Decarbonized LNG: Creating a path to sustainable Arctic development

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Abstract. One of the most urgent issues of the global energy complex is its decarbonization. But it is impossible to make such a transition overnight; therefore, a transitional fuel is needed, such as gas. Natural gas has the lowest carbon emissions rate of all hydrocarbons fuels, it is vastly deposited and due to development of LNG technologies can be transported almost everywhere. The Russian Arctic zone is excellent for LNG production, as there are huge gas reserves concentrated there, the climate allows an optimal LNG production and there is a convenient logistics route. LNG production in this region must be as harmless as possible and with the lowest CO₂ emissions to preserve a sensitive environment. Decarbonized LNG is a liquefied gas with lowered amount of CO₂ emissions from production to consumption, or they were compensated by offset loans. This concept is quite new, but it allows gas to build a bridge to low-carbon future. This article explores all the ways of building carbon-neutral LNG value chain in Arctic and suggests the optimal way of providing sustainable development in region’s energy complex.

1. Introduction
Now, one of the most urgent issues of the global fuel and energy sector is its decarbonization: it’s wildly believed that extra carbon emissions result in global warming. First answer to the problem was to move away from hydrocarbon fuels and switch to renewable energy. But it is impossible to make such a transition overnight, and some sectors of energy complex could not be decarbonized only by using RES, therefore a transitional fuel is needed, such as gas. Natural gas has the lowest carbon emissions rate of all hydrocarbons fuels, it is vastly deposited and due to development of LNG technologies can be transported almost everywhere. Those conditions force us to pay close attention to the development of the LNG industry. The Russian Arctic zone is excellent for LNG production, as there are huge gas reserves concentrated there, the climate allows for cheaper LNG production with lower CO₂ emissions and there is a logistics route (the Northern Sea Route – the NSR), which allows cargo to be delivered both to the Asia-Pacific countries and to Europe. But considering Arctic a very climate-sensitive region, we need to be more persistent with decarbonizing our energy sources there and not only ban usage of highly intensive carbon fuels – such as oil products and coal but also limit CO₂ emissions from natural gas.

Decarbonized gas is a gas which production had lowered amount of CO₂ emissions, or they were compensated by offset loans. This concept is quite new, but its introduction confirms the fact that gas is really a transitional fuel and its share in the global energy balance will only increase. LNG
Decarbonization is a process that producers are interested in, they need to demonstrate their interest to their customers and stakeholders that they are as environmentally sustainable as possible.

There are two ways to decarbonize LNG: (1) Compensation for greenhouse gas (GG) emissions and (2) Reducing greenhouse gas emissions.

Offsetting or compensation for GG emissions is discussed briefly later in this article despite that it does not directly affect the reduction of carbon dioxide emissions at LNG production sites.

Today LNG is truly a global commodity and contributes to the growth of gas demand and consumption. The Russian Arctic zone is ideally suited for the development of the LNG industry as there are huge gas reserves concentrated there. Carbon-neutral cargo is already being delivered from the YAMAL LNG plant, and PJSC NOVATEK and its subsidiary TotalEnergies SE have signed a memorandum of cooperation in the field of decarbonization, hydrogen and renewable energy and are negotiating on decarbonization of LNG production, which means capturing CO2 emissions and injecting it into wells, as well as active use of wind energy, development of the use of renewable energy in Yamal.

It is very important to carry out the process of decarbonization of natural gas liquefaction at every stage of its production: from direct production to regasification at the consumption stage. This can be done in the following ways: capturing CO2 emissions during production and liquefaction, using renewable energy sources as energy sources for the plants themselves, creating a liquefaction technology with the least amount of CO2 emissions, delivering LNG on tankers that do not use petroleum products as fuel, mixing gas with hydrogen during regasification, thereby reducing emissions. It is especially important to understand that for this approach to be effective, it is really necessary to monitor greenhouse gas emissions throughout the entire value chain.

2. Decarbonizing LNG value chain

Decarbonizing the LNG supply chain faces challenges. One of the pillars of reducing our carbon footprint is a robust system for emission monitoring, reporting and ongoing verification of equipment, which will be provided on a regular basis with data that in turn will contribute to understanding the impact of emissions in the supply chain. However, at this stage, there is no such national or global system, and with a lack of data, it is difficult to achieve decarbonization of the entire supply chain. Of course, the lack of a global emission control system is not the only problem that will have to be faced with decarbonization:

- a fragmented gas value chain, where companies' reporting and obligations often cover only their own operations and not the entire chain;
- lack of a consistent methodology for measuring emissions;
- lack of appropriate certification bodies to ensure the reliability of emission estimates for various elements of the value chain.

