



DANISH MARITIME AUTHORITY

Full report

North European LNG Infrastructure Project
A feasibility study for an LNG filling station infrastructure
and test of recommendations



Co-financed by the European Union
Trans-European Transport Network (TEN-T)



MAN Diesel & Turbo



Observers



Consultants





Foreword

The background for this project is the development of shipping as a green transport mode. This demands new technologies, for example new fuels instead of oil-based fuels. Natural gas in the form of liquefied natural gas is an obvious alternative as it has environmental and climate advantages compared to oil-based fuels.

From 1 January 2015, new regulations on the sulphur content of fuel for shipping in the Baltic Sea, the North Sea and the English Channel will come in force. Accordingly, the sulphur content has to be decreased from 1.0 % to 0.1 %, setting the competitiveness of short sea shipping under pressure compared with land-based transport and especially trucks.

Liquefaction of natural gas is necessary for transport and storage as 1 cubic metre of LNG corresponds to 600 cubic metres of natural gas. But a new fuel demands an infrastructure for storage and distribution, and a structure of LNG filling stations must be set up.

The project focuses on this issue and comes up with recommendation encompassing the LNG supply chain spanning from LNG import terminals and liquefaction of natural gas in Europe to ships as end-users.

The recommendations target the problems of setting up such an infrastructure, what must be done to solve each problem and who has to do it.

The project partners are states, ports, gas and LNG terminal companies and companies from the maritime cluster, hereby representing the LNG supply chain.

The project forms part of a larger project co-financed by the EU on LNG infrastructure and deployment in ships with two full-scale pilot LNG cruise ferries serving the south-western part of Norway and the European continent through the Port of Hirtshals.

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Executive Summary

Introduction

In order to improve the environment by developing shipping as a green means of transport the International Maritime Organization (IMO) demands that the sulphur content in maritime fuel for use in the North Sea, the English Channel and the Baltic Sea – Sulphur Emission Control Areas (SECA) – be decreased from 1.0 % to 0.1 % after 1 January 2015. This regulation affects the overall competitiveness of short sea shipping as well as of industries relying on cost-efficient transportation.

Therefore, ship owners must consider new fuels and/or technologies to develop the competitive edge of short sea shipping. For the time being there are three possible compliance strategies: switching to marine gas oil (MGO), continue to operate on high sulphur fuel oil, but install scrubbers to wash the sulphur from the exhaust gas, or consider natural gas engines. The investment cost for the marine gas oil strategy is limited, but the oil is expensive, while the last two alternatives demand rather large investments, but with the benefit of cheaper fuels.

Bunker fuels are currently supplied to ship owners through a cost-efficient infrastructure of bunker tanks in ports, bunker ships and barges and direct filling when the ship is lying alongside a quay. Such an infrastructure does not exist for natural gas and represents a chicken-and-egg problem. Natural gas providers will not establish an infrastructure until a sufficient demand arises and ship owners will not invest until natural gas is available. Furthermore, natural gas is very voluminous, but if cooled down to minus 162 degrees Celsius it becomes a liquid (LNG – liquefied natural gas) and more dense. Through liquefaction 600 cubic metres of natural gas are condensed to 1 cubic metre, thereby making natural gas suitable for storage, transport and bunkering.

An infrastructure of marine LNG bunkering (filling) stations has two dimensions: a “soft” dimension focusing on regulations and industry standards, etc. and a “hard” dimension focusing on the physical system consisting of terminals, bunker ships and tank trucks, etc., i.e. basically the same elements as those of the oil-based fuel infrastructure system.

This study focuses on the development of an LNG filling station infrastructure based on these two dimensions and along the LNG supply chain from large European LNG import terminals and/or liquefaction plants to the use on board ships. The infrastructure is analysed from the business case point of view for ports, LNG providers and ship owners.

The outcome of the work are recommendations which target the challenges of setting up such an infrastructure, what must be done to solve each problem and who has to do it. In this executive summary, the focus is on what has to be done and not by whom. The project partners include states, ports, natural gas and LNG terminal companies and selected other companies from the maritime cluster, hereby representing the LNG supply chain. Furthermore, the project has received funding from the EU Trans-European Transport Network, Motorways of the Sea.

Supply of LNG

At present, large LNG import terminals exist in the United Kingdom, the Netherlands and Belgium and additional terminals are likely to be established by 2020 in France, Finland, Germany, Poland, the United Kingdom and the Baltic countries. In the Netherlands and Belgium, the increase in LNG imports is expected

to be managed by existing LNG terminals. These terminals primarily serve the gas grid and cannot be directly used for maritime purposes.

For marine customers, a system of small- and medium-scale terminals, feeder ships bringing LNG from the import terminal to these small and medium-scale terminals and bunker ships, etc. must be established. An adequate number of large LNG terminals with this possibility are important in bringing down the associated costs from a large terminal. A number of small-scale terminals are expected to be established in Denmark, Norway, Sweden and Finland by 2020 as well as in Germany, Belgium and the Netherlands.

Large import terminals are mainly found in major ports, and investments at the import terminals are required to supply LNG to feeder and bunker ships as well as tank trucks and for the direct filling of ships. Medium-sized LNG storage tanks are likely to develop in existing ports without their own LNG import terminal, but with ample traffic in its vicinity. A large number of ports with a rather small demand for LNG can have the LNG trucked from a nearby port or install an LNG tank, and thus the service will mainly rely on truck filling, which will often be sufficient for serving small ferry routes and regular liner traffic with a limited demand for LNG.

An LNG bunkering infrastructure consisting of fixed terminals, bunker ships and tank trucks, etc. will encompass differences in composition as well as capacities. Furthermore, it is important to work out migration strategies for the LNG infrastructure in the different ports/port areas as the market is envisaged to grow rapidly in the years 2015-2020, bearing in mind that it is vital to reap economies of scale. The following recommendations are made as regards logistical aspects on suitable bunkering solutions:

- Ship-to-ship (STS) bunkering is to be the major bunkering method, where receiving vessels have a bunker volume of or above 100 m³;
- The tank truck-to-ship (TTS) bunkering solution is used as a supplement in all sizes of terminals for receiving vessels with bunker volume requirement of a few m³ up to 200 m³;
- Bunkering directly from the terminal to a ship via a pipeline (TPS), facilitated by a tailor-made installation will be utilised for large bunker volumes and primarily for recurrent customers.

LNG containers delivered and loaded on the ships to be used as fuel tanks may become an important introductory solution and as a complement in a growing maritime LNG market.

Economic and Financial Aspects in the LNG Supply Chain

The overall assessment from this work is that LNG is a viable fuel for shipping considering the marine gas oil alternative. The question of availability of the anticipated required volume of marine gas oil after 2015 is often discussed, and limited availability will lead to increased prices. The same issue is not raised with regard to the availability of LNG. However, necessary decisions on building a more fine meshed supply infrastructure have to be taken.

Estimates of future fuel prices contain a large number of uncertainties; however the price tag for the infrastructure costs in bringing LNG from import terminals to the end-user is important if LNG is to be a competitive fuel for shipping. Furthermore, the business case for the LNG supply chain is characterized by large uncertainties making the business case sensitive with regard to the estimated payback time. In addition, shorter payback times are generally demanded when the uncertainties are greater.

In this study, the annual LNG demand is predicted to reach 8.5 million m³ in 2020 and to 14 million m³ in 2030. It is foreseen that in order to meet this demand, more than 40 small scale LNG terminals will have to be established throughout the SECA in 2015, complemented by medium sized terminals, tank-trucks and bunker vessels. From an economic and financial point of view, the following recommendations are provided:

- The price tag for LNG infrastructure must be based on an average internal rate of return for infrastructure investments below 12 % in order to reach a competitive LNG price;
- Coordinated efforts on investments to avoid sub-optimizing are needed for establishing a “critical minimum” level of LNG infrastructure to meet the demand in 2015-2020;
- Business cases or plans for specific investment projects must be developed, partly as a result of the work in port clusters or the like;
- Local or regional port clusters or the like must stress the development of the local market for LNG, including possible synergies with land-based demand;
- A European funding scheme is needed for the development, construction and operation of LNG bunker vessels/barges in the early market introduction phase.

Safety Aspects and Risk Assessment in the LNG Supply Chain

Large-scale LNG has a good safety record, and confidence in LNG as a bunker fuel must be built up. The following recommendations are made:

- Specific focus is put on regulations and industry standards for small- as well as medium-scale handling;
- Guidelines on adequate risk modelling approaches are developed in order to enable fair and harmonized assessment of various projects;
- A method of reporting incidents and accidents related to the bunkering of LNG as a ship fuel. Such data are necessary to build up risk models for small-scale LNG;
- Off-shore and on-shore safety regulations are harmonized;
- LNG bunker vessel traffic, etc. must be considered similar to other dangerous cargo movements.

Technical and Operational Aspects in the LNG Supply Chain

Furthermore, it is recommended to develop guidelines specifically devoted to LNG bunkering, including:

- The use of systems that, in case of emergency situations, will stop the flow of LNG and LNG vapours, a so-called emergency shutdown system (ESD);
- The use of systems that, in case the emitting and the receiving unit move away from each other, will enable a rapid disconnection of arms/hoses transferring LNG and natural gas vapours, a so-called emergency release system (ERS) and/or breakaway couplings;
- Tailored training of personnel involved in LNG bunker operations;
- Technical as well as operational measures to minimize methane releases.

The Permit Process

The introduction of LNG as a marine fuel is not only a question of technology and economy but also safety, as concerns are often raised both by the general public and local authorities with the siting of LNG facilities. The differences in the safety concerns related to large-scale LNG meant for the natural gas grid and related to LNG for maritime use must be addressed. Furthermore, the environmental and climate advantages to be gained from the use of LNG, e.g. on the emission of noxious gases, must be communicated, meaning that:

- Investors must handle the public consultation process in a proper and well-targeted way in order to shorten the permit process;
- Guidelines for the siting of small- and medium-scale terminals will facilitate the site selection process;

- National authorities can introduce a coordinated permit process, e.g. in the form of a “one stop shop” in which the authorities concerned cooperate closely in order to shorten the process time.

Summary – North European LNG Infrastructure Project

Introduction

The International Maritime Organization (IMO) requires that the sulphur content in maritime fuel for use in the North Sea, the English Channel and the Baltic Sea – Sulphur Emission Control Areas (SECA) – be decreased from 1.0 % to 0.1 % by 1 January 2015. The purpose is to improve the environment by developing shipping as a green means of transport. This regulation affects the overall competitiveness of short sea shipping as well as of industries that rely on cost-efficient transportation. To illustrate the magnitude of the fuel usage business, it can be mentioned that, during 2010, around 12 million tonnes of fuel were consumed by ships sailing within these sea areas, primarily fuel oil with sulphur content of up to 1.0 %.

Ship owners must therefore consider new fuels and/or technologies to develop the competitive edge of short sea shipping. From a ship owner's point of view, there are currently three main possible compliance strategies: shift to the fuel marine gas oil (MGO), install a scrubber system to "wash" the sulphur from the exhaust gas, or install engines fuelled by natural gas. The investment cost related to MGO is limited but the oil is expensive. The last two alternatives require relatively substantial investments but the fuels are cheaper.

Bunker fuels are supplied to ship owners through a cost-efficient, since long established, infrastructure of port bunker tanks, bunker ships, barges and, when the ship is lying alongside a quay, direct filling. Such an infrastructure does not exist for natural gas. This represents a chicken-and-egg problem. Providers of natural gas will not establish an infrastructure until sufficient demand arises while ship owners will not invest until natural gas is available. Furthermore, natural gas is very voluminous, but if it is cooled down to minus 162 degrees Celsius it becomes a liquid (LNG – liquefied natural gas). Through liquefaction 600, cubic meters of natural gas can be condensed to one cubic meter, thereby making natural gas suitable for storage and transport.

An infrastructure of marine LNG filling stations has two dimensions: a "soft" dimension concerning regulations, technical and safety standards: and a "hard" dimension comprising the physical system of terminals, storage, bunker ships and tank trucks, etc., essentially the same elements as those of the oil-based fuel infrastructure system.

This study focuses on the development of an LNG filling station infrastructure based on these two dimensions. It covers the LNG supply chain from large LNG import terminals and/or LNG plants liquefying natural gas to LNG, to use on board ships. The infrastructure is also studied from a business case point of view for ports, LNG providers and ship owners. The operational outcome of the work consists of recommendations targeting the problems of setting up such an infrastructure, what must be done to solve each problem, and by whom.

The project partners represent actors in the LNG supply chain; states, ports, natural gas suppliers, LNG terminal companies and companies from the maritime cluster. The project has received funding from the EU Trans-European Transport Network, Motorways of the Sea.

Supply of LNG

The availability of LNG as a marine fuel is imperative if it is to become a realistic compliance strategy for ship owners. The starting point for supplying LNG as a marine fuel within Northern Europe are large scale

import terminals. In general, these terminals are built to import gas to national gas networks and they must be expanded to include facilities to load feeder ships and/or trucks. However, for a full network infrastructure, more LNG terminals or storage facilities will be needed. These small and medium sized intermediary terminals will be centered within ports; they can be onshore in the form of tanks or offshore e.g. as vessels. Furthermore, small-scale LNG liquefaction plants fed from national gas grids could be seen as part of these intermediary LNG terminals.

LNG terminals then serve the end-users through a combination of trucks, pipelines, jetties (pier for mooring), bunker barges, and feeder vessels as illustrated in Figure 1. Ships are bunkered (fuelled) in port or bunkered further afield using feeder vessels.

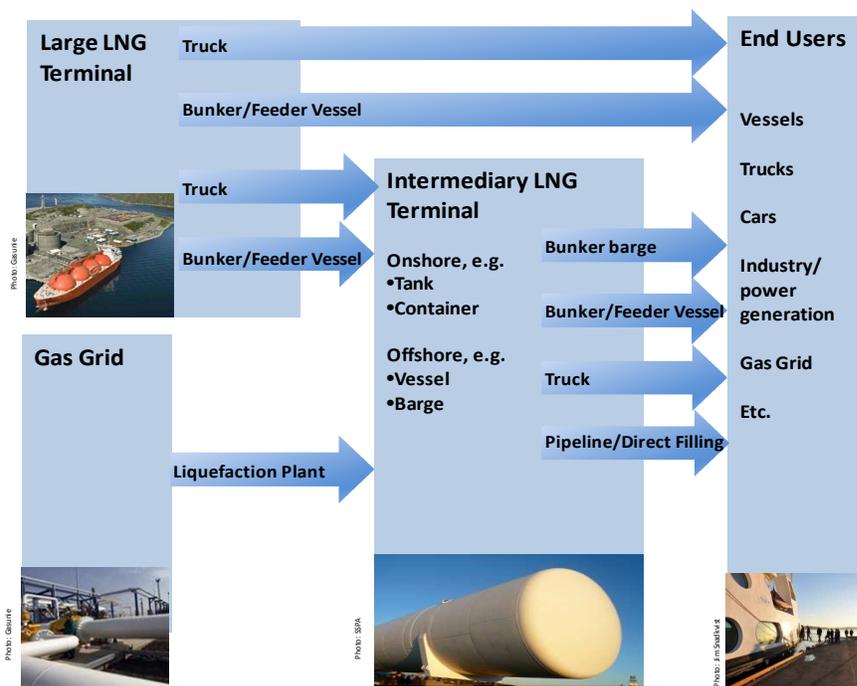


Figure 1 Infrastructure arrangements for supplying different end-users with LNG fuel through large, medium and small terminal/ storage facilities

In this study, large, medium and small-scale storage capacity for terminals and LNG ships within the maritime LNG infrastructure is referred to as shown in Table 1 below. These orders of magnitude are important for understanding the interrelation between the different components of the system.

Table 1 Applied definitions of large, medium and small-scale in different activities or aspects

Activity/Aspect	Large scale	Medium scale	Small-scale
On shore storage capacity	Import terminal $\geq 100,000 \text{ m}^3$	Intermediary terminal 10,000-100,000 m^3	Intermediary terminal $< 10,000 \text{ m}^3$
Ship size, LNG capacity	LNG carriers 100,000 – 270,000 m^3	LNG feeder vessels 10,000-100,000 m^3	LNG bunker vessels 1,000-10,000 m^3 LNG bunker vessels/barges 200 – 1,000 m^3
Tank trucks			40 – 80 m^3

Status and Plans for the North European LNG Terminals

In the map below, Figure 2, it can be seen that large LNG import terminals exist at present in the United Kingdom, the Netherlands and Belgium¹. By 2020, large import terminals are likely to have been established in Northern Europe, in France, Finland, Germany and Poland². In the United Kingdom additional terminals are expected due to an increased demand. In the Netherlands and Belgium, an increase in LNG imports is expected to be managed by existing LNG terminals.



Figure 2 Existing and planned production plants and LNG terminals in the SECA
Source: Gas Infrastructure Europe, 2011, ÅF, 2011, Gasnor, Gazprom.

¹ The figures in this map refers to names and sizes of the different plants, facilities and terminals. A list is included in Appendix 4.

² This refers only to the terminals that are decided.

In the Baltic countries, a prime reason for LNG import facilities is to achieve increased diversity of energy supply and hence to provide alternative supply routes of gas. For all countries, short sea shipping and its potential LNG demand is a secondary factor as for the whole SECA area.

A number of small- and medium-scale terminals are expected to be established in Denmark, Norway, Sweden and Finland by the year 2020. Furthermore, there are plans for investments in small-scale facilities such as LNG bunkering berths (quay for bunkering) in Germany, Belgium and the Netherlands that will supplement existing LNG storage terminals, refer to Appendix 4.

Bunkering and Delivery to Customers

Bunkering, as in transferring fuel to ships, is a core aspect of the maritime LNG supply chain. The main bunkering solutions analysed in the study are Ship-to-Ship (STS), Truck-to-Ship (TTS) and bunkering directly from Terminal-to-Ship via Pipeline (TPS). The three bunkering solutions are illustrated in Figure 3 below. All solutions can be used in parallel and can be complementary in situations, if for example there are different types of vessels to be served or if there is a peak demand for LNG fuel in the terminal.

Containerized solutions, that is LNG containers delivered and loaded on to the ship to be used as a fuel tank or used for intermediary storage and transport, may become essential early solutions in the LNG market. However, as the operations are still not extensive and no guidelines exist, the use of containers is still an uncertain solution that would benefit from further detailed analysis.

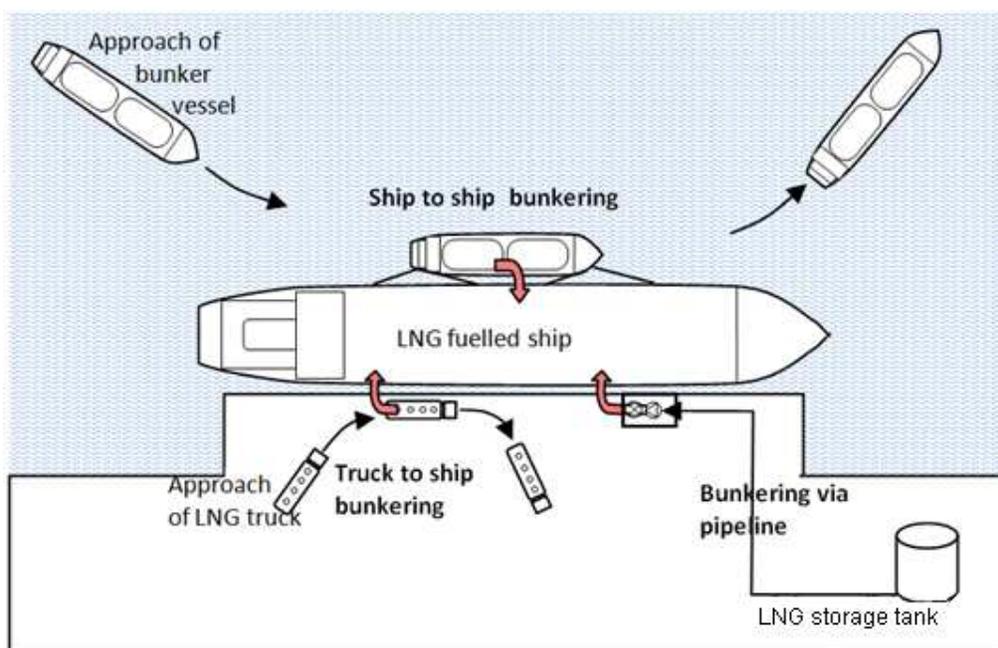


Figure 3 Various types of bunkering solutions

Recommendation

Terminal investors and port authorities together with suppliers will have to decide the principal layout of the bunker facilities for each individual port:

- Ship-to-ship (STS) bunkering is recommended to become the major bunkering method, where receiving vessels have a bunker volume from 100 m³. One LNG bunker vessel per receiving vessel only is appropriate if the turnaround time in port is to be kept short for customers. Typical capacity for LNG bunker vessels may be around 1,000 to 10,000 m³ (Recommendation no.1a);
- Tank truck-to-ship (TTS) bunkering is recommended for all sizes of terminals, where receiving vessels have a bunker volume requirement of a few cubic meters up to 200 m³ (Recommendation no. 1b);
- The LNG terminal-to-ship via pipeline (TPS) bunkering solution is recommended for all different sizes of bunkering volumes and in terminals with recurrent customers and available space for associated bunker facilities (Recommendation no. 1c).

Other Requirements for an LNG Bunkering Port

In order to select the best solution for an individual port, the following critical parameters have been identified: the LNG bunkering volumes, physical limitations in port, logistic issues, types of vessels and shipping companies, investment and operating costs, safety, technical and operational regulations, environmental and regulatory issues. All the parameters need to be taken into consideration even though bunkering volumes are often the determining factor.

Supply Costs of the Different Fuel Alternatives

Price Developments of LNG Versus Oil Based Fuel Types

The study has examined the future costs of LNG as a bunker fuel and compared it to the competing fuel choices of Heavy Fuel Oil (HFO) and Marine Gas Oil (MGO).

The costs of supplying any bunker fuel are made up by two main parts:

- Price of the fuel at the major European import hubs;
- Infrastructure costs
 - The costs of storage;
 - The cost of transshipment between hubs and local port facilities and further to the end-user.

Price of LNG, HFO and MGO at Major European Import Hubs

In Europe, the LNG price is fixed relative to pipeline gas price, which in turn typically follows the lead of competing fuels such as crude oil or other oil products.³ In the study, price forecast for HFO have been used based on crude oil price forecasts from the UK Department for Energy and Climate Change (DECC)⁴. From this forecast and different designed⁵, possible relative price for MGO versus HFO and LNG versus HFO respectively, six different fuel price scenarios have been defined.

The price scenarios comprising “Central” and “High” for MGO and “Low”, “Central” and “High” for HFO and are described in Table 2. For proper comparability, the prices are expressed in €/tonne fuel after adjustment for different specific energy content of the fuels respectively.

Table 2 Six scenarios’ price levels relative to HFO for MGO and LNG and corresponding fuel prices

Scenario	MGO price level [relative to HFO price at energy equivalence]	MGO import price [€/tonne fuel]	LNG price level [relative to HFO price at energy equivalence]	LNG import price [€/tonne fuel]
1.	Central; 1.6 times the HFO-price	875	Low; 0.5 times the HFO-price	315
2.	Central; 1.6 times the HFO-price	875	Central; 0.7 times the HFO-price	440
3.	Central; 1.6 times the HFO-price	875	High; 0.9 times the HFO-price	570
4.	High; 2.2 times the HFO-price	1200	Low; 0.5 times the HFO-price	315
5.	High; 2.2 times the HFO-price	1200	Central; 0.7 times the HFO-price	440
6.	High; 2.2 times the HFO-price	1200	High; 0.9 times the HFO-price	570

Import prices, based on a forecast HFO price of 520 €/tonne.

The relative import prices are of course interesting as such but they are also used in the report for analysis of future demand of LNG when completed with infrastructure cost for distribution.

Infrastructure Costs within Northern Europe

The cost for storage, transshipment and handling of the fuels adds on to the import prices shown above to create the end user price.

For the HFO and MGO fuel cases, this report has used a cost of €10/ tonne for infrastructure costs. This figure seems to be low but different players on the actual markets have confirmed it.

For estimating the infrastructure costs of LNG, three model port cases have been considered: large, medium and small scale terminal installations, these are specific cases of the more general examples given in Figure 1 and Table 1.

³ LNG-delivery prices are typically based on the US Henry Hub natural gas prices (NYMEX) and adjusted for local differences between the LNG delivery point and the Henry Hub gas price.

⁴ The future HFO price is derived by using linear regression analysis (assuming a linear relationship between HFO and crude oil prices).

⁵ The designed has been made after studying historical MGO and LNG prices relative to the HFO price.

Large scale, Case I, is defined as a facility that is incremental to an existing LNG import terminal. Medium and small scale, Cases II and III respectively, would be “purpose built” installations with storage capacity of 20,000 m³ and 2 x 700 m³, respectively. The three port cases are based on projected numbers from ports and reflect actual traffic and calls. The cases therefore involve equipment to meet the local foreseen LNG bunkering demand, but also supplementary equipment that is required in order to meet demand in nearby ports and land-based demand. The main characteristics of the port cases are presented in Table 2.

The economic lifetime of the terminal as a whole is assumed to be 40 years. Bunkering vessels and trucks are assumed to have an economic lifetime of 20 years. For the three model port cases referred to in this investment analysis, it is assumed that of all bunkering operations, the share being LNG bunkering is 9 % in year 2020 and 18 % in year 2030.

Table 3 Main characteristics of three port cases providing LNG as bunker fuel

LNG Port Case	Large scale - Case I	Medium scale - Case II	Small-scale - Case III
Throughput	204 000 m ³ /yr	343 000 m ³ /yr	52 000 m ³ /yr
Tank size	(no separate tank)	20 000 m ³	2* 700 m ³
Tank turnover/year	n/a	20	44
Installations for import, bunkering and other transfer to end-users	<p>One bunkering berth including one jetty (pier for mooring) and associated equipment.</p> <p>One small scale bunkering vessel, 4 000 m³;</p> <p>Two tank trucks, 50 m³ each.</p> <p>One LNG tank-truck filling station;</p>	<p>One bunkering berth including one jetty (pier for mooring) and associated equipment.</p> <p>Two small scale bunkering vessels, 3 000 m³ and 4 000 m³;</p> <p>One tank truck, 50 m³.</p> <p>One LNG tank-truck filling station;</p>	<p>One bunkering berth and associated equipment.</p> <p>One tank truck, 50 m³.</p> <p>One LNG tank-truck filling station;</p>

The financial implications from an investment point of view and associated needed income to finance the investments are shown in Table 4 below.

Table 4 Infrastructure costs (including transshipment costs) for the three LNG port cases analysed

LNG Port Case	Large scale - Case I	Medium scale - Case II	Small-scale - Case III
Total initial investment cost [million €]	69	137	15
- thereof investment in bunker vessels [million €]	32	60	-
Total operational cost [million €/yr]	10	17	3,0
- thereof fixed operational costs of bunker vessels [million€/yr]	2	4	-
- thereof fuel costs for bunker vessels [million€/yr]	0.5	1	-

Case I: LNG import terminal; Case II: medium sized LNG terminal with potential passing traffic; Case III: small scale LNG terminal

Table 5 Distribution Costs per tonne for the three Port Cases

	Case I	Case II	Case III
Needed income to reach 8 years pay-back [€/tonne LNG]	136	157	211
Needed income to reach 10 years pay-back [€/tonne LNG]	118	137	194
Needed income to reach 12 years pay-back [€/tonne LNG]	107	125	183
Needed income to reach 15 years pay-back [€/tonne LNG]	95	112	172

As can be seen above, the trans shipment and handling cost in the studied cases range from about 118 to 194 €/tonne of LNG assuming a pay-back time of 10 years. For small-scale solutions, the cost will be higher per unit of LNG, especially if capacity utilization is low.

Figure 4 below shows how the trans shipment and handling cost increases with higher Internal Rate on Investments (IRR)s on the investment for each of the 3 cases.

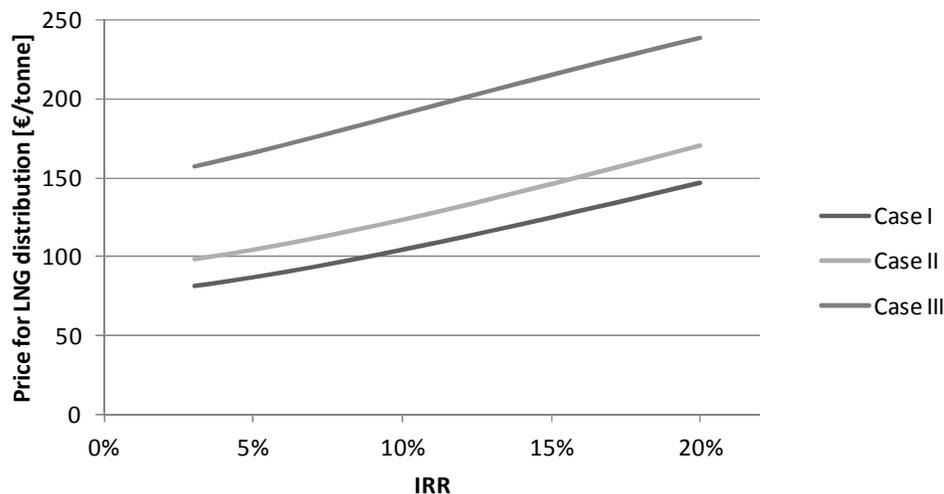


Figure 4 The price for LNG distribution as a function of IRR for the terminal

In the following economic and financial analysis in section 4 as seen from the ship owners point of view, a cost of 170 €/tonne is added on the LNG price in Europe. Slightly lower investment IRRs, that is, longer pay-back times, will give LNG a competitive advantage over other compliance strategies.

On Board Delivered Fuel Prices

With the distribution costs assumed above, the price scenarios for the end-user prices are as follows:

Table 6 Price scenarios with end-user prices in €/tonne

Scenario name	MGO price level	MGO price €/tonne	LNG price level	LNG price €/tonne
1. Low LNG_Central MGO	Central	885	Low	485
2. Central LNG_Central MGO	Central	885	Central	610
3. High LNG_Central MGO	Central	885	High	740
4. Low LNG_High MGO	High	1210	Low	485
5. Central LNG_High MGO	High	1210	Central	610
6. High LNG_High MGO	High	1210	High	740

HFO price is in all scenarios assumed to be 530 €/tonne

Recommendation

Prices for maritime LNG corresponding to internal rates of return below 12 % for investments in maritime LNG supply infrastructure are recommended in order not to hamper market development. It may be required that financial institutions, the EU and the EU member states create business incentives for land-based LNG infrastructure investments in order to attract investors. (Recommendation no. 2)

Demand for LNG from Shipping

The Demand for Marine Fuels in the SECA

14,000⁶ ships entered SECA waters in 2010. 2,200 of these were confined to the SECA region and a further 2,700 were present for more than 50 % of their time. These ships for the time they are in SECA waters consume around 12 million tonnes of fuel⁷. Assuming a fleet growth rate of 2 %, more than 17 million tonnes can be expected to be used within the SECA in 2030.

⁶ This is the number of individual ships that are registered during year 2010 in the SECA through the mandatory Automatic Information System (AIS). Source: IHS Fairplay

⁷ The fuel consumption is calculated by IHS Fairplay based on AIS-data for actual ships sailing in SECA with installed power and velocity being known factors. Different assumptions regarding individual ship energy consumption over a year may alter this figure.

Economic and Financial Aspects for the Shipowner

From a shipowner's point of view, there are for the time being three main possible compliance strategies: install a scrubber system to "wash" the sulphur from the exhaust gas, shift to MGO which has a low sulphur content or install engines fuelled by natural gas, stored on board as LNG. MGO is more expensive but requires minimal investment; the other alternatives require relatively substantial investments but the fuels are cheaper.

The choice will be based on the shipowners' views of the relative future prices of the different fuels and their view of the life of their investment. The study has considered various permutations in analysing potential demand, considering separately retrofit of existing vessels and LNG use in new build vessels.

The economic and financial analysis from the shipowners' point of view has been based on the pay-back method as the simplest and perhaps most illustrative measure of comparing compliance strategies and one which is used widely within the shipping industry.

Using MGO is the compliance strategy with the lowest investments cost, and the highest operational cost. Hence, using MGO has been chosen as a "baseline" to which the other compliance strategies are compared. For a starting point, four ship types are considered⁸, each with three compliance strategies for each of the price scenarios 1, 2 and 3 from section 3.4.

For new buildings, the analysis in most cases shows pay-back times for the LNG compliance strategy of around 2 years – slightly less with low LNG prices (scenario 1) and up to four years with higher LNG prices (scenario 3). The HFO & scrubber strategy has generally slightly shorter pay-back times than any of the LNG options, and in the scenario 3 with high LNG prices the difference is more marked. Retrofitting has slightly longer pay-back times, however still within range of 2-4 years.

Demand from Shipping

Detailed information regarding the present fleet in terms of sizes of individual ships and installed main engine power, the age of each individual ship and sailing patterns (i.e. energy used within the SECA) are used to assess the demand. The fleet is assumed to grow with 2 % every year. With 2 % of the fleet being phased out through natural fleet replacement every year, there would thus be 4 % of new builds per year. Apart from new builds that can possibly opt for LNG, it is shown that newer ships, those less than ten years old, can be economically retrofitted to use LNG depending on the price development scenario.

In this study, the demand analysis is further reviewed from the point of view of the demand development's sensitivity to different factors, primarily the fuel prices. With different price development scenarios, the 14,000 existing ships and new builds will be assumed to opt for different compliance strategies.

Alternatively, bunker statistics could have been used. However bunker statistics are not available in many ports and the uncertainties of these data are considerable, for example since it is not possible to differentiate between fuels used within and outside the SECA.

⁸ RoPax/RoRo vessel, deadweight 4,200 tonnes, estimated consumption 4,000 tonne LNG per year;

Costal tanker/bulk carrier, deadweight 10,000 tonnes, estimated consumption 6,000 tonne LNG per year;

Container ship, deadweight 9,000 tonnes, estimated consumption 6,500 tonne LNG per year;

Big RoRo, estimated LNG consumption 9,800 tonnes/year.

At a LNG price of 610 €/ tonne and the MGO price 875 €/tonne, which is the central price scenario (Central LNG-Central MGO), this results in an LNG demand of 4.2 million tonnes in 2020. The demand stems from ships retrofitting to LNG propulsion as well as the estimated use in new builds as illustrated in the figure below.

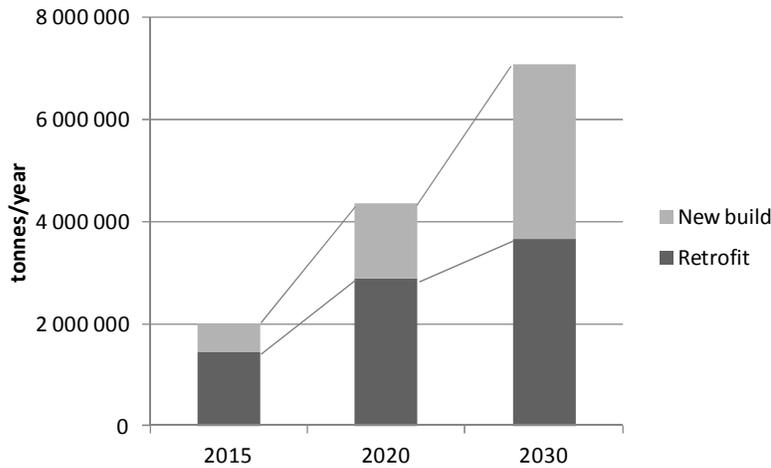


Figure 5 LNG demand from retrofits and new buildings when assuming the central price scenario (Central LNG-Central MGO)

Higher LNG prices, scenario 3, give lower demand and vice versa. A range of possible demand development scenarios are reviewed, ranging between 1.8 and 5.5 million tonnes in 2020. The figure below shows the 3 scenarios with different LNG prices (Scenario 1-3) and MGO prices at the central level. The other 3 scenarios (Scenario 4 to 6) result in quite similar demand development as Scenario 1 to 3.

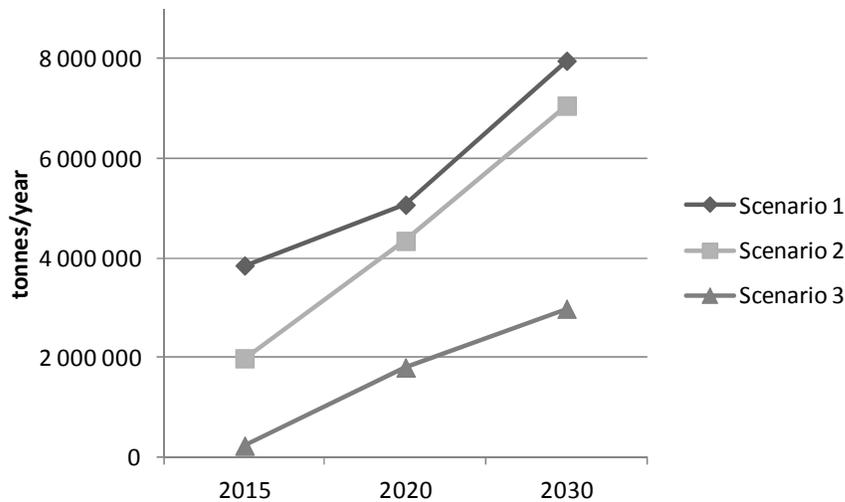


Figure 6 LNG demand in the three scenarios with MGO prices at the central level

Figure 7 very clearly expresses the impact of the LNG price level for a market take off in 2015.

The need for maritime LNG infrastructures will initially and to a high degree be based on local and regional demands connected to existing or planned line traffic, fishing boat stations or other regular traffic which in turn is connected to other ports. Besides the maritime demand, land based customers are discussed in the coming sections.

LNG Demand from Ships Sailing Beyond the SECA Region

The large ports in Northern Europe, such as Port of Rotterdam, St. Petersburg and Gothenburg provide significant parts of their bunker volumes to ships sailing outside the SECA. In the order of three times the fuel used within the SECA are provided from the ports in SECA. In Port of Rotterdam, more than 90 % of the bunker fuel is sold to long haul shipping spending the vast majority of its time outside SECA. If IMO regulations will be introduced reducing the sulphur dioxide emissions throughout the world⁹ and if LNG is a sufficiently low cost option compared to alternative compliance strategies the feasibility of investing in LNG will be higher in these ports.

Land Based Demand

Natural gas is likely to continue to play a key role in the EU's energy-mix in the coming decades and gas can gain importance as the back-up fuel for variable electricity generation. The total gas consumption in SECA is forecasted to remain at today's level in the period up to 2020. The gas consumption is expected to increase in all countries in SECA except of Denmark, Germany and the United Kingdom.

The total demand of LNG in SECA is forecasted to increase by 140 % over the period up to 2020, from 39 bcm to 93 bcm (29.5 million tonnes to 70.5 million tonnes) as gas production within the region declines. The largest increase is expected in the United Kingdom, followed by the Netherlands, Germany and France. A major change during the period is that only three countries within SECA were importing LNG in 2010, while all countries except Norway are expected to be importing LNG by 2020.

⁹ It is planned that by 2020, the sulphur content of fuel will be limited to 0.5 % throughout the world.

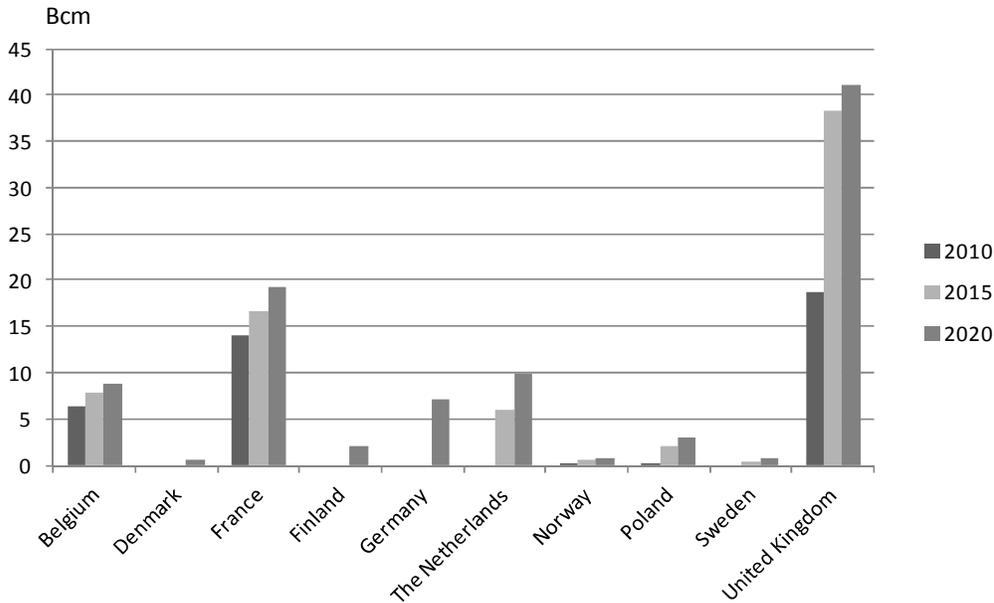


Figure 7 Forecast of LNG demand in SECA 2010, 2015 and 2020, Bcm

Source: AF, 2011, Gasnor 2011.

This growth in LNG importation is the principal driver behind the expansion in the number of LNG terminals presented at section 2.1 and figure 2. The regasified LNG will be primarily fed into national gas networks. There will be opportunities for land based LNG demand to be fed by small and medium terminals in areas that are unserved by national gas networks, most notably Sweden and Finland. This has already developed in Norway.

Business Cases for Ports

In the report is accounted for critical properties that are deciding for a port's suitability for establishment of a LNG terminal. It is also included analysis of some business cases for LNG ports and LNG terminal components.

The results from the analysis of the three port cases from section 3 is presented in Figure 9 below. The diagrams there show the required throughputs to get a specific IRRs at each of the studied port cases. between 3% and 20% under fuel scenario 2.

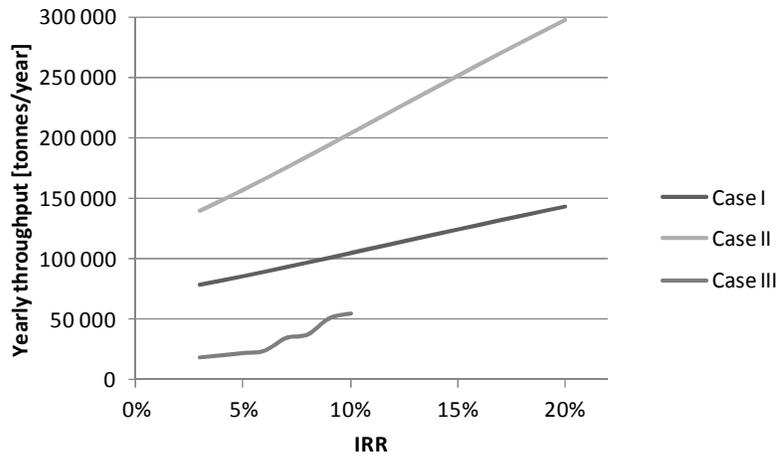


Figure 8 Breakeven throughput for the port cases at different internal rate of return

Table 2 in section 3.3 shows typical throughputs for bunkering at typical terminal installations. Individual port operators can use the graph to see which order of magnitude IRR might be achieved for a particular total throughput.

The figures indicate that on the projected bunkering volumes of our example cases they would need additional land based demand equal to 30,000 tonnes, 70,000 tonnes and 25,000 tonnes respectively to achieve a 12% IRR equivalent to a 10 year payback time.

The figure also emphasizes the importance of high utilization rate of the installed terminal equipment and thus the importance of thorough analysis and planning of the specific investment projects.

Recommendation

It is recommended that business cases or plans are developed for specific investment projects. Port authorities, potential investors in terminals, shipowners and other stakeholders could be the driving forces for specific local and regional developments with the support of already existing EU schemes and funding. (Recommendation no. 3)

It is recommended that local, and regional port clusters or similar, with the participation of all relevant stakeholders meet the challenge regarding the establishment of a “local” LNG infrastructure, a minimum supply. All parties involved in the development such as port authorities, shipowners, local communities, permit authorities and other stakeholders need to be involved and the work must be supported by relevant EU and/or national authorities. (Recommendation no. 4)

The Development of an LNG Filling Station Network

The potential for LNG supply from large, medium and small terminals has been examined and so has the shipping and land based LNG demand. The study has then examined how a network of terminals – filling stations – might develop such that supply can meet demand and vice versa. The two key difficulties here are that sufficient filling stations need to exist to provide an adequate network of bunkering terminals and at the same time sufficient demand materialises to ensure the financial viability of individual terminals.

Scenarios for Infrastructure Development

In the report (Chapter 9) there are estimations of how much LNG could be sold in different sub-regions of the SECA and hence create a forecast of the geographical allocation of the demand. In the same chapter there is also a model to estimate the spread.

In the analyzed demand development scenarios, it can be concluded that a large part of the demand will be from liner shipping confined to the different sub-regions of the SECA and on scheduled routes. A small portion of ships will have LNG tanks less than 200 m³ and will need regular fuelling. This means the supply structure must be such that it can frequently supply small volumes at a variety of specified locations. However, as can be seen in Table 41, the majority (between 66 and 87 %) of ships have tanks between 100 and 3,000 m³.

Table 7 The maritime LNG demand confined to different sub-regions of the SECA and its most suitable bunkering solution

SECA sub-region	LNG tank size for ships confined to the region	Proportion [% m ³]	Most suitable bunkering solution
English Channel	< 100 m ³	4%	Tank truck-to-ship, TTS
	100 m ³ < tank < 3,000 m ³	66%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	3 000 m ³ < tank < 10,000 m ³	30%	Ship-to-ship, STS
North Sea	< 100 m ³	6%	Tank truck-to-ship
	100 m ³ < tank < 3,000 m ³	82%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	3 000 m ³ < tank < 10,000 m ³	12%	Ship-to-ship, STS
Skag/Katt	< 100 m ³	2%	Tank truck-to-ship
	100 m ³ < tank < 3,000 m ³	87%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	3,000 m ³ < tank < 10,000 m ³	11%	Ship-to-ship, STS
Baltic Sea	< 100 m ³	2%	Tank truck-to-ship
	100 m ³ < tank < 3,000 m ³	87%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	3,000 m ³ < tank < 10,000 m ³	12%	Ship-to-ship, STS

Tramp shipping and other non-linear shipping that is not confined to sub-regions but that sail in the SECA add up to the overall maritime demand¹⁰. The proportion of bunkering via pipeline versus ship-to-ship bunkering will influence the overall design of an appropriate supply structure. In the case illustrated in Table 9 below, equally much pipeline bunkering and ship-to-ship bunkering is assumed. The geographic demand scenarios in the model further includes a projected land based demand. For countries with a gas grid, this demand is assumed to be entirely taken care of via the large import terminals. For countries without a gas grid, the country wise land based demand is assumed to be proportionally spread over the different terminals within the country.

Together, the maritime demand and the land-based demand add up to geographically allocated demand.

In this way, it can be outlined how the supply infrastructure would need to develop in order to effectively meet the medium and small-scale demand in different scenarios, and it can be evaluated if the investments in supply will be feasible or not given their assumed through-put and specified LNG price. For the maritime demand development as specified in the Scenario 2 (Central LNG-Central MGO) above and together with the projected land based demand per country, it is found that a possible and feasible infrastructure development can be as presented in Table 42 below.

Table 8 Number of small size and medium size terminals, bunker vessels and tank trucks required to meet the maritime LNG demand in SECA as projected in the central price scenario (Central LNG- Central MGO)

Year		2015	2020	2030
Maritime demand to be supplied by small and medium terminals, vessels and trucks [tonnes]		1,590,000	3,630,000	6,212,780
Number of terminals	Medium size terminal – Case II	7	9	11
	Small size terminal – Case III	13	23	38
Number of bunker vessels	Bunker Vessel - 1,000 m ³	9	19	28
	Bunker Vessel - 3,000 m ³	1	3	5
	Bunker Vessel - 4,000 m ³		1	1
	Bunker Vessel - 10,000 m ³	1	1	1
Number of trucks	Truck - 50 m ³	5	6	8

The infrastructure must develop in a cost efficient way, which will include interim strategies, for example starting with mobile solutions, offshore as well as on land ahead of moving to fixed land-based terminals. It can be shown for example that if the proportion of ship-to-ship bunkering can be increased in early years, the number of small scale on shore terminals can be decreased and the overall infrastructure cost can be kept lower. The example in above refers to 50% of the medium sized ships being bunkered via TPS (Tank to Ship via Pipeline) throughout the period.

The existing and planned LNG infrastructure, along with the estimated marine LNG demand development as presented previously, suggest that the existing and planned storage volumes in the countries bordering the

¹⁰ This demand is assumed to be allocated as follows: 35 % in the English Channel, 35 % in the North Sea, 20 % in Skagerrak and Kattegat, and 10 % in the Baltic Sea.

SECA will be sufficient during the initial years. However, a good availability throughout the three seas (Baltic Sea, North Sea and English Channel) will require investments in small and medium LNG terminals, trans shipment, i.e. bunker vessels and flexible storage solutions such as bunker barges. Some of these investments may have very low capacity utilization in the first years, thereby affecting the cash flow negatively.

Recommendation

To provide a solid base for a positive development of the market before and after 2020 it is recommended that actors in the LNG supply chain should efficiently coordinate efforts and communicate in order to meet and help generate maritime LNG demand. Responsibility for such actions is recommended to lie with most of the LNG market actors: EU and national authorities, ports, LNG suppliers, traders and end-users. (Recommendation no. 5)

Distribution of fuel is critical for the continued development of the LNG market. There is a need for floating small and medium LNG infrastructure in form of feeder vessels, bunker vessels and bunker barges. It is recommended to establish a funding scheme for development, construction and operation of LNG bunker vessels and barges in the early stage of LNG as a marine fuel introduction of the market. (Recommendation no 6)

Business Models for Establishment of an LNG Bunkering Infrastructure

Ports and Terminals

There are many different models of port and terminal operation and ownership across the region. In Table 10 below, typical providers of the major components in the LNG bunkering supply chain are listed.

Table 10 Provision of the major components in the LNG bunkering supply chain

Component	Provider/ Operator
Port external structure (external breakwaters, sea locks etc)	National Government or Port Authority
Port internal structure (internal quays, jetties and locks, shared access routes)	Port Authority
Land for siting of storage and terminals	Port Authority
Jetty/ quays serving the LNG storage, both loading and unloading	Port Authority or Terminal Owner/ Operator
LNG terminal and storage	Terminal Owner/ Operator
Feeder vessels and barges	Bunkering Service Providers
Tank trucks	Terminal Owner/ Operator

Berths	Port Authority or Terminal Owner/ Operator
Anchorage	Port Authority

In the report Chapter 10, legal, operational and financial models (or business models) for six different ports are reviewed. The ports are Zeebrugge, Hirtshals, Szczecin/Swinoujscie, Rotterdam, Gothenburg and Nynäshamn, representing a wide range of size and conditions of ports with existing or planned LNG terminals.

In the report, there are also described business models for bunkering service and LNG import terminals specifically.

Financing

It has been recognized at several points in the analysis of demand and supply that demand will only fully materialize if adequate supply exists, conversely the supply will only materialize if developers of the supply infrastructure are sure that the demand will materialize.

This conundrum is common in major infrastructure development, particularly in the energy sector. Investment basis to materialize such development is mainly:

- Public;
- Contractual;
- Incremental;
- Merchanting.

In the report these four alternatives have been assessed and a likely path for investment basis can be summarized as follows:

1. Major bunkering ports with existing or planned LNG facilities – merchant investment;
2. Bunkering ports within range of bunkering vessels from (1) – merchant investment;
3. Ports with substantial captive traffic – RoRo, RoPax, liners, supply vessels, fishing, tugs – it could be expected that investment would proceed on the basis of contracted demand;
4. Ports with modest captive traffic but strong land-based demand – contracted demand;
5. Bunkering ports without nearby LNG – on a merchant basis but only a level of basic demand has been established across the region.

Investment in LNG bunkering infrastructure is expected to be private sector financed in the main although some port authorities are expected to initiate projects and there is a case for public financial support in the early stages of network development.

Investment Risks and Risk Mitigation

Investors, be they from the public or private sector will face significant investment risks. The study has analysed the principal risks faced by a prospective investor in an LNG filling station and the means available to mitigate those risks which can be summarized as in Table 11.

Table 11 Financial risks and risk mitigation

Risk		Risk Mitigation
Construction	Project is built to time, cost and performance specification	EPC ¹¹ contract for construction or ship mounted temporary solutions
Volume	Demand from customers materialises	Contracts with "lead" customers and/ or ship mounted
Supply	LNG can be procured to meet demand	Back to back contracts ¹² with shippers/ importers
Gas quality	LNG meets customers' specification	Back to back contract with shipper/ importer
LNG Selling Price	LNG can be sold at a price to cover costs	Long term contract ¹³ , indexed to HFO/ MGO
LNG Cost Price	LNG can be procured at a competitive price	Long term supply contract, indexed to HFO/ MGO
Operating risk	Terminal can be operated and maintained properly	O & M contract ¹⁴

Institutional Issues

There are institutional issues which will delay or hamper network investment and are worthy of further consideration:

- Early years' competition: it will take time to establish effective competition between LNG filling stations. This may deter shipowners. Further study is needed on mechanisms to maintain competitive pricing at the bunkering points;
- Taxation: marine fuels have their own tax exemptions within the EU fiscal framework but there is uncertainty among prospective stakeholders that the present definition is clear in including marine use of LNG;
- LNG Procurement: the market for LNG is characterised by long term contracts with thin liquidity. Further study is needed on the extent to which this prove a constraint to the development of medium and small terminals;
- Model contracts: shipowners may contract with filling stations and either shipowners or filling stations could contract with LNG shippers or importers for LNG supplies. The development of model contracts will assist all parties in the supply chain.

