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JUSTIFICATION OF ECONOMIC BENEFITS OF ARCTIC LNG TRANSPORTATION BY SEA

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Russian Arctic is the largest exporter of domestic natural gas, which brings significant income to the federal budget. The major share of natural gas extracted in the Arctic is transported via pipelines in the direction of European countries. For a number of reasons EU is continuously reducing its consumption of Russian natural gas, among other things by increasing the import of liquefied natural gas (LNG). All this is happening against the background of global markets refocusing from pipeline gas to LNG. An obvious solution here would be to increase LNG production in the Russian Arctic with its subsequent transportation by sea. Taking into account remote location of Arctic gas fields from the main sales markets, there is a need for comparative cost analysis of transportation via pipelines and LNG tankers.

The authors developed a method of assessing the costs of pipeline and sea transportation under comparable conditions. Calculations have been made for gas transportation to Germany, Italy, Turkey and China. As a result, it has been demonstrated that sea transportation of 1,000 m^3 of natural gas is cheaper than pipeline transportation by the average value of 106.3 USD (–40.2 %) across all the routes in question. Performed calculations prove the economic benefits of sea transportation of Arctic LNG to the existing and potential markets for natural gas. Such results are justified by the need of rational replacement of pipeline gas by LNG in European markets (especially in Southern Europe, where LNG has a greater competitive advantage) and increasing export of liquefied natural gas to the Asia-Pacific Region. Suggested measures will allow to reduce the costs of sea LNG transportation, which will give Arctic natural gas a competitive edge on the global and regional gas markets.

Key words: Arctic; natural gas; LNG; transportation cost; Arctic LNG projects

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Introduction. Russian Arctic possesses a vast amount of mineral resources, primarily hydrocarbons. Reserves of oil, natural gas, gas condensate and bituminous coal in the Arctic are estimated around 646 billion BOE (barrels of oil equivalent), including 233 billion BOE of measured, indicated and inferred reserves and approximately 413 billion BOE of probable ones. That is roughly 1/5 of the total amount of hydrocarbon reserves worldwide, natural gas having the major share in the reserves structure and accounting for 73.8 % of the total. Russian Arctic zone accumulates around 17 % of the total Arctic oil and 70 % of Arctic gas [11, p. 61-63].

Oil and gas incomes of the Russian federal budget amount to 39.58 % (2017) of the total income [8, p. 269-271]. Russian Arctic is responsible for 17 % of total oil and over 85 % of total natural gas production in the country. Development of oil and gas resources is actively transferred to the Arctic continental shelf and is becoming the critical pillar of Russian Arctic Policy in the areas of rational subsea use and development of subsea resources of the Arctic continental shelf [9, p.62].

The major share of Arctic natural gas today is transported to the customer via pipeline in the direction, which has become traditional since the times of «Soyuz» pipeline – to European countries. However, in the last decades there was practically no increase in the demand for natural gas on this market, nor is it predicted in the longer term (consumption in 2001 – 475.5 billion m^3, in 2016 – 480.7 billion m^3, in 2040 – 510 billion m^3).

Moreover, the share of Arctic natural gas in the European import decreases, because European Union declares energy security of its member states its top priority and therefore diversifies natural gas suppliers in order to eliminate the risk of geopolitical use of national pipeline systems. All the above-mentioned measures result in the share of Russian natural gas in the total European import decreasing from 41 to 35 % in the period from 2001 to 2016.

At the same time, over 50 % of European gas consumption is covered by import, 4/5 of which is supplied by the «Great Four» – PAO «Gazprom» (Russia), Statoil ASA (Norway), Sonatrach (Alge-

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ria) and N.V.Nederlandse Gasunie (Netherlands) [13, p. 96]. Thus, despite the fact that EU countries are still dependent on imported natural gas, the amount of supplies between major market players is being reallocated, and not in favour of Russia. At the same time, the main alternative to pipeline gas is innovative liquefied natural gas (LNG) [2, p. 73-82].

Global LNG consumption grows approximately 6 % a year, whereas the same numbers for pipeline gas are only 2.4 % a year; the share of LNG in the consumption of natural gas for energy purposes has reached 10 % [3, p.49]. The share of LNG in the global export is also constantly growing and already reaches 32 % – 346.6 billion m^3 of natural gas out of total 1 084.1 billion m^3 (2016). The trend of replacing pipeline gas with LNG is clearly visible in the last several years. It is forecasted that the pattern is going to continue in the longer run (until 2040) [5, p.69-77].

