Greener Shipping in the Baltic Sea

June 2010

MANAGING RISK DNV

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Executive summary

The environmental situation in the Baltic Sea is drastically worsened in recent years, and the shipping industry is one of several contributors to local pollution, particularly in terms of NOx, SOx, and particle emissions.

With the objective of saving the marine ecosystems in the Baltic Sea, several actions are being implemented; one of these is emission reduction requirements for the shipping industry. These requirements are being implemented gradually and will have full force in 2015 and 2016, leaving shipowners a limited number of options for modifications to their ships if they want to continue trade in the Baltic Sea. Of these options, LNG fuelled engines is the best option both from an environmental and an economic point of view. An LNG fuelled ship reduces the emissions of NOx by 85–90%, and SOx and particles by close to 100% compared to today's conventional fuel. In addition LNG fuelled ships will come with 15–20% reduction in net GHG emissions. Implementing LNG fuel on a significant portion of the fleet is the best and most cost-efficient solution for reducing environmental emissions in the Baltic Sea.

Baltic shipping statistics

In 2008 the trade volume in Baltic Sea shipping was 822 million tonnes[1]. This constitutes about 11% of the global shipping trade volume and makes the Baltic Sea one of the areas in the world with the highest density of ships; about 2,000 ships are present in the Baltic Sea at any point in time.

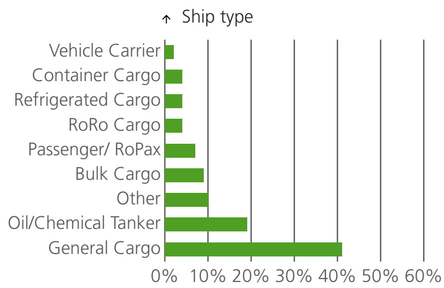
About 58% of the trade is exports through a few dominant ports, with oil exports from the Russian ports in Primorsk and St. Petersburg being major contributors. About 33% of the trade is imports through a large number of smaller ports. The remaining 9% is domestic trade for the countries with Baltic Sea coastlines.

As the graphs illustrate, more than 40% of the ships trading in the Baltic Sea are general cargo ships. These are typically ships that do not cross larger oceans; they stay for the most part, if not inside the Baltic Sea, at least in Northern Europe. Oil and chemical tankers, bulk carriers, and passenger ferries are other major ship types operating in the Baltic Sea.

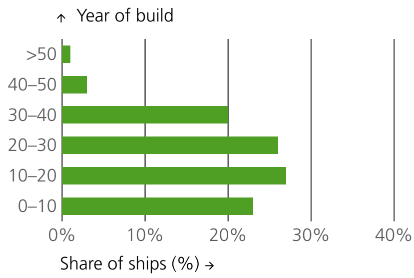
The age of the ships operating in the Baltic Sea is fairly evenly distributed from new to about 40 years old, meaning there is a continuous replacement of old vessels, and it takes about ten years to replace 25% of the fleet.

Baltic Sea shipping in 2008 emitted about 135,000 tonnes SOx, 393,000 tonnes NOx and 18.9 million tonnes CO_2. This is the same amount of NOx and twice the amount of SOx as the total land-based emissions from Sweden and Denmark combined. Although passenger and RoPax vessels only account for approximately 5% of the ships operating in the region, they are accountable for approximately 27% of the emissions. The dominant ship types, general cargo ships and oil/chemical tankers, are accountable for only 14% and 7% of the emissions, respectively[2] .

Ship type distribution[2]



Ship age distribution[2]



The Baltic Sea is slowly dying

«The environmental situation in the Baltic Sea has drastically changed over the last decades. Human activities both on the sea and throughout its catchment area are placing rapidly increasing pressure on marine ecosystems. Of the many environmental challenges, the most serious and difficult to tackle with conventional approaches is the continuing eutrophication of the Baltic Sea. (…) Clear indicators of this situation include problems with algal blooms, dead sea-beds, and depletion of fish stocks. Such problems call for immediate wide-scale action to put an end to the further destruction of the Baltic Sea environment and to avoid an irreversible disaster. Failure to react now would undermine both the prospects for the future recovery of the sea and its capability to react to the projected stress by the climate change. Furthermore, inaction will affect vital resources for the future economic prosperity of the whole region and would cost tenfold more than the cost of action.»

