Both international¹ and EU legislation² are imposing stricter limits on the emissions of seagoing vessels in European waters. MARPOL Annex VI requires the use of fuels with a maximum 0.1% sulphur content in Emission Control Areas (ECAs) from January 2015. On top of this, on a global scale, the same IMO instrument requires the global sulphur cap to be reduced from the current 3.5% to 0.5% by 2020 or 2025, depending on the results of a feasibility review planned for 2018. Moreover, Sulphur Directive 2012/33/EC requires the use of fuels with a maximum 0.5% sulphur content in all EU waters (non-ECAs) from 2020, regardless of the results of the IMO review.

Concerning nitrogen oxides (NOx) emissions, MARPOL Annex VI also requires that a marine diesel engine installed on a ship constructed on or after 1 January 2016 must, in addition, comply with TIER III NOx standards in ECAs, significantly reducing the total weighted cycle emission limit of NOx in shipping. These regulations will therefore enforce the use of propulsion systems that reduce sulphur emissions, either by using alternative cleaner fuels or, alternatively, by cleaning the exhaust gases. One of the possible solutions to comply with future legislation is the use of Liquefied Natural Gas (LNG) as a shipping fuel.

Currently, the global shipping greenhouse gas (GHG) emissions amount to around 1 billion tonnes a year. At present they account for 3% of the world’s total and 4% of the EU’s total emissions. By 2050, however, carbon dioxide (CO2) emissions from the shipping industry, if no measures are taken to reduce them, are expected to have increased between 240% and 600%³ according to the OECD ITF Transport Outlook 2015. In addition, the availability of fossil fuels, their costs and energy security are matters of concern.

As a shipping fuel, LNG has proven to be a serious alternative to conventional heavy- and low-sulphur fuel oil. LNG-propelled ships emit hardly any particulate matter (PM), about 90% less sulphur oxides (SOx), up to 90% less NOx and 20-25% less CO2, representing a good solution for both reduction of relevant substances and GHG emissions. The environmental benefits of LNG, as an alternative fuel for shipping, therefore show good potential to be greener than fuel oils and distillates, even taking into account the production and transport process.

Even though LNG, and Natural Gas, are well known to society and shipping, being carried around the globe in very large quantities as an important part of the Energy Market, there are several concerns regarding its utilisation as an alternative fuel for shipping, not only concerning safety but also environment, which require a coordinated and effective engagement of all stakeholders involved.

The current prices in Europe and the USA suggest that LNG can be offered at a price similar to that of heavy fuel oil (HFO). This makes LNG a commercially attractive alternative when compared to low-sulphur marine gas oil (MGO), which is currently frequently used in order to comply with emissions regulations.

¹ MARPOL Convention, Annex VI - http://www.imo.org/OurWork/EnvironmentPollutionPrevention/AirPollution/Pages/Air-Pollution.aspx

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LNG IN SHORT

1. Availability
   The availability of LNG is on the increase. Currently, Sweden, Finland, Belgium, the Netherlands and the UK are the only EU Member States that have LNG refuelling facilities for vessels. However, in Germany, Poland and in the Baltic States, there are plans to construct such facilities in the short term. France, Spain, Italy, Denmark and Greece also have plans for the near future. Additional LNG refuelling facilities across the EU would support shipping in complying with the 0.5% maximum sulphur content requirement that will be mandatory for all EU waters outside the Sulphur Emission Control Areas (SECAs) as of 2020.

2. Pricing
   The pricing scheme for LNG fuel has not yet been fully developed. Existing contracts are predominantly index-linked to the price of oil, HFO or MFO.

3. Sustainability
   LNG has significant environmental benefits and is available in many countries all over the world. This makes LNG a sustainable fuel option for the shipping industry. In 2013, the Commission established the European Sustainable Shipping Forum (ESSF), in which experts, maritime operators, and policy makers work together to set up the technical and regulatory framework for the uptake of LNG.

4. Safety
   The safe operation of LNG installations, either ashore or onboard, is top priority. In order to meet the challenges of a more widespread use of LNG as a shipping fuel, the wider LNG community, policy makers, technical authorities, ship owners and associations have shared information and experience, have identified possible hazards and developed control measures, leading to the development and adoption of safety requirements, standards and guidance (IGF Code, ISO Technical Specifications, amongst others).