Therefore, economic prospects of pipeline gas are dwindling as compared to LNG. Among other things, it is expressed in dismissal of the so-called Groningen pricing model, which implies that natural gas can only be sold in terms of long-term gas export contracts [14, p.31]. Hence, both pipeline gas and the algorithm of contract price calculation, based on Rotterdam stock exchange prices (FOB ARA Barges), are losing their innovative significance. LNG trading originated in the form of long-term contracts, but it has undergone drastic changes since then with an increase in spot trading on special LNG hubs. This leads to LNG becoming a self-sufficient global product [12, p. 57-67].

With this in mind, PAO «NOVATEK» develops large LNG projects in the Russian Arctic: «Yamal LNG» и «Arctic LNG-2». It must be emphasized that implementation of large-scale infrastructure projects in oil and gas business will have a positive impact on socio-economic development of the Arctic regions [e.g. 10, p.275-279].

As part of the project «Yamal LNG», based on the reserves of South Tambey deposit, a town of Sabetta was founded on the western shore of the Ob Bay with an LNG plant nearby. The first line with the capacity of 5.5 Mt started its operation, since the end of 2017 LNG is being loaded onto Arctic gas tankers Arc7 [1, p.55]. After the start of 2^{nd}, 3^{rd} and 4^{th} lines in 2018-2020 total capacity of the project will reach 17.5 Mt. LNG is shipped to Europe and Asia Pacific, since April 2018 – under long-term contracts.

The «Arctic LNG-2» project, based on Salmanovsloye (Utrenneye) deposit, implies construction of a 16.5-18 Mt plant, the operation of which is planned to start in 2022-2025. The key difference from the former project is the concept of LNG plant located on gravity-based structure (GBS) offshore platforms, whose erection in the Kola Bay requires construction of four artificial islands [7].

Hence, taking into account implementation of the above-mentioned projects, by 2025 total production of Arctic LNG will have reached 35.5 Mt (almost 14 % of LNG trading amount in 2016). At the same time due to remote location of Arctic fields from the main consumers, implementation of Arctic LNG projects requires justification of economic benefits that sea transportation has over conventional pipelines.

Methodology. Economic justification of sea transportation benefits is based upon comparative analysis of transportation costs for 1,000 m^3 of natural gas extracted from Arctic fields in the largest gas-bearing region of the country (Yamal, Nadym-Pur and Pur-Tazov regions in West Siberia [6, p.15-18]) to the key existing and potential consumers of Russian gas.

Transportation costs for 1,000 m^3 of piped natural gas can be calculated as follows:

$$\mathrm{CP}_{\mathrm{pipeline}} = \frac{E_{\mathrm{pipeline}}}{100} r,$$

where $\mathrm{CP}_{\mathrm{pipeline}}$ – transportation costs for 1,000 m^3 of piped natural gas, USD; E_{pipeline} – pipeline length of the selected route, km; r – average piping costs for the selected route, USD per 1,000 m^3 per 100 km.

The final destination in this calculation is the border of gas consuming country.

Transportation costs for 1,000 m^3 of LNG shipped by sea can be calculated as follows

$$\text{CP lng} = L + \frac{\left(\frac{E\ln g \cdot 2}{S/24} + 1\right) dfr}{C} + \frac{GTit}{C} \cdot 2 + Tr + \text{P},$$

where CPlng – transportation costs for 1,000 m^3 of LNG shipped by sea, USD; L – liquefaction costs for 1,000 m^3 of natural gas, USD; Elng – length of the sea route, nautical miles (nm); S – gas tanker speed, knots; *dfr* – daily freight costs, USD; C – tanker LNG tonnage, thousand m^3; GT – gross registered tonnage of the vessel; *it* – icebreaker assistance rate per unit of gross registered tonnage, USD; Tr – cost of transshipment services from icebreaker tanker to a conventional vessel per 1,000 m^3 (if applicable), USD; P – toll for the passage through the Suez Canal per 1,000 m^3 (if applicable), USD.

Discussion and results. The final destination in this calculation is the port of LNG shipment with a regasification terminal (CIF shipment). The shipment costs consist of the vessel round trip (i.e. including the way back to the initial port for the next shipment) and a day allocated for LNG loading or unloading.

The following translation coefficients have been used: 1 tonne of LNG = 1.38 thousand m^3 of natural gas in a free state; 1 m^3 of LNG = 572.6 m^3 of natural gas in a free state; 1 MMBtu = 35.99 thousand m^3 of natural gas in a free state.