– HELCOM

In order to mitigate the environmental situation in the Baltic Sea, measures must be implemented for several key sources of pollution; run-off from farming, untreated domestic and industrial waste water, and shipping. For shipping, the chosen course of action is to implement stricter environmental legislation controlling the environmental emissions allowed for ships.

[1]Baltic Port List 2008.
[2]Emissions of NOx from Baltic shipping and first estimates of their effects on air quality and eutrophication of the Baltic Sea, Stipa, Jalkanen, Hongisto, Kalli and Brink, 2007.

Committed environmental legislation

NEW INTERNATIONAL LEGISLATION ON MARITIME ENGINE EMISSIONS FOR 2010–2020

Enforcement	Reference	Legislation	Legislator	Area	Target	Consequences	Ship owner's typical options
01.01.2010	2005/33/EC	Sulphur content in fuel <0.1% when at berth in EU harbours and in canals	EU	EU	Sailing and new ships	Possibly equipment adaption, higher voyage costs	a) Change to 0.1% sulphur in bunkers at berth and in canals b) Use LNG as fuel
01.07.2010	IMO Annex VI	Sulphur content in fuel <1% in SECAs	IMO	SECA	Sailing and new ships	Possibly equipment adaption, or exhaust gas purification. Higher voyage costs	a) Use bunkers <1% sulphur b) Use bunkers >1% sulphur together with scrubbers c) Use LNG as fuel
01.01.2011	IMO Annex VI	Reduction of NOx to Tier II level, approx. 20% below current Tier I level	IMO	Global	Newbuilds	Choice of special engines, or exhaust gas purification. Higher voyage and capital costs	a) Choose (or modify to) low-NOx engines b) Use Tier I rated engines with SCR, EGR, HAM, water emulsion etc. c) Use LNG as fuel
01.01.2012	IMO Annex VI	Sulphur content in fuel <3,5%, progressively towards 0,5% sulphur by 2020 (maybe later)	IMO	Global	Sailing and new ships	Perhaps higher voyage costs	a) 2012: Change to 3,5% sulphur in bunkers. Towards 2020: Low-sulphur fuel or conventional fuel with scrubber is required b) Use LNG as fuel
01.01.2015	IMO Annex VI	Sulphur content in fuel <0,1% in SECAs	IMO	SECA	Sailing and new ships	Higher voyage costs, possible equipment adaption or exhaust gas purification	a) Use bunkers <0,1% sulphur b) Use bunkers >0,1% sulphur together with scrubbers c) Use LNG as fuel
01.01.2016	IMO Annex VI	Reduction of NOx to Tier III level in ECAs, approx 75% below Tier II level	IMO	ECA	Newbuilds	Exhaust gas purification (unless significantly improvement of engines). Higher voyage and capital costs	a) Install exhaust gas purification such as SCR, possibly other measures b) Use LNG as fuel

As a response to the environmental challenges the Baltic Sea is facing, the International Maritime Organisation (IMO) has established the area as an Emission Control Area (ECA).

In order to reduce SOx emissions in ECAs, IMO requires reduction of fuel sulphur content. From 1 July 2010 the fuel sulphur content must be below 1%, and further be reduced below 0.1% from 1 January 2015. EU directive 2005/33/EC, valid from 1 January 2010, already limits the fuel sulphur content to 0.1% while at berth in EU harbours and inland waterways. To comply with these requirements ships must either change fuel quality or fuel type or clean the exhaust gas to a corresponding emission level.

In order to reduce NOx emissions globally, IMO specifies existing and future NOx emission limits for marine engines, namely Tier I, II. The Tier II limit for NOx emissions will from 1st January 2011 require a 20% reduction in NOx emissions for new ships compared to the current Tier I standard. For ECAs, a Tier III will be enforced, requiering another 75% NOx reduction for ships built after 1 January 2016.