5. Rules & regulation
   The new mandatory code for ships fuelled by gases or other low-flashpoint fuels (IGF-Code) was adopted by IMO’s Maritime Safety Committee (MSC) in June 2015 and will enter in force, along with the respective SOLAS amendments, in January 2017. The IGF-Code finalisation was the result of several expert discussions and many working meetings at IMO, in different sub-committees and within MSC itself, aiming to minimise the risk to the ship, its crew and the environment. The IGF-Code, with regard to the nature of the fuel involved, contains mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuels, focusing initially on LNG. Meanwhile, before the entry in force of the IGF-Code, IMO’s Interim Guidelines for the use of gas as a shipping fuel (Resolution MSC.285 (86)) contain the relevant safety concepts and have been the reference international requirements for the design of LNG-fuelled ships. Classification Societies have also produced extensive documentation with guidance and Class requirements regarding LNG as fuel for ships. Germanischer Lloyd issued their own guidelines and interpretations in April 2010 and other Class Societies have followed in a similar manner, issuing rules for the construction of LNG-fuelled vessels. In the meantime, work has started at ISO TC 67 on standards for LNG bunkering. The assessment of the existing rules, standards and guidelines, conducted by DNV GL as mandated by the European Commission DG-MOVE, shows that from a legal point of view, there are no major obstacles for the use of LNG - either for seagoing vessels and inland waterway vessels - and the development of small-scale LNG plants. In recent years, the legislation and regulation, previously prohibiting the use of LNG as a fuel for seagoing vessels or inland waterway vessels, have been adapted to allow the use of LNG as a fuel. As far as LNG bunkering is concerned, one key challenge is faced: the ship-shore interface. LNG bunkering procedures are not regulated at an international/European level, nevertheless, specific LNG bunkering procedures have been issued or are in a preparatory stage for several ports and organisations, like IACS, IAPH, SIGTTO/ SGMF. Furthermore, EU-wide standards for LNG bunkering installations and requirements for LNG bunkering equipment are still lacking, even if work on this is currently being developed by ISO. Even though these standards are not strictly required from a legal point of view, they are complementary to other requirements and provide a harmonised ground for safe, good practice with LNG.

A list of current rules and regulations on LNG as a shipping fuel can be found on page 14 of this brochure.

Stakeholder analysis on LNG as a shipping fuel

The European Commission’s Directorate-General for Mobility and Transport (DG MOVE) has mandated PwC and DNV GL to analyse the current attitude towards LNG as a shipping fuel. In Q4 2014 and Q1 2015, this research was conducted through an online questionnaire and personal interviews with 52 stakeholders mainly from the industry and a few authorities, academics and non-government organisations (NGOs). An overall indication of the results:

- The compliance with ECA zone requirements and the connected positive environmental effect are the major motivation for stakeholders to engage in LNG as a shipping fuel.
- Financing of LNG as a fuel, and the pricing of LNG itself, are among the most critical issues hindering the transition to LNG as a shipping fuel. For many companies, especially shipping companies, LNG does not offer a profitable business model yet. The higher equipment (engine and tank) costs are not offset by savings in fuel or operating expenses.
- The lack of a complete harmonised set of standards and regulations is perceived as an issue. The overall conviction, however, is that the industry is developing and that this will not be a major barrier in the future.
- The ‘chicken-and-egg problem’ (stakeholders waiting for each other to take the first step) remains – it can only be overcome by initiating and implementing local or point-to-point consortia between shipping lines, gas suppliers and other relevant stakeholders.

4 DNV GL, Analysis and evaluation of identified gaps and of the remaining aspects for completing an EU-wide framework for marine LNG distribution, bunkering and use, Final Report 2015
Advantages of using LNG

Dr. Aad Correljé is Associate Professor at TU Delft and a research fellow with the Clingendael International Energy Programme (CIEP) of the Clingendael Netherlands Institute for International Relations. In this capacity, he has been researching the energy sector for over twenty years. His current research focuses on the public and private decision-making processes regarding oil, water and gas. Correljé sees many advantages in the transition to LNG as a shipping fuel.

‘Firstly, LNG is made of Natural Gas, which is abundantly available in many places all over the world,’ says Correljé. ‘The Natural Gas resources are immense and can provide us with energy for a very long time. Secondly, when cooled down to -162°C, the gas liquefies and its volume is reduced by 600 times. This enables it to be stored in tanks or transported by tankers, large-scale ships, or even smaller vessels or tanker trucks. So transport is no longer dependent on a network of pipelines, which has always been the case. This is a tremendous advantage, and certainly good news for those countries that have enormous amounts of Natural Gas, but no local market. All they have to do is build a liquefying factory to bring their gas to the market. And thirdly, LNG is a very cost-efficient fuel.

Disadvantages

There are also some disadvantages to using LNG, admits Correljé. The energy density of LNG, for instance, is less than that of petroleum. If weight and volume are important, petroleum is the most concentrated form of energy. In addition, there is the safety question. ‘Authorities are wary of LNG because of an increased risk,’ he says. ‘Never before has LNG been used

This is definitely the moment to seriously consider LNG as a fuel, since the regulations to reduce emissions of all pollutants are becoming stricter. As a consequence, ship owners who need to replace ships will be forced to think about a cleaner fuel. And owners of ships still running on oil fuel will have to install cleaners, filters and scrubbers to meet the regulations and to be able to continue operating. On top of the investment costs, additional maintenance will be necessary. I think all of this points in the direction of LNG.’
to propel ferries with 200 people aboard. However, LNG has so far proven to be safe in terms of its good track record of over 50 years of use. But potential risks (see “Pros and Cons of LNG in Shipping”, page 9) have to be managed well, e.g. by strict standards & regulations, well-defined procedures and continuous training of all people involved.

Developing an LNG infrastructure

Having researched public and private decision-making processes regarding energy over a long period of time, Correljé has developed clear ideas about the development of an LNG infrastructure. ‘Such a development requires collaboration. Ship owners, ship builders, developers of technologies, governments, port authorities, they all have to link up and develop some kind of a consistent environment in which the right decisions can be made. This is policy driven, since there is no direct economic advantage. It has to do with the environment.’

