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THE EVOLUTION OF SHIP'S SAVING ENERGY POLICY IN THE WORLD

O.O. Petrychenko. PhD; M.O. Кulakov, PhD; D.O. Prytula, master (NU «OMA»)

Environmental problems and rising fuel prices lead to the need to search for alternatives. The main goal in this matter is to find all kinds of energy sources that will lead to a decrease in CO2 and sulfur emissions into the atmosphere and can be used more efficiently than the currently used types of fuel [1]

The International Maritime Organization has introduced the most severe measures in the Emission Control Areas - in such regions it is possible to use only such fuel that contains no more than 0.1% sulfur. These areas include: Baltic Sea, North Sea, Caribbean Sea, North America (including Canada), USA [2]. The coordinates of all such areas are defined in Chapter VI of the MARPOL convention [3].

Now let's consider what requirements apply to all other areas. For the first time, measures for areas other than ECA were introduced in 2005, when the IMO obliged all ships to use fuel with a sulfur content of not more than 4.5%. In 2012, this figure was reduced to 3.5%. On January 1, 2020, the IMO 2020 convention was adopted, which introduces much stricter restrictions on the fuel - the permissible amount of sulfur in the fuel should not exceed 0.5%. Or the second option is possible - installation of a scrubber. In this case, the vessel is allowed to transport fuel with a sulfur content of more than 0.5%, due to the principle of the scrubber operation, because of which the outgoing gases are 98% cleaned of oxide elements, which prevents damage to the atmosphere [4]. According to a report from the MPA (Maritime and Port Authority) Singapore, almost all ships calling in Singapore comply with the IMO 2020 requirement. The only exception were a couple of ships that were subsequently detained [5]. Another way to comply with IMO 2020 standards is to switch to other types of fuel, such as liquefied gas and others. Also, IMO has plans to reduce greenhouse gas emissions by 50% by 2050.

There are several types of scrubbers [6], but the principle of operation is the same for all of them. In the picture (fig. 1) a simplified diagram of the scrubber operation is shown, which in reality can have up to several dozen nozzles

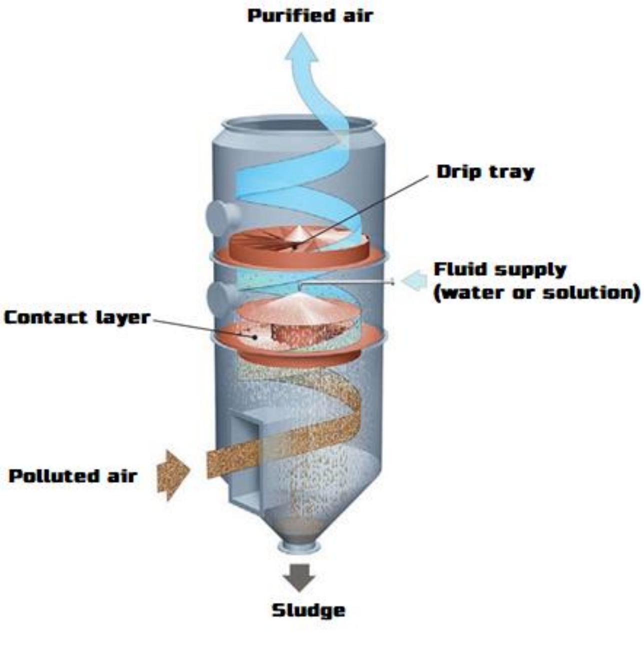

Fig. 1 - The principle of scrubber’s operation on ships

There are scrubbers with open and closed cycles. The first type takes water for purification from the kingston box and pumps it through a scrubber, purifying the air from sulfur, after which this water is discharged overboard.

In scrubbers with a closed cycle, about the same thing happens, only the water as a result does not drain overboard, but remains on the ship and is discharged in ports as sludge. There is also a hybrid system (fig. 2) that includes the ability to use both of these cycles.