Industry organizations and companies are beginning to fill these gaps, developing their own methodologies and setting their own emission targets. The first step in tackling value chain greenhouse gas emissions is to accurately identify these emissions. Because supply chains are global and not fully integrated, this calculation can be challenging, and there is a clear need for many sectors to develop practical and accurate approaches to defining it.

There are several ways to reduce greenhouse gas emissions throughout the entire LNG production chain:

- It is necessary to capture CO2 emissions at each stage;
- Use liquefaction technologies with the lowest greenhouse gas emissions;
- Use alternative types of energy to support production;
- Use LNG as fuel for the tankers that deliver it;
- For regasification, mix gas with hydrogen to reduce emissions during consumer use.
In the process of gas liquefaction emissions occur at the following stages [1].

*At a stage of source gas preparation:*
- Sulfur capture, tail gas installation and incineration;
- Refrigeration units;
- Power generation.

*At a stage of liquefaction:*
- Emissions of CO$_2$, SO$_x$, H$_2$S, NO$_x$ and particulate matter from exhaust pipes from gas turbine drives, which are the main source of CO$_2$ emissions;
- Increase the temperature of the cooling water and ambient air.

*At a transportation stage:*
- Emissions of CO$_2$, SO$_x$, NO$_x$ and particulate matter from propulsion engines of gas carriers;
- Flue gas emissions.

*At a regasification stage:*
- CO$_2$, SO$_x$ and NO$_x$ emissions from submerged combustion evaporators;
- Return of cold sea water;
- Mist formation if ambient evaporators are used to heat LNG.

As shown in Figure 1 [2], most of the CO$_2$ emissions are from the gas treatment and liquefaction stage, followed by LNG shipping and LNG regasification.

Thus, CO$_2$ emissions in the LNG supply chain can be significantly reduced using the following best available technologies:
- Improving the efficiency of the plant for liquefaction cycles and equipment.
- CO$_2$ re-injection from amine sequestration unit
- More efficient propulsion system for the movement of ships.
- Utilization of LNG cold at receiving terminals.

If the transportation distance is short and there are renewable energy sources such as hydropower or solar energy, CO$_2$ emissions can be further reduced. In short, a zero-emission LNG supply chain is possible [1].

In the situation of decarbonization of the LNG production process, the example of the Canada LNG plant in British Columbia, Canada is indicative. Greenhouse gas emissions from the liquefaction of gas at Canada LNG will be lower than any facility currently operating anywhere in the world: 35 percent lower than the world's most efficient plants and 60 percent lower than the global average.
value since LNG Canada will produce LNG that is produced and liquefied using renewable hydropower from the BC Hydro network [4].

Already, in the Russian Arctic Zone, NOVATEK is using renewable energy sources based on solar panels and wind generators, which feed the telemechanics systems for controlling the crane nodes of trunk pipelines and well pads of gas condensate fields. The company also has the Arctic Cascade liquefaction technology, the uniqueness of which is that it uses a natural cold climate, provides for the primary separation of ethane from natural gas in order to use it as a refrigerant in the first liquefaction cycle. The second cycle is performed with cooled nitrogen as a refrigerant.

NOVATEK actively cooperates with foreign partners in the field of decarbonization of the LNG production chain. For example, at the moment it is signed:

- memorandum of cooperation in the field of decarbonization, hydrogen and renewable energy with the subsidiary company TotalEnergies SE;
- agreement on cooperation in the development and implementation of innovative technological solutions in the field of compressor units and power generation from Baker Hughes for Novatek LNG projects with Baker Hughes.

The agreement will begin with a pilot program for the introduction of hydrogen mixtures into the main process of natural gas liquefaction in order to reduce carbon dioxide emissions at LNG facilities, including at the Yamal LNG complex of Novatek. Baker Hughes will provide engineering and turbomachinery equipment for the conversion of existing natural gas liquefaction lines to Yamal LNG for operation on hydrogen mixtures, and not only on methane. The plant's liquefaction production lines currently use a Frame 7/1EA single-shaft gas turbine provided for this project by Baker Hughes, which can be upgraded to run on hydrogen mixtures. Hydrogen mixtures provide significant opportunities for the natural gas sector to reduce the carbon emissions of turbomachinery for LNG.

Other technological solutions that are currently still not competitive in the market, such as carbon capture and storage, may become so with policies imposing carbon costs. Natural gas can be decarbonized through carbon use and storage (CCUS), or by mixing with hydrogen or biogas, a gas made from biological materials.

CCUS includes capturing carbon dioxide from the combustion of gas or other fuels in power plants and elsewhere, and either using it, which also includes capturing CO2 from the atmosphere, for example, in enhanced oil recovery or other industrial processes, or storing it underground.