Governments

But even though the transition to LNG is a shared responsibility, Correljé thinks national governments play a crucial role. ‘We talk about rules, which have been developed and implemented by governments. Clarity in rules and conditions is important; it offers a license to operate. Governments should create certainty over a longer period of time. They have to make sure certain developments will take place. Secondly, governments are in a position to subsidise research in order to find out which kind of developments should be supported and what kind of rules are best fitting to the development of technology. The whole body of rules should be clear and provide certainty to ship owners, ship builders and developers alike. It is clear that governments have to take the first step.’

European Commission and international organisations

Since the shipping industry is a typical cross-border industry, legislation cannot be a matter of national governments only. ‘The European Commission is doing a good job,’ says Correljé. ‘It takes the initiative, provides information and supports LNG. And there are various international organisations that support the harmonisation of standards and the overall promotion of LNG as a maritime fuel: IMO, EMSA, SIGGTO and SGMF just to name a few. It is extremely important to develop clear directives, which leave room to be interpreted in the local situation. But, if all the right steps are taken, I am convinced that LNG will be the next-generation fuel.’

‘The cleanest fossil fuel available and a serious answer to the stricter regulations’
In a project mandated by the European Commission, PwC and DNV GL conducted a series of interviews (supported by an online questionnaire) with a variety of stakeholders across Europe: shipping companies, port authorities, gas suppliers and others. The goal was to get their up-to-date view on LNG as a shipping fuel. The project’s main objective was to get an understanding of the opportunities (positive side) and barriers (risks and critical aspects) of LNG as a fuel. As the chart shows, every respondent is familiar with LNG as a shipping fuel. There are, however, significant differences when it comes to specific knowledge and behaviour.

**Opportunities related to LNG as a shipping fuel**

The main opportunities related to LNG are the compliance with environmental regulation, economic benefits and the higher flexibility in energy sourcing:

**Environmental opportunities**

It is generally agreed that the most significant opportunity of LNG as a shipping fuel lies in the positive environmental effects, such as the reduction of NOx, SOx and PM. There is some doubt, however, about the effect of LNG on GHG emissions: nearly 20% of respondents do not think it is (very) likely that these will actually be reduced. There is also some concern about methane slip and noise levels.

**Economic opportunities**

The majority of the respondents agree that it is (very) likely that the introduction of LNG will have positive economic effects, although many of them argue that these effects depend on the shipping time spent in ECAs. This is supported by detailed analysis, as 78% of the respondents (highly) agree that LNG prices can compete with those of conventional fuel oils. Some interviewees, however, emphasise that LNG prices can only compete with low-sulphur fuel oils like MGO and low-sulphur heavy fuel oil (LSHFO), which in turn are required to comply with environmental regulation. Other frequently mentioned economic benefits are lower OPEX for LNG engines, excess supply of LNG, and the creation of jobs. However, the most frequently mentioned, by 85%, were the potential business opportunities for bunkering infrastructure.
Energy sourcing opportunities
Energy sourcing opportunities are only beneficial to stakeholder groups, such as port authorities, that want to offer a broad range of fuels. For most others, the ubiquity of MGO and HFO in ports across the world will suffice.

Barriers to the further use of LNG as a shipping fuel

Although there are strong arguments towards using LNG as a fuel, there are also some disadvantages.

![Figure 3 - Barriers for LNG as a shipping fuel](image)

<table>
<thead>
<tr>
<th>Barrier Description</th>
<th>Very unlikely</th>
<th>Unlikely</th>
<th>Likely</th>
<th>Very Likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative perception</td>
<td>10%</td>
<td>56%</td>
<td>28%</td>
<td>6%</td>
</tr>
<tr>
<td>Inadequate standards &amp; regulation</td>
<td>34%</td>
<td>48%</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>Insufficient safety &amp; security</td>
<td>6%</td>
<td>55%</td>
<td>33%</td>
<td>6%</td>
</tr>
<tr>
<td>Uncertain financial situation</td>
<td>2%</td>
<td>8%</td>
<td>43%</td>
<td>47%</td>
</tr>
</tbody>
</table>

**Negative perception**
Two-thirds of the respondents argue that negative perception does not form a serious stumbling block for the introduction of LNG as a shipping fuel. Many interviewees add that gas is already part of their daily lives, and that it is ‘greener’ than conventional fuel oils. Detailed analysis, however, indicates that the negative perception of (local) interest groups may become an obstacle in the future. It has been argued that emotions and a lack of objective information can play a role in this.

**Inadequate standards and regulation**
Inadequate and often different international standards and regulations are generally seen as a serious barrier to the use of LNG as a shipping fuel. Examples are the slow permitting process and the lack of harmonisation. It is expected that the introduction of the IGF Code will help decrease the issue.

**Perception of methane slip**
The stakeholders analysis revealed that some stakeholders don’t believe that total GHG will be reduced through the use of LNG as a shipping fuel, considering the entire life-cycle of LNG. Methane release events, throughout the entire LNG life-cycle, from extraction to utilisation as fuel for ships, were indicated as having potential to reduce the positive environmental impact of LNG as an alternative fuel in shipping. Being 20-25 times more powerful than CO2 as a GHG during a 100-year time span, methane deserves from the wider LNG community (suppliers, users and researchers) a careful approach.