WHAT IS AN ECA?
The International Maritime Organisation (IMO) controls pollution from ships through the "International Convention on the Prevention of Pollution from Ships", known as MARPOL 73/78. The MARPOL Convention has been amended by Annex VI titled "Regulations for the Prevention of Air Pollution from Ships". This annex sets limits on NOx and SOx emissions from ship exhausts, and prohibits deliberate emissions of ozone depleting substances. The IMO emission standards are commonly referred to as Tier I, II, and III. The requirements are split in two categories: global requirements and more stringent requirements applicable to ships in Emission Control Areas (ECA). An Emission Control Area can be designated for SOx and PM, or NOx, or all three types of emissions from ships. The Baltic Sea and the North Sea are already defined as ECAs and other areas are considered.

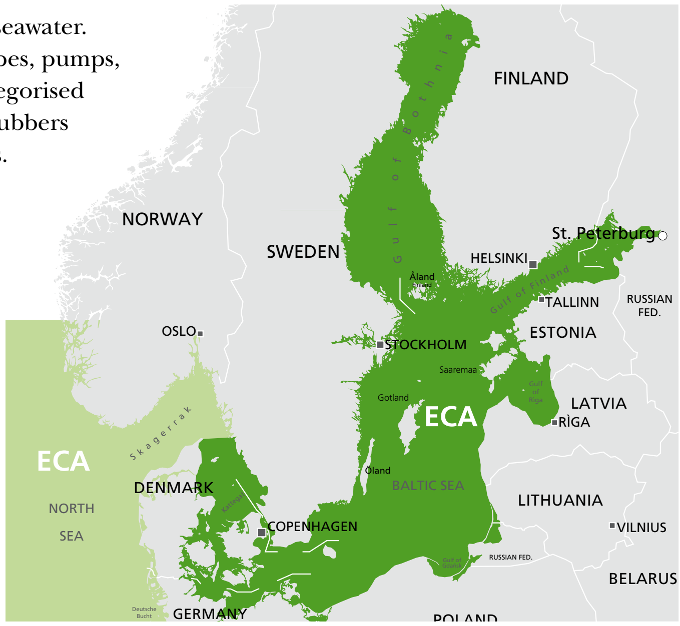
TECHNOLOGICAL SOLUTIONS

Based on a review of existing marine engine technology and expected technology development, shipowners currently have three choices if they wish to continue sailing in ECAs from 2015: Switch to low sulphur fuel, install an exhaust gas scrubber, or switch to LNG fuel (liquefied natural gas).

Marine Gas Oil (MGO) and Marine Diesel Oil (MDO) can be supplied with sulphur content below 0.1%. Switching to such fuel only requires minor modifications to the fuel system onboard the ships. On the negative side, the availability of low sulphur fuel is already limited and rising demand is expected to increase its price uncertainty. An exhaust gas scrubber can be installed to remove sulphur from the engine exhaust gas by using chemicals or seawater. Scrubbers require significant alterations onboard: Additional tanks, pipes, pumps, and a water treatment system. The sulphur-rich sludge produced is categorised as special waste, to be disposed of at dedicated facilities. Moreover, scrubbers increase the power consumption, thereby increasing its CO_2 emissions.

The third alternative is to fuel the ship with LNG. Natural gas is the cleanest form of fossil fuels available, and when fuelling a ship with LNG no additional abatement measures are required in order to meet the ECA requirements. However, an LNG-fuelled ship requires purpose-built or modified engines and a sophisticated system of special fuel tanks, a vapouriser, and double insulated piping. Available space for cylindrical LNG fuel tanks on board ships has been a key challenge, but new hull integrated tanks are expected to simplify this issue.

For new ships delivered after 1 January 2016, exhaust gas purification by Selective Catalytic Reduction (SCR) or LNG fuel are the only two currently available abatement measures to meet Tier III requirements.



The solution is LNG

Of the three alternative concepts for meeting the ECA requirements, LNG offers the best economics to shipowners and the best environmental effect to the Baltic Sea. Over the past few years the technical obstacles to implementation of this solution have been addressed and eliminated, and LNG as fuel has already been tested and proven on 20 ships currently sailing in Norwegian waters. Furthermore, LNG operations are proven safe with a track record from LNG carriers through the past 40 years without any major safety incident recorded.