¹¹ EPC is a contract for engineering, procurement and construction that transfers all the cost and performance risks of constructing a plant to a contractor.

¹² Back to back are contracts entered into by a party for the purchase of LNG from a supplier and its sale to a customer or customers such that the terms of each contract are carefully matched and the party in the middle then carries little or no risk

¹³ Long term contract in this context means a contract whose duration matches or exceeds any financing used in the project, typically 12-20 years.

¹⁴ O&M is a contract for the operation and maintenance of a plant that transfers all risks of operating and maintaining a plant to a contractor.

Safety Aspects and Risk Assessment in the LNG Supply Chain

Long term experience of large scale LNG handling shows that the present regulatory schemes ensure a high level of safety with few serious accidents reported. It is essential that any proposals for adaptation or liberalization of the established regulatory schemes with respect to small- and medium scale LNG handling will be approved only if it can be ensured that the established high level of LNG safety is maintained.

Detailed safety assessments of proposed modifications based on Formal Safety Assessment (FSA) techniques may be applied to verify that the overall safety level is maintained. New and revised regulations and guidelines that have been identified as needed are particularly urgent as regards to small-scale LNG bunkering operations. For reasons of clarity and uniformity, it is important that national and international regulators are specific with regard to rules applicable for different installation sizes.

Recommendation

National and international regulators are recommended to define quantitative figures specifying when regulations on small scale LNG handling and bunker operations are applicable. The figures may specify limits in terms of total tank capacity of the tank from where the LNG fuel is bunkered and flow rate in, or diameter of the pipes/hoses during bunkering operations. (Recommendation no.7)

For medium scale installations, such as intermediary LNG terminals as well as loading of LNG feeder and bunker vessels, it has been concluded that most of the established regulations and procedures are adequate and will ensure a high level of safety without any conflict with the efficiency and economic requirements for making LNG an attractive fuel option.

A well performed and presented safety assessment is instrumental to a straightforward permit process (refer also to recommendation no 14). There are many different model approaches and software used for the calculation and estimation of possible outcomes of various accidental events. A fair and harmonized assessment of various projects would be facilitated by national guidelines for adequate risk modeling approaches.

Recommendation

National authorities and international regulators are recommended to develop guidelines for adequate risk modelling approaches to be applied in safety assessment and risk assessment of bunkering concepts and facilities with the aim to facilitate fair and harmonised assessment of various projects. (Recommendation no. 8)

While preparing the assessment, it became clear that statistics are not currently entered in such a way that bunkering incidents are directly traceable. Rather, this information is included as part of different types of reported incidents and thereby difficult to find and handle.

Recommendation

The EU and national authorities are recommended to establish a harmonised way of categorisation and reporting of incidents and accidents related to bunkering of LNG as ship fuel as well as other bunker fuels. (Recommendation no. 9)

Bunkering LNG will be regulated from the land as well as the sea side of the quay. There may be cases in which it is unclear which safety regulation applies. In order to maintain a high level of safety, it is important that safety regulations are harmonized so that they provide the same safety level for the different operational options; ship-to-ship, tank-truck-to-ship and tank-to-ship via pipe-line.

Recommendation

The EU and national authorities are recommended to harmonise regulations and safety requirements for both land-based and sea based bunkering activities in order to attain a consistently high safety level and to avoid making safety issues a competitive factor between different bunkering modes. (Recommendation no. 10)

The ISO 28460:2010 standard (that specifies the requirements to ensure a safe transit of an LNG carrier – typically very large - and its cargo through a port) has been reviewed within this study. LNG bunker vessel traffic can be considered similar to other dangerous cargo and it is therefore not necessary to introduce new regulations. The ISO standard may also be applicable for LNG bunker vessels and barges with proposed minor modifications.

Recommendation

The IMO, national authorities and port authorities are recommended to consider LNG bunker vessel traffic to be similar to other dangerous cargo vessel traffic and avoid introducing special requirements for LNG bunker boat traffic. (Recommendation no. 11)

Technical and Operational Aspects in the LNG Supply Chain

Bunker operations create a safety issues for example on safety and exclusion zones. In contrast to large scale handling of LNG that involves few and occasional LNG transfer operations, bunkering of LNG fuelled ships will require many small and frequent operations.

Ship-to-ship transfer is an important operation in a maritime bunkering infrastructure. However, compared to existing LNG handling, ship-to-ship bunkering is a new type of operation which is done in a different manner, and hence this is the area with the largest need for new operational guidelines. This includes operational manuals and guidelines regarding the allocation of responsibilities. Other guidelines that are needed are regarding the safety zones according to which non-authorized people have restricted access.

STS bunkering is the main area for on-going studies and projects.

Truck-to-ship bunkering is by definition a relatively small operation and the truck driver normally has a large responsibility. The need for the introduction of different operational guidelines is therefore likely to be minimal in this case. Terminal-to-ship via pipeline bunkering is very similar to existing operations at larger terminals. There is most likely already an exclusion zone that can be adjusted for the LNG case. Moreover, there are most likely well trained personnel on the shore side, which means that there is less need for introducing new operational guidelines or standards.

One key challenge for safe and efficient LNG bunkering is to determine hazard areas in which accidental releases and fire scenarios may cause burn injuries and to define the appropriate size of exclusion zones. This is especially important in view of the fact that the commercial viability of LNG as bunker fuel is linked to whether or not bunkering operations can also be accepted during loading and unloading cargo or passengers.

Recommendation

It is recommended to develop guidelines specifically devoted to LNG bunkering. This may well be done by the working group¹⁵ within the International Standardizations Organization (ISO) currently developing guidelines for LNG bunkering (Recommendation no. 12). Examples of safe operational practices include:

The use of systems that, in case of emergency situations, will stop the flow of LNG , both liquid and vapour, a so-called emergency shutdown system (ESD);(Recommendation no. 13)

The use of systems that, in case the delivering and the receiving unit move away from each other, will enable a rapid disconnection of arms/hoses transferring the fuel (liquid and gaseous natural gas), a so-called emergency release system (ERS) and/or breakaway couplings;(Recommendation no. 14)

Tailored training of personnel for LNG bunker and feeder ships (Recommendation no. 15a)

Tailored training for people involved in LNG bunker operations;(Recommendation no. 15b)

Technical as well as operational measures to minimize methane releases.(Recommendation no. 16)

The Permit Process

A well-planned, well-targeted public consultation process is instrumental to a smooth and time-efficient permit process. To date, the following countries in the SECA have been involved in consultation processes and in acquiring an approval of an Environmental Impact Assessment, EIA, for an LNG terminal: Belgium, Finland, the Netherlands, Norway, Poland, Sweden and the United Kingdom. Information on public consultation processes has been gathered and assessed for the different countries with this experience. It has to be noted that to date, most lessons learned from permit procedures within SECA refer to large scale LNG import terminals. Norway is the only country with extensive records from small scale terminals and the permit process for these are generally in the order of one year.

One of the findings is that a major reason for a long permit processes is stakeholders' reluctance to accept infrastructure projects in general. It is therefore crucial for the project developer to handle the public consultation process in a proper way. A major reason for public opposition is that people are insufficiently or incorrectly informed about planned projects. Early, good communication between the project developer, authorities, other economic activities and the general public is therefore essential.

As both public, local and regional authorities as well as the media in general have little knowledge of LNG, it is vital also to communicate the advantages of LNG as a fuel.

¹⁵ ISO TC 67/Working Group 10

Recommendation

In the public consultation process, it is important for the project developer to;

- Establish early, good communication between the project developer, the authorities, other economic activities and the general public;
- Perform an adequate safety analysis, including all external and internal risks, and take adequate time to communicate the results to the general public, the neighbours of the establishment and the authorities concerned;
- Define the project well with regard to capacities and dimensions and consider several alternative locations (refer also to recommendation no 5 on financial and economic aspects);
- “De-mystify” handling of LNG fuel when it comes to safety aspects. This can for example be done by communicating the exceptional safety record of LNG operations – not a single fatality among the general public has occurred anywhere in the world in connection to LNG operations;
- Communicate the advantages of LNG as a fuel, e.g. reduced emissions and reduced engine noise;
- Communicate the necessity of establishing an LNG filling station infrastructure to be able to use LNG as a fuel in the maritime sector;
- Elaborate information to the stakeholders that is target group specific. That is, information specifically addressed to certain stakeholder groups.
(Recommendation no. 17)

There is also a need to develop guidelines for the siting of small and medium scale LNG terminals and LNG filling stations, as there may be conflicts between safety aspects and the need to locate LNG facilities close to the customers in the port to be competitive.

Recommendation

National authorities and the Society of International Gas Tanker and Terminal Operators (SIGTTO) are recommended to develop guidelines on the siting of small and medium scale LNG terminals and LNG filling stations based on national and international regulations with a view to possible international harmonisation.(Recommendation no. 18)

Furthermore, the complexity of the permit procedures is a strong contributing factor to long permit processes. Many countries in North Europe require two or more permit processes with two or more authorities involved. One way to reduce the time needed for the permit procedure is to create a coordinated permit process.

Recommendation

National authorities are recommended to develop one single coordinated process for the permitting process, in which the authorities concerned cooperate closely. This is recommended to be introduced at the national level. (Recommendation no. 19)



1 Study Perspective

The main driver for the project ‘A feasibility study for an LNG infrastructure and test of recommendations’ is the sulphur restrictions on fuel being imposed on the maritime sector and within the SECA (Sulphur Emission Control Area) that covers the Baltic Sea, the English Channel and the North Sea. The restrictions that will be in force by January 2015 will lead shipowners to act and opt for low sulphur alternatives for fuelling ships. One possibility for the shipping industry to meet the new requirements, is to shift to the fuel Liquefied Natural Gas (LNG). However, the LNG option will rely on an LNG bunkering facilities to be developed and established.

The Danish Maritime Authority has taken the initiative to this project within the European Union TEN-T¹⁶ programme Motorways of the Seas.

1.1 Objectives

This project aims to prepare a feasibility study and set up a number of recommendations addressed to central stakeholders with regards to different aspects of the establishment of an LNG bunkering infrastructure within the SECA.

1.2 Methodological Approach

The feasibility is analysed in basically two interlinked parts: the maritime demand and the maritime supply chain infrastructure. There will be “hard” aspects such as terminals and bunker vessels and “soft” aspects such as regulatory and industry standards.. For an overview of the analytical approach, refer to Figure 14 below.

One chief facet for this study is the shipowners’ point of view and how LNG can become a vital option for them. In Figure 6, the red box in the left upper corner represents the ship owners’ compliance strategies.

The shipowners’ options will be assessed including investment cost calculations and operational cost calculations, in Chapter 4. This is also the outset for the demand development scenarios that is further assessed later on in Chapter 9. The study centres around balancing demand and supply of LNG as is illustrated by the figure. Two most important factors determining the demand is the cost and availability, also compared to other options than LNG. A brown and a blue arrow illustrate these two aspects in the figure. The price of LNG is firstly studied from the point of view of LNG import prices, refer to Chapter 5 and the box “LNG import price” in the figure 6. The cost for infrastructure is further analysed in more detail and its results brought back into the assumed LNG price, represented by the brown box and arrow in figure 6.

- Projections of the present bunkering demand in the SECA are made to estimate how the maritime LNG demand can develop in the short, medium and long term, given different conditions and possible alternative compliance strategies (Chapter 9), bridging the red box with the blue.

¹⁶ Trans-European Transport Network

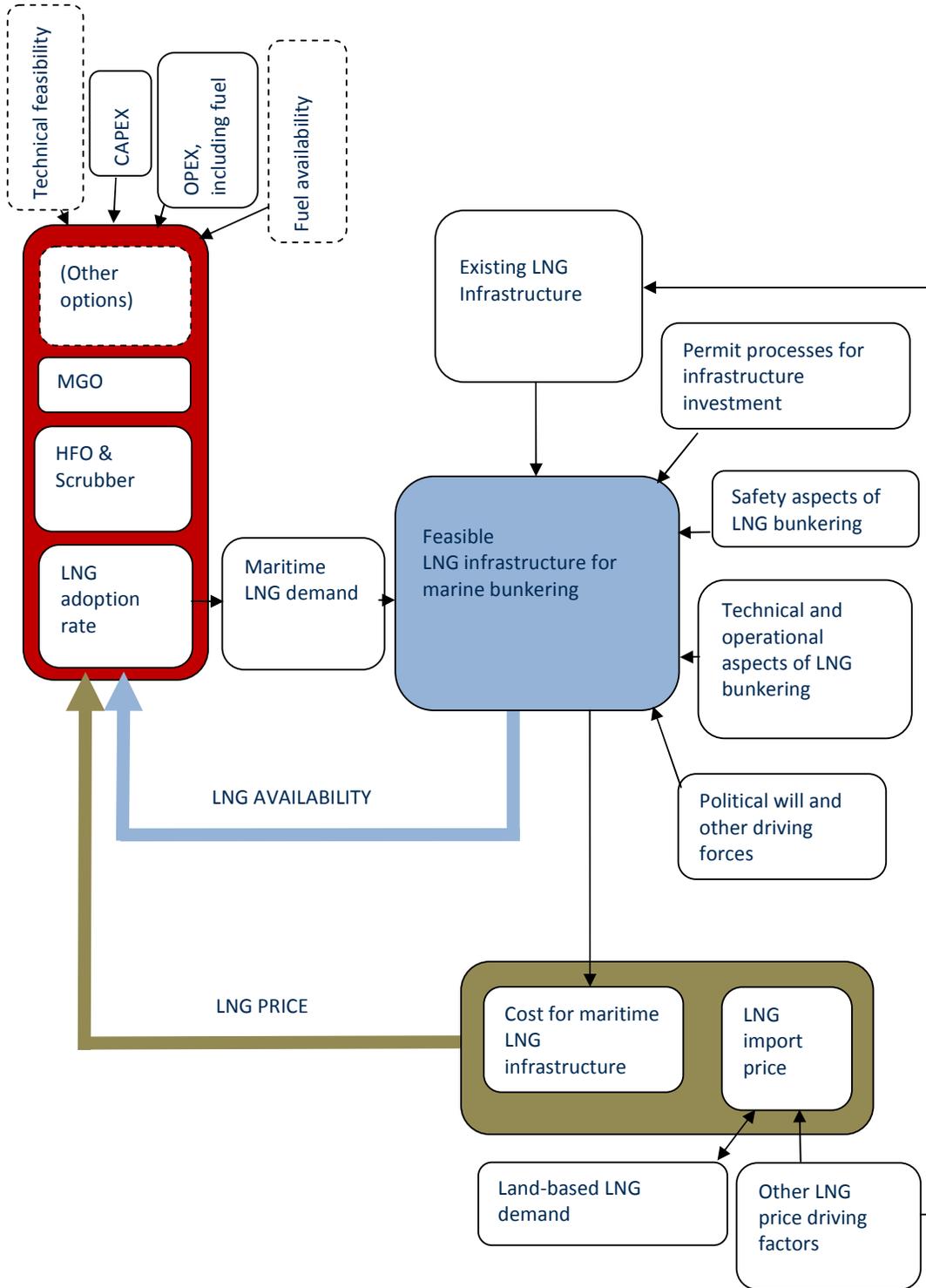


Figure 14 Overview of the feasibility study

The base for these estimates is AIS¹⁷-data on vessel movements in the SECA while other data statistics and features of the market complement it. The adoption rate for different segments of ships bunkering within SECA has been estimated together with ship market analysts¹⁸.

Cost estimates and other factors influencing the likely demand for LNG are developed together with representatives from the shipping industry and from motor suppliers.

Illustrated by a blue, central box “Feasible LNG infrastructure for marine bunkering”, the study expands on the LNG alternative to include also the availability and further details in supply infrastructure, which is in line with the scope for the study. Here, details regarding the different ships’ bunkering needs will be central, being the link between supply and demand.

Therefore, another principal perspective of the analysis is the LNG-terminal operator’s and some possible system solutions and operational models for LNG filling stations will be assessed:

- A large import terminal;
- A medium sized port with passing traffic but without an import terminal;
- A small port without an import terminal.

These principal options are presented in the end of Chapter 6, and centre on three various types of bunkering solutions, being the link between supply and demand:

- Ship-to-ship at quay or at sea¹⁹;
- Tank truck-to-ship;
- Stationary tank-to-ship.

The selected terminal options have been subject to investment cost calculations and operational cost calculations, refer to Chapter 7. For estimating costs, contacts have been made with a number of terminal operators and also some of those who plan to establish.

Together with an inventory of the existing LNG infrastructure in the countries bordering the SECA, a review has also been made of the major driving forces for the infrastructure development, refer to the first parts of Chapter 6. In the end of Chapter 10, the expected general market development for LNG and the market drivers are presented for the relevant countries bordering the SECA to which, in most cases; the maritime LNG demand is complementary.

Conditions for and definitions of scenarios with different types of terminals and bunkering facilities in the region, including integration with land-based systems and investment costs has been screened and summarised in Chapter 10. These scenarios have been based on a few different scenarios for the LNG demand development.

¹⁷ Automatic Identification System.

¹⁸ IHS Fairplay.

¹⁹ Including LNG bunker barges.

The business case for different potential LNG suppliers and other stakeholders such as port authorities, public utilities/the state, the energy industry and other private operators has been reviewed from an investment and operational point of view in Chapter 11.

Safety aspects of these main bunkering options have been assessed as summarised in Chapter 12, following the Formal Safety Assessment (FSA) approach. A Hazid (Hazard Identification)-workshop has been arranged and the results from this activity are summarised in the chapter. Based on results from the safety analysis, recommendations are developed and presented. In the same chapter, responses to the safety concerns are reviewed in terms of the technical and operational aspects

In order to develop practical recommendations as far as possible based on practical experiences and real data, Chapter 12 have primarily elaborated established bunkering solutions. For the feasibility of an LNG filling station infrastructure, Innovative solutions are as well interesting. Therefore some possible non-conventional LNG bunkering solutions are presented in Chapter 6, but they are neither assessed in detail as regards for example safety risks and operational guidelines, nor from the business cases point of view.

A review of the relevant lessons learned from the public consultation process as well as national regulations concerning permit process for LNG facilities has been made, see Chapter 13. Focus in the review of national regulations has been on the public consultation process, since public opposition is identified as a key problem for project developers and one main reason for long permit processes. Information has been gathered through interviews, written contributions and a literature review.

In the end of this report, there is a summary of recommendations. They are presented on a format that should be easily tested and reviewed. The recommendations refer to this report and its appendices.

The project has also accessed input from the in-kind contributors and other partners in the study through a series of meetings and workshops. There have been open reference group meetings at two occasions and two open project meetings discussing the baseline report and the initiation of recommendations' formulation respectively. Lastly, three workshops were arranged and hosted by port authorities with tangible plans for LNG supply. At the workshops, the recommendations have been tested, discussed and validated with partners of the project as well as local partners around the port. All in all, the workshops have attracted around 150 persons.

1.3 Limitations to the Study

The study focus is on LNG and therefore other potential compliance strategies are only briefly covered for reference. No details or estimates about for example the required infrastructure for handling of waste for scrubbers are made or for any other infrastructure requirements that alternative compliance strategies may have.

The study is much driven by the aim to develop environmental friendly shipping and there is no analyse regarding how shipping relates to other transport modes.

The environmental concerns covered by this study are mainly bound to the emission regulations set by the IMO, in particular, the Tier II that limits sulphur oxides and Tier III that limits nitrogen oxides. Other environmental targets for the shipping industry, such as diminished carbon dioxide emissions are not studied, only to the extent to ascertain that implementation strategies of policies may interrelate.

The permit process for an LNG terminal includes various steps that differ from country to country. This study does not claim to be exhaustive on the planning process including the permits that a terminal investor

must seek. Instead, the aim is to focus on those parts that can be unintentionally postponing or hindering the investment.

The calculations of pay-back times and other financial key figures must be viewed as generic examples for explanatory purposes. Although the calculations are based on relevant assumptions, each specific case will in practice of course differ from these hypothetical examples.



2 Background

2.1 European Maritime-Based Logistics

An efficient intermodal transportation network, integrating land, sea; inland waterways and air transport, is identified as an important aspect of sustainable development of the transport sector in the European Union (EU). One of goals of the EU is to establish a Trans-European Transport network (TEN-T).

Under the umbrella of TEN-T, the concept Motorways of the Seas has been designed in order to expand existing and to introduce new inter-modal maritime logistics chains, shifting cargo traffic from heavily congested land-based networks to locations with more available spare capacity, i.e. the environmentally-friendly waterways. The potential within rail and inland waterways are also included in the maritime-based logistics. The sea areas selected to be Motorways of the Seas, including the Baltic Sea and the seas of the Western Europe, are shown in Figure 15 below. Port efficiency and hinterland connections are a vital part of the Motorways of the Sea.

The policy of the European Commission is to support short sea shipping including Motorways of the Sea, as it is regarded as highly efficient in terms of environmental performance and energy efficiency and as potentially alleviating land traffic congestion problems.

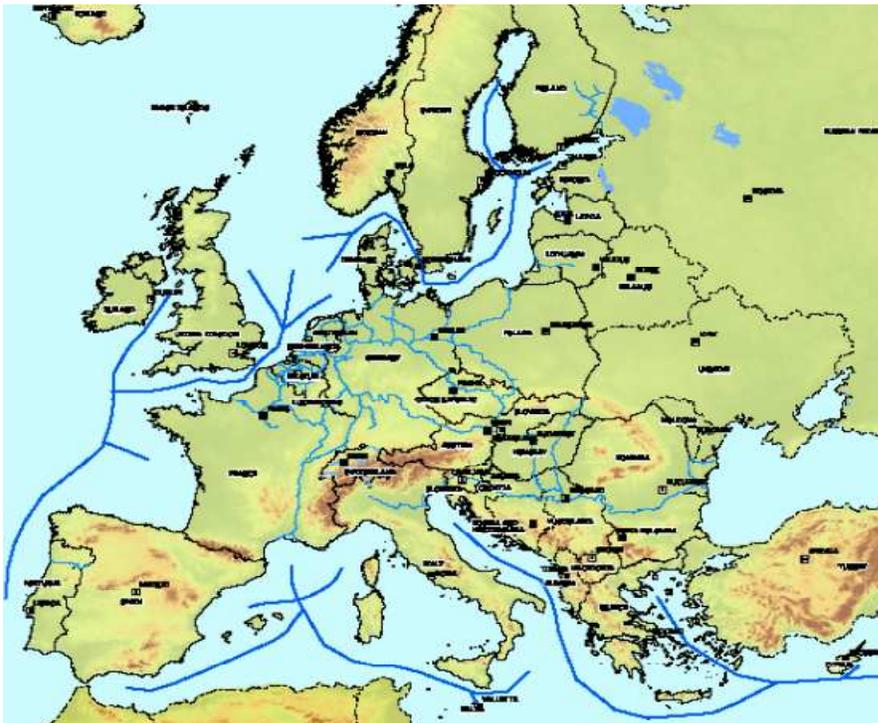


Figure 15 Map of the Motorways of Sea (MoS).

Source: European Commission, http://ec.europa.eu/transport/maritime/doc/motorways_sea_2004_07_30_map.pdf

2.2 Parallel EU-activities

The EU is a major actor at the regional level and there are intensive networking mechanisms between the EU, the member states and the public as well as the private sector including Non Governmental Organizations (NGOs) and other organizations through its strategies and funding of programmes and projects. Some of the programmes having synergies with the LNG feasibility study are the following:

- Effship;
- Clean North Sea Shipping;
- Clean Baltic sea Shipping;
- BunGas;
- Markis²⁰;
- LESAS²¹.

Much EU funded support is concentrated around the Baltic Sea by providing support to a large number of projects. Several of these projects are conducting studies related to same issues as concerns the current studies. Beyond the Baltic Sea, there is also a project, Markis, which addresses Kattegat and Skagerrak. However, apart from this ongoing study, there appear to be few, if any, collaborative efforts integrating the entire SECA region as such.

The eastern Baltic countries are defining their future investments in gas infrastructure under a regional cluster which is the EU funded Baltic Energy Market Interconnection Plan (BEMIP). Another cluster is the North Seas Countries' Offshore Grid Initiative (NSCOGI), which is used for reaching regional agreements.

2.3 Environmental Regulations of the Shipping Industry

In order to illustrate the environmental impact of the shipping industry the following comparison can be made. In 2008, air emissions from shipping in the Baltic Sea emitted about 135,000 tonnes sulphur oxides (SO_x), 393,000 tonnes nitrous oxides (NO_x) and 18.9 million tonnes carbon dioxide CO₂²². Regarding NO_x and SO_x, this is the same amount of NO_x and twice the amount of SO_x as the total land-based emissions from Sweden and Denmark combined. The Baltic Sea represents 25% percent of the SECA in terms of fuel use.

The environmental impact of shipping at large can be segmented in 5 categories as advocated by the Clean Shipping Project initiative. These categories are:

- SO_x and PM emissions;
- NO_x emissions;
- CO₂ emissions;
- Chemical releases from vessels;
- Waste generation (solid as well as liquid waste).

²⁰ Maritime Competence and Innovation Cooperation in the Skagerrak and Kattegat.

²¹ Mostly concerned with the Netherlands and the in-land water ways.

²² HELCOM, http://www.helcom.fi/shipping/emissions/en_GB/emissions/

Traditionally, focus has been on the shipping sectors' effect on air emissions and pre-dominantly on local pollution related to NO_x, SO_x and PM emissions. The introduction of ECAs (explained further in the next section) is an attempt to address this aspect and reduce the environmental footprint of the shipping industry.

During the last few years, the focus on shipping's impact also on green house gas emissions has attracted interest from society at large and legislators. A summary of studies within this area can be found in Appendix 1.

There are conventions and agreements made both on an international basis and a regional (EU) basis. There are many organisations dealing with shipping in different ways. The most relevant is the International Maritime Organization (IMO), part of the United Nations, which is responsible for safety and security of shipping and developing international regulations.

The MARPOL 73/78 Convention²³ by the IMO is the main international convention to prevent pollution by ships. Air pollution is regulated²⁴ in Annex VI "Regulations for the prevention of Air Pollution from Ships" (which came into effect in 2005).

A revised version of Annex VI came into effect in July 2010. The Annex VI has been incorporated in the EU Directive 2005/33/EC1 amending Directive 1999/32/EC relating to a reduction in the sulphur content of certain liquid fuels and amending Directive 93/12/EEC. There is a new directive under way, incorporating the 2015 provisions set by IMO as well as other changes.

Besides the new IMO regulations on sulphur emissions there are several other drivers that are induced to reduce the environmental footprint of the shipping industry;

- Tier III regulations on NO_x emission from new engines from 2016
- Energy Efficiency Design Index (EEDI)²⁵, which is an international directive regulating the energy efficiency (new ships);²⁶
- Ship Energy Efficiency Management Plan (SEEMP)²⁷, which is an international directive regulating (all ships);
- EU Staff working paper on Pollutant Emission Reduction from Maritime Transport and the Sustainable Waterborne Transport Toolbox – suggest several incentives/disincentives to support the development of a cleaner shipping industry in the European Union.

²³ "International Convention on the Prevention of Pollution from Ships". The "1997 Protocol" to MARPOL also referred to as 1997 Protocol (Tier I) which includes Annex VI, became effective 12 months after being accepted by 15 States with 50% of world merchant shipping tonnage.

²⁴ It applies retroactively to new engines greater than 130 kW installed on vessels constructed on or after January 1, 2000, or which undergo a major conversion after that date. Most marine engine manufacturers have been building engines compliant with the above standards since 2000

²⁵ Energy Efficiency Ship Index

²⁶ At date, not all ship types are included in the EEDI. The types of ships that are currently included are: Bulk carrier, Gas carrier, Tanker, Container ship, General cargo ship, Refrigerated cargo carrier, Combination carrier.

²⁷ Ship Energy Efficiency Management Plan

2.4 Emission Control Areas

Stricter emission requirements, than those globally required, are regulated in specifically designated geographical areas. An Emission Control Area (ECA) can be designated for SO_x or NO_x, or both emission types from ships. There is an ECA in North America, which includes most of the US and Canadian coasts. Regulations addressing NO_x & SO_x emissions in the North American ECA come into effect in 2012.

The Baltic Sea, the North Sea and the English Channel are together designated as an ECA for SO_x emissions reductions, hence Sulphur Emission Control Area (SECA). The restrictions for the SECA according to the IMO and EU are:

- 1.0 % as the maximum allowable sulphur content of bunker fuel (from July 1, 2010);
- 0.1 % as the maximum allowable sulphur content of bunker fuel (from January 1, 2015).



Figure 16 An overview of the SECA - The North Sea, including Kattegat and Skagerrak, the English Channel and the Baltic Sea.

Note: The directly affected countries are displayed in green. The shaded areas indicate the partner countries of this study.

Source: Swedish Maritime Agency, 2009.

The countries bordering the SECA, are the United Kingdom, France, Belgium, the Netherlands, Germany, Denmark, Poland, Latvia, Lithuania, Estonia, Baltic Russia, Finland, Sweden and Norway (see Figure 16).

These new very strict regulations regarding sulphur will of course affect the whole shipping industry operating within the SECA area. Typically they may induce migration of ships and/or a modal shift to land-based transport. They may further reduce global competitiveness for industries in the bordering countries.²⁸

This study is focusing on the feasibility, for the shipping industry utilizing the SECA area, of using LNG as bunkering fuel to correspond to the new requirements.

²⁸ The modal shift is regarded by for example EMSA and also by the Swedish Maritime Administration; *Konsekvenser av IMO:s nya regler för svavelhalt i bränsle* (Consequences of the New Regulations on Sulphur in Fuels by the IMO).



3 The Bunker Fuel Demand within SECA

3.1 Overview of the Shipping Industry in the SECA

Ship operators from all over the World run ships that trade all or part of their time in the North European SECA.

In 2010, there were 14,014²⁹ ships trading in the region. More than two thirds (71 %) of the number of ships were run by European ship operators, while just a little over half in terms of ship dwt capacity. This implies that the larger ships have a higher share of non-European ship operators. Among the European ship operators, the ones from Greece, Germany, Denmark, Norway, the United Kingdom and the Netherlands are dominating. Ship types that are most frequently seen in the region are tugs and general cargo vessels if measured in number of ships and RoRo³⁰, tankers and bulk carriers if measured in dead weight (dwt).

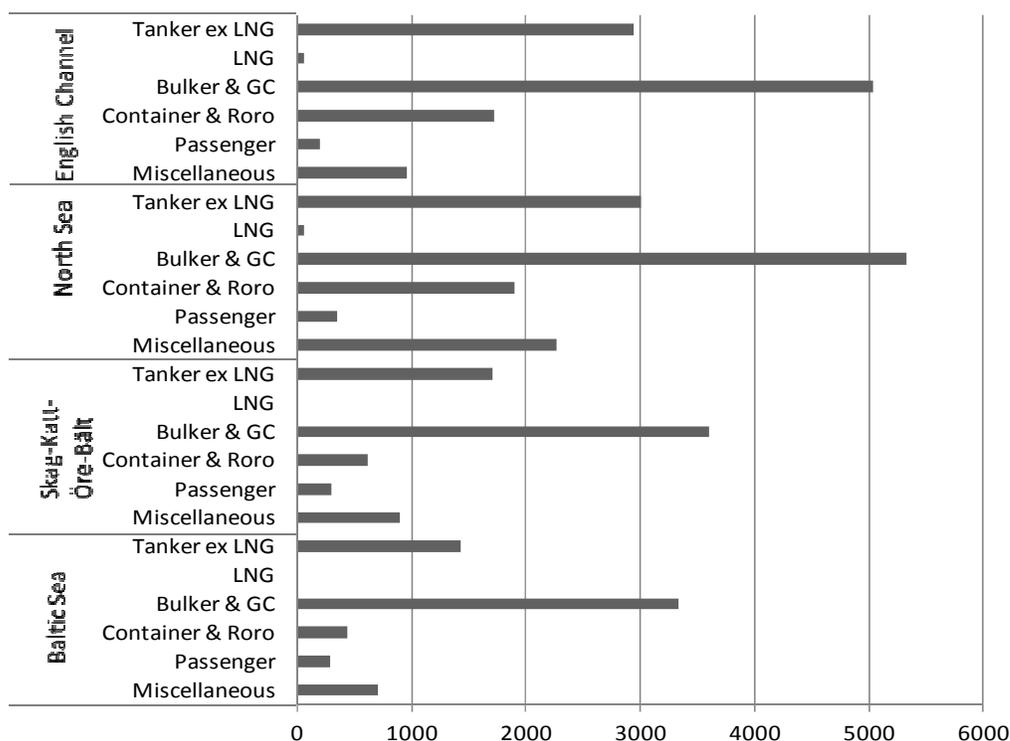


Figure 17 Number and the categories of ships in the SECA sub-regions 2010 by major vessel type.

Source: IHS Fairplay

²⁹ This is the number of individual ships that are registered during year 2010 in the SECA through the mandatory Automatic Information System (AIS). Source: IHS Fairplay

³⁰ Roll-on, roll-off

Naturally, the highest share of vessels that spend 100 % of their time in SECA are found in the inner parts of the SECA, i.e. in the Baltic Sea. Consequently, the highest share of ships that spend between 1 % and 49 % of their time in SECA is found in the English Channel.

It is also in the English Channel that the largest average size of vessels is found. This is a consequence of the higher frequency of large, deep sea vessels that sail between Europe and other continents.

In the ports of the SECA there are about Bn 2.3 tonnes of cargo handled in a year, of which Bn 1.1 tonnes in the North Sea ports, Bn 0.5 tonnes in the Baltic Sea, almost equally much in the English Channel and close to Bn 0.2 tonnes in the ports located round the waters between Sweden and Denmark. Germany handles slightly more cargo in their ports in the Baltic Sea than they do in the North Sea. Due to the large port in Gothenburg, Sweden handles more cargo at their west coast than in the Baltic Sea.

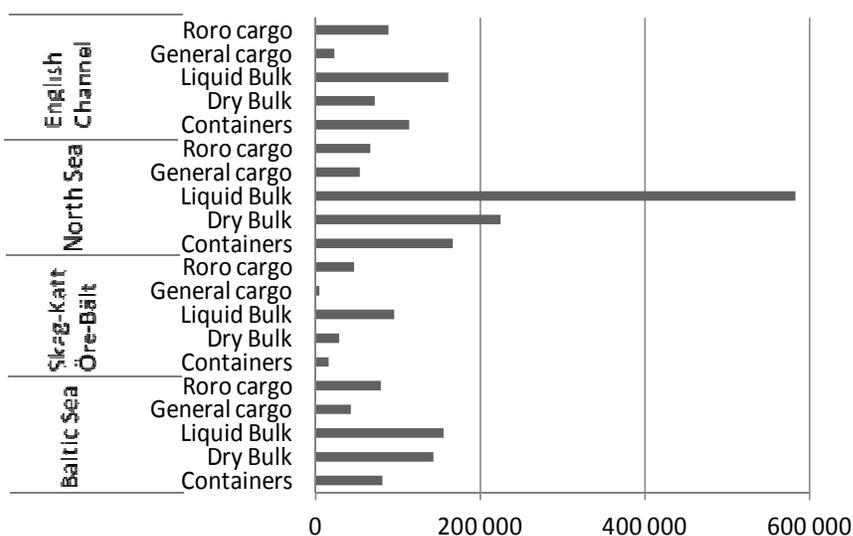


Figure 18 Port cargo volumes, 1,000 tonnes 2009.

Source: IHS Fairplay

Roughly Bn 1 tonnes of the cargo are liquid bulk, Bn 0.5 tonnes are dry bulk, Bn 0.4 tonnes are containerized cargo and the remaining volumes are divided between RoRo and other general cargo.

The shipping activities in the SECA can, as outlined above, be defined as international and short sea shipping. An overview of the cargo sea routes of the Baltic Sea and North Sea is shown in Figure 11.

Further data regarding the shipping activities and bunker fuel demand in the whole SECA area accounted for in the next chapter and in Appendix 2 in both cases based on AIS-data compilations³¹.

³¹ Automatic Identification System is a very high frequency (VHF) radio-based system which enables the identification of the name, position, course, speed, draught and cargo of ships

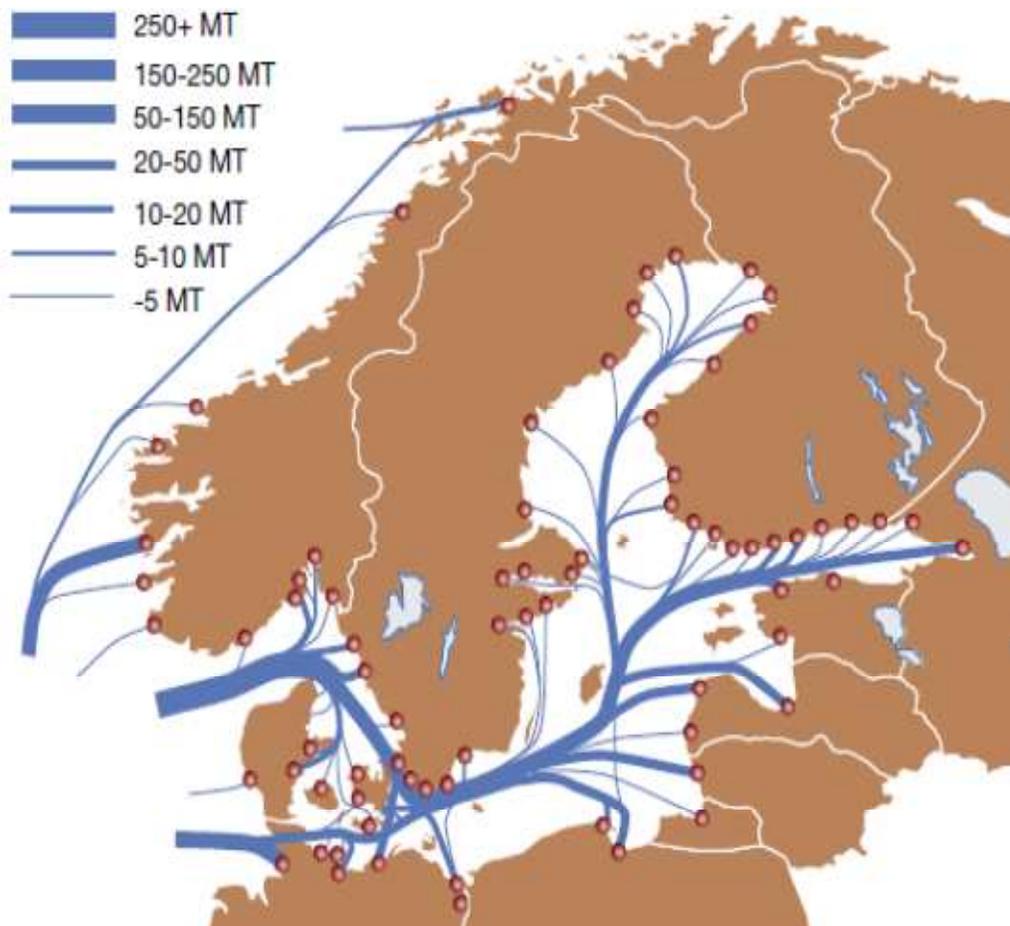


Figure 19 Sea routes, all cargo, TEN-T ports 2003. MT stands for million tonnes (per annum).
Source: SMA et.al, Baltic Maritime Outlook, 2006.

3.2 Bunker Fuel Use in the SECA

Based on AIS-data compilations³² and the calculated fuel consumptions of those vessels while they were sailing within the SECA (and the specified sub-regions) the total amount of bunker fuel used in SECA during 2010 can be summed up to 12 million tonnes, refer to the AIS-data tables and calculations in Appendix 2. In Figure 20 below, the amount of fuel used in the different sea areas is presented together with major ports.

³² Compiled by IHS Fairplay for the SECA.

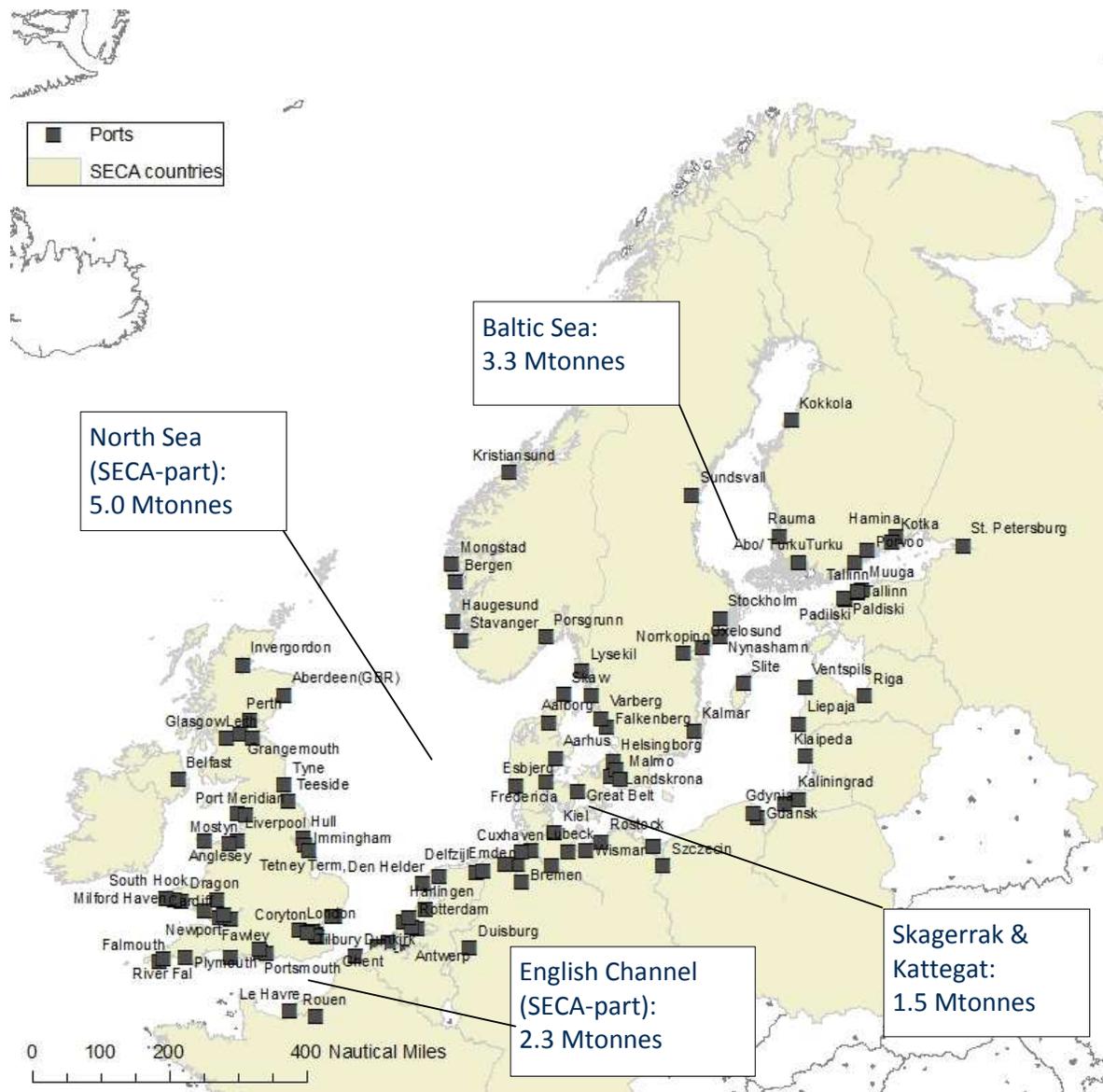


Figure 20 Ports within SECA and current fuel use within SECA and its sub regions.

Source; AF internal analysis, 2012

There is no direct link between fuel consumption and location of bunkering of fuel. It is only the ships that spend 100 % of their time within the SECA that also safely can be assumed to be bunkering there, see the diagram in Figure 21. The calculated 12.0 tonnes of fuel consumed are as mentioned above only while the vessels are within the SECA. The majority of the vessels spend less than half of their time within the SECA. For those vessels that spend part of their time outside of the SECA any assumption of bunkering stands the risk of being over or under estimated.

What can be established though is that the more time a vessel spends within the SECA and the longer the distance from the SECA border line it trades, the higher is the likelihood that the ship bunkers fuel within the SECA.

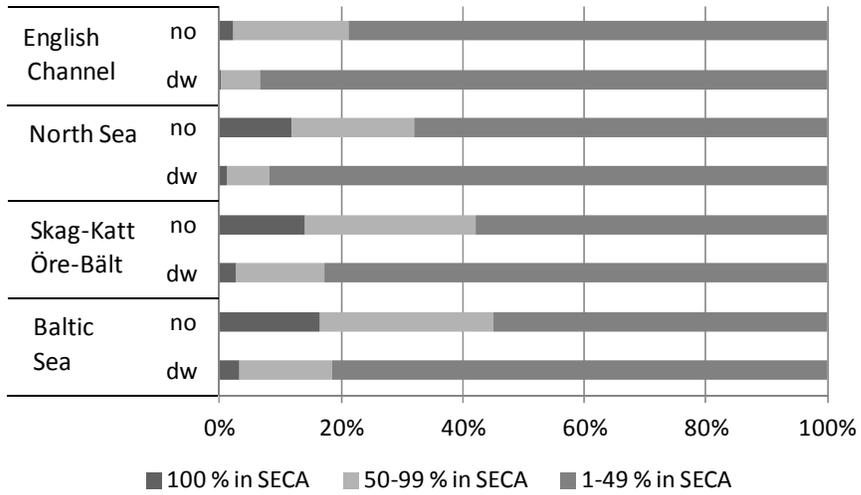


Figure 21 Ships' distribution of time spent in SECA based on no of ships & dwt



4 Shipowners' Compliance Strategies

In the short and intermediate term there are two realistic alternatives besides LNG to meet with the new regulations: to continue to use heavy fuel oil (HFO) but add a scrubber to decrease sulphur emissions; and to use marine gas oil (MGO) as fuel. All alternatives will impose large costs on shipowners and their businesses.

Which strategy, if any, that will come to dominate, is largely dependent on economic aspects such as investment costs as well as operational costs and above all the future fuel prices.

4.1 Heavy Fuel Oil with Exhaust Gas Scrubber

It would be possible to comply with the SECA requirements by applying an 'end of pipe' solution and use scrubbers for SO_x (and PM) removal in combination with either Selective Catalytic Reduction (SCR) or Exhaust Gas Recirculation (EGR) for NO_x cleaning. This combination is a strong candidate to fulfil the requirements in SECA 2015 and ECA Tier III.

The advantages of the scrubber technology are that readily available HFO can be used also in the future. The infrastructure, and hence the availability, of HFO is also good and the shipowners do not need to retrofit or replace their engines. Scrubber tests show that the sulphur emissions are reduced to almost zero and the PM content in the exhaust gases is significantly reduced.

The disadvantages include the required capital investments in scrubbers as well as the wastes produced by the scrubbers. The infrastructure for scrubber waste deposition in ports is not yet in place and no praxis or regulations exist that regulate the port's responsibility to handle such waste. In July 2011, the IMO issued a resolution giving guidelines for reception facilities under the Marpol Annex VI. This may become a service that can be charged for.

Other disadvantages with scrubbers are that the proportion of CO₂ in the exhaust gases is not reduced and that any scrubbers used to fulfil the SECA requirements must be IMO certified. Scrubbers also occupy space and in some cases cargo capacity might be reduced (depending on if space otherwise used for cargo needs to be claimed or not).

4.2 Marine Gas Oil (MGO)

Conventional marine fuels are commonly divided into two categories: residual fuel oil and distillates. Residual fuel oil, often referred to as Heavy fuel oil (HFO), is the heaviest marine fuel with respect to viscosity and sulphur content. Distillate fuels can be further divided into two categories, Marine gas oil (MGO) and Marine diesel oil (MDO).

Using MGO gives low sulphur emissions that match the SECA demands. Particulate matter in exhaust gases is also reduced. NO_x and green house gases will remain at the same level as when using HFO. To comply with NO_x Tier III, SCR or EGR is needed when operating on MGO.

MGO does not require extra volume for storage tanks, and retrofitting of the engine gives only small or no investment costs. However, fuel prices are already at a rather high level and are in general believed to continue to rise, to some extent due to limited refinery capacity.

4.3 Liquefied Natural Gas (LNG)

The LNG-fuelled gas engines have proven to be reliable and it is a low-sulphur fuel. Exhaust gas emissions such as SO_x and PM are negligible, and the NO_x³³ emissions are below the Tier III limits for Otto cycle engines.

Liquefied Natural Gas (LNG) is natural gas stored as liquid at -162°C. The predominant component is methane with some ethane and small amounts of heavy hydrocarbons. Due to the low temperature, LNG has to be stored in cryogenic tanks. LNG has a high auto ignition temperature and therefore needs an additional ignition source, i.e. a pilot fuel, to ignite in combustion engines. Natural gas is lighter than air and has a narrow flammability interval. It can be combusted in two stroke gas engines or in four stroke Otto engines.

LNG storage tanks require much more space than traditional fuel oil tanks. This may reduce cargo capacity, depending on type of vessel, type of fuel tank and potential for adequate location of the LNG tanks on-board.

The gas engines have proven to be reliable and it is a clean and low-sulphur fuel. Exhaust gas emissions such as SO_x and PM are negligible. NO_x can be reduced by approximately 80-90 % for Otto cycle processes, and 10-20 % for Diesel cycle processes. LNG contains less carbon than fuel oils, reducing the CO₂ emissions first and foremost from tank to propeller³⁴.

4.4 Dual Fuel

LNG can be used in engines being able to run on either liquid fuel oils or gaseous fuel. The idea is to use LNG inside SECA and another fuel outside the SECA and/or let the fuel used outside SECA be determined by the relative fuel prices. Such engines can be either two stroke diesel engines or four stroke engines with the working principle based on the Otto cycle when operating on natural gas and on the Diesel cycle when operation on fuel oils.

For four stroke engines, the working principle is based on the Otto cycle when operating on natural gas, and the Diesel cycle is the basis for operation on fuel oils. The ignition source is a small amount of fuel oil which is injected and ignited by the compression heat; the burning oil ignites the gas. The two stroke engine applies high pressure gas injection together with pilot diesel oil and the fuel oil that ignites first, and the gas is ignited by the burning fuel oil. This engine can run on fuel oil only or on a mixture of gas and fuel oil. The engine has no or almost no methane slip, but cannot meet Tier III NO_x regulation without further counter-measures such as EGR or SCR.

³³ Strictly speaking, NO_x compliance is outside the scope of this study. Nevertheless, it is included in the calculations since when investing in new ships, NO_x compliance also needs to be taken into account – a decision which ought to be taken in conjunction with choosing an SO_x compliance strategy. Some of the LNG engines need no NO_x reducing measures, so omitting the NO_x aspect would miss their competitive advantage.

³⁴ However, for Otto cycle process operation in dual fuel engines, methane slip is a problem but the engine manufactures are working on diminishing the problem. Methane is an aggressive greenhouse gas and when including both CO₂ and methane emissions, LNG does not always give a reduction in greenhouse gases emissions compared to fuel oils. Methane slip is however not a problem for engines operating on gas in the Diesel cycle. (Litehauz et al, 2010)

4.5 Investment costs and operational costs for the fuel alternatives

Investment costs and operational costs for the fuel alternatives are presented in Appendix 3. The costs are described as specific costs but also in real terms for four typical vessels.

The four typical vessels, two RoPax/RoRo vessels of different size, a Coastal tanker/Chemical tanker/Bulk carrier, a container ship (700-800 TEU) are also described in Appendix 3. A fishing vessel is also presented as it in a more distant future may become a category of ships adapted to LNG.

The typical ships have been selected to be representative of the traffic in SECA and are chosen to illustrate the cost of retrofitting and building new ships complying with the future SECA regulations. The chosen vessel types are of course to be seen as examples of each type category but huge variations exist in all categories and in all respects.

4.6 Comments

The new regulations concerning the sulphur content of shipping fuel will impose large costs on shipowners and their businesses. For the small “type ships” discussed in Appendix 2, the choice can be between investing 2-6 M€ in exhaust gas cleaning or an LNG engine or, alternatively, switch to a low-sulphur fuel which would increase fuel costs by 60 % to 120 % which will be showed in the next chapters. None of the alternatives comprises any direct economic benefit, so when the term pay-back is used in different circumstances (for instance in the demand analysis made in Chapter 8) it is a matter of putting higher investment cost for one alternative against higher operational costs for another.

There are a number of other factors related to economy that it may be fruitful to take into account when shipowner makes a more detailed comparative analysis of the compliance strategies.

For example, bunkering LNG may take longer than bunkering fuel oils. This could in many cases lead to loss of profitable time at sea. If this will be the case and how much time is lost is case-specific and dependent on how the ship is operated, the bunkering capacity of the terminal (including bunker barges etc.) and many other factors.

This operational cost analysis has not considered costs of the need for extra education of the staff concerning fuel handling and use. Also, the potential requirement for special licenses for handling LNG may inflict some costs, as may environmental investigations preceding the granting of permissions to handle LNG in ports (and such costs will ultimately be transferred to the LNG end customers).

A detailed investment calculation should include the cost that might arise when using LNG as a fuel if valuable cargo space should be occupied with LNG-tanks. Taking this into account would (sometimes considerably) decrease the viability of the LNG compliance strategy. The risk of losing cargo space is probably most relevant for container vessels – in the other ship types studied there may be margins.

For the scrubber compliance strategy, high scrubber availability is important. Scrubber waste handling may pose a problem, demanding extra time in port or at least special fees to pay.

