

LNG as a sustainable and safe fuel

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Abstract. Burning LNG to obtain heat and electric energy reduces greenhouse gas emissions considerably compared to burning coal in coal-fired plants. LNG is by many considered to be an ideal source of energy for the transition to zero greenhouse gas emissions. In the process of evaluating the sustainability of using LNG, all the emissions to the air must be considered. This also applies to the emissions resulting from the process of cooling the methane to liquid form for transport and the emissions resulting from heating the LNG to methane for easy energy production. Another source of pollution, that must not be forgotten, is the release of methane through leaking valves, etc. Methane is a very powerful greenhouse gas; in the short term, it is much more powerful than the CO₂ from burning methane. As all gas facilities require safety valves, it is also important that the methane is not vented into the atmosphere but burned in case of an emergency in the process facilities or during regular maintenance activities.

1. Introduction

CO₂ is a greenhouse gas that contributes to global warming. It is a goal internationally to reduce the emission of CO₂ into the environment, and all contributions to this goal are being considered. According to the US Energy Information Administration [1], the CO₂ emission per million BTU (BTU stands for British Thermal Unit, a measurement of heat energy, defined as the amount of heat needed to raise one pound of water by one degree Fahrenheit) is 95.99 for coal (113.67 for coke) and 52.91 for natural gas (i.e., methane used for heating). This shows the benefit of burning gas compared to coal.

Furthermore, burning coal will give rise to the emission of Sulphur, depending on the cleanliness of the coal. Likewise, gas is normally cleaned at the production site using energy to separate out CO₂ from the well stream, and other compounds that, to a varying degree, contaminate the gas. The well stream will, however, normally include smaller amounts of other types of high-value hydrocarbons, like propane, butane, and condensate (light oil). Of concern is that production of gas from shale which often leads to heavy pollution, due to the high use of energy in the production process.

The transport of the energy is not included in the CO₂ release numbers given above. Coal is relatively easy to transport in bulk and is easily available on the world market. Gas, however, is more difficult to transport; large volumes are transported by pipelines that are costly to build but efficient to run. For long-distance transport, compressor stations are needed to keep the pressure in the pipeline to secure the flow. An alternative to pipeline transport is to cool down the natural gas to Liquefied Natural Gas, LNG, for transport by specially built vessels. Note that the volume of

the natural gas is compressed 600 times when cooling it to - 162 °C. LNG is now available from several producers, competing for the market, see Figure 1.

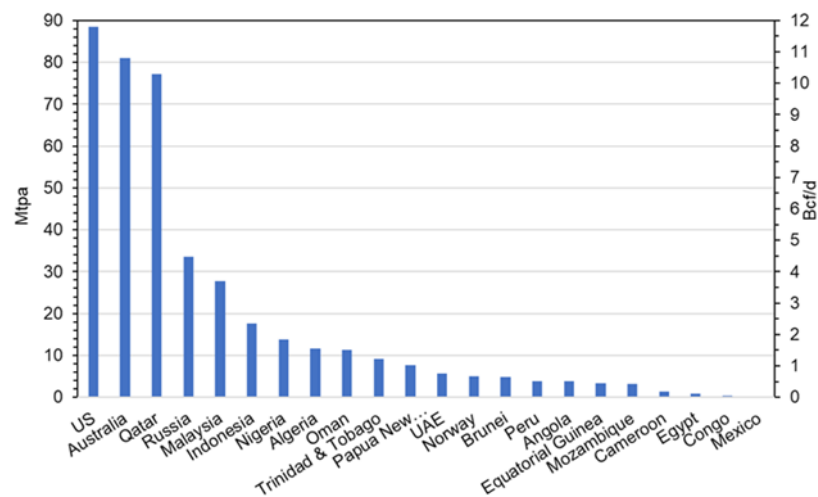


Figure 1. In 2024, there were 22 countries exporting LNG, led by the USA, Australia, Qatar, Russia, and Malaysia. Combined, these top exporters accounted for 75% of the world's total [2].

It should be noted that the LNG export from Russia is just above 33 million tons per year, and that new producers such as Angola and Mozambique (Figure 2) are starting to export LNG and are planning to expand their LNG production.



Figure 2. The Coral Sul Floating LNG production vessel offshore Mozambique. Photo: ENI

The availability of LNG on the world market has made it possible for countries previously basing their electricity production on pipeline gas to continue to use their electricity-generating system based on gas. Regasification units transferring LNG to gas are required to ensure this. Thus, European countries previously having imported a large volume of Russian gas have been able to transfer their energy production to the use of LNG. Specifically, Lithuania could be mentioned, where a ship-based regasification unit was anchored as a liquefied natural gas import terminal (Figure 3) in the port of Klaipėda when it was decided to stop gas import from Russia.