The authors have created formulas customized for mathematical modeling of extraction and transportation of natural gas from the Russian Arctic [4, p.705-716] in order to calculate the costs of its pipeline transportation and sea LNG shipment. Let us calculate these costs for the selected routes: to Northern Europe (Germany), Southern Europe (Italy and Turkey) and Asia Pacific (China). The choice of destination countries can be explained by the opportunity to compare both transportation cost figures under comparable routes.

The calculations were based on the following input data. The average costs of gas piping vary depending on the land across which the piping occurs. The average cost across the unified gas supply system in Russia and transit countries amounts to 5.5 USD per 1,000 m^3 per 100 km; for Belgium, Germany, Slovakia and Austria it is 2.5 USD per 1,000 m^3 per 100 km; for China – 2.0 USD per 1,000 m^3 per 100 km.

The liquefaction costs for 1 MMBtu of natural gas equal 2.85 USD, i.e. for 1,000 m^3 they are 102.57 USD. Regasification costs amount to 15 USD. In order to ship LNG to Northern Europe or directly to Asia Pacific across the Northern Sea Route, Arctic tankers Arc7 are used. Shipment to Southern Europe and to Asia Pacific across the «southern» route through the Suez Canal is carried out using conventional tankers without an ice-class; LNG transshipment from Arc7 to conventional vessels takes place in the port of Zeebrugge. Arc7 speed in ice (Kara Sea in winter-spring season, other Arctic seas in summer-autumn season under difficult ice conditions) amounts to 10 knots, speed of both tanker types in open water reaches 18 knots.

Arc7 tonnage is 172.6 thousand m^3 of LNG (98,830.76 thousand m^3 of free-state natural gas), conventional tanker's tonnage equals 145 thousand m^3 of LNG (83,027 thousand m^3). Arc7 daily freight rate is 110,000 USD, conventional tanker's – 33,500 USD. Transshipment costs for 1,000 m^3 of natural gas in Zeebrugge are 4.6 USD; Suez Canal toll (round trip) equals 6.37 USD per 1,000 m^3 of free-state natural gas or around 9 USD per 1 tonne of LNG.

Icebreaker assistance is required in the Kara Sea in winter-spring season and in other Arctic seas in summer-autumn season under difficult ice conditions. Relevant costs can be calculated using gross registered tonnage of the vessel (128,806 units) and icebreaker assistance rate per unit of gross tonnage: 5.42 USD for Kara Sea in winter-spring season, 4.38 USD for other Arctic seas in summer-autumn season.

The costs of pipeline transportation have been calculated for Bovanenkovo and Urengoy gas fields, the costs of sea LNG shipment – for South Tambey gas condensate field. To make the calculations more comparable to each other, the authors added additional expenses on gas transportation between the fields to the average costs: for the route «South Tambey – Bovanenkovo» (total dis-

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tance 170 km) they equal 9.35 USD, for the route «South Tambey – Urengoy» (760 km) they are 41.8 USD. Comparison between pipeline transportation ($CP_{pipeline}$) and sea shipment (CPlng) of 1,000 m^3 of natural gas from South Tambey gas condensate field along the main routes is presented in the Table.

Comparison between the costs of pipeline transportation and sea shipment of natural gas (USD/1,000 m^3)

Transportation route	Pipeline transport		Sea shipment	
	Distance, km (average)	$CP_{pipeline}$ (average)	Distance, km	CPlng
South Tambey – Germany	4270	235.84	4700	152.98
South Tambey – Italy	5570	279.38	8840	152.06
South Tambey – Turkey	5720	293.95	10330	153.56
South Tambey – China, through Suez Canal	7370	247.60*	24000	165.0
South Tambey – China, across Northern Sea Route	7370	247.60*	11600	151.0

* The cost of piping 1,000 m^3 of natural gas across 100 km via the Power of Siberia pipeline is approximately 6.3 USD, via major Chinese pipelines – 2 USD.

Russian Arctic gas can be transported to Germany via three main routes: «Bovanenkovo – Northern Sea Route / Northern Sea Rote-2 – Germany» (total distance 4,294 km); « Bovanenkovo – Yamal – Europe – Germany» (4,160 km); «Urengoy – Yamal – Europe – Germany» (3,860 km). The transportation costs for 1,000 m^3 of gas across these routes are 236.17, 228.80 and 212.30 USD respectively. Taking into account additional expenses on gas transportation from South Tambey field, the average costs of pipeline transportation of Russian Arctic gas to Germany equal 235.84 USD per 1,000 m^3.