MGO seems to be an attractive wait-and-see strategy with low investment costs for actors who believe that LNG may have a breakthrough sometime in the mid-term future. However, if many actors use that strategy the MGO demand – and hence price – will increase (and LNG development may be slower). This is further discussed in Chapter 5.



5 The Supply Costs of LNG and Competing Bunker Fuels

The basis for the end-users' fuel price are the hub price. In this chapter all prices should be understood as hub prices (import prices), the costs for distribution to users are discussed and defined in Chapter 6 and 7.

5.1 Historical prices and price relations of HFO, LNG and MGO

Conventional marine fuels used by commercially operating ships are commonly divided into two categories: residual fuel oil and distillates. Residual fuel oil, often referred to as heavy fuel oil (HFO), is the heaviest marine fuel with respect to viscosity and sulphur content. Distillate fuels can be further divided into two sub-categories: marine gas oil (MGO) and marine diesel oil (MDO). When residual fuel oil is blended with distillates, the blend is called intermediate fuel oil (IFO).

5.1.1 Historical Prices

Bunker fuel prices vary greatly. As with most petroleum products, different bunkers are bought and sold in their respective regional markets, which are commonly interlinked with the development of the crude oil market.

For Europe, the “standard reference” for crude oil price is Brent Blend, the price of crude oil extracted from the North Sea. The Brent Blend price is obtained from the international petroleum exchange in London and based on future contracts. Prices are given in USD, the common currency for petroleum products. Brent Crude oil is usually given as a price per barrel (normally converted into metric tonnes (MT) with a conversion factor of 7.5 barrels per MT).

Figure 22 below illustrates the strong correlation between marine fuel prices and Brent prices in Europe.



Figure 22 Historical prices in \$/tonne of HFO, MGO, LNG (average of all locations in Belgium) and Brent oil.

Source: AF analysis, 2012

As can be seen in the figure, bunker fuel prices are very volatile in both the short and the long term. In addition, it can be observed that the prices of MGO, HFO and Brent oil have generally increased since around mid-2003. For example, the average price of HFO during the 24-month period from January 2004 - December 2005 was \$194/tonne (€140/tonne); over the January 2009 – December 2010 period the average price of HFO was \$400/tonne (€300/tonne), equivalent to a 106% increase in the average price. For MGO a 40% increase in average price was observed between the same time periods; Brent oil showed a 52% increase in average prices between the same time periods.

Figure 22 indicates that LNG prices are consistently lower than HFO, MGO and Brent oil prices, although there are a few months in which LNG prices briefly 'spike' above HFO prices. This conclusion is also valid if fuel prices are considered on an energy equivalence basis³⁵.

LNG prices also showed significant volatility during the period, especially from mid-2004 onwards. However, it should be noted that LNG prices have, on average, been slightly less volatile than the other shown fuels in Figure 22. The average monthly price of LNG in the January 2004 – December 2005 period was only 0.5 % lower than during the January 2009 – December 2010 period.³⁶

It is also interesting to note that during the period from January 2001 to around January 2005 LNG prices showed markedly lower levels of month-to-month variation compared to the month-to-month price variation seen from around January 2005 onwards.

5.1.2 Price Relations

Given the strong correlation between the fuel prices, bunker fuel prices may be effectively estimated for many fuels based on Brent oil price forecasts developed by well respected institutes. The degree of correlation between the prices of HFO and Brent oil price was calculated to be 0.97. The degree of correlation between monthly HFO, MGO and LNG prices during the period for which historical price data was available has also been analysed (correlation values are shown in Table 9). To summarise, relatively strong positive correlations have been found in the analyses of HFO against MGO (0.92), and MGO against LNG (0.88). A low degree of correlation (0.68) between LNG and HFO prices was observed.

³⁵ When discussing relative fuel prices below, prices are related to each other on an energy basis (per GJ). This is done since one tonne of LNG contains much more energy than one tonne of HFO or MGO. From a ship fuel perspective, one GJ HFO is (more or less) equivalent with one GJ LNG or MGO whereas one tonne HFO is not replaced by one tonne of LNG or MGO.

³⁶ Given the fact that LNG prices have historically been derived through long-term purchase and sales contracts (wherein price data is typically not publicly observable), it is difficult to obtain a long-term historical price series for LNG at a specific location within the project SECA region. For the purposes of this analysis, historical LNG price data (January 2001 to August 2011) published by the International Energy Agency were used. This data series specifies the monthly LNG price as an average of LNG prices at all points of LNG purchase/sale in Belgium.

Table 9 Degree of correlation between fuel prices of HFO, MGO and LNG.

Fuel 1	Fuel 2	Level of correlation (0-1)
HFO	MGO	0.92
HFO	LNG	0.68
LNG	MGO	0.88

Source: AF analysis, 2012

Since the fuel prices correlate – and since relative prices are decisively important in the analysis of shipowners’ compliance strategies – it is fruitful to study how the LNG and MGO prices relative to HFO have developed during the studied period, see Figure 23 MGO price relative to HFO and LNG price relative to HFO below.

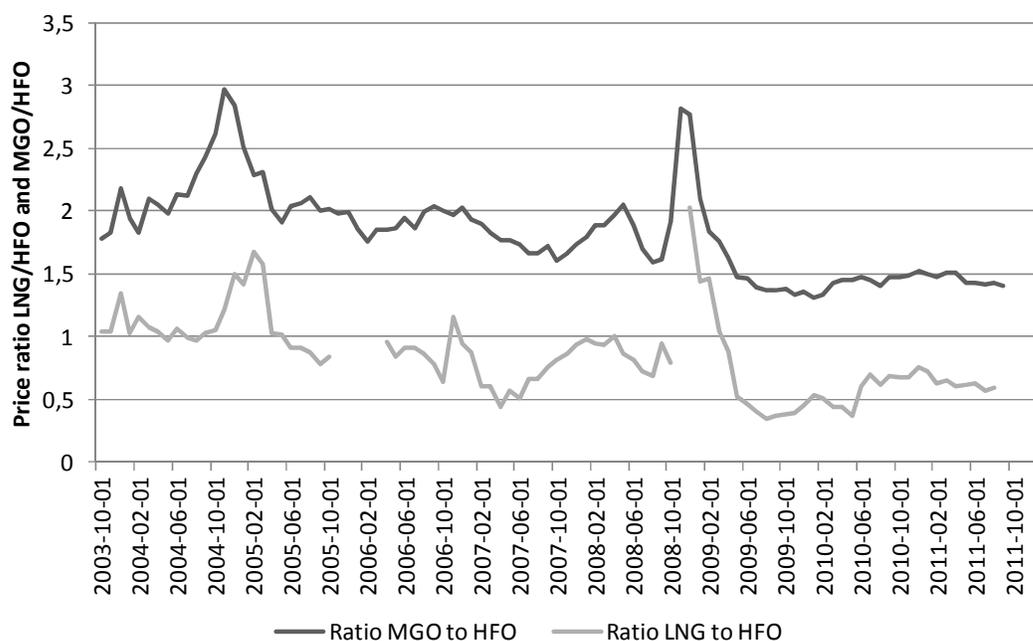


Figure 23 MGO price relative to HFO and LNG price relative to HFO.

Prices are at import hub and based on prices per GJ.

Source: AF analysis, 2012

5.2 Forecasting Fuel Prices

Predicting the near- to medium-term future development of bunker fuel prices is not straightforward, but some key factors which are likely to influence price developments can be identified.

The price of bunker fuels with low sulphur content can be expected to rise (while all other factors remain relatively similar across fuel types). This price increase will be driven by heightened demand for low-sulphur fuels as increasingly stringent sulphur emission controls are put in place, such as SECA. Demand for bunker fuels with high sulphur contents will decrease.

Bunker fuel prices are also likely to be influenced by the following factors:

- The prevailing levels of supply, and hence prices, of competing fuels for shipping, in particular gas, LNG and crude oil;³⁷
- The rate / proportion of shipowners who make a fuel switch from bunker fuels to alternative fuel sources, including LNG;
- Overall demand for shipping activities, regionally and globally; and
- The timing (and level of success) of attempts to equilibrate bunker fuel refining capacity and demand.³⁸

In this study, import price forecasts for HFO, MGO and LNG have been developed. The methodology used and the resulting price forecasts are described in this section.

5.2.1 The Base for the Crude Oil Price Forecast

For the purpose of forecasting future LNG and oil prices, a survey of available long-term forecasts produced by reputable institutes was undertaken. Specifically, the analysis resulting in price forecasts was based on the 'Fossil Fuel Price Forecast' produced by the UK Department for Energy and Climate Change (DECC), updated in June 2010. The price forecasts made by the US Energy Information Administration (EIA), published in the Administration's Energy Outlook 2011 was used to benchmark and quality-check the forecast based on the DECC forecast. Both of the above price forecasts are highly trusted by industry players in the oil and gas sectors.

5.2.2 Estimating Future Crude Oil Fuel Prices and HFO Prices

In order to forecast crude oil prices up to 2030, the DECC price forecast's Central scenario was used³⁹. Specifically, the forecasted rates of growth in oil prices were calculated. Then the average oil prices in 2010 and up to July 2011 were calculated, and the predicted annual rates of price growth in each year up to 2030 were applied on that average price.

In this way, a base scenario for the future crude oil price was developed. For that scenario, DECC assumes that the global economic recession eases off but depressed demand keeps prices low in the short term. In the medium term, global economic growth picks up and pushes strong demand for energy in the medium term to 2030. Investment is made and supply is sufficient to meet demand. To forecast HFO prices, a regression analysis was applied using historical data of crude oil prices and HFO prices as shown in Figure 22 above. That analysis resulted in an average future HFO import price of 520 €/tonne (715 \$/tonne).

³⁷ United States Environmental Protection Agency, 2008. Global trade and fuels assessment – future trends and effects of requiring clean fuels in the energy sector. EPA420-R-08-021.

³⁸ In Europe, this is likely to be related to the rate of closure of some refining capacity, due to the excess in capacity in that region. In the region east of Suez, there is a requirement to upgrade refining capacity.

³⁹ DECC also presents a Low and a High scenario, but since this report's analyses are based on MGO/LNG prices *relative* HFO, only one HFO price scenarios is needed.

5.2.3 Estimating Future MGO Prices

The forecast of relative MGO prices was based on the historically strong correlation between MGO and HFO prices as shown above in Figure 23 MGO price relative to HFO and LNG price relative to HFO.. Based on that figure two relative price levels for the future were assumed; 1.6 and 2.2 respectively. The latter relative price level represents the assessment that MGO prices will increase significantly (due to the above-mentioned judgment that low-sulphur fuel will become more expensive), to a level which has only seldom been reached during the last ten years. The assumed price level for MGO relative HFO of 1.6 represents the view that it will be only moderate increases in relative MGO price compared to the relative price level during 2010 to 2011.

5.2.4 Estimating Future LNG prices

Figure 23 above can also be used for creating scenarios regarding future LNG prices. Based on the figure three levels of future LNG prices were estimated: 0.5, 0.7 and 0.9. These levels also correspond very well to DECC's three LNG price scenarios, named Low, Central and High, which DECC summarizes like this:

Low case

New production comes on-stream and combined with falling demand, results in a significant price fall. There is a glut of LNG supply in the Atlantic basin as the United States approaches self-sufficiency and more United States production comes on-stream. It is assumed that the European market is liberalized which means that the oil-gas link no longer holds.

Central case

Prices are expected to weaken in the short term due to low global demand and a glut of LNG. In the medium term the link between oil and gas prices is expected to remain in place. Continued use of oil-linked contracts is driven by a number of factors such as the greater depth of the traded oil market enabling better hedging of risks. Timely investment enables supply to remain sufficient to meet growing demand. LNG trading, capacity and storage capacity increase.

High case

The desire of buyers to ensure security of supply means that long-term contracts remain in place. There is limited potential for substitution in energy generation and in energy-intensive industries, meaning that demand remains strong despite high prices. Investments in gas production and LNG are not made in a timely fashion and are insufficient to meet continued growth in demand.

5.2.5 Results – Price Scenarios

As explained above, the MGO and LNG prices were derived from a forecasted HFO price of 520 €/tonne using assessments of relative MGO and LNG prices. Table 10 below summarizes the relative price levels chosen and the resulting absolute prices of MGO and LNG. Later in the report, the so-called Scenario 2 is used as base line, e.g. sensitivity analysis regarding pay-back time is based on that scenario.

Table 10 Price levels relative HFO for MGO and LNG as well as corresponding fuel prices in €/tonne fud for the six different price scenarios.

Scenario name	MGO price level	Relative MGO price	Absolute MGO price (€/tonne)	LNG price level	Relative LNG price	Absolute LNG price (€/tonne)
1. LowLNG_CentralMGO	Central	1.6	875	Low	0.5	315
2. CentralLNG_CentralMGO	Central	1.6	875	Central	0.7	440
3. HighLNG_CentralMGO	Central	1.6	875	High	0.9	570
4. LowLNG_HighMGO	High	2.2	1200	Low	0.5	315
5. CentralLNG_HighMGO	High	2.2	1200	Central	0.7	440
6. HighLNG_HighMGO	High	2.2	1200	High	0.9	570

Import prices, based on a forecasted HFO price of 520 €/tonne. The relative prices are expressed on an energy basis (i.e. €/GJ MGO divided by €/GJ HFO or €/GJ LNG divided by €/GJ HFO).

5.3 Some Considerations Regarding The LNG Market

5.3.1 LNG Price Driving Factors

The various factors that impact LNG prices and shape the trends of LNG price developments have been analysed. In Table 11 these driving factors are specified and the level of significance as regards impact on LNG prices is assessed for each factor. A brief overview of how some of the driving factors can shape LNG prices is also given.

Table 11 Driving factors of LNG prices in the area studied

Very important	Important	Fairly important
Supply	Changes in the energy fuel merit order ⁴⁰ to favour low-carbon energy generation	Delivery and shipping costs
Demand	Major events within the energy sector (e.g. the Fukushima nuclear disaster in Japan)	Technology development and improvement
Oil-gas price link	General economic activity (nationally/internationally)	Transport distance
Short-term versus long-term pricing	Price speculation	Weather and climatic effects
Supply contract negotiations		

⁴⁰ The Merit Order is the order in which different energy generation technologies will be called on / chosen to generate. The order of selection is typically related to each generation fuel / technology's short-run marginal costs of production. However, in more recent times the Merit Order in a number of jurisdictions has been adapted to ensure that low-carbon energy generation technologies are favoured in terms of being selected to run.

Short- versus Long-term Pricing

Short-term demand can be quite inelastic, and this has considerable implications for LNG prices if short-term pricing is predominant within a market. In other words, short-term pricing can result in large variations in LNG prices over relatively short periods.

Long-term pricing approaches would be expected to ensure that changes in LNG prices are less volatile and the widespread use of 'take-or-pay' clauses in long-term purchase agreements further ensures that long-term pricing approaches result in more uniform LNG unit purchase prices. This subject is further discussed below in Section 5.3.2 where the continued dominance of long term pricing despite increasing use of short-term pricing is described. Most trading in short term markets is nonetheless tied to longer-term sales contracts and agreements, and hence an open and transparent market (which would be associated generally with short-term pricing) has not yet taken root in LNG markets.

Supply Contract Negotiations

Given that most LNG trading today remains tied to long-term supply agreements, the agreement reached by the supplier and purchaser in setting the purchase price, will have a substantial impact on the overall amount paid for LNG over the long term. Whilst this is self-evident, it is important to note that, as in many markets, different industry players have different potentials and abilities to negotiate supply contracts. The outcome is that some players can achieve supply contract conditions that are significantly more favourable than those that can be achieved by other industry players.

In general, if an industry player holds a significant market share, has a large purchase demand, and/or requires a purchase agreement covering a relatively long period, they should be in a position to negotiate more favourable supply contract terms compared to smaller, less established or powerful organisations that demand supply contracts over shorter periods.

Merit Order

The relative demand for LNG at any one time will be shaped by its place in the overall merit order (in other words, the attractiveness of LNG compared to other energy fuels at a particular time – and not only in the maritime sector). LNG's place in the merit order will be shaped by for example price (compared to other fuels) as well as the level of fiscal (support) framework for LNG and other government policies to promote particular fuel types. In countries with effective policies for encouraging/increasing the use of low-carbon energy generation, investing in LNG infrastructure would be expected to be a more attractive option (all other factors remaining equal) compared to investing in infrastructure for carbon-intensive fuels (such as coal).

Major Events in the Energy Sector

The level of demand for LNG, which has implications for its price, may be significantly impacted by major events with local, national, regional and/or international implications.

The disaster at the Fukushima nuclear power plant in Japan in early 2011 strongly influenced public and government opinion in many nations around the world concerning future use of nuclear power. In this

instance and in general terms, there is a reduced appetite for future use of nuclear power as a consequence of the disaster. Germany, for example, announced that it will completely phase out nuclear power by 2022.⁴¹ This effectively means that other energy sources will need to be used to fill the gap in the energy supply balance that would have been met by nuclear power generation. The exact impact on demand for LNG as a consequence of major events in the sector will vary from country to country, but given the overall increase in demand for LNG and its various attributes, it seems likely that future demand for LNG will increase as a result of this particular event.

Major events in the energy sector will naturally not always result in increased demand for LNG. In some cases, events will tend to result in increased demand for other energy fuel / generation types; for example, major improvements in the cost profiles of renewable energy generation technologies would not be expected to increase overall demand for LNG.

Speculation on LNG Prices

Speculators make high-risk trades in LNG volumes, speculating on market price movements, in order to generate profits from variations in LNG market prices. Excessive speculation has the potential to distort market prices significantly, and can therefore drive up LNG prices to levels that do not reflect the real value of the LNG. Given the need to protect consumers from excessively-high fuel prices, regulatory authorities undertake a role in ensuring that price speculation activities do not push fuel prices up to levels that are unaffordable for consumers.

Technology Development and Improvement

Technologies in the ship transport sector are developing fast. Recent years have seen a clearly observable trend towards significantly larger LNG carriers, reducing transport costs per tonne LNG everything else being equal.

Delivery and Shipping Costs

The cost of shipping LNG naturally affects the overall LNG price. Any variations in shipping costs could therefore generate an (albeit relatively minor) impact on the price of LNG.

Whilst LNG tankers have been operating for decades and LNG shipping technology is well established, the costs of shipping may change in the future. This could be due to changes in shipping charter rates, or economy of scale benefits in the manufacture of ships.

5.3.2 LNG Contracts

There is a growing tendency for LNG producers to opt for self-contracting of LNG. Whilst the proportion of LNG trade related to short-term or spot pricing has increased significantly over the past twenty years, the majority of short-term trades remain linked to longer-term self-contracting supply agreements. This means that prices are still not fully transparent.

⁴¹ BBC News, 2011. Germany: Nuclear power plants to close by 2022. Received from <http://www.bbc.co.uk/news/world-europe-13592208>

Market Players

The key LNG market players are today exposed to a higher degree of competition within the LNG markets than was previously the case. This competition has been mainly driven by the growth in the use of short-term contracting, increasing flexibility in contract agreements and some growth in international trade of LNG.

Industry players are increasingly becoming engaged in all stages of the LNG value chain, making the market more vertically-integrated. There has also been a noticeable shift towards the domination of the market by a small number of large (typically well-established and international) industry players.

Self-Contracting in the LNG Market

Self-contracting is the term used to describe when LNG producers sell LNG volumes to downstream organizations, which are their own marketing arms, for onward secondary trading.⁴² There is a growing trend for industry players to use short-term (i.e. less than four years) LNG supply contracts; this has to some extent been driven by the increasing use of self-contracting in the LNG market. Self-contracting has proliferated in the LNG market for two main reasons:

- It can provide long-term security of off-take to liquefaction projects;
- An LNG marketer can maintain the option of selling LNG volumes on the spot market, if this option is economically attractive.

If a market player invests in a portfolio of upstream and downstream positions (and uncommitted ships) they can decide where to send LNG on a short-term basis and take advantage of favourable price terms.⁴³ For example, Total has built up its repertoire of LNG export positions in each of the three exporting regions as well as developing its import positions in France, Mexico and India.

Self-contracting in LNG markets tends to result in greater volumes and more flexibility in LNG trading. Short-term or spot agreements represent around one fifth of all LNG trade deals at the present time (see the figure below). This is more than double the proportion of total LNG deals which were short-term or spot deals during the period between 1990 and 2000 (equivalent to between 4% and 9% of all agreements), see Figure 24 below. The reduction of long-term contract periods, as well as the willingness of companies⁴⁴ to take part in projects not covered by fixed long-term contracts, is also increasing the share of flexible volumes.⁴⁵

⁴² <http://www.risk.net/energy-risk/feature/1523343/lng-pricing-moving-forward>.

⁴³ BP group, 2010.

⁴⁴ As an example, within the Bonny Island LNG project in Nigeria, the three initial project trains were assigned and committed to the more traditional contract format of long-term take-or-pay agreements which were concluded between the venture and European buyers. Conversely, for trains 4 and 5 of the project, both Shell and Total (which both hold equity shares in the project) self-contracted some volumes of LNG. In other words, whilst trains 4 and 5 of the Bonny Island project were not covered by fixed long-term contracts, both Shell and Total participated in the project.

⁴⁵ Ruester, 2010. Resource Markets WP-RM-19. Recent dynamics in the global liquefied natural gas industry.

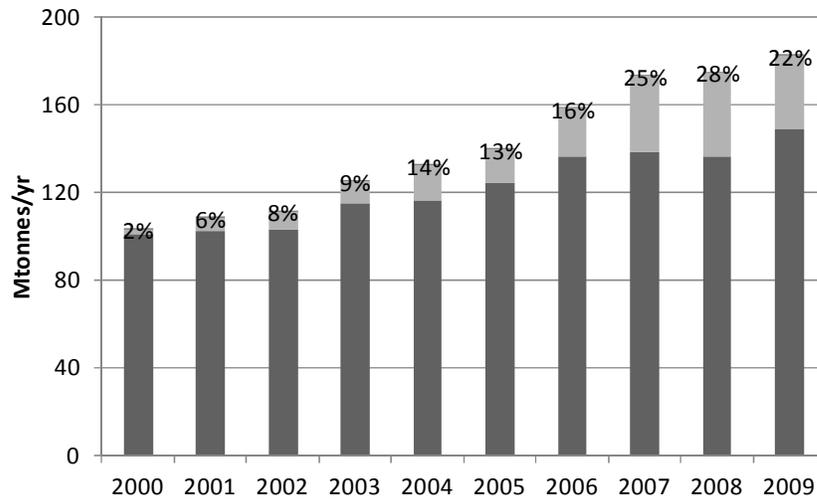


Figure 24 Growth of short-term LNG trades as a proportion of overall LNG trades during the period 2000 to 2009.

Source: AFinterna analysis, 2011, based on data from BP group, 2010.

However, in reality the majority of spot price deals and agreements today are still linked to long-term contracts (only 5% of spot deals are not linked to long-term contracts, or self-contracting). In other words, whilst there is a larger volume of LNG trading on spot prices, the majority of these prices are not set in a transparent way. That is, the liquidity of LNG markets is not improved by self-contracting.

Liquidity in the LNG Market

Market liquidity is a term used to describe the ease with which an asset can be bought and sold within a market without affecting the asset's price. Markets with high levels of liquidity are generally characterised by high levels of trading activity and multiple offers/bids for the purchase of assets. Conversely, a market with a very low level of liquidity is characterised by trades which take place mainly through bilateral purchase / sales contracts.

Traditionally the LNG market has been characterised by bilateral, point-to-point, long-term contracts, which make the market rather inflexible, with just a small portion of LNG volumes available for short-term, flexible deals. As a consequence, the above-mentioned ease is normally represented by the share of short-term and spot deals over the total volumes traded. This share has markedly increased in recent years (shown in Figure 24 above), implying that the LNG market has become significantly more liquid.

The increased flexibility and liquidity in today's LNG market compared to early LNG markets is a result of a number of factors, including:

- Changes within the structures of long-term contracts;⁴⁶
- The growth of the short-term market, and a reduction in the volume of long-term contracts;

⁴⁶ For example, long term contracts are increasingly accompanied by flexible shorter-term agreements, strategic partnerships between, and vertical integration of market players.

- A reduction in average contracted volumes;
- A reduction in take-or-pay requirements;⁴⁷
- The growing inclusion of free on-board agreements allowing cargo diversions.⁴⁸

The particular conditions for the sale of LNG between a seller and buyer are set out within a sales contract. As described above, the characteristics of LNG contracts have changed markedly in recent years, with a noticeable impact on LNG market flexibility and liquidity. Some of the main components of current typical LNG contracts (i.e. contracts which increase the level of market flexibility and liquidity) include the use of:

- Take or pay obligations (which can be monthly or yearly);
- Slots delivery programme;⁴⁹
- Carry-forward, build-up quantities;⁵⁰
- Quantities / volume of trade;
- Other clauses (e.g. force majeure, liabilities, and penalties).

The relative ease with which LNG can be transported over long and short distances and the technology of natural gas liquefaction enable gas to be traded between regions that until recently were essentially isolated markets. The gas markets in different regions of the world can today be regarded as being constituents of a global gas market, because price signals are efficiently transmitted from one region to another.

While prices in the Asia Pacific are indexed to crude oil prices, gas pricing in the USA is driven by supply and demand and further set by gas-to-gas competition. In Europe, LNG is priced relative to pipeline gas, typically following the lead of competing fuels such as crude oil or other oil products, even though its indexing may also include elements of coal, electricity or inflation indexation. LNG-delivery prices are typically based on Henry Hub⁵¹ natural gas prices and adjusted for local differences between the LNG delivery point and the Henry Hub gas price.

⁴⁷ Take or pay contracts are commonly used within long-term LNG and natural gas sales contracts. They specify that the buyer must pay for a contractually-determined minimum volume, even if delivery of the gas is not taken. The purpose of take or pay contracts are to mitigate (either fully or partially) the volume risk on the seller. If there is a 100% take or pay obligation, it means the buyer is obliged to pay for 100% of the contracted volume (regardless of whether that volume is taken), whereas with a take or pay obligation of 60% a buyer is only obliged to pay for 60% of the contracted volume. In most contracts take or pay levels are typically set at 90% of the total contracted volume. As an example, if the take or pay level is set at 90% of the total contracted volume and a buyer only accepts delivery of 75% of the total contracted volume, the buyer must pay for this 75% volume at the rate agreed within the contract (typically set by a detailed purchase price formula). The buyer is also obliged to pay for the 'missing' 15% of the total contract volume (i.e. the difference between the contracted and the accepted volumes); normally, this 15% volume would be paid for at a lower payment rate (i.e. a lower unit price per MMBtu) than the rate used within the contract. A further component of take or pay contracts are 'make up rights'. In the example outlined above, make up rights would allow the buyer to receive the 15% contracted volume at a later date by paying the remainder of the price for the gas (i.e. paying the remaining amount at a rate which is 20% of the standard rate). Similarly, 'carry forward' rights within take or pay agreements allow that if a take or pay requirement has been exceeded by a buyer during a given time period, the excess can be offset within the obligation of the next period.

⁴⁸ Cargo Diversion rights allow an LNG buyer to divert cargoes of LNG to other destinations. These rights are attractive to LNG buyers because they give greater flexibility and can lower a buyer's total costs. A buyer might opt to divert a cargo if, for example, it was experiencing a technical issue or financial constraint at a particular terminal,⁴⁸ or in order to manage a cargo portfolio across a number of LNG terminals.

⁴⁹ A 'slot delivery' programme specifies the different time periods in which a ship is permitted to enter a port, undertake LNG import / export activities, and then leave the port. The slots delivery programme allows industry players to coordinate their activities with users of a port and helps to avoid a port becoming congested.

⁵⁰ A carry-forward is a provision within a long-term take-or-pay contract, wherein a buyer that purchases more than its contracted volume in a particular year can offset this against a volume undertake in subsequent years without sanction or punishment

⁵¹ Henry Hub is a location in the state of Louisiana, United States – an intersection point on the gas pipeline network. Henry Hub is the pricing point for natural gas futures which are traded on the New York Stock Exchange. Prices at Henry Hub are considered to be the primary price of natural gas in the United States' gas market; this is because Henry Hub gas prices show strong correlations with the price of gas traded in the unregulated United States gas market.



6 LNG Supply Chain

This chapter illustrates the LNG supply chain, which is indispensable to the availability of LNG as a marine bunker fuel. Up-stream infrastructure and related facilities are discussed in the first subchapter, followed by alternatives to the downstream maritime LNG supply chain. Bunkering solutions are reviewed from operational and logistics perspectives and critical parameters that determine bunkering solutions and the suitability of facilities for terminals that provide LNG bunkering are investigated. This is further illustrated by three port cases that demonstrate suitable infrastructure needs and bunkering solutions at different conditions.

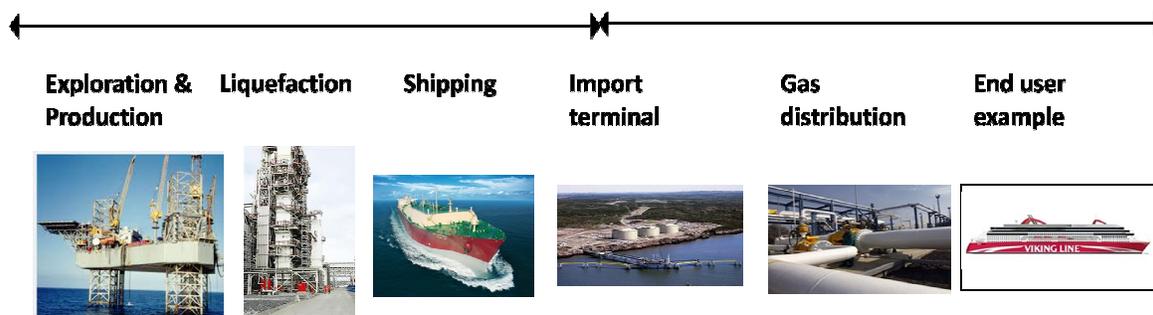


Figure 25 LNG Supply Chain.

6.1 Up-stream LNG Supply Chain in Northern Europe

6.1.1 Production Plants in SECA and Adjacent Areas

Most of the world's LNG production capacity is located outside Europe and LNG is shipped to Europe to large import terminals. However, there are nine production plants in Northern Europe today, five of which are located in Norway, one in Sköldvik in Finland, and three in the vicinity of St Petersburg in Russia. All production plants, except for Melkøya in Norway, are small-scale-plants, producing in the range of 2,500 to 300,000 tons of LNG a year. In Melkøya, 4.3 million tonnes of LNG are produced a year. The annual total liquefaction capacity in the region is 4.8 million tonnes.

Production capacity is expected to increase within a few years. For example, Gazprom has plans to establish a large-scale LNG plant at Shtokman-Teriberka, about 100 kilometres north-east of Murmansk, with a production capacity of 7.5 million tonnes LNG a year. The plant is expected to come into operation in 2017/2018.

There are also plans for instance in Kaliningrad and Vyborg or Greifswald for small- to mid-scale liquefaction plants. The main purpose of these plans will to supply the maritime sector with LNG.

All in all, the production capacity is expected to increase from 4.8 million tonnes a year to 13.5 million tonnes when the Shtokman-Teriberka plant becomes operational.

All existing, planned and proposed plants⁵² are listed in Appendix 4.

6.1.2 Import Terminals

Today there are import terminals in Belgium, the Netherlands, the United Kingdom, Sweden and Norway. The LNG infrastructure of Norway is different from the other countries in that there are already more than 40 existing small-scale LNG terminals. Most of the Norwegian terminals have a storage capacity of less than 1,000 m³ and altogether they account for less than 1 % of the total storage capacity in the region. The total LNG storage capacity in the region was approximately 2 million m³ in 2011.

Storage capacity in Northern Europe is expected to increase in the near future, due to expectations of a growing LNG demand. There are plans to establish an additional 15 terminals in Poland, Estonia, Lithuania, Latvia, Sweden, Finland, Germany, France and the United Kingdom in the near future, Figure 26.

Figure 26 below shows the location of existing, planned and proposed LNG terminals and production plants. The details of each LNG facility shown on the map below are listed in tables in Appendix 4. Discussions are also on-going about establishing LNG terminals at several other locations in the area, for example in Helsingborg, Sundsvall (Sweden), Hirtshals (Denmark), Oslo, Mongstad, Helgelandsbase (Norway) and Silae (Estland). Furthermore, discussions are on-going of establishing small-scale LNG bunker facilities in the Netherlands⁵³. These projects are not shown on the map.

⁵² To the knowledge of the authors.

⁵³ Gasnor, November, 2011.

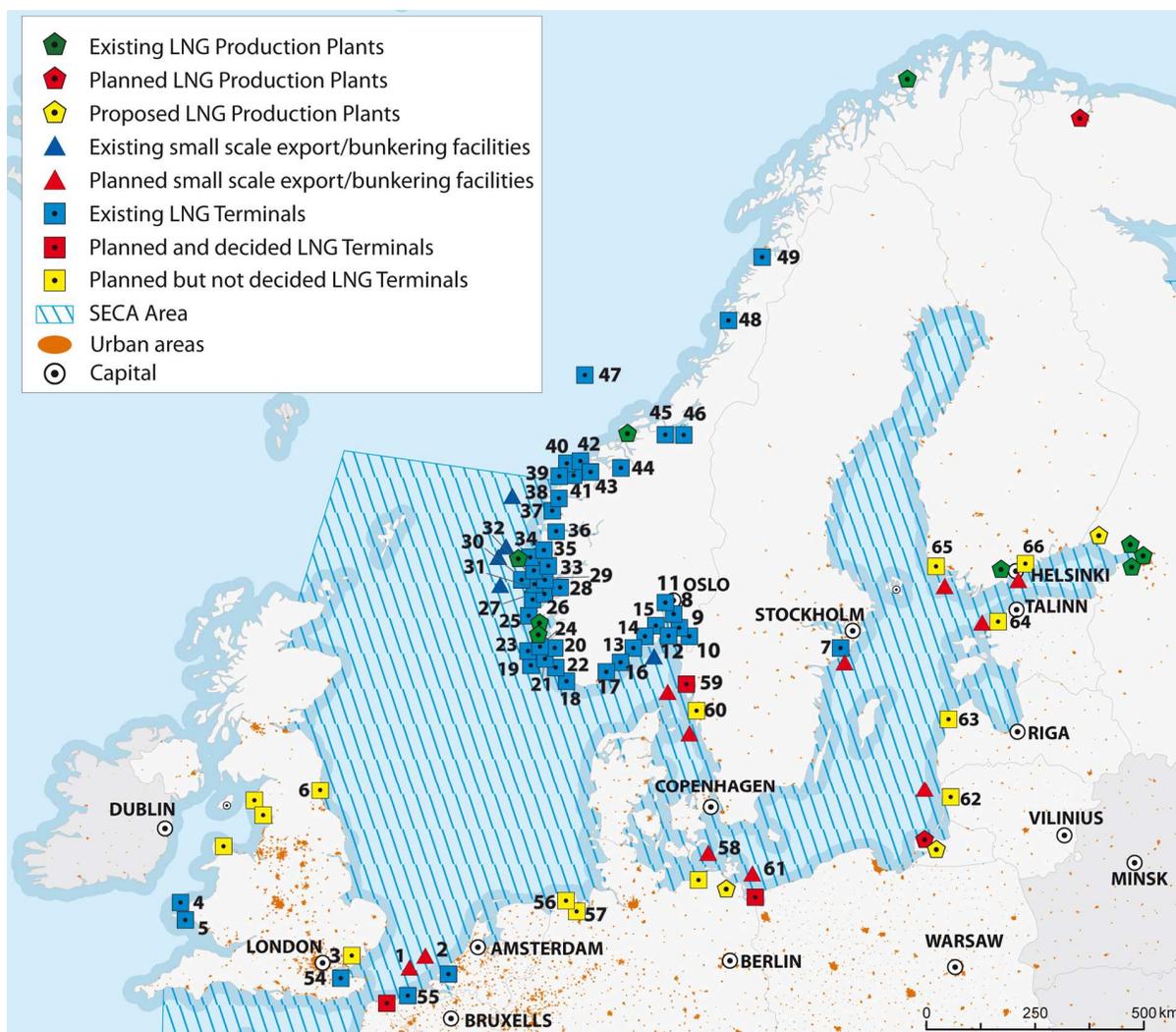


Figure 26 Existing and planned production plants and LNG terminals in SECA.

Note: Gazprom's proposed production plants will be either in Vyborg or Greifswald.

Source: Gas Infrastructure Europe, 2011; ÅF, 2011; Gasnor, Gazprom.

6.1.3 Location of Existing LNG Terminal Infrastructure

The locations of the existing LNG terminal infrastructure and most of the planned infrastructure in Europe are strongly correlated to extensions of the natural gas network. The main task of the majority of the existing and planned LNG import terminals in Europe is to deliver natural gas to the network. LNG importation implies a possibility for the countries in Northern Europe to meet the gas demand, in times when the indigenous natural gas resources in northern Europe are in decline, to improve the security of supply and to diversify the gas supply. For the countries in the East Baltic Sea region, all of whom today are dependent on gas supply from Russia, diversified supply is a prioritized question. Therefore, the establishment of LNG import terminals is an interesting alternative in these countries.

However, the LNG terminals in Norway, Nynäshamn (Sweden) and the planned terminal in Turku (Finland) and Lysekil (Sweden) are exceptions from the “normal way” of locating a terminal, i.e. close to the natural

gas network. Establishing these terminals implies a possibility to supply industrial customers and the transport sector with natural gas in areas where there are no gas networks.

The development of LNG terminals in Northern Europe shows that there are synergies between the build-up of an LNG terminal infrastructure and industrial use. For instance, the terminal in Nynäshamn, Sweden is located close to the Nynas refinery and the terminal also serves the town gas grid in Stockholm. As for the planning of terminals in Finland, the developers are looking for locations that offer one or several large industrial energy consumers within a radius of 400 km from the planned terminal location. In Swinoujscie, Poland, the planned terminal location is in the immediate vicinity of a power station and a chemical plant. The economies of scale for LNG terminals drive the aim to find synergies between different users of LNG.

6.2 Down-stream LNG Supply Chain

When LNG is used as a fuel for ships or other end users, the supply chain is extended by several steps that take place after the LNG import terminal. Different supply options, from LNG import terminals to ships, are illustrated in Figure 27 and are described below.

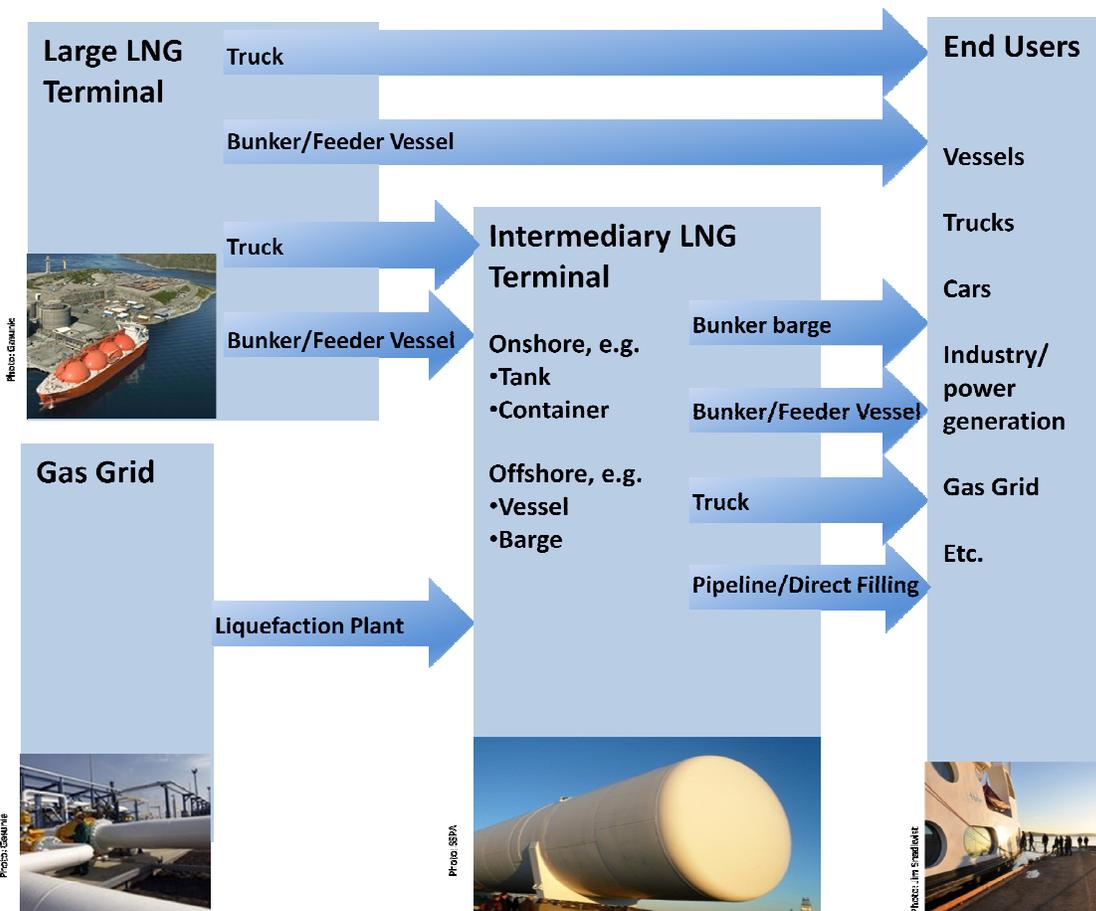


Figure 27 Different pathways for supplying different end-users with LNG fuel.

To develop an infrastructure that supports the use of LNG as a ship fuel, distribution and bunkering concepts, as well as quantities of LNG handled, must be characterised by scales of magnitude different from those used

to describe existing LNG import terminal handling, which is normally large in scale. The feasibility of a maritime LNG supply structure will, to a large extent, concern small and medium large solutions. To facilitate discussion of the results presented in this report, the definitions given in Table 12 are used to characterise what is described as large-scale, medium-scale and small-scale LNG handling. The definition of small-scale (and medium-scale) will also be important for the actors taking part in the development of the emerging infrastructure, as it is among the factors that may potentially affect how regulations are formulated and adopted.

It should be noted that the intermediary terminals could be fed either from the seaside or the landside. When from landside the terminal is completed with a plant for liquefaction of CNG. The principals for bunkering are the same for both cases.

Table 12 Applied definitions of large, medium and small-scale terminals.

Activity/Aspect	Large scale	Medium scale	Small-scale
On shore storage capacity	Import terminal $\geq 100,000 \text{ m}^3$	Intermediary terminal 10,000-100,000 m^3	Intermediary terminal $< 10,000 \text{ m}^3$
Ship size, LNG capacity	LNG carriers 100,000 – 270,000 m^3	LNG feeder vessels 10,000-100,000 m^3	LNG bunker vessels 1,000-10,000 m^3 LNG bunker vessels/barges 200 – 1,000 m^3
Tank trucks			40 – 80 m^3

$\emptyset = \text{diameter}$

While LNG tank trucks are almost always of the same size, approximately 40-80 m^3 , LNG bunker vessels and intermediary LNG tanks can vary considerably in size. LNG bunker vessels may have capacities ranging from 1,000 m^3 to 10,000 m^3 , depending on distance to supply, bunkering location, type of clients served and total bunker volume.

It should be noted that the intermediary terminals could be fed either from the sea side or the land side. When from land side the terminal is completed with a plant for liquefaction of CNG. The principals for bunkering are the same for both cases.

Small-scale liquefaction plants are sometimes advantageous, because the capital investments required to sustain them are reasonable. Furthermore, the compact sizes of these plants enable the production of LNG close to the locations where it will be used. These plants also make it possible for customers without access to natural gas pipelines to be supplied with natural gas. LNG is normally transported from these plants to industries and other customers by LNG trucks or LNG vessels.

6.2.1 Intermediary LNG Terminals

Intermediary LNG terminals may be used if the distance from LNG import terminal plants to end-users is longer than what is economically feasible for bunker vessels or trucks to cover. The range of economically feasible distances is approximately up to 100 nautical miles for bunker vessels, assuming current bunker vessel practices⁵⁴, and 350-600 kilometres for trucks, refer to chapter 9. Longer distances are possible for

larger volumes. Intermediary terminals may also be needed if it is necessary to bunker at faster rates and if it is necessary to bunker to such consumers as harbour tugs, fishing vessels or ferries.

Intermediary terminals can, therefore, vary considerably in size. In full-scale applications, terminals in large ports can be as large as 100,000 m³, while LNG terminals serving small fishing vessels or tugboats through pipelines at bunkering quays may have capacities of as little as 50 m³.

Many existing intermediary terminals are stationary onshore LNG tanks. LNG containers, which are used to transport LNG by railway, sea, river or road, can also be used to store LNG onshore. Furthermore, offshore terminals may serve as intermediary terminals. Offshore terminals may be either vessels or barges. In both cases, bunker vessels and small-scale LNG-fuelled vessels are capable of mooring alongside vessels/barges and LNG bunkers⁵⁵. The advantages of offshore terminals over stationary tanks are lower investment costs and shorter lead times⁵⁶. It can also be easier to find suitable locations for offshore terminals. Another advantage is that they can be moved if required, which means that more flexible solutions can be developed.

6.2.2 Small- and Medium-sized LNG Carriers

Small- and medium-sized LNG carriers are needed when LNG is to be distributed further from large-scale import terminals to intermediary terminals including vessels or barges. There are two categories of small- and medium-sized LNG carriers: LNG bunker vessels and LNG feeder vessels. Furthermore, LNG can be transported by barges, which can be either self-propelled or unpowered.

LNG bunker vessels are smaller than LNG feeder vessels and are easier to manoeuvre in port basins. In general, LNG bunker vessels are approximately 1,000 to 10,000 m³ in size and are used for bunkering receiving vessels either in or out of port. This issue is further discussed in Section 6.3.1, Ship-to-Ship Bunkering (STS). The purposes of feeder vessels are regional distribution of LNG and the bunkering of very large vessels. LNG is loaded at larger import terminals/liquefaction plants and transported to receivers along coastlines. In the Netherlands, development of infrastructure that supports LNG propulsion of barges that travel inland waterways is also in process.⁵⁷ The primary receivers are varying-sized intermediary LNG terminals and large vessels in need of large quantities of LNG as bunker fuel. The size and dimensions of LNG feeder vessels can vary, depending on market demands, depths and other physical limitations of the ports and bunker sites to be used. The typical cargo capacity of LNG feeder vessels is approximately 7,000 to 20,000 m³.

There is only one LNG vessel in the world today that can be described as an LNG bunker vessel, the Pioneer Knutsen. However, the Pioneer Knutsen is mainly used as an LNG feeder vessel, to deliver LNG to very small intermediary terminals along the Norwegian coast. It should be noted that no orders for LNG bunker vessels exist today, but designs have been developed. LNG bunker vessels will be an essential part of the future LNG filling station infrastructure in Northern Europe. The current lack of LNG bunker vessels is an obstacle to bunkering in, e.g., Nynäshamn/Stockholm (Sweden) and will most probably be an obstacle to the bunkering of LNG in other terminals and small-scale jetties to be commissioned in the coming 3-4 years.

⁵⁵ This kind of solution can also be applied to conventional bunkers, Dimethyl ether (DME), methanol etc.

⁵⁶ World LNG Report 2010, International Gas Union, 2010.

⁵⁷ Staatscourant 2011 nr. 3770, Officiële uitgave van het Koninkrijk der Nederlanden. Investeringsimpuls LNG-vulpunten binnenvaart.

There are only slightly more than 20 small-scale LNG vessels in the world. The existing fleet is listed in Appendix 4. The number of vessels is increasing. The Norgas fleet of LNG carriers can be seen as an especially vital addition to the small- to mid-size LNG fleet in Northern Europe.

6.2.3 LNG Trucks for Regional Distribution

Regional distribution of LNG is carried out by heavy-duty trucks that serve, for example, nearby industries, other ports in given regions and transportation within ports. LNG trucks are also used to transport LNG from small-scale liquefaction plants to customers who are not connected to gas networks. Examples of countries where LNG is distributed by truck are Norway, Sweden, Finland, Belgium, Germany, the Netherlands, Poland, Spain, Turkey and Russia. LNG terminals that distribute LNG regionally by truck are equipped with loading and unloading facilities. Flexible hoses are used to transfer LNG between truck and terminal. Truck capacities vary from 40 to 80 m³ of LNG.

6.3 Bunkering Solutions

In this section three types of bunkering solutions analyzed are (see Figure 28):

- Ship-to-ship bunkering (STS), at quay or at sea;
- Tank truck-to-ship bunkering (TTS);
- LNG intermediary terminal-to-ship via pipeline (TPS).

Further, the possibility of using containerised solutions, wherein entire tanks/containers are replaceable, is also briefly described.

Many factors need to be taken into account when deciding on suitable bunkering solutions – for example, distance, traffic intensity, volume, frequency, safety, vicinity to other LNG bunkering ports and land-based demand.

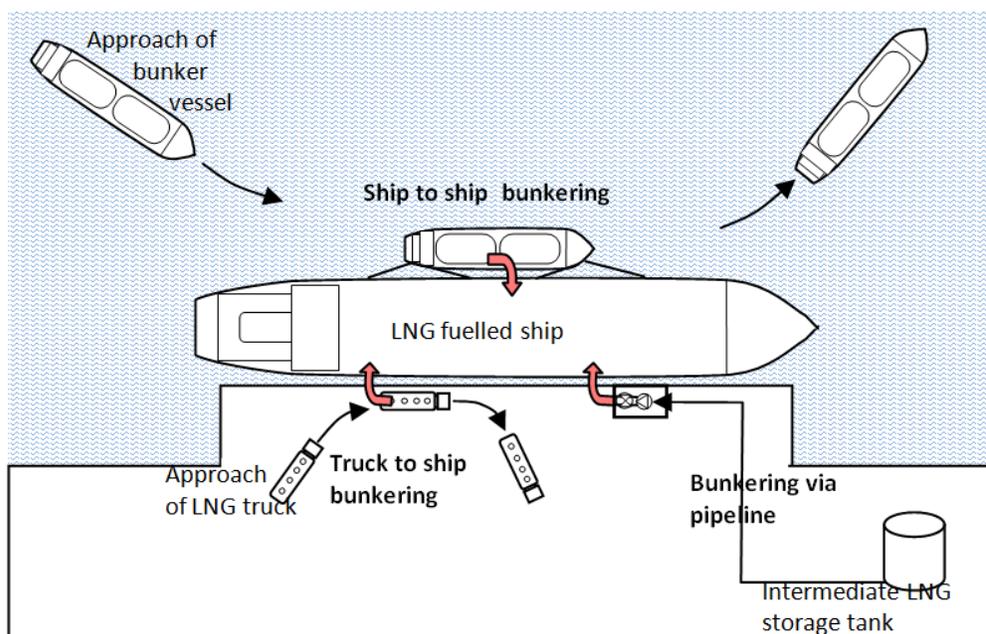


Figure 28 Three types of bunkering solutions.

6.3.1 Ship-to-ship (STS) Bunkering

Ship-to-ship operations may be performed alongside quays, but it is also possible to bunker at anchor or at sea during running. However, the feasibility of the latter is restricted by heavy weather, including strong winds, waves, visibility, ice, currents, and tides.

Opportunities for good mooring are to be provided when bunker vessels are moored alongside receiving vessels. The proper fenders and correct qualities and quantities of mooring lines/wires are necessary for STS bunkering. The bunker system also needs to be designed in such a way that it allows safe, efficient movement of both LNG bunker vessels and receiving vessels. The time required to moor LNG bunker vessels needs to be based on the turnaround times of receiving vessels, which have a substantial impact on bunkering operations.

For operational reasons, and from both a practical and a time-efficiency point of view, the quantities of LNG to be delivered by bunker vessels cannot be too small. Volumes not less than approximately 100 m³ are reasonable for these operations. Typical capacities of LNG bunker vessels may range from approximately 1,000 to 10,000 m³. Small vessels or barges can also be used in some ports with capacities of less than 1,000 m³.

Ship-to-ship bunkering is expected to be the major bunkering method for receiving vessels that have bunker volumes of 100 m³. This is mainly due to its high degree of flexibility, which allows all types of vessels to be served both at quay and at sea, but is also due to high loading rates and large possible bunkering volumes.

6.3.2 Tank Truck-to-Ship (TTS) Bunkering

Tank trucks are inexpensive to invest in, compared to other alternatives, and provide a flexible means of bunkering receiving vessels with small LNG bunker volumes. This solution is suitable for small volumes, up to 100-200 m³, of bunker fuel, before another solution must be considered. The upper limit only holds if the turnaround time is long enough for bunkering activities, which require 3-4 truckloads.

Truck capacity varies from 40 to 80 m³ of LNG, depending on tank design and regulations. The maximum capacity allowed varies between countries, due to differences in national transportation and vehicle regulations and road infrastructure.

6.3.3 LNG Terminal-to-ship via Pipeline (TPS)

Pipeline connections from LNG terminals to receiving vessels are a third means of bunkering. The terminal to pipeline solution facilitates tailor-made operations for high loading rates and large volumes, which means that bunker times can be kept short. The pipeline solution is suitable for specialized solutions, e.g., high-frequency liner shipping services with short turnaround times and niche ports with high frequencies of low-volume delivery sizes by, for instance, tugs, utility vessels and fishing boats.

Depending on requirements and logistical options, the sizes of LNG tanks may vary, from very small (20 m³) to very large (100,000 m³).

Berth access and distance between source and receiving vessel are essential factors in the success of pipeline to ship solutions. The main limitations of the solution relate to the challenges associated with long liquid LNG pipelines. For longer distances, it is difficult to fuel LNG directly from LNG terminals, from technical, operational and economic perspectives. This implies that storage tanks must be situated in close proximity to the berths where bunkering operations are performed.