Methane release can occur during all stages of LNG life-cycle. The particular case of methane emissions resulting from internal engine combustion have been particularly addressed and discussed. Incomplete gas combustion leading to the emission of small amounts of methane into the atmosphere, the so-called ‘methane slip’, contributes negatively to the environmental impact of LNG. Engine technology is the way to address this problem. Different engine concepts are available today for using LNG as a shipping fuel. Working on gas only or in dual fuel arrangements, four-stroke engines have been undertaking serious design improvements to minimise methane slip, whilst in modern two-stroke engines, this has already been practically eliminated during combustion.

Stakeholders’ concerns represent a key highlight on the need to take into account adequate methane emissions mitigation plans, optimisation of LNG-fuelled ships’ transport efficiency and adequate design of the LNG supply chain, minimising transport/distribution footprint for this alternative fuel.

**Insufficient safety and security**
80% of respondents argue that insufficient safety and security is (very) unlikely to be a stumbling block. Almost the same goes for the general safety risks of handling LNG and the higher safety risks due to an increased number of players on a small-scale LNG market. These are seen by respondents as slightly more likely to be an obstacle, with 46% and 50% respectively. Most interviewees argue that it is a matter of training the crews and bunker suppliers to ensure safety. The risk of sabotage and terrorism is regarded as a (very) unlikely barrier in the transition to LNG.
The large majority of the respondents are more or less confident that LNG will be adopted across the value chain. Only 8% are not confident that this will happen. As a matter of fact, gas suppliers are most confident about the adoption. Nearly 90% of these industry professionals have indicated that they have already been involved and will continue with LNG activities (versus 50% of ship owners).

Approximately 70% of the respondents have already been involved in LNG activities and two-thirds are planning to do so in the near future. However, there are also respondents who believe that they or their organisations will definitely not be involved in LNG activities. This could be attributed to conservatism, as many interviewees argue that they are waiting to see how the market will develop before they start adapting their businesses. The interviews have shown that many stakeholders are actively assessing their potentials, for example through feasibility studies, cost-benefit analyses, etc. Some of them have already formulated concrete plans for market entries, but these have been paused or vetoed, mainly due to uncertain financial situations.

The uncertain financial situation is generally perceived as the most important barrier to the further uptake of LNG as a fuel. Many companies claimed that it is difficult to have a quick payback on the cost of converting to LNG. Much of this is due to uncertainty about prices, taxation and legislation. Moreover, there is also the risk of the costs being higher than expected due to the immaturity of the small-scale LNG market.

**Confidence in LNG uptake**

The large majority of the respondents are more or less confident that LNG will be adopted across the value chain. Only 8% are not confident that this will happen. As a matter of fact, gas suppliers are most confident about the adoption. Nearly 90% of these industry professionals have indicated that they have already been involved and will continue with LNG activities (versus 50% of ship owners).

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**Figure 4 – Confidence in the adoption of LNG as a shipping fuel across the value chain**

<table>
<thead>
<tr>
<th>Confidence Level</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Confident</td>
<td>8%</td>
</tr>
<tr>
<td>Somewhat Confident</td>
<td>24%</td>
</tr>
<tr>
<td>Confident</td>
<td>41%</td>
</tr>
<tr>
<td>Very Confident</td>
<td>27%</td>
</tr>
</tbody>
</table>

**Figure 5 - Involvement in LNG activities**

<table>
<thead>
<tr>
<th>In the past 12 months</th>
<th>In the coming 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitely yes</td>
<td>72%</td>
</tr>
<tr>
<td>Probably yes</td>
<td>4%</td>
</tr>
<tr>
<td>Probably not</td>
<td>9%</td>
</tr>
<tr>
<td>Definitely not</td>
<td>15%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In the past 12 months</th>
<th>In the coming 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitely yes</td>
<td>63%</td>
</tr>
<tr>
<td>Probably yes</td>
<td>17%</td>
</tr>
<tr>
<td>Probably not</td>
<td>7%</td>
</tr>
<tr>
<td>Definitely not</td>
<td>13%</td>
</tr>
</tbody>
</table>

**Partnering with other organisations to enable or accelerate LNG activities**

<table>
<thead>
<tr>
<th>In the past 12 months</th>
<th>In the coming 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitely yes</td>
<td>63%</td>
</tr>
<tr>
<td>Probably yes</td>
<td>17%</td>
</tr>
<tr>
<td>Probably not</td>
<td>7%</td>
</tr>
<tr>
<td>Definitely not</td>
<td>13%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In the past 12 months</th>
<th>In the coming 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitely yes</td>
<td>58%</td>
</tr>
<tr>
<td>Probably yes</td>
<td>24%</td>
</tr>
<tr>
<td>Probably not</td>
<td>7%</td>
</tr>
<tr>
<td>Definitely not</td>
<td>11%</td>
</tr>
</tbody>
</table>

The majority of the respondents state that they would partner other organisations to either enable or accelerate their LNG activities. These include, amongst others, development of storage facilities, converting vessels to LNG, cooperating with NGOs to develop further standardisation and guidelines. Over 70% of the gas suppliers have already partnered with other organisations to enable or accelerate LNG activities (versus 43% of ship owners and managers).