Russian Arctic gas can be transported to Italy via two main routes: «Bovanenkovo – Northern Sea Route / Northern Sea Rote-2 – Italy» (total distance 5,579 km, including territories of Germany, Slovakia and Austria – 1,285 km) and «Urengoy – Druzhba – Italy» (5,254 km, including territories of Slovakia and Austria – 803 km). The transportation costs for 1,000 m^3 of gas across these routes are 268.30 and 264.88 USD respectively. Taking into account additional expenses on gas transportation from South Tambey field, the average costs of pipeline transportation of Russian Arctic gas to Italy equal 279.38 USD per 1,000 m^3.

Russian Arctic gas can be transported to Turkey via two main routes: «Urengoy – Blue Stream – Turkey» (total distance 4,709 km) and «Urengoy – TurkStream – Turkey» (5,220 km). The transportation costs for 1,000 m^3 of gas across these routes are 259.00 and 287.10 USD respectively. Taking into account additional expenses on gas transportation from South Tambey field, the average costs of pipeline transportation of Russian Arctic gas to Turkey equal 293.95 USD per 1,000 m^3.

Russian Arctic gas can be transported to China via the route: «Urengoy – Power of Siberia-2 – China» (total distance 2,700 km). The transportation costs for 1,000 m^3 of gas across these routes are 169.40 USD. However, it should be emphasized that most customers in China are located in industrial regions of the country, mainly in the South-East. Therefore, it would be more accurate to calculate the costs of transportation not to the border line, but to the main customers. The costs of further transportation from the North-West to South-East of China range from 65.60 (Beijing, 3,280 km across China) to 90.80 USD (Guangzhou, 4,540 km) per 1,000 m^3 of natural gas. Taking into account additional expenses on gas transportation from South Tambey field, the average costs of pipeline transportation of Russian Arctic gas to China equal 247.60 USD per 1,000 m^3.

Therefore, the average cost of pipeline transportation across all the routes in question equals 264.19 USD per 1,000 m^3.

Let us calculate the cost of sea LNG transportation to Germany via two routes: «South Tambey (Sabetta) – Zeebrugge – Belgian gas transmission system – Germany» (both transshipment terminal for Yamal LNG project and regasification terminal are located in Zeebrugge); «South Tambey

(Sabetta) – Brunsbüttel / Stade (Germany)» (in one of the ports Germany is planning to build its own regasification terminal). Total length of the sea route from Sabetta to Zeebrugge is 2,537.80 nm, including 485.96 nm in Kara Sea and 2,051.84 nm in open water. After regasification natural gas will be transported to Germany via Belgian gas transmission system (total length 230 km). The transportation costs via this route in winter-spring season are 153.64 USD, in summer-autumn season – 139.51 USD per 1,000 m^3. Total length of the sea route from Sabetta to Brunsbüttel / Stade is 2,429.81 nm, including 1,943.85 nm in open water. The transportation costs via this route in winter-spring season are 132.34 USD, in summer-autumn season – 118.21 USD per 1,000 m^3. Taking into account additional expenses on gas transportation from Bovanenkovo and Urengoy fields, the average costs of sea LNG transportation of Russian Arctic gas to Germany equal 152.98 USD per 1,000 m^3.

Let us calculate the cost of sea LNG transportation to Italy via the route «South Tambey (Sabetta) – Zeebrugge – Livorno (Italy) » (Livorno has its own regasification terminal LNG Toscana). Total length of the sea route from Sabetta to Zeebrugge and its costs have been calculated earlier. In Zeebrugge LNG is transshipped to a conventional tanker. Total length of the sea route from Zeebrugge to Livorno is 2,235.42 nm. The transportation costs via the entire route from Sabetta to Livorno in winter-spring season are 142.07 USD, in summer-autumn season – 127.94 USD per 1,000 m^3. Taking into account additional expenses on gas transportation from Bovanenkovo and Urengoy fields, the average costs of sea LNG transportation of Russian Arctic gas to Italy equal 152.06 USD per 1,000 m^3.

Let us calculate the cost of sea LNG transportation to Turkey via the route «South Tambey (Sabetta) – Zeebrugge – Aliağa (Turkey)» (Aliağa has regasification terminals Aliaga LNG and Etki LNG). Total length of the sea route from Sabetta to Zeebrugge and its costs have been calculated earlier. In Zeebrugge LNG is transshipped to a conventional tanker. Total length of the sea route from Zeebrugge to Aliağa is 3,039.96 nm. The transportation costs via the entire route from Sabetta to Aliağa in winter-spring season are 143.57 USD, in summer-autumn season – 129.45 USD per 1,000 m^3. Taking into account additional expenses on gas transportation from Bovanenkovo and Urengoy fields, the average costs of sea LNG transportation of Russian Arctic gas to Turkey equal 153.56 USD per 1,000 m^3.

