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# Removing Barriers to the Use of Natural Gas as Maritime Transportation Fuel


UNITED NATIONS

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

# Removing Barriers to the Use of Natural Gas as Maritime Transportation Fuel

**ENERGY SERIES No. 54**

**UNITED NATIONS**
New York and Geneva, 2017

# Note

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# Acknowledgements

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Driven by its purpose of safeguarding life, property and the environment, DNV GL provides classification and technical assurance along with software and independent expert advisory services to the maritime, oil & gas and energy industries. Operating in more than 100 countries, DNV GL also provides certification services to a wide range of industries related to maritime transport options and risk mitigation.

Mr. Tellkamp is a member of the ECE Group of Experts on Gas.

ECE/ENERGY/116

UNITED NATIONS PUBLICATION
*Sales No. E.18.II.E.4*
ISBN 978-92-1-117149-5
eISNB 978-92-1-362959-8
ISSN 1014-7225

# Foreword

In 2015, the Group of Experts on Gas of the United Nations Economic Commission for Europe (UNECE) published a report on the increasingly critical role of liquefied natural gas (LNG) in the global energy landscape. The Group noted that the share of LNG was poised to grow dramatically in the foreseeable future.

This report on Removing Barriers to the Use of Natural Gas as Maritime Transportation Fuel is another step in our exploration of the catalytic role of natural gas in attaining the Sustainable Development Goals, and in particular Goal 7 – to ensure access to affordable, reliable, sustainable and modern energy for all. The report demonstrates the business case for using LNG as a fuel in maritime transport, for both LNG tankers and – increasingly since 2000 – other ships. Currently, there are over 300 ships powered by LNG. This is a positive development in view of the significant environmental benefits of LNG compared to heavy fuel oil and diesel both of which dominate today's market for international shipping bunkers.

The report identifies drivers, key enablers, gaps and barriers to the use of LNG as fuel in maritime transport. Reducing the use of heavy hydrocarbons and increasing the use of LNG in maritime transport could help reduce carbon dioxide emissions and other pollution arising from international trade. This is a step in the right direction as we confront the challenges associated with climate change and air quality.

Olga Algayerova<br>
Executive Secretary<br>
United Nations Economic Commission for Europe

# Acronyms and Abbreviations

**$CO_2$** Carbon dioxide

**ECA** Emission Control Area

**ECE** United Nations Economic Commission for Europe

**GEG** Group of Experts on Gas

**GHG** Greenhouse gas

**GIIGNL** The International Group of Liquefied Natural Gas Importers

**GWh** Gigawatt hour

**IGF** International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels

**IMO** IGF Code - International Maritime Organization

**LNG** Liquefied Natural Gas

**LPG** Liquefied Petroleum Gas

**MARPOL** International Convention for the Prevention of Pollution from Ships

**NIMBY** Not in my back yard

**NOx** Nitrogen oxides

**SOLAS** International Convention for the Safety of Life at Sea

**SOx** Sulphur oxides

**TEN-T** Trans-European Transport Networks

# Contents

**Foreword** .......... **3**
**Introduction** .......... **7**

**2. LNG as marine fuel** .......... **8**

2.1 Drivers .......... 10

2.2 Key enablers .......... 13

2.3 Gaps and barriers .......... 19

**3. Conclusions** .......... **22**

# List of Figures

Figure 1 LNG value chain and stages of development .......... 7

Figure 2 Status gas-fuelled ships as per August 2017 .......... 8

Figure 3 Operating area gas-fuelled ships as per August 2017 .......... 9

Figure 4 Global footprint of gas-fuelled ships in operation .......... 9

Figure 5 Main drivers for technology uptake .......... 10

Figure 6 Sulphur regulation for global shipping .......... 11

Figure 7 Examples of factors affecting fleet growth .......... 12

Figure 8 Six key enablers for LNG as marine fuel .......... 13

Figure 9 Global LNG bunker infrastructure in operation, under development and under discussion .......... 14

Figure 10 Safety regulation along LNG supply chain – overview .......... 15

Figure 11 Example of accumulated cost compared to HFO baseline .......... 16

Figure 12 Modalities in LNG infrastructure .......... 17

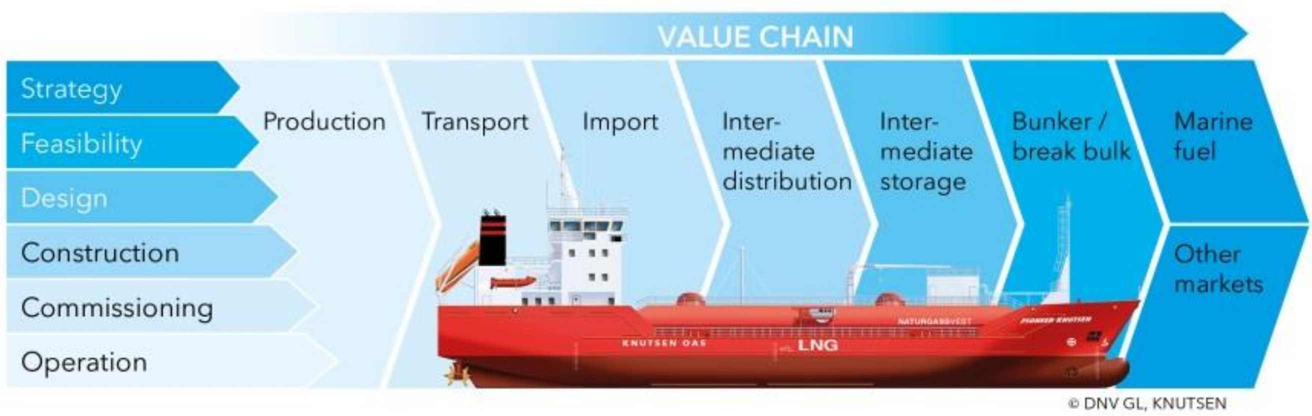
# 1. Introduction

In 2016 the United Nations Economic Commission for Europe (ECE) Group of Experts on Gas established a task force to explore removing barriers to the use of natural gas as a transportation fuel. The work of the task force focussed on the use of natural gas in transportation to facilitate and accelerate the commercialization of natural gas, including renewable methane, as a fuel for the road and marine sectors. NGVA Europe (Natural & Bio Gas Vehicle Association Europe) led the task force with respect to on-road vehicles and coordinated its activities with key NGV stakeholders and international partners. Asociación Ibérica del Gas Natural para la Movilidad (GASNAM[1]) provided preliminary inputs regarding maritime use of natural gas. This present report has built on those initial inputs with significant contributions by DNV GL[2]. The report summarizes findings to date on the main barriers to the use of natural gas in maritime transport to inform the Group of Experts on Gas on appropriate approaches to their removal.

This report considers not only gas-fuelled ships, but also the supply chain. It acknowledges that – other than the established bunker industry – LNG as fuel for ships is an industry in its infancy and has not been commoditized: there is no spot market, contract models are individually negotiated, quality standards are under development, the number of suppliers is small, and so forth.

All activities and segments of this emerging industry can be seen in Figure 1.

Figure 1
**LNG value chain and stages of development**




*Source: DNV GL*

1 http://gasnam.es/
2 https://www.dnvgl.com/

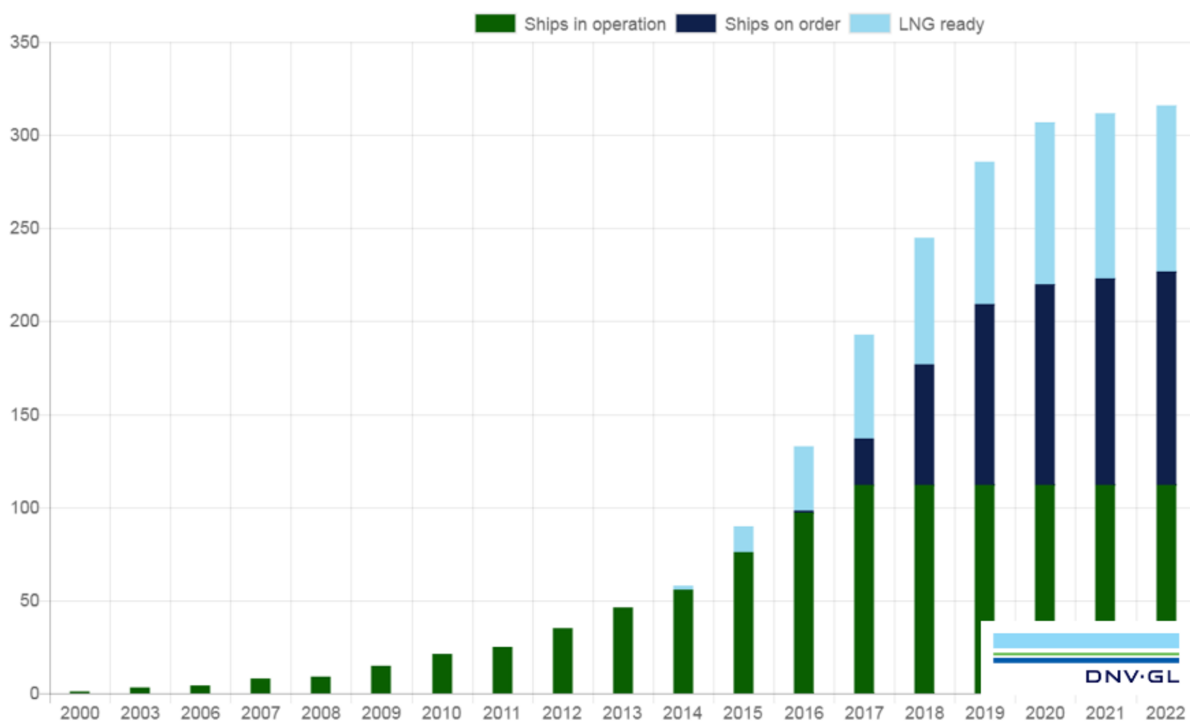
# 2. LNG as marine fuel

LNG has been used as fuel for ships for decades. LNG transported by LNG tankers continuously evaporates creating boil-off gas. On many such ships the gas is sent to machinery, notably the boilers and the auxiliary and main engines.

Since 2000, LNG is also used in ships that are not LNG tankers. A passenger ship was built in Norway in order to demonstrate the technical feasibility of LNG-fuelled ships that are not LNG tankers. At the time of writing of this report the number of non-tanker ships using LNG as fuel has grown to 99 ships in operation plus 93 on order. Ships in all ship segments are using LNG as fuel. The main geographical areas where LNG-fuelled ships are deployed are the European Union, Norway and the United States.

Figure 2 shows ships in service (green) and confirmed ships on order (blue) as of January 2017: 99 ships are in operation, 78 will be delivered before end of 2019, 91 ships will be delivered before end of 2021, including the ships delivered in the years before. The lead time for ship building is about two to three years. This means that more ships will be ordered with delivery in 2019 and onwards, increasing the number of ships on order significantly. In addition, ships that are "LNG-ready" are on order. "LNG-ready" means that all necessary preparations[4] have been done to convert a ship to easily use LNG as fuel, but the expensive equipment has not yet been not installed.

Figure 2
**Status gas-fuelled ships as per August 2017**

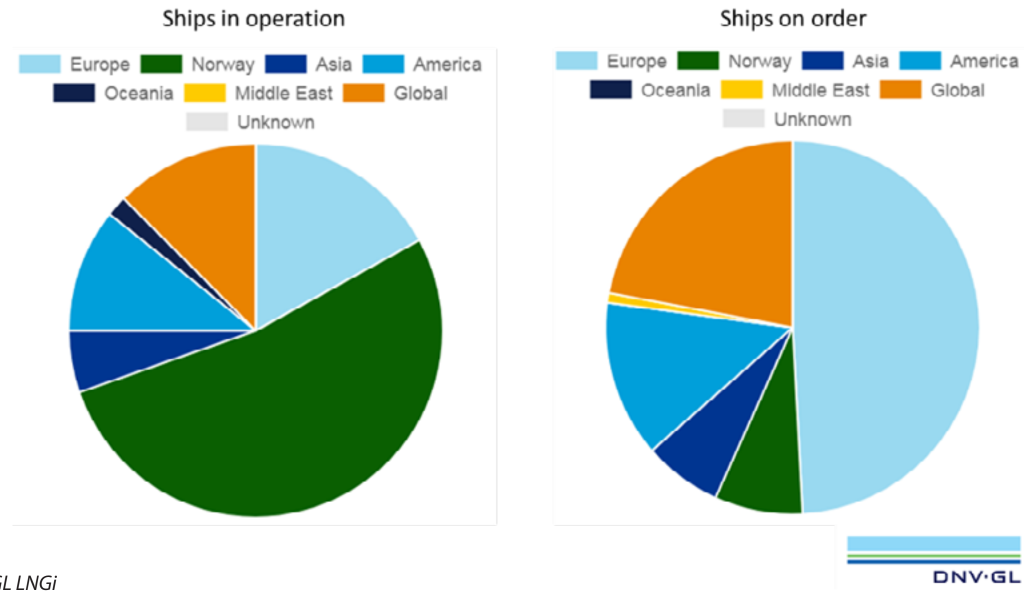



*Source: DNV GL LNGi [3]*

[3] LNGi is DNV GL's LNG intelligence portal: lngi.dnvgl.com

[4] Aspects that are expensive to change: space and foundation for LNG tank, routings for pipes kept free, safety distances for ventilation and safety valves are kept, engine chosen that can be easily converted, etc.

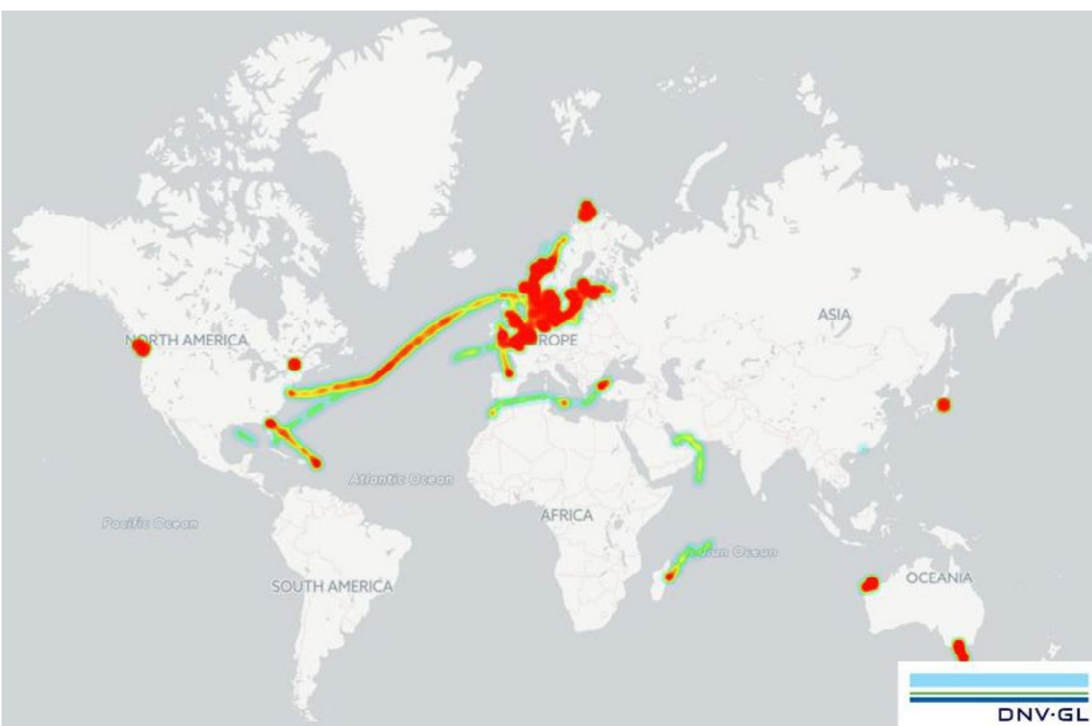
Figure 3
**Operating area gas-fuelled ships as per August 2017**




*Source: DNV GL LNGi*

Gas-fuelled shipping was perceived as a Norwegian niche-market. However, figure 3 shows clearly that this is no longer the case– the majority of ships on order is for operation outside Norway. The international spread of gas-fuelled ship operations is shown in Figure 4, which is a heat map using a signal that ships have to broadcast every few minutes. Red traces show high intensity, light green lowest intensity in ship operations. The highest concentration of gas-fuelled ships is in Northern Europe, while the United States is also increasing the use of gas-fuelled ships. Single ships using gas as fuel also operate in South America and the Far East.

Figure 4
**Global footprint of gas-fuelled ships in operation**



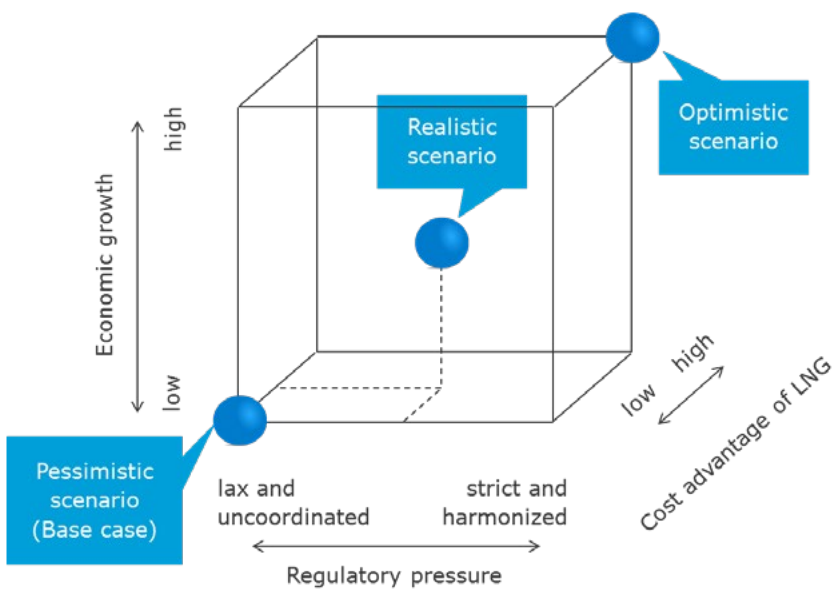

*Source: DNV GL LNGi*

It is worth stressing that the technology for using LNG as fuel for ships is mature and available for most applications.

## 2.1 Drivers

Shipping is traditionally an industry with compliance-based operations. It is also closely linked to the global economy. The motivation for shipping to adapt new technologies is driven by three factors: regulation, economic growth and cost competitiveness of the new technology. Figure 5 demonstrates these drivers for use of LNG as fuel for shipping.

Figure 5
**Main drivers for technology uptake**




*Source: DNV GL*

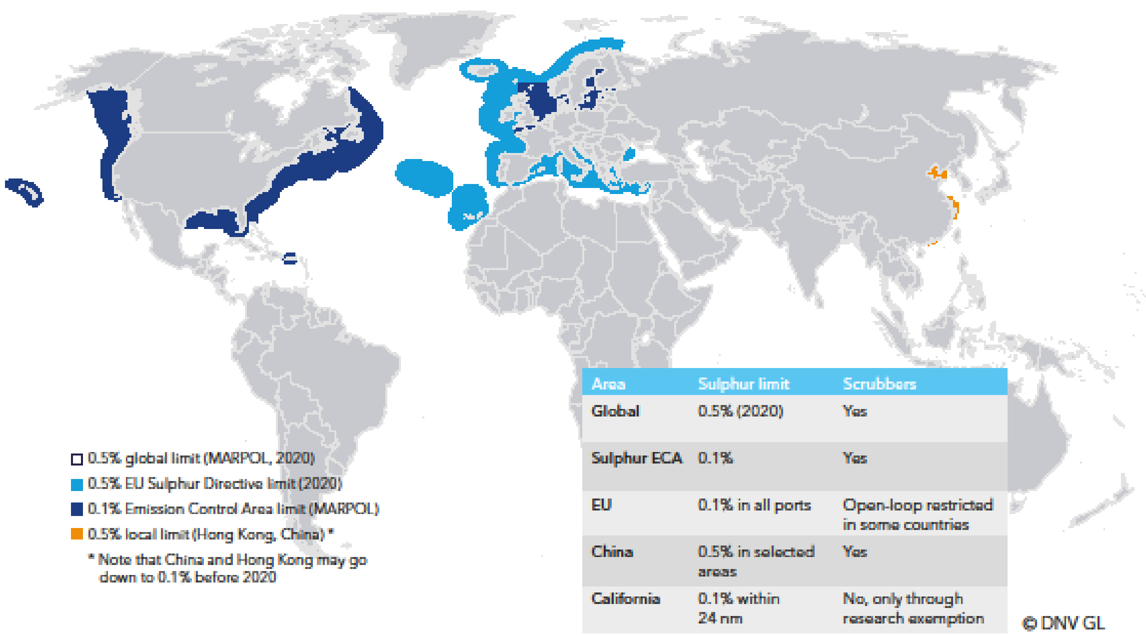
### 2.1.1 Regulation

Figure 6 illustrates the regulatory pressure on shipping in the context of LNG. International regulation of emissions to air for shipping falls under the mandate of Annex VI of the IMO MARPOL[5] Convention. Effective 1 January 2015, all ships need to use fuel with a sulphur content of less than 0.1 per cent in the dark blue Emission Control Areas (ECA)[6]. Outside of these areas, the sulphur content is limited to 3.5 per cent. From 1 January 2020, ships need to use fuel of a sulphur content of maximum 0.5 per cent outside the dark blue areas. At the time of the writing of this report, the orange areas are areas where the People's Republic of China is testing the impact of a 0.5 per cent limit.