BEST ECONOMIC PERFORMANCE

DNV has established economic models for the abovementioned three solutions for meeting the ECA requirements. These models were developed for comparing the three different ECA abatement measures, hence only differential costs between low sulphur fuel, scrubbers and LNG fuel are included. Revenue is not included in the models.

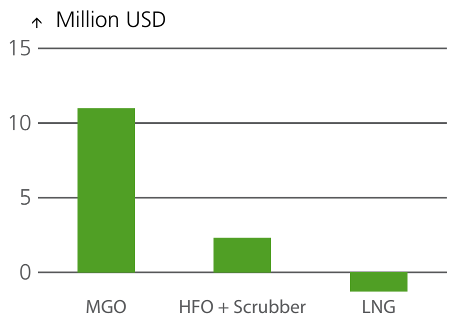
An example calculation is presented here for a typical Baltic Sea cargo ship of approximately 2,700 gross tonnes, 3,300 kW main engine and 5,250 yearly sailing hours.

New ships with LNG propulsion typically have an added investment cost of 10–20%. The additional cost is mainly due to the sophisticated LNG storage tanks, the fuel piping system and in some cases a slightly larger ship. Based on experience from ships built and currently under construction, the additional investment cost for the LNG fuelled typical Baltic Sea cargo ship mentioned above has been estimated to USD 3.6 million. There is little experience and limited available information on scrubber installation costs, but DNV believes a realistic estimate to be around USD

Liquefied natural gas (LNG) is natural gas that has been temporarily converted to liquid form for efficient storage and transport. Natural gas becomes liquid at –163°C where it takes up only 1/600 of the space of the gas. This source of energy, consisting mainly of methane, originates from multiple gas fields worldwide, and global reserves are still rich. Natural gas is mostly used in power generation, and in industrial and domestic use.

Over the past four decades LNG trade has grown to become a large and flexible market with good access to spot cargos. This means that the availability of LNG is not going to be a limiting factor for a potential growth in the distribution and consumption of natural gas in the Baltic Sea: Even with a 100% conversion of the shipping fleet in the Baltic Sea to LNG fuel it will only have an incremental effect on the global LNG market.

Present value of costs over 20 years relative to conventional fuel



1 million for this particular engine size. Investment costs for changing to MGO will in general be small compared to LNG propulsion or scrubbers, and has been considered negligible in the analysis.

DNV's fuel price estimates are based on bunker statistics and projections for MGO and MDO and on long-term contract prices plus distribution mark-up for LNG fuel.

In a 20 year perspective, which would be a conservative lifetime for a ship, it is estimated that the LNG solution has the lowest present value of costs with USD 4 million less than the scrubber option and USD 12 million less than the MGO option.

The same calculations have been done for retrofits with a life-time of ten years. These calculations conclude that LNG fuel is still the best option.

In general, the economic advantage of LNG fuel is strengthened with increasing fuel consumption. Note that the ship presented above had a relatively small engine and a modest number of sailing hours, and still the LNG fuel option was found most cost efficient. Including possible future taxes on emissions such as NOx and CO_2 further benefits the LNG case.

«WITH FAIR FUEL PRICING, ECONOMIC CALCULATIONS STRONGLY FAVOUR LNG»

SENSITIVE PARAMETERS TO THE ECONOMIC ANALYSIS

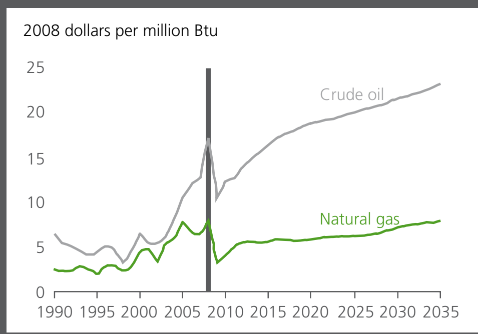
Fuel price

LNG bought on the international market on long-term contracts costs around 6–8 USD/mmbtu*. For comparison, crude oil is being traded around 15 USD/mmbtu. Assuming all other costs (mainly process and distribution) equal, this should make LNG available to shipowners at about half the price of oil-based fuels.

In Norway, LNG in small volumes is sold at around 18 USD/mmbtu, i.e. the whole potential for savings to the ship-owners is being consumed by small scale liquefaction and expensive distribution. In order to bring down the price of LNG, it must be bought from full scale liquefaction plants and efficient distribution must be established.

Investment costs

The added investment cost of choosing LNG fuel for new ships is expected to decrease in the future. By how much and how soon is largely dependent on the number of LNG-fuelled ships being contracted. LNG investment costs will also vary significantly between ship types and must be assessed from case to case. Investment cost for retrofitting LNG machinery will vary even more between ship types, but experience indicates that it can be profitable even without ECA requirements.

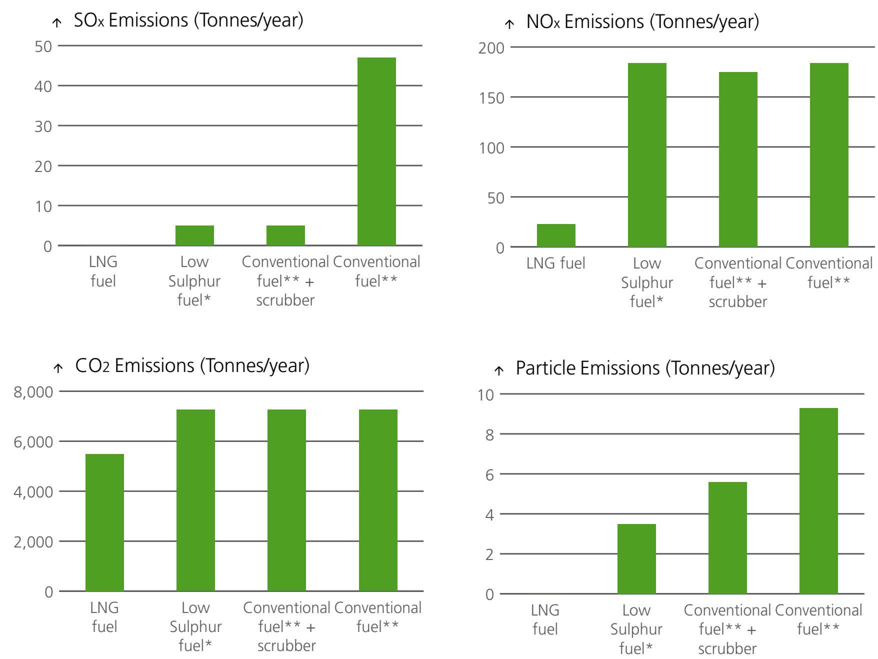


*million British thermal units

BEST ENVIRONMENTAL IMPACT

Of the three options for meeting the ECA requirements, LNG fuel has the lowest emission of all three local pollutants NOx, SOx, and particles, as well as the global green house gas CO_2: NOx emissions are reduced by 85–90%, SOx and particles by close to 100%, and net GHG emissions by 15–20%.

«LNG OFFERS CLOSE TO ELIMINATION OF LOCAL POLLUTION FROM SHIPPING»



* Low sulphur fuel contains maximum 0.1% sulphur

**Conventional fuel as per 1 July 2010, containing maximum 1% sulphur

Of currently proven technology, LNG is the only one of the three options mentioned above that both meet the 2015 SOx demands and the 2016 Tier III NOx requirements. To obtain equally low levels of NOx emission from engines with conventional fuel, Selective Catalytic Reduction (SCR) technology is required. It is ▶

still uncertain whether SCR technology and scrubbers will function jointly, and if they will be sufficiently efficient.

The above discussion about environmental effects is focusing solely on emissions during LNG combustion. However, by considering the entire life cycles of these fuels, LNG fuel is still the better option: It has lower acidification and eutrophication potential than all other marine fuels, and the GHG emissions from the lifecycle is the lowest[3].

IMPACT ON THE BALTIC SEA

The potential for reduction of ship emissions in the Baltic Sea is significant. Based on the conclusions of LNG fuel being the most economical choice for shipowners in ECAs, there is reason to be hopeful that LNG will become a common fuel in the Baltic Sea.

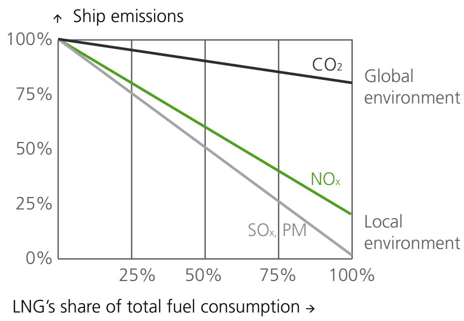
There are different types of issues to consider for the various types of ships when assessing whether to go for LNG fuel, scrubber, or low-sulphur conventional fuel. As an example, the RoPax vessels responsible for 27% of the emissions in the Baltic Sea will have to make special considerations about timing in port because bunkering of LNG may not be allowed at the same time as passengers are embarking or disembarking.

In addition to newbuildings, DNV expects that a significant number of refittings will be done in the near future for newly built ships where LNG tanks relatively easily can be installed.

The graph shows how increasing the share of LNG fuel used in the Baltic will reduce total ship emissions. It shows that if a significant number of ships are switched to LNG fuel the shipping industry will eliminate close to all its emissions that impact the local environment.

Ship emission reduction potential

Baseline
135,000 t SO_x, 400,000 t NOx
19 million CO_2, unknown PM



TECHNICALLY NO SHOWSTOPPERS

LNG fuelled engines are available from several suppliers, e.g. Wärtsilä, Rolls-Royce, MAN Diesel, and Mitsubishi Heavy Industries. There are two main engine concepts: Dual fuel engines and LNG lean burn mono fuel engines. The dual fuel engine, which runs on both LNG and conventional fuel, is a flexible solution when the availability of LNG fuel is uncertain. In LNG mode these engines only consume a minor fraction of conventional fuel. The lean burn mono fuel engine gives a simpler installation onboard and is a good choice when operating in regions with a developed grid of LNG bunkering stations or for ferry routes with dedicated ferries.

Currently the engine manufacturers focus on eliminating the so-called methane slip, where a small trace of gas fuel passes non-combusted through the engine and is emitted with the exhaust gas. This is expected to be solved in the near future. Another focus area is development of non-cylindrical tanks suitable for fitting in hulls with less available space.

All technical issues have been solved. The industry is now working on optimising design.

«EFFICIENT MARITIME ENGINES AND FUEL SYSTEMS FOR LNG ARE AVAILABLE»

LNG IS SAFE

LNG operations have an excellent safety record. LNG tankers have been in operation for 40 years, now counting a fleet of about 350 ships, and LNG has been used as marine fuel since 2001, now for 20 ships, all sailing in Norwegian waters.

In the Baltic region, rules and standards according to EU regulations will be applicable for LNG fuel operations and equipment. In addition, the IMO IGC Code and SIGGTO guidelines offer guidance and should be applied. IMO's interim guideline for gas-fuelled vessels, i.e. LNG-fuelled vessels, are recommended and intended to be used until the IGF Code comes into force. In addition national and port regulations are applicable. For LNG bunkering operations and bunker stations, no harmonised standards or operational procedures exist, but there is ongoing work on this, e.g. through the Gothenburg STS project, a joint industry project looking at procedures and requirements for safe ship-to-ship transfer and LNG bunkering operations.

Until formalised standards and procedures are in place, stricter case-by-case risk analysis will be required to ensure sufficient levels of safety, but this is not a showstopper for LNG-fuelled ships.

«LNG FUEL ON SHIPS WILL REQUIRE SPECIFIC OPERATIONAL PROCEDURES, BUT THE OPERATIONS ARE, AND WILL CONTINUE TO BE, SAFE»

The particular safety concerns for LNG compared to other hydrocarbon fuels are:

- **Cryogenic temperatures (frost burns, brittle fracture)**
- **Dense gas plumes: As long as the gas is dense it will be above the Upper Flammability Limit (UFL) and not ignite**
- **Gas explosions: Natural gas has lower flame velocities than other hydrocarbons, hence risks due to gas explosions are considered less severe.**
- **LNG is normally stored at low pressure and the risks associated with high pressure releases and BLEVEs (Boiling Liquid Expanding Vapour Explosion) is considered lower than for other hydrocarbons**

[3] "Marine fuels from a lifecycle perspective", Selma Bengtsson, Chalmers University of Technology

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What needs to be done

The application of LNG fuel in ships has developed a lot slower than should be expected based on the superior qualities of LNG compared to other fuels. What needs to be done is to start building efficient infrastructure for LNG fuel; governments should move first and require LNG fuel for publicly operated ships.

ESTABLISH INFRASTRUCTURE

There is no established infrastructure for supply of LNG fuel for ships in the Baltic Sea today. The following options for LNG fuel infrastructure have been considered:

1. Natural gas from pipeline and small scale liquefaction for further distribution to bunker stations
2. Full size LNG carriers (about 145,000 m³) from the international LNG market anchored in a suitable location for further distribution to bunker stations
3. Full size LNG carriers from the international LNG market delivers to local LNG import terminal which serves as a hub for further distribution to bunker stations
4. Ships bunker LNG fuel directly from a LNG import terminal

Option 1 above is how LNG fuel is made available to most of the LNG-fuelled ships operating in Norway today, but this is not considered a viable solution from a longer-term economic point of view: Liquefaction of LNG is highly dependent on economies of scale. As a consequence, small scale liquefaction results in LNG with a very high cost per unit.

Options 2 and 3 above, based on buying LNG from efficient large scale plants on long term contracts, offer the most competitive solutions in terms of LNG price. Transportation of LNG from hubs to bunker stations can be done by small LNG carriers, e.g. 20,000 m³.

Option 4 is not considered realistic because such terminals cannot accommodate a large number of ships. The large scale LNG import terminals which are projected in the Baltic Sea will be dedicated to a fleet of arriving full size LNG carriers, and will not be equipped for receiving smaller ships for bunkering operations. To add such a service to the normal large scale operations of these terminals will probably not be efficient.

A number of LNG import terminals are planned to start up in the Baltic area by 2014, which can be considered as part of a future supply infrastructure for LNG fuel. These terminals are shown on the map below.

The proposed terminals in Wilhelmshaven, Estonia, Lithuania, and the Świnoujście LNG terminal in Poland

Proposed LNG import terminals in the Baltic area[4]

are potential hubs for LNG fuel because they are large terminals capable of receiving full size LNG cargos from the international market. The proposed terminals in Sweden are potential bunker stations and suppliers of LNG to local industrial consumers.

GOVERNMENTS MOVE FIRST

Widespread use requires an LNG fuel supply infrastructure and a large fleet of LNG-fuelled vessels. These two are mutually interdependent: Shipowners will not invest in LNG-fuelled vessels until an LNG fuel supply infrastructure is in place, and LNG fuel suppliers will not invest in infrastructure until there is a large fleet of LNG-fuelled vessels. The challenge is how to get started. Here is room for close cooperation and coordination between government bodies and the private sector. Through active use of planning tools such as the Baltic strategy and TEN-T, the EU, as well as its member states' governments, can provide valuable political pull in order to get the infrastructure in place.

In conclusion, the 2015 and 2016 ECA requirements represent a golden opportunity for governments not only to achieve a big leap in environmentally friendly shipping in the region, but also to develop solutions which may in turn be exported to other regions. Authorities with interests in the Baltic Sea and other ECAs should recognise this rare opportunity. Governments should encourage the establishment of LNG bunkering infrastructure in the Baltics, and if they in addition require LNG fuel for new state owned or contracted ships, e.g. ferry routes and military and coast guard vessels, the shipping industry will follow.

Conclusion

LNG fuel is the supreme solution to compliance with the upcoming ECA requirements; it has the best environmental impact and is the most cost-efficient solution. The implementation of this solution should be speeded up, the main challenge being an insufficient LNG fuel infrastructure. If a significant number of ships are switched to LNG fuel, nearly all local polluting emissions from the shipping industry will be eliminated. The industry cannot immediately convert all ships to run on LNG, but new ships, publicly or privately owned, should run on LNG.

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