Organisations with whom the respondents and their organisations would partner are:

- Industry associations, expert groups and other platforms: ESSF, SMGF, WPCI/IAPH, LNG platforms
- Governmental institutions:
  - European Commission, local authorities
  - Energy suppliers
  - Port authorities
- Shipyards
- Classification societies
- Technical committees, universities and other research institutions
## Pros and Cons of LNG as a Shipping Fuel

### Advantages

**Environmental advantages**
LNG has a number of environmental advantages in comparison with conventional fuels, such as the reduction of SOx, NOx, PM and CO2 from engine exhaust emissions. The reductions are as follows:
- SOx up to 95%
- PM nearly to 100%
- CO2 emissions up to 25%
- NOx up to 90%

Any slip of methane during bunkering or usage needs to be avoided to maintain the levels of CO2 reduction.

**Compliance**
Following from its favourable environmental performance, LNG allows ships to meet MARPOL Annex VI requirements for both worldwide trades and operation in ECAs as its sulphur content is well below the Annex VI requirements for ECAs.

**Maturity of technology**
All the technology involved in the adoption of LNG as fuel for shipping can be considered to be sufficiently mature, notwithstanding all the research in areas like internal combustion engines for methane slip reduction, or in consequence modelling of LNG-related hazardous events.

**Transport**
LNG is mainly transported in liquefied form by ship or truck. For reasons of cost-efficiency, pipeline transport is only used for very short distances. One big benefit of LNG is the fact that it can be transported over larger distances without being dependent on pipeline grids.

**Price**
LNG is expected to be less costly than MGO, which will need to be used within the ECAs if no other technical measures are implemented to reduce SOx emissions. Current low LNG prices in Europe and the USA suggest that a price – based on energy content –  below that of HFO seems possible, even when taking into account the small-scale distribution of LNG.

**Availability**
Generally, Natural Gas sources are diverse and large quantities reserves have been identified worldwide, with a capacity to feed a potential LNG fuel market uptake for many decades.

### Disadvantages

**Incompatible with existing engine types**
The use of Natural Gas as fuel is not compatible with existing liquid fuel engines. Modification to traditional engines and fuel system is required.

**High investment costs**
Using LNG as a shipping fuel will require more expensive ship technology to be in place; most notably the gas engine, the gas fuel system and the LNG storage tanks including insulated piping. This construction cost premium is increased by the initial size of the market, hence lacking economies of scale. The necessary investment for the LNG-ready technology can be between 10% and 30% higher compared to the investment for conventional ship technology.

**Increased safety requirements**
The LNG-particular Risk & Safety profile leads to additional safety requirements over traditional fuels, resulting in increased cost and operational limitations (special bunkering safety requirements, safety zones, considerations with regard to simultaneous operations (SIMOPS), etc.).

**Ship design challenge**
LNG’s energy density is lower than that of, for example, MGO, around 30% to 40% lower than diesel and gasoline, in MJ per unit volume. This requires an LNG tank and space which is about 2.5 to 3 times the volume of a conventional fuel/gas oil tank, for similar autonomy in comparison with a conventional fuel/gas oil engine.

**Methane slip**
Methane slip is caused by an incomplete combustion in the engine leading to the emission of small amounts of methane into the atmosphere, mixed with the combustion gases. Even though engine technology is evolving towards a zero-methane emission goal, this is still an important point when it comes to the optimisation of overall LNG environmental benefits.

**Lack of infrastructure**
The current lack of widespread LNG bunker facilities makes it difficult for ships to rely on LNG as a fuel, especially when they cannot depend on regular seagoing routes. Only relatively few bunker facility sites – including bunker barges or fuelling racks – have been established, most of these are concentrated in ECAs such as those in the Baltic Sea, most notably in Norway.

To promote LNG infrastructure across the EU, Directive 2014/94/EU establishes that Member States shall ensure, by means of their national policy frameworks, that an appropriate number of LNG refuelling points are put in place at maritime ports (by 31/12/2025) and inland ports (by 31/12/2030), to enable LNG seagoing ships and waterway vessels to circulate throughout the TEN-T Core Network.

**Cumbersome authorisation processes**
Permitting processes need to be further harmonised. Approvals are needed from various government authorities when building an LNG bunkering facility with the potential to create delays in specific projects and, therefore, leading to undesirable uncertainties in cost and time.

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New regulations as a challenge
The strict emission regulations for the ECA waters, which became effective in the beginning of this year but were announced long before, made him realise they had to find a sustainable solution. At Fjord Line, the new regulations were seen as a challenge rather than as a setback, since the regulations forced them to look at their business with different eyes. ‘In 2009, we decided to build two new vessels,’ Larsen says. ‘At the time, we already knew that new regulations were to become effective from 1 January 2015. This meant that for the ECAs, we had to significantly reduce the emission of sulphur on the vessels. In order to solve this problem, we started searching for a sustainable solution.’

Protecting the environment
Larsen soon discovered LNG as a fuel for their ships, and Fjord Line started building two new LNG-powered vessels. It turned out to be an educational experience, but he is proud that the two LNG-powered passenger vessels are now operational between Denmark and Norway. ‘The decisive factors that made us choose LNG as the fuel for our vessels were the new regulations to protect the environment. These are imposed by the IMO and the European Union, and become stricter every year. Today we discuss harmful contents in anti-fouling paints, reduction of NOx emission and the likes, in relation to the International Convention for the Control and Management of Ships’ Ballast Water and Sediments (BWM), adopted in 2004. As an industry we have no alternative but to follow these regulations.’

Building an LNG-fuelled vessel
Compared to oil-based fuels, the use of LNG reduces CO₂ emission by 25% and the emission of NOx by the huge amount of 90%. And when it comes to the emission of SOx and PM, there are none. However, Larsen says, there are still some impediments in switching to LNG. ‘Building a vessel running on LNG fuel is more expensive than building one on oil-based fuels, such as diesel. Obviously, this depends on the size of the vessel, the tank size, the distances the ships travels, etc. It goes without saying that a ship carrying containers all over the world cannot be...’

‘Infrastructure is of the utmost importance’
costly. LNG is relatively new and that makes it more complicated. If you come here with a vessel and you want to bunker fuel oil, you just call a fuel supplier to get a small bunker barge on the side of your vessel, or a fuelling truck to get you fuelled. It doesn’t work that way with LNG.’

Common rules
In a number of European countries, the use of LNG as a shipping fuel is under discussion. There is a growing interest in LNG and many (international) work groups are investigating the possibilities for its use. Larsen is a member of a few of these groups, which has made him aware of the differences between countries, and of the fact that most authorities work in a different way. But, as he has experienced, things are about to change. ‘All kinds of stakeholders have started discussions in order to develop common rules for the use of LNG. And they have to talk to one another, because LNG is the future of the shipping sector. I know that some people talk about battery-driven ships but, considering the power requirements for large vessels, I think this is, as yet, not a feasible alternative. I believe LNG is the future.’

Infrastructure
Even though the cost of building an LNG-fuelled vessel may discourage ship owners to switch to LNG, Larsen realises there is another, even more serious impediment. ‘Infrastructure is of the utmost importance. Here, in Denmark, there is currently no infrastructure at all. In Norway, where we have been using LNG for the last 15 years, the infrastructure is much better. But it gives me hope to see that many LNG-related projects are under development, especially here in the North Sea, but also in the Baltic region. We are momentarily working on two different projects, one here in Hirtshals, which will be a bunker facility.’ Patience is important, says Larsen, as these developments do not happen overnight. ‘You need approvals from different authorities for your plans and have to make sure that the safety regulations are in order. These processes are time-consuming and costly. LNG is relatively new and that makes it more complicated. If you come here with a vessel and you want to bunker fuel oil, you just call a fuel supplier to get a small bunker barge on the side of your vessel, or a fuelling truck to get you fuelled. It doesn’t work that way with LNG.’

Novelty in infrastructure
According to Art 6 of Directive 2014/94/EC, Member States agreed that they will ensure, by means of their national policy frameworks, that an appropriate number of refuelling points for LNG, including LNG terminals, tanks, mobile containers, bunker vessels and barges, will be put in place at maritime ports in order to enable LNG inland waterway vessels or seagoing ships to circulate throughout the TEN-T Core Network Ports by 31 December 2025. Larsen, however, thinks that maritime ports will need more time, and maybe even more money, to ensure circulation through the TEN-T Core Network. ‘The oil industry may have good intentions’, says Larsen, ‘but they also wait around to see what is happening. In the Netherlands, for example, the industry is building terminals for small-scale LNG. That is a novelty, because up until now there were only facilities for large vessels. But this too is a slowly moving process; we must realise the industry consists of only a few players.’

Freight capacity
It has often been argued that LNG-fuelled vessels need big tanks, and as a consequence loading capacity is decreased. According to Larsen, this may be true for container ships, which are built to maximise the intake of containers, but it has no influence on the freight capacity of the vessels they use. In addition, new regulations are being developed. Regulations on the tank size, the places where the tanks may be installed, etc., which offer more possibilities. In the future an oil tanker could, for instance, place the LNG tanks on deck to maximise freight space below decks.

Fuel for the future
Apart from the fluctuation of the oil prices, it is getting more and more difficult and expensive to win oil, whether offshore or in the Arctic. There are, however, huge resources of Natural Gas available all around the world, which can be transformed into LNG; from the Nordic to Australia and also in the USA. LNG is also relatively cheap but, because of the missing infra-structure, that quality cannot be fully appreciated yet. ‘It is a chicken-and-egg situation,’ says Larsen, ‘but as soon as the infrastructure is in order, and I have every reason to believe it will be in short term, LNG will be recognised as the fuel for the future. It is definitely here to stay.’
Changing attitudes
João Carvalho has worked for maritime companies in the private sector for most of his career. Four years ago, the Portuguese government asked him to amalgamate the four independent institutes for road-, rail-, maritime- and air traffic into one organisation: IMT (Instituto Mobilidade e Dos Transportes, I.P.). ‘My government thinks, and so do I, that LNG is the future. It is cheaper and the gas resources are enormous, whereas the oil resources will not last very long. Moreover, LNG is the cleanest fossil fuel in the world. So in fact, it is not the future but the present we are talking about. With our institute we are trying to change the attitudes of our stakeholders by informing them, by sharing ideas and by telling them to go ahead with the LNG process in order to remain successful.’ Carvalho, however, has always known that this would not be an easy task. ‘Entrepreneurs think about profit, about return on investment, and want to see it today, if possible. So we have to tell them to think about tomorrow, the environment, and about how quickly things can change. Just take a look at what is happening in the Baltic area. In the south of Europe, in the Mediterranean and on the Atlantic Coast, we must follow this example to stay in the game.’

International cooperation
When it comes to new developments, Portugal is usually one of the last European countries to step in. So the ministers of transport of the EU Member States were surprised when Carvalho announced in 2010 that Portugal, just like the countries in the north of Europe, wanted to stimulate the use of LNG in order to protect the environment. ‘We contacted countries that are similar to us, like Spain, Italy and Cyprus, and worked together on an LNG project. We did not only invite governments to partake in the discussion, but also ship builders, ship owners, shipping agents and port terminals. After finishing this project, we are now preparing another one by the name of LNG-2, which will start soon. Our country has a leading role in this project and we are glad that this time France will also take part in it.’

Legislation
According to Carvalho, one of the most important aspects for the transition to LNG is legislation. That must be the same everywhere. A ship owner who sails from...
Rotterdam to Lisbon must be able to rely on the same rules during the entire journey. So harmonisation has top priority and by 2025, at the latest, all the regulations concerning LNG should be the same everywhere. But the responsibility does not solely lie with Europe. Carvalho has emphasised the importance of harmonisation between IMO and all the initiatives from the European Commission at a regulatory level. IMO’s key role in setting the standards for safety and environmental performance of international shipping is here, as Carvalho indicates, an important reference for EU initiatives that, at regional level promote and support LNG as an alternative fuel. All the directives of the European Union should be designed to harmonise with the standards set by the IMO.

Creating facilities now
Carvalho emphasises that, in order to remain competitive, it is vital for all European harbours to have LNG fuelling facilities. ‘If a vessel comes to your port and you cannot supply LNG, it will go somewhere else. We therefore fully support the Directive on the deployment of alternative fuels infrastructure. This should be implemented in all maritime ports of the European Union before the end of 2025. But I recommend creating these sooner. As soon as possible.’ As for the national governments, these have a facilitating role, says Carvalho. They should offer conditions and give out concessions of land to build LNG facilities. That is what they are successfully doing in Portugal. The port of Sines, in the south of Portugal, is already supplying LNG. Both the Port of Lisbon and the port of Leixões participate in the project to find out how they can develop into a port with LNG facilities.

Synergy
As the chairman of an institute that is aimed at all Portuguese transport sectors, Carvalho cannot be satisfied with only transforming the shipping industry. ‘We are currently discussing that, if the maritime sector embraces LNG, the road sector must follow. This means that every 250 to 300 km, there must be a service station with LNG fuelling facilities for trucks. I think this synergy between road and sea transport is very important and we, and our stakeholders, take this very seriously. I think we will be able to surprise Europe within the next five years with what we will have achieved by then.’

The right time
Many will argue that, because of the economic situation, this is not the right time to make a major transition such as the switch to LNG. But Carvalho absolutely disagrees with this. ‘Usually, it is best to start investing in a situation like this. In Portugal, we are transforming our economy in a time of crisis. Ship owners or harbour authorities who invest now will reap the benefits by the time the price of oil reaches peak level. Their investments will then start to pay off and increase their competitive edge. I therefore think this is the opportune moment to make the transition to LNG.’ But there is another responsibility, maybe even more urgent than profitability and competitiveness, he says. ‘Think of the future, think of the environment and think of how similar this transition is to the transition from coal to oil. It is our generation that has to do it.’
- The **International Convention for the Prevention of Pollution from Ships (MARPOL)** is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It is issued under the IMO and sets the regulation on the maximum percentage of sulphur content in fuel allowed in ECAs.

- The **International Code for the Construction of Gas-Fuelled Ships (IGF Code)** is a code recently adopted by the IMO that defines requirements for the construction of gas-fuelled, seagoing vessels achieving an equivalent level of safety, reliability and dependability compared to conventional oil-fuelled machinery.

- The **International Code for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)** is a code by the IMO with the purpose of providing an international standard for safe transport by sea of liquefied gases in bulk and certain other substances. It prescribes the design, construction standards and equipment that these ships should carry in order to minimise the risk to the ship, its crew and the environment.

- The **International Convention on Standards of Training, Certification and Watch Keeping for Seafarers (STCW Convention and Code)** describes the minimum standards of competence for seafarers. Recently, IMO issued specific Interim Guidance on Training for Seafarers on ships using gases or other low flashpoint fuels (STCW.7/Circ.23).

- The **European Agreement Concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN)** specifies the conditions for the transportation of dangerous goods via inland waterways (including LNG).

- The **Rhine Vessel Inspection Regulation (RVIR)** issued by the Central Commission for the Navigation of the Rhine (CCNR), for the navigation on the River Rhine, and the **Directive 2006/87/EC** issued at EU level, define the technical rules and requirements for inland waterway vessels to be allowed to navigate on the Rhine and main other EU waterways. It is expected that in 2016 at the latest, the use of LNG as a fuel will be possible in both legal regimes and that the appropriate regulations concerning the vessel, the personnel, the operation of LNG powered vessels and traffic rules will be adopted.