TPS is thus not always possible, due to limited space, in combination with the constraints of safety measures and other on-going terminal activities. The TPS solution also has limitations when it comes to flexibility, since bunkering operations take place in fixed positions. However, it is possible to use different types of barge solutions as intermediary terminals, which makes TPS (in combination with STS) more flexible and may also reduce regulatory limitations and interference with other activities in port areas.

6.3.4 LNG Containers Loaded On Board and Used as Fuel

LNG tank containers loaded on vessels may be used as alternatives to the above-described solutions. LNG tanks are mounted in frames with the dimensions of standard ISO containers, and the required amounts of fuel are achieved by loading sufficient numbers of units on board. This is, to some extent, a solution for container vessels and RoRo vessels where existing container cranes or terminal tractors may be used also for LNG tank containers.

The drawbacks of this solution relate to safety and the fact that storing LNG tank containers on-board reduces loading capacity. It has yet to be determined whether the IGF Code⁵⁸ can allow for such an arrangement and, if so, how such a system should be designed. Due to operational concerns and limited potential for the use of on-board LNG containers in most shipping segments, compared to the other solutions outlined, the storage of LNG tank containers on-board is not analyzed in detail in this report. However, this method might be developed for niche markets in the future. For example, Wärtsilä⁵⁹ is looking into the possibility of using LNG containers that are connected to gas systems on ships via flexible hoses and quick couplings in docking stations.

6.3.5 Types of Bunkering Solutions for Various Vessels

Depending on the particularities and characteristics of receiving vessels, suitable bunkering methods vary. Features that affect the selection of solutions are, for example, sizes and bunkering volumes of receiving vessels, time in port and geographical coverage. In Table 13, possible bunkering solutions for various ship types are shown. “1” is the most suitable LNG bunkering solution, as detailed in the matrix legends below.

⁵⁸ The International Code for Gas Fuelled vessels which is under development by IMO

⁵⁹ Technical specification LNGPac-ISO, Wärtsilä, Internal report, December 2011.

Table 13 Suitable LNG bunkering solutions for various types of vessels.

Type of vessel / Type of bunkering	STS	TTS	TPS
RoPax / RoRo Vessels	1	3	2
Tugboats (vessels occupied in port areas)	3	1	1
Coastal Tankers / Bulk Carriers	1	3	3
Container Feeder Vessels	1	2	2
LNG Feeder Vessels	1	3	1
LNG Bunker Vessels	2	2	1
LNG Tankers (140,000 m ³)	2	3	1
Naval / Coast Guard Vessels	2	1	2
Offshore Supply Vessels	2	1	2
Smaller Passenger Vessels	2	1	1
Larger Fishing Vessels	1	2	1
VLCC (Very Large Crude oil Carrier)	1	3	2

Source: SSPA, FKAB, White Smoke, SMTF(Swedish Marine Technology Forum) (2011).

	Matrix Legend
1	Most suitable LNG bunkering solution
2	Suitable LNG bunkering solution, though not the best
3	Unsuitable LNG bunkering solution for this vessel type

6.3.6 Advantages and Disadvantages of the Different Bunkering Solutions

From logistical and operational perspectives, there are advantages and disadvantages to each of the three bunkering solutions. The most important of these are summarised in Table 14, below.

Table 14 Advantages and disadvantages of the different bunkering solutions, from logistical and operational points of view.

	STS Ship-to-ship	TTS Tank truck-to-ship	TPS Terminal-to-ship via pipeline
Advantages	Flexibility	Flexibility	Availability
	High loading rate	Low costs (investment and operation)	Large bunkering volumes are possible
	Large bunkering volumes are possible		Quick bunkering procedures are possible
	Bunkering at sea (enlarged market)		
Disadvantages	Manoeuvrability in port basins	Small quantities	Fixed to certain quays
	High costs (investments and operations)	Low loading rate	Occupy terminal space

Ship-to-ship bunkering is a flexible solution that allows for high loading rates and volumes but has high investment and operational costs. Operations may be performed in quay, but it is also possible to bunker at anchor or at sea during transport. Manoeuvrability in port may be a problem for ports with limited basins. The tank-to-ship via pipeline solution also allows for quick bunkering of different LNG volumes at high rates and in an efficient manner. However, this method requires a fixed installation that may not be suitable for all receiving vessels. Further, sunk costs that cannot be recovered may be a problem if changes need to be made in terminal. Tank truck bunkering is an inexpensive and flexible solution but is only suitable for smaller LNG volumes.

6.4 Three Port Cases for bunkering of LNG

6.4.1 Introduction

This chapter takes a logistical approach to the distribution of LNG within port areas. The purpose is to present suitable examples for possible levels of investments including storage tanks, berths, jetties, pipelines, bunker vessels, tank trucks and also costs for distributing LNG to receiving vessels for different types of terminals. Quantification of necessary facilities, sizes and numbers of LNG filling tanks, bunker vessels and tank trucks are summarized for three port cases with different types of terminals.

The first case represents a large LNG terminal with import facilities. Case 2 consists of a medium-sized LNG intermediary terminal with potential passing traffic suitable for LNG bunkering. The third case is a small LNG intermediary terminal.

Vessel positions tracking based on AIS data is used to examine the structure of the potential LNG fleet for three existing ports. The number of ship calls for different ship segments and sizes was extracted by using vessel position tracking based on AIS data for 2011. The AIS data is important input to the description of the

scenarios as this gives a good idea of the potential customers operating in the region, as well as size, age, bunker consumption and bunker frequency of their fleet.

Three various types of bunkering solutions are used in the port cases: ship-to-ship (STS), tank truck-to-ship (TTS), and bunkering of ship from the terminal using a pipeline (TPS). There is no contradiction in using more than one method per port. Different bunkering solutions can complement one another if various types of vessels are to be served or if there is peak demand for LNG fuel at a terminal.

6.4.2 Methodology

In order to select appropriate bunkering methods and equipment, a methodology to estimate the need of facilities was developed. The elements are illustrated in Figure 29 below.

First, the expected LNG bunkering volumes for 2020 were estimated in each port using the following data:

- **Expected annual number of calls in 2020:** The number of ship calls, divided by ship segment and size, and using vessel position tracking based on AIS data for 2011, was calculated. Expected growth is 2 % per year between 2011 and 2020;
- **Average bunker delivery size:** The expected tank size of each ship segment was estimated⁶⁰. On average, 80 % of the tank of each receiving vessel is expected to be loaded during bunker operations;
- **Share of fleet that bunkers LNG:** The share of the total fleet that bunkers LNG was calculated, using estimates of retrofit and new building rates for each ship segment until 2020. The methodology used to estimate these rates is outlined in Appendix 2;
- **Share of total calls with bunker operations:** These figures can only be estimated for individual port cases. It is impossible to know exact, correct amounts, as these depend on such factors as market development, prices, competition with bunkering ports, bunkering consumption, ownership, and shipping service networks.

The assumptions are mainly based on information, obtained from different stakeholders, regarding economical and financial aspects as well as technical and operational aspects. Input has also been received from In Kind Contributors and external companies. The results led to a preliminary proposal for port equipment. After a financial analysis and an examination of capacity utilization of the facilities the design was refined.

⁶⁰ The figures were confirmed by Port of Rotterdam.

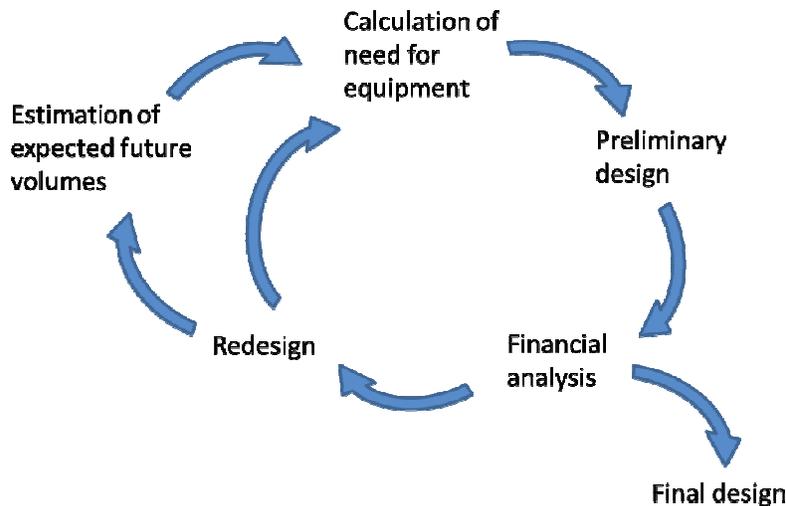


Figure 29 Illustration of the methodology to calculate the need for equipment in an LNG terminal.

Subsequently, the need for suitable facilities was derived from expected LNG volumes, taking into account appropriate bunkering solutions for each ship segment; capacity utilisation of vessels, trucks, pipelines, berths and filling stations; and the number of fillings at each intermediate terminal per year. Potential LNG volumes for each port and suggested solutions are presented in the subchapters below. There is no contradiction in using more than one method per port. Different bunkering solutions can complement one another if different types of vessels are to be served or if there is peak demand for LNG fuel at a terminal.

Vessel Statistics

AIS data for the three port cases is obtained from *vesseltracker.com* for the periods February 11 to March 11, 2011, and between June 11 and July 7, 2011. The periods are expected to present a whole year as they cover both winter and summer months. The collected data is extrapolated to a whole year. Data was examined for three ports, all with different characteristics, in order to obtain a starting point for the generic port cases. The selection of ports was based on:

1. Sizes;
2. Geographical coverage (the Baltic Sea, the North Sea and the English Channel);
3. Ports with and without an LNG import terminal, and;
4. Divers types of vessel traffic (RoRo, ferries, bulk, container and general cargo).

For each studied port the different types of vessels were divided into categories based on sizes. AIS data for the following parameters was obtained for all the ports:

- Name / IMO-number;
- Type of vessel (RoRo, Container vessel, tanker, tugs, fish boat, etc.);
- Length;
- Age;
- Fuel consumption, and;
- Number of port visit.

Assumptions -Fleet

A forecast for 2020 is used, where the expected growth of the total fleet per year is 2 % between 2011 and 2020. Table 15 shows an estimation for how large share of the total fleet that bunkers LNG in 2020, calculated and divided by segment using estimates of retrofit and new building rates⁶¹.

Table 15 Share of LNG fuelled vessels in the fleet divided by segment.

Type of vessel	Share (%)
Small RoRo/RoPax	60 %
Large RoRo/RoPax	16 %
Small tankers	6 %
Large tankers	0 %
VLCC/ULCC	0 %
Small Bulk Carriers	10 %
Large Bulk Carriers	0 %
Small Container Vessel	2 %
Large Container Vessel	0 %
Very Large Container Vessel	0 %
Small General Cargo Vessel	45 %
Large General Cargo Vessel	6 %
Fishing Vessel	17 %
Tugs	0 %
Utility Vessel	31 %

Source: www.portofhirtshals.dk, 2011

Assumptions - Bunker Vessel

Regarding bunker vessel, one is used per receiving vessel, and only 80 % of the receiving vessel's tank is filled up per bunkering activity.

The following assumptions were made for the bunkering time and rate of different ship segments, see Table 16.

⁶¹ The methodology used to estimate these rates is outlined in Appendix A.

Table 16 Bunkering time and rate for the ship segments.

Ship types	Size	Average bunkering time (h)	Bunkering rate m ³ /h
Small RoRo/RoPax	<180m	1	200
Large RoRo/RoPax	>180m	2	400
Small tankers	<25,000 DWT	3	1,500
Large tankers	25,000-200,000 DWT	4	2,000
VLCC/ULCC	>200,000 DWT	6.7	2,000
Small Bulk Carriers	<35,000 DWT	3	1,000
Large Bulk Carriers	>35,000 DWT	4	2,000
Small Container Vessel	<2,000 TEU	3	1,000
Large Container Vessel	2,000-8,000 TEU	4	2,000
Very Large Container Vessel	>8,000 TEU	6.7	2,000
Small General Cargo Vessel	<5,000 DWT	2	1,000
Large General Cargo Vessel	>5,000 DWT	4	1,000
Fishing Vessel	All sizes	0.75	60
Tugs	All sizes	0.75	60
Utility Vessel	All sizes	0.75	60

Loading times of LNG bunker vessels differs depending on the capacity of the loading equipment and the cargo capacity of the LNG bunker vessel. Notice the difference between loading rate and bunkering rate. A small bunker vessel with approximate cargo capacity of 1,000 m³ and with a loading capacity of 500 m³/h, takes about 2 hours to load, while a medium sized bunker vessel, approximate cargo capacity 3-4,000 m³, has a loading time of 3 to 4 hours, given an average loading capacity of 1,000 m³/h. The larger a bunker vessel is the larger is the loading capacity. For a large bunker vessel with a cargo capacity of 7-10,000 m³, the loading capacity is 2,000 m³/h, contributing to a loading time of 3.5-5 hours. LNG Supply Chain.

Time between bunkering operations

The required average time between bunkering activities is: 2.5 hours for a vessel, 1.5 hour for a truck and 1 hour for loading through a pipeline. This includes time for filling up the vessel tanks, time before and after the bunkering of the receiving vessel including transport time of the bunkering unit to the right position, waiting time, etc.

Pipeline

When bunkering via pipeline the bunkering rate is 400 m³/h for normal terminal tanks and 200 m³/h for Type C tanks.

Tank truck

For a tank truck both the loading rate and bunkering rate is 60 m³/h. In average, 85 % of the tank truck is loaded at the filling station.

Intermediary terminal

When an intermediary tank is filled by the LNG feeder vessel 85 % of the intermediary tank is loaded, in average.

Capacity utilisation

It is assumed that the port is open 24 h/day, 7 days a week. For calculation of capacity utilization for vessels and trucks the following times are used:

- time for loading (see rates above),
- time for loading preparation (1h/vehicle and 2h/vessel),
- time for bunkering (see rates above),
- time for bunkering preparation and transport to receiving vessel (see “Time between bunkering” above);

Maintenance of vessels, pipeline and trucks; bunkering at sea that, includes significant longer transport times; or the time the LNG bunker vessel is used as a feeder vessel transporting LNG between terminals are not included in the calculations.

Bunkering solutions for the three cases

Port Case I: An LNG import terminal

- Small RoRo/RoPax use 70 % ship-to-ship bunkering (STS) 30 % truck-to-ship (TTS);
- Utility vessels use 100 % TTS;
- All other vessels use ship-to-ship bunkering.

Port Case II: A medium-sized LNG intermediary terminal with potential passing traffic

- Small RoRo/RoPax use 20 % TTS and 80 % Terminal-to-ship via Pipeline (TPS);
- Large RoRo/RoPax use 50 % STS and 50 % TPS;
- Utility vessels use 100 % TTS;
- All other vessels use ship-to-ship bunkering.

Port Case III: A small LNG intermediary terminal

- Small RoRo/RoPax use 50 % TTS and 50 % TPS;
- All other vessels use a pipeline for bunkering.

6.5 Description of the Three Port Cases

The selection of ports is based on size, geographical coverage, distance to an intermediary terminal and ports with diverse types of vessel traffic, see Table 17.

Table 17 Characteristics of the three ports included in the study.

	Port Case 1	Port Case 2	Port Case 3
Size	Large	Medium	Small
Geographical area	The English Canal	The North Sea	The Baltic Sea
Distance import terminal	Within the terminal	Short distance	Longer distance
Vessel traffic	All types	All types, passing traffic	Mainly RoRo/ferry liners

6.5.1 Port Case I – An LNG Import Terminal

Port Case I represents a large port with an LNG import terminal located somewhere in the English Channel. The port accommodates a large number of large vessels, both liner shipping and tramp shipping, from various vessel segments, including bulk, tank, container, RoRo and general cargo (see Figure 30). The large share of utility vessels is mainly due to dredging activities.

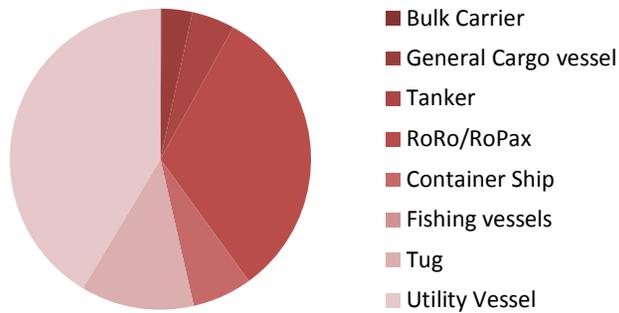


Figure 30 Traffic share (number of calls) in Port Case I.

The total volume of LNG handled in Port Case I in 2020 is anticipated to be approximately 200,000 m³ (see Table 18). This volume is expected to increase a great deal after 2020, due to a general increase in LNG as a bunker fuel and a shift of fuel for the very large tankers and container vessels that the port accommodates. None of these vessels are expected to run on LNG in 2020.

Calculation of annual LNG consumption for Case I is shown in Table 18.

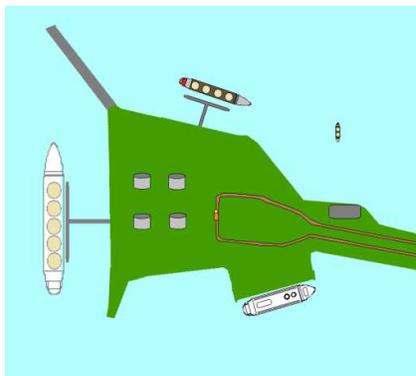
Table 18 Expected annual LNG consumption 2020 for Port Case I.

Ship type	Expected annual No. of calls 2020 (m ³)	Average bunker delivery size (m ³)	Share of fleet that bunker LNG	Share of total calls with LNG bunker operation	No. of LNG bunker operations	Bunkering method	Annual LNG (m ³)
Small RoRo/RoPax	4,346	320	60 %	12 %	313	STS 70 % / TTS 30 %	100,133
Large RoRo/RoPax	2,423	640	16 %	15 %	58	STS	37,222
Small tankers	818	2,400	6 %	12 %	6	STS	14,141
Large tankers	159	8,000	0 %			STS	0
Small Bulk Carriers	24	2,400	10 %	12 %	0,3	STS	686
Small Container Vessel	588	2,400	2 %	12 %	1	STS	3,387
Large Container Vessel	397	8,000	-			STS	0
Very Large Container Vessel	381	16,000	-			STS	0
Small General Cargo Vessel	358	1,600	45 %	12 %	19	STS	30,891
Large General Cargo Vessel	342	3,200	6 %	15 %	3	STS	9,839
Tugs	2,574	36	-			TTS	0
Utility Vessel	8,772	36	31 %	8 %	218	TTS	7,831
	21,182				619		204,131

LNG import terminals that already have large LNG storage tanks located close to berths have greater competitive advantage than ports that need to invest in intermediary terminal tanks. Even if these are designed to distribute LNG to the land side, large investments have already been made. This means that feeder costs and intermediary storage tanks can be avoided. It is therefore suggested, that import tanks may serve the functions of intermediary terminals equipped with the facilities needed to load LNG bunker vessels and LNG tank trucks.

One LNG bunker vessel, with a size of 4,000 m³, is suitable for Port Case I. This vessel could handle the largest bunker volumes, as shown in the column “Average bunker delivery sizes” in Table 18 above. Two tank trucks are necessary to provide bunker fuel to the smallest RoRo vessels and utility vessels. With two trucks, bunkering time could be kept shorter than it would otherwise be with one truck, and receiving vessels could avoid having to wait. Tank trucks only handle smaller volumes but are a flexible and cost-efficient solution. A pipeline could only be used if the distance to tanks were short and if there were enough space. This is probably not often the case for many larger terminals, since most of these are designed to unload large LNG carriers and to provide land-based industries with LNG. Thus, no pipeline is suggested for this port case.

The main characteristics of Port Case I are shown in Figure 31.



Port Case I: Main characteristics of an LNG import terminal

- The import terminal tank is used to provide LNG;
- One bunkering berth;
- One medium-sized bunker vessel (4,000 m³), with 20 % capacity utilization.
- One LNG truck filling station;
- Two tank trucks, 50 m³ each with 19% capacity utilization.

Figure 31 A schematic outline of Port Case I

A critical number of facilities, of a certain size, are necessary even at an early stage and even if capacity utilization is low initially. However, strategies to better match supply and demand by increasing capacity in small steps should be applied when suitable. Even though the capacity utilization (CU) of all facilities and equipment is expected to be relatively low in 2020, the market is expected to grow at a faster rate after 2020. The port accommodates many large vessels, e.g., large tankers, large and very large container vessels. These are not expected to change to LNG before 2020, but between 2020 and 2030, they may contribute substantially to the volumes handled in the import terminal. Thus, it is necessary to have unutilized vessel capacity, vehicles, facilities and berths to handle a future increase in volume.

6.5.2 Port Case II – A Medium-Sized LNG Intermediary Terminal with Potential Passing Traffic

Port Case II is a medium-sized port that accommodates diverse vessel traffic. There is a focus on general cargo, tanker and RoRo shipping, see Figure 32. The port has no import terminal and is located in the North Sea, only a few nautical miles from passing traffic calling neighbouring ports. This means that the number of potential customers is far bigger than the number of customers who actually call at the port. Two-thirds of the calls are vessels that the port accommodates, and 1/3 is passing traffic. Only 1-2 % of passing traffic is expected to bunker at the port or at sea. The column “Share of total calls with LNG bunker operations” in Table 18 above includes both. These volumes are included in the analysis for this port case and in Figure 32.

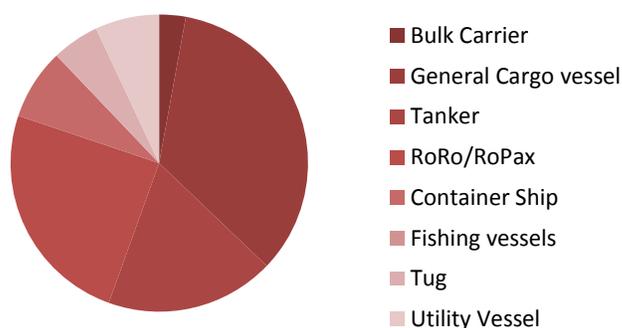


Figure 32 Traffic share (number of calls) in Port Case II.

Total expected volume in 2020, including passing traffic, is approximately 343,000 m³. Calculation of annual LNG consumption for Case 2 is shown in Table 19.

Table 19 Expected annual LNG consumption 2020 for Port Case II.

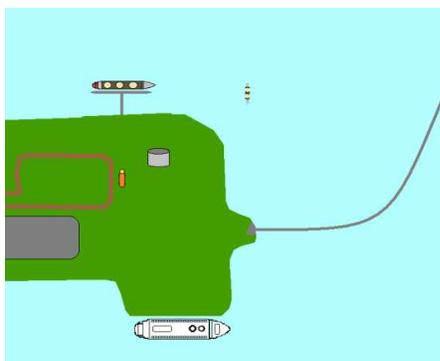
Ship type	Expected annual No. of calls 2020 (m ³)	Average bunker delivery size (m ³)	Share of fleet that bunker LNG	Share of total calls with LNG bunker operation	No. of LNG bunker operations	Bunkering method	Annual LNG (m ³)
Small RoRo/RoPax	1,708	320	60 %	6 %	58	TTS 20 % / ITS 80 %	18,446
Large RoRo/RoPax	3,496	640	16 %	8 %	43	STS 50 % / ITS 50 %	27,743
Small tankers	3,337	2,400	6 %	6 %	12	STS	29,793
Large tankers	516	8,000	0 %			STS	
VLCC/ULCC	0		0 %				
Small Bulk Carriers	127	2,400	10 %	6 %	1	STS	1,892
Large Bulk Carriers	501	8,000	0 %		0	STS	0
Small Container Vessel	1,629	2,400	2 %	6 %	2	STS	4,847
Small General Cargo Vessel	5,284	1,600	45 %	6 %	147	STS	235,859
Large General Cargo Vessel	1,955	3,200	6 %	6 %	7	STS	23,267
Fishing Vessel	0		17 %				
Tugs	1,088	36	0 %				
Utility Vessel	1,502	36	31 %	6 %	29	TTS	1,039
	21,142				300		342,885

To handle the volumes in Port Case II without investing in new tanks within the next few years, a 20,000 m³ tank is suggested. This means that the number of fillings per year will be around 20 (if 85 % of each tank is

loaded, on average). If volumes are significant, all bunker solutions are applicable, as they are complementary. Two bunker vessels are suggested, with sizes of 3,000 m³ and 4,000 m³. To handle the bunker volumes of the largest vessels, an LNG bunker vessel of 4,000 m³ is suitable. This vessel could handle all the large receiving vessels, while a smaller, more flexible bunker vessel could handle the smaller bunker volumes. A smaller vessel would maneuver more easily in the port basin. This setup would also allow for further expansion of the LNG market and would not create queues in port. Only one bunker vessel per receiving vessel is appropriate, if the turnaround time in port is to be kept short for clients.

To transport LNG between the import terminal and the intermediary terminal, the bunker vessel could also act as a feeder vessel. LNG bunker vessels can be used both to transport LNG fuel from import terminals to intermediary terminals and to bunker receiving vessels in ports without import terminals. One berth for two vessels with LNG is enough, see Figure 33.

The terminal in Port Case II also needs a tank truck, to handle the bunker volumes of small RoRo vessels and utility vessels. Further, a pipeline that connects to the intermediary terminal and provides bunker fuel to RoRo vessels at the RoRo berth(s) is suggested.



Port Case II: Main characteristics of a medium-sized port with passing traffic and without an import terminal

- One intermediary LNG tank, 20,000 m³ (No of fillings/year: 20);
- One bunkering berth;
- Two medium-sized bunker vessels, one 4,000 m³ and one 3,000 m³ each with 20 % capacity utilization;
- One LNG truck filling station;
- One tank truck, 50 m³ with 5 % capacity utilization;
- One pipeline with 2 % capacity utilization.

Figure 33 A schematic outline of Port Case II.

As investments in vessels, intermediary tanks and related equipment, e.g., jetties, berths, anchorage points, etc. are comprehensive, they should be divided into smaller steps, if possible. However, this is not possible in the case of intermediary tanks, because such tanks are investments that need to be made at an early stage. However, Port Case II can invest in one vessel first and wait for larger volumes, as discussed above in the case of the import terminal (Port Case I). It will probably be some years before large volumes bring about the need for the largest vessels. There is, therefore, a low theoretical level of capacity utilization by the tank truck and the pipeline. In this analysis, the terminal is expected to be open 24 hours/day, 7 days/week. As the time needed for preparation and bunkering is short, the actual utilization of facilities will, consequently, be low. This is generally the case for all types of equipment in ports.

6.5.3 Port Case III – A Small LNG Intermediary Terminal

The third port is a small port in the Baltic Sea that services mainly liner RoRo vessels and regional ferries, see Figure 34.

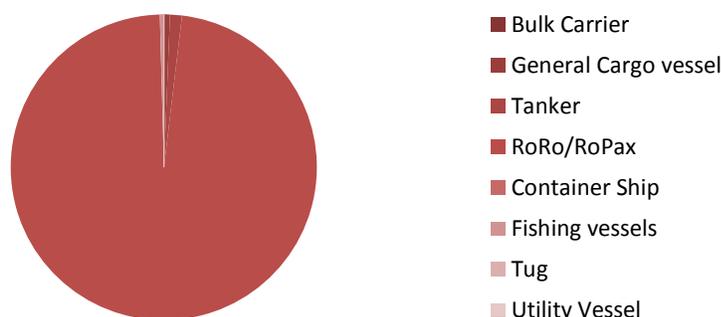


Figure 34 Traffic share (number of calls) in Port Case III.

The LNG volume is expected to be approximately 52,000 m³ in 2020. This is a high figure for a small port, a result of the high frequency of liner RoRo shipping services. Calculation of annual LNG consumption for Case 3 is shown in Table 20.

Table 20 Expected annual LNG consumption 2020 for Port Case III.

Ship type	Expected annual No. of calls 2020 (m ³)	Average bunker delivery size (m ³)	Share of fleet that bunker LNG	Share of total calls with LNG bunker operation	No. of LNG bunker operations	Bunkering method	Annual LNG (m ³)
Small RoRo/RoPax	4,791	320	60 %	4 %	115	TTS 50 % / ITS 50 %	36,795
Large RoRo/RoPax	2,550	640	16 %	5 %	20	ITS	13,058
Small tankers	95	2,400	6 %	4 %	0	TTS	549
Small General Cargo Vessel	48	1,600	45 %	4 %	1	TTS	1,373
Fishing Vessel	32	36	17 %	5 %	0	ITS	10
	7,516				137		51,785

The solution suggested for Port Case III includes one tank truck, one pipeline with a capacity of 200 m³/hour and two connected insulated pressurized tanks (so called “Type C” tanks) of 700 m³ each, see Figure 35. As the risks associated with these types of investments are quite high for small ports, a flexible solution that does not require high sunk costs is desirable. The use of insulated pressurized tanks that can be connected in series can contribute to the building of an intermediary terminal with expansion possibilities, if investments are made in smaller steps. This “stepped investment method” will bring supply in better line with demand, increasing the capacity utilization of the port’s facilities.

As the liner RoRo vessels almost always call at the same berth and as turnaround time, in general, is short, a pipeline is a suitable means of handling the largest volumes. A tank truck, in complement, would increase the flexibility of the bunkering services offered at Port Case III. The main characteristics of Port Case III are shown in Figure 35.



Port Case III: Main characteristics of a small LNG intermediary terminal

- Two LNG C-Type tanks, 2 x 700 m³ (No. of fillings/year: 44/tank);
- One LNG truck filling station;
- One tank truck, 50 m³ with 20 % capacity utilization;
- One pipeline with 3 % capacity utilisation.

Figure 35 A schematic outline of Port Case III.

For small ports, tank trucks and pipelines are often the most suitable solution, considering the high costs associated with ship-to-ship bunkering for small volumes. However, LNG bunker vessels can be used in smaller ports if they are also used for bunkering in other ports, as well. Thereby, volumes can be increased and, consequently, average cost per cubic meter decreased.

6.6 Result

Table 21 Port Case I – An LNG import terminal.

LNG volumes/year	204,131 m ³				
	Number of units	Size (m ³)	Volumes per week and unit (m ³)	No. of bunkering per week and unit	Capacity utilisation per unit (%)
Bunker vessel	1	4,000	3,197	6	20
Tank trucks	2	50	364	7	19
No. of berths for loading bunker vessels:					1
Capacity utilisation of berth:					6 %
No. of filling stations for loading trucks:					1
Capacity utilisation of filling station:					17 %
No. and sizes of intermediary terminal:					0
No. of filling of tank/year:					0 times/year

Table 22 Port Case II - A medium-sized LNG intermediary terminal with potential passing traffic.

LNG volumes/year	342,885 m ³				
	Number of units	Size (m ³)	Volumes per week and unit (m ³)	No. of bunkering per week and unit	Capacity utilisation per unit (%)
Bunker vessel	1	4,000	3,325	2	8
Bunker vessel	1	3,000	2,628	2	8
Tank trucks	1	50	91	2	5
Pipeline	1	400 m ³ /h	551	1	2
No. of berths for loading bunker vessels:					1
Capacity utilisation of berth:					6 %
No. of filling stations for loading trucks:					1
Capacity utilisation of filling station:					2 %
No. and sizes of intermediary terminal:					1 tank á 20,000 m ³
No. of filling of tank/year:					20.2 times/year

Table 23 Port Case III - A small LNG intermediary terminal.

LNG volumes/year	51,785 m ³				
	Number of units	Size (m ³)	Volumes per week and unit (m ³)	No. of bunkering per week and unit	Capacity utilisation per unit (%)
Tank trucks	1	50	391	8	20
Pipeline	1	200 m ³ /h	605	2	3
No. of berths for loading bunker vessels:					0
Capacity utilisation of berth:					-
No. of filling stations for loading trucks:					1
Capacity utilisation of filling station:					9 %
No. and sizes of intermediary terminal:					2 tanks á 700 m ³
No. of filling of tank/year:					44 times/year

7 Cost for LNG Terminals

Investment costs and operational cost for terminals are of course interesting as such but they are also decisive when it comes to defining of the total supply cost for fuel for bunkering.

The fuel price scenarios in Chapter 5 fuel prices at hub. To obtain a relevant price forecast for the fuels, the cost of the small-scale infrastructure also needs to be considered, i.e. costs for storage, loading and transshipment should be added to the hub price in order to estimate the fuel price for end-users (shipowners). A cost of 10 €/tonne is assumed for the existing HFO and MGO infrastructure⁶³. This chapter focuses on estimating the cost of LNG infrastructure as nominal costs and specific costs per tonne LNG.

The specific costs per tonne are practically very dependent on the type and size of terminal as well as of the yearly LNG turn over at the terminal. This situation is handled through working with three terminal cases that have an assumed development of LNG turn over during the life time.

In Chapter 6 three bunker solutions for three port cases are developed. These port cases are further analysed in Appendix 5, where the capital and operational cost associated with each case are estimated.

The three studied terminals are an LNG import terminal (in table headings abbreviated Case I), a medium-sized LNG intermediary terminal with potential passenger traffic (Case II) and a small-scale intermediary terminal (Case III).

7.1 General Assumptions

The economic lifetime of the terminal is assumed to be 40 years. Bunkering vessels and trucks are assumed to have an economic lifetime of 20 years, i.e. they have to be replaced after half the studied period. When calculating the Life Cycle Cost (LCC) of the investments, a Weighted Average Cost of Capital (WACC) of 8% is used.

Shipping and terminal operation are capital-intensive industries and are characterized by high fixed costs and economies of scale. Port capacity is fixed in the short term and investments are in general made step wise. There will thus be a high level of unutilised capacity initially and in forthcoming years in the LNG terminals.⁶⁴

In Cases I and II it is assumed that the terminals can handle a doubling of initial volumes without the need for new investments in tanks, bunker vessels and other facilities etc. It is also assumed that the terminals' throughput is doubled between 2015 and 2020 and from there grow with a further 75 % until 2030. The growth has the same rate as implied in later demand analysis which is based on fuel price Scenario 2 from Chapter 5. Completing investments are of course assumed to be done when the capacity ceilings are reached.

⁶³ This figure seems to be low but has been confirmed by players on the actual markets.

⁶⁴ For example, the bunker vessels in the studied cases are only used a small fraction of the time. They can therefore easily handle a much larger throughput than is demanded 2015, which is seen as unutilised capacity.

In Case III, the small-scale intermediary terminal has a great deal of passenger traffic, which is assumed to consist of early adopters and hence the demand is not assumed to grow so much after 2020. Also in Case III, a growing demand would result in investment in a new thermos tank and the specific cost of LNG would thereby not decrease as much as in Cases I and II where a growing demand could be met without enlarging the terminal.

Based on the terminals' total costs the necessary revenue in €/tonne LNG is calculated as a function of desired pay-back time.

7.2 Methodology

The investment analysis should be seen as indicative with a high degree of uncertainty. The methodology used is that a list of cost items needed to “build” a terminal is first defined. The three terminal Cases are then “built” by choosing the necessary items. In Appendix 5 it is shown which cost items are used when “building” the three terminal cases.

The most characteristic items are the tank sizes, the size/number of bunkering vessels used, capacity utilization and throughput. These characteristics are summarized in the table below. It should be noted that the large case terminal has no separate storage tank since it is located in a port where LNG is imported and hence the maritime supply infrastructure can connect to that tank.

For the sake of simplicity, it is assumed that one single player builds and operates the LNG terminal. This assumption is made to illustrate the costs in that part of the value chain. In reality, it is by no means certain that the same actor will build, own, operate etc. the LNG-terminal.

Table 21 Main characteristics of three port cases providing LNG as bunker fuel.

LNG Port Case	Large-scale - Case I	Medium scale - Case II	Small-scale - Case III
Throughput	204 000 m ³ /yr	343 000 m ³ /yr	52 000 m ³ /yr
Tank size	(no separate tank)	20 000 m ³	2* 700 m ³
Tank turnover/year	n/a	20	44
Installations for import, bunkering and other transfer to end-users	<p>One bunkering berth including one jetty (pier for mooring) and associated equipment.</p> <p>One small-scale bunkering vessel, 4 000 m³; Two tank trucks, 50 m³ each.</p> <p>One LNG tank-truck filling station;</p>	<p>One bunkering berth including one jetty (pier for mooring) and associated equipment.</p> <p>Two small-scale bunkering vessels, 3 000 m³ and 4 000 m³; One tank truck, 50 m³.</p> <p>One LNG tank-truck filling station;</p>	<p>One bunkering berth and associated equipment.</p> <p>One tank truck, 50 m³.</p> <p>One LNG tank-truck filling station;</p>

The terminal owner/operator will of course also require revenues from handling the LNG. The price needed for distribution in €/tonne LNG can be calculated (so as to cover the terminals' costs, including costs for bunker vessels).

To show the impact of desired pay-back times for terminals, this average price (during the period of increasing demand 2015-2030) was calculated for pay-back periods of 8, 10, 12 and 15 years.

The cost items/components needed to “build” the three different terminals are listed in the Appendix 5 together with estimated costs and short explanations of how the costs were estimated. The largest investment costs are associated with the LNG tanks, bunkering vessels and jetties. The operating costs are also important and are also accounted for in Appendix 5.

Another, potentially large, investment cost is the cost for dredging, preparing the land and building quays, additional infrastructure etc. Such costs are not included in the analysis since they are very site-specific and could be regarded as cost neutral versus competing fuel solutions.

7.3 Results and Conclusions

7.3.1 Main Results

The main results concerning the three studied cases are shown in Table 24 below. Although it is only a case study of three conceivable cases, ship movements in or close to three real ports give a good estimate of the cost range for providing LNG.

Table 24 Resulting costs for the three terminal cases.

	Case I	Case II	Case III
Total initial investment cost [million €]	69	137	15
- thereof investment in bunker vessels [million €]	32	60	0
Total operational cost [million €/yr]	10	17	3,0
- thereof operation of bunker vessels [million€/yr]	3	5	0
NPV total investments [million €]	76	151	16
NPV operational cost [million €]	208	419	39
	Case I	Case II	Case III
Cost per tonne LNG with 8 years pay-back [€/tonne]	136	157	211
Cost per tonne LNG with 10 years pay-back [€/tonne]	118	137	194
Cost per tonne LNG with 12 years pay-back [€/tonne]	107	125	183
Cost per tonne LNG with 15 years pay-back [€/tonne]	95	112	172

Case I: LNG import terminal; Case II: medium sized LNG terminal with potential passing traffic; Case III: small LNG terminal

When comparing Case I (import terminal) and Case II (medium sized intermediary terminal), it can be seen that the total cost is lower for the Large terminal since no separate tank is needed because the LNG is taken directly from the import terminal. Other studies show a significant economy of scale in the LNG terminal business, based on the fact that the specific tank cost (in €/m³ LNG) decreases when the tank size increases. Another conclusion is that the cost per unit LNG is very high for the kind of small terminals studied here. All

this implies a third conclusion: that the capacity utilization needs to be high in order to decrease specific costs. However, in the early stages capacity utilization is very low, meaning that there is a great deal of free capacity in the terminal.

As was seen above, the average infrastructure cost in the studied cases ranges from about 120 to 200 €/tonne LNG in the three studied cases, provided that the terminals have a pay-back time of 10 years and provided the demand develops as outlined in Scenario 2 in Chapter 0. However, the cost in Case III with a small LNG terminal could, with a lower capacity utilization, easily be as high as 250 €/tonne LNG. Case III in this study has very high capacity utilization, which is not the case in the other two cases.

The average cost corresponding to 10 years' pay-back time for Case II and Case III (which will be the majority of the terminals) is used as input in the later demand analysis base case (i.e. 170 €/tonne).

7.3.2 Alternative analysis with IRR

An alternative way to analyse the situation is to calculate how the transshipment and handling cost changes with changed requirements on Internal Rate on Return (IRR) on the investment for each of the 3 cases. The relations are shown in Figure 36 below.

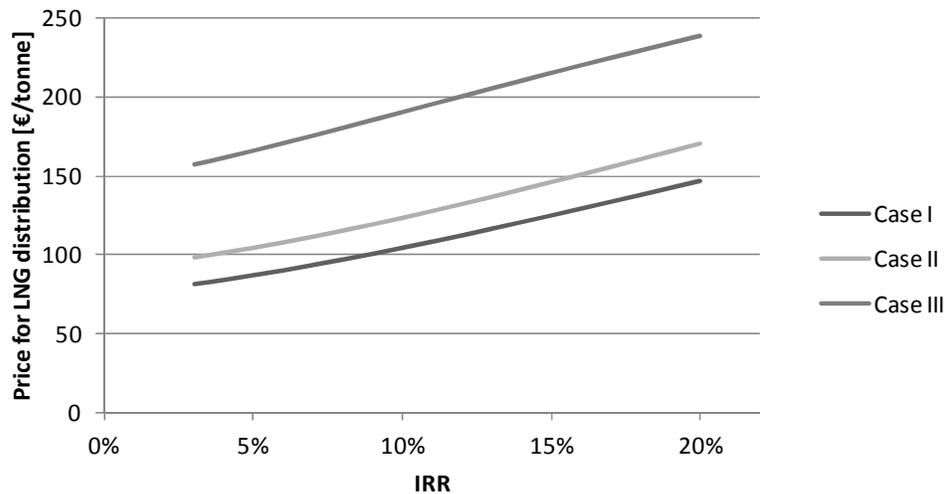


Figure 36 The price for LNG distribution as a function of IRR for the terminal

From the figure, corresponding IRR to get the LNG distribution cost of 170 €/tonne, is 7 %, 20 % and 23 % respectively for the three cases.

7.3.3 Concluding Remarks

With the distribution costs assumed above, the price scenarios for the end-user prices are as follows (based on Scenarios for import fuel price from Chapter 5).

Table 25 Price scenarios with end-user prices in €/tonne.

Scenario name	MGO price level	MGO price	LNG price level	LNG price
1. LowLNG_CentralMGO	Central	885	Low	485
2. CentralLNG_CentralMGO	Central	885	Central	610
3. HighLNG_CentralMGO	Central	885	High	740
4. LowLNG_HighMGO	High	1210	Low	485
5. CentralLNG_HighMGO	High	1210	Central	610
6. HighLNG_HighMGO	High	1210	High	740

HFO price is in all scenarios assumed to be 530 €/tonne

The cost of LNG distribution (and hence the price) can be significantly lower in an import terminal with large land-based demand, or substantially higher in remote small terminals with low utilisation.

Regardless of price scenario, the economy of scale when building terminals has been highlighted in this chapter, which rests on the fact that costs for tanks, bunker vessels, etc. display a decreasing specific cost (e.g. €/tonne) as size increases.

Another closely-related conclusion from this chapter is that it is important to achieve high capacity utilization in order to decrease the specific costs. But since investments in terminals take place stepwise (a tank or bunker vessel cannot be expanded continuously) capacity utilization will often be low to begin with. The studied terminals therefore have a high specific cost. Consequently, the terminal owner/operator will have to charge very high prices, make losses, or need support until capacity utilization (i.e. the demand) increases.

Development during the first years is of utmost importance because a growth in LNG use may create a positive spiral (an increasing demand gives decreased specific infrastructure costs, which could lead to further increases in demand). It is therefore recommended for those who invest in maritime LNG supply infrastructure to set prices such that shipowners opt for LNG, i.e. advisably corresponding to an IRR on investments of less than 12% for the first years, refer to recommendation no. 2.



8 The Demand for LNG as a Fuel for Shipping in the SECA Region

As was described in the previous chapters, a new LNG infrastructure is needed to be established. The LNG demand will be affected by the cost of this infrastructure (since the costs affect the price of LNG), which was further accounted for in Chapter 7.

Other factors that influence the LNG demand are the availability of LNG, the competing compliance strategies (Chapter 4), the relative cost of conversion to LNG (Appendix 3) and of course the competing fuel import prices (Chapter 5).

The fleet's suitability for LNG propulsion (which will depend on vessel type, age, shipping patterns, etc.), which is described in this Chapter is also an essential parameter for the assessment of the LNG demand.

8.1 Methodology for Demand Calculation

8.1.1 Methodology Overview

In this study, the demand for LNG is studied from two perspectives. Firstly, costs associated with the three above mentioned compliance strategies are applied to all ships sailing in the SECA, to obtain an estimate of the number of ships that would benefit from converting to LNG operation. That is, by using a bottom-up analysis approach where the life cycle cost⁶⁵ is minimized, the share of ships converting to LNG propulsion can be estimated.

The demand analysis is based on AIS data from IHS Fairplay of ship movements during 2010 broken down into 75 sub categories of ships (e.g. "Bulkier < 10,000 dwt" or "Container vessel, 1-1,999 teu"), each sub category divided into six age bands and four geographic areas (for a more detailed description, see Appendix 2). For each sub category and age band (and geographic area), the number of ships, their average installed power and fuel consumption were given as input to the model. Based on this and assumed investment costs (described in Appendix 3) and fuel prices (Chapter 5), the annual life cycle cost (investment cost plus operational cost) for the three compliance strategies could be calculated for retrofitted ships as well as new builds. That is, the compliance cost is calculated regarding each sub category and age band as "one unit" since only the sub category's *total* fuel consumption is known.

Which strategy gives the lowest life cycle cost is of course dependent on the remaining lifetime of the ship. Generally, a short remaining economic lifetime will favour options which have low capital costs – in this case MGO. The capital cost is annualized assuming a ship life time of 25 years. This means that for retrofitting ships, the economic lifetime of the investment is the remaining life time of the ship (i.e. 25 years minus actual age). When calculating the annual capital cost, a 10 % weighted average cost of capital is assumed.

⁶⁵ With life cycle costs is meant the sum of the studied investment cost and operational costs. The future costs are transferred to present value using the weighted average cost of capital.

As just described, three annualized life cycle costs for the ships in each sub category and age band are calculated: the cost of the LNG strategy, the HFO strategy and the MGO strategy. Before these three costs are compared to find the least-cost strategy for each ship sub category, the MGO life cycle costs are decreased by 5 %. This modification reflects the attractiveness for shipowners of doing as little as possible and minimise investment, which would mean that MGO would be slightly more favoured than if only economic factors were considered. This would represent a slowly adapting market.

For the LNG strategy, the life cycle costs are also modified to reflect that some sub categories of ships will be more inclined to choose the LNG strategy and some will be less inclined. The LNG life cycle cost for sub categories that are assessed to be early LNG adopters (e.g. ferries, RoRo and other with fixed routes) are decreased by up to 10 %, whereas the LNG life cycle cost for sub categories that are assessed to be slow in changing to LNG are increased by up to 20 %. After this modification of costs, the life cycle cost for the three different compliance strategies is compared for each sub category of ships (and age band) and it is assumed that the shipowners opt for the strategy with the lowest life cycle cost for the remaining lifetime.⁶⁶

The above described methodology is used for calculating an LNG demand as presented below. After that, a second perspective for studying the future LNG demand is used by performing pay-back calculations for four “type ships”. This method of comparing investments is more common among shipowners and is thus a good complement to the minimization of life cycle costs.

8.1.2 Investment Analysis Prerequisites

The input used for investment and operational costs for the shipowners are taken from Appendix 3. In short, the investment cost is estimated based on the installed power of the engines (main and auxiliary) using rules of thumb (€/kW)⁶⁷ concerning scrubbers, SCR, engines, generators and electric system, motor conversion and LNG fuel system including tank.

The operational costs for scrubbers and SCR, based on energy (main engine power [kW] * time at sea [hours/year]) are also found in Appendix 3.

Personnel costs, costs for education, fee for bunkering, costs for port fees/licenses etc are also considered, although the differences between the fuel alternatives are small in this respect. This is an arduous task since the costs vary widely from case to case depending on ship type, where bunkering is done etc, so simplified generalizations had to be applied.

8.2 Fuel Price Scenarios Used in the Demand Analysis

The LNG demand is of course heavily dependent on the LNG price, as well as the price for competing fuels. To study that effect, the demand was calculated for six different fuel price scenarios, as summarized in below. These fuel price scenarios refer to prices paid by the end-user (shipowner) and are outlined in Chapter 5 and 7.

⁶⁶ Although it is acknowledged that the average time of owning a ship is much shorter than an assumed economic lifetime of 25 years and that the economic lifetime in many investment analyses is therefore shorter, this study uses an investment horizon for retrofitting being the same as the remaining economic lifetime of the ship calculated as 25 years minus actual age today.

⁶⁷ Provided by MAN Diesel & Turbo and Wärtsilä.

Table 26 Price levels for MGO and LNG as well as corresponding fuel prices in €/tonne fuel⁶⁸ for the six different price scenarios.

Scenario name	MGO price level	MGO price	LNG price level	LNG price
1	Central	885	Low	485
2	Central	885	Central	610
3	Central	885	High	740
4	High	1210	Low	485
5	High	1210	Central	610
6	High	1210	High	740

Scenario 2 is chosen as “baseline”, i.e. unless otherwise stated Scenario 2 is the price scenario used. In that scenario the relative MGO and LNG prices are at the price level named Central.

8.3 Maritime LNG Demand from Retrofitted Ships

Following the methodology just outlined, Figure 37 below shows the LNG demand from ships that would be economically viable to retrofit to LNG propulsion. As can be seen, in some scenarios a very high fuel demand is economically viable to shift to LNG by 2015. The LNG demand is of course dependent on the fuel price, the LNG price being much more important than the MGO price. This can be interpreted as HFO and LNG being the main competitors for many ship segments; the MGO price is projected to be so high it will not be the main alternative to LNG for many ship segments (depending on their relation between installed power and fuel consumption). Consequently, the LNG demands shown in the figure below are very similar for Scenario 1 and 4, Scenario 2 and 5, and Scenario 3 and 6, respectively.

⁶⁸ Note that one tonne of LNG contains much more energy than one tonne of e.g. HFO. Thus it is often more fruitful to compare relative fuel prices in terms of e.g. € per energyunit. This approach is used in Chapter 7.

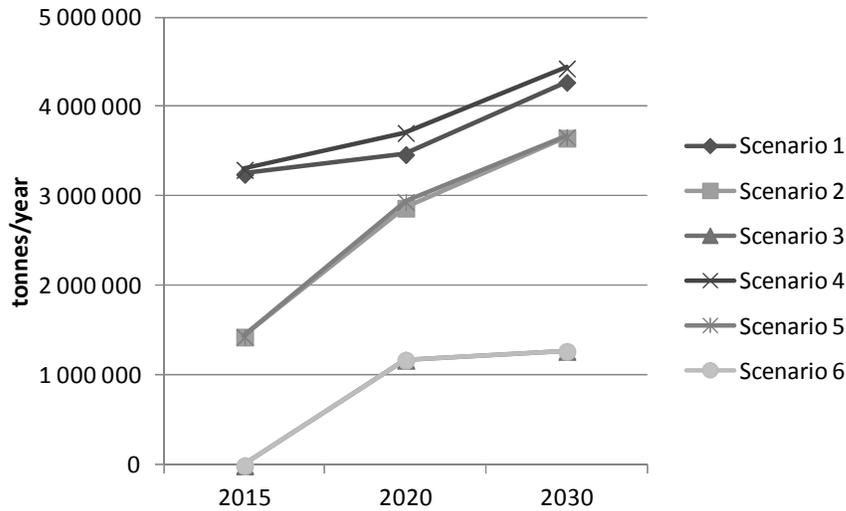


Figure 37 LNG demand from ships viable for retrofit in the six fuel price scenarios
Source: AF internal analysis

8.4 Maritime LNG Demand from New Builds

There will also be room for a significant share of LNG-propelled new builds. How much is determined by for example investment costs, operating costs and fuel costs relative to other options. As in the retrofit case, the LNG demand from new builds sailing in SECA can be shown as a function of fuel price scenario, see Figure 38.

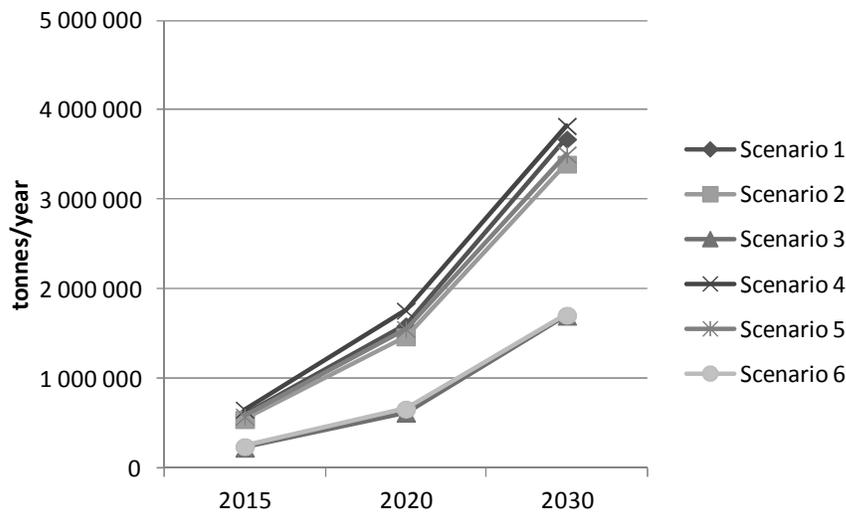


Figure 38 LNG demand from new builds in the six fuel price scenarios

8.5 Aggregate Demand for LNG in Ships as a Function of Bunker Fuel Prices

Combining the demand from ships retrofitting to LNG propulsion with its estimated use in new builds⁶⁹ results in an aggregated demand for LNG as illustrated in the figure below.