The country of Vietnam could, in the same way, import LNG to compensate for falling offshore gas production, rather than to increase the burning of coal [3].



Figure 3 Lithuania's LNG terminal Independence was leased from the Norwegian shipowner Høeg from 2014 and eventually bought by Lithuania in 2024. (T. Biliunas/BNS).

2. Rising concerns

Concerns are, however, rising about whether the large reduction in CO₂ emissions and greenhouse gases is real [4]. When changing from coal to LNG, it must be noted that the production (the cooling of the methane), transport, and regasification of LNG require energy. The loss of energy due to these processes must be included in the calculation of the total emission. According to Pospíšil et al. [5]: "Liquefaction of Natural Gas is an energy-demanding process, and based on the performance evaluation of real-life liquefaction terminals, the energy need of the process was determined to be equivalent to up to 10% of the supplied natural Gas. The energy spent on the liquefaction process can; however, be recovered by the utilization of the cold from the LNG during the regasification process." During the transport, some LNG will, furthermore, boil off and be transferred to natural gas. To avoid the direct release of the natural gas to the atmosphere, the boil-off gas should be used to fuel the vessel's engines.

The most challenging aspect of LNG production and use is the release of methane during the process of generating, transporting and burning the LNG. Methane is a very powerful greenhouse gas; although it has a much shorter atmospheric lifetime than carbon dioxide (CO₂) – around 12 years compared with centuries, methane has 25 times the global warming potential of CO₂ [6]. UNEP's Climate and Clean Air Coalition [7], furthermore, claims that "methane is much more efficient than CO₂ at trapping radiation. Per unit of mass, methane has a warming effect 86 times stronger than CO₂ over 20 years. Over 100 years, methane is 28 times stronger." The European Commission [8] similarly claims that "on a 100-year timescale, methane's global warming potential is 29.88 times that of carbon dioxide and 82.5 times more on a 20-year timescale."

To reduce the emission of methane, any intended release of gas from the process must, therefore, be stopped; no excess gas should be vented but burned (although this will increase the

direct release of CO₂ to the atmosphere). It must be noted that all facilities handling gas must have safety equipment, ensuring pressure release in case of emergency or required maintenance.

There are examples where venting has been preferred to hide the visible burning of gas and the emission of CO₂. Such actions are not compatible with the sustainable use of gas or LNG. One example is the large oil field Johan Sverdrup in the North Sea. The emission of CO₂ is very limited as the field facilities are powered by electricity from the shore, and the development is considered to be environmentally clean. However, gas that must be released during the production for equipment testing or for safety reasons is not burned but released through cold venting. [9]. In 2024, 412 tons of methane gas were released. Note that the other oil and gas fields on the Norwegian shelf also release methane directly into the atmosphere. Another example is the Leviathan gas field offshore Israel, where excess gas is released and not burned.

An important measure during the handling of LNG is to ensure that all equipment is regularly maintained and that leakages of methane are avoided. The low temperature of the LNG furthermore calls for the use of cryogenic materials to avoid leakages, in particular steel and sealings used for valves [10].

Some environmentalists claim that LNG represents a stronger greenhouse warming potential than coal. It is possible to challenge such statements; however, the associated release of methane should be considerably reduced. IEA [11] has investigated the benefits of using LNG versus coal. IEA states that: “Globally, on average, LNG results in about 25% less emissions than coal.” Furthermore, IEA reports that “emissions from LNG supply could be cut by more than 60% using today’s technologies – and many measures could be implemented at low or moderate cost. Reducing methane leaks alone could cut annual emissions by close to 90 Mt CO₂-eq, or 25% of total LNG emissions, and around half of that reduction could be realized at no net cost. Reducing flaring at the LNG facilities and fields providing feed gas could lower annual emissions by a further 5 Mt CO₂-eq.”

A recent concern is that the supply of LNG is being restricted by the closure of the Hormuz Strait for the transport of LNG from Qatar and the facilities in the Gulf, and through the sanctions against Russian oil and gas, Figure 4. This shows that a mix of sources for energy is needed to ensure the energy needs of a country. It should be noted, however, that the LNG production capacity is on the increase worldwide, for example, in African countries, in Indonesia, and in Australia.



Figure 4. LNG tanker at port in Sabetta, where NOVATEK has its YAMAL plant. Photo: NOVATEK. Note the icebreaking capability of the LNG carrier. The international sanctions against the use of oil and gas from Russia are disturbing the LNG market.