To reduce the carbon footprint not only in the LNG transportation, but also, for example, in the marine shipment sector, it is possible to use LNG as a fuel for marine transport. The maritime sector is responsible for 90% of trade as well as 3% of total greenhouse gas emissions. One option to reduce emissions is to use more environmentally friendly fuel for ships. LNG is a cleaner fuel, better air quality and lower greenhouse gas emissions. Liquefied natural gas is competitively priced against conventional fuels as well as other alternatives.

Great attention is paid to the NSR, its development, at the moment the vessels that pass through it use fuel from petroleum products, thereby causing irreparable harm to the nature of the Arctic region. In order to reduce greenhouse gas and CO2 emissions, ships should be converted to LNG or other more environmentally friendly fuel, this solution will not only reduce emissions from transportation, but also reduce harm along the entire LNG production chain in total.

In addition to greenhouse gas and CO2 emissions, fuel oil fuels emit sulfur oxide during combustion, these emissions also need to be controlled and reduced to preserve the sensitive environmental background in the Arctic region of the Russian Federation.

Since January 2020, the global fuel content limit of 0.50% for all navigation areas has entered into force, this requirement is introduced in addition to the restrictions of 0.10% of sulfur in the North American and American regions of the Caribbean, Northern Sea and The Baltic Sea. International Maritime Organisation proposes to introduce similar restrictions in the Arctic region starting from 2025 and then all ships using the Northern Sea Route will be forced to switch to clean fuels, such as LNG.
3. Compensation for GG emissions

LNG sellers are preparing bids for the supply of carbon neutral LNG as more buyers seek additional environmental and sustainability measures. A carbon neutral LNG cargo is a liquefied gas cargo whose emissions are offset by compensation. Typically, this takes into account greenhouse gas emissions over the entire life cycle of a product (from extraction to end use), but at this stage there are differences in market approaches, which once again reflects the lack of a single and reliable system for tracking emissions. Such buyers tend to work with LNG sellers who best understand the need to manage and control emissions, while sellers who do not have such a focus may be excluded from the pool of potential suppliers.

Sellers either invest directly in offset credit production or offer to mediate buyers looking to interact with credible projects. The ability to transparently control and offset carbon emissions for LNG buyers can also generate additional revenue for LNG sellers.

To account for the full climate impact of LNG activities, carbon neutrality needs to be broadened to include more than just emissions CO₂ but also methane emissions are the largest components of emissions in the LNG value chain, the total of which can then be expressed in CO₂ equivalent. To declare a cargo carbon neutral, stakeholders involved in the LNG trade agree to buy carbon credits for an equivalent amount of the greenhouse gas emissions associated with the cargo. Each credit represents one ton of CO₂ removed or reduced in the atmosphere as a result of emission reduction projects.

Based on the Greenhouse Gas Protocol, which is the most widely used standard for accounting for greenhouse gases, product lifecycle emissions can be categorized and measured according to three categories:

- Category 1 emissions - direct emissions from own or controlled sources.
- Category 2 emissions are indirect emissions from the production of purchased energy.
- Category 3 emissions are all indirect emissions (not included in Scope 2) that occur in the reporting company's value chain, including emissions from both mining and processing.

Lifecycle emissions of a product are all emissions associated with the production and use of a particular product, from extraction to end-use, including emissions from raw materials, production, transportation, storage, sale, use and disposal.

The classification of categories can be interpreted in different ways depending on the type of activity of the given company (manufacturer, trader, utility, etc.), which can sometimes be confusing and lead to double counting problems.

On average, life cycle emissions of a typical LNG cargo (~ 175,000 cubic meters) are typically estimated at around 250,000 tonnes of CO₂ equivalent. This amount may vary depending on various factors such as: the source of the LNG, the type of liquefaction technology, the vessel used to transport the LNG, or the equipment and procedures used at the regasification terminal. According to the GHG conversion factors of the UK government, about 75% of greenhouse gas emissions from LNG are associated with its consumption (i.e. combustion of natural gas) [11].

There are already a number of examples of the supply of carbon neutral LNG cargoes in the market (for example, Shell, Tokyo Gas, JERA, ADNOC, Total and CNOOC - all of these companies were involved in carbon neutral cargo deals). Buyers in Japan, Korea, Singapore and Thailand have approached suppliers for carbon offset solutions during supply negotiations. The first such cargoes in Asia were one-time transactions. Shell announced five carbon neutral LNG shipments sold to buyers in Northeast Asia, starting with the first two shipments at Tokyo Gas and GS Energy in June 2019. Shell sold two shipments to CNOOC in June and one to CPC in March. While others are just starting to think about reducing their carbon footprint, Shell has built a portfolio of natural projects that produce certified carbon offsets as part of its goal of being carbon neutral by 2050.
4. Conclusion
Decarbonization of LNG production in the Russian Arctic zone is necessary for several reasons:

- preservation of a sensitive ecological background in the region;
- reduction of greenhouse gas and CO2 emissions;
- maintaining the competitiveness of Russian LNG on the world market and
devolution of LNG as a bunkering fuel of choice.