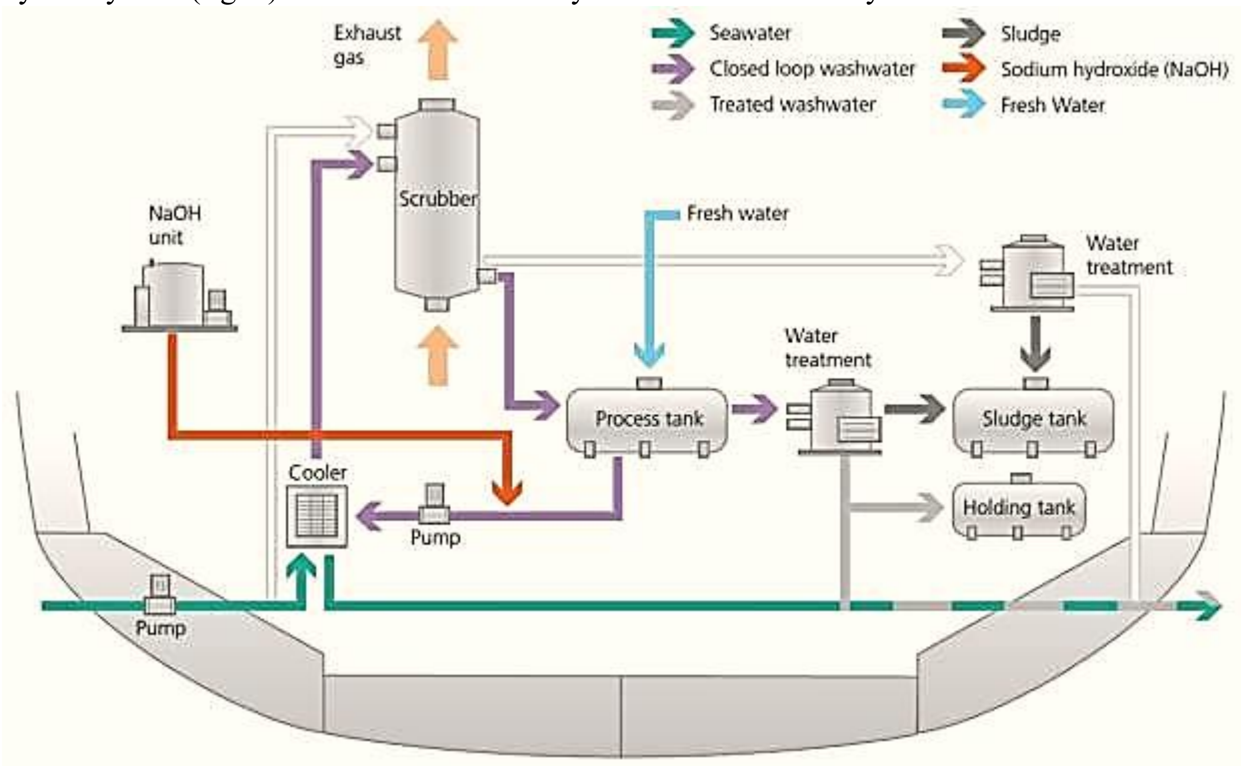

Fig. 2 - Schematic diagram of the operation of the hybrid cycle scrubber

According to DNV GL statistics, there are 4669 vessels equipped or being built with a scrubber. One fourth of these all ships are bulk carriers, half are container ships and tankers, and the rest are ships of all other types. Almost ¾ of the vessels were re-equipped with scrubbers, but did not have them initially.

The second option to meet IMO 2020 requirements is to buy and use VLSFO - very low sulfur fuel oil [7]. Firstly, it is worth noting that for a complete transition of the vessel from heavy fuel to low-sulfur fuel, it is necessary to completely clean the entire system of fuel tanks, pipes and equipment for fuel processing.

Another possible cons of this fuel is that the researchers found higher soot emissions in the low sulfur VLSFO fuel than its predecessor, high sulfur fuel oil (HSFO). This is stated in the report submitted by Finland and Germany to the International Maritime Organization (IMO). The presented research results, funded by the German Environment Agency and with technical support from the classification society DNL GL and engine manufacturer MAN Energy Solutions, show that new marine fuel mixtures with a sulfur content of 0.50% may contain a large percentage of aromatics, which have a direct impact on soot emissions (fig.3).

The submitted documents urge the inclusion of aromatics in the ISO 8217 marine fuel specification. A number of research and production associations have already called for a ban on low-sulfur, aromatic marine fuels for use on ships, especially those sailing through Arctic waters.

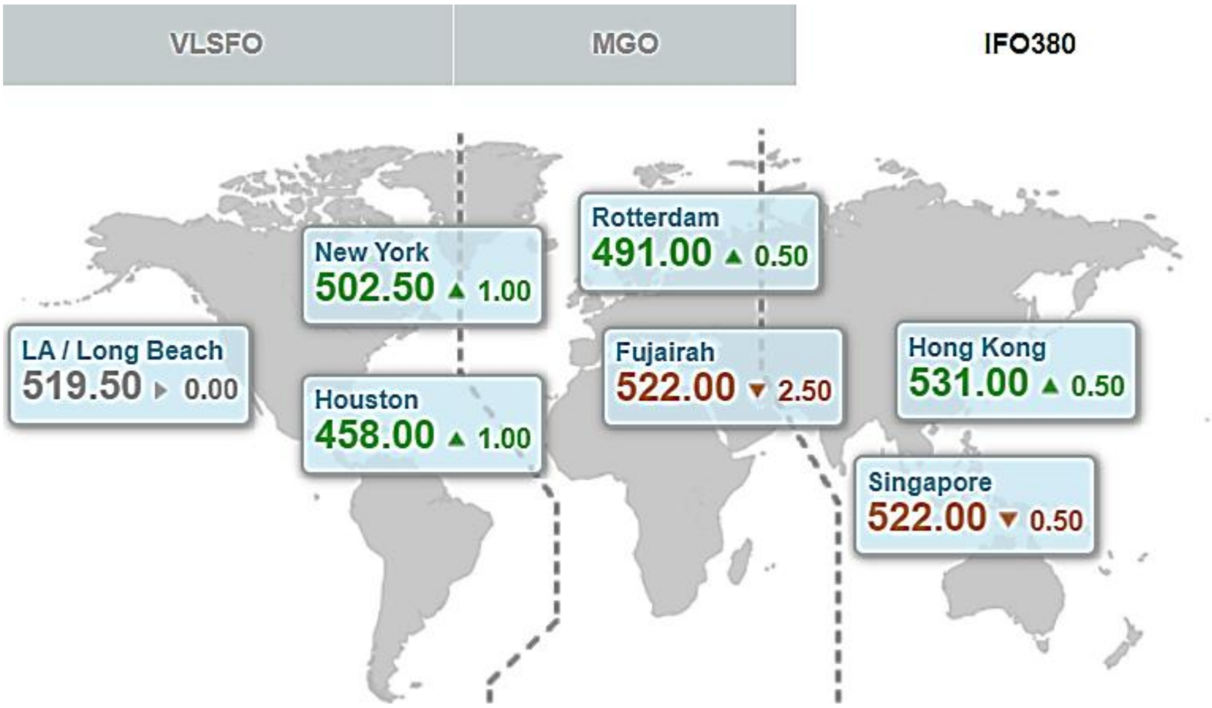

Fig. 3 - Heavy fuel prices in different countries of the world

Thus, the initial conclusion can be drawn that the advantages of using low sulfur fuel instead of installing a scrubber are not obvious. First, the complete conversion of a vessel from heavy fuel to low-sulfur fuel is quite expensive and not an easy process. Secondly, it is much more expensive in the long run. Thirdly, a number of studies show that even this fuel can be harmful to the environment. Therefore, it makes sense to consider what other types of fuel can be used in shipping (fig. 4).

Fig. 4 - Low sulfur fuel prices in different countries of the world

First of all, when considering alternative fuels, we need to understand that they should be evaluated according to three criteria; availability, environmental sustainability, security.

The list of the most promising alternative fuels includes: LNG (Liquified Natural Gas); LNG (liquefied natural gas); electricity; Methanol fuel (fig.5).

LNG was first used as a fuel in gas carriers in the 1960s. The cargo on board was used as a power source for the main engine, and thus almost zero fuel costs were ensured when loading ships [8]. This has made a significant contribution to the development of technology and the use of LNG as a fuel.

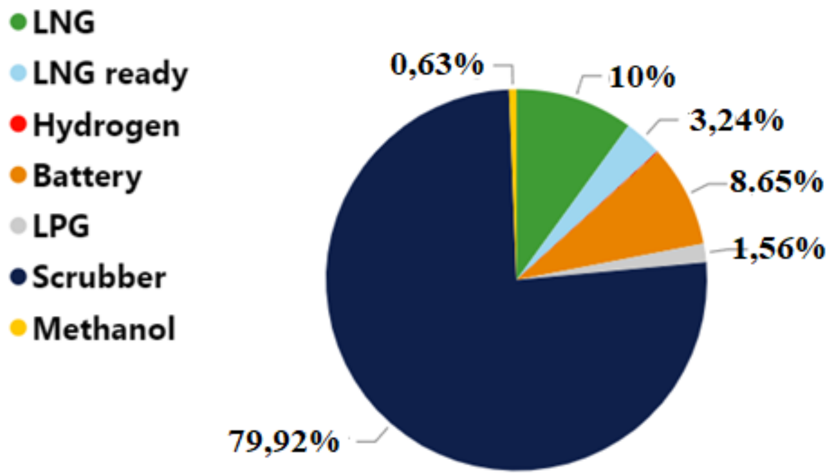

Fig. 5 - The total number of ships using different types of fuel

Comparing prices for low-sulfur fuel and gas is quite problematic (fig. 4), since this difference depends a lot on the tendencies of the world market, which tend to change very fast.

Now let's look at the impact of natural gas on the environment. First of all, it should be said that sulfur emissions when using gas are up to 90% less than when using heavy fuel. Natural gas is also popularized because its CO2 emissions are lower than coal or oil, but on the other hand, methane, the main component of natural gas, is 25 times more potent as a greenhouse gas than CO2. Consequently, methane leakage during the extraction, transportation and use of natural gas can, in principle, negate the benefits obtained from the switch to another type of fuel. The US Environmental Protection Agency estimates the leakage to be 1.3%, while other researchers suggest a leakage rate of up to 3%, particularly in shale gas production. Most natural gas engines currently operate using the Otto cycle, an engine combustion principle in which combustion air is premixed with natural gas before entering the engine[9]. It has been shown that this combustion medium often results in an increased concentration of methane in the exhaust, commonly referred to as methane slip. This leakage is approximately 3%.

According to DNV GL calculations, a total methane leak of 5.5% (including production / transportation and combustion) will bring greenhouse gas emissions from LNG to levels equivalent to those from diesel. Therefore, the problem must be solved by reducing leaks both during production and during combustion in engines. While there are no regulatory requirements to reduce methane slip in marine engines, various technologies can be used to address this issue. In Otto cycle engines, the amount of unburned methane can be reduced by means of an EGR system, which improves combustion stability, or by post-treatment of the exhaust gases. Diesel engines can use a high pressure dual-fuel injection concept, resulting in reduced NOX emissions. With this approach, natural gas does not mix with air before entering the engine. Instead, it is injected directly into the combustion chamber during the compression stroke following pilot diesel injection. Engine manufacturers say this technology limits methane slip to about 0.1% slip, which virtually eliminates the problem.

In conclusion, it can be said that the use of LNG can reduce greenhouse gas emissions by up to 25%, provided that methane leaks can be eliminated during the production and combustion stages. In practice, some leaks are to be expected and best practices and appropriate technologies should be used to minimize them. This can lead to real reductions in greenhouse gas emissions by 10-20% compared to conventional petroleum-based fuels.

Obviously, fossil LNG cannot be classified as an environmentally friendly fuel, but it has the advantage of reducing sulfur and nitrogen oxides emissions as well as reducing greenhouse gas emissions when used correctly.

In terms of safe use, LNG has a number of advantages over other fuels:

- methane vapors are lighter than air and dissipate quickly, unlike other fuels, which accumulate on the ground and pose a great fire hazard, as well as leave stains, sludge and other dirty residues. Thus, LNG is completely safe for the marine environment.

- methane is non-toxic.

- All LNG tanks are double-walled and very thick, which makes them much stronger and more reliable than tanks for other fuels and chemicals.

Batteries today are the most common storage facility where electricity can be stored and used in the future to power a ship. There are 337 battery powered vessels in operation worldwide today, with another 195 under construction. Such vessels are divided into two types: hybrid ships, completely electric.

Depending on the method of generating electricity on the grid, energy losses can be reduced. The potential for reducing emissions largely depends on the structure of electricity: in regions with a high level of use of renewable sources or nuclear energy, emissions of both greenhouse gases and other pollutants will be low (fig. 6).

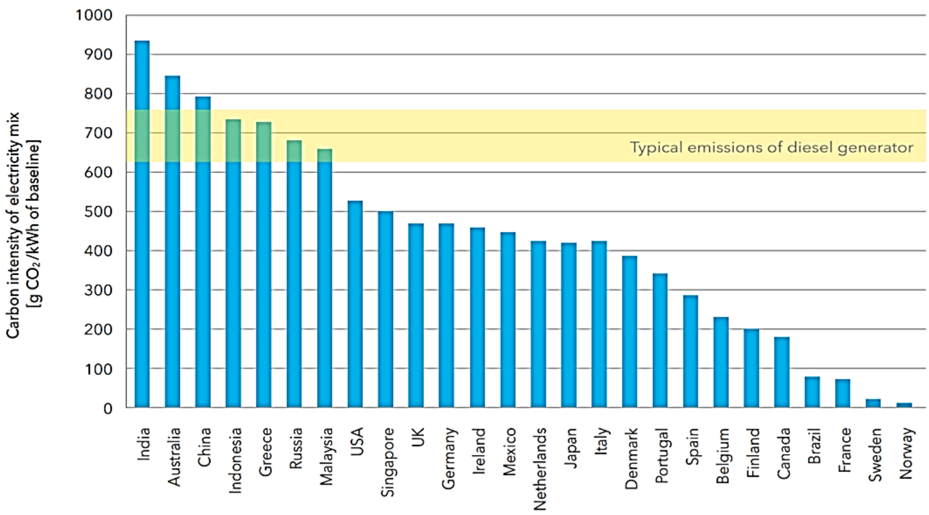

Figure 6 - Specific carbon emissions in electricity production in different countries

The figure shows the carbon intensity of electricity structure in different countries, expressed in grams of CO2 equivalent emitted per 1 kWh of electricity produced. Other emissions such as NOx, SOx and particulate matter will show similar trends. The differences between countries can be attributed to the extent to which carbon-free energy sources have penetrated into each country's electricity mix [10].

Using onshore electricity also provides significant reductions in local emissions, which is an advantage for ships operating near densely populated areas such as local ferries. Operating costs can be low, provided the electricity price is competitive with the prices of marine fuel.

Methanol is an alternative fuel, otherwise called methyl or wood alcohol. Interest in methanol as a marine fuel increased after Stena Line decided to convert one of its vessels to use methanol as a solution to the low sulfur fuel problem.

First of all, methanol has a big advantage over other alternative fuels - it is similar to current marine fuel in the sense that it is liquid. This means that the existing fuel storage and refueling infrastructure will require only minor changes for methanol processing, which will require relatively modest infrastructure investment costs compared to the large investments required to build liquefied natural gas (LNG) terminals or power supply systems [11]. What's more, the ship's engine can also run on low sulfur fuels, switching to them and back to methanol completely painlessly, with both systems completely isolated, with separate fuel and supply tanks and separate bunkering manifolds (fig.8).

The toxicity charge was used to counteract the development of methanol. In fact, methanol is one of the five major marine chemicals that have been safely handled for over 50 years. Methanol is no more toxic than heavy or low sulfur fuels. With proper handling of this fuel, personnel will not come into contact with it in any way.

Methanol has been shipped worldwide for decades. It is available worldwide through existing infrastructure in over 100 ports around the world and there is no difficulty in purchasing methanol for bunkering. Methanol is either available or in close proximity to many ports. Since methanol bunkering is similar to distillate fuel, very few modifications to the existing bunkering infrastructure are required. There are currently several global bunkering suppliers and trading platforms interested in supplying methanol fuel for ships.

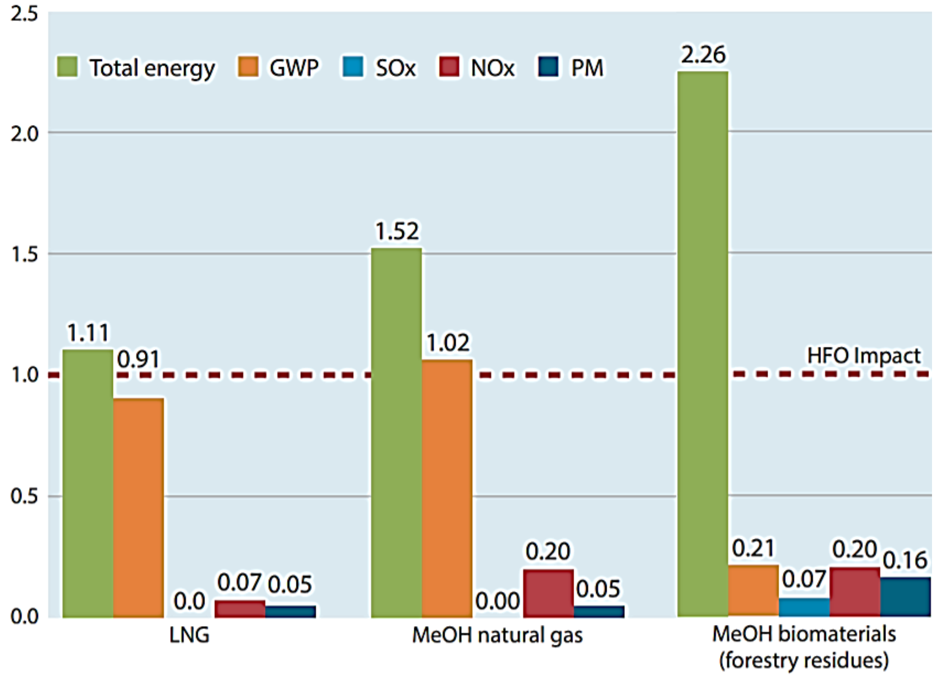

Fig. 8 - Comparison of emissions during LNG and methanol production

For a more visual conclusion, a general table is presented for assessing different parameters of all considered types of fuel:

The scrubber is the most profitable in the long term, since for several million the shipowner gets the opportunity to supply the vessel with the cheapest fuel, which pays off in just a couple of years. It is also easy to install on a ship and can be done in most docks in the world. However, the scrubber does not solve the problem of pollution at all and has no long-term prospects given that the IMO plans to further tighten the requirements for environmental pollution from ships [12]. In an accident, a heavy fuel oil spill is a terrible natural disaster that destroys all flora and fauna in the vicinity.

Low sulfur fuels are quite expensive, but still cheaper than LNG. For the complete transition of the vessel to this type of fuel, it is necessary to flush all tanks and systems, however, in comparison with the installation of systems for other alternative types of fuel, this is a much easier process. It is supplied to all parts of the world. Against the background of heavy fuel, low-sulfur fuel has a much milder effect on the environment, but in comparison with other alternatives, it still loses [13]. When spilled, the impact of this fuel is no better than a heavy one. In the next few decades, this fuel will definitely meet IMO standards, but in the distant future it may happen that it will not meet the standards.

Today Liquefied natural gas is the most expensive of all fuels compared in this work. Equipping a vessel with an LNG power system requires a complete redesign of the vessel's fuel system, and it should be borne in mind that LNG takes up a larger volume with the same energy efficiency as other fuels, which further reduces its profitability [46]. It is not possible to supply a vessel with gas in all ports of the world and it will take more time before LNG bunkering systems are available everywhere. With due observance of the standards during the production of LNG and its use, this fuel has almost no effect on the environment. During a spill, the gas evaporates quickly and does not harm the environment.

Electricity is a very controversial alternative and highly dependent on the place of its production. In some countries, like Norway, it is the best choice for local ships, as it is cheap there and generating electricity causes minimal damage to the environment. Electricity itself during use does not affect the environment in any way. To make a ship capable of sailing exclusively on electricity, you need to install a completely different power system than a fuel one, which is very costly and problematic. If the batteries are damaged, it can have catastrophic consequences for the vessel itself, its crew and cargo, and for the environment [14]. The prospects for electricity as an independent fuel are dubious. Most likely, electricity can become an auxiliary form of energy to reduce the cost of the main fuel. It is also possible that the system of supplying the ship with electricity in the port will become relevant, which will allow shipowners to save well.

Methanol is the most promising, but so far underestimated fuel. It is cheaper than LNG and takes up less space with the same energy efficiency, making it more competitive with low sulfur fuel than gas. Converting a vessel to methanol requires doing the same as converting to low sulfur fuel, which is not a difficult process. As long as methanol is available in few ports in the world and in order to begin its mass use, its production must acquire a large scale. Its impact on the environment is the most beneficial both in extraction and in use. Also, its significant advantage is that methanol is a renewable resource. In an accident, methanol quickly reacts with water and dissolves, making it harmless.

During the search and analysis of information for this report, such types of energy sources as hydrogen and ammonia were also considered. However, at the moment they absolutely cannot provide competition to the types of fuel described in this work, since their production and price are much more expensive, they take up even more space than LNG, during an accident they pose a great danger to the ship's crew and the environment. From the point of view of the impact on the environment, the use of these two types of fuel with proper technologies can be even more harmless than that of methanol, but the development of such technologies has not yet been completed.

Thus, according to the findings of this research, methanol is the most likely fuel for the near future.

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