- **Directive 2012/33/EU** of the European Parliament and of the Council of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels. New sulphur emission limits were globally adopted in 2008 by the IMO and transposed in 2012 into Directive 2012/33/EU. A revised directive introduced requirements which entered into force on 1 January 2015 that marine fuels used within ECAs are not used if their sulphur content exceeds 0.10 %, and 0.5% as from 1 January 2020 in all other EU sea areas. These requirements have generated an increased interest amongst the shipping industry in the potential of using alternative fuels.

- **Directive 2014/94/EU** of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure. The directive requires Member States to develop national policy frameworks for the market development of alternative fuels and their infrastructure, foresees the use of common technical specifications for recharging and refuelling stations, paves the way for setting up appropriate consumer information on alternative fuels, including a clear and sound price comparison methodology. The Member States have two years to submit their national policy frameworks. The Commission will then assess and report on those national policy frameworks in order to ensure coherence at Union level.
LNG is a Natural Gas that is cooled down to -160 degrees Celsius and, as a result, becomes a liquid. Subsequently, it can be stored or transported. At its final destination, it can be warmed back to its original gaseous state in order to make it fit for use. The production chain reads as follows.

1. **Natural Gas extraction and processing**
   After the raw Natural Gas is extracted, it is cleaned from impurities such as fluids and non-methane hydrocarbons during the purification process. The largest volumes of Natural Gas are extracted by the USA, Russia, Canada, Iran, Norway, China and Qatar.

   The most notable gas players are Gazprom, Gasnor and Qatar Gas.

2. **Natural Gas liquefaction**
   During the liquefaction process, the Natural Gas is filtered to dispose of components such as dust, acid gases, helium, water, and heavy hydrocarbons. It is cooled down further (cryogenic refrigeration) to the boiling point of approximately -162° Celsius at ambient pressure, at which point it liquefies.

   The most notable Natural Gas liquefiers are Qatar Gas, Petronas, APPEA and Pertamina.

3. **LNG transport, storage**
   In a liquid state, its volume is 600 times smaller than in its gaseous state, whereas its energy content stays the same. This enables it to be economically transported over sea by specially designed LNG carriers. These carriers have double hulls in order to protect the cargo system from leaks or damage.

   The most notable LNG overseas traders are Exxon Mobile, Royal Dutch Shell and BP.

4. **Small-scale LNG distribution**
   LNG can be distributed on a small scale from liquefaction and regasification terminals or from satellite storage facilities. Specially designed bunker vessels are used for sea transport. LNG can be transported over land by tanker trucks or railway tankers.

   The most notable LNG distributors are Gasnor and Skangass.

5. **Safety**
   LNG explosions or flammability depend on several factors, such as evaporated gas concentrations, loss of containment rates or enclosure, amongst other environmental aspects. Ignition can occur under a narrow range of 5-15% gas concentration in air and the consequent possible fire hazard takes different shapes, depending on the release event and media in which it takes place. In the meantime, LNG tankers have sailed approx. 100 million miles without any major accidents. On the other hand, more frequent accidents occur at gas and oil production plants all over the world.
OVERVIEW OF USEFUL ADDRESSES / WEBSITES

For further information on all possible aspects of LNG as a shipping fuel, please contact one of the following organisations or websites.

Industry associations and websites giving an overview of LNG as a fuel:
More on LNG for shipping
SGMF, The Society for Gas as a Marine Fuel
IAPH, International Association of Ports and Harbours
INTERTANKO, International Association of Independent Tankers
IBIA, International Bunker Industry Association

International bodies:
International Maritime Organisation (IMO)
International Organisation for Standardisation (ISO)
Society of International Gas Tanker & Terminal Operators (SIGTTO)
Oil Companies International Marine Forum (OCIMF)
Intergovernmental Organisation for International Carriage by Rail (OTIF)

European bodies:
European Commission (EC), Directorate-General for Mobility and Transport (DG MOVE)
European Committee for Standardisation (CEN)
United Nations Economic Commission for Europe (UNECE)
Central Commission for the Rhine (CCNR)

Classification societies:
Classification societies are NGOs that establish and maintain technical standards for the construction and operation of ships and offshore structures. They also validate that construction is done according to the standards and carry out regular surveys to ensure compliance.

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<th>No</th>
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<td>American Bureau of Shipping</td>
<td>ABS</td>
<td>May 2011</td>
<td>Guide for propulsion and auxiliary systems for gas-fuelled ships</td>
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<td>2</td>
<td>Bureau Veritas</td>
<td>BV</td>
<td>May 2011</td>
<td>Safety rules for gas-fuelled engine installations in ships: Rule note NR 529 DT R01 E</td>
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<td>Guidelines for the issuance of ship fuel gas</td>
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<td>11</td>
<td>Polish Register of Shipping</td>
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<td>July 2012</td>
<td>Guidelines on safety for Natural Gas-fuelled engine installations in ships; publication No. 88/P</td>
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<td>12</td>
<td>Italian Register</td>
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<td>June 2011</td>
<td>Rules for the classification of ships, Amendments to part C, Chapter 1: New Appendix 7 - Gas-fuelled ships</td>
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<td>13</td>
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