However, with all the need to implement decarbonization policies in the LNG industry, there is still no industry body established to develop guidelines for measuring, reporting and verifying carbon emissions from LNG cargo and carbon neutral LNG cargoes. Energy companies voluntarily provide grants for third-party research and development in order to gain knowledge about emissions in value chains. However, what is now voluntary emission data reporting may become a commitment when regulations change as governments in many countries pledge more efforts to tackle climate change.

Regulatory policies vary from country to country in terms of what is taken into account in the chain of production, transportation and consumption of LNG. Greenhouse gas regulation is constantly evolving and governments can begin to regulate cross-border carbon emissions. Some governments provide subsidies for carbon sinks and carbon sequestration facilities, and such subsidies are likely to grow.

Public action to reduce emissions in both LNG exporting and importing countries increases the uncertainty in the industry, and changes in government policies pose a significant risk. However, buyers and sellers continue to enter into 20-year long-term contracts that do not directly address the potential impact of decarbonization, be it commercial, regulatory, large-scale or legal [6].

To implement LNG decarbonization, an integrated model needs to be developed that will ensure financial viability and emission reductions. In order to start producing and supplying clean gas, technological and regulatory changes must be implemented at every stage of the chain: from the well to delivery to the consumer.

Exporting and importing countries have a role to play by expanding regulatory legislation, companies also need to be involved in this process by offsetting carbon emissions from their LNG cargo or exploring other options, such as reducing gas flaring, using carbon capture and storage technologies, as well as other technologies that will reduce emissions. Decarbonisation processes are financially costly, so companies should place financing at the center of their emission reduction strategies. A very important aspect that companies must solve together with the state is the distribution of the increased costs of the chain between its participants, including, among other things, consumers, as end users and taxpayers.

LNG trade has shown significant growth over the past decade, and according to most forecasts, global LNG demand is set to double by 2040 [11]. However, the climate change emergency calls for a determined effort by the natural gas sector to reduce carbon emissions in order for such growth to become a reality.

Regulatory requirements can heighten attention to greenhouse gas emissions in the LNG supply chain. The Covid-19 crisis and growing customer and investor awareness can also heighten interest in sustainability and demand for low-carbon activities. In this way, suppliers and buyers can voluntarily use offset solutions to maintain the value of their products and even create a competitive advantage, making LNG a premium product and a differentiator. In this context, carbon neutral LNG trading achieved through offsetting mechanisms is likely to become more frequent, regardless of the price level of LNG.

Quantifying and certifying emissions in the LNG supply chain is challenging, but not impossible. This requires the implementation of a reliable and recognized monitoring, reporting and verification system. This will require cooperation between buyers and sellers and efforts on both sides so as not to delay its development. When it comes to offset mechanisms, not all initiatives are of the same quality and therefore different emission reduction standards must be carefully evaluated and compared.

Finally, before any offsetting, avoiding and reducing emissions in the LNG value chain should remain a priority as they are the fastest, most efficient and sustainable ways to achieve carbon
emissions. Since ecosystems are affected by climate change, the more global warming progresses, the more difficult it will be to implement solutions to reduce emissions. Consequently, carbon offsets should not replace emission reductions, but they may well be an important part of the industry's efforts to curb climate change.

From the above, we can conclude that for the successful implementation of decarbonization of the LNG supply chain in Arctic region, it is necessary:

- Strengthen emissions regulations (including carbon pricing mechanisms);
- Expand access to government support for technologies;
- Political decision on the allocation of any additional costs associated with decarbonization of the LNG chain;
- Ban usage of highly emitting hydrocarbons for energy production on LNG sites;
- Stimulate fuel switch for maritime transport in Arctic region.

Especially it should be noticed that LNG from Arctic region already has the lowest carbon footprint: both in terms of emissions during production - due to low ambient temperatures, less energy is spent to liquefy gas than in warmer regions, and in the case of emissions during combustion - during pre-cleaning stage of the gas before the liquefaction process, most of the CO2 is removed from it.

From all the above, we can conclude that the production of carbon-neutral LNG in the Arctic zone is really promising and competitive, but it requires a lot of effort. An important factor for the decarbonization of Arctic LNG is the ultra-sensitive environmental background. Any intervention can lead to an environmental disaster and/or damage to population, flora and fauna. It is necessary to reduce greenhouse gas emissions as much as possible in order to avoid an even greater increase in temperature, as well as not to pollute the region with traces of human activity.

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