3. The Safe Use of LNG

Safety measures related to the transport and storage of LNG have proven reliable, as specific requirements in standards are implemented. For example, Eurocode 1 for the design of structures [12] defines LNG units to be in high consequence class. The International Standardization Organization (ISO) has issued several ISO standards for the handling of LNG. Thus, the handling of methane gas and LNG necessitates constant safety awareness. Risk analysis of all aspects of the handling and use of LNG is recommended (see ISO/TS 16901:2022 [13]). Concerns must be taken regarding the offloading in harbour facilities, and the placement and design of storage tanks, which potentially could leak. Note that LNG leakages cause a very low temperature cloud to escape, freezing everything in the cloud to death. And at a certain mix of methane and air, the LNG vapor will lead to explosions, if ignited [14].

Vinnem [15] discusses the risk associated with the operation of an LNG plant in an urban area, Risavika Bay near Stavanger, Norway, see Figure 5. Note that the LNG plant is located next to an international ferry terminal. It is shown that the risk to people (including the risk to third party personnel) is in the ALARP region, and that the risk should have been reduced through mitigating measures. Of concern is that for onshore facilities, there was no obligation at the time of facilities planning, to carry out risk analysis, while for offshore facilities, the authorities have required proper risk analysis. ISO/TS 16901:2022 [13] was, however, later prepared to ensure risk analysis of onshore plants for Liquefied Natural Gas.

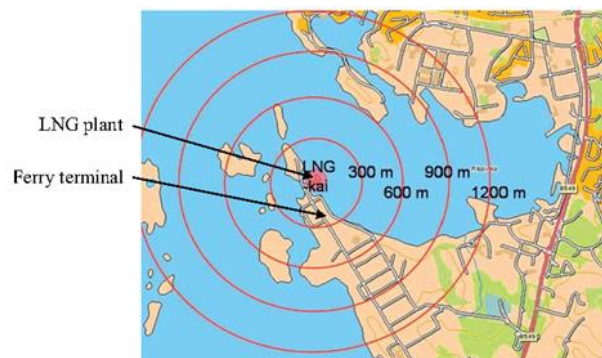


Figure 5. Location of the LNG plant in Risavika Bay, on the SW coast of Norway.] [15].

It can be noted, however, that ships transporting LNG in and out of the harbour are followed by tugboats that are linked to the ships to stop the ships quickly in case of urgency, see Figure 6.



Figure 6. LNG carrier sailing into Risavika, Tananger, Norway, supported by a tug. Photo: The author.

4. Limitations regarding the use of LNG

It can be documented that LNG is not a suitable fuel for vessels working in a dynamic positioning (DP) mode, as the reaction time is too long for LNG-fueled engines to react as quickly as needed for a vessel in a DP mode. In the case of DP vessels, it is necessary to have backup from batteries that will give an immediate reaction to adjust the location of the DP vessel [16]. The need to carefully evaluate the selection of the best fuel for a task should be highlighted.

At present, LNG is in high demand and there is a limited supply caused by the closure of the Hormuz Strait. The LNG capacity is increasing worldwide, however. The world's increasing population needs energy, and LNG is a type of energy that is available until it may be substituted by other sources that pose less harm to the environment. Those who question this (see, for example, [17], must consider realistic alternatives.

5. Conclusions

LNG is provided by many gas companies, and the LNG industry is constantly expanding. Safety measures related to transport and storage of LNG have proven reliable; however, it must be recognized that handling methane gas and LNG require a constant safety awareness. Risk analysis of all parts of handling and use of the LNG is recommended. Concerns must be taken regarding the offloading in harbour facilities, and the placement of storage tanks, as LNG leakages cause a very low temperature cloud when escaping, freezing everything to death. At a certain mix of methane and air, explosions will also occur.

The question of whether LNG is a sustainable source of energy is difficult to answer. The following measures should be fully implemented to ensure that LNG is a sustainable and safe energy carrier:

- Boil-off gas during transport should be used to fuel the vessel's engines.
- Methane release during the production, transport, regassification, and use should be kept to an absolute minimum.
 - o This can be achieved by burning (rather than venting) excessive gas that must be released for safety and maintenance reasons, and ensuring that all valves and possible leak points are maintained and kept tight.
- Safe use of LNG is key to successful use. Careful procedures and constant maintenance are required. Site-specific risk analyses are obligatory [13].
- There are technical limitations to the use of LNG, as demonstrated by limited use for stand-by vessels offshore. The engineers must be consulted to ensure that LNG is a suitable fuel for new tasks.

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