Let us calculate the cost of sea LNG transportation to China via the following routes: «South Tambey (Sabetta) – Zeebrugge – Caofeidian / Tianjin (China)» (above mentioned ports near Beijing have regasification terminals Hebei Tangshan Caofeidian LNG and Tianjin respectively); «South Tambey (Sabetta) – Zeebrugge – Yangshan / Rudong (China)» (above mentioned ports near Shanghai have regasification terminals Shanghai Yangshan and Jiangsu Rudong LNG respectively); «South Tambey (Sabetta) – Zeebrugge – Shenzhen / Dongguan / Zhuhai (China)» (above mentioned ports near Guangzhou have regasification terminals Guangdong Dapeng LNG I, Guangzhou Dongguan LNG and Guangdong Zhuhai LNG respectively); «South Tambey (Sabetta) – Northern Sea Route – Caofeidian / Tianjin (China)»; «South Tambey (Sabetta) – Northern Sea Route – Yangshan / Rudong (China)»; «South Tambey (Sabetta) – Northern Sea Route – Shenzhen / Dongguan / Zhuhai (China)».

Total length of the sea route from Sabetta to Zeebrugge and its costs have been calculated earlier. In Zeebrugge LNG is transshipped to a conventional tanker. Total length of the sea route from Zeebrugge to Chinese ports through Suez Canal equals: to Caofeidian / Tianjin – 11,339.09 nm, to Yangshan / Rudong – 10,745.14 nm, to Shenzhen / Dongguan / Zhuhai – 9,989.20 nm. The transportation costs via the entire route from Sabetta to the ports are 166.25, 165.14 and 163.73 USD per 1,000 m^3 respectively.

Total length of the sea route from Sabetta across the Northern Sea Route to the Bering Strait equals 2,370.41 nm. The length of further transportation to Chinese ports is: to Caofeidian / Tianjin – 3,785.10 nm, to Yangshan / Rudong – 3,542.12 nm, to Shenzhen / Dongguan / Zhuhai – 4,287.26 nm. The transportation costs via the entire route from Sabetta to the ports are 145.17, 143.92 and

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147.96 USD per 1,000 m^3 respectively. Under difficult ice conditions, taking into account icebreaking assistance, the transportation costs will reach 156.59, 155.34 and 159.18 USD per 1,000 m^3 respectively. Taking into account additional expenses on gas transportation from Bovanenkovo and Urengoy fields, the average costs of sea LNG transportation of Russian Arctic gas to China equal 172.95 USD per 1,000 m^3.

Therefore, the average cost of sea LNG transportation across all the routes in question equals 157.89 USD per 1,000 m^3.

Conclusions. Basing on the above-mentioned calculations, let us carry out a comparative analysis of pipeline and sea (LNG) transportation of Russian Arctic gas via the routes in question. Sea shipment of 1,000 m^3 of natural gas as compared to pipeline transport is: for Germany – 82.86 USD cheaper (–35.1 %); for Italy – 127.32 USD cheaper (–45.6 %); for Turkey – 140.39 USD cheaper (–47.8 %); for China – 74.65 USD cheaper (–30.1 %). Across all the destinations, sea LNG shipment of 1,000 m^3 of natural gas is on the average 106.30 USD cheaper (–40.2 %) than pipeline transportation.

Calculations carried out by the authors confirm that sea transportation of Arctic LNG to the key existing and potential markets is economically more feasible than its pipeline transportation. Hence, the need arises to replace the natural gas piped to European markets for LNG (especially for Southern Europe, where LNG has greater competitive advantage) and to increase LNG export to Asia Pacific region. Taking into account current development trends of global and local markets, this will allow Russia to maintain and even increase its share in the global import of natural gas, to enter new markets and to diversify gas transportation routes.

However, certain conditions have to be met to make Russia a competitive exporter of LNG:

• continuation of already started projects and implementation of new ones associated with LNG production and transportation;

• growth of investments into proprietary liquefaction technologies that will enable cost reduction;

• ice-class optimization of LNG tankers, which can take into account operation experience of Arc7 tankers under Yamal LNG project, as lower ice-class vessels have lower freight rates;

• localization of LNG tanker construction in Russian dock yards;

• increasing state support for companies working in LNG production and transportation, as well as in development of relevant technologies.

Described measures allow to reduce the costs of sea LNG transportation, which would increase competitive advantage of natural gas in the global and local markets.

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