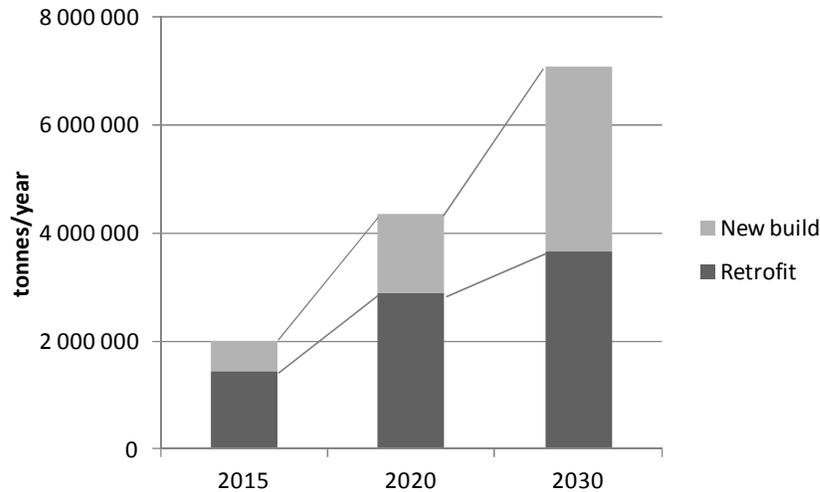


Figure 39 LNG demand from retrofits and new builds in Scenario 2

Source: AF internal analysis 2012

This calculation of LNG demand is made for a number of different prices of LNG and MGO relative to HFO. The HFO price is used as a “baseline” for the analysis since it is the most common fuel today and probably the fuel of the three that will have the most stable price in the near-term future. That is, the LNG demand is estimated as a function of the two variables price relation LNG:HFO and price relation MGO:HFO (on an energy unit basis).

In order to illustrate the demand’s sensitivity to different developments in relative fuel prices, the LNG demand is visualized as a surface. A projection for the LNG demand for each of the three years 2015, 2020 and 2030 are shown below. Note that although the analysis is based on relative prices, the figures visualizing the results are shown with absolute LNG and MGO prices. It is also assumed that by 2030 stricter sulphur regulations will also apply outside the North European SECA, resulting in LNG being a more favourable option for ships sailing only part of the time within SECA.

⁶⁹ Combined with the above mentioned assumptions of a new build rate of 4% per year and a phase out of 2% per year.

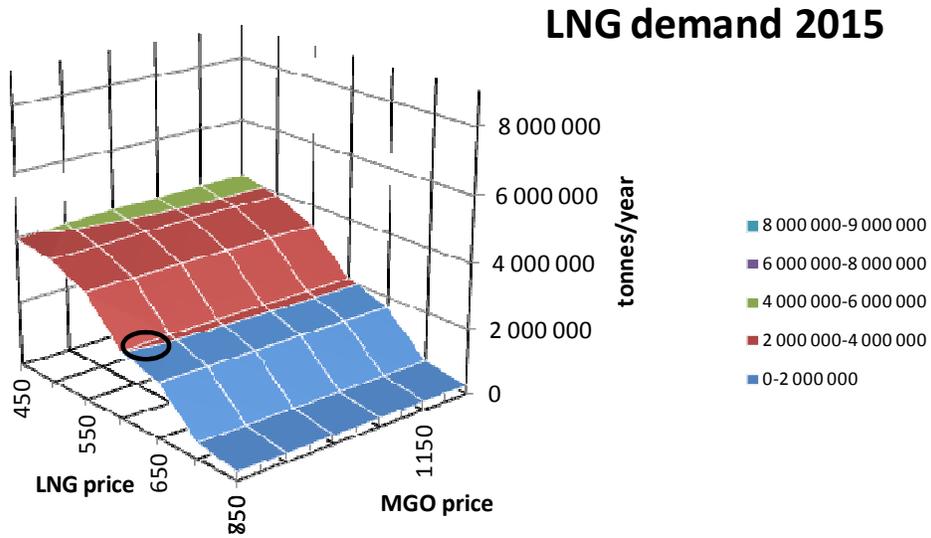


Figure 40 Estimated LNG demand for use within SECA 2015 [tonnes /year].
Prices in €/tonne. The circle represents the chosen base scenario (Scenario 2). Source; AF internal analysis 2012.

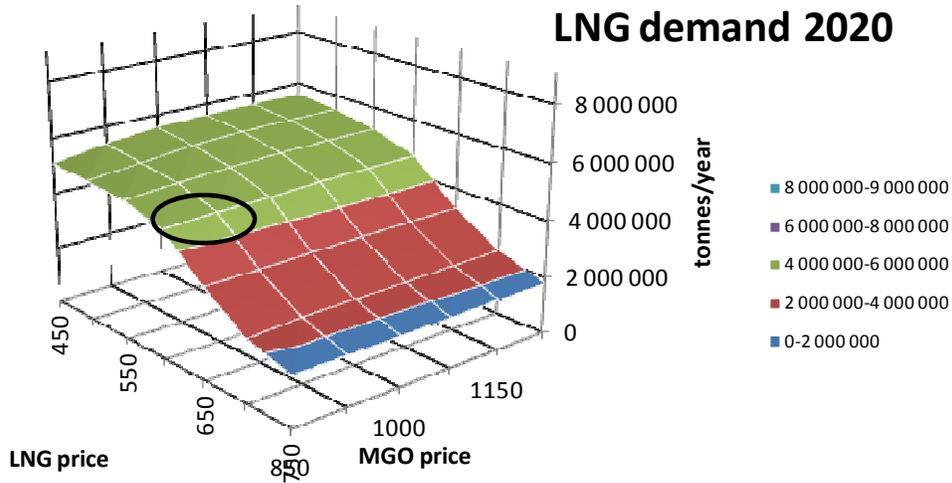


Figure 41 Estimated LNG demand for use within SECA 2020 [tonnes /year].
Prices in €/tonne. The circle represents the chosen base scenario (Scenario 2). Source; AF internal analysis 2012.

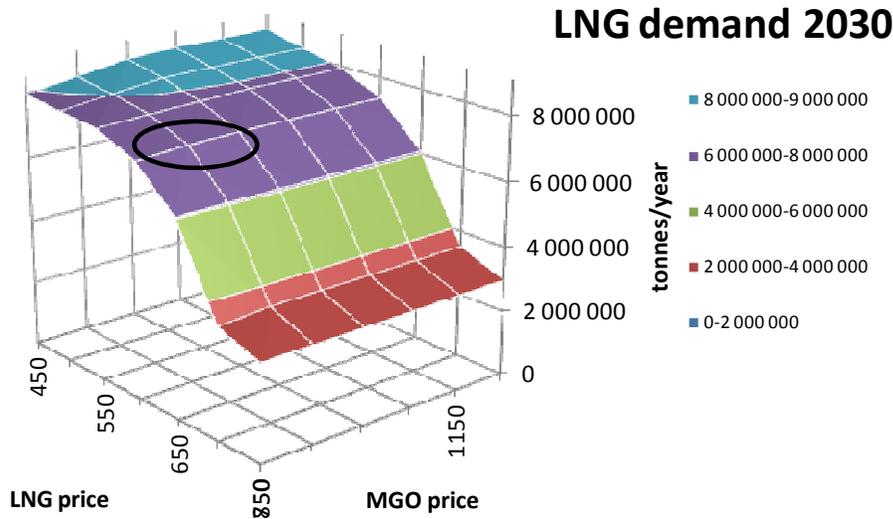


Figure 42 Estimated LNG demand for use within SECA 2030 [tonnes /year].
 Prices in €/tonne. The circle represents the chosen base scenario (Scenario 2). Source; AF internal analysis 2012.

It is however also interesting to look at the geographical distribution of the demand within SECA, and which type of ships generate this demand. As can be seen in Figure 43, container ships and RoRo as well as passenger ships represent the largest share of the demand. Geographically, there is a small LNG demand in the English Channel whereas the other areas are about the same size demand-wise. Note that the figure only considers ships spending 100% of their time in the SECA. The reason for this is that they can be seen as constituting the backbone of the fleet bunkering LNG in SECA.

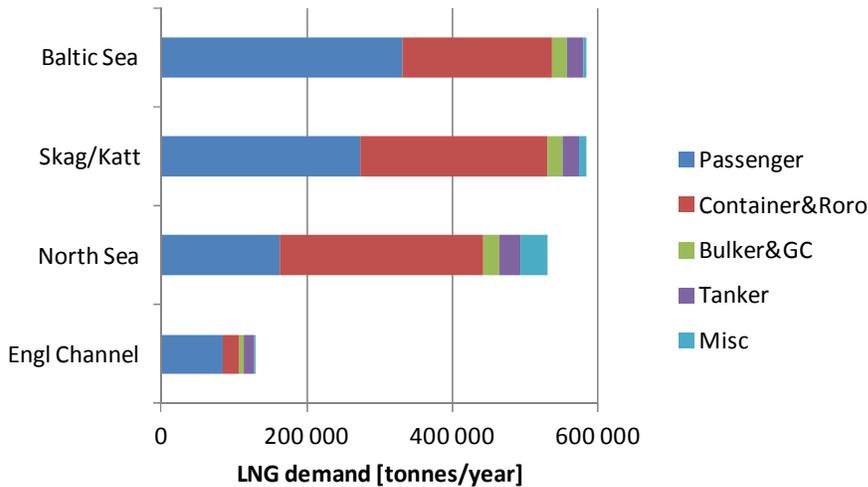


Figure 43 Annual LNG demand 2020 for different sub regions of the SECA for ships being 100% of the time in SECA (Scenario 2).
 Source; AF internal analysis, 2012.

Studying the whole demand (i.e. also ships operating only part of the time within SECA) in the different sub-regions results in the figure below. This demand is interesting when discussing the development of different scenarios for infrastructure development (Chapter 9).

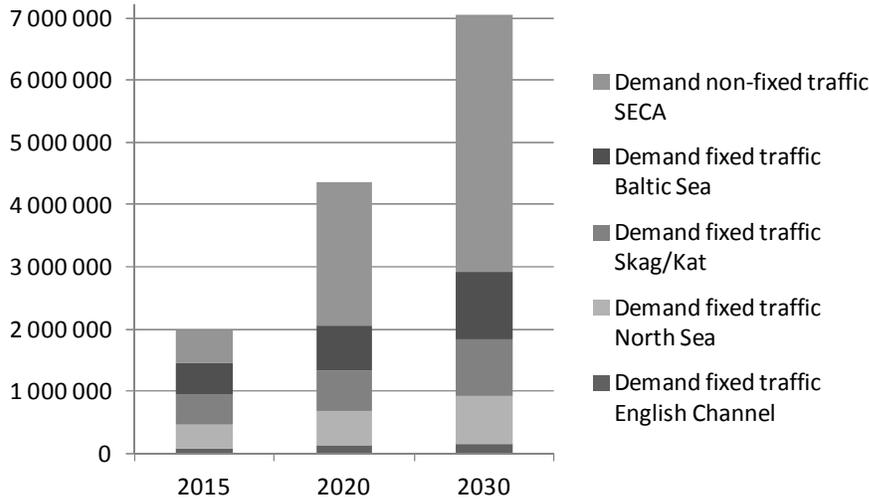


Figure 44 LNG demand in Scenario 2 divided in demand from fixed traffic in the different sub regions and non-fixed traffic

Source: AF internal analysis, 2012.

8.6 Benchmarking of the Demand Forecast

The above presented forecast of LNG demand can be compared to previous studies projecting the LNG demand, see Figure 45 below. Scenarios are built from the study from GL on Expected demand for LNG as ship fuel in the Baltic Sea (P.Same, 2010) and data sheets from IHS Fairplay and their estimates on the world fleet LNG conversion rates. The benchmarking scenarios are described in the diagram label, and are complemented by the predicted total demand development based on the one hand fuel *used* within the SECA (IHS Fairplay) and the total estimated amount of bunker fuel *sold* within the SECA (SSPA). As can be seen in the figure the demand in Scenario 1 and 4 (with low LNG prices) is higher than in the studies used for benchmarking. Also in Scenario 2 and 5 (LNG prices at Central level) the LNG demand is slightly higher than in the other studies, whereas the scenarios with high LNG price (Scenario 3 and 6) show a lower LNG demand than in the studies used for comparison.

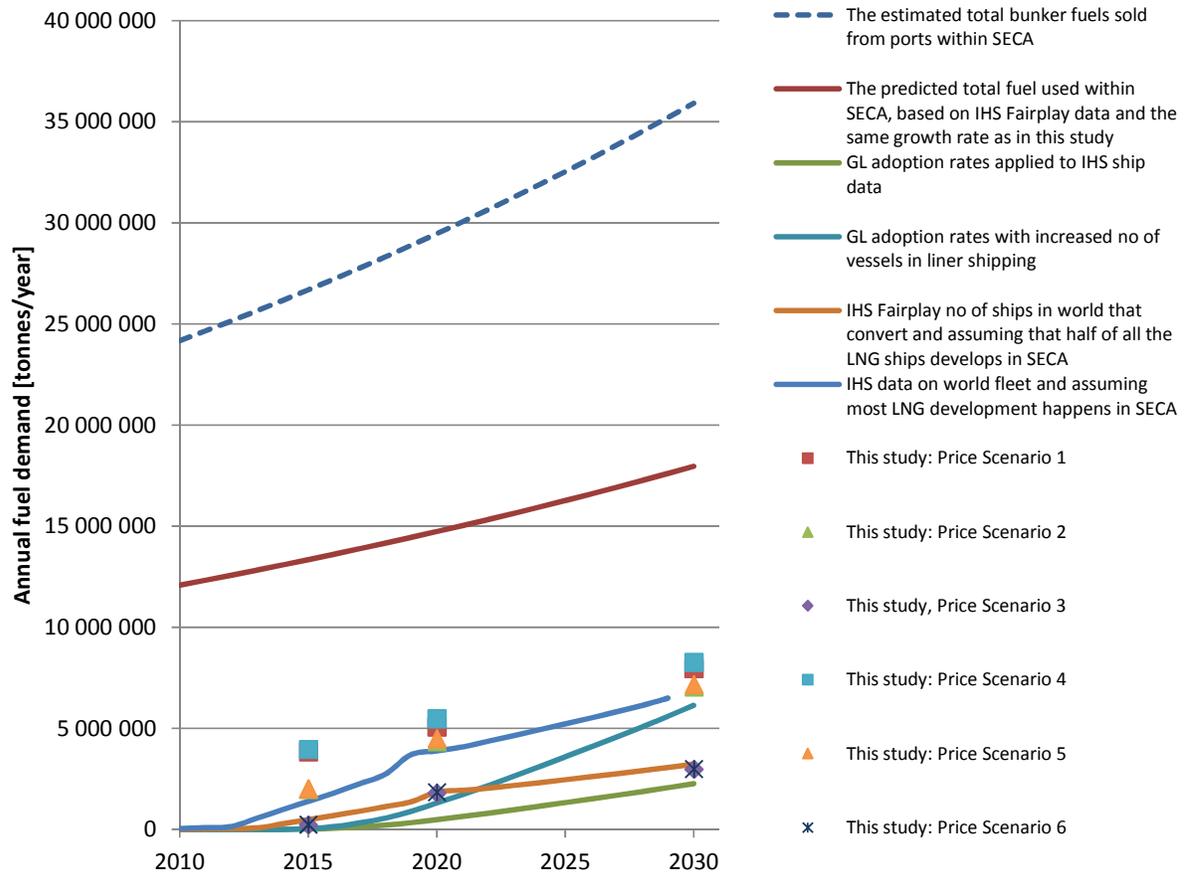


Figure 45 LNG demand forecast in this study’s scenarios compared to other studies.
 Source: AF, 2012

8.7 Pay-back Analysis from a Shipowner’s Point of View

In the demand analysis presented above, the demand was calculated assuming that each shipowner would minimize the life cycle cost of complying with the SECA regulations. That analysis resulted in an LNG demand as a function of LNG and MGO prices relative to HFO. However, shipowners also commonly base their investment decisions on pay-back times, i.e. they compare how many years are needed for the respective investments to generate revenues (or cost savings) that add up to the same amount as the investment. In order to do this, a “baseline” has to be defined, to which the investment alternatives are compared. In this case, the MGO compliance strategy is chosen as baseline since it is the strategy with lowest investment costs and highest fuel costs.⁷⁰ Investment analyses are then performed for three “type

⁷⁰ HFO could also be chosen as base line, since HFO prices may be more stable than MGO prices and since HFO is the fuel used today. However, since the HFO alternatives have higher investment costs than MGO but lower operational costs, the term “pay back” would then denote the time after which the higher fuel costs for MGO have offset the lower investment. Also, after 2015 it may be more useful to use MGO as the base alternative for comparisons.

ships”, both as new builds and as retrofitted. The type ships are further described in Appendix A, providing a summary of the most important parameters. In the analyses, special attention is paid to the fuel price, as further explained in Chapter 5 and 7. To take the uncertain price development into account, some of the price scenarios outlined above in 8.2 are used, i.e. the three price scenarios with moderate relative MGO price but three different LNG price levels. Note again that all three compliance strategies only contain costs, there are no economic benefits and the pay-back analysis aims at suggesting a “least cost” alternative.

The results of the pay-back analysis show pay-back times between around two years to slightly less than four years if compared to the MGO strategy, see Table 27 below. For low and moderate LNG prices the LNG compliance strategy has about the same pay-back time as scrubbers. The most important parameter for determining pay-back time is the relation between fuel use and installed engine power. A high fuel use per installed kW results in lower pay-back times.

For high LNG prices, Scenario 3, the pay-back times for LNG is longer than for scrubbers. Still, the pay-back times for both HFO/scrubber and LNG is short in the studied cases. The reason is the high price difference between MGO and HFO/LNG.

As complement, the effect of higher retrofit prices is studied. With the fuel prices of Scenario 3 and a higher price for LNG retrofit (750 €/kW instead of 600 €/kW as in all the other studied cases) the pay-back time for the LNG option increases by one year. Ships with low fuel use in relation to installed power, e.g. RoRo:s, are affected to a greater extent. For the same reason, such ships in general also have a longer pay-back time.

It could also be interesting to compare the “pay-back time” for the LNG strategy with the alternative to continue as usual – i.e. with HFO but without installing a scrubber. Seen from that perspective, the LNG strategy would have “pay-back times” ranging from 8-15 years in Scenario 1, 50-80 years in Scenario 2 and in Scenario 3 the LNG fuel costs are higher than HFO and consequently an LNG investment will have no “pay-back time”.

Table 27 Pay-back times relative the MGO compliance strategy for three fuel price scenarios and three different ship types.

	Retrofit				New builds			
	RoRo ^a	C. tank ^b	C. ship ^c	Big RoRo ^d	RoRo	C. tank	C. ship	Big RoRo
Scenario 1. Low LNG prices^e								
-HFO/Scrubber	2-3 yr	2-3 yr	1-2 yr	2-3 yr	1-2 yr	2-3 yr	1-2 yr	1-2 yr
-LNG	1-2 yr	2-3 yr	1-2 yr	2-3 yr	1-2 yr	2-3 yr	1-2 yr	1-2 yr
Scenario 2. Central LNG prices^f								
-HFO/Scrubber	2-3 yr	2-3 yr	1-2 yr	2-3 yr	1-2 yr	2-3 yr	1-2 yr	1-2 yr
-LNG	2-3 yr	2-3 yr	1-2 yr	2-3 yr	2-3 yr	2-3 yr	1-2 yr	2-3 yr
Scenario 3. High LNG prices^g								
-HFO/Scrubber	2-3 yr	2-3 yr	1-2 yr	2-3 yr	1-2 yr	2-3 yr	1-2 yr	2-3 yr
-LNG	2-3 yr	3-4 yr	2-3 yr	3-4 yr	2-3 yr	3-4 yr	1-2 yr	3-4 yr
Scenario 3. High LNG prices with high LNG retrofit prices (750 €/kW)								
-LNG	3-4 yr	4-5 yr	3-4 yr	4-5 yr				

MGO prices are at the Central level as defined in Chapter 7.

^a A RoRo/RoPax ship (deadweight 4,200 tonnes, engine power 5,400 kW, LNG consumption 2,700 tonnes/year).

^b A costal tanker/chemical tanker / bulk carrier (deadweight 10,000 – 25,000 tonnes, engine power 8,500 kW, LNG consumption 3,200 tonnes/year).

^c A container ship (700-800 TEU, deadweight 9,000 tonnes, engine power 8,000 kW, LNG consumption 4,500 tonnes/year)

^d A RoRo/RoPax ship (engine power 21,000 kW, LNG consumption 9,800 tonnes/year).

^e Fuel prices are as in Scenario 1 as defined in Chapter 5 and 7 and summarized above in 8.3

^f Fuel prices are as in Scenario 2 as defined in Chapter 5 and 7 and summarized above in 8.3

^g Fuel prices are as in Scenario 3 as defined in Chapter 5 and 7 and summarized above in 8.3.

8.7.1 Sensitivity Analysis

To show the effect of varying two of the investment analysis' most important factors , a sensitivity analysis is presented in this section which shows how a change in fuel price and capital cost affects the pay-back times. To be able to do this, one of type ship – the new build Container ship – was chosen, but the results would be similar for the RoRo and Coastal tanker / Bulk carrier (see Appendix A for a description of the ships). The base assumptions used are taken from the Central price scenario 2 with fuel prices of 530 €/tonne HFO, 885 €/tonne MGO and 610 €/tonne LNG, respectively.

As before, MGO is used as a reference since it is the alternative with lowest investment cost and highest fuel costs and the pay-back method therefore makes sense. Note that the figures below presenting pay-back times as a function of the price relations between LNG and MGO and between HFO and MGO respectively have two horizontal axes. Also note that the values used in the base case (Scenario 2) are indicated by short vertical lines. First, the impact of varying the relative fuel prices is shown, see Figure 46 below. Here it is seen that the LNG pay-back time first increases more or less linearly but at a price ratio around 0.8 the pay-back time begins to increase more rapidly. If LNG will be priced against marine fuel oils rather than in relation to land-based use of natural gas, the price relation may be closer to 1, which would result in long pay-back times.

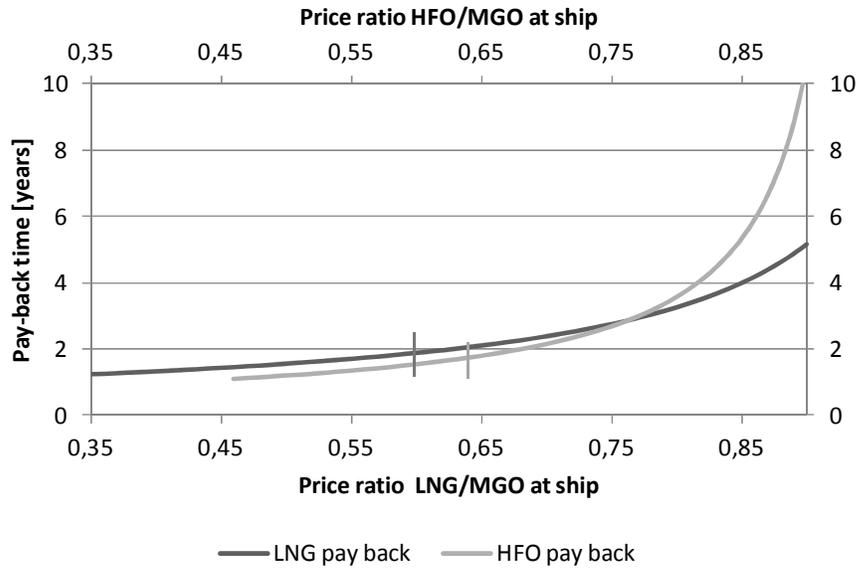


Figure 46 Pay-back time for a shipowner compared to MGO as a function of price ratios LNG/MGO and HFO/MGO at ship.

Source: AF internal analysis 2012

Also, the pay-back time's dependence on the machinery-related investment cost for the LNG new build was studied. A 10% change in investment cost changes the pay-back time with 0.5 years. This illustrates how decreasing cost, for example due to increased volumes of new builds, could lead to decreased pay-back times.

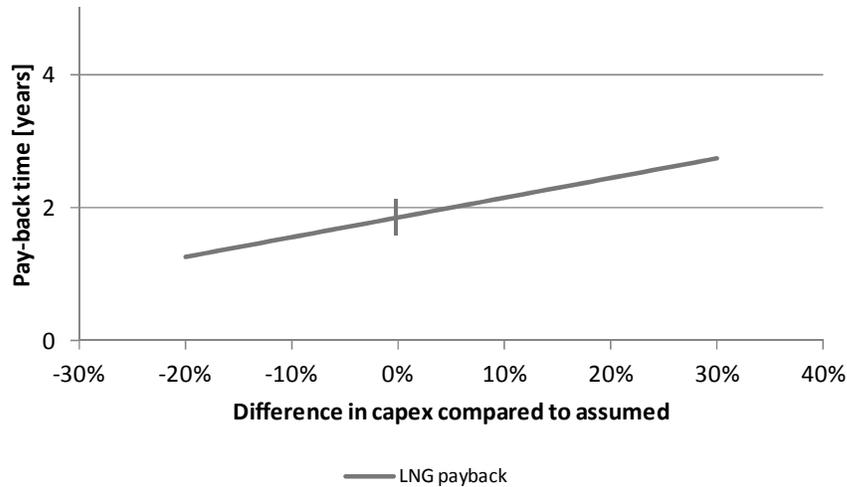


Figure 47 Pay-back time compared to MGO as a function of changed LNG machinery-related investment costs.

Source: AF internal analysis, 2012

8.8 Conclusions

Considering the above-mentioned limitations of this study, LNG is a viable compliance strategy from shipowners' point of view, with short pay-back times (compared to MGO) in many of the studied cases. One key issue for the demand analysis is of course the LNG price development. The importance of price development can be seen in the pay-back analysis just presented as well as in the demand forecast based on minimizing ships' life cycle costs, where high prices (relative HFO) significantly reduced the projected LNG demand. The price of LNG will depend on the cost of supplying the LNG, which is estimated and discussed in the next chapter.

- LNG is a viable compliance strategy from shipowners' point of view, with short pay-back times (compared to MGO) in many of the studied cases.
- LNG prices (relative its HFO etc) have a decisive impact on the demand.
- The LNG price will be heavily dependent on the cost for supplying the LNG.



9 Critical port criteria and business analysis for LNG bunkering

Different ports have different prerequisites for establishing LNG facilities. Differences in market, environmental restrictions and infrastructural shortcomings etc are some parameters that need to be taken into consideration when listing critical port criteria for LNG bunkering. The purpose of this chapter is to map different parameters to consider as critical for LNG bunkering and establishing LNG infrastructure for individual terminals located in Northern Europe. Identified parameters are listed and described below, divided into seven groups of criteria: market, economic, technical, logistics, safety, environmental and regulatory.

The chapter also includes analysis of business cases for ports, separate bunkering vessels and trucks as well as for standalone LNG terminal operation.

9.1 Critical port criteria for LNG bunkering

9.1.1 Market criteria

Ports are highly affected by changes in the market situation and by new competitors entering the market. Considering the volatility of the port activity and shipping industry, these parameters need to be taken into very careful consideration before the establishment of an LNG terminal. Market aspects of LNG bunkering are the most important ones for ports in this context. Market criteria for LNG bunkering are shown in Table 28.

Table 28 Market criteria for LNG bunkering.

Parameter	Comment
Import volumes/storage	The size of the terminal should be a result between import flows and consumption, dependent on approximated storage times and handling issues
Size of terminal	When planning a terminal consideration should be taken to future feeder capacities, if it is assumed to increase and if it will be used as bunker tonnage etc.
Export	Expected LNG export terminals for further feeder activities or for local bunkering processes must have technical systems for loading LNG vessels
Physical attributes in port	Port layout and the distance to competing LNG bunkering providers, expansion versus market needs
Local/regional customers	A combination of sea based and hinterland demands have a positive impact on interests in a terminal construction
Bunkering volumes	Suitable bunkering solutions – depends on volume and frequency
Feeder/bunkering	A bunker vessel can be used for both ship-to-ship bunkering or for imports of LNG fuel for intermediary tanks
Security in supply	Imports of LNG, with vessels or other means. Smaller terminals will be more dependent on feeder traffic from larger ones

Localisation of terminal	Layout and localization of the terminal are also affected by hinterland demands and the possibilities to distribute LNG or natural gas to end consumers
Downstream distribution	Local gas grids
Municipal planning	An LNG terminal is a question for municipal physical planning and decision processes regarding environmental analysis and handling interests of conflict
Rules and regulations	Rules and regulations for bunkering in ports, ship-to-ship or by other means will have an impact on market potential although there is an uncertainty to what level
Number of passengers	In accordance with assumptions as to what kind of traffic that will convert to LNG bunkering first, regular traffic and passenger ferries are highly ranked. Ports with high passenger circulation in the area constitute a large market potential
Marine traffic in vicinity	Potential customers are the passing traffic outside the port

9.1.2 Economic criteria

There are significant costs associated with LNG strategy and infrastructure. Economic aspects, see Table 29, such as investment as well as operational costs will most likely decide the future LNG strategy for ports. Economical feasibility for different terminal cases is further analysed in section 9.2.

Table 29 Economic criteria for LNG bunkering.

Parameter	Comment
Investment costs	Investments in the form of quays, supervision and broadening of fairways, etc. Positive affecting factors can be dedicated partners, e.g. a region/country that can provide part of the investment costs (conduct construction work for ports, etc). Loan terms may differentiate depending on which country a terminal will be built in
Operational costs	Different operational costs (for example personnel costs, fee for bunkering, port fees and fairway dues) vary depending on ship type, bunkering location, etc.
Reasonable price of LNG	Most advantageous prices for conventional bunker today are a consequence from lower distribution costs and large volumes. It is assumed to be the same for LNG
Incentive of investments	Port should have finances for investments, risks during financial crises, etc.
Financing	Banks knowledge for judging feasibility of LNG bunkering is probably low and depends on how sponsors are integrated in the LNG value chain and how they plan to utilise this capacity

9.1.3 Technical criteria

The technical aspects cover both vessel dimensions and, on a more detailed level, coupling and hose connections. This is also linked to the size of the terminal and physical prerequisites for the bunkering activities. Technical criteria for LNG bunkering are summarized in Table 30.

Table 30 Technical criteria for LNG bunkering.

Parameter	Comment
Proper vessel dimensions	Length, beam, maximum draught, speed, manoeuvrability, traffic density
Storage capacity at terminal	Has an impact on pressure and connecting hoses/valves. Permanent storage facilities of different construction types are available as are a variation of different flexible technical solutions
Access to main trunk line	Easy access to main trunk line for connection to natural gas transmission while high costs are likely when connecting an LNG terminal with existing local gas grid
Land area availability	Land area available for jetty and LNG terminal
Possibilities to distribute LNG	Close location of railway and intermodal terminal for future LNG fuelling or LNG distribution in competition with pipeline gas. Competitive with nearby vehicle fleet for LNG versus grid distributed gas
Bunkering capacity	Vessels can use trucks for bunkering but depending on the size of the vessel. It should be taken into account that pump capacity for a truck is limited and bunkering times will therefore be longer

9.1.4 Logistic criteria

A distribution system requires its individual infrastructure and varies according to distribution flows. Large terminals require deeper port basins and larger storage areas while smaller terminals most likely can be used by smaller vessels, hence requiring less depth in basins and fairways, and not the same advanced solutions for cargo handling and bunkering. Distribution by rail requires close-by tracks and railway capacity. The terminal must be equipped with suitable loading/unloading systems for LNG. If LNG is to be regasified and distributed via the local gas grid appropriate equipment is necessary. Logistics criteria are shown in Table 31.

Table 31 Logistic criteria for LNG bunkering.

Parameter	Comment
Size of area for LNG terminal	Size of the terminal can be limited by suitable areas and/or quay areas for storage and process facilities
Physical attributes of port	The layout of port in the aspect of vessels able to call at the port. Possibility to anchor and relatively protected anchorage spaces for bunkering are necessary
Location of LNG terminal	The distance to competing LNG bunkering providers
Port infrastructure	Activities in the port cannot be affected by LNG handling
Surrounding infrastructure	When distributing with trucks a well-functioning road infrastructure is needed together with suitable gas stations. Geographical proximity to regional or European road, rail or gas grids with capacities, safety and quality of road/tracks are attractive factors. Possible backup deliveries of LNG
Cargo	Different cargoes may require different carriers
Manoeuvrability	Fairways and basins are limiting factors due to maximum depth, length and width. Since LNG carriers require less depth than oil tankers, the length of the vessels is of greater concern. Not only fairway is limiting but length of quay as well. A large terminal used by large LNG vessels (VLGC) requires a depth of 12.5 meters, a length of 345 metres and a width of 53 metres
Hoses/arms	Only Norway has a bunkering system for LNG today. Bunkering is mainly done with trucks or from smaller intermediary tank installations. The use of flexible hoses is most common but loading arms can be found
Fairway	Depth, width, speed limitations, wind, waves, currents, navigational aids, bank clearance, turn radius, tides, visibility, ice, submerged cables and pipelines need to be taken into account

9.1.5 Safety criteria

There are also safety criteria that have an effect on appropriate methods of bunkering LNG and suitable location of LNG tanks and equipment, see Table 32. These are for example safety zones, emergency preparedness, passengers and safety precautions for employees and equipment, and avoidance of parallel activities in the terminal due to the handling of dangerous goods.

Table 32 Safety criteria for LNG bunkering.

Parameter	Comment
Separation of activities	Separation of hazardous activities and the LNG fuel
Exclusion/safety zones	Increased bunker and feeder traffic involves higher interaction with other traffic flows in the port and fairway areas
Terminal siting	Depending on localization, safety zones and parallel activities can be affected.
Fairway suitability	Access to tugboats and pilots in combination with tonnage
Parallel cargo/pax handling	Safety precautions when handling passengers and cargo parallel to bunkering operations.
Mooring arrangements	Limited or faulty mooring arrangements affect safety and can have consequences in combination with port/basin layout.
Emergency preparedness	Different cargoes require different carriers.
Safety precautions	In case of any LNG leak or accident emergency preparedness is essential to minimize consequences.
Educating personnel	LNG handling close to public areas, human factor and the bunkering process itself are seen as the largest risk factors.

9.1.6 Environmental criteria

Due to the infrastructural adjustments an LNG strategy of course generates certain environmental impact that need to be taken into account. Some significant impact that have to be taken in account are listed in Table 33, below.

Table 33 Environmental criteria for LNG bunkering.

Parameter	Comment
Knowledge of sensitive areas	Protection of wildlife areas and ecosystems
Regulated noise level	Distance to populated areas (dB)
Controlled methane slips	Methane slips affect the environmental status significantly
Knowledge of fishing/land usage	Expansion of ports/LNG terminals cannot affect existing fishing waters or land extractions (sand and minerals)

9.1.7 Regulatory criteria

LNG carriers must follow general international rules for safety and environmental protection put into force by the IMO, as well as rules and guidelines stipulated by class societies, flag states and individual nations.

On top of this there are rules, laws, standards and guides for design, construction, operation and maintenance regarding LNG facilities and LNG vessels. In some cases where the regulations are applied to terminals, they can limit and influence the design and capacity of LNG vessels, or vice versa. Hence, several regulations must be examined from both aspects. Difficulties in rules and regulations are that different rules apply for hinterland perspective and sea perspective. The border often lies at the quayside, where the vessel and equipment fall under sea-based restrictions while other processes fall under hinterland regulations. Regulatory criteria are shown in Table 34.

Table 34 Regulatory criteria for LNG bunkering

Parameter	Comment
Unite local versus regional regulations	Laws for explosives and dangerous goods are often national and form the activities and restrictions on the land side while sea based regulations are more international and therefore less restrictive.
Proper interpretations	A gas tanker is defined without regard to its capacity, meaning an LNG bunker vessel is classified as a tanker having to fulfil all requirements as described for a gas tanker in the IGC-Code.
Rules and regulations	Rules and regulations for bunkering in ports, ship-to-ship or by other means will have an impact on market potential although there is uncertainty as to what level.
Port authority regulations	Port authority regulations for handling of gas/LNG ships are crucial to facilitate handling of gas to vessels during parallel passenger handling etc.
Municipal planning	A LNG terminal is a question for municipal physical planning and decision processes regarding environmental analysis and handling interests of conflict.
Environmental considerations	Rules and regulations protecting the environment cannot be violated: Natura 2000, Ramsar, UNEP, etc.

9.2 Business Models for Ports

9.2.1 Financial Viability of Large, Medium and Small Ports

The study has further analyzed the three Port Cases: Large (labeled Case I below), Medium (Case II) and Small (Case III) from Chapter 6. For each of the port cases were calculated (also in Chapter 6) typical capacities that could be achieved for each type of port under fuel price scenario 2. Table 35 below shows these shows again the summarized typical throughputs.

Table 35 LNG volumes in Port Case I, II and III, in m³ of LNG.

Case	Case I - Large	Case II - Medium	Case III - Small
Total annual LNG [m3]	204,131	342,885	51,785
Total annual LNG [tonne]	93,000	155,800	23,500

To convert m³ to tonnes divide by 2.2

Based on the investments costs from Chapter 7, the throughputs of LNG that each case would require to achieve a certain IRR (at a margin of €170/ tonne LNG) can be calculated.

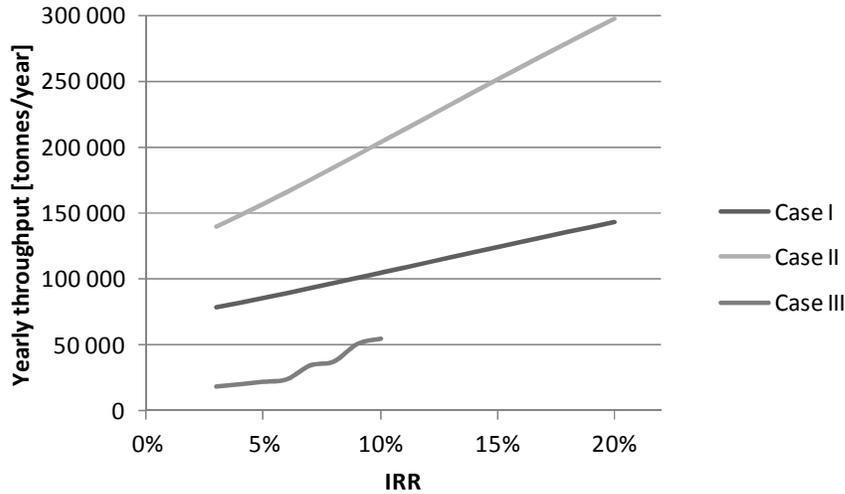


Figure 48 Yearly throughputs needed to achieve breakeven at different levels of IRR.

Individual port operators can use this table in conjunction with the graph to see what order of magnitude IRR might be achieved for a particular port with known number of bunkering operations by particular types of vessel.

The figures indicate that on the projected volumes of our example cases of Large, Medium and Small would need additional throughput of 30,000t, 70,000t and 25,000t respectively to achieve a 12% IRR equivalent to a 10 year payback.

For the small and medium port cases the additional demand would need to be land based. The large port cases are based on the addition of break bulk and reloading facilities being added to existing or planned large scale LNG import facilities. In nearly all cases these are sited at ports that have large bunkering volumes already of traditional marine fuels. Thus demand for the large port cases is likely to be boosted by ships on voyages that are mainly outside the SECA waters which have not been included in the analysis.

Land-based demand in the SECA region is accounted for in Appendix 6.

9.2.2 Sensitivity to Different Margins

Table 36 below shows the sensitivity of the throughput levels to different margins for the 3 port model cases where margin is the difference between the price the LNG is sold as bunker fuel and its delivered price at the LNG import hub.

Table 36 Breakeven throughput for the different port cases and price development scenarios

Breakeven throughput by type of port and margin on price	Margin: 44 €/tonne	Margin: 170 €/tonne	Margin: 300 €/tonne
Bunkering supply facilities added to existing import terminal (Port Case I)	Not feasible	146,250 tonnes/year	46,000 tonnes/year
New intermediary terminal with bunkering supply facilities (Port Case II)	Not feasible	182,000 tonnes/year	57,750 tonnes/year
New small terminal with bunkering supply facilities (Port Case III)	Not feasible	29,000 tonnes/year	6,000 tonnes/year

For the lowest margin (44 €/tonne), the throughput needed to cover costs is very large and it is not realistic for the small port case (Case III) to achieve the required throughput from bunkering activities because of practical limitations such as bunker flow rates and ship turnaround times.

9.2.3 Financial Viability of Bunker Vessels

The small case includes 1 truck and the medium case includes 2 bunker vessels and 1 truck so that it is possible to service demand in nearby ports that do not have more local LNG facilities.

The throughput needed to achieve breakeven at different IRRs and distances to customer has been examined for bunker vessels so that the viability of individual bunker vessels can be seen. This is illustrated in figures Figure 49 and Figure 50 below. The capital and operating costs are those used within the individual port cases I and II where bunker vessels are used as part of the port model and summarized in Table 37 below.

Table 37 Principal assumptions for Bunker Vessel capex and opex

	Vessel - 3,000 m ³ LNG	Vessel - 10,000 m ³ LNG
LNG storage capacity [m ³]	3,000	10,000
Gross capacity [tonnes]	1,364	4,545
Net capacity [tonnes]	1,091	3,363
Life [years]	20	20
Capital cost [€]	38,100,000	55,200,000
Average speed [km/hour]	16	17
Turnaround time [hours]	12	12
Vessel availability [%]	97%	97%
Daily fuel cost [€]	7,407	13,333
Running cost [€/km]	19	33
Annual operating cost [€]	1,987,222	2,446,852

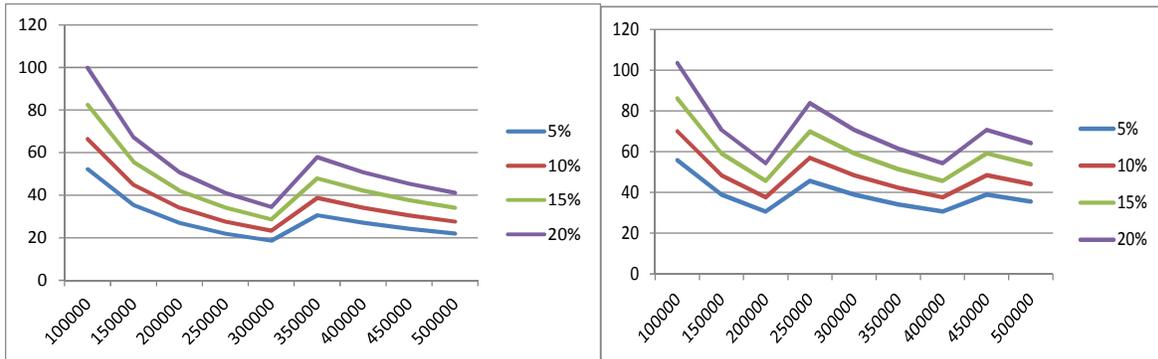


Figure 49 Margin per tonne of LNG (€) required by an operator of 3000m³ bunker vessels with annual throughputs between 0 – 500000 tonnes and an average customer distance of 50km (left hand graph) and 150km (right hand graph) at IRRs between 5 – 20%.

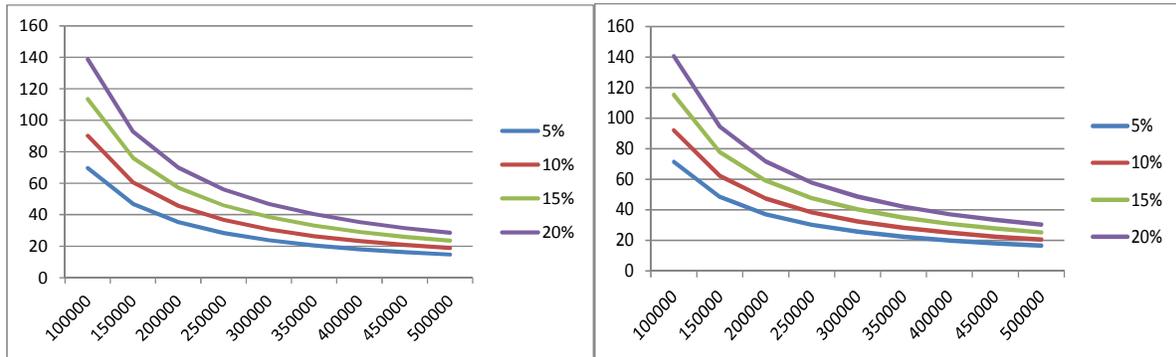


Figure 50 Margin per tonne of LNG (€) required by a 10000m³ bunker vessel operator with annual throughputs between 0 – 500000 tonnes and an average customer distance of 50km (left hand graph) and 150km (right hand graph) at IRRs between 5 – 20%.

For the 3,000 m³ vessels the margin required for breakeven falls with throughput until the point that second and third vessels are required to manage the volume. For 10,000 m³ vessels only one ship is required to manage the throughput and hence costs fall with rising volume. The ship has spare capacity and hence costs are not sensitive to distance.

9.2.4 Financial Viability of Individual Trucks

The viability of an individual tank truck has been examined. Using a capital cost of 500,000 € and a 10 year life an analysis has been undertaken of the margin that would be required between selling price of LNG and purchase price of LNG from a small or medium import terminal to achieve breakeven at different levels of IRR, throughput and average distance to customer. The two graphs below illustrate the results for average customer distances of 100km and 200km from the import terminal. Table 38 below gives the principal assumptions used.

Table 38 Principal assumptions for Tank truck capex and opex

Item	Cost
Life [years]	10
Capital cost [€]	500,000
Capacity [tonnes]	25
Average speed [km/hour]	70
Turnaround time [hours]	2
Driver salary [€]	35,000
Driver annual hours	1,760
Vehicle availability	70%
Running cost ^{a)} [€/km]	4
Fixed cost per year [% of capital cost]	1,5%

a) fuel and depreciation

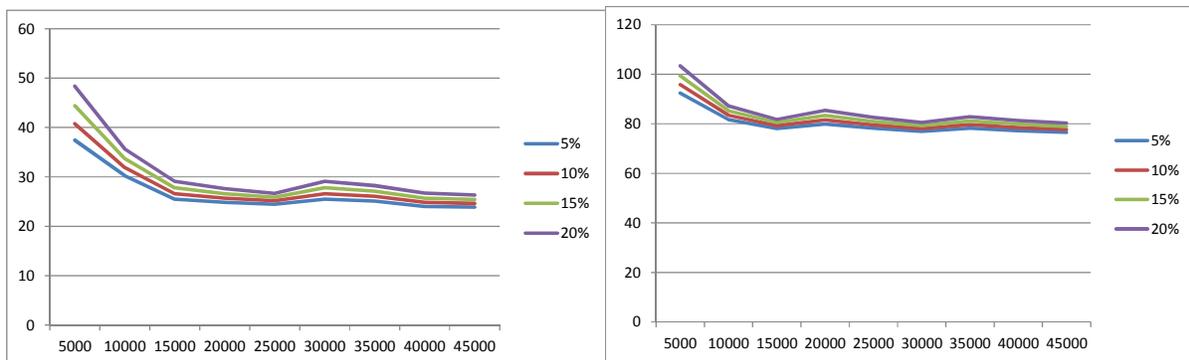


Figure 51 Margin per tonne of LNG (€) required by a tank truck operator with annual throughputs between 0 – 45000 tonnes and an average customer distance of 50km (left hand graph) and 200km (right hand graph) at IRRs between 5 – 20%.

A single truck will need more drivers as distances and throughputs increase, up to 5 if its utilisation is very intense. There is a limit to the throughput of a single truck, again dependent on distance and truck availability, at which point additional trucks are required to meet throughput. The costs rise markedly with distance and suggest that the customer base will need to be predominantly local for a tank truck based LNG supply to be viable. The breakeven cost is not particularly sensitive to IRR since the opex costs are high relative to the capex.

9.2.5 Financial Viability of Small and Medium Terminals

The viability of small and medium terminals has also been examined on a standalone basis, that is from the standpoint of an investor who will develop the LNG transshipment and storage facility without investing in bunker vessels or trucks. An analysis has been undertaken of the margin that would be required between the price of LNG from a large import terminal and the selling price of LNG to customers of the small/ medium facility to achieve breakeven at different levels of IRR. These customers might include tank trucks and bunker vessels as well as ships calling to bunker.

The principal assumptions are those used in the build up of the port cases and are summarised in Table 39 below. Figure 52 shows the breakeven margin for a small and a medium terminal at different levels of IRR.

Table 39 Principal assumptions for small and medium terminal capex and opex.

	Small terminal	Medium terminal
LNG-tank storage capacity	700	50,000
Gross capacity [tonnes]	318	22,727
Net capacity [tonnes]	255	18,182
Tank turnover [times/year]	50	50
Life [years]	40	40
Capital cost, tanks [€]	7,000,000	80,000,000
Capital cost, other [€]	685,000	37,870,000
Total capital cost [€]	7,685,000	117,870,000
Terminal fixed cost [€]	210,000	2,100,000

Terminal availability	100%	100%
Tank operation	0.11	0.11
Delivery cost [€/tonne]	4.65	4.65
Annual opex [€]	165,000	1,650,000

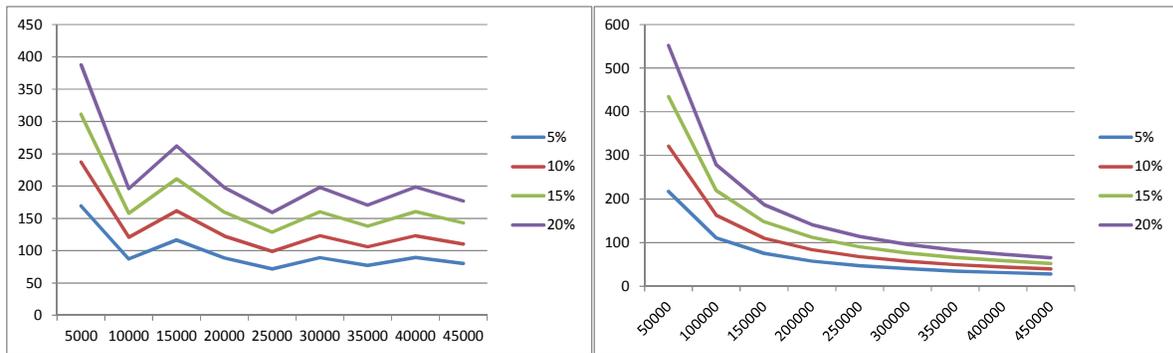


Figure 52 Margin per tonne of LNG (€) required by a small terminal operator with throughputs up to 45,000 tonnes (left hand graph) and a medium terminal operator with throughputs upto 450,000 tonnes (right hand graph) at IRRs between 5 – 20%.

The level of capex is significant and thus breakeven cost is sensitive to IRR as well as throughput. It is noticeable that the small terminal will add additional tanks as throughput rises and hence the costs fluctuate when each further tank is added until throughput rises to make the additional tank fully utilised. In the medium case the facility is not fully utilised and additional throughput would be possible with further reductions in breakeven cost. Demand for LNG makes such levels unlikely though.

9.2.6 Financial Viability of Small-scale Liquefaction

There may be opportunities for small-scale liquefaction facilities to provide LNG to shipping with gas extracted from a national gas network.

The costs of the liquefaction will be relatively high, of the order 150 – 300 €/ tonne. On top of this will need to be considered the procurement of gas. As a strategy for a bunkering facility it may be worth consideration where there is access to low cost pipeline gas. Such cases will need to be considered on a case-by-case basis.

9.2.7 Specific Cases

The foregoing is very general. It will provide a guide to prospective investors in terminal facilities, bunker vessels or trucks on an order of magnitude basis of what an investment might achieve. However, investment costs are very location specific and need to be examined on a case-by-case basis.

9.2.8 Financial Viability of Small Scale Liquefaction

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The costs of the liquefaction will be relatively high, of the order 150 – 300 €/ tonne. On top of this will need to be considered the procurement of gas. As a strategy for a bunkering facility it may be worth consideration where there is access to low cost pipeline gas. Such cases will need to be considered on a case-by-case basis.

9.2.9 Comment

The foregoing is very general. It will provide a guide to prospective investors in terminal facilities, bunker vessels or trucks on an order of magnitude basis of what an investment might achieve. However, investment costs are very location specific and need to be examined on a case-by-case basis.



10 The Financial Feasibility of an LNG Filling Station Network

The demand for LNG from ships and land-based demand for LNG has been examined and the potential for supply from large, medium and small terminals has been examined. The study has then examined:

- how a network of terminals – filling stations – might develop such that supply can meet demand and;
- how a network might develop that is financially viable.

The two key difficulties here are that sufficient filling stations need to exist to provide an adequate network of bunkering points and at the same time sufficient demand materialise to ensure the financial viability of individual terminals.

We consider the development of an LNG Filling Station Network in three steps:

- **Network Model:** The demand for LNG in ships discussed in Chapter 8, the Supply of LNG to Ships discussed in Chapter 6 and the land-based demand for LNG (as described and analysed in Appendix 6) leads to looking at the likely size of the network in 2015, 2020 and 2030 and the LNG that will consequently be consumed using a network development model using an iterative approach to balance supply and demand;
- **Model Results:** We look then from the perspective of individual ports using the standard cases that we have defined of large, medium and small to identify from all the ports within the region how many are likely to have sufficient demand to justify an LNG filling station and if the density of this network is sufficient to meet vessels fuelling needs;
- **Financial viability and development:** the need for financial support to ensure the network is developed to satisfy LNG demand.

10.1 The Network Development Model

In order to analyse how a network of LNG filling stations might develop up to the year 2030 a network development model has been constructed as a tool. The model methodology consists of the following steps:

- **Overall Maritime demand:** the results of the potential maritime demand for each of the years 2015, 2020 and 2030 are used as an input, broken down by demand confined to the specific regions of SECA and non-fixed demand, and analysed separately for each of the 6 fuel price scenarios used in the report.

Based on the LNG price scenarios used in this study, the demand development has been calculated in Chapter 6. In the case when LNG costs 610 €/tonne and MGO 885 €/tonne (Scenario 2), the total demand is assumed to be reaching more than 4.3 million tonnes in 2020. In this case, a significant part results from retrofitted ships, and this demand could be approaching 2 million tonnes already in 2015, refer to Figure 53. However, with respect to possible limitations in retrofitting capacity, it is assumed that total demand in the SECA area starts at 1 million tonnes.