In the dark blue area around North America, NOx emissions are limited to Tier III level[7] for ships built after 1 January 2016.

Using gas-fuelled engines is generally beneficial with regards to emitting $SO^x$, $NO^x$ and PM[8]. The net advantage regarding $CO_2$ is under discussion, but ideally up to some 25 per cent reduction may be realized.

Figure 6
**Sulphur regulation for global shipping**




| Area | Sulphur limit | Scrubbers |
|---|---|---|
| Global | 0.5% (2020) | Yes |
| Sulphur ECA | 0.1% | Yes |
| EU | 0.1% in all ports | Open-loop restricted in some countries |
| China | 0.5% in selected areas | Yes |
| California | 0.1% within 24 nm | No, only through research exemption |

*Source: DNV GL*

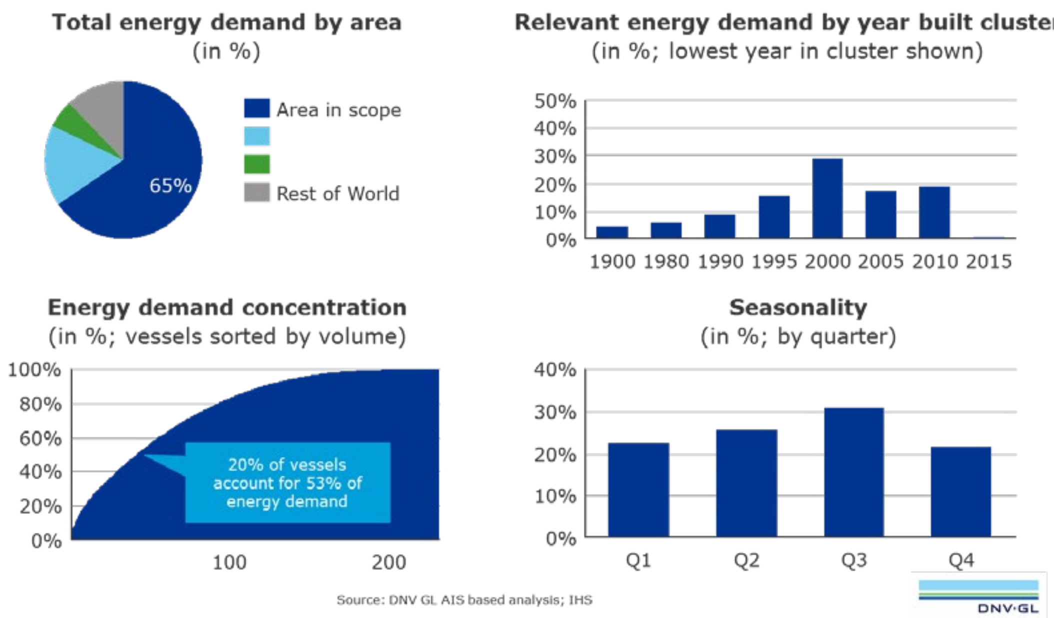
[5] International Maritime Organization, Maritime Pollution
[6] With a limit of 1 per cent up to 31 December 2014
[7] MARPOL Annex VI has three levels for NOx, with Tier III being by far the strictest
[8] 100 per cent reduction, 80 – 90 per cent reduction and 100 per cent reduction, respectively

## 2.1.2 Economic growth

Shipping and ship building have been in a very bad economic state for several years. The current downturn has been characterized as one of the longest ever. Shipyards, largely in the Far East, are running out of business. Shipping companies are consolidating. Some evidence shows that there are cases of ships being recycled at an age as early as seven years.

Thorough analysis, taking into account regional factors, shows that a strong case for gas-fuelled ships does exist. Figure 7 shows how clusters of year build, distribution of demand over areas, fleet composition with concentration of energy demand and seasonality need to be assessed in order to evaluate whether there is a justification to use LNG as fuel for shipping.

Figure 7
**Examples of factors affecting fleet growth**




*Source: DNV GL*

## 2.1.3 Cost advantage of LNG

Shipping is a capital intense industry using assets with a traditionally long life expectancy. Two cost types define the viability of an investment – capital cost (CAPEX) and operational cost (OPEX).

Using LNG as fuel affects both CAPEX and OPEX. Due to the cryogenic nature of LNG and respective technologies, CAPEX is higher than for a ship using traditional fuel that is compliant with the emissions regulations. However, if compliance with emissions regulations cannot be guaranteed by the choice of fuel alone and exhaust treatment technologies need to be installed, the disadvantage in CAPEX is reduced for gas-fuelled ships. On the other hand, the outlook indicates that LNG delivered free on board may be cheaper than low-sulphur traditional fuels. This is the main OPEX advantage when using LNG as fuel.

The key OPEX driver is the cost of infrastructure.

LNG will benefit most post 1 January 2020, when the global sulphur cap is introduced. Ships that are currently under consideration to be built and which will sail a significant proportion of their time in ECAs are likely to be fuelled with LNG.

## 2.2 Key enablers

Figure 8
**Six key enablers for LNG as marine fuel**


*Source: DNV GL*

In order to allow the use of LNG as marine fuel to grow, six key enablers need to be in place as shown in Figure **8**. Overall, it can be concluded that in Western Europe no showstoppers exist to the use of LNG as marine fuel

### 2.2.1 Access to LNG

Cost effective access to LNG is vital for establishing LNG as fuel for ships. "Access" relates to physical access as well as commercial access: where to get LNG and how to purchase it and under what terms. The LNG industry is used to long-term take-or-pay contracts, whereas shipping is used to a spot market for bunker fuels. In other words, both industries are working on different timescales. This needs to be – and increasingly is – bridged commercially by LNG bunker suppliers.

Physical access includes reload capability of LNG terminals to load not only large tankers of a capacity of 165,000 m3 or more but small LNG bunker supply vessels of 10,000 $m^3$ capacity or less. Being aware of this need, terminals are being extended with reloading jetties that are dedicated to small vessels; the GATE terminal in Rotterdam being the latest example. This is reducing the CAPEX for LNG bunker supply vessels since a second manifold for accessing large terminals is no longer needed.

Figure 9 shows global developments of LNG bunker infrastructure in the various stages i.e. in operation (green), decision made (dark blue), and under discussion (light blue).

Figure 9
**Global LNG bunker infrastructure in operation, under development and under discussion**


*Source: DNV GL LNGi*

In summary, each ship that wants to use LNG as bunker fuel will be able to get supply. However, the supply might not be secured as easily as it is the case for traditional fuels, and significantly more lead time may need to be factored in for setting up the necessary logistics and for getting all the necessary permits in place. The use of LNG as ship fuel has now started with ships on regular trades. An increasing number of ships on tramp trades i.e. when the ship does not have a fixed schedule or published port of call are using LNG as fuel in Northern Europe, where access to LNG can be provided by LNG bunker suppliers.

## 2.2.2 Logistics

The logistics for use of LNG as marine fuel need to be safe and reliable. "Safe" in an health, safety and environment (HSE) sense, "reliable" from the ship owner's perspective as the owner depends on fuel supply in the quantity and quality as needed at a location where needed and at a time when needed. The logistics for supplying LNG as fuel needs to fit with the use of the ship. In most cases, LNG needs to come to the ship – most ships will not move to get LNG for bunkering.

Broadly speaking, shipping has two main operating patterns: on a fixed trade for a period of time, or on tramp. Ships on a fixed trade sail like buses or railcars on fixed schedules with fixed berths in the ports they are calling at i.e. the terminals are fixed. Their trading patterns are very predictable, and logistics mainly need to ensure that the delivery of LNG at the intended terminal or berth is possible.

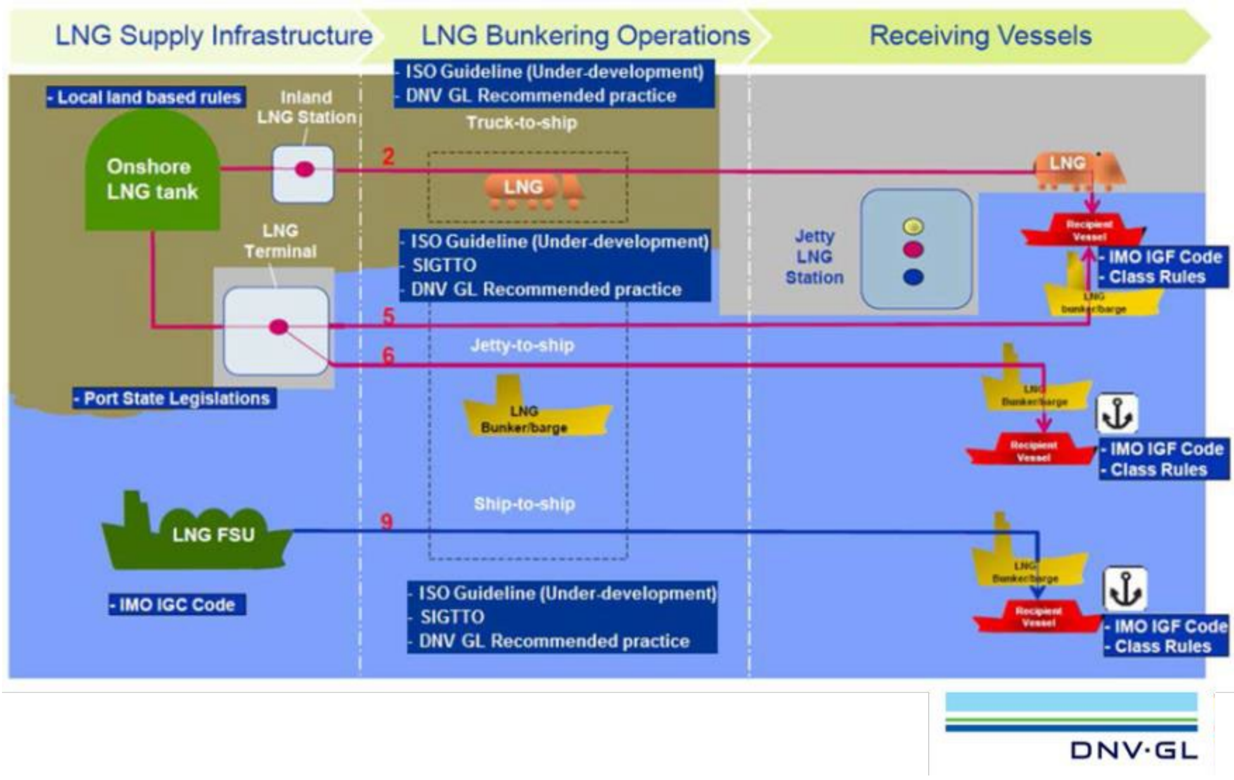
Trade patterns for ships on tramp have a fundamentally different characteristic. They are called for one voyage to pick up goods at a point in the world and to deliver within an agreed period at another point in the world. It is inherent to the very nature of this pattern that it is very unpredictable. A ship may be mobilized to sail half around the world for picking up cargo, and then sail again half around the world for delivery.

A potential exemption to this rule of thumb that LNG needs to be brought on-board re ships on a back-to-base pattern. For example, port service vessels such as tugs, pilot boats, port ferries and similar are stationary in one port. They have a fixed berth and scheduled downtimes. Often these vessels share bunker supply in a port. This common use of one supply point may also demonstrate the case for the use of LNG – depending on local interests.

## 2.2.3 Legal Certainty

With regard to environmental legislation, legal certainty has been provided by the decision of IMO MEPC 709 in October 2016 to introduce a global cap of 0.5 per cent sulphur for marine fuels by January 2020, see Figure 6. With regard to ship design and construction, the introduction of the IGF Code10 by IMO MSC11 with effect from 1 January 2017 has provided legal certainty for ship design.

Figure 10
**Safety regulation along LNG supply chain – overview**




*Source: DNV GL*

9 70th meeting of IMOs Maritime Environmental Protection Committee
10 International Code for Ships using Gases and other Low Flashpoint Fuels
11 Maritime Safety Committee

Not fully clear however, is the picture where ship regulation and onshore regulation meet. DNV GL has performed a thorough study for European Commission Directorate-General for Mobility and Transport (DG MOVE)[12] *"Analysis and evaluation of identified gaps and of the remaining aspects for completing an EU-wide framework for marine LNG distribution, bunkering and use".*

The gaps analysed are located mainly towards the right end of the value chain for LNG as fuel, at the interface between maritime and onshore regulation, see Figure 1. A key aspect is that maritime regulation is harmonized globally, whereas onshore regulation can fall under the responsibility of a manifold of local authorities. However, no showstoppers have been identified. A list of recommendations for addressing the gaps is provided in the aforementioned DNV GL study.

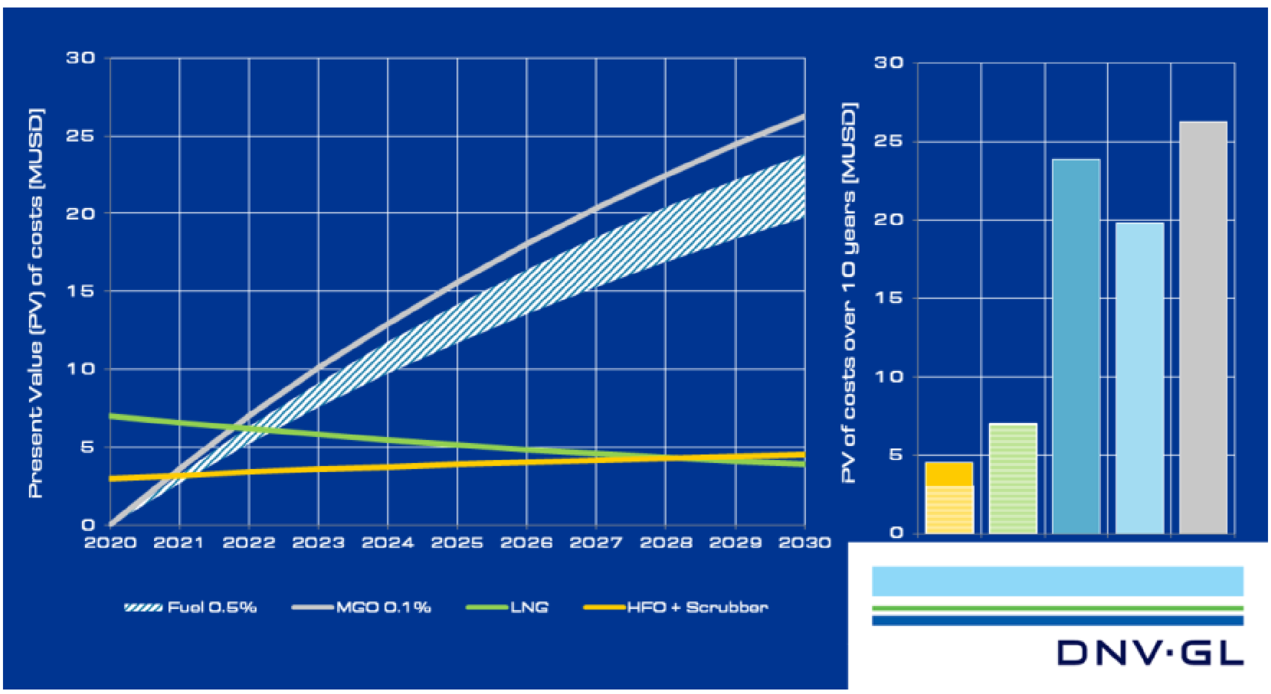
## 2.2.4 Investment Climate

**Ships**

The investment climate is decisive for the uptake of LNG as fuel for ships as the CAPEX has to be balanced by the OPEX, and the total investment needs to be competitive with alternative options. These are

1. Heavy fuel oil with a scrubber.
2. Compliant heavy fuel oil of 0.5 per cent sulphur content.
3. Compliant marine diesel oil or marine gas oil with a sulphur content of 0.1 per cent.

Figure 11
**Example of accumulated cost compared to HFO baseline**




*Source: DNV GL*

Figure 11 shows a present value calculation for the different compliance options for one particular scenario. The scenario is mainly characterized by prices for fuel, CAPEX, and OPEX other than fuel costs, depreciation and rate of interest. Depending on these values the attractiveness of the options vary significantly.

A number of options are in use for supporting the choice of cleaner fuels in order to stimulate investments. Examples include:

[12] https://ec.europa.eu/transport/sites/transport/files/modes/maritime/studies/doc/2015-12-lng-lot1.pdf

1. Governmental tax on emissions. For example, tax on NOx in Norway.
2. Industry run funds as alternative to taxes. For example, NOx funds in Norway.
3. Governmental investment in pilot applications. For example, EC TEN-T and CEF schemes; German scheme to support the uptake of low emission fuels.
4. Governmental investment in development of new technologies. For example, German scheme for development of low-emission technologies for ship propulsion.

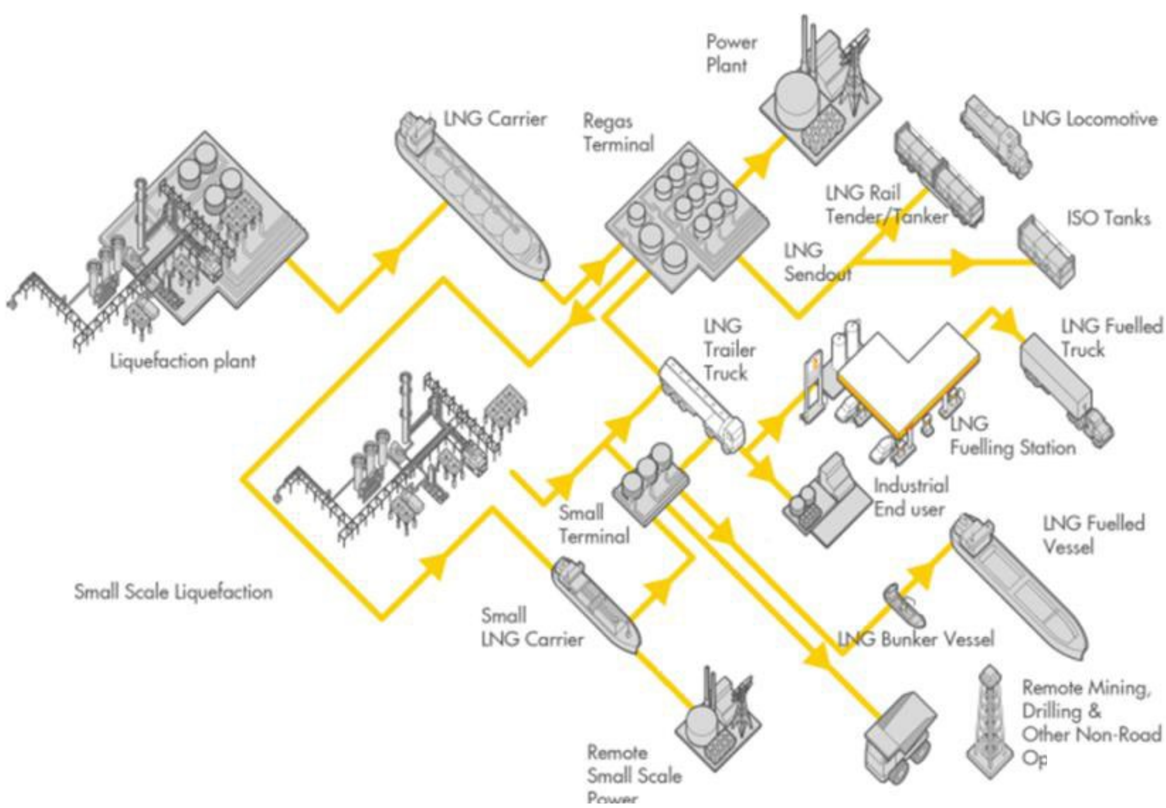
For suppliers of LNG as fuel, it is of utmost importance to understand who would be in charge of each of the costs. Often ships are owned by company A, the owner, technically managed by company B, the ship manager, and chartered out (leased out) to company C, the charterer. The owner is responsible for all CAPEX, whereas the charterer is responsible for the cost of fuel. If increased CAPEX leads to reduce fuel costs and maybe other OPEX, an agreement between the owner and charterer needs to be found.

**Infrastructure for LNG bunkering**

LNG infrastructure comprises only three main elements:

- Production
- Transportation
- Storage.

Figure 12
**Modalities in LNG infrastructure**




*Source: Shell*

However, whilst the infrastructure can appear relatively simple the situation becomes complex when the modalities of implementation at different scales and via different methods are taken into account. For example, production ranging from a few tonnes a day to millions of tonnes a year; storage in atmospheric tanks or in pressurized tanks; storage of less than 30 m3 up to storage of several hundreds of thousands of m3; and transport by sea, rail or road. Figure 12 provides an overview of the complexity.

The key challenge for investing in a downstream LNG infrastructure is to raise the utilization of the infrastructure up to levels where payback times are acceptable for investors or investing companies.

LNG bunkering infrastructure is in general unlikely to be developed by established ship bunker companies. The reason is that the existing bunker business is characterized by a spot market with high transaction volumes but low margins, and that high investments are needed for building an LNG bunker supply chain.

Oil and gas majors are active in developing LNG bunker supply chains (for example Shell's LNG bunker supply vessel currently under construction), downstream companies (for example Engie's LNG bunker supply vessel delivered in QI 2017), newly established companies (for example BominLinde LNG's LNG bunker supply vessel on order) and joint ventures (for example Shells' and Keppel's joint venture in Singapore).

A common pattern is that LNG bunker investments are linked with investments into other LNG supply such as feedstock for industry in order to reduce the investment costs per unit.

### 2.2.5 Competence

Competence, knowledge and skills are relevant at three levels:

1. Policymakers and C-Level decision makers need to have the competence to give the right directions for safe and cost-effective introduction of LNG as ship fuel and the development of a safe and cost-effective LNG bunker supply chain.
2. At the organizational level, those in charge of developing regulations and businesses need to have the right knowledge for developing a safe and cost-effective LNG bunker infrastructure.
3. At the operational level, a skilled workforce is needed for building and operating installations.

These three levels are addressed differently. The main instruments for reaching policymakers and C-Level decision makers are industry-run instruments. An example at the national level in Germany is the "Maritime LNG Platform"[13] and at the international level "Sea\LNG"[14].

The second level is addressed by instruments provided by the European Commission like ESSF[15], and industry organizations like shipowner associations, shipbuilder association etc.

On board seagoing ships, skills are identified by available standards[16], and provided by international regulation[17] and by model courses recommended by IMO. On the shore.no particular competence standard or model courses for training of personnel directly involved in LNG operations or indirectly related to LNG operations exist. There are, however ISO technical specifications for LNG facilities on land[18] or LNG bunkering[19], and recommended practices for LNG bunkering, of which the first one was published by DNV GL[20] in early 2014.

13 http://www.lng-info.de/en/
14 http://sea-lng.org/
15 European Sustainable Shipping Forum
16 DNVGL-ST-0026:2014-04 "Competence related to the on board use of LNG as fuel"
17 The international Convention on Standards of Training, Certification and Watchkeeping (STCW)
18 ISO TS 16901 "Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface"
19 ISO TS 18683 "Guidelines for systems and installations for supply of LNG as fuel to ships"
20 DNVGL-RP-G105 "Development and operation of liquefied natural gas bunkering facilities"

An instrument used by the European Commission are projects funded under the Trans-European Transport Network (TEN-T) framework. These initial projects had the purpose of building sufficient competence as a basis for decision making. Examples are the COSTA (CO2 & Ship transport emissions abatement by LNG) project in Portugal or Archipelago LNG in Greece, to name a few.

### 2.2.6 Acceptance

Public acceptance of LNG as fuel for ships is linked to two factors: fear or concern by the public based on being wrongly informed or not informed at all, and by the view on emissions pertinent to LNG-fuelled ships.

The first factor, fear, has an element of "not in my backyard" (NIMBY). Sometimes LNG is confused with other substances and wrongly perceived as being more dangerous than well-known fuels.

The second factor can be split into two items: the undisputed benefits in reducing local emissions for $NO_X$, $SO_X$ and PM[21], and in a discussion about the net impact on greenhouse gas (GHG) emissions. Pertinent to the discussion about GHGs are two main topics: the net reduction of direct $CO_2$ emissions from gas-fuelled engines, and the slip of methane along the value chain and in the engines. The subject is complex since important factors such as engine technology– two-stroke engines in diesel-cycle have for example virtually no methane slip (methane that is not used as a fuel in an engine and essentially escapes into the atmosphere) - and engine generation, old converted diesel engines generally have a higher methane slip than new designed gas engines.

Both NIMBY and GHGs need to be addressed proactively and in a very transparent way. In the best case scenario, the local population would support the introduction of gas as fuel including the necessary local storage. An example is the German city of Brunsbüttel, where the Kiel Canal enters the North Sea. Pollution by ships is a serious issue and reduction of emissions is needed. As a result of well planned and executed communications, the possible future local storage of LNG was not objected to by the population.

## 2.3 Gaps and barriers

Figure 8 shows the key enablers for using LNG as marine fuel. No showstoppers exist that prevent the enablers from being put in place. However, in some areas gaps and/or barriers exist which are discussed in this part of the report.

### 2.3.1 Easy access to LNG

No particular gaps and barriers have been identified. More and more LNG terminals are building re-export capabilities for truck filling or loading small ships such as LNG bunker supply vessels. LNG import terminalsexist at all European coastlines or are under development in the Baltic and in Russia.

### 2.3.2 Reliable and safe logistics

The key gap for logistics is of a regulatory nature on the ship/shore interface, where marine regulation and onshore regulation meet. This can prevent cost-effective solutions from being developed in a short timeframe.

The reason for this is that the two regulatory regimes – marine and onshore – are very different in nature: marine regulation is by its nature global, whereas onshore regulation is national, regional or very local in its nature.

[21] Nitric oxides, sulphur oxides, particulate matter

### 2.3.3 Legal certainty

Harmonization of legislation for LNG distribution and LNG bunkering has been addressed by a report produced by DNV GL for DG MOVE, "Analysis and evaluation of identified gaps and of the remaining aspects for completing an EU-wide framework for marine LNG distribution, bunkering and use". Parts of the executive summary of that study are quoted:

*"The assessment of the existing rules, standards and guidelines shows that from a legal point of view, there are no remaining major showstoppers for the use of LNG as fuel - both for seagoing vessels and inland waterway vessels – nor for the deployment of LNG bunker facilities.*

*Recently, legislation and rules previously prohibiting the use of LNG as fuel for seagoing vessels and inland waterway vessels have been adapted or are being adapted to allow the use of LNG as fuel. The bulk of the proposed recommendations mainly address issues where further harmonisation is possible. An important harmonisation opportunity is the bunkering activity itself, which is today not harmonised in EU ports. Furthermore, EU-wide standards for LNG bunkering installations and requirements for LNG bunkering equipment are missing. Some suggested standards are not strictly required from a legal point of view but are perceived as strong enablers, disseminating codes of good practice.*

*One of the specific aims of this study was to identify harmonisation opportunities with respect to following focus areas: permitting, quantitative risk assessment and incident reporting. Most important findings are summarised below.*

*The design of the permit process and the related practices vary between the Member States. In some Member States permitting procedures are considerably more complex than in others. Several factors are leading to slow and inefficient permit processes. There are on-going initiatives to speed up the overall permit process via e.g. all-in-one permits with only one authority coordinating, and via specific LNG guidance documents. In some Member States specific regulation is in force to smoothen the permit process for selected critical projects.*

*Although the permit processes are well enforced by law in the EU Member States, the overall process is not fully transparent to all involved parties, this includes information on milestones and deliverables, authorities responsible, documents to be produced. …. In addition various Member States have no clear time targets for the different steps in the permitting procedure and/or no enforcement/consequences if the delays are not respected.*

*The responsible authorities are not always familiar with LNG and its benefits. This in combination with lack of LNG skilled people (specific knowledge on LNG and LNG installations) at authorities and clear standards might lead to an overkill of environmental studies to be executed for LNG developments. Some Member States have already created platforms to share best practices and information between all LNG stakeholders.*

*The current risk assessment (e.g. QRA) practices and risk acceptance criteria are identified to provide recommendations for harmonization and improvements to LNG bunkering risk assessment practices across EU Member States and ports. EU countries apply different methodological approaches and criteria to determine and assess external risk for LNG establishments that are subjected to the Seveso directive. It is found that harmonization of the latter is difficult to achieve due to the fact that each Member State has transposed their own interpretation and implementation of the directive in their legislation. For non-Seveso LNG establishments and activities, EU-wide harmonization of the risk assessment approach seems feasible.*

*Several other more specific knowledge gaps have been identified that should be considered as potential improvements in the overall risk analysis process of small scale LNG infrastructure and activities.*

*The current incident reporting structure needs to be adapted to be able to efficiently capture data from LNG bunkering incidents and the lessons learned. The aim of such an updated reporting structure is to capture LNG specific incident data in a European database and to make these data accessible for all relevant stakeholders. The proposed database will combine data from existing databases (e.g. eMARS, EMCIP, ADR, port databases, …). This necessitates that the mentioned existing databases are populated and thus implies that detailed incident reporting routines are in place and followed.*

*The incident database should be implemented at EU level and should cover all incidents, accidents and near–misses with (potential) implications on safety and operations related to the small scale LNG value chain.*

*The preceding part has resulted in a long list of potential interventions (via recommendations) that could help achieve the overall study objective, namely the reduction of emissions by shipping and to stimulate harmonisation across EU and further serves as input to the analysis of the social, economic and environmental impact. The impact assessment is meant as a key tool to ensure that Commission initiatives and EU legislation are prepared on the basis of transparent, comprehensive and balanced evidence. The analysis was ultimately aimed at achieving insight into the (policy) ways of stimulating the use of LNG as clean shipping fuel."*

### 2.3.4 Favourable investment climate

As a result of the crisis in global shipping and ship building, and from the international financial crisis, banks are now very thorough in their due diligence when assessing new projects. Access to capital is not as easy as it was in the pre-Lehmann times.

European governments including the European Commission are however, making funds available to

- Develop technologies
- Build technology demonstrators
- Back the investments of first movers

The key barrier for the uptake of LNG as fuel for ships at the time of writing of this report is the too low price difference of LNG compared to low sulphur Marine Gas Oil or compared to Heavy Fuel Oil combined with exhaust treatment.

Ship fuel is exempted from taxes. Consequently, tax incentives are not an instrument to promote using LNG as ship fuel. The additional investment for the LNG equipment needs to be financed from the price differential of LNG and other low sulphur fuels based on market prices.

### 2.3.5 Competences, knowledge & skills

Closely linked to Chapter 2.3.3, competence and knowledge on side of authorities has in cases proven to be a barrier. Cases where product specific aspects have not been understood by authorities, such as flammability, dispersion etc., have led to lengthy approval processes. A similar situation was seen with authorities who did not accept ships as safe, even though they had been certified according to IMO's International Convention for the Safety of Life at Sea (SOLAS) and Class Rules.

### 2.3.6 Public acceptance

Public acceptance varies significantly around the world. In general a NIMBY attitude not specifically linked to LNG may slow down the development of LNG bunkering in some areas.

# 3. Conclusions

Downstream LNG and LNG bunkering is an industry in its infancy. LNG-fuelled shipping and consequently LNG bunkering has for historic reason been driven by development in one single country, Norway. As of 2017, development outside Norway has a higher momentum than in Norway. LNG bunker is not yet a commodity business, as is for example established bunkering of heavy fuel oil or distillates. Today, in order to secure the future supply of LNG for a ship under construction, the LNG bunker supply needs to be secured and fixed for the time the ship will enter service while the ship is being designed.

Only recently are owners confronted with 20 year take-or-pay contracts when they want to buy LNG as bunker fuel. It has also been only recently that port authorities have heard about LNG bunkering and hence are increasingly prepared to give permits for LNG bunkering – if they do not have already put in place a full updated port regulation that takes bunkering of LNG into account.

With the IGF Code, IMO has provided a technical regulation to ensure safe design and operation of gas-fuelled ships. IMO has put a regulation in place that will prevent the use of high sulphur fuels globally from 2020.

With the MARPOL Annex VI regulation limiting the sulphur content in the fuel to 0.5 per cent from 2020 globally, and to 0.1 per cent today in designated ECAs, a tool is in place to enforce the use of low sulphur fuels and to encourage use of LNG as fuel for ships. Check and enforcement of compliance is in the hands of individual countries. If the enforcement – and a strict process of fining violations – of this regulation is harmonized it would support the uptake of LNG as ship fuel.

Taking into account the high investments needed to further develop technology and infrastructure, regions like the European Union and countries such as Germany have put in place innovation and funding schemes which are co-financing prototype projects and development of new technologies.

The shipping industry could be described as (a) very conservative, (b) under high commercial pressure, (c) possibly facing the beginning of a major shift in how container shipping is organized globally, and (d) by its nature an international and global business. To accelerate the introduction of LNG as a marine fuel, it is recommended to take these attributes into account and to consider actions that reflect the global nature of shipping.

In general, there are no obstacles to introducing LNG as ship fuel. Depending on the specific port, country or region where LNG supply is under development, it is issues largely related to local regulations that need to be addressed carefully and in advance of deployment of ships into that area.

Removing Barriers to the Use of Natural Gas as Maritime Transportation Fuel

Currently there are over 300 ships powered by liquefied natural gas (LNG). This number is increasing.

LNG has significant environmental benefits over heavy fuel oil and diesel that dominate today's international shipping bunkers.

The report analyses drivers, key enablers, gaps and barriers to the use of LNG as fuel in maritime transport. As such, it could be a step in the right direction as the world confronts the challenges of climate change and air quality.

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ISBN 978-92-1-117149-5

Layout and Printing at United Nations, Geneva – 1800308 **(E)** – June 2018 – 1,106 – **ECE/ENERGY/116**