills affect every level of the Arctic food chain.

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[13] http://www.arctis-search.com/Discharges+from+Ships+in+the+Arctic&structure=Marine+Transport+and+Logistics

[14] “The Bering Strait: Reducing risk through international cooperation and capability improvements” - Jeremy McKenzie and others, Watson Institute, 2015

Oil spill cleanup in ice-covered waters is an extremely complex process, and there are very few response measures to these kinds of spills. Consequently, the main focus to ensure the region's safety should be prevention of oil spills.

A considerable increase in anticipated oil shipment volume in the Russian Arctic (up to 30 ml. t by 2025, and up to 40 ml. t by 2030) dramatically increases the risk of spills during oil transfer and shipment.

As the natural resources of the Arctic are being developed, environmental protection, including oil spill prevention measures, is being given special attention. But the effectiveness of oil spill cleanup measures in Arctic conditions still raises questions.

National and International Marine Fuel Standards

Marine fuel requirements are covered in GOST-R 54299-2010 (ISO 8217:2010) “Marine Fuels”. The standard concerns oil and gas condensate-based fuels, and in effect constitute a translation of the international ISO/FDIS 8217:2010 “Petroleum products – Fuels (class F) – Specifications of marine fuels” standard.

According to GOST requirements, distillate fuels cannot contain more than 1-1.5% of sulfur, and no more than 1.5% for heavy fuel oils. Although the current requirements exceed those of the IMO (3.5%) with the exception of the ECAs, the GOST standard does not comply with the IMO regulations that come into effect in 2020, where maximum sulfur levels for all marine fuels cannot exceed 0.5%.

International sources, unlike GOST, also specify the contents of certain fuel types. For instance, IFO380 contains 98% HFO and 2% distillate fuels, while IFO180 – 88% HFO and 12% distillate fuels.

GOST 56021-2014 introduces several LNG fuel types:

- type A – high purity fuel with constant heating value, used as fuel for combustion engines and power stations with limited adjustment ranges;
- type B – for use as fuel in combustion engines;
- type C – for use in power stations.

Table 7. Main characteristics of LNG according to GOST 56021-2014

	Value for each type		
	A	B	C
Blend composition, mole fraction, %	specification mandatory		
Wobbe index range (top) under standard conditions,[15] MJ/m³	47.2 – 49.2	not rated	41.2 – 54.5
Lower heating value under standard conditions, MJ/m³	not rated	31.8 – 36.8	31.8
Mole fraction of methane, no less than %	99.0	80.0	75.0
Mole fraction of nitrogen, no more than %	not rated	5.0	5.0
Mole fraction of CO_2, no more than %	0.005	0.015	0.030
Mole fraction of oxygen, no more than %	0.020		
Mass fraction of hydrogen sulfide, no more than g/m³	0.020		
Mass fraction of mercaptan sulfur, no more than g/m³	0.036		
Motor Octane Number (MON), no less than,	not rated	105	not rated
Quality requirements after regasification		GOST 27577	GOST 5542

Source: GOST 56021-2014

On customer's request LNG can be produced with mass fraction of total sulfur no more than 0.010 g/m³. In terms of mass, LNG has higher calorific capacity but, due to its low density, larger fuel tanks are required when using LNG.

Table 8. Heating value of different fuel types

	DM (MGO)	RM (HFO)	LNG
Molecular formula	C8 – C20		CH4
Density, kg/m³	860 – 900	920 – 1010	422
Lower heating value, MJ/kg	41.4 – 43.3	40.5 – 41.4	50.02
Boiling point, °C	180 – 360		- 162
Flash point, °C	>60	61	-187
Lower explosive limit, volume %	0.5		4.4
Upper explosive limit, volume %	7.5		15 – 17
Self-ignition point, °C	250 – 300		595

Source: DNV, DNV, GOST-R 54299-2010

[15] when 1 cal = 4,1868 J

Compared to oil-based fuels, LNG has the highest calorific value in terms of mass. However, LNG's lower density requires larger fuel propellant systems in order to store LNG aboard ships.

An estimation of LNG switch for bulk carrier has been made with the following assumption: the volume of LNG tanks is equal to the volume of oil fuel tanks, e.g. switch to LNG will keep the cargo capacity the same as previously.

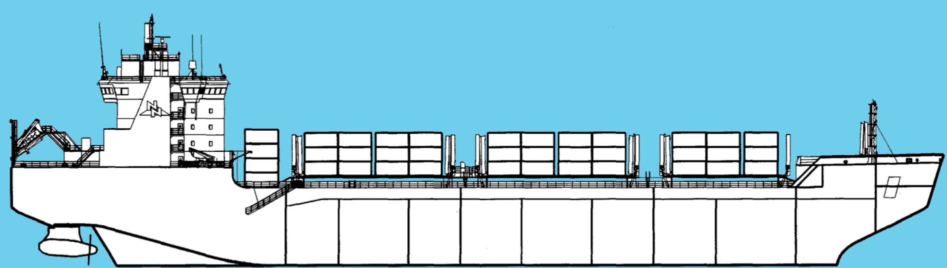
The estimation demonstrates that reliable shuttle shipping in the Arctic is possible with LNG even in complicated ice and weather conditions. The amount of LNG that can be stored in oil fuel tanks is enough to safely traverse along the route with two bunkering points. The LNG amount is sufficient even with the only bunkering in summer conditions.

Figure 15. A comparison of using LNG and diesel fuel in a Monchegorsk type vessel (winter time)

Source: Author's estimates

Deadweight – 18 thousand tons
Shipowner – Norilsk nikel
Ice class – Arc 7
Diesel consumption – 1700 tons per trip

Space lost for LNG switch – 13%
Cost of diesel – 30000 rubles/t
LNG cost – 21500 rubles/t



	Diesel	LNG
Route	Murmansk – Dudinka – Murmansk	Murmansk – Dudinka or Dudinka – Murmansk
Length of the route, km	5400	2700
Bunkering point	Murmansk	Murmansk and Sabetta
Volume of fuel, m³	2725	2370
Weight of fuel, t	2500	1000
Fuel reserve, %	38	28

LNG refueling is possible in the Yamal area so additional LNG tanks are not required.
The weight of the fully laden vessel is decreased by 1500 tons or 8 % of its deadweight
Fuel economy will be 14.45 ml. rubles per trip.

Environmental Efficiency of LNG

LNG has been safely transported along shipping routes for more than 40 years. LNG is considered to be a promising fuel around the world that will allow the shipping industry to meet current new environmental requirements on marine fuel.

According to Total[16], the use of LNG for bunkering will reach 35 ml. t by 2030. Recent estimates show that in 2017 the use of LNG for bunkering is expected to increase to 20-40 ml. t/year.

Table 9. An outlook on the use of LNG for bunkering around the world

	2020	2025	2030
LNG for bunkering, ml. t	10	15	30-35

Source: LNG AS MARINE FUEL: CHALLENGES TO BE OVERCOME Pablo Semolinos Gunnar Olsen Alain Giacosa Total, 2011

LNG Spills

Due to its physical qualities LNG doesn't cause the same amount of environmental damage as oil in the event of a spill on land, ice, or water. Over the years that LNG has been in use, there have been no major accidents that have led to large quantities of LNG being spilled on land, or water. According to DNV-GL, throughout the years of LNG shipping the largest spill contained 40m^3 of LNG.[17]

LNG storage temperature is considerably lower than atmospheric temperature, even during Arctic winters.

So in case of a spill, LNG vaporizes and dissipates in the atmosphere in a short period of time.

Methane, being the main component of LNG, has a relatively narrow range when steady combustion is possible (9-15%) and high temperature of self-ignition (595 °C) and that allows an estimate of the risk of fire after the spill as acceptable.

A detailed study of the LNG combustion conditions in the event of a large-scale spill into the water was conducted by the US Department of Energy.[18]

[16] LNG AS MARINE FUEL: CHALLENGES TO BE OVERCOME Pablo Semolinos Gunnar Olsen Alain Giacosa Total, 2011

[17] Gas carrier update DNV-GL № 01 2015

[18] Liquefied Natural Gas Safety Research. Report to Congress, May 2012 US Department of Energy

Atmospheric Emissions from the Use of LNG

The switch away from oil fuels and the use of LNG considerably reduce environmental emissions from shipping. Considering the limited, even today, use of HFO in the Russian Arctic, it should be enough to focus exclusively on the environmental impact of ships using diesel propulsion systems in this study.

In any case, using gas as a marine fuel leads to a reduction in atmospheric emissions, with SO_x and particulate matter demonstrating the most noticeable decrease, and NO_x emissions cut by 80%. Greenhouse gas (GHG) emissions from using LNG are also lower. Methane emissions, however, have a very significant effect, including methane slips in gas and converted dual-fuel engines.

The environmental sustainability of LNG greatly depends on the modes and types of marine engines used. The most common propulsion systems are two-stroke and four-stroke diesel engines.

For the following estimates of the atmospheric emissions caused by the use of HFO and LNG, 2011 and 2013 emission factors were applied, as well as anticipated emission factors that will be achieved thanks to new advances in technology.

Table 10. Pollutant emissions when using HFO and LNG, kg/t

	HFO		СПГ	
	2011	2030	2013	2030
CO_2	3130	3130	2751.1	2751.1
CH_4	0.3	0.3	26.5	3.0
N_2O	0.08	0.08	0.05	0.05
other hydrocarbons	2.4	2.4		
SO_2	54	10.8		
NO_x	78	74.958	23.0	23.0
CO	7.7	7.4		
PM	5.3	4.24		
BC	0.35	0.35		
OC	1.07	0.856		

Source:
HFO – Future emissions from shipping and petroleum activities in the Arctic G. P. Peters, T. B. Nilssen, L. Lindholt, M. S. Eide, S. Glomsrød, L. I. Eide, and J. S. Fuglestvedt

LNG as an alternative fuel for the operation of ships and heavy-duty vehicles, Federal Ministry of Transport and Digital Infrastructure (BMVI) 19 December 2011, Germany

EVALUATION METHODOLOGY

In the Russian Arctic the following types of shipments are expected to develop:

- LNG shipments, oil shipments within the borders of the Russian Arctic region, coal shipments from the new projects planned to start-up in the Arctic;
- transit shipments between Europe and Asia;
- coastal and port operations, fishing vessels;
- international shipments from/to Russian ports.

  (International shipments from/to the ports of Murmansk and Arkhangelsk are not addressed.)

New Projects in the Arctic Region (LNG, oil, coal)

For each type of shipment the following steps apply:

- cargo traffic evaluation;
- an evaluation of shipping vessels and their characteristics;
- an estimate of shipping emissions from the use of LNG and oil-based fuels.

Table 3 demonstrates the estimated cargo traffic volume along the NSR under different projections.

In order to evaluate the environmental impacts and economic factors a model, described in supplementary materials to the study "Future emissions from shipping and petroleum activities in the Arctic" by G. P. Peters, et al.,[19] has been used.

Fuel consumption calculations were carried out using the following formula:

$$F = R \times D / V$$

where R is nominal fuel consumption value, which equals to 225 g/kW of energy;

D – travel distance of the vessel;

V – average movement speed of the vessel, adjusted to each season;

$$D = \sum N \times L$$

N – number of routes;
L – length of route.

19 «Future emissions from shipping and petroleum activities in the Arctic» by G. P. Peters, T. B. Nilssen, L. Lindholt, M. S. Eide, S. Glomsrød, L. I. Eide, and J. S. Fuglestvedt, 2011.

In order to calculate the number, time of shipping operations and nominal fuel consumption the following parameters, related to the movement speed, have been used.

Table 11. Average movement speed of vessels, depending on the season

Year	Average Speed, knot (km/h)
Summer-Fall	13.5 (25)
Winter-Spring	9 (16.7)

Source: Author's estimates

In 2030 the volume of cargo traffic from the Arctic industrial projects may exceed 100 ml. t. There are also shuttle-tankers, which deliver oil from the Prirazlomnaya platform and Varandey terminal and which completely meet the current and future (16.8 ml. t of oil) cargo traffic demands.

Table 12. Main types of vessels and estimates of the number required to provide shipments along the NSR for key development projects

	Volume of Cargo Traffic in 2030	Dead-weight, thous.t	Sample Vessel	Main Engine Output, kW	Distance, km		Travel Time, days Summer-Fall / Winter-Spring		Required Number of Vessels	
					Westward	Eastward	Westward	Eastward	Westward	Eastward
TOTAL	**104.4**									
Petroleum Products	**69.4**									
Oil and Condensate	**36.7**									
Prirazlomnaya	3.0	70	Mikhail Ulyanov, Kirill Lavrov	26 100	1000		3.0 / 4.5		**2**	
Varandey	12.0	73	Kapitan Gotskiy, Timofei Guzhenko, Vasiliy Dinkov	27 550	1000		3.0 / 4.5		**3**	
Novoport	8.5	42	Shturman Malygin, Shturman Albanov	32 000	2500		7.6 / 11.4		**6**	
Payyach	5.0	40		32 000	2500		7.6 / 11.4		**4**	
Yamal LNG	0.8	42		32 000	2150		6.5 / 10.0		**2**	
Dolginskoye	7.0	70		27 550	1000		3.0 / 4.5		**2**	
Other	0.4									
LNG	32.7									
Yamal LNG	16.5	98	Cristof de Margerie	45 000	4800	8900	14.5 / 22	27.0	**9**	**15**
Arctic LNG 2	11.0	98		45 000	4800	8900	14.5 / 22	27.0	**6**	**11**
Pechora LNG	5.2	98		45 000	3600	9800	10.9 / 16.5	29.7	**3**	**6**
Concentrates and Ores	1.0									
Norilsk Nickel	0.7	18	Yenisei, Zapolyarniy, Monchegorsk, Naedzhda	18 000	2700		8.2 / 14		**2**	
Pavlovsk Deposit	0.3	10		18 000	800		2.4 / 4		**2**	
Mayskoye Mine	0.1	10		18 000	5000		15.2 / 23		**2**	
Coal	30.0									
Taibass	30.0	23 75	Pomorye Nordic Bothnia Nordic Oshima	9 480 40 000	1900		5.8 / 10		**22** **8**	

Source: Author's estimates

For oil shipments from the Novoport oil deposit, 4 additional tankers are required, and another 4 – for the Payyach oil deposit, so in total the LNG carrier fleet will consist of 36 vessels with 80 000 t deadweight each.

Table 13. Fuel demand and atmospheric emissions during shipments from Arctic industrial development sites in 2030 (in winter-spring conditions)

Shipments	HFO	LNG
Fuel Consumption, thous.t	4 920	4 028
CO_2, ml.t	15	11
CH_4, thous.t	1	12
N_2O, t	394	201
other hydrocarbons, thous.t	12	–
SO_2, thous.t	53	–
NO_x, thous.t	369	93
CO, thous.t	36	–
PM, thous.t	21	–
BC, thous.t	2	–
OC, thous.t	4	–

Source: author's estimates based on the values in **Table 10**

In order to meet the needs of the Arctic projects, 81 vessels are required in total.

Fuel demand will reach more than 5 ml. t of oil fuels and around 4 ml. t of LNG.

Transit

There were no direct assessments of transit data conducted in Russia. There are, however, findings presented in several international studies such as:

- Future emissions from shipping and petroleum activities in the Arctic G. P. Peters, T. B. Nilssen, L. Lindholt, M. S. Eide, S. Glomsrød, L. I. Eide, and J. S. Fuglestvedt, 2011;
- Future Climate Impacts of Trans-Arctic Shipping, Scott R. Stephenson Arctic Frontiers January 23, 2014;
- Arctic shipping emissions inventories and future scenarios, J. J. Corbett, 2010.

Among the general information on the development of the shipping industry presented in these studies, for the purpose of this study the most interesting data-sets relate to transit shipments along the NSR.

One assessment, conducted by Stephenson (2014), focused on the routes, connecting the European ports of Hamburg and Rotterdam with the Asian ports of Busan, Tianjin and Yokohama. Toll-free transit volume along the NSR can grow up to 726 ml. t per year if vessels of Polar Class 6 are used, which would amount to almost 43% of current transit through the Suez Canal.

Table 14. Transit forecast of the NSR

	Arctic Routes – maximum fee for the use of the NSR		Arctic Routes – minimum fee for the use of the NSR		The Suez Canal
	no ice-class	Polar Class 6	no ice-class	Polar Class 6	N/A
Number of Trips	715	3916	4489	8545	14152
Cargo Traffic Volume, t	60 775 000	332 860 000	381 565 000	726 325 000	1 698 240 000
CO_2, t	12 668 899	68 153 696	77 589 317	163 184 049	547 425 442
CH_4, t	1214	6532	7437	15 641	52 469
N_2O, t	324	1741	1983	4171	13 992
SO_x, t	218 569	1 175 814	1 338 601	2 815 315	9 444 400
NO_x, t	315 711	1 698 398	1 933 535	4 066 567	13 641 912
BC, t	1417	7621	8676	18 247	61 214
OC, t	4331	23 298	26 524	55 785	187 139

Source: Future Climate Impacts of Trans-Arctic Shipping, Scott R. Stephenson Arctic Frontiers January 23, 2014

The study paradoxically indicates large transit volumes – at the maximum of more than 1 bl. t, which in practice would make the NSR equal in importance to the Suez Canal.

Peters' assessment is more reserved when it comes to transit. Although the researcher doesn't project traffic volume directly, he estimates fuel consumption and atmospheric emissions of 9 ml. t CO_2 in 2030 and 16.3 ml. t CO_2 in 2050, which corresponds to 18 ml. t and 27 ml. t per year in transit volume.

Incidentally the primary CO_2 emissions in the Arctic region are from oil and gas production. SO_x emissions reduction is due primarily to the introduction of strict regulations on sulfur content in marine fuels.

Overall the estimates of the international experts on the transit cargo volume fluctuate between 18-390 ml. t in 2030 and 27 ml. t -1 bl. t in 2050.

Russian experts, in turn, demonstrate utter pessimism. For instance, M. Grigoryev, CEO of Gekon Ltd.[20] , expects just 2 ml. t cargo traffic along the NSR in 2025.

In the studies mentioned above the assessments of emissions and fuel consumption rates was conducted in comparison to fuel oils (HFO/IFO).

When evaluating transit volume both options of 2 ml. t and 18 ml. t transit volume in 2030 are considered.

Table 15. Atmospheric emissions comparison during transit along the NSR

Fuel Type Transit Volume	HFO		LNG	
	2 ml.t	18 ml.t	2 ml.t	18 ml.t
Fuel Consumption, thous.t	132	1190	108	974
CO_2, ml.t	0.41	3.73	0.30	2.68
CH_4, thous.t	0.04	0.36	0.32	2.92
N_2O, t	10.58	100	5.41	48.73
other hydrocarbons, thous.t	0.32	2.86	–	–
SO_2, thous.t	1.43	12.8	–	–
NO_x, thous.t	9.91	89.3	2.49	22.42
CO, thous.t	0.98	8.81	–	–
PM, thous.t	0.56	5.05	–	–
BC, thous.t	0.05	0.42	–	–
OC, thous.t	0.11	1.02	–	–

Source: author's estimates based on the values in **Table 10**

When evaluating the use of LNG the conversion of the HFO and LNG lower calorific values using the data from **Table 8** is used.

The use of LNG allows for significant reductions in the emission rates of primary pollutants, bringing SO_x and BC, soot emissions down to a minimum.

[20] http://neftianka.ru/dlya-vsyakoj-bochki-degtya-najdetsya-lozhka-meda/

Coastal and Port Operations, Fishing Vessels

Since there is currently no data on cargo traffic volumes for these categories of vessels, this section will have to be finalized at a later date.

Nevertheless, based on the data presented in the study "Arctic Marine Shipping Assessment 2009 Report" by the Arctic Council and based on the number of vessels registered in Russian marine ports, an assessment of fuel consumption in the Arctic region of Russia was conducted (not including the carriers of the Varandey and Prirazlomnaya sites).

According to this assessment, 439 vessels, registered in the Russian ports, consume about 276 000 t of marine fuels per year, which leads to the following emission rates:

Table 16. Atmospheric emissions comparison during fishing, coastal and port operations

	HFO	LNG
Fuel Consumption, thous.t/year	276	226
CO_2, ml.t	0.86	0.6
CH_4, thous.t	0.08	0.7
N_2O, t	22.06	11.3
other hydrocarbons, thous.t	0.66	–
SO_2, thous.t	14.89	–
NO_x, thous.t	21.50	5.2
CO, thous.t	2.12	–
PM, thous.t	1.46	–
BC, thous.t	0.10	–
OC, thous.t	0.30	–

Source: Author's estimates based on the AMSA data for the Arctic region

It is expected that the use of LNG by the existing fleet will considerably decrease atmospheric emissions. Due to the lack of detailed information on the existing operation and future development of port operations in the Arctic region, in the forecast for 2030, fuel consumption rates and atmospheric emissions should be considered unchanged.

LNG POTENTIAL

Currently, LNG is most actively used in Norway.

In that country and in the world, the following types of vessels on LNG are used:

1. tankers;
2. bulk carriers;
3. tows and service vessels;
4. container ships;
5. passenger vessels;
6. icebreakers.

In order to evaluate the possibility of retrofitting vessels to run on LNG, it's crucial to consider the age and maintenance requirements of the fleet. When old vessels are retrofitted, there is often not enough space to allocate for the LNG storage tanks on these vessels.

In the Arctic region, shipping is complicated by difficult ice conditions, lack of industrial development, and small settlements and communities. All of these factors necessitate large-scale and long-term activities to develop the region's infrastructure.

At the same time, there is also no modern infrastructure in the Arctic that would allow large-scale use of oil fuels, even though oil fuel demand is expected to reach 5-6 ml. t by 2030.

So far the ongoing modernization of the NSR fleet in the Arctic does not include the use of LNG for bunkering as its core idea, which does not instill much confidence in the possibility of a long-term switch to LNG.

For some shipping sectors the switch to LNG will be attractive. If the political will is there, and if the NSR is advertised as the first international marine shipping corridor operating on LNG, the opportunities and prospects of the use of LNG will reach their full potential. In addition, Russian gas will move into a new promising and booming market of LNG bunkering.

In effect, strict compliance with the existing and planned environmental regulations guarantees the attractiveness of a switch to LNG in the long term. If the use of LNG is sufficiently cost effective, it can ensure the dominance of LNG on the bunkering fuel market in the Arctic region.

If for the already existing fleet there is no need for significant investment into infrastructure, and if there is a way to deliver the needed amount of low-sulfur fuels, then, with the expected cargo traffic, and the corresponding fuel demand of 5-6 ml. t, the possibility of providing the required volume of oil marine fuel at competitive prices comes into question.

Quality assessment of using LNG on new ships demonstrates increased investment costs, certain limitations on load-carrying capacity due to a need for larger fuel tanks, and lower operational costs. Some assessments also demonstrate that total cost increase of shipping using LNG will not lead to a tangible cost increase.

The main advantage of LNG in the Arctic is that it will continue to be easily available in the long term and that it meets current and planned environmental requirements.

The development of infrastructure for LNG bunkering will also improve the ecological and social situation for the areas around the Arctic ports.

According to the allocation plan of the LNG production plants along the NSR (see Figure 14.), the development of LNG bunkering infrastructure will affect:

- Murmansk;
- Arkhangelsk;
- Dikson;
- Tiksi;
- Anadyr.

The total costs of organizing one port to provide LNG bunkering will fluctuate starting at 15 ml. EUR minimum or approx 1 bl. rubles.

Initial Investment Costs

There is a considerable price difference when switching from HFO to MGO, but it's not linked to updating the coastal infrastructure, or re-constructing the vessel's fuel system. Installing scrubbers leads to rather significant investment costs, while operational costs remain practically unchanged.

There is a limited amount of data to be found on the price of vessels operating on LNG and on the price of retrofitting a vessel to run on LNG.

The available data indicates the following when it comes to investment costs:

- for a bulk carrier with ice-class, 70 000 t deadweight and a 40MW engine unit, the additional costs come up to $26.7 ml.;
- for a tanker with a 12MW engine unit and 75 000 t deadweight, the additional costs to use LNG amount to $9.5 ml.;

High-output vessels of a high ice-class are required to operate in the Russian Arctic.

Nevertheless, the price difference is related exclusively to the types of fuel systems and ship's engines, so for the present calculations the range from $9.5 to $26.7 ml. for vessels with 12MW and 40MW engine units respectively, or 790-670 $/kW can be used.

When there is virtually no modern infrastructure for storing and distributing fuel oils in the Arctic, for the purposes of this study it can be assumed that there is no difference in initial investment costs in infrastructure for LNG and for oil fuels, in sense with the expected growth of cargo traffic volume. As a result, the cost difference will only appear as an acquisition cost difference for ships operating on LNG and fuel oils.

Operating Costs

The primary benefit of using LNG, aside from the fact that this type of fuel meets the existing and new environmental requirements, is its relatively low price.

In the past 6 years LNG price per energy unit has become considerably lower than fuel oil prices, which creates additional benefits for the use of LNG alongside the environmental ones.

As a rule, main LNG consumption hubs are situated distinctly far away from its production centers, so shipping LNG to consumers increases its price.

Russian projects in the Arctic ensure LNG production at lower prices, thanks to new world-class deposits and the use of cold environments.

According to Yamal LNG, the price per mmbtu is 4 US dollars. This means that 1 ton of LNG costs around 208 $/t and an opportunity to offer LNG to buyers at the price of 328 $/t, or a little more than 21 000 RUB.

Figure 16.
Price history for main and alternative fuels

Source:
DNV Future shipping energy sources and lessons learned, May 2016

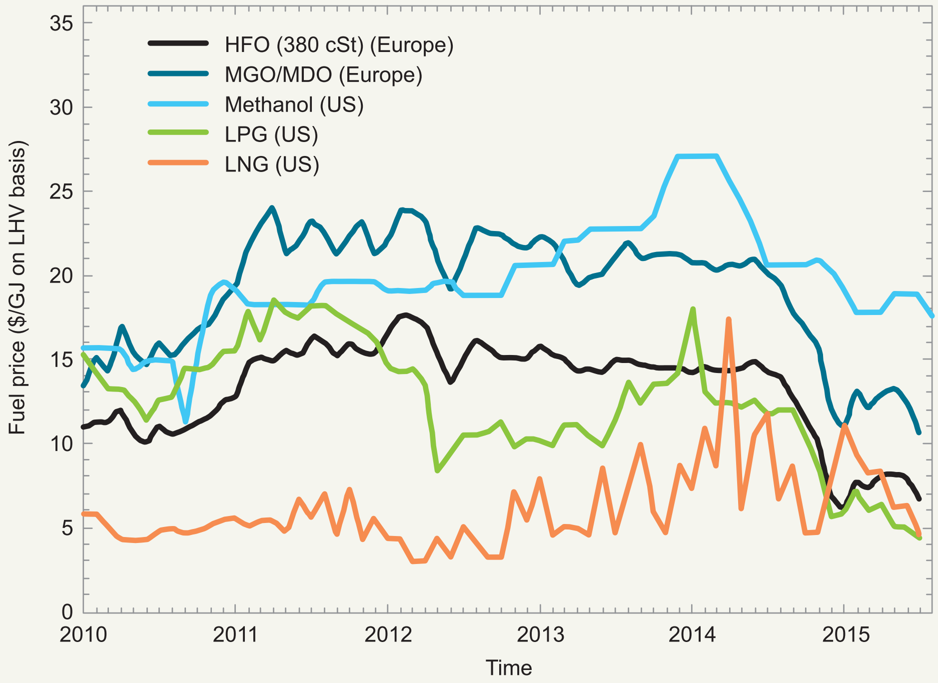


Figure 17.
Expected LNG prices in the Arctic region of Russia and LNG plants worldwide, $/mmbtu

Source:
Yamal LNG, LNG-Congress, 2015

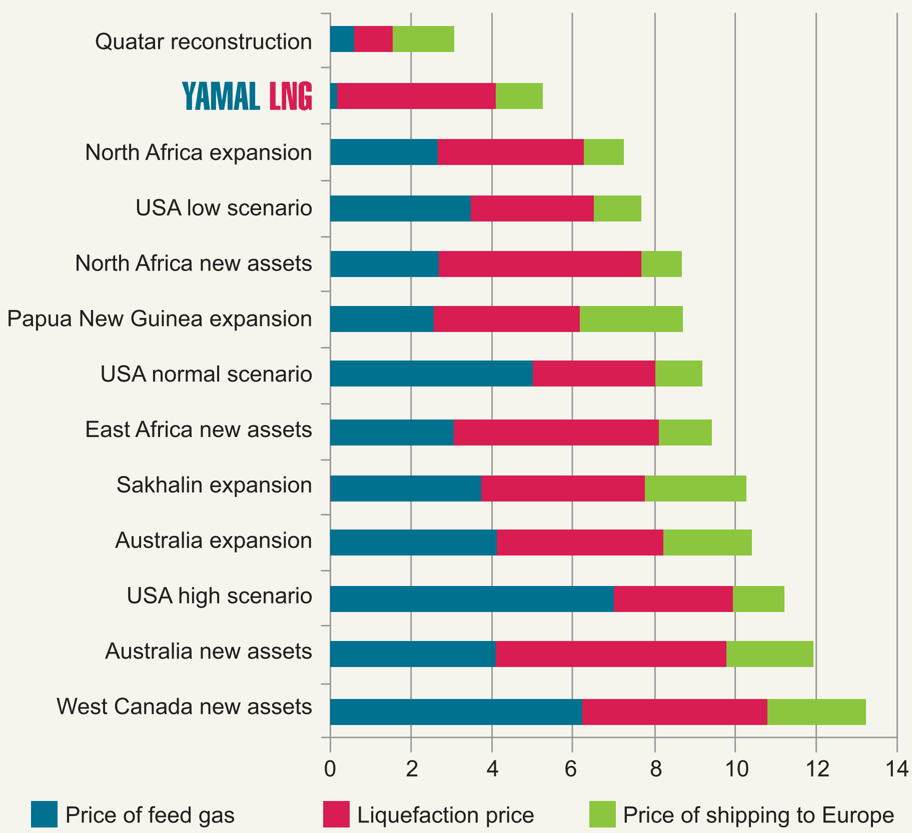


Table 17. . An assessment of LNG for bunkering value chains in different regions of the Arctic, $/t

Value Chain on Yamal Peninsula	Yamal Area	Value Chain in Eastern Arctic Seas	Tiksi/ Murmansk	Pevek
			+ 2000 km	+ 4000 km
Price of Yamal LNG	208	Price of Yamal LNG	208	208
		LNG Carrier Refueling	30	36
		Shipping, days	4	7
		Freight Cost of a Shuttle Vessel – 3000 t, thous.$/day	35	35
		Total Freight Cost, thous.$	259	519
		Shipping Cost, $/t	86	173
		Transshipment to Inland Storage	30	36
		Storage for 1 Month	85	103
Transshipment to Bunkering Vessel	25	Refueling of Bunkering Vessel	30	36
Operation Costs of Bunkering Vessel	70	Operation Costs of Bunkering Vessel	84	101
Refueling of the Customer	25	Refueling of the Customer	30	36
Total	328	Total	554	692
Total, RUB	21 320	Total, RUB	36 003	44 993
Cost of Diesel Fuel, RUB/t	30 000	Cost of Diesel Fuel, RUB/t	65 718	70 000

Source: Author's estimates

When transporting LNG to bunkering hubs in the Eastern Seas of the Russian Arctic, the value chain is longer, and transportation on shuttle tankers, transshipment and LNG storage are added to the price. The costs of transshipment to a bunkering vessel, operation costs, and refueling of customers' ships were calculated based on the business plan data of a bunkering project in the Baltic Sea. For the Yamal region the same prices were used as for the Baltic Sea, for the + 2000 km zone (Tiksi/Murmansk region) a multiplier of 1.2 was used, and for the +4000 km zone (Pevek region) a multiplier of 1.44.

LNG costs and tendering data of the diesel fuel for ships and customers in the Tiksi, Pevek and the Yamal regions in 2016 have been used for a comparison. Naturally, around LNG production plants the bid-offer spread amounts to 30% compared to diesel fuel, but in the East Arctic ports it increases to 50%.

Based on the estimates presented in the “Initial Investment Costs” section, an evaluation of LNG cost effectiveness and likelihood of return on investment has been conducted for main vessel types in operation or expected to be in operation for oil, coal, and ores and concentrates shipments.

In order to calculate fuel costs, diesel and LNG fuel estimates for the Yamal region from **Table 17** were used.

The analysis conducted demonstrates a high competitive advantage of the ships using LNG as a marine fuel. The cost effectiveness of using LNG grows considerably when shipping traffic volumes and yearly route distances grow. As a result, payback period when switching to using LNG as marine fuel equals 2.5 to 5.5 years.

Table 18. An estimate of cost effectiveness of using LNG for cargo shipping as part of the Arctic industrial projects

	Deadweight, thous.t	Output, kW	Difference in Capital Expenditures on the Fleet, thous.$	Number of Vessels	Average Travel Distance per Vessel, km	Estimated Fuel Costs for the Fleet, thous.$		Difference in Fuel Costs, thous.$	Difference in Fuel Costs per Vessel, thous.$	Payback Period
						HFO	LNG			
Oil and Condensate										
Prirazlomnaya	70	26 100	17 422	2	69 000	13 986	8 137	5 849	2 924	–
Varandey	73	27 550	18 390	3	114 667	59 050	34 356	24 695	8 232	3.8
Novoport	42	32 000	21 360	6	169 167	202 375	117 743	84 633	14 105	2.7
Payyach	40	32 000	21 360	4	156 250	124 615	72 502	52 114	13 028	3
Yamal LNG	42	32 000	21 360	2	62 350	17 147	9 976	7 171	3 585	–
Dolginskoye	70	27 550	18 390	2	100 000	34 332	19 974	14 357	7 179	4.5
Concentrates and Ores										
Norilsk Nickel	18	18 000	14 250	2	99 900	22 408	13 037	9 371	4 686	5.2
Pavlovsk Deposit	10	18 000	14 250	2	22 400	5 024	2 923	2 101	1 051	–
Mayskoye Mine	10	18 000	14 250	2	50 000	11 215	6 525	4 690	2 345	–
Coal										
Taibass	23 75	9 480 40 000	7 505 26 700	24 8	206 625 190 000	292 917 378 831	170 420 220 405	122 497 158 426	5 104 19 803	2

Source: Author's estimates

SUMMARY AND CONCLUSIONS

The development of the Arctic region is a priority for Russia in the XXI century. The most active development will be in the mining of natural resources.

Regional development projects will lead to an increase in cargo traffic volume, which at the maximum scenario is expected to reach 100 ml. t by 2030. Global climate change will add to this number another 2 ml. t at a minimum and up to 1 bl.t at most of transit traffic.

Both transit and domestic shipment will create a huge traffic that need to be serviced using new standards and shipping safety requirements.

In order for these economic development and shipping projects to be effective, a large-scale expansion of port infrastructure, navigational, rescue, support and maintenance services, as well as the creation of bunkering infrastructure all along the NSR, are needed.

The main obstacles to the use of LNG as bunkering fuel are:

1. safety of use;
2. economics;
3. luck of infrastructure development;
4. technological development;
5. reliability of fuel supply.

The development of the Arctic will require technological refurbishment of the fleet that can go together with introducing the use of LNG for bunkering. This is, first and foremost, due to:

1. the change in cargo and supply chain of the Norilsk industrial district;
2. development of shelf and onshore deposits in the Arctic;
3. an increasing exploration on the Arctic shelf;
4. the start of LNG production on the Yamal Peninsula using icebreaker assistance for vessels;
5. the government-sponsored Arctic development program (including military development).

All Arctic vessels have to be an ice-class, and, despite climate change and the melting of ice caps, this requirement will remain for a long time. Most likely, all Arctic vessels will be operating there on a permanent basis, without relocating to other regions.

The best option would be to build new ships that would immediately be able to use LNG.

Considering the age of ships in the Arctic region of Russia, another possible option is retrofitting the old vessels so that they can use LNG.

One obstacle when it comes to switching to LNG is the reduction in net load-carrying capacity, due to the placement of LNG storage tanks on board. However, the assessments from the pervious chapters demonstrate that enough volume of LNG can be stored within the volume of fuel oil tanks to ensure comfortable passage along the shuttle Arctic shipping routes.

LNG can be delivered from large-scale projects in the Arctic, such as Yamal LNG and Arctic LNG, as well as from the projected Pechora LNG production plant. Other than that, there were previously project proposals submitted for LNG production plants in Norilsk, Yakutia, Arkhangelsk and on the Chukotka Peninsula. LNG shipments to the Arctic region are also possible from the Baltic LNG projects when shipping along the White Sea-Baltic Canal is open. LNG vessels traveling along westbound routes will be able to make use of LNG terminals operating in Europe.

The placement of current and future LNG production plants is favorable to the creation of a marine shipping corridor along the NSR, where LNG will be used as bunkering fuel.

The accessibility of LNG and short delivery distances, as well as the reliability of LNG shipments from different production facilities, will ensure significant cost competitiveness of the NSR, compared to other routes, which, hopefully, can substantially increase transit cargo traffic along the NSR.

In terms of size, LNG production projects in the Arctic conform to the international standards. This makes it possible to consider the use of LNG not just for bunkering, but also in the following market segments where it can reduce the need to deliver fuel oils to the Arctic:

- power supply for shelf exploration and for marine platforms;
- floating and onshore power plants;
- floating and onshore gas storage units for community use;
- gas and power supply for communities using floating platforms along the NSR and the Arctic river basins;
- marine port development with regard to ecological vulnerability of the environment when it is faced with intense human economic activity.

The development project of the Pavlovsk deposit on Novaya Zemlya intends to use LNG to supply power to industrial facilities. The total energy demand is 30-40 MW. In order to generate the energy, it is planned to use dual fuel turbine engines, operating on liquefied natural gas (LNG). The yearly quantity of LNG required to sustain the mining processing plant comes up to 50 000-60 000 t.[21] The use of LNG as a utility product allows to avoid limitations on energy consumption in the Arctic.

The Russian Arctic Strategy[22] stipulates environmental protection measures and active use of local energy resources, which should encourage the use of LNG in the Arctic region both for bunkering and for providing energy to communities and industrial projects.

LNG can be used for bunkering when:

- operating in large ports: Murmansk, Arkhangelsk, Dudinka;
- operating in the newer ports, such as Sabetta;
- for transit shipping.

Without solving the bunkering issue in Murmansk and Arkhangelsk, LNG shipping cabotage operations along the coast are unlikely to develop.

Shipping using LNG will help to develop shipments along large Siberian rivers and from seas to rivers (such as the Yenisei, the Ob, and the Lena River). This can lay the groundwork for developing gas infrastructure along the rivers for inland communities, as well as create an anchor point for bunkering operations of marine and river vessels.

Increased competition on the global LNG market necessitates the search for new LNG market segments, and Russia's internal industrial and bunkering market can present an effective solution for the Russian LNG industry.

When developing large-scale LNG production and oil and coal extraction projects, due to the expanding cargo traffic volume along the NSR, LNG consumption may reach 5 ml. t, which exceeds the expected production output of the Pechora LNG project.

The main obstacle to the development of the Arctic is its lack of infrastructure, but lack of technological and regulatory standards also present a significant problem. Gazprom JSC plays a significant role with regards to this issue, as it has commissioned the development of national LNG bunkering standards.[23]

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[21] Rosatom, Pavlovsk project, October 2015

[22] Arctic development strategy and national security of Russian Federation to 2020

[23] Open invitation to tender № 0001/16/7/0002861/ПАО Газпром/ЗП/ГОС/Э/22.09.2016

Table 19. Shipping structure and atmospheric emissions comparison for LNG and HFO, 2030

Type of Fuel	Transit				Arctic development projects		Fishing, Coastal Shipping	
	HFO		LNG		HFO	СПГ	HFO	СПГ
Volume of Shipments in 2030	2 ml.t	18 ml.t	2ml. t	18 ml.t	104 ml.t		–	
Fuel Consumption, thous.t	132	1190	108	974	4 920	4 028	276	226
CO_2, ml.t	0.41	3.73	0.30	2.68	15	11	0.86	0.6
CH_4, thous.t	0.04	0.36	0.32	2.92	1	12	0.08	0.7
N_2O, t	10.58	100	5.41	48.73	394	201	22.06	11.3
Other Hydrocarbons, thous.t	0.32	2.86	–	–	12	–	0.66	–
SO_2	1.43	12.8	–	–	53	–	14.89	–
NO_x	9.91	89.3	2.49	22.42	369	93	21.50	5.2
CO	0.98	8.81	–	–	36	–	2.12	–
PM	0.56	5.05	–	–	21	–	1.46	–
BC	0.05	0.42	–	–	2	–	0.10	–
OC	0.11	1.02	–	–	4	–	0.30	–

Source: Author's estimates based on ratios (see **Table 10**)

Without doubt, LNG is a fuel that causes less severe environmental impacts, particularly when it comes to CO_x, NO_x, SO_x emissions. However, even though in theory CO_2 emissions should decrease by 20% compared to oil fuels, the real CO_2 decrease will only amount to 8%. This is due to irregularities of gas engines that allow for methane slips. Additionally, the greenhouse effect caused by methane emissions considerably reduces the positive impact of decreased CO_2 emissions when using LNG. Technological advances do however allow us to project a 9-fold decrease in methane emissions per used fuel unit by 2030.

In the absence of heavy shipping traffic today, high seasonal variability in cargo shipments doesn't allow for the evaluation of the probability of large-scale LNG use as engine fuel. Even though environmental impacts of using LNG become particularly clear when the traffic and cargo flow are most intense.

CO_2 emissions would be cut by 4.7 ml. t after a switch to using LNG instead of oil-based fuels, with the volume of other pollutants also expected to fall, with the exception of methane whose emissions will increase by 12 and 14.3 thous.t/year for transit 2 mln.t and 18 mln.t respectively.

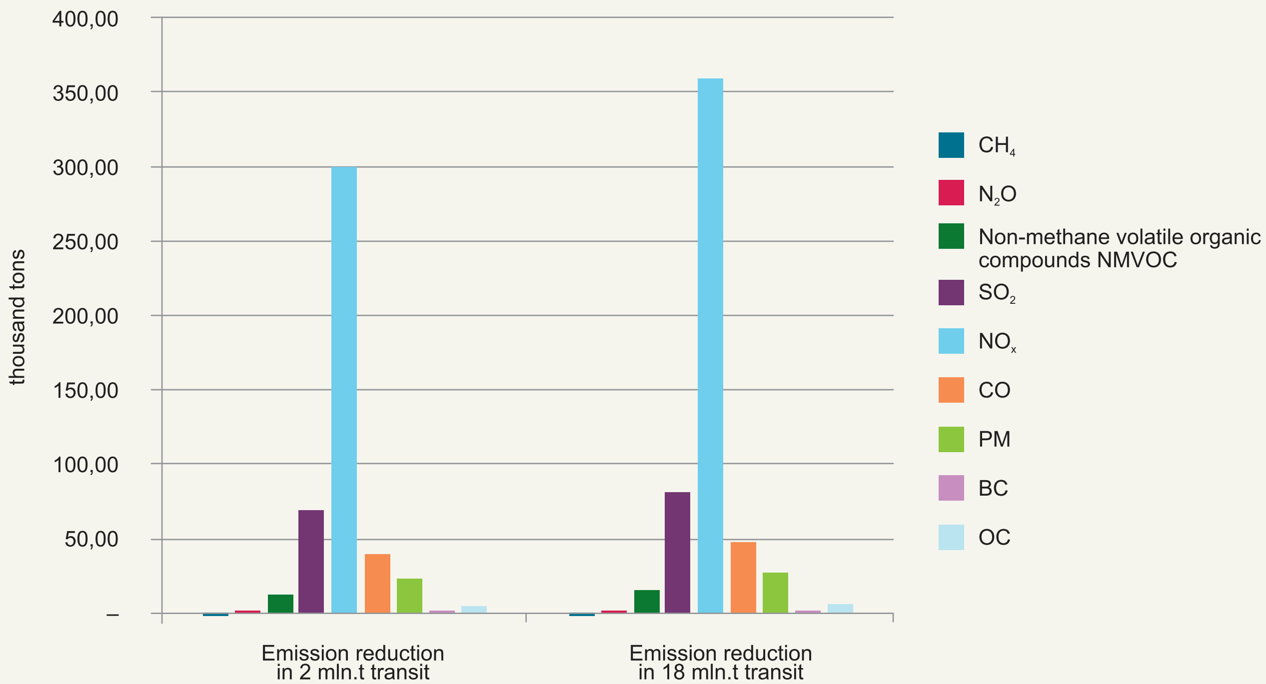

Figure 18. The reduction in harmful emissions in the Arctic region when using LNG as marine fuel (with the exception of CO_2)

Source: Author's estimates

Shipping along the NSR will require considerably less fuel (compared to the Suez Canal), due to a much shorter route between Europe and Asia, which leads to additional revenue, and using LNG can further increase the economic benefits.

The use of vessels, operating on LNG, for coal, oil and metal shipping makes it possible to recover the costs of gas equipment and special engines within the first 2.5-5.5 years, which demonstrates the high competitive advantages of using LNG in the Arctic.

The intensive development of the Arctic calls for up to 5-6 ml. tons marine fuel shipments per year, as well as for the development of transshipment, storage and bunkering infrastructure for oil, coal, and gas transit and shipment. Under conditions where the Russian government has to create such infrastructure practically from scratch and availability of huge amounts of LNG, it should pay particular attention to a quick transition from oil-based fuels to LNG, which will enable shipping and transit costs reductions and will ensure the protection of sensitive Arctic ecosystems from harmful emissions and dangerous oil spills.

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