With a higher LNG price (740 €/tonne) as in Scenario 3, the demand development will be slower. It starts at 0.2 million tonnes in 2015 and reaches 2.9 million in 2020, refer to Figure 54.

Further to the total demand, Figures 40 and 41, show the LNG demand from ships that are confined to the respective SECA sub-regions.

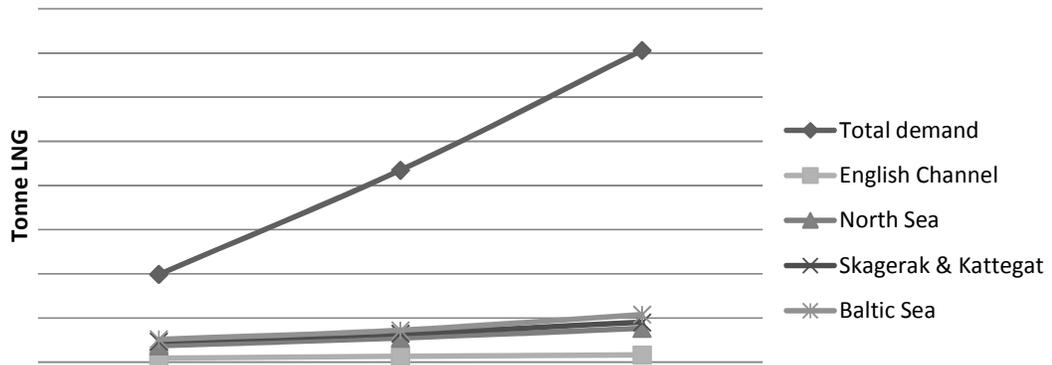


Figure 53 The predicted LNG demand in SECA if price scenario 2 prevails.
Source; AF analysis, 2012

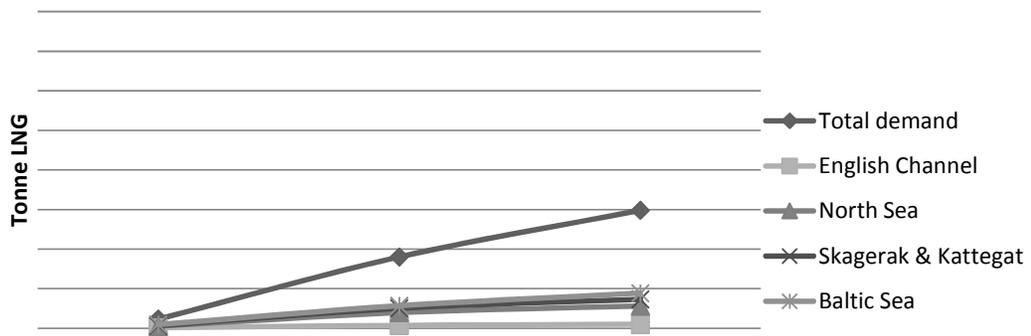


Figure 54 The predicted LNG demand in SECA if price scenario 3 prevails.
Source; AF analysis, 2012

These demand development scenarios are based on that LNG is readily available. Any shortage in supply would of course challenge the demand development.

Table 40 below summarises the LNG demand scenarios (in tonnes of LNG) that are used in the model.

Table 40 The LNG demand scenarios used in the model for 2015, 2020 and 2030.

		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
2015	Total demand SECA 2015 [tonnes]	3,852,183	1,989,651	234,446	3,965,834	2,022,389	251,077
	Non-confined	2,195,221	531,776	12,214	2,296,471	548,485	28,845
	English Channel	120,207	91,828	8,363	120,207	92,153	8,363
	North Sea	454,055	375,704	50,361	463,611	382,630	50,361
	Skagerrak	527,689	470,827	67,914	529,532	474,781	67,914
	Baltic Sea	555,011	519,516	95,594	556,012	524,341	95,594
	2020	Total demand SECA 2020 [tonnes]	5,071,909	4,348,467	1,803,600	5,481,510	4,507,457
Non-confined		2,913,802	2,295,834	258,240	3,252,563	2,407,049	302,589
English Channel		142,457	132,139	71,196	145,543	136,523	71,196
North Sea		595,628	548,752	398,650	645,377	567,781	398,650
Skagerrak		669,748	647,342	506,076	680,296	658,532	506,076
Baltic Sea		750,273	724,400	569,438	757,732	737,573	569,438
2030		Total demand SECA 2030 [tonnes]	7,962,508	7,059,646	2,982,315	8,263,862	7,177,799
	Non-confined	4,881,098	4,142,814	696,181	5,070,275	4,159,761	707,268
	English Channel	176,402	164,828	99,074	179,487	170,296	99,074
	North Sea	842,713	770,516	566,520	924,315	812,631	566,520
	Skagerrak	939,898	902,767	732,455	956,591	927,134	732,455
	Baltic Sea	1,122,397	1,078,721	888,086	1,133,194	1,107,977	888,086

- Land based demand:** from Appendix 6 we have analysed potential land based demand for LNG on a country-by-country basis for 2015 and forward. For countries that have established gas grids it is assumed that land based demand for LNG is from customers connected to the grid and demand will be satisfied by imports to existing and planned large LNG import terminals. For those countries without established gas networks the land based demand for LNG will be met through medium and small-scale import terminals; demand will be smeared proportionately across the terminals that the model identifies as feasible for a particular geographical setting;
- Ship demand:** detailed AIS data on ship movements and categories has been analysed to produce input data for each major category of shipping that is projected to be using LNG in 2015, 2020 and 2030, further categorized by weight. For each of these the annual mileage and annual LNG consumption has been calculated (refer to Appendix 2). Average sizes of fuel tanks have been used to derive annual number of bunkering operations as well as number of calls. The LNG demand this generates is further analysed between ships confined to one of the SECA regions and those not confined.
- Bunkering methods:** the tank sizes of different categories of vessels that are confined have been used to approximate the most likely bunkering method between tank truck (TTS), pipeline (TPS) and ship-to-ship (STS), further broken down by region of the SECA. For tanks up to 100 m³ bunkering

via tank truck would be the most suitable. For tanks between 100 m³ and 3000 m³, ship-to-ship bunkering or bunkering via a pipeline would be more appropriate. However, tank truck-to-ship, TTS, can be suitable up to 200 m³. The proportion of bunkering via pipeline versus ship-to-ship bunkering will influence the overall network development and is one of the parameters of the model on which sensitivity can be applied. Table 40 below summarises the results and input to the subsequent analysis; ships that are not confined are taken as using STS bunkering as they are principally larger vessels⁷¹. A small portion of ships will have tanks less than 200 m³ and will need regular fuelling. This means the supply structure must be such that it can frequently supply small volumes at a variety of specified locations. However, as can be seen in Table 41, the majority (between 66 and 87 %) of ships have tanks between 100 and 3,000 m³.

Table 41 The maritime LNG demand confined to different sub-regions of the SECA and its most suitable bunkering solution.

SECA sub-region	LNG tank size for ships confined to the region	Proportion [% m ³]	Most suitable bunkering solution
English Channel	< 100 m ³	4%	Tank truck-to-ship, TTS
	101 m ³ < tank < 1,000 m ³	58%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	1001 m ³ < tank < 3,000 m ³	8%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	3 001 m ³ < tank < 4,000 m ³	10%	Ship-to-ship, STS
	4, 001 m ³ < tank < 10,000 m ³	20%	Ship-to-ship, STS
North Sea	< 100 m ³	6%	Tank truck-to-ship, TTS
	101 m ³ < tank < 1,000 m ³	68%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	1001 m ³ < tank < 3,000 m ³	14%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	3 001 m ³ < tank < 4,000 m ³	4%	Ship-to-ship, STS
	4, 001 m ³ < tank < 10,000 m ³	8%	Ship-to-ship, STS
Skag/Katt	< 100 m ³	2%	Tank truck-to-ship, TTS
	101 m ³ < tank < 1,000 m ³	74%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	1001 m ³ < tank < 3,000 m ³	13%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
	3 001 m ³ < tank < 4,000 m ³	5%	Ship-to-ship, STS
	4, 001 m ³ < tank < 10,000 m ³	6%	Ship-to-ship, STS
Baltic Sea	< 100 m ³	2%	Tank truck-to-ship, TTS
	101 m ³ < tank < 1,000 m ³	74%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS

⁷¹ The non-confined bunkering demand is assumed to be allocated as follows: 35% in the North Sea, 35% in the English Channel, 20% in Skagerrak & Kattegat and 10% in the Baltic Sea.

1001 m ³ < tank < 3,000 m ³	13%	Bunkering vessel (ship-to-ship), STS or pipeline to ship, TPS
3 001 m ³ < tank < 4,000 m ³	8%	Ship-to-ship, STS
4, 001 m ³ < tank < 10,000 m ³	4%	Ship-to-ship, STS

- **Demand allocation:** overall maritime demand for the selected demand scenario is allocated by the model on the basis of the ship demand and scaled accordingly. Together, the confined maritime demand and the land-based demand add up to geographically allocated demand;
- **Truck numbers:** the model calculates how many trucks there must be in order to carry out the number of bunkering operations that will meet ship types and demand in each geographical area. The model calculates for each sea area or country: how many loads can one single truck manage per week and per year based on rough estimates of turnaround time, that is distances and the time involved for a bunker operation and assuming that end users may be located in the outskirts of each region;
- **Vessel numbers:** the model calculates the annual demand through vessels (1,000 m³, 3000m³ and 4,000 m³). It is built up from the residual confined demand that is not serviced from TPS plus the non-confined demand for the area. The number of single bunker operations required through vessels and the number of possible operations per vessel and year for different areas, results in the required number of vessels;
- **Large terminals:** the model assumes that bunkering equipment is added to all of 10 existing and planned large import terminals and 4 medium sized intermediary terminals as shown in Figure 56⁷². Complementing an import terminal with bunkering services would typically require an investment as presented in Port Case I;
- **Small terminals:** the model then calculates the number of small fillings stations (Case III) that would be required, starting by calculating the annual demand from the <100 m³ tanks and 100m³ <tanks<3000 m³. Here the demand can be more or less depending on whether vessels or onshore terminal-to-ship via pipe-line, TPS, is used. This can be toggled in the model. The model sums the demand through small terminals and gives the number of terminals based on the assumed annual throughput used in the case (50 000m³/year for the small case, Case III).
- **Small and Medium storage:** then, for each truck and vessel, there has to be sufficient intermediary supply as well, thus a structure of trucks, vessels and intermediary storage can be selected. For each sea area, there is a suggested number of small and medium sized storage terminals, vessels and trucks (trucks for maritime bunkering). Then if there is a land-based demand – it is necessary to have an import terminal or an intermediary medium sized terminal in that country. The number of trucks, number of small storage and number of medium vessels (3000 m³) are estimated. As regards small storage, the figure is multiplied with a factor 2, to allow that bunkering can be at either end of the route as a backup in case of delays in the route schedule.

⁷² There are also 42 very small existing import terminals in Norway. These very small terminals does not contribute any significant part of the supply in the North Sea, but are included in the map for consistency.

An illustration of the logistic chain in which the different assets are quantified by the model is given in Figure 55 below. The number of required bunkering operations of different type are brought into an bottom-up analysis quantifying the number of trucks, vessels and storage tanks of different size (from right to left in Figure 55).

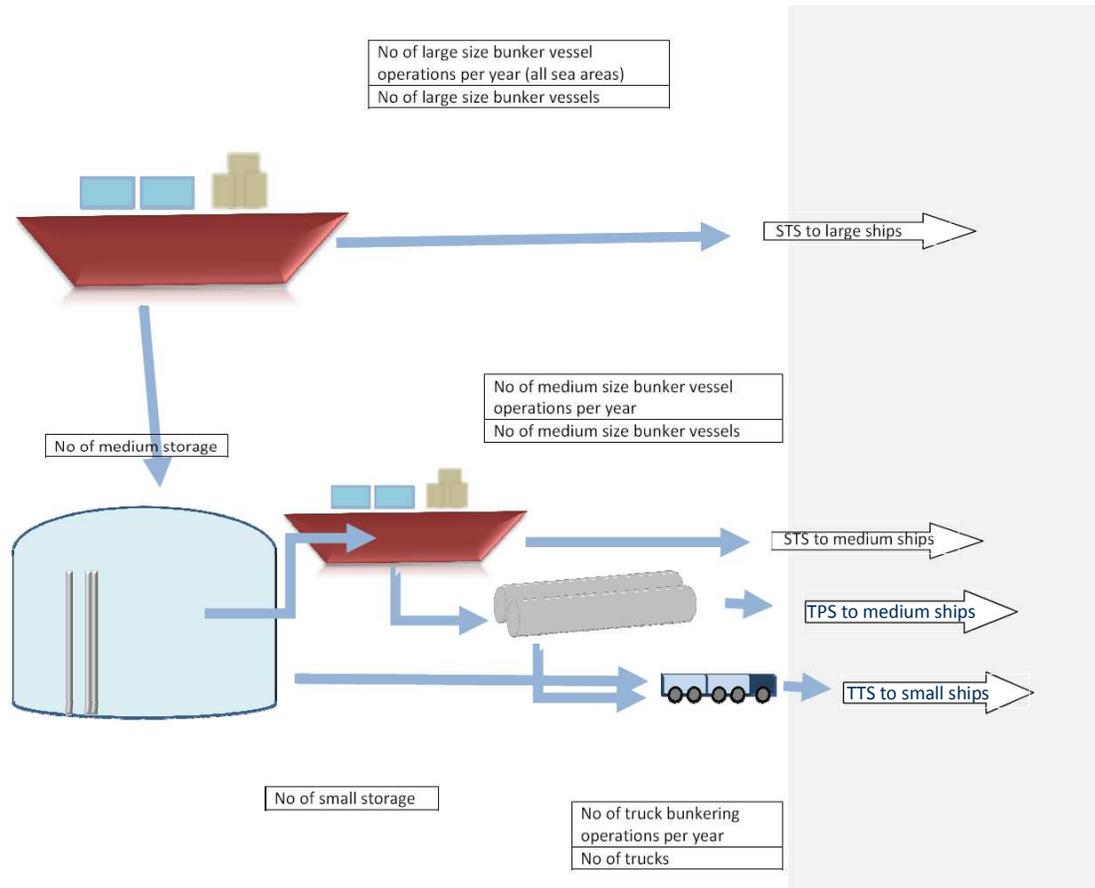


Figure 55 Structure of quantified parts of the supply chain in the network model

- **Equilibrium:** the model can compare infrastructure requirements and overall cost depending on if medium sized vessels (100-3000) with fixed routes (confined demand) will be bunkered via TPS solutions in ports, or via 3000 m³ vessels (at quay or at sea). In the first case, more small-scale intermediary storage will be required. In the latter, more bunker vessels will be required
- **Individual port feasibility:** these quantitative estimates are then checked from a feasibility point of view. The required number of new terminals is calculated as the need as in the earlier steps minus already existing terminals – these are assumed to add on facilities so that they can directly bunker small and medium ships.

10.1.1 Outputs of the Modelling

Results for a feasible LNG filling station infrastructure – the macro view

The structure starts from adding bunkering equipment to all of 10 existing and planned large import terminals, 4 existing intermediary terminals and as shown in **Figure 56**.

In addition to the existing terminals, more new small and medium scale terminals are projected as presented in Table 42. In 2015, the model calculates that 7 medium terminals and 13 small terminals of the kind presented in Port Cases II and III will be required. In 2020, 9 new medium sized terminals and 23 small sized terminals are projected and in 2030 11 new medium sized terminals and 38 small sized terminals.

Table 42 Number of small size and medium size terminals, bunker vessels and tank trucks required to meet the maritime LNG demand in SECA as projected in the central price scenario (Central LNG_ Central MGO).

Year		2015	2020	2030
Maritime demand to be supplied by small and medium terminals, vessels and trucks [tonnes]		1,590,000	3,630,000	6,212,780
Number of terminals	Medium size terminal – Case II	7	9	11
	Small size terminal – Case III	13	23	38
Number of bunker vessels	Bunker Vessel - 1,000 m ³	9	19	28
	Bunker Vessel - 3,000 m ³	1	3	5
	Bunker Vessel - 4,000 m ³		1	1
	Bunker Vessel - 10,000 m ³	1	1	1
Number of trucks	Truck - 50 m ³	5	6	8

The existing and planned LNG infrastructure, along with the estimated marine LNG demand development as presented previously, suggest that the existing and planned storage volumes in the countries bordering the SECA will be sufficient during the initial years. However, a good availability throughout the three seas (Baltic Sea, North Sea and English Channel) will require investments in small and medium LNG terminals, transshipment, i.e. bunker vessels and flexible storage solutions such as bunker barges. Some of these investments may have very low capacity utilization in the first years, thereby affecting the cash flow negatively. The above simplified calculations give the number of LNG filling stations by type and per SECA sub-region as illustrated in Table 43 and **Figure 56** below.

Table 43 The number of existing and new medium and small-scale terminals that will be required in different sea-areas to meet the demand in the central price scenario (Central LNG_ Central MGO)

		Import - existing or confirmed	Medium - existing or confirmed	Medium - new	Small - new
English Channel					
	2015	1	-	-	-
	2020	1	-	1	-
	2030	1	-	2	1
North Sea					
	2015	4	-	1	2
	2020	4	-	1	5
	2030	4	-	1	9
Skagerrak & Kattegat					
	2015	-	1	-	8
	2020	-	1	1	11
	2030	-	1	2	15
Baltic Sea					
	2015	4	3	2	3
	2020	4	3	2	7
	2030	4	3	2	13

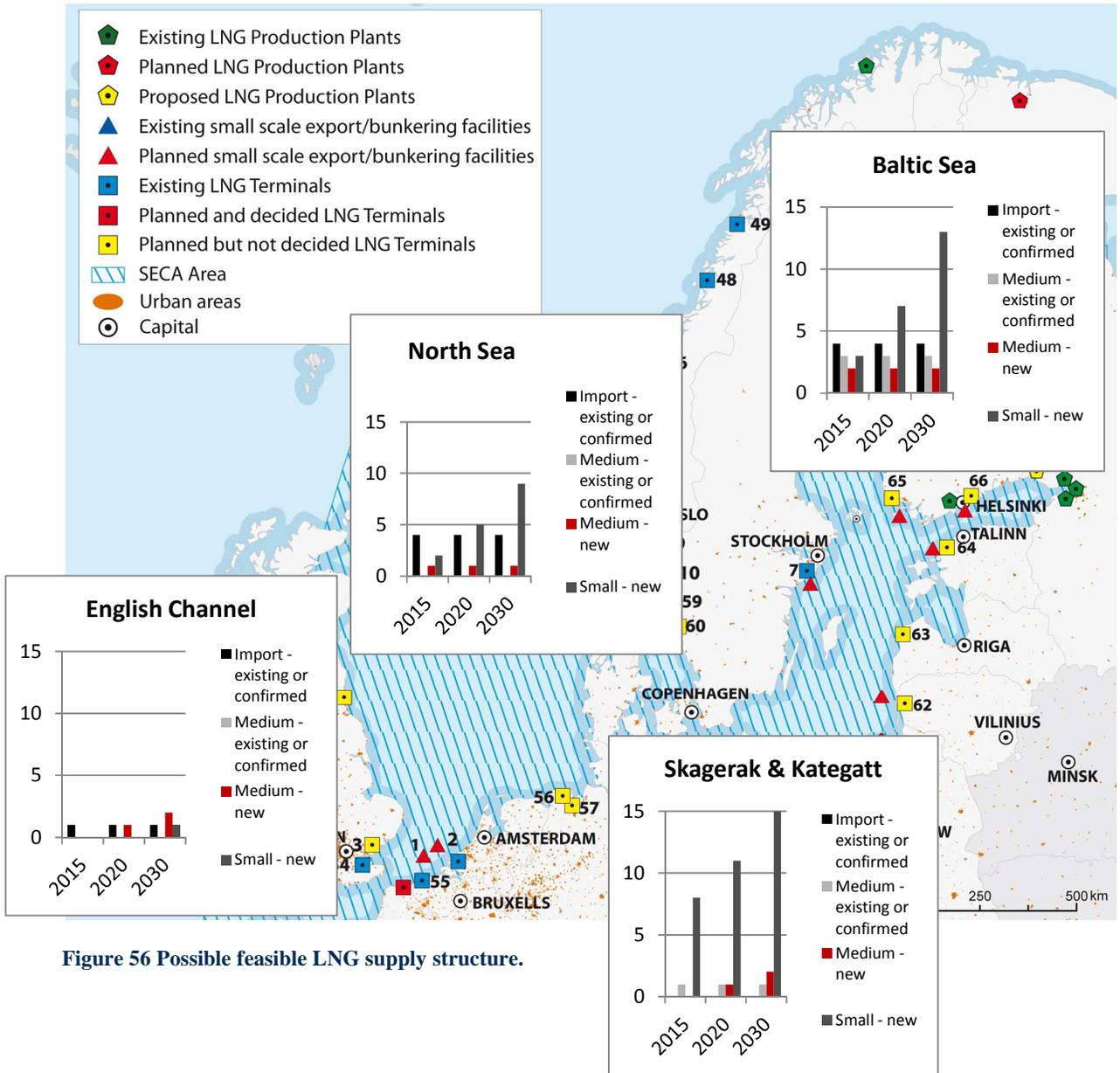


Figure 56 Possible feasible LNG supply structure.

A critical element in the outset will be to cover costs for the bunker vessels that will have to sail long distances for small quantities. Also small terminals will experience low capacity utilization in the outset. In a macro view, their cost can be covered. However, there is a challenge to find operational models and business cases that can retain sufficient cash flow the first years.

The structure in Figure 56 sufficiently meets a demand somewhat higher than as predicted in price scenario 2. In a macro perspective, the costs can be covered by the LNG price being 570 €/tonne, if the import price is 470 €/tonne. That is, the margin needs to be 100 €/tonne. This is lower than anticipated in the individual port cases, implying that optimizing the structure helps pressing overall costs since the overall capacity utilization will be higher.

The infrastructure must develop in a cost efficient way which will include interim strategies, for example starting with mobile solutions, offshore as well as on land ahead of moving to fixed land-based terminals. It can be shown for example that if the proportion of ship-to-ship bunkering can be increased in early years, the number of small-scale on shore terminals can be decreased and the overall infrastructure cost can be kept lower. The example in **Figure 56** above refers to 50% of the medium sized ships being bunkered via TPS (Tank-to-ship via Pipeline) throughout the period. If on the other hand, 80% of the medium sized ship are bunkered via STS bunkering, more vessels and less small-scale terminals would be required and the required margin would decrease, refer to Figure 57.

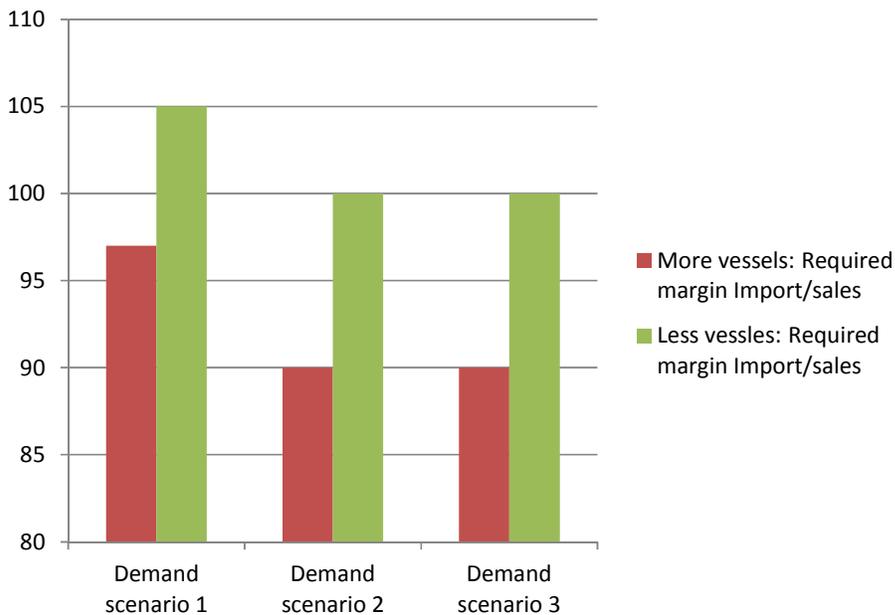


Figure 57 Margin required between LNG import price and LNG bunkering price from a macro perspective and with a sufficient supply structure for the different demand scenarios based on more or less bunker vessels.

The Path of Network Development

The modelling indicates the development of the Northern European LNG bunkering infrastructure will first see existing large import terminals expand their supply chains from land-based focus to also include LNG as bunkering fuel. When the import terminal is located in an area with dense vessel traffic, it is suitable to have the bunkering facilities within the port. Actual developments at Gate, Zeebrugge and Nynashamn support the modelling results.

The advantages of using existing infrastructure are that the import terminal can be used for export of LNG to vessels, and that knowledge of LNG and cooperation among actors are already established. Thereby, the investment in terminal facilities can be kept lower, which have a positive effect on the LNG price.

There is also a need for bunkering facilities in other part of the region, where there are no existing import terminals and production plants. Many ports, for example in the Baltic Sea, Skagerrak and Kattegat, have high-frequency liner shipping services that operate in a limited geographical area. The liner shipping is confined to its route and requires bunker fuel in the area where it operates. Therefore, in this analysis, priority has been given to the ships confined to the four sea sub-regions respectively and that small-scale bunkering solutions, on-shore or offshore must be sufficient to meet this demand; locally and throughout the year.

Other ports, for example on the east coast of Great Britain, have many ship calls as well as high-density vessel traffic passing by the ports, which involves great potential volumes for LNG bunkering of vessels. LNG also needs to be available in these types of ports. Thus, there is a need for complementary LNG bunkering facilities in other parts of Northern Europe, depending on the characteristics of the port, including types and number of potential customers, physical limitations in port, and possibilities to build terminals and infrastructure to store and transport LNG in a safe and efficient manner.

10.2 Network Viability

In the analyzed demand development scenarios, it can be concluded that a large part of the demand will be from liner shipping confined to the different sub-regions of the SECA and on scheduled routes. Tramp shipping and other non-liner shipping that is not confined to sub-regions but that sail in the SECA add to the overall maritime demand⁷³.

In this way, it can be outlined how the supply infrastructure would need to develop in order to effectively meet the medium and small-scale demand in different scenarios, and it can be evaluated if the investments in supply will be feasible or not given their assumed through-put and specified LNG price.

A feasible LNG filling station or maritime LNG bunkering infrastructure development is when demand and supply are in equilibrium. As with most infrastructure investments, there is a benefit of scale and large-scale solutions typically have lower cost per specific capacity. Higher margins at the suppliers' side between LNG import prices and LNG sales prices to the ships allow for a more fine-meshed supply infrastructure, but too large margins will deter ship owners and hamper demand development. Refer to Chapter 7 and to recommendation no. 2.

The individual investors in terminals and bunker vessels will have to investigate the feasibility of a specific case. From the point of view of the individual ports, it is in very few cases feasible to invest in LNG terminals based on solely the LNG demand from ships specifically calling at that port. If there is land-based demand, and if ships from other nearby ports can be served via bunker vessels or trucks, feasibility is more likely.

⁷³ This demand is assumed to be allocated as follows: 35 % in the English Channel, 35 % in the North Sea, 20 % in Skagerrak and Kattegat, and 10 % in the Baltic Sea.

The breakeven throughput for different margins on import prices leads to a picture of the number of ports where it can be feasible to invest in an LNG terminal based on solely the demand from ships calling at this port that are SECA confined.

The large ports in Northern Europe, such as Port of Rotterdam, St. Petersburg and Gothenburg provide significant parts of their bunker volumes to ships sailing outside the SECA. In the order of three times the fuel used within the SECA are provided from the ports in SECA. In Port of Rotterdam, more than 90 % of the bunker fuel is sold to long haul shipping. If IMO regulations will be introduced reducing the sulphur dioxide emissions throughout the world⁷⁴ and if LNG option is a sufficiently low cost option compared to other solutions the feasibility of investing in LNG will higher in these ports.

10.2.1 The Gap between Network Needs and Viable Development

It is important to achieve a cost efficient infrastructure to decrease the costs per m³ LNG by reaping economies of scale, also by considering end-users other than ships. However, strategies to increase capacity in smaller steps to better match supply and demand should be applied where appropriate. This applies to each individual port well as the entire area.

Table 42 summarises the projected number of new medium and small terminals in 2015, 2020 and 2030 under fuel scenario 2. For different levels of IRRs Figure 58 below shows the amount of land based demand that is required on an annual basis for an individual terminal to be financially viable.

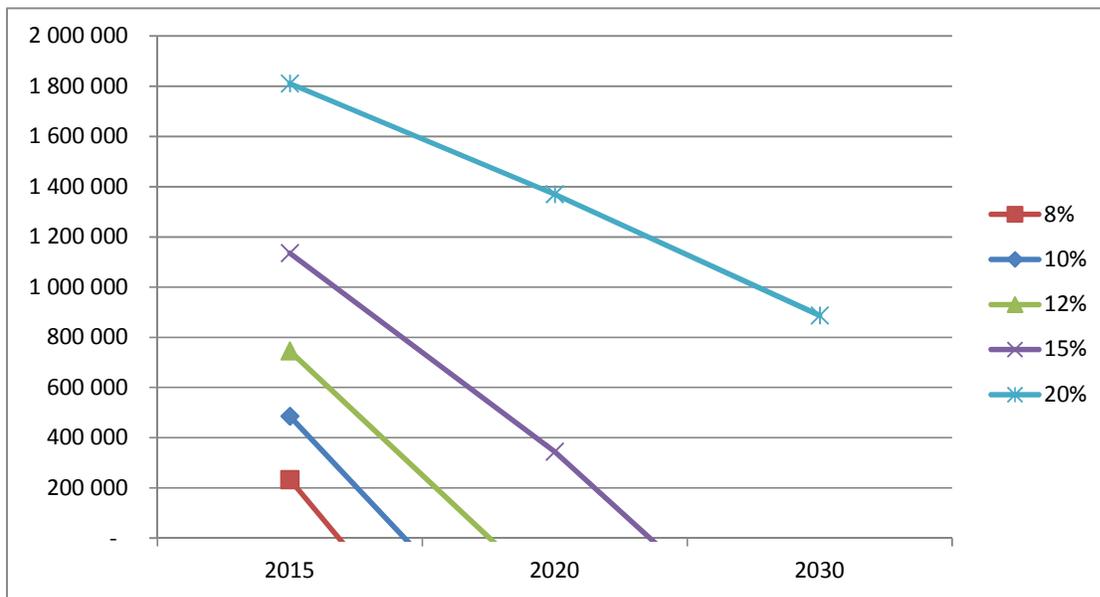


Figure 58 Amounts of non-grid land based LNG demand (in tonnes) required within the SECA for individual terminals to be viable at different IRRs between 8% and 20%.

⁷⁴ It is planned that by 2020, the sulphur content of fuel will be limited to 0.5 % throughout the world.

The land based demand, which will go through the small and medium terminals, falls significantly if investment in terminal infrastructure requires IRRs of 5% or below. Compared to the projected land-based demand in the countries without extensive natural gas grid networks, the land-based demand will be sufficient (160 000 tonnes in 2015, 400 000 tonnes in 2020, and above 3 million tonnes in 2030). This implies that investors in small and medium terminals may have to accept less than 8% in 2015, but already in 2020 the IRR can be above 15%.

10.2.2 Financial Viability

The indicative IRRs on small and medium terminal investment are low, particularly in the early years as throughput builds on the back of growing demand.

Bunker vessels can confer great flexibility on the development of the network by providing flexible and mobile bunkering solutions. But a critical element in the outset will be to cover costs for the bunker vessels that will have to stand idle for part of their time until demand builds. In a macro view, their cost can be covered. However, there is a challenge to find operational models and business cases that can retain sufficient cash flow in the early years.

The recommendations could present cases for co-financing or for soft loans. Loan financing with payment holidays or periods of grace could be helpful in the early years of an investment while demand builds to sustainable levels. The economic equilibrium model indicates cumulative investment of €1.2 billion required by 2015 and €1.8 billion by 2020.

10.2.3 Land-based Demand

From the analysis above it can be realised the importance of land-based demand for the development of an LNG bunkering infrastructure. The total demand of LNG in SECA is forecasted to increase by 140 % over the period up to 2020, from 39 bcm to 93 bcm (29.5 million tonnes to 70.5 million tonnes) as gas production within the region declines. The largest increase is expected in the United Kingdom, followed by the Netherlands, Germany and France. A major change during the period is that only three countries within SECA were importing LNG in 2010, while all countries except Norway are expected to be importing LNG by 2020.

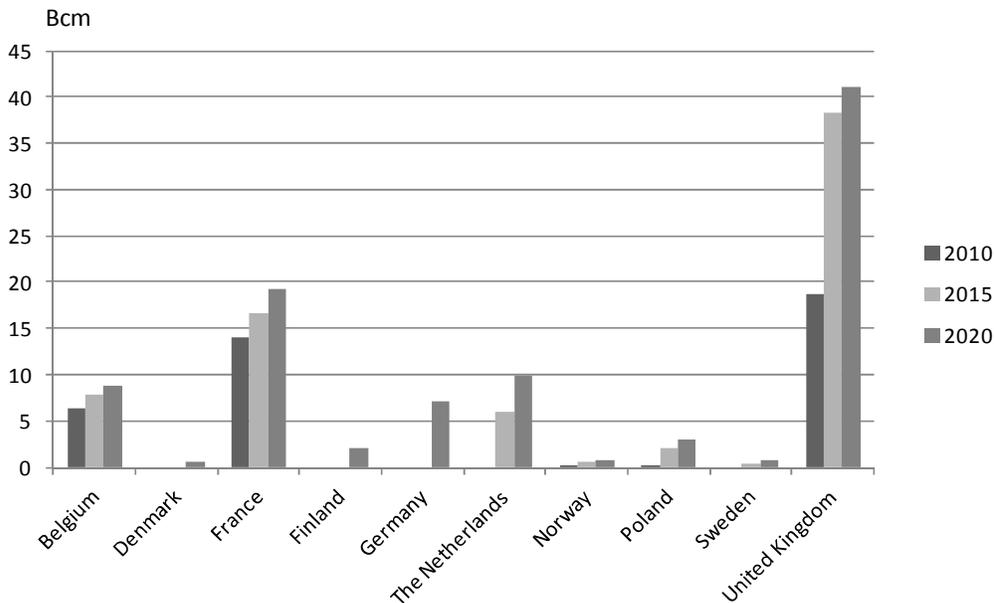


Figure 59 Forecast of LNG demand in SECA 2010, 2015 and 2020, Bcm

Source: AF, 2011, Gasnor 2011.

This growth in LNG importation is the principal driver behind the expansion in the number of LNG terminals presented at section 2.1 and figure 2. The regasified LNG will be primarily fed into national gas networks. There will be opportunities for land based LNG demand to be fed by small and medium terminals in areas that are unserved by national gas networks, most notably Sweden and Finland. This has already developed in Norway. A detailed presentation of forecasted land-based LNG demand is made in Appendix 6.

10.3 Conclusions

A feasible infrastructure will rely on existing import terminals constructing bunkering jetties for LNG fuelled vessels along with their other constructions.

The most important initial demand is likely to be the liner shipping with fixed routes and relatively small tanks, especially in the Baltic Sea and Skagerrak & Kattegat. Therefore, it will be important for the feasibility to capture and met this demand as early as possible as the sulphur regulations are introduced.

Supplying a scattered fleet based on the large import terminals and a few bunker vessels is only possible if small and intermediary storage tanks or bunker barges can buffer LNG for bunkering and if appropriate bunkering facilities are arranged at these sites. Even so, in the initial years, careful planning and optimization of supply patterns is required in order to avoid unnecessarily long transshipment or truck journeys for small quantities.

The small and intermediary terminals will in most cases be feasible only if they can also benefit from a land-based demand loads in the vicinity such as industries or energy companies with a natural gas demand. It will be important for the individual ports authorities and terminal investors to investigate and under-pin the local land-based market for LNG and to negotiate the import prices with the supplier in order to make business feasible.

11 Operational Models for Terminals

In the preceding sections it has been shown what might be financially viable in terms of individual ports/terminals and of overall development of an LNG filling station network. That does not mean that this infrastructure will necessarily be built; financial viability is a necessary but not sufficient condition. In addition the business model for the LNG bunkering process will need to be considered, investors and financing will be needed, clarity that the principal risks those investors face can be mitigated and that any institutional barriers can be overcome. We consider these in turn:

- Stakeholders
- Business Models
- Financing
- Investment Risks and Risk Mitigation
- Institutional Development.

11.1 Stakeholders

Important stakeholders for the development of an LNG filling station infrastructure in Northern Europe include the potential investors in LNG terminals and maritime supply infrastructure are important, i.e:

- Terminal Operators (TO's);
- Bunker vessel operators
- Port Authorities; and,
- Storage System Operators (SSO's).
- Investors in gas supply infrastructure are important, including:
 - Gas suppliers;
 - Transmission system operators (TSO).

Furthermore, the shipping industry and its administration are also stakeholders:

- Maritime administrations in Northern Europe;
- Classification societies;
 - International Association of Classification Societies (IACS) members;
 - Non IACS members.

Other stakeholders include municipalities around the potential terminals, and the general public.

Banks and financial institutions play a central role as well in the establishment of an infrastructure, since it is a long-term investment. Natural gas markets are gradually shifting into increasingly open markets due the possible transportation of LNG, which implies that new business models and model contract agreements may develop. In this context, it is important that the suppliers understand the prerequisites of the shipowners when turning to them.

One key aspect of this study is to facilitate the interaction between different stakeholders and their different perspectives on the infrastructure development. It is important to interact regularly around the challenge of transferring the shipping industry in Northern Europe into a more environmentally concerned activity. Especially when regarding such a complex issue as the establishment of a new infrastructure.

In this report there are recommendations that are specifically addressed to certain central stakeholders. Apart from the specific issues brought up in these recommendations, a general recommendation must be to recapitulate and spread lessons learned on a regular basis and to create fora for interactions.

11.2 Operational Models

11.2.1 Ports and Terminals

There are many different models of port and terminal operation and ownership across the region. It is most common that a port authority is municipally owned or managed. Cargo-handling and stevedoring activities fall mainly into the responsibility of private operators who lease areas from the port company. The port companies have a large degree of freedom in setting lease fees. Generally service tariffs are decided by the private operators without interference from the port authorities. Reference tariffs have to be published, but they can be confidentially negotiated with the users. Bunkering services are also predominantly the responsibility of private operators, and service providers set bunker prices according to market conditions.

The components of an LNG bunkering port are shown in Table 27 below together with the parties that can provide those components. From this it can be seen that there is no standard model, but that the development of any LNG bunkering facility will require participation and collaboration between port authorities, gas shippers and private sector bunkering companies.

Table 27 Provision of the major components in the LNG bunkering supply chain in the region.

Component	Provider/ Operator
Port external structure (external breakwaters, sea locks etc)	National Government or Port Authority
Port internal structure (internal quays, jetties and locks, shared access routes)	Port Authority
Land for siting of storage and terminals	Port Authority
Jetty/ quays serving the LNG storage, both loading and unloading	Port Authority or Terminal Owner/ Operator
LNG terminal and storage	Terminal Owner/ Operator
Feeder vessels and barges	Bunkering Service Providers
Tank trucks	Terminal Owner/ Operator
Berths	Port Authority or Terminal Owner/ Operator
Anchorage	Port Authority

For port authorities the majority ownership and control rests with the local municipality in many cases although this takes many different forms with Port Authorities ranging from departments of the municipal government to autonomous companies with shareholding. Regional and national government also feature in some ownership models.

11.2.2 6 Specific Examples

The study has had cooperation from a number of port authorities and summary details of the business models for 6 of them illustrate the range of business models in use in the SECA region. More detailed information is presented in Appendix 7.

Zeebrugge

The Port Authority is responsible for major infrastructure such as the construction of quay walls and jetties, terrain, paving and road works. The maintenance of this infrastructure also lies within its competence.

Land areas within the port are given to private operators through concessions. The private companies load and unload their clients' ships and offer storage facilities. In addition to the concessions, the Port Authority has two other main sources of revenue: the duty on vessel tonnage and the duty on a vessel's cargo.

A public private partnership of Fluxys, Flanders and the Port of Zeebrugge has been established to finance the LNG Terminal project.

Hirtshals

In relation to the establishment of an LNG terminal, the Port of Hirtshals is cooperating with the Norwegian gas company Gasnor, with whom it has signed a letter of intent concerning future plans. Gasnor will own and operate the LNG terminal and will deliver LNG to the terminal with its own ships (similar to the system at Gasnor's existing LNG terminal in Norway). As operator, Gasnor will manage the LNG terminal and sell and deliver LNG from the terminal to the end user.

Szczecin and Swinoujście

External breakwaters are the responsibility of the national government, internal docks, quays and jetties are the responsibility of the port authority. Cranes, gantries, pontoons are either leased to private operators by the port authority or built by them.

For prospective terminal investors Szczecin and Świnoujście Seaports Authority provides access infrastructure, including quays, roads and rail tracks, as well technical infrastructure (electricity, telecommunication, water, sewage, etc.). Additionally, the port provides land designated for preferential long-term lease. At the same time, the Ports Authority offers its support for project development.

Responsibility for the LNG terminal in Świnoujście is distributed as follows:

- Polish LNG (PLNG) – overall project, terminal operator, shore regasification terminal;
- Port Authority Szczecin-Świnoujście – quay owner, mooring, ship platform, linesman;
- Maritime Office in Szczecin (Polish Maritime Authority) – exterior breakwater, navigational issues, VTS, markings, navigational safety.

The LNG project will be executed by four entities as defined in the LNG Terminal Act namely:

- Polskie LNG – Construction and subsequent operation of the LNG terminal;
- Maritime Office in Świnoujście – construction and subsequent maintenance of infrastructure to ensure access to the external port, including a new breakwater plus overall maritime traffic control;

- Szczecin and Świnoujście Seaports Authority – construction of port infrastructure, including a special berth/jetty for the LNG carrier ships infrastructure and subsequent handling of the LNG carriers within the new harbour and jetty areas;
- GAZ-SYSTEM – construction and subsequent operation of the approx. 6 km connection gas pipeline and 74 km gas transmission pipeline connecting the terminal with the transmission grid and coordination of the LNG project.

The pipeline to connect the terminal to the Polish gas grid is to be co-financed by the EU (European Energy Programme for Recovery) and GAZ-SYSTEM

Private operators that use land and other facilities within the port are charged fees or lease rentals by the port authority. Private operators are free to set their charges to customers according to market conditions. Vessel operators are charged by the Port Authority for tonnage dues, quay dues and passenger dues according to tariffs set by Port Authority.

Rotterdam

The Port Authority is owned jointly by the municipality (70%) and Government (30%). External structures are a shared responsibility between Port Authority and Government. Port infrastructure (quays, jetties, internal locks and shared roads and pavements) is the responsibility of the Port Authority while the private sector port provides services of cargo handling, technical and nautical services and provides the port superstructure (warehouses, cranes, gantries, pontoons and terminal buildings) related to that.

The GATE (Gas Access To Europe) Terminal is located on the Maasvlakte in Rotterdam and is the first import terminal for liquefied natural gas in the Netherlands. The terminal consists of three storage tanks and two jetties. The founding partners of the GATE terminal are Royal Vopak N.V. (Vopak) and N.V. Nederlandse Gasunie (Gasunie). The partnership brings together the product expertise of gas in Gasunie and the tank terminalling storage expertise of mass liquid products of Vopak. The current capacity is contracted to four customers, Dong Energy, EconGas, E.ON Ruhrgas and Essent.

Vopak and Gasunie are developing a small-scale LNG facility at the Port of Rotterdam as a spin-off from GATE Terminal. This includes creating infrastructure to enable (re)loading for new LNG markets. Vopak and Gasunie aim to facilitate the small-scale LNG services. Small-scale LNG is described as the distribution and consumption of LNG in small volumes (volumes from 50-20,000 m³) via break bulk activities. Break bulk activity is the process of loading LNG from a (large) LNG terminal (e.g. Gate) into LNG break bulk vessels of 7,500-20,000 m³ and LNG bunker barges from 500 up to 1,000 m³ and 50 m³ trucks. The capacity is estimated to be around 3 million m³ LNG for barges and sea going vessels plus 100 000 m³ for trucks.

Gothenburg

Generally in Sweden two models of seaport governance co-exist. A small number of seaports have a traditional structure, where the municipal port management is separate from the stevedoring company. Several seaports are administered (in whole or in part) by municipally owned corporations referred to as "Port Authorities", which also provide cargo handling services.

A Port Authority may own both the land and its facilities, own the facilities but rent the land, or rent both from the municipality. The industry-owned ports are usually owned by one or more industrial companies and mainly handle the owners' products. In general, all ports in Sweden operate under market conditions and are subject to the Swedish Companies Act.

In February 2010, the company “Göteborgs Hamn AB” was divided into one municipally owned company (Göteborgs Hamnbolag AB) and three terminal companies run by external operators.

Göteborgs Hamnbolag acts as the Port Authority / Landlord and is responsible for the infrastructure of the port. As the Port Authority, the Port of Gothenburg will:

- Facilitate the real estate and quays;
- Facilitate the infrastructure;
- Support ship-to-ship LNG bunkering by developing regulations;
- Facilitate the exchange of knowledge (bunkering, procedures and safety);
- Market LNG as a ship fuel;
- Provide port tariff incentives.

The three terminals are the Skandia Container terminal, the Älvsborg Ro-Ro terminal and the Gothenburg Car Terminal. The new owner of the Älvsborg Ro-Ro terminal are DFDS and C.Ports (a sister company of the Belgian shipping company Cobelfret), while the new owners of the Gothenburg Car Terminal are Logent AB. The Skandia container terminal has recently been bought by APM Terminals, a member of the Danish group AP Moller-Maersk.

Gothenburg Energy (GE), in cooperation with the Port of Gothenburg, called LNG GOT, is trying to introduce LNG as a ship fuel in Gothenburg. A new terminal with a planned volume of 10,000 m³ will be built. Their main objective is “to construct a terminal which will be able to receive deliveries of liquefied natural gas for further delivery to bunker boats which will supply the vessels.” The planned LNG terminal will be located at Skarvikshamnen and use the existing quay. Today, Skarvikshamnen is among other things an oil and gas depot for PREEM. The structure of the new terminal has not yet been finalised but Gothenburg Energy will most likely be responsible for investment in the terminal itself while the Port of Gothenburg will make the land and quays for the terminal available. The Port of Gothenburg will also make the investments for rebuilding and dredging the quay.

Nynäshamn

The Port of Nynäshamn is a fully owned subsidiary of the Ports of Stockholm. The Ports of Stockholm is owned by the City of Stockholm. The LNG terminal is the first in Sweden and is for unloading LNG from vessels and storing LNG. The terminal is owned by AGA GAS. Plans exist to upgrade the Nynäshamn terminal to make it possible to unload LNG to bunkering vessels for fuelling other vessels. This will be a relatively small investment compared to the initial investment, which was valued at around € 150,000.

From these general business models of port operation it is considered in turn:

- how existing bunkering services are provided across the region and then;
- how existing and planned LNG terminals have been developed

Based on this the discussion then examines the Business Models that need to be considered for an LNG filling station network.

11.2.3 Bunkering Services

The study has considered the business models that exist for HFO and MGO bunkering in the region. 4 general models can be described:

- Port based models: the bunkering service provider owns storage tanks and jetties for bunkering, often supplemented by barges which the provider may own or charter;
- Regional models: the bunkering service provider operates a fleet of bunkering vessels to ships over a region that is within range of its vessels, the provider may have storage tanks and jetties in more than one port; the bunkering vessels can be owned or chartered;
- Filling station models: the bunkering service provider has anchorages that he leases from a port authority and which are then serviced by barges or feeder vessels which the provider may own or may charter;
- Trader models: the bunkering service provider will source fuel to the customers' requirements and charter a bunkering vessel to deliver.

In the first case the international oil companies, or specialist subsidiaries thereof, are heavily present, for example Lukoil, Rosneft (RN-Bunker), Gazpromneft, plus specialist firms such as Vopak AppliTek and Simon. In the second and third cases some of the main providers are specialist private sector bunkering companies, for example: North Sea Group, Oliehandel Klaas de Boer, OW Bunker, Falmouth Oil Services, Whitaker and Atlas. Examples of the fourth case would be Cockett Marine Oil and Cargill ETM.

11.2.4 LNG Import Terminals

LNG import terminals are different from pipelines as there is no one-to-one relationship with the source of supply, but rather a multiple-to-one relationship – global regasification capacity is more than twice the liquefaction capacity, a ratio that is generally expected to continue. Their flexibility is their main advantage but could also prove a drawback, as illustrated by the 10 % utilisation rate of the US terminals in 2009. Thus, the era for LNG supplies dedicated to one market/terminal is coming to an end and being replaced by an era with a mixture of relatively flexible LNG destined for liquid markets or held by aggregators⁷⁵.

Financing, or even the construction of regasification terminals, depends on how sponsors are integrated in the LNG value chain and how they plan to utilise this capacity.

- The first case is the historical one of an LNG terminal built by the purchaser of the LNG and underpinned by a long-term contract and by the buyer's demand. That would be the case of LNG terminals in emerging markets such as China, but also in Europe (Rovigo, Italy). The buyer can have a share in the liquefaction project to help it move forward.
- The second case would be the terminal built by an aggregator (such as ExxonMobil, Shell, Total, BP, BG, GDF Suez, Repsol or Gas Natural) to take advantage of arbitrage opportunities – ideally, such terminals would be in different regions. To date they have essentially been spread between Europe, the United States and India. Such terminals would be built typically in the most liquid markets; these terminals, however, also have physical limits and are unable to absorb unlimited volumes.

⁷⁵ An aggregator is a party that combines the demands of several customers to contract for the supply of gas, or in this case LNG.

- The final option is for a private company / firm – in some cases the unbundled TSO76 – to build a terminal and fund it, underpinned by long-term binding agreements with users: GATE in the Netherlands and the Isle of Grain (UK) are examples of such terminals.

Zeebrugge, Swinoujście, Gothenburg and Nynäshamn all follow this model, but also with close cooperation or partnership with the local port authority who takes responsibility for provision of land and construction of some infrastructure.

An interesting development is that of floating regasification and storage units (FRSU) and LNG regasification vessels (LNGRV), due to shorter lead times and lower investment costs than land-based terminals. In SECA there are plans to establish an FRSU in Klaipėda, Lithuania and Port-Meridian in the United Kingdom.

11.2.5 Tariffs and Payments

The basis of charging between the different elements in the ship fuel bunkering chain are:

- For lease of land for terminal and storage facilities – annual lease payments for the term of the lease that are set by port authorities; there is competition for the market if not in the market;
- For berthing, harbour dues and tonnage dues – set by port authorities with a set of tariffs published; there is competition between ports and because ports play a wider role in regional economic development there is an incentive for charges to be kept low ;
- For fuel – for HFO and MGO the market is competitive and transparent, bunker fuel providers are free to set their own prices and these are not regulated by ports (the issue of LNG prices as a bunker fuel is discussed further later in the section).

11.2.6 Business Models for LNG Filling Stations

From the discussion above the business models that look most relevant for the different elements in the LNG bunkering supply chain are likely to be:

- **Terminal site and quays** – this is provided by port authorities to terminal owners on a lease basis in return for annual lease payments;
- **Large terminal** – the one example of an bunkering facility in the region so far (at GATE, Rotterdam) is being developed and financed by the joint owners of the existing main terminal, one of whom is a national gas company and the other a major operator of fuel storage and transshipment facilities; they will lease land from the port authority. This is the model foreseen for Nynäshamn as well;
- **Medium/ Small terminal** – examples so far see energy companies, alone or in joint venture, leading the development acting in coordination with port authorities who take responsibility for construction of supporting infrastructure
- **Feeder vessels** - the bunker industry model has seen feeder vessels owned by specialist bunkering service providers who may also own port storage facilities for HFO and MGO; such vessels are also available to charter to fuel traders and to bunker service providers who do not own their own vessels.

⁷⁶ Transmission System Operator

In Norway vessels are contracted on charter to Gasnor but they are owned by Antony Veder. Antony Veder has also ordered a new LNG carrier with a cargo capacity of 15,600m³ which will be long-term time chartered by Skangass AS..

- **Tank trucks** – tank trucks generally appear to be owned by truck transport companies. This is the case with AGA gas who use tank trucks that are provided by a truck transport company, although the LNG tanks themselves are owned by AGA.

Feeder vessels are an important component of the bunkering supply chain. At present it is not clear that the specialist providers that serve the HFO and MGO market see an opportunity in LNG, whereas the companies that invest in LNG terminal capacity so far are not investors or operators in bunker vessels. The same situation would appear to apply to tank trucks where the companies investing in the large-scale terminals are not present in truck distribution.

11.3 Financing

It has been recognised at several points in the analysis of demand and supply that demand will only fully materialise if adequate supply exists, conversely the supply will only materialise if developers of the supply infrastructure are sure that the demand will materialise.

This conundrum is common in major infrastructure development, particularly in the energy sector. It is useful to consider some examples from elsewhere in energy infrastructure to illustrate how the mutual and reciprocal uncertainties over demand and supply can be overcome and how these might apply in the specific case of a network of LNG bunkering points within SECA.

These alternatives might be categorised as:

- Public
- Contractual
- Incremental;
- Merchanting.

11.3.1 Public Investment

There are three cases where public investment might be appropriate and necessary.

A basic network of LNG filling stations and/ or LNG bunker vessels will need to exist (or be concretely planned) to give shipowners the confidence to proceed with LNG conversion or new build. The early stages of this network might need to be financed ahead of firm demand for LNG being apparent. This would be an appropriate role for public sector financing, either in the form of co-financing, soft financing, financial guarantee mechanisms or some combination thereof.

As has already been highlighted in the discussion of business models port authorities have been participating in the medium and small-scale LNG terminals that are already planned or under development in the region by providing necessary quays and other port infrastructure, supplemented by national government providing external infrastructure in some cases. This is an appropriate support to maintain the competitive position of the port in its wider economic development role.

For small-scale LNG import facilities in areas otherwise un-served by any gas distribution network and there could be a case for an argument of public benefit. A municipality or regional government might support

investment in such circumstances. The argument would extend though to the incremental costs of the infrastructure necessary to bunkering shipping from that facility.

11.3.2 Merchancing

The bunkering industry at present is characterised by merchancing, that is the providers of bunkering services compete in the market place to supply ships without the benefit of long term contractual arrangements. Investment in storage facilities and bunker vessels is made to meet demand that is perceived to exist by investors and operators but without firm contracts generally in place. However individual investments are small in relation to the overall bunkering market in the region; the market is mature and transparent. This will not be the case for LNG terminals serving the bunkering market.

The power market can illustrate the issue. Privately financed merchant plant have appeared in the international power industry but they have been the exception rather than the rule. They have appeared where there has been a properly functioning and highly transparent wholesale electricity market with predictable demand. The merchant plant needed to be able to demonstrate that it would be cost competitive against existing generators. The market would need to be liquid and all players would need to be able to see market prices. These factors together could be used to convince financiers that the plant output could be sold at prices which covered costs in the medium to long term.

The example is useful as it illustrates the conditions that will need to be present for investors to consider developing LNG bunkering facilities on a merchant basis, that is without contracting customers in advance. It is expected that those firms that are already substantial players in the supply of bunkering fuels might take the view that the potential demand is sufficiently transparent to them because of their existing customer base in the shipping industry, and their presence in the market sufficiently strong, that they are prepared to take market risk.

11.3.3 Contractual Bases

In most cases though it can be expected that the investors and customers could align their interests and create the necessary certainty to allow investment to proceed through contractual arrangements, as has been commonplace in power generation and LNG gasification. This would see major shipping customers agreeing to purchase minimise volumes of LNG over a period of years from a particular bunkering point and in return infrastructure investors agreeing to provide and deliver fuel at the agreed price. The period is likely to be long enough to give comfort to both parties that their respective investments in the shipping and the supply infrastructure will be paid for. The price is likely to be flexed in line with competing fuels and the price of LNG at the hub.

There will be few customers whose usage will be sufficient to guarantee the volumes necessary to give necessary assurance to investors and to their financial backers that the demand uncertainty has been removed. Customers that are aligned to regular routes will be able to predict their usage with confidence, RoRo, RoPax, liners and vessels such as tugs and fishing vessels might fall in this category. Some of these customers will need to be banded together to provide the necessary commitments on volume to allow investment to proceed. This is not uncommon; it works best where there is one dominant customer who can provide “base load” and smaller players can be added to top up the demand. The dominant customer can take the lead in putting the necessary contract conditions in place with smaller players essentially being takers for what the largest players have negotiated.

Little major infrastructure is financed directly by investors. It is usual for the financing burden to be shared with banks, commonly through a non-recourse financing mechanism – project financing. This makes

essential the need to have contracted customers to a level that will justify the investment and take away the uncertainty of demand.

Contractual bases have been used extensively in power generation, in gas transmission and, perhaps most topical, in the development of LNG gasification plants themselves. In the case of the initial LNG plants around the world they have been financed on the basis of long term (10-12 year) take or pay contracts with customers for the LNG. In turn the LNG has been used in power generation where the power plant will have a long term take or pay contract for the sale of its power to a utility. The utility can take demand risk in these cases because first its customer base is wide, stable and diverse and second because contracting for the output of one power plant will be only incremental in the scale of its overall operations. On both grounds the risks for the utility are small and manageable.

11.3.4 Incremental Investment

Established players might be more willing to invest where there are existing LNG import (or export) facilities. Here the investment in the additional infrastructure to allow bunkering of ships is greatly reduced and might allow investors to have additional confidence to adopt a merchanting view of their market, that is that the potential demand is sufficiently large when weighed against the demand necessary to cover costs that they are prepared to take market risk. GATE at Rotterdam and Nynäshamn illustrate the point.

These two are not mutually exclusive and those locations that enjoy substantial bunkering traffic and have existing LNG facilities will have the most favourable conditions for investors to take market risk both because the demand is more transparent to them and because the costs on investment are diluted.

11.3.5 Summary

From this we can see a likely path of potential network development;

1. Major bunkering ports with existing or planned LNG facilities – merchant investment;
2. Bunkering ports within range of bunkering vessels from (1) – merchant investment;
3. Ports with substantial captive traffic – RoRo, RoPax, liners, supply vessels, fishing, tugs – it could be expected that investment would proceed on the basis of contracted demand;
4. Ports with modest captive traffic but strong land-based demand – contracted demand;
5. Bunkering ports without nearby LNG – on a merchant basis but only a level of basic demand has been established across the region.

Investment in LNG bunkering infrastructure is expected to be private sector financed in the main although some port authorities are expected to initiate projects and there is a case for public financial support in the early stages of network development.

Terminal development in Europe has been underpinned by firm demand from customers (except in the case of aggregators). This is in common with other forms of infrastructure development where it is usual for the infrastructure developer to enter into firm contracts with prospective customers ahead of investment. In turn this gives a firm revenue stream which then facilitates financing of the project. There is scope for this approach to be used to progress individual port filling stations that can identify sizeable creditworthy customers who would be prepared to enter into contracts for the delivery of LNG ahead of investment. This will work for shipowners as well who could have a contracted source of LNG ahead of building or retrofitting vessels to use LNG. Stakeholder co-ordination and cluster groups would help coordinate between prospective investors and shipowners here.

11.4 Investment Risks and Risk Mitigation

Investors, be they from the public or private sector will face significant investment risks. The study has analysed the principal risks faced by a prospective investor in an LNG filling station and the means available to mitigate those risks which can be summarized as Table 44.

Table 44 Financial risks and risk mitigation.

Risk		Risk Mitigation
Construction	Project is built to time, cost and performance specification	EPC ⁷⁷ contract for construction or ship mounted temporary solutions
Volume	Demand from customers materialises	Contracts with "lead" customers and/ or ship mounted
Supply	LNG can be procured to meet demand	Back to back contracts ⁷⁸ with shippers/ importers
Gas quality	LNG meets customers' specification	Back to back contract with shipper/ importer
LNG Selling Price	LNG can be sold at a price to cover costs	Long term contract ⁷⁹ , indexed to HFO/ MGO
LNG Cost Price	LNG can be procured at a competitive price	Long term supply contract, indexed to HFO/ MGO
Operating risk	Terminal can be operated and maintained properly	O & M contract ⁸⁰

There are opportunities to support investment through structured guarantee products, that is for policy makers to make guarantees available to prospective investors to effectively insure against some of these risks

There are a comparable set of risks for shipowners that also need to be considered if the circularity and reciprocity between demand for fuel and availability of fuel is to be resolved.

As has been discussed, in other forms of infrastructure development it is usual for customers to contract with the infrastructure developer who then facilitates financing of the project. There is scope for this approach to be used to progress individual port filling stations that can identify sizeable creditworthy customers. Because it is unlikely that any single ship operator could guarantee the throughput for financial viability it is to be expected that a number of operators will need to be contracted to allow a particular project to proceed. It is believed that to help the necessary linkages and understanding of the opportunity that exists for co-ordinated action there is a strong case for fostering Stakeholder co-ordination and cluster groups.

It is worth noting that LNG powered ships built up to now or presently under construction have not been financed on ordinary market conditions but with support from the Norwegian NOx-fund⁸¹ or support from

⁷⁷ EPC is a contract for engineering, procurement and construction that transfers all the cost and performance risks of constructing a plant to a contractor.

⁷⁸ Back to back are contracts entered into by a party for the purchase of LNG from a supplier and its sale to a customer or customers such that the terms of each contract are carefully matched and the party in the middle then carries little or no risk

⁷⁹ Long term contract in this context means a contract whose duration matches or exceeds any financing used in the project, typically 12-20 years.

⁸⁰ O&M is a contract for the operation and maintenance of a plant that transfers all risks of operating and maintaining a plant to a contractor.

national governments and the EU. However, the way ahead is not to subsidise shipping but to set up a cost efficient LNG infrastructure.

It is important to achieve a cost efficient infrastructure to decrease the specific costs per m³ LNG by reaping economies of scale, also by considering end-users other than ships. However, strategies to increase capacity in smaller steps to better match supply and demand should be applied where appropriate. This applies to each individual port well as the entire area.

11.5 Institutional Issues

There are institutional issues which will delay or hamper network investment.

Once the LNG filling station network is established then it can be expected that some degree of competition will be established between filling stations. This competition can be expected to drive prices of LNG bunker fuels towards hub prices plus infrastructure costs. An issue remains however that it will take time for the network to be established to a point where competition will be established. In this development period operators of LNG filling stations will have the choice of whether they price their sales on a basis that reflects their costs or whether they take advantage of the limited choice of LNG fuelling points and price their LNG fuel against the price of the next alternative, which is MGO. There are 2 aspects to this, the actual likelihood that it will occur and the perception on the part of shipowners that it could occur which would then deter investment by them in LNG fuelled ships.

It is expected that part of the network will develop through contractual arrangements between ship operators/owners and potential infrastructure investors. In this it is expected the price of LNG bunkering fuel would be fixed within the contract for a period that will cover the recoupment of investment costs. Such a period might be 10 years and it could thus be expected that the network will have developed at the time such contracts expire. Furthermore in open negotiations the prices on which these contractual arrangements might proceed would be cost reflective.

Customers at these ports that were not party to the original contract arrangements or customers at facilities that were speculatively built facilities would not be covered by contract. It can be expected that while the facilities are below capacity it will be in the operators interest to attract new entrants to the use of LNG and thus to price at or close to cost reflectivity. Once the operator approaches capacity and has achieved breakeven throughput then one short term strategy for him might be to price against MGO, another strategy might be to invest in additional capacity and expand the customer base. If he does price against MGO then other ports might be encouraged to develop capacity to compete, which might give a short term problem but in the medium term will encourage network development.

The perception of shipowners might however be different. Contractual arrangements made on a bilateral basis at local level will not be transparent to external parties. If there are short term instances of operators pricing LNG against competing fuels then this is likely to be transparent to shipowners as the price will be revealed when a shipowner seeks fuel supplies. This may become a deterrent in some limited cases. Some consideration needs to be given how price transparency might be improved

⁸¹ In Norway, nitrogen oxides (NOx) reduction policies has been a driver for investing in LNG fuelled ships. A NOx fund was established 2007. Being a member in this fund means you can apply for monetary support for investments that decrease the NOx emissions in Norway. A member can get up to 75% of investments for such measures.

Marine fuels for commercial use are exempt from taxation within the EU member states including VAT. Stakeholders have expressed concern that it is not clear across all jurisdictions that LNG would necessarily fall within the current definitions of Marine Fuels. There is a possibility that at least VAT might be applied and, while this could be recovered as the fuel would effectively be exported the additional complexity and cash flow implications could provide an uncertainty and potential barrier to investment.

The LNG market has historically developed through the use of long term take or pay contracts with gasifiers and shippers. The spot market is relatively small and undeveloped. Contract quantities are generally large, normally linked to the fuel consumption of power generating plant. Procuring smaller quantities to meet the needs of individual bunkering points may be problematic, particularly if flexibility is needed to vary contract quantities as demand grows. The LNG market to date is highly specialised with a limited number of major players. It can be expected this will provide a significant barrier to prospective infrastructure investors. Means to address this, possibly by further research and design of purchasing clubs or developing links to brokers who are interested in developing the bunkering market in the long term.

The means by which the infrastructure might develop and the role that long term contracts between ship operators and infrastructure developers might be used to mitigate demand risks has been discussed previously. Within this it was highlighted that it is unlikely that a single ship operator could guarantee sufficient volume at a particular location for development to be feasible; it would be necessary to pool the needs of several different users of a particular port to guarantee sufficient volume to achieve viability. In this context the development of contractual arrangements between the potential customers and prospective developer will be problematic. Such contracts will be complex and expensive to draft and negotiate. To allow drafting to proceed there will need to be some agreement between the parties how such costs will be met. This will provide an initial barrier. The development of standard contracts between prospective developer and prospective customers, both for the negotiation phase and for the purchase and sale of fuel itself could be useful tools for encouraging such contractual groupings to develop.

The study therefore has made 4 observations on institutional issues which would justify further consideration:

- Early years' competition: it will take time to establish effective competition between LNG filling stations. This may deter shipowners. Further study is needed on mechanisms to maintain competitive pricing at the bunkering points;
- Taxation: marine fuels have their own tax exemptions within the EU fiscal framework but there is uncertainty among prospective stakeholders that the present definition is clear in including marine use of LNG;
- LNG Procurement: the market for LNG is characterised by long term contracts with thin liquidity. Further study is needed on the extent to which this prove a constraint to the development of medium and small terminals;
- Model contracts: shipowners may contract with filling stations and either shipowners or filling stations could contract with LNG shippers or importers for LNG supplies. The development of model contracts will assist all parties in the supply chain.



12 Technique and Safety

12.1 Introduction to Safety, Technical and Operational Aspects

This chapter focuses on technical solutions and safety issues related to the use of LNG as ship fuel. The detailed technical assessments are presented in Appendix 8 - Overall Bunkering Technology.

The presentation is divided into three main operational phases representing different types of hazards and technical solutions. The three operational phases were also analyzed separately in the safety assessment process and follow the chronological order as illustrated in Figure 60 below. The three operational phases are:

- Loading/discharging of feeder vessel or bunker vessel/barge at import, production or intermediary terminal
- A feeder vessel or bunker vessel/barge transiting a port
- LNG Bunkering, which is subdivided into three modes of bunkering:
 - ship-to-ship, at quay or at sea (STS)
 - tank truck-to-ship (TTS)
 - LNG terminal-to-ship via pipeline (TPS)

For the TTS bunkering concept, only safety aspects related to the bunkering phase were addressed in the study. The loading of LNG tank trucks is considered as well established technique and road traffic with LNG trucks is subject to detailed national and local safety regulations.

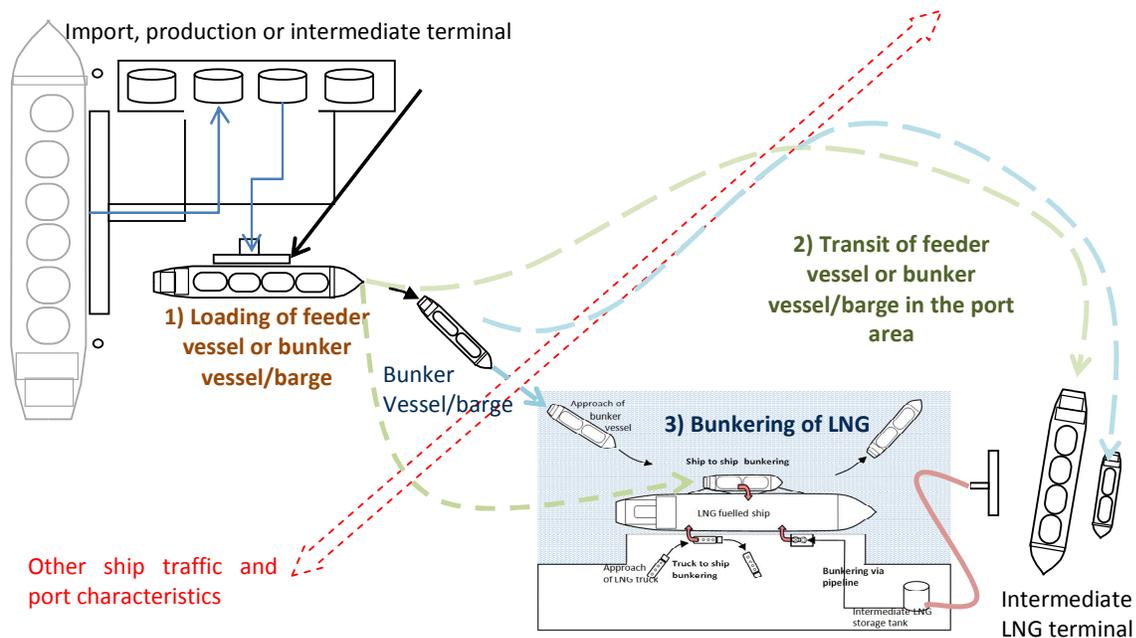


Figure 60 Three operational phases addressed in this chapter.

Source: SSPA

12.1.1 Loading/Discharging of Feeder Vessel or Bunker Vessel/Barge at Import, Production or Intermediary Terminal

The loading of the LNG feeder vessel, the bunker vessel or the bunker barge will in most cases take place close to an import terminal with large-scale storage capacity in land-based tanks. The LNG feeder vessels and LNG bunker vessel are generally much smaller than the import vessels and the loading is therefore likely to be conducted at dedicated jetties designed to accommodate small size LNG carriers or feeders and bunker vessels. In order to avoid long on-shore pipelines, these jetties will probably be constructed close to or within the area of the large import terminal. Hereby they will also fall under corresponding safety regulations and be subject for similar safety assessment routines and restrictions with respect to public access and siting considerations. Even if the LNG quantities loaded for distribution to other ships is relatively small, basically the same stringent technical and safety requirements will apply to LNG feeder and bunker vessels as to the large import vessels.

This operational phase also includes situations where loading or discharging of LNG take place at intermediary LNG terminals providing a link for local distribution of LNG as a ship fuel in a port area or region. The LNG handled in the intermediary terminal as well as in the import terminal is still considered as hazardous cargo and the facilities and activities follow established technical standards and safety requirements accordingly.

12.1.2 A Feeder Vessel or Bunker Vessel/Barge Transiting a Port

Different opinions and approaches on how to handle the situation when a new type of hazardous cargo like LNG is introduced, transported and handled in the port, have been identified. Examples where lack of knowledge and scaremongering has generated very restrictive policies and permit processes are well known, e.g., from the USA. In most European countries with active plans for introduction of LNG as a ship fuel, the basic policy is, however, to consider the LNG handling in a similar way as other hazardous substances transported and handled in the port⁸².

The LNG feeder vessels and LNG bunker vessels will be designed and constructed according to stringent classification rules and regulations for gas carriers. The basic rules for gas carriers are prescribed by the IGC Code⁸³ issued by IMO, in which LNG is specifically listed as one of the substances covered by the code. The code is designed to ensure that gas carriers, including LNG bunker vessels, will be equally safe as other types of ships and will not pose any additional risk contribution to the ship traffic situation at sea and in ports. Gas carriers constructed according to the code are known to be very robust with high integrity of the LNG tanks. It is therefore recommended that port by-laws or national legislation should apply the same rules and regulations for vessels and barges carrying LNG as a cargo as for other vessels or barges carrying other types of hazardous goods.

Examples of port specific aspects that can be addressed by port by-laws or national regulations for LNG bunker vessels and other vessels carrying hazardous gas, include:

⁸² NMD (Norwegian Maritime Directorate) <http://www.sjofartsdir.no/no/Aktuelt/Tillater-transport-av-nedkjolte-gasser/> & Rotterdam Port presentation October 21st 2011.

⁸³ The IGC Code is an International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

- Pilotage;
- Use of tugs;
- Use of VTS;
- Anchorages.

This will affect how ports can adapt to small-scale LNG handling and facilitate LNG introduction with a smooth implementation in a port or terminal.

12.1.3 LNG Bunkering

The presented possible technical solutions of LNG bunkering identified in section 6.3 are essentially based on existing and functioning techniques used in Norway, proposals presented in industry development projects and experience from expertise among the project partners and IKCs. The design of feasible bunkering solutions is a complex balance between safety requirements, operational aspects and cost-efficient technical equipment.

As the establishment of an LNG infrastructure in Europe is still at an early phase the technical and operational aspects of the LNG supply solutions are central. Much of the analysis conducted within this feasibility study is parallel to other initiatives working on similar tasks such as the ISO TC67/WG10 LNG marine fuel committee, the IGF working group (who are developing an IMO standard for gas-fuelled ships, currently released as a draft code (IGF Code⁸⁴), as well as other relevant initiatives encountered during the course of the work.

Technical solutions outlined for LNG bunkering are based on concepts with flexible transfer hoses of different dimensions and numbers depending on the LNG bunker demand of the receiving ship. A simplified general bunkering concept is illustrated in Figure 61 showing a number of essential components. For graphical simplification reasons many subsystems e.g. the valves in the vapour return line are not included in the figure.

⁸⁴ The International Code for Gas Fuelled vessels. Under development.

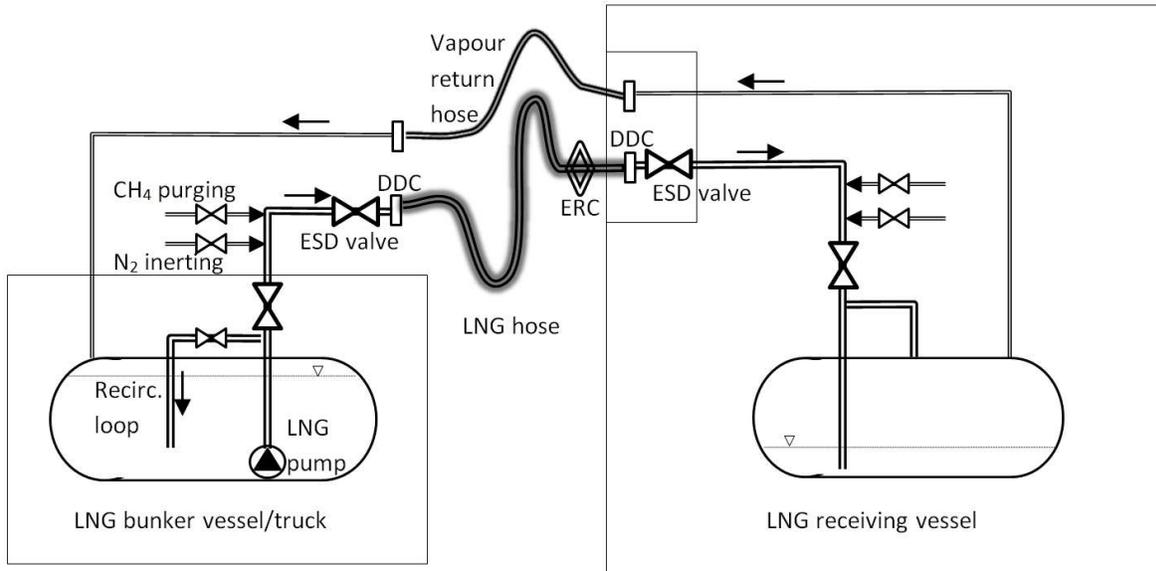


Figure 61 Schematic bunkering concept with LNG flow line, vapour return line and basic system components.

Looking at the above figure, LNG fuelled vessel is represented by the components in the box on the right side. The submerged pump in the bunker vessel tank pumps the LNG through the LNG hose to the receiving vessel. In addition to the main tank closing valves the bunker line also includes two Emergency Shut Down (ESD) valves located close to the hose connection flanges on the respective vessels. These may be activated and closed automatically or manually if leakage is detected or in case of any other deviation from normal operation. In large-scale LNG facilities, the shutdown time is normally 28 seconds for corresponding ESD devices in order to prevent excessive surge pressure peaks. For a small or medium scale bunkering system it is, however, assumed that the indicated recirculation loop or similar devices can absorb the surge pressure in case of a rapid closure of an ESD valve. As an integrated part of the LNG hose an Emergency Release Coupling (ERC) or a Safe Breakaway Coupling (SBC) (sometimes also called ESD2) is arranged providing a “weak link” in the LNG line in case the distance or relative motions between the vessels would exceed the limits of stretching the hose. The ERC or SBC would then disconnect the vessels and close both ends of the separated coupling. The hose connection flanges in the figure are also arranged with Dry Disconnect Couplings (DDC) in order to prevent any spill or venting of the hoses when stowed away on the bunker vessel after the bunkering operation.⁸⁵

Before the bunkering operation starts the hoses must be purged and cooled by pumping or blowing vaporized LNG in either direction between the ships depending on their relative pressure relations. After the bunkering, the LNG hoses should be drained from LNG and before disconnecting both the LNG hose and vapour return hoses it should preferably also be inerted by nitrogen purging. The manifolds and bunkering system on board the receiving vessel is to be purged and inerted according to the regulations prescribed in the IGF Code.

There are a number of manufacturers providing hoses suitable for LNG bunkering operations in dimensions ranging from 1 to 16 inches fabricated from multilayer composite material and double hoses with the inner

⁸⁵ LNG ship-to-ship bunkering procedure. Swedish Marine Technology Forum, 2011.

hose protecting and insulated by an outer hose. The pressure strength and probability of leakage or rupture of such hoses are considered equally good as for pipe manifold systems as long as minimum bending radius, etc. are observed.

The bunkering concept outlined above may apply to STS and PTS bunkering modes and can provide safe systems with a minimum of operational discharge of LNG and methane. Existing LNG tank trucks are normally not equipped with vapor return lines and small-scale TTS bunkering systems are sometimes associated with some operational LNG spill and venting of gas. Venting of minor amounts of boil off gas from tank trucks are also considered as normal operations during transport and idle periods.

An example from a TTS concept for LNG fuelled inland vessels in the Netherlands indicates that boil off gas is used to purge the hoses from the ship to the LNG truck for removal of oxygen before the bunkering and that the flow is vented from the tank truck. After the bunkering the hoses are drained from LNG and the pressurized vapor in the hoses is vented to the atmosphere. For a system using 10 m of 4 cm diameter hose the vented quantity of methane was estimated to be 1- 5 m³ per bunkering event. By modifying the procedures and prevent venting of parts of the piping systems, the vented volume is reduced to about 1 m³.⁸⁶

In order to make the introduction of LNG as ship fuel attractive it is considered important to design the bunkering concepts with the aim to minimize the operational release of methane during bunkering (Recommendation No 16).

12.2 The Safety Assessment Approach

This chapter briefly introduces the safety assessment approach applied in the feasibility study and the following chapters include identification of potential risks, efficient risk control options and measures to ensure that adequate safety requirements are developed and applied in the process of introducing LNG as ship fuel and the associated infrastructure development. The risks associated with the provision and use of LNG differs significantly from the risks connected to marine fuel oil handling. It is therefore of utmost importance that the possible and feasible technical solutions and proposals for new regulative schemes identified in this study are subjected to thorough safety considerations and that a framework for risk analysis is established.

For safety issues in the maritime industry and in the maritime safety rule-making process in particular, the Formal Safety Assessment (FSA) approach is well established. It is developed within and recommended by the IMO and it is widely adopted in the maritime communities in Europe.

The FSA process is primarily designed for maritime applications and ship safety but the scope of this study also includes safety issues in the port. The FSA approach is followed in applicable parts but the applied methodology and terminology also refer to established standards in the area of industrial safety assessment, such as ISO 31000:2009, IDT⁸⁷ and IEC/ISO 1010:2009⁸⁸. The methodology in general as well as the risk analysis tools and techniques applied, are described in detail in Appendix J to ensure full transparency of the analysis and the output accuracy.

⁸⁶ LNG fuelled inland vessels and the Port of Rotterdam. L. Feenstra, Port of Rotterdam, draft report Jan 2012

⁸⁷ Risk management – Principles and guidelines (ISO 31000:2009, IDT)

⁸⁸ Risk management - Risk assessment techniques (IEC/ISO 1010:2009)

The main points of outcome from the applied safety assessment approach in this study include the following:

- Safety assessment considerations on technical and operational aspects presented for the outlined LNG supply chain;
- Identification of critical safety issues and hazards associated with distribution of LNG to and in the port area;
- Identification of critical safety issues and hazards associated with various modes of bunkering of LNG;
- Framework and methods to ensure that safety management structures and risk assessment are established, implemented and applied in the development of operational procedures on LNG handling;
- Identification of areas where new regulative instruments need to be developed and implemented and methods applicable in the rule-making;
- Identification of areas and phases in the permitting process where specific safety issues need to be addressed;
- Systematic presentation of safety considerations and applicable risk reduction approaches seen from the shipowners' as well as ports' and LNG providers' perspective.

The safety assessment presented was conducted with the focus on three separate aspects of LNG bunkering safety. These specifically addressed the port, the bunkering operation and the need for new safety regimes respectively. Strategies related to these aspects normally involve different types of stakeholders and authorities and the decision-making process differs and may entail various modes of safety assessment approaches. The safety-related recommendations presented with regard to these aspects will thus also be directed at different stakeholders.

General safety aspects and risk assessment are in detail discussed in Appendix 9, specific port and terminal safety aspects are found in Appendix 10 and examples of operational guidelines at LNG bunkering are found in Appendix 11.

In Appendix 9 there are also comments to ISO 28460:2010 – “Installation and equipment for LNG – ship to shore interface and port operations”. The comments are related to possible implementation of this standard also for small-scale LNG activities.

12.2.1 Safety Issues Regarding LNG in the Port and its Distribution

Special consideration is paid to safety requirements imposed by other established activities in the port area and with regard to other flammable or hazardous substances handled. Safety considerations to be addressed in the strategic planning process are the location of the port, the distance to residential areas and potential exposure of third parties.

12.2.2 Safety Issues Regarding Bunkering Operations

A number of optional concepts and layouts of bunkering systems is described in the report and specific critical safety issues and hazards associated with the various modes of bunkering LNG are identified. Various solutions from small-scale bunkering from trucks ashore to bunkering from dedicated LNG bunker vessels, and to land-based filling stations with large storage tanks or supplied by pipelines need to be subjected to careful safety assessments by reliable and transparent methods that allow for a comparative analysis and consistent output.

A general approach for a hazard identification process for the presented bunkering systems is outlined, including representative scenarios of operational failures, incidents and accidents and their respective consequences. Accident statistics concerning LNG bunkering are scarce and not conclusive and it is important to ensure that detailed incident and accident reporting routines are established in order to facilitate future identification of proactive safety measures. (Recommendation No 9)

12.2.3 Needs and Development of New Regulations, Operational Procedures and Safety Standards

The legal and regulative framework for LNG handling and bunkering issues is complex and often characterised by split responsibilities and authorities between land/port and sea/ship. Different safety regulations apply to an LNG bunker vessel and a land-based bunker filling station even if they handle the same amount of LNG at the same location. With the aim of harmonised regulations and consistent safety requirements, potential gaps, overlaps or contradicting conditions in existing safety-regulating schemes have been identified and areas where new regulative instruments may need to be developed and implemented are described.

Modern goal-related rule-making from the authorities often means that classification societies and other industry organisations need to develop detailed technical prescriptive standards and recommendations. Specifically, it will be important to specify what to be considered as small scale handling, and what rules that will apply for what sizes (recommendation no. 7)

12.3 The Risk Concept and LNG Handling

Somewhat varying terminology and definitions are sometimes applied in different business sectors and in different countries. In order to clarify the discussion presented, some basic risk concepts and terminology applied in this study are explained below:

- Hazard – A potential to threaten human life, health, property or the environment;
- Risk – the combination (product) of the frequency (probability) and the severity of the consequence of an unwanted event;
- Risk reduction may be achieved by either preventive measures (frequency reducing measures) and/or by mitigation measures (consequence-reducing measures);
- Accident – An unwanted event involving fatality, injury, loss or environmental damage;
- Consequence – The outcome of an accident;
- Safety – Freedom from unacceptable risks.

12.3.1 Scaling of Risk with Regard to Quantities Handled and Number of Handlings

Many of the safety issues discussed in the study refer to known data and experience gained from large-scale handling of LNG and loading/unloading of LNG carriers. For the development of an infrastructure for LNG as a ship fuel, the various distribution and bunkering concepts and the quantities of LNG handled are characterised by other scales of magnitudes. In order to facilitate discussion of the results presented in this report, the rough definitions given in Chapter 6 are applied to characterise what is described as large-scale, medium-scale and small-scale LNG handling.

The established large-scale ship transportation and handling of LNG from production sites to land-based consumers has a very good safety record based on stringent regulative structures, safe design and operational procedures, as well as professional, well-trained personnel.

When the imported LNG flow will be distributed and divided into a large number of smaller transportation flows, the number of transfer operations as well as the number of staff involved will increase dramatically. This is schematically illustrated in Figure 62. The figure represents sea transportation of LNG and STS bunkering but tank trucks on the road will also contribute to a distributed network of small-scale high frequency LNG transportation. (As can be seen the definitions of large-scale and smaller scales LNG handling differs a bit from the definitions used generally in the report. The definitions in Figure 45 however are related more to a shipping perspective rather than a terminal perspective.)

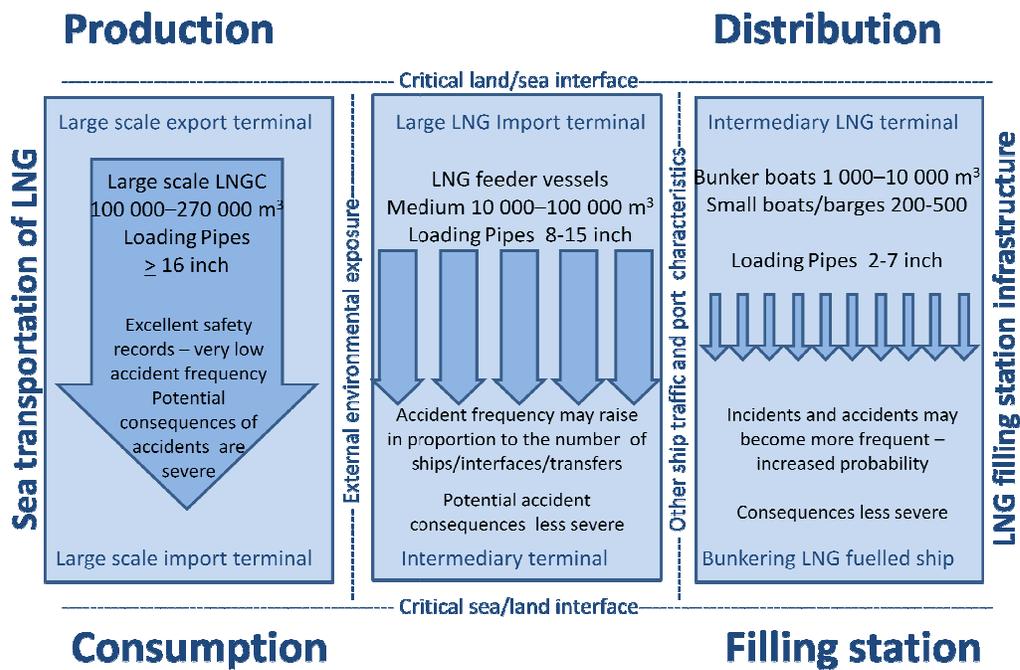


Figure 62 Schematic illustration of differences between large-scale, medium scale and small-scale LNG.
 Source: SSPA, 2011

Safety requirements imposed by the established regulative structures are strict and generally based on large-scale LNG handling and associated potential severe consequences of accidents. The severity of the potential consequences of various accident scenarios are often proportional to the quantity of LNG handled and for small-scale and medium scale LNG handling, the consequences will be correspondingly smaller. When discussing adaptation or liberalisation of the established regulative schemes with respect to small-scale LNG handling it should be an indispensable condition that the established high level of LNG safety should be maintained even if some requirements may be less strict when operations are downscaled.

The concept of downscaling with regard to this condition is illustrated by the risk matrix in Figure 63.

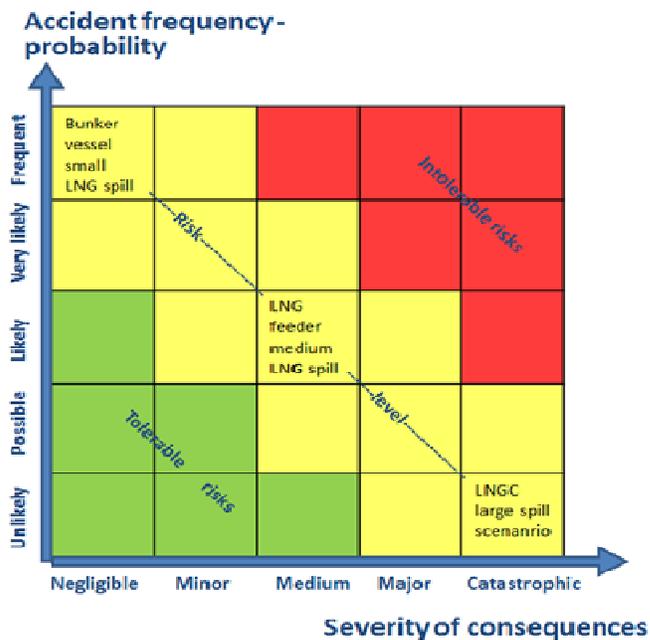


Figure 63 Schematic risk matrix illustrating the concept of maintained risk level for large, medium and small-scale handling of LNG.

Source: SSPA, 2011

12.4 Historical Experience of Accidents with LNG Bunkering of Ships

Compilation and statistical analysis of historical accident data often provide valuable background data for the hazard identification process when maritime safety issues are addressed. In the field of LNG bunkering, however, the area is new and only limited experience has been gained from a few years of operations and trial applications. In Norway, a number of passenger vessels, ferries and other vessels are operated with LNG fuel and various types of land-based LNG bunkering facilities are installed with tanks or arranged by means of mobile LNG road tankers. So far, no accidents have been reported from Norwegian LNG bunkering facilities or bunkering operations and no records or statistics are available from existing incident reporting systems and routines.

In the future we will probably gain more experience of LNG bunkering incidents and hazards and it is considered important to collect maritime incident statistics in such a way that information on LNG bunkering incidents can be extracted and analysed to gain proactive safety measures. (Recommendation No 9).

More information on historical experience from accidents with LNG carriers has been compiled in Appendix 9.

12.5 Identified Hazards

12.5.1 The Hazard Identification Process

A Hazard Identification (HAZID) workshop was conducted at SSPA Sweden process on 12-13 September 2011. In addition to the consultant team, 19 representatives from IKC organisations, authorities and other organisations also took part. See Appendix 12 for more details on the HAZID process.

12.5.2 Objectives and methodology of the HAZID

The objectives of the HAZID workshop were as follows:

- To identify hazards associated with LNG handling and distribution in the port and with the bunkering process;
- To rank the identified hazards in order to identify areas to be subjected to specific consideration and further analysis for the LNG bunker infrastructure development.

The workshop was conducted as a structured brainstorming where a number of operational phases and potential accident scenarios were discussed from a “what-if” perspective. A generic port, accommodating different port activities and ship traffic ranging from small passenger boats and RoRo ferries to large container vessels and tankers, was considered in order to cover different types of bunkering ports. For the purposes of this study, risks related to aspects of human life and health were primarily considered and hazards and accident scenarios that may lead to release of LNG were specifically addressed.

The scope of the HAZID was divided into three different operational phases:

- Loading and unloading of the bunker feeder vessel at an intermediate storage facility;
- Transit of feeder tanker or bunker boat in the port area;
- Bunkering operations.

12.5.3 Output of the Hazard Identification Phase

For each of the operational phases addressed, a number of possible accident scenarios with potential release of LNG were identified. Based on estimations of the probability of occurrence and the severity of the consequences for the identified accidents, a relative risk ranking was compiled by combining the probabilities and the consequences into risk index figures and plotting them into a risk matrix as illustrated in Table 45.

12.5.4 Risk Index and Ranking of Identified Hazards

Based on the estimated probability and consequence rankings in the completed HAZID forms, a combined risk index is derived by adding the probability and consequence ranking figures. The ranking figures roughly represent logarithmic scales and thus the risk index sum represents the product of the probability for and the severity of the consequences of the respective accidental events.

The ranking by use of estimated risk index figures is primarily intended to generate a relative ranking, but the scales may also be used to provide an indicative classification in terms of tolerable, broadly acceptable and unacceptable risks according to the established ALARP concept. ALARP means As Low As Reasonably

Practicable and is the main guiding principle for how to handle risk scenarios identified in the broadly acceptable zone between tolerable and unacceptable risks. For this study it was considered relevant to define the yellow ALARP area as hazards attributed with risk index figures > 4 but ≤ 6.

Table 45 Plotted ID tags of identified hazards and their respective risk indices.

<i>Risk index classification of identified hazards</i>					
<i>Consequence level</i> <i>Frequency level</i>	1 Negligible	2 Minor	3 Medium	4 Major/ significant	5 Catastrophic/ Major
5 Frequent	3				
4 Very likely	2				
3 Likely		6, 10	5		
2 Possible		8	4		
1 Unlikely				7	1, 9

Source; SSPA, 2011

In total, approximately 155 hazards and accident scenarios were identified and listed and 52 of those are attributed with preliminary probability and consequence figures. The following ten examples were found to be attributed with a risk index figure of 4, 5 or 6. It should be noted that the complete list in Appendix 12 includes more hazards ranked with a risk index of 4, 5 or 6. Identified hazards with a risk index < 4 in the green area are considered acceptable and not subject to further analysis or risk control measures.

1. Hard collision feeder/bunker vessel during transit from loading to unloading or bunkering;
2. Interaction with pleasure craft and bunker boat forced to manoeuvre during transit;
3. Leakage due to technical failure during bunkering from land-based facility;
4. Leakage from bunker connection and activation of ESD during ship-to-ship bunkering;
5. Overfilling risk because of difficulty to predict filling level in the receiving tank;
6. Mooring failure during bunkering alongside another ship and activation of ERS;
7. Fire scenario with oil fire in combined oil-LNG bunker vessel;
8. Blackout and grounding of bunker vessel;
9. High speed collision from large ship during LNG bunkering at anchorage at sea;
10. Pressure build-up due to liquid LNG left in vapour return lines after bunkering.

The numbers in the list are plotted in the risk matrix in Table 45 above. A large number of other important LNG risk and safety aspects were also addressed during the HAZID discussions and are listed in Appendix 12.

As a final part of the hazard identification, other documentation and ranked output hazard lists from similar exercises were reviewed to identify potential omitted hazards and some complementary hazards were added.

12.5.5 Risks Imposed by Factors Related to Managerial and Organisational Aspects

Sabotage and terror attacks directed at LNG storage tanks and bunkering facilities are sometimes identified as a potential scenario resulting in an LNG release. Attacked LNG facilities will not detonate but may cause large local fire scenarios and are not considered attractive terror targets.

Basically, the existing International Ship and Port Facility Security Code (ISPS Code) regulates issues to prevent sabotage and provides an adequate risk control regime regarding security issues in the port area. Terrorism and sabotage are not useful to address by means of probabilistic models and together with the aspects mentioned above, this issue is not further elaborated in this study.

12.6 Risk Analysis

Risk analysis of the main hazard scenarios identified during the hazard identification process, has been carried out in a semi-qualitative manner. Data from literature and previous accidents and incidents involving LNG carriers was reviewed for relevant information for input, as there have not been to date any releases reported for bunkering of LNG fuelled vessels. Qualitative risk contribution trees were developed for some of the highest ranked scenarios.

The analysis is based on the bow-tie approach as illustrated in Figure 64 below, focusing mainly on accident events that may result in release of LNG. For each identified accidental events associated with LNG release, the green left hand side of the bow-tie represents possible causes behind the release event separated into four main categories errors, failures and contributing factors. On the green side marked “Operation” there are also three levels of preventive safety barriers indicated which all must fail if the accidental event should occur. After the release is manifested the red side marked “Emergency” includes mitigating or consequence reducing safety barriers aiming at escalation control and mitigation of final consequences. The next chapter, “Risk Control” presents examples of possible preventive and mitigating risk reduction measures in separate sub-sections.

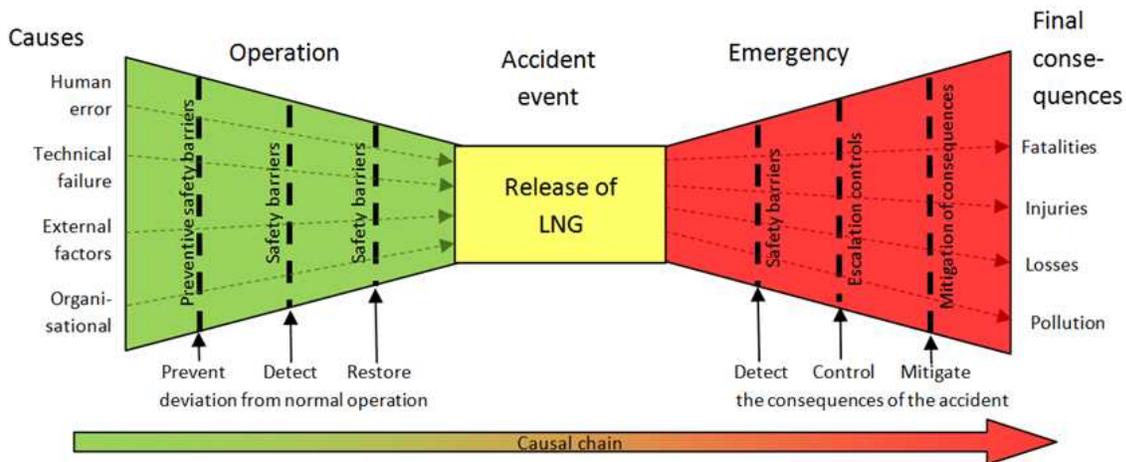


Figure 64 The Bow-tie approach representing different levels and character of existing and new safety barriers.

12.6.1 Causes and Probabilities of LNG Release During Loading/Unloading of Feeder or Loading of Bunker Vessel

Installations like medium-size loading jetties located in the vicinity of large-scale import terminals may provide an important distribution link in a future LNG fuel infrastructure. Loading operations of LNG feeder vessels at such installations will increase the number of potential hazardous activities and thereby also add to the existing accident probability figures. Existing large-scale unloading activities are regulated and governed by well-established safety regimes and corresponding regimes will also be applied for the additional medium-size activities. The medium terminal facility and the crew of the LNG feeder vessel will all be dedicated professional staff members specifically trained for and with daily experience of LNG handling.

From a safety perspective the activities may be considered comparable with existing activities in the existing import terminal but a number of specific potential accident causes may be identified as the following

- LNG feeder vessels and bunker vessel loading at the distribution terminal are smaller than large-scale import vessels and thereby more vulnerable due to higher likeliness of damage from collisions with other ships;
- The location of the medium-size distribution terminal may be arranged closer to port entrance channels and other port activities and possibly more exposed to potential interaction with other ship traffic flows in the port, wake induced surge effects, etc.;
- The introduction of a new distribution terminal close to established activities may also introduce new potential hazard scenarios with cascading escalation of accident and fire consequences.

The above mentioned potential accident causes are all related to the siting and layout of the medium size distribution terminal and can basically be reduced by careful planning including navigational safety assessment and special consideration paid to the siting with regard to potential cascading domino effects.

12.6.2 Causes and Probabilities of LNG Release during Transit of LNG Feeder or Bunker Vessel in the Port Area

For the transit phase to, or within, the port area a number of “standard” maritime accident types are identified and historical experiences and statistics are also available for their occurrence. Such accident types include collision, grounding, bridge/quay allision, engine room fire, blackout, rudder failure, etc. The causes may be human error, technical failure, external causes from extreme weather or interacting traffic or causes related to deficiencies in managerial systems. Such events may occur with LNG feeder vessels or LNG bunker vessels as well as with other vessels operating in the port area; however, the probability that they will cause release of LNG is generally very low. Present design regulations ensure that the vessels’ LNG tanks are well protected and only extreme collision events with perpendicularly hard-striking large vessels are considered to cause loss of cargo integrity.

The probability of such events and other navigational hazards can be assessed by thorough navigational safety assessment or fairway suitability assessment. Such assessment studies may include the use of ship simulation technology to compare various fairway layouts, identification of operational weather windows, identification of ship interaction effects and the development of best operational practices. Important port-specific characteristics to be particularly considered in such studies are as follows:

- Traffic intensity, crossings, meetings and overtaking scenarios;
- Fleet composition, size and type of tonnage;
- Fairway width, bends and manoeuvring areas;
- Water depth, sea bed and shoreline characteristics, bank effects, etc.;

- Environmental condition, wind, waves, current, tide, visibility, etc.;
- Available tug assistance and rescue resources.

Output from such port- and ship-specific navigational safety assessments may be recommendations regarding risk reduction measures that address VTS functions, special safety procedures or operational weather restrictions. There are, however, already well-established regulative schemes for ship traffic with hazardous cargo including liquid flammable gases and it is often considered that no special requirements or procedures need to be introduced to ensure safe transit in the port with LNG feeder vessel or bunker boats merely because they are carrying LNG. (Recommendation No 11)

12.6.3 Causes and Probabilities of LNG Release during the Bunkering Operation

For the STS bunkering concept with a bunker vessel moored alongside the LNG-fuelled vessel, technical or human error related failures as well as external causes are listed as potential initiating factors of LNG spill during bunkering. Leaking flanges, broken hose connections, excessive relative motions between the ships are examples of events that will activate the ESD systems but are also events that may lead to the release of LNG on the vessels or into the water. A self-propelled bunker barge may be smaller than a bunker boat and equipped and classified for operation in inland waterways and sheltered port areas, but should in all other safety aspects comply with the same requirements as normal LNG bunker vessels. Safety aspects of unpropelled bunker barges are not specifically addressed in this study and it is generally considered difficult to achieve adequate manoeuvring and mooring properties to ensure safe and efficient LNG bunkering.

For the TTS bunkering concept, similar scenarios may occur and result in the release of LNG on the ground at the quayside or into the water. The activity is basically a land-based activity and governed partly by other legal frameworks than the STS bunkering. From a safety perspective, however, it is important to try to harmonise regulations and safety requirements to achieve a high and consistent safety level for both land-based and sea-based bunkering activities. On the land side, the available number of supervising staff is normally restricted to the truck driver himself and it may therefore be important to develop and incorporate requirements regarding automatic ESD systems also for truck loading concepts.

Bunkering from land-based terminals, PTS concepts, can be arranged in various sizes and layouts. Bunkering from fixed facilities at dedicated quays or from floating pontoon based filling stations are conducted by professional and trained staff. Depending on the quantities handled and distance from the storage tank to the berth, there may be restrictions on the type of activities that can take place at the quay side during bunkering.

12.6.4 Categories of Outcomes after LNG Release

A number of potential outcomes and consequences following an accidental release of LNG are identified and normally attributed to one of the following categories (more information is found in Appendix J):

- Cryogenic damage - metal embrittlement and cracking, structural failure;
- Cryogenic injuries - frost burns;
- Asphyxiation – if the air oxygen is replaced methane asphyxiation may occur;
- Reduced visibility due to unignited vapour clouds;
- Thermal radiation from fire - delayed or immediate ignition of vapour clouds (flash fire), LNG pool fires or flame jets;
- Rapid phase transition, RPT;
- Vapour cloud explosion (in confined spaces and enriched with other hydrocarbons);

- Boiling liquid expanding explosions (BLEVE);
- Rollover and sloshing in LNG tanks;
- Geysering – expulsion of LNG from a quiescent liquid in piping.

Fire scenarios

On the basis of the HAZID session and experience from previous LNG establishment projects, it is clear that various fire scenarios and the extent and magnitude of thermal radiation generally constitute the dimensioning criteria for necessary risk control measures.

LNG spilled into the water vaporises very quickly and if ignited the emitted heat from the flames is very high. (The Surface Emissive Power [SEP] is in the order of 220 kW/m^2 , which is significantly higher than for a propane pool fire and about 60% more than a gasoline pool fire⁸⁹.) If the spill is small and not ignited the vapour cloud formed will disperse relatively quickly to concentrations below the Lower Flammability Level (LFL) of 5% and does not pose any hazard. The Upper Flammability Level (UFL) for methane in air is about 15% and above this concentration the gas is too rich for burning. In case of a very large LNG spill without immediate ignition, the extent of the vapour cloud within the flammable range between the LFL and UFL may become wide in particular if spread over a sea area; but if the cloud is spread over urban land areas it will most likely encounter an ignition source within 1.5 km and burn back to the source⁹⁰. For large unconfined pool fires it is not considered practical to extinguish the fire and the fire will continue until the fuel is consumed or the feeding source stopped. A vapour cloud burns back to the source of release, either as a “fire ball” if the vapour is mixed with air in a way that the fuel can rapidly be consumed or as a slower burn referred to as a “flash fire” (Luketa-Hanlin, 2006). These fires generate relatively low pressures and thus there is a low potential for pressure damages.

Figure 65 illustrates the formation of an LNG pool and vapour cloud for a large-scale spill.

⁸⁹ LNG Fire Protection & Emergency Response. IChemE, BP International 2007.

⁹⁰ Melhem G.A. Understand LNG Fire Hazards. IoMosaic 2007.

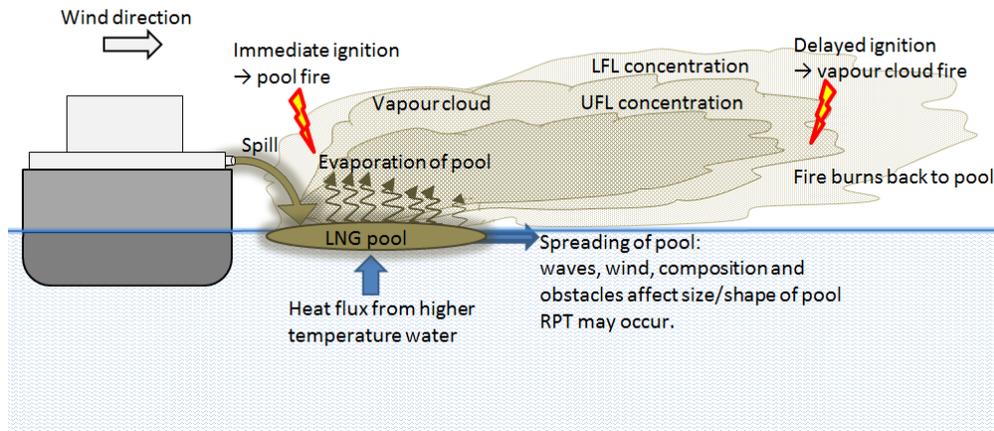


Figure 65 Possible outcome of LNG spill over water.

Source: SSPA (Based on Luketa-Hanlin, 2006).

For the LNG bunkering operations addressed in this study credible accidental LNG spills are, however, small and the fire scenarios of main concern are small pool fires, flash fires from small vapour clouds and flame jets from leakage in pressurised LNG pipes or hoses.

Cryogenic Damage and Injuries

This refers to the damage caused by the contact of the cold liquid with humans or with ship or infrastructure materials. Contact with skin can result in cryogenic burns. Lung damage from breathing the cold vapours is also possible. The LNG can cause damage to ship structures on contact, resulting in embrittlement and/or fracture of metals and materials that are not designed for such cold temperatures.

Asphyxiation

Released LNG could be an asphyxiant for a ship's crew, nearby passengers, bunker boat crew, emergency response crew and others in the vicinity if the gas reaches concentrations where it replaces enough air that results in a deficiency of oxygen. This could occur in enclosed spaces or if there is a large release close to people. According to Hightower et al. (2004), their study of large LNG spills notes that this is considered to be less of a concern than potential fire.

Rapid Phase Transition (RPT)

This phenomenon can occur when the very cold LNG comes into contact with water, which is much warmer. Explosive boiling results as the liquid transitions quickly into a gas, and shock waves and overpressure can result, similar to an explosion. Combustion is not involved; RPT is considered a physical or mechanical expansion with a high pressure energy release (Luketa-Hanlin, 2006). Hightower et al. (2004) report that effects will be limited to the area near the spill source. Experimental studies described in a review by Luketa-Hanlin (2006), found that when RPTs were produced during the spills, most occurred early and were generally located near the spill point. Delayed RPTs were observed in a few cases. Luketa-Hanlin (2006) stated that the occurrence of RPTs appeared to correlate with water temperature and depth of penetration of the LNG into the water.

An unconfined spill of LNG into water will spread and boil at a very high rate (Luketa-Hanlin, 2006). For a spill confined in calm water there may be some ice formation, but for unconfined spills only small amounts of ice formation have been observed, due to the large heat source provided by the water and the turbulent interface (Luketa-Hanlin, 2006). There is a high vaporization rate that is maintained due to contact with the water, which is at a much higher temperature. The high vaporization rate leads to a greater distance to the Lower Flammable Limit (LFL) of the vapour cloud. The vapour formed is initially denser than the surrounding air because it has a lower temperature. The vapour cloud from unconfined spills is stated to travel at roughly the wind speed before becoming buoyant and dispersing. Luketa-Hanlin (2006) states that the length of the vapour cloud will be much greater than its width because the wind will elongate the cloud.

Explosions

LNG in its liquid state is not explosive (IMO; Hightower et al., 2004)⁹¹. Certain conditions may, however, result in damaging overpressure from a vapour cloud fire. These include having a confined fuel-air cloud in spaces such as a ship's hull or tank, which may occur in some scenarios (Hightower et al., 2004). Detonation is noted to be possible where there is a high degree of confinement, strong mixing with air and large ignition sources (Luketa-Hanlin, 2006).

Rollover

All LNG storage facilities are equipped with safety vent valves to release excess pressures that can cause cracks and other structural failures. When rollover occurs, the pressure in the LNG tank rises to very high levels and LNG vapour is vented to the atmosphere at an uncontrolled rate contributing to additional safety concern.

Rollover occurs when stratified LNG comes to equilibrium, in other words when two densities approach equality. Mixing of two layers leads to release of heat that further generates vapour. The vapour may exceed the venting capability of the tank.

Each layer is initially uniform with upper layers lighter than the lower. As the LNG tank is affected by surrounding heat through the walls of the tank, liquid next to the walls warms slightly, becomes less dense and rises to the top of the tank where it evaporates.

The bottom layers are also affected by heating but because of the hydrostatic pressure of the upper layers the heated liquid cannot evaporate. Hence, it superheats, meaning lower layers become warmer and less dense. When two layers approach the same density they mix rapidly causing the lower layer, which has been superheated, to give off a large amount of vapour that rises to the surface. This phenomenon is called rollover and it can cause a dramatic vapour expansion and increase in internal tank pressure.

In bunker tanks of limited volume and tanks in moving ships and trucks stratification and rollover phenomena are considered unlikely and have not been reported in literature.

⁹¹ Hightower, M., Gritzko, L., Luketa-Hanlin, A., Covan, J., Tieszen, S., Wellman, G., et al. (2004). *Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water*. Albuquerque, New Mexico: Sandia National Laboratories.

Sloshing

Sloshing is a phenomenon that occurs when LNG carriers are operating at intermediate loading conditions. It is generally referred to as liquid motion in the cargo tank due to free surfaces, and causes high impact pressures on the walls and ceiling of the tank that lead to damage. Roll motions and wave action contribute to LNG liquid being more likely to induce into resonance. Characteristics of the impact pressures vary with factors such as the shape of the cargo tank, filling height, amplitude and periods of ship motions. These parameters have an impact on how fluids in the tank will respond to motion of the vessel. The general understanding is that motion in a small vessel tends to be relatively large in comparison with those of large vessels making procedures established for large LNG carriers not fully applicable for smaller carriers. Reduction of sloshing can increase loading levels.

Risk Control

A number of existing and possible new risk control measures were discussed and listed during the HAZID workshop. The identified important areas addressed operational issues, technical devices/systems as well as regulative aspects. A number of the identified measures are also incorporated in the recommendations formulated on the basis of this safety assessment and presented in the recommendations from the study.

The risk models presented and risk control measures discussed are not quantified in detail and therefore it is not possible at the present stage to conduct a stringent cost-benefit analysis for comparison of the risk reduction efficiency and costs associated with the respective risk control measures discussed and the recommendations presented. Detailed studies on the LNG bunker infrastructure development may require a more thorough cost-benefit analysis for port-specific projects and comparison of optional risk control options in general.

Preventive and mitigating measures at LNG Terminals are further discussed in Appendix 13.

13 Permit Processes and Consultation with Authorities and the General Public

Long permit processes may be an obstacle for the establishment of an LNG filling station infrastructure in Northern Europe. Current average duration of permitting procedure for energy infrastructure projects, from submission of application document to issuing of the permit is typically four years⁹². Stakeholders' reluctance to accept energy infrastructure projects is one of the main reasons for long processes. Project developers identify public opposition as a key problem, along with the complexity of the permitting procedure⁹³. Therefore increasing stakeholder acceptance is one of the most important challenges to be addressed in making permitting procedures more effective. However, most of the experiences of the permit procedure today in SECA is valid for large-scale LNG import terminals. So far, Norway is the only country (and Sweden to a limited extent) which has experiences of handling permit process for small and medium scale LNG terminals and bunker facilities.

In order to obtain an overview of the permit procedure for LNG facilities an inventory has been carried out of national regulation concerning establishment of LNG facilities in the SECA countries, with a special focus on the consultation processes.

Furthermore, information about experiences of public consultation processes has been gathered through interviews and surveys among stakeholders in existing LNG projects in the region. This information is presented by country in Appendix 14. Common experiences from the countries in are described in this chapter.

13.1 Provisions of Public Consultations in the EIA Directive

The national regulations of the public consultation process and information to the public are governed by the EIA Directive (85/337/EEC). The EIA Directive has no threshold value for LNG storage facilities, it is up to each Member States to determine whether projects concerning "surface storage of natural gas"- shall be made subject to an EIA. The EIA Directive defines minimum requirements for the public consultation procedure. According to the Directive, environmental authorities, affected Member States and the public must be informed and consulted. The provisions on public participation in the EIA Directive were strengthened by the introduction of Directive 2003/35/EC. The amendment included among other things provision on early public consultation in the decision-making procedure, detailed list of information to be provided, reasonable time frames for the process. Detailed requirements on the consultation process are however to be decided by the Member States.

13.2 The Seveso Directive

The permit procedure and the consultation process for LNG storage facilities are also affected by the Seveso II Directive. The Seveso Directive is the main piece of EU legislation that deals specifically with the control

⁹² Permitting procedures for energy infrastructure projects in the EU: evaluation and legal recommendations, Roland Berger Strategy Consultation, 2011

⁹³ Permitting procedures for energy infrastructure projects in the EU: evaluation and legal recommendations, Roland Berger Strategy Consultation, 2011

of on-shore major accident hazards involving dangerous substances. It defines a number of requirements for the operators of establishments where a certain amount of dangerous substances is present. The provisions broadly fall into two main categories related to the two-fold aim of the directive, that is control measures aimed at the prevention of major accidents and control measures aimed at the limitation of consequences of major accidents.

There are two levels of controls in practice. All operators of establishments coming under the scope of the directive need to send a notification to the competent authority and to establish a major accident prevention policy. All establishments which hold more than 50 tonnes of LNG (equivalent to 110 m³) are coming under the scope of the directive. In addition, operators of upper tier establishments 200 tonnes (equivalent to 440 m³) need to establish a safety report before the construction is commenced. The safety report must include identification of major hazards, risk assessment and necessary measures to prevent such accidents. They also need to establish a safety management system and an emergency plan.

The Directive also imposes several obligations on competent authorities⁹⁴, of which the most important are to examine the Safety Report and to communicate their conclusions to the operator, to ensure that the public liable to be affected is informed on safety measures. The competent authority also has to identify groups of establishments with possible "domino effects" and take into account land-use planning implications of major-accident hazards.

The latter implies that Member States shall control the siting of new establishments, modifications to existing establishments and new developments in the vicinity of existing Seveso sites where this could increase the risk or consequences of a major accident. Furthermore, the public shall be able to give its opinion when planning new establishments according to the Seveso Directive.

13.3 Required Permits in SECA

Establishment of LNG storage facility requires several permits in all countries in SECA. The requirements vary between the countries, but some permits are needed in almost all countries i.e. building permit, environmental permit and, permit for handling and storage of dangerous goods. In the United Kingdom and Germany the environmental assessment of the project is a part of the planning permit.

13.4 Requirements on Environmental Impact Assessment (EIA)

The upper threshold value in Seveso Directive, 200 tonnes of LNG, is the threshold value for when an EIA is required in Denmark, Sweden and France. In Finland the need of EIA is decided case-base-case-basis, while an EIA normally is required for the building permit and/or spatial planning in Germany and the United Kingdom. In the Netherlands an EIA screening is obliged for storage of LNG that holds larger quantities than 170 m³ LNG, i.e. 76 tonnes of LNG.

⁹⁴ The competent authority is an organization possessing the legal authority, jurisdiction, qualification, or legally required mental ability to perform the task, in this case the implementation of the Seveso Directive in the national legislation. Which the competent authority is in each country when it comes to implementation of the Seveso Directive differs.

13.5 Number of Processes

In the United Kingdom and the Netherlands there is one single permit process and one single authority responsible for handling the permit process for projects of certain sizes. In the other countries there are two or more permit processes required and two or more authorities involved. In Poland, the permitting procedure comprises four processes; the EIA procedure, the Planning Permissions process, the Designation of Land process and the Building Permit process⁹⁵.

Few processes and process steps probably lead to lower and faster overall procedure. The relevant authorities and the developer need fewer resources and less time to produce and verify documents and to oversee processes. One way to tackle delays is thus to integrate the processes within the permit procedure into one single progress, in which the authorities concerned cooperate closely (Recommendation no 19). The creation of a “one stop shop” in the countries where several processes are needed would most likely shorten the duration of the permit procedure.⁹⁶ This question has to be handled at national level by the national governments. This is in accordance with the proposal from the European Commission, on guidelines for trans-European Energy infrastructure and repealing decision No 1364/2006/EC, which propose that each Member State shall designate one national authority which shall be responsible for facilitating and coordinating the permit granting procedure (“one-stop-shop”) for projects of common interest⁹⁷.

13.6 Duration of the Permit Procedure

The duration of the permit procedure varies to a large extent, mostly between different projects, but also between different countries. In the Netherlands and UK, which are the only countries with one single permit process in SECA, the average duration for energy infrastructure project is about one year. This is short compared to many other EU countries. However, experience from Dragon LNG terminal in the United Kingdom shows however that the permit process can take four years. In Sweden and Poland, the average duration time for energy infrastructure project is about four years, while the process takes about three years in Germany⁹⁸. As there are almost no experiences of permit procedure for small or medium sized LNG infrastructure facilities outside Norway, there are no information of the average duration of the procedure of these kind of infrastructure projects. In Norway the average duration of the process is about one year.

13.7 Public Consultation

Public consultation is an important part of the permit procedure in all SECA countries, in accordance with the EIA Directive. According to Article 6 (2) of the EIA Directive, the public shall be informed ‘early’ in the in the decision-making process and, at the latest ‘as soon as information can reasonable be provided’. Article 6 (4) of the Directive provides that Member States should be required to take the necessary measures to ensure that the public concerned are given ‘early and effective opportunities’ to participate in the procedure,

⁹⁵ Permitting procedures for energy infrastructure projects in the EU: evaluation and legal recommendations, Roland Berger Strategy Consultation, 2011

⁹⁶ Ibid.

⁹⁷ COM (2011) 658 final, Proposal for a Regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC.

⁹⁸ Ibid.

and to express comments and opinions when all options are open for the competent authority. However, more details how the public consultation should be carried out is not specified in the Directive, and thus it varies between the countries.

Table 46 provides an overview of the stages at which countries in SECA provide for public consultation. This means those stages where the public can actively comment and provide input to the decision-making procedure. These stages are mainly:

- The screening phase; this is the process by which a decision is taken on whether or not EIA is required for a particular project;
- The scoping phase; when the key environmental issues are identified. In this phase it is possible to influence the content and structure of the environmental report before submission of the report;
- The consultation phase is the phase when the environmental report is published, before decision is taken and when all options are open to the competent authority.

In Belgium, Denmark, Finland, Sweden, the Netherlands and the United Kingdom the public consultation is carried out both in the scoping phase and the consultation phase. In Norway, France and Poland the public consultation is carried out in the consultation process. In Germany, members of the public may be involved in the scoping phase by the competent authority. No country in SECA is involving the public already in the screening phase, but this is the case in some EU-countries, for example in Spain and Czech Republic.

Countries that allow for public consultation already in the scoping phase define this as an effective public consultation and emphasize that public involvement already at this stage helps to improve the quality of the environmental report⁹⁹.

The timeframe of the consultation processes are regulated in all SECA countries except for in Sweden. The timeframe varies between two weeks to eight weeks. About two weeks is used for the scoping phase, while the timeframe for the consultation phase varies between four to eight weeks in a majority of the countries in SECA.

⁹⁹ Permitting procedures for energy infrastructure projects in the EU: evaluation and legal recommendations, Roland Berger Strategy Consultation, 2011

Table 46 Overview of stages of public consultation and time-frames for different stages.

Public Consultation	Stage(s) of consultation	Time-frames for consultation
Belgium	Brussels: Scoping phase and consultation phase Walloon: Scoping phase and consultation phase Flanders: Scoping phase and consultation phase	Brussels: 15 days for the scoping phase, 30 days for the consultation phase Walloon: 15 days for the scoping phase, different time-frames for the consultation phase dep. on project category Flanders: Scoping phase: n/a, 30 days for the consultation phase
Denmark	1) Scoping phase (for projects on land falling under the scope of the Danish Planning Act) 2) Consultation phase	1) Minimum 2 weeks (typically 4 weeks) 2) Minimum 8 weeks
Finland	1) Scoping phase 2) Consultation phase	1) 30-60 days 2) 30-60 days
France	Consultation phase (level of consultation varies depending of project size/significance)	Minimum 30 days (the "public inquiry" lasts between one and two months, the "simplified procedure" lasts one month and the maximum length of the "public debate" procedure is four months (plus two additional months in certain cases))
Germany	Consultation phase	Depends upon relevant provision of the sector law applicable to the specific approval procedure, however a minimum period of six weeks and maximum period of two months
The Netherlands	1) Scoping phase 2) Consultation phase	1) 6 weeks 2) 6 weeks
Norway	Consultation phase	Minimum 6 weeks
Poland	Consultation phase	21 days
Sweden	1) Scoping phase 2) Consultation phase	No fixed frames, depends on the nature of the project. Fixed on a case-by-case basis by the competent authority
The United Kingdom	1) Scoping phase 2) Consultation phase	2) Minimum 21 days

Source: Study concerning the report on the application and effectiveness of the EIA Directive, COWI, June 2009

In Denmark, Sweden, Norway and Finland the detailed arrangements for public participation and consultation procedures are left to the discretion of the competent authority. The practical arrangements depend on the nature and complexity of the project in question and are targeted in individual cases. In Norway, for example, the public consultation process has been a limited part of the permitting process for the small-scale terminals, which have been built. Finland specifies that besides the official public consultation taking place twice during the EIA procedure (at the scoping stage and when the EIA report is finalised) more extensive public participation (meetings, workshops, group interview, etc.) is possible and quite common. Possible extensive public participation is arranged by the developer on a voluntary basis.

In the United Kingdom, the developer is forced by law to carry out an extensive consultation before submitting the application for the project. The developer must also submit a proposal for the structure and handling of the public consultation to the relevant authority, in this case the Infrastructure Planning

Commission (IPC). After the application for the project has been submitted, the IPC holds a second public consultation involving all stakeholders.

In the Netherlands the developer enters into direct dialogue with parties potentially affected by the project before the official start of the permitting procedure. The developer interacts directly with affected municipalities and even with citizens, providing information about the planned project and discussing its potential impact. This early direct dialogue between developer and stakeholders is reported as being very successful¹⁰⁰.

13.8 Information to the Stakeholders

Experiences from existing LNG facilities show that early and good communication between the operator, authorities and the general public is essential for an efficient permit procedure. Taking into account safety and environmental concerns throughout the project can help to ease the concerns of local authorities and local politicians. As both public, local and regional authorities as well as the media in general have little knowledge of LNG it is vital to communicate the advantages of LNG as a fuel, e.g. reduced emissions and reduced engine noise (Recommendation no. 17).

It is vital that information is target-group-specific. This means that information is prepared in a way that stakeholders can easily understand: texts should be easily accessible, with pictures explaining the project and its impact. Moreover, different target groups – affected landowners, people living close by and potentially concerned with health impacts, NGOs and individuals with environmental concerns – should be differentiated in terms of their concerns.

13.9 Establishing and Examination of Safety Reports

The safety report, which operators that hold more than 200 tonnes of LNG have to submit to the competent authority before the construction commences, is also an important part of the permit procedure. Experiences from existing LNG facilities show that performance of an adequate safety report is instrumental to a straightforward permit process.

Today many different assessment approaches and software models are used for calculations and estimation of possible outcome of various accidental events and in particular for LNG fire scenarios. The output result and accuracy may vary significantly and it is often difficult for reviewing authorities and decision makers to compare different alternatives and to evaluate safety assessments results. Therefore is recommended that national authorities shall develop guidelines on adequate model approaches to be applied for risk assessment of LNG bunkering facilities would facilitate fair and harmonised assessment of various projects (Recommendation no. 8).

¹⁰⁰ Permitting procedures for energy infrastructure projects in the EU: evaluation and legal recommendations, Roland Berger Strategy Consultation, 2011

13.10 Sites for New Establishments

Experiences from existing LNG terminals show the importance of a well thought-out location of the establishment, as well as considerations of different locations. The Seveso Directive includes requirements on the operator/project developer to provide “sufficient information to the competent authorities to enable decisions to be made in terms of the siting”. Further, the competent authority shall control the siting, whether the new establishment could increase the risk or consequences of a major accident. LNG intermediary terminals and LNG filling stations must be located close to their customers in the port to be competitive. Such requirements may create conflicts with safety aspects. Today there are guidelines available regarding the sites for large-scale LNG import terminals, but no guidelines regarding small-scale LNG infrastructure. Therefore it is recommended that national authorities and the Society of International Gas Tankers and Terminal Operators (SIGTTO) shall develop guidelines on the sites for intermediary LNG terminals and LNG filling stations, based on national and international regulations with a view to possible international harmonisation (Recommendation no. 18).

13.11 Conclusions Regarding the Permit Process

- It is crucial for the operator to handle the public consultation process in a proper way. A major reason for public opposition is that people are insufficiently or incorrectly informed about planned projects. Therefore an early and good communication between the operator, authorities and the general public is essential for an efficient permit process;
- As both public, local and regional authorities as well as the media in general have little knowledge of LNG it is vital to communicate the advantages of LNG as a fuel;
- Experiences from existing LNG facilities show that performance of an adequate safety report is instrumental to a straightforward permit process;
- Today many different assessments approaches are used for calculations and estimation of possible outcomes. Development of guidelines for safety assessments and risk analysis of LNG bunkering concepts and facilities would facilitate fair and harmonized assessment of various projects;
- Intermediary LNG terminals and LNG filling stations must be located close to their customers in the port to be competitive. Such requirements may create conflicts with safety aspects. The development of guidelines on the siting of intermediary LNG terminals and LNG filling stations, based on national and international regulations, is therefore considered to be urgent;
- The permit procedure could be shortened by establishing one single process, on which the authorities concerned cooperate closely, for example in the form a “one stop shop”.



14 Recommendations

14.1 Recommendations for the Maritime Supply Chain

Recommendation no. 1a regarding bunkering solutions; ship-to-ship (STS)

Why:

The ship-to-ship bunkering operation may be performed alongside a quay, but it is also possible to bunker at an anchorage or at sea during transportation. This means that the potential customers include also passing vessels. Further, the ship-to-ship bunkering can be carried out in neighboring ports, which do not have adequate facilities for LNG bunkering.

Only one LNG bunker vessel per receiving vessel is appropriate if the turnaround time in port should be kept short for the clients. Typical capacity for LNG bunker vessels may be around 1,000 to 10,000 cubic meters. Further, small vessels or barges can also be used in some ports with a capacity of less than 1,000 m³. For operational reasons, both practical and time-consuming, the quantity of LNG to be delivered from a bunker vessel cannot be too small. Volumes between 100 m³ and 20,000m³ are suitable for these operations. If the volumes are larger than 10,000m³, a LNG feeder vessel can be used for bunkering.

What:

The ship-to-ship (STS) bunkering solution is recommended to be the major bunkering method, where receiving vessels have a bunker volume from 100 m³.

Who:

- Terminal operators, large and medium sized terminals;
- Port authorities;
- Bunker vessel operators.

When:

In the planning and investment phase for terminal facilities and LNG bunker vessels.

Read about recommendation 1a in:

6.3.1 Ship-to-ship (STS) Bunkering

Recommendation no. 1b regarding bunkering solutions; tank truck-to-ship (TTS)

Why:

Tank trucks are inexpensive to invest in and they provide flexible solutions for bunkering of receiving vessels with small LNG bunker volumes. The truck capacity varies between 40 to 80 m³ of LNG. LNG bunker volumes of approximately 200 m³ represent the upper limit and are only suitable if the turnaround time is long enough for the bunkering activities, as this requires 3-4 truckloads, and if the safety level is acceptable.

Tank trucks can also be used for regional distribution of LNG to serve nearby industries not connected to the gas network or other ports that want to provide vessels with LNG fuel. This is economically feasible if the distance is not too long for the trucks to cover, which, in general, corresponds to approximately 350-600 kilometres.

What:

The tank truck-to-ship (TTS) bunkering solution is recommended in all sizes of terminals, where receiving vessels have a bunker volume requirement of a few cubic meters up to 200 m³.

Who:

- Terminal operators, all sizes;
- Port authorities;
- Tank truck operators.

When:

In the planning and investment phase for terminal facilities and tank trucks.

Read about recommendation 1b in:

6.3.2 Tank Truck-to-Ship (TTS) Bunkering

Recommendation no. 1c regarding bunkering solutions; terminal-to-ship via pipeline (TPS)

Why:

The terminal to pipeline solution can facilitate a tailor-made operation with possible high loading rate and large volumes. The solution requires a fixed installation and a relatively short distance between the LNG terminal and the receiving vessel. Due to space restrictions, the solution can be problematical to realize in some terminals. The terminal-to-ship via pipeline solution is suitable for specialized solutions, e.g. high frequent liner shipping services with short turnaround time, niche ports with high frequency of low volumes delivery sizes such as tugs, utility vessels and fishing boats, etc.

What:

The LNG terminal-to-ship via pipeline (TPS) bunkering solution is recommended for all different sizes of bunkering volumes and in terminals with available space for associated bunker facilities.

Who:

- Terminal operators, all sizes and typically those with frequent liner shipping calls or other steady customers;
- Port authorities;
- Ship operators; e.g. liner shipping companies, utility vessel operators, tug boat operators.

When:

In the planning and investment phase for terminal facilities.

Read about recommendation 1c in:

6.3.3LNG Terminal-to-ship via Pipeline (TPS)

14.2 Recommendations Regarding Economic and Financial Aspects

Recommendation no. 2 regarding the internal rate of return (IRR) for investments in fixed LNG infrastructure

Why:

For terminal investors it is important to achieve high rates of return on their investments.

Too high retail prices seen from a shipowner's point of view would hamper the demand and hereby the market growth. Apart from the LNG price (import price), investment and operational costs from the LNG infrastructure are central factors influencing the minimum retail price that suppliers can apply. In this study, these costs are roughly estimated to correspond to 120 – 200 €/tonne LNG if it is assumed that an IRR of 12 % is applied. Such prices would make LNG competitive compared to the HFO & scrubber and MGO compliance strategies (for moderate LNG import prices of 300-450 €/tonne). This would imply internal rates of return for terminals not more than ten (Small) to fifteen (Large and Medium terminals) percent. Thus a key issue for the LNG maritime infrastructure development will be to find investors that accept such internal rates of return, with the uncertain market situation in mind.

The infrastructure costs also incorporate costs from the maritime LNG infrastructure with bunker ships and trucks and so on.

What:

It is recommended to create business incentives for land-based LNG infrastructure investments enabling retail prices for maritime LNG corresponding to internal rates of return below 12 % for investments in maritime LNG supply infrastructure.

Who:

Financial institutions as the main arm backed by EU and Member State initiatives.

When:

Until 2020.

Read about recommendation 2 in: 7 Cost for LNG Terminals, 8.7 Pay-back Analysis from a Shipowner's Point of View and 10.2 Network Viability.

Recommendation no. 3 regarding elaboration of business cases or plans including bunkering and operation with LNG

Why:

There is a possibility to get support from relevant EU or national authorities for project planning and also for further execution of investments. Investments could be either directed towards ships or on shore small and medium LNG terminals.

To get such support it is important to present business cases that are feasible and relevant.

What:

It is recommended that business cases or plans are developed for specific investment projects.

The cases or plans should at least include:

- Demand analysis;
- Planning of terminal capacity, design and site;
- Planning of terminal operation;
- Integration with land-based LNG/CNG;
- Rough financial and economical calculations.

Who:

Port authorities, potential investors in terminals, shipowners and other stakeholders.

When:

EU calls regarding business case studies have already been issued and further are expected.

Read about recommendation 3 in: 9.1Critical port criteria for LNG bunkering, 9.2 **Business Models for Ports**, 10.2.1The Gap between Network Needs and Viable Development, 10.2.2Financial Viability and 10.2.3Land-based Demand.

Recommendation no. 4 regarding establishment of cooperation in port clusters or similar on the development of maritime LNG fuel infrastructures

Why:

The need for maritime LNG infrastructures will initially and to a high degree be based on “local” demands connected to existing or planned line traffic, fishing boats stations or other regular traffic which in turn are connected to other ports. Furthermore demand from other non maritime end-users must be incorporated.

To establish the “minimal infrastructure” / “secured market” it is important that all these “local” demands are mapped and estimated at an early stage.

It is necessary that the central stakeholders in the “local” LNG supply chain participate. Port clusters with port authorities, LNG providers and ship owners etc. must be instrumental in this work.

What:

It is recommended that local and regional port clusters or similar, with participation of all relevant stakeholders take up the challenge on establishment of a “local” LNG infrastructure. The work must incorporate the business case as well as environmental concerns.

The main object for the networks would be to:

- Assess existing and future demand potential for LNG-fuel for ships at those ports and their hinterlands;
- Plan and co-ordinate the development of LNG-bunkering possibilities within the port and hinterland;
- Define possible integration with land-based LNG or CNG demand/availability;
- The work must have an international dimension as most ships serve different ports and hereby develop the Motorways of the Sea concept.

Who:

Port authorities, ship owners, local communities, permit authorities and other stakeholders. The work must be supported by relevant EU and/or national authorities.

When:

These activities are particularly important in the coming ten years, with an emphasis on the early years. The maritime LNG infrastructure development is envisaged to face particularly important years 2012 and up to 2016, as a rapid growth in demand is foreseen from 2015 and onwards. However, the development is foreseen to continue and therefore the ‘lessons learned’ process will be vital.

Read about recommendation 4 in: 9.2 Business Models for Ports, 11.4 Investment Risks and Risk Mitigation, 11.5 Institutional Issues.

Recommendation no. 5 regarding an early creation of a “minimal infrastructure and secured market”

Why:

The maritime LNG infrastructure business is characterized by positive feedback, meaning that an increasing demand may lead to decreasing prices and further increased demand, as well as the hen-and-egg problem (both LNG users and infrastructure providers will have difficulties investing in LNG before the other party does).

Therefore it is important to quickly establish a “minimal infrastructure” / “secured market” of e.g. 9 million m³ per year in 2020. That volume would provide a solid base for a positive development the years after 2020. But an extensive infrastructure can, and will, not be built all at once so it is important to coordinate efforts and investments.

What:

It is recommended that:

- Actors in the LNG supply chain efficiently coordinate efforts and communicate in order to meet and help generate maritime LNG demand;
- Demand from other than maritime end users must be included in order to create economies of scale;
- A “minimal infrastructure” enabling a “secured market” is quickly established.
-

Some important measures for early market introduction are suggested in Recommendation no 2, 3, 4 and 6.

Who:

EU and national authorities, ports, LNG suppliers, traders and end users.

When:

Work has already started but it can be made even better as from today.

Read about recommendation 5 in: 10 The Financial Feasibility of an LNG Filling Station Network and 11 Operational Models for Terminals.

Recommendation no. 6 regarding the need of bunkering vessels/barges - a floating infrastructure

Why:

There is a need for floating small and medium LNG infrastructure in form of feeder vessels, bunker vessels and bunker barges.

Medium sized LNG feeder vessels ($> 10,000 \text{ m}^3$) are already on the market and more are ordered and these are expected to be able to cover the initial introduction of LNG as marine fuel. In addition, bunker vessels/barges ($< 10,000 \text{ m}^3$) are needed to supply LNG to vessels. Today, with the exception of Pioneer Knudsen, no LNG bunker vessel or barge exist.

Therefore it is instrumental to have a number of bunkering vessels/barges, which distribute LNG to the LNG fuelled vessels. For investment in such vessels/barges pay-back times of below ten years should be compared to technical life times of twenty to twenty five years.

What:

It is recommended to establish a funding scheme for development, construction and operation of LNG bunker vessels/barges in the early stage of LNG as marine fuel introduction on the market.

Who:

Primarily EU backed by Member State initiatives.

When:

As soon as possible (since ship delivery time is around two years) and until 2020.

Read about recommendation 6 in: 10.1The Network Development Model and 10.1.1 Outputs of the Modelling

14.3 Recommendations Regarding Safety Issues

Recommendation no. 7: Define what to be considered as small scale LNG handling

Why:

Much of the techniques and procedures proposed for application in the LNG bunkering infrastructure development refer to downscaling of established techniques and procedures applied in the large scale LNG import industry. In order to be able to assess the risks associated with small scale LNG handling and bunkering operations and to outline adequate regulations, it is important to be size specific. Quantitative figures must be defined to specify the limits when established large scale regulations and when new small scale LNG regulations should be applied. Tank volumes, flow rate, pressure and dimensions of the bunker lines are safety related variables that can be used to specify size specific requirements.

What:

Define quantitative figures specifying when regulations on small scale LNG handling and bunker operations are applicable. The figures may specify limits in terms of total tank capacity of the tank from where the LNG fuel is bunkered and flow rate in, or diameter of the pipes/hoses during bunkering operations.

In this study, tank capacities of 10,000 m³, and bunkering pipe/hose diameters of $\varnothing < 7$ inches are used to describe what is considered as small scale LNG handling.

Who:

National and international regulators.

When:

Introduction of size specific and quantity related requirements are important for all new regulatory regimes that will be elaborated for small scale LNG handling and ship bunkering.

Read about Recommendation no. 7 in: 11.2.3 Bunkering Services

Recommendation no. 8 regarding guidelines for risk modelling in the safety assessment of LNG bunkering concepts and facilities

Why:

The safety assessment and risk analysis of LNG bunkering concepts and facilities usually includes identification of relevant design cases for possible LNG release accidents and estimations or calculations of the associated consequences.

Today many different model approaches and software are used for calculations and estimation of possible outcomes of various accidental events and in particular for LNG fire scenarios. This also reflects different purposes and different projects. The output result and accuracy may vary significantly depending on the model approaches applied and it is often difficult for reviewing authorities and decision makers to compare different alternatives and to evaluate safety assessment results. It may, however, be difficult to elaborate general guidelines that will be internationally accepted.

The use of appropriate risk modelling tools will also facilitate identification of adequate and efficient preventive and mitigating risk control measures.

What:

Develop guidelines for adequate risk modelling approaches to be applied in safety assessment and risk assessment of bunkering concepts and facilities with the aim to facilitate fair and harmonized assessment of various projects.

Who:

National authorities.

When:

It is considered likely that the development and implementation of such guidelines can be accomplished by 2013 or 2014. Safety assessment methodology and risk modelling for LNG bunkering facilities may be included in guidelines/standards under preparation within ISO TC67/WG10.

Read about Recommendation no. 8 in: 13.9 Establishing and Examination of Safety Reports

Recommendation no. 9 regarding the routines for accident and incident reporting systems for LNG bunkering

Why:

Accident statistics on LNG bunkering today is scarce and not conclusive. In order to facilitate future identification of proactive safety measures it is important to ensure that the reporting reflects that an incident or accident is related to LNG bunkering by a specific and harmonised categorisation. Today it is difficult to extract and analyse accident data specifically related to bunkering accidents from the established maritime casualty data bases and statistics.

What:

Establish a harmonised way of categorisation and reporting of incidents and accidents related to bunkering of LNG as ship fuel. This could be done through existing systems but it is important that specific LNG bunkering issues can be specifically addressed and that incident data can be extracted separately for analysis.

Such systems should be designed and managed recognizing the needs for international harmonization and facilitation of cross border exchange of information and experience on LNG incidents.

Who:

- National authorities;
- EU.

When:

To ensure possibilities for proactive actions and rulemaking, the system should be in place from the start of the operation of the LNG bunker filling stations.

Read about Recommendation no. 9 in: 12.2.2 Safety Issues Regarding Bunkering Operations

Recommendation no. 10 regarding harmonisation of land-based and sea based regulative requirements on LNG bunkering with the aim of a consistent safety level for various modes of bunkering

Why:

Maritime regulations usually refer to international codes or standards whilst the land-based regulations often vary a lot from country to country. Optional bunkering modes or concepts are governed under different jurisdiction frameworks if the bunkering takes place from a tank truck on the quay side or if it takes place on the outside of a moored LNG fuelled ship from an LNG bunker vessel. Some of the safety issues may be rather similar but the legal safety requirements may vary significantly.

What:

In order to attain a consistent high safety level and to avoid making safety issues a competitive factor between different bunkering modes, it is recommended to harmonise regulations and safety requirements for both land-based and sea based bunkering activities.

Who:

This is a general viewpoint to be considered primarily in the national rulemaking process.

- National authorities;
- EU.

When:

Decisions to go for a land-based or a sea based bunkering concept are taken early in the planning phase and it is important to strive for harmonised regulative requirements and consistent safety levels from the start of the LNG bunkering establishment.

Read about Recommendation no. 10 in: 12.1.1 Loading/Discharging of Feeder Vessel or Bunker Vessel/Barge at Import, Production or Intermediary Terminal

Recommendation no. 11: Avoid introduction of specific regulations and requirements for traffic with LNG feeder and LNG bunker vessels

Why:

Stringent international codes and national regulations for ship design and traffic with hazardous cargo including liquid flammable gases are well established and generally considered to ensure an adequate safety level for sea transportation of most types of dangerous cargo and hazardous materials.

LNG is one of the substances listed and considered in these regulative frameworks and it is therefore not considered necessary to introduce special requirements or procedures for traffic with LNG feeder vessels and LNG bunker boats only because they are carrying LNG. Depending on the port specific conditions and traffic situation it may, however, still be important to review and assess the feasibility and potential risks associated with the projected LNG bunker vessel traffic and to compare it with the present bunker vessel traffic in the port.

What:

Consider LNG bunker vessel traffic similar to other dangerous cargo vessel traffic and avoid introduction of special requirements for the LNG bunker vessel traffic.

(There is, however, an obvious need for new regulations and procedures to be introduced for the LNG bunkering operations.)

Who:

- IMO;
- National authorities;
- Port authorities.

When:

The recommendation can be considered as an initial basic approach for the rulemaking process for the LNG bunker filling station infrastructure but it should be subject to revision when more experience is gained.

Read about Recommendation no. 11 in: Causes and Probabilities of LNG Release during Transit of LNG Feeder or Bunker Vessel in the Port Area

14.4 Recommendations Regarding the Technical and Operational Aspects

Recommendation no. 12 regarding the need for new guidelines and standards for LNG bunkering

Why:

There is a lack of standards and guidelines for LNG bunkering. Neither the SIGTTO LNG ship-to-ship guideline nor ISO 28460:2010 standards provide adequate guidelines. The IGF and IGC code does not at present provide guidelines or standards for bunkering.

What:

It is recommended to develop dedicated guidelines for LNG bunkering. This may well be done within the ISO TC 67/Working Group 10, currently developing guidelines for LNG bunkering. Furthermore bunkering and transfer equipment for LNG will to some extent be covered by the IGF code (design criteria for LNG fuelled vessels developed by IMO).

It is recommended that the ISO TC 67/WG10 and IGF WG development guidelines are developed in such way that it enables safe LNG transfer (bunkering) even when a vessel is involved in cargo handling and passengers embark/disembark. Examples of such safe practices include:

- Emergency shutdown system (ESD) (Recommendation no. 13);
- Emergency Release System and/or break away couplings (ERS) (Recommendation no. 14);
- Training of personnel involved in the operation (Recommendation no. 15a and b);
- Reduction of methane release (Recommendation no. 16).

It is also important to use already established terms and definitions, and not to introduce any new terminology which could lead to confusion.

The guidelines should include a **defined methodology** to develop local supplements for ports and terminals. Operational guidelines for bunkering of LNG can be found in Appendix H in the Draft Feasibility Report.

The SMTF (Swedish Maritime Technology Forum) work on LNG bunkering procedures can be used in the work.

Who:

- Port authorities and national authorities;
- ISO TC 67/WG 10 and IGF.

When:

- Effective immediately: For a case by case study with FSA studies;
- 2013-2014: ISO TC 67/WG 10 new guidelines and new IGF code.

Recommendation no. 13 regarding the use of an Emergency Shutdown System (ESD) and communication system

Why:

The functions of an Emergency Shutdown (ESD) system is to stop cargo liquid and vapor flow in the event of an emergency and to bring the cargo handling system to a safe, static condition. It has been identified that there is a need for an Emergency Shut Down system (ESD) to minimize risks and reduce the size of safety zones thus enabling LNG operations even during cargo and passenger handling.

What:

An Emergency Shutdown System (ESD) and communications connection based on SIGTTO electric link system is recommended for all LNG fuelled vessels, LNG bunker/feeder/barges and small scale LNG terminals to be used when loading, discharging and bunkering LNG.

It is recommended that the system for bunkering operations on the bunkering and receiving part be so designed that it enables very quick detection of leakage and failures. It is also recommended to be able to close ESD valves very quick, thus reducing the amount of LNG released to the air in case of emergency. As a result the systems must be able to withstand the surge pressure that will be the result of the quick closing of ESD valves. Suggested closing time of ESD valves is 5 seconds or less. A data and telephone link, as suggested by SIGGTO, is recommended to be implemented for ship-to-ship bunkering. This link is meant to exchange the most important data for a fast, safe and reliable bunkering, loading and discharging.¹⁰¹

The SIGGTO link should be used in LNG bunkering:

- Ship-to-ship;
- Truck-to-ship;
- Terminal and pipeline to ship.

Who:

- National Authorities;
- ISO TC 67/WG 10;
- IMO IGF Committee.

¹⁰¹ This system is described in the SIGTTO recommendation "ESD ARRANGEMENTS & Linked Ship/Shore Systems for Liquefied Gas Carriers".

When:

- Effective immediately: For a case by case study with FSA (Formal Safety Assessment) studies;
- 2013-2014: ISO TC 67/WG 10 new guidelines and new IGF code.

Recommendation no. 14 regarding the use of Emergency Release Systems (ERS) during LNG bunkering

Why:

An Emergency Release Systems enables a rapid disconnection of arms/hoses when bunkering LNG in case of excessive drift of the vessel/barge or for a truck accidentally moving away from the operating area or design envelope. It has been identified that there is a need for such Emergency Release Systems (ERS). This is to minimize risks and reduce the size of safety zones thus enabling LNG operations even during cargo and passenger handling.

What:

It is recommended to use an emergency release system **or** a breakaway coupling when bunkering LNG.

It is recommended that the system be so designed that the emergency release system or break away coupling, when activated, initiates an emergency shutdown (ESD).

This applies to LNG bunkering:

- Ship-to-ship;
- Truck-to-ship;
- Terminal and pipeline to ship.

Who:

- National Authorities;
- ISO TC 67/WG 10;
- IMO IGF Committee.

When:

- Effective immediately: For a case by case study with FSA studies;
- 2013-2014: ISO TC 67/WG 10 new guidelines and new IGF code.

Recommendation no. 15a regarding the need for review of training of crew onboard small scale LNG vessels carrying LNG as a cargo

Why:

A potential problem if LNG was to take a larger share of the market for maritime fuels is the need for well-trained crew. Today, the crew of a LNG bunkering/feeder vessel (ocean going) would need the same competence as the crew of a large IGC tanker, a competence which few have and which takes long time to achieve. One way of solving this would be to change the criteria for training, possibly referring to the smaller amounts that are handled on a bunker vessel. This problem is however short lived since as soon as people are getting experience there will be crew available with certificates up to current STCW standard.

What:

It is recommended that, for an introduction period, the need for long experience onboard LNG vessels in order to be certified to work onboard an LNG vessel for small scale distribution and bunkering can be substituted with training.

A limitation is that it may be difficult to change the existing rules for vessels that fall under the IGC code, which is likely to be the case for seagoing bunker vessels. An option may be to have bunker vessels/barges that keep to inland waterways.

Who:

- IMO;
- EU and the MARKIS project;
- Training institutions.

When:

As soon as possible.

Recommendation no. 15b regarding the need for establishing training of personnel onboard LNG fuelled vessels and in terminals on handling of LNG

Why:

It is considered very important that the involved operators, both onboard vessels and in terminals, are trained to a sufficient level in order to maintain the safety record for LNG handling. Today there is a lack of specified training for crews working onboard LNG fuelled vessels handling LNG and in small scale terminals.

What:

It is recommended that the training requirements for all actors in the LNG chain (crews on both LNG bunker vessels and on gas fuelled vessels, bunker operators, port authority etc.) be reviewed and if needed be changed in order to meet the different levels of requirements that may arise from the different types of handling of LNG that is anticipated as a result of a the usage of LNG as a maritime fuel.

The review could also include an estimation of the possibilities to achieve a certain level of training among a sufficient number of personnel within a reasonable timeframe.

Who:

- IMO;
- EU and the MARKIS project;
- Training institutions.

When:

As soon as possible.

Recommendation no. 16 regarding measures to minimise methane release in the LNG bunker supply chain and operations

Why:

The main objective of introducing LNG as an alternative ship fuel in SECA is to reduce the sulphur emissions but it also offers a reduction of greenhouse gas (GHG) emissions by reducing the CO₂ emissions. The benefits regarding reduced greenhouse gas emissions gained by the transition from oil to LNG will, however, be counteracted if normal supply and LNG bunkering operations are associated with methane release. Furthermore the on-board use of LNG as fuel and the associated methane slip is an indirect potentially negative aspect of the transition from oil to LNG and continued efforts to minimize methane slip from LNG engines is also important.

What:

It is recommended to design and construct all processes and equipment used in the LNG bunker supply chain including bunkering operation and onboard consumption of LNG in such a way that all sources of release or slip of methane are minimized as far as reasonably practicable. Procedures for monitoring and equipment for measurements under normal operational conditions must also be seen as part of the minimization ambition.

Who:

- LNG bunkering equipment designers and manufacturers;
- Operators of LNG fuelled ships.

When:

Technical measures and efforts to reduce the operational releases of methane is an on-going process that must continue and be emphasized during the development and establishment of the LNG bunker infrastructure.

Read about Recommendation no. 16 in: 12.1.3 LNG Bunkering

14.5 Recommendations on the Permit Process

Recommendation no. 17 regarding communication during the public consultation process

Why:

Project developers identify public opposition as a key problem when it comes to permit processes. A major reason for public opposition is that people are insufficiently or incorrectly informed about planned projects. Furthermore, public, local and regional authorities and the media in general have little knowledge of LNG.

To increase public acceptance better communication is needed. According to the EIA Directive (Article 2(2)) the public concerned shall be given early and effective opportunities to participate in the environmental decision-making procedures and shall be entitled to express comments and opinions when all options are open to the competent authority before the decision is taken.

What:

For communication during the public consultation process, it is recommended:

- To establish early, good communication between the project developer, the authorities, other economic activities and the general public;
- To define the project well with regard to capacities and dimensions and to consider several locations;
- To perform an adequate safety analysis, including all external and internal risks, and taking adequate time to communicate the result with the general public, the neighbors of the establishment and the authorities concerned;
- To demystify handling of LNG when it comes to safety aspects. This can for example be done by communicating the exceptional safety record of LNG operations – not a single major general public fatality has occurred anywhere in the world because of LNG operations;
- To communicate the advantages of LNG as a fuel, e.g. reduced emissions and reduced engine noise;
- To communicate the necessity of establishing an LNG filling station infrastructure to be able to use LNG as a fuel in the maritime sector;
- To elaborate information to the stakeholders that is target-group-specific. This means that information is prepared in a way that different stakeholder groups can easily understand.

Who:

Project developers of LNG terminals and bunkering facilities.

When:

Communication with the public and authorities concerned is an essential part of the permit process.

Read about Recommendation no. 17 in: 13.8 Information to the Stakeholders

Recommendation no. 18 regarding guidelines on siting of small and medium scale (intermediary) LNG terminals and land-based LNG filling stations

Why:

There are guidelines available regarding the siting of large scale LNG import terminals. Small and medium scale LNG terminals with land-based filling as well as bunkering services must be located close to their customers in the port to be competitive. Such requirements may create conflicts with safety aspects. The development of guidelines on the siting of intermediary small and medium sized LNG terminals, LNG tank truck filling stations and LNG bunker stations is therefore considered to be urgent.

Terminals and filling stations handling > 50 tonnes of LNG are covered by the Seveso Directive but different praxis are applied in various countries.

Some national guidelines suggesting various safety distances between small and medium sized LNG tanks and other activities are available and may be useful for elaboration of harmonised guidelines. SIGTTO has published corresponding guidelines for large LNG terminals and the LNG business sector should also be interested in facilitation of safe and competitive siting of intermediate small and medium terminals with bunkering services and land-based LNG filling stations.

What:

Develop guidelines on siting of small and medium scale intermediary LNG terminals and land-based LNG filling stations based on national and international regulations with a view on possible international harmonization.

Who:

- SIGTTO;
- National authorities.

When:

It is considered likely that the development and implementation of such guidelines can be accomplished by 2013 or 2014. It is, however, important that the development of new guidelines must not be referred as a reason for delaying of pending applications and establishments.

Read about Recommendation no. 18 in: 13.10 Sites for New Establishments

Recommendation no. 19 regarding creation of a coordinated permit process

Why:

Long permit procedures may be an obstacle for the development of an LNG infrastructure in Northern Europe. Current average duration of the procedure is four years. One reason of long processes is that there are two or more permit processes required and two or more authorities involved in many countries in SECA. The process could be shortened by integration of these processes into one single process at national level. However, one stop shop will most likely only be relevant for large LNG facilities, which are of significant importance for the energy supply.

The experiences are mainly based on large scale installations not small and medium scale with lower risks.

What:

One single coordinated process for the permitting process, in which the authorities concerned cooperate closely is recommended to be introduced at the national level, e.g. in the form of a “one stop shop”.

Who:

National authorities.

When:

It is urgent to shorten the permit procedure for LNG facilities as soon as possible to be able to establish an LNG infrastructure in 2015.

Read about Recommendation no. 19 in: 13.5 Number of Processes

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15.6 List of Units

Wh	Watt hour
kWh	kilo Watt hour (1,000 watt hours) 1kWh = 3.6 MJ
MWh	Mega Watt hour 1,000,000 watt hours
MJ	Mega Joule, 1,000,000 Joule, = 1MJ = 0.28kWh
MBTU	Million British Thermal Unit, 1 MBTU = 293 kWh = 1,055 MJ
kW	kilo Watt, 1,000 Watt, 1 kW=1.34 hp =3.6 MJ/h
MW	MegaWatt = 1,000 kW= 1,000,000 W

15.7 List of Appendices

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15.8 List of Abbreviations

AIS	Automatic Identification System is a very high frequency (VHF) radio-based system which enables the identification of the name, position, course, speed, draught and cargo of ships
ALARP	As Low As Reasonably Practicable
BCM	Billion cubic meter
BEMIP	Baltic Energy Market Interconnection Plan
BLEVE	Boiling liquid expanding explosions
BP	British Petroleum
Bunkering vessel	A bunker vessel, bunker barge or other floating movable object able to deliver LNG as bunker fuel for ships
BV	Bureau Veritas
CNSS	Clean North Sea Shipping Project
CNG	Compressed Natural Gas
CO ₂	Chemical formula for Carbon dioxide
DECC	UK Department for Energy and Climate Change
DF	Dual Fuel
DNV	Det Norske Veritas AS
DMA	Danish Maritime Authority
DWT	Dead Weight Ton
EC	European Commission
ECA	Emission Control Area
EEC	European Economic Community
EEDI	Energy Efficiency Design Index
EGR	Exhaust Gas Recirculation
EIA Directive	EU Directive
EMSA	European Maritime Safety Agency of the European Commission
ERS	Emergency Release System
ESD	Emergency Shut Down
ESD-1	Same as ESD
ESD-2	Same as ERS
EU	European Union
EUROGAS	Natural Gas Industry of the European Union
FiFi	Diesel Engine Driven or Electric Motor Driven Fire Pumps: 2X1200 m ³ /h or one 2400 m ³ /h, Fire Monitors:2X1200 m ³ /h@120m and a Remote Control System
FO	Fuel oil, any type of oil based fuel commonly used as ship fuel today
FSA	Formal Safety Assessment
GIIGNL	The International Group of Liquefied Natural Gas Importer
GIIGNL handbook	The third edition of LNG Custody Transfer Handbook published by GIIGNL in 2011
GE	Gothenburg Energy
GL	Germanischer Lloyd SE
GPM	Gallons per minute

HAZID	Hazard Identification
HELCOM	Helsinki Commission is a Baltic Sea Action Plan
HFO	Heavy Fuel Oil
HAS	UK Hazardous Substances Authority
IALA	International Association of Lighthouse Authorities
IEA	International Energy Agency
IGC Code	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. A new version of the code is under development by IMO
IGF Code	The International Code for Gas Fuelled vessels which is under development by IMO
IKC	In Kind Contributors
IMO	International Maritime Organization (www.imo.org)
IPC	UK Infrastructure Planning Commission
IR	Infra Red
ISO	International Organization for Standardization
ISPS Code	International Ship and Port Facility Security Code
ISGOTT	International Safety Guide for Oil Tankers and Terminals
LBG	Liquefied Biogas
LFL	Lower Flammability Limit
LNG	Liquefied Natural Gas
LNGRV	Liquid Natural Gas Regasification Vessel
LPG	Liquefied Petroleum Gas
MARKIS	Maritime Competence and Innovation Cooperation in the Skagerrak and Kattegat
MarPol	The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto
MBTU	One thousand British Thermal Unit
MCM	Million cubic meter
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
MoS	Motorways of the Seas
MSC	The Maritime Safety Committee
MT	Million Tonnes(per annum)/metric tones
Mtoe	Million Tonnes of oil equivalent
NGO	Non Government Organization
NMD	Norwegian Maritime Directorate
NO _x	Nitrogen Oxides
NPV	Net Present Value
NSCOGI	North Seas Countries' Offshore Grid Initiative
NYMEX	Henry Hub natural gas prices
OCIMF	Oil Companies International Marine Forum
OECD	Organisation for Economic Co-operations and Development
PEC	Pilot Exemption Certificate
PM	Particulate matter

RoRo	Roll on Roll Off
RoPax	Roll on Roll Off and Passenger
RPT	Rapid phase transition
SCR	Selective Catalytic Reduction
SECA	SOx Emission Control Area describes an area where the adoption of special mandatory measures for SOx emissions from ships is required according to Annex VI of MarPol
SEEMP	Ship Energy Efficiency Management Plan
SIGTTO	Society of International Gas Tanker and Terminal Operators
SIGTTO guidelines	The First edition of LNG Ship-to-ship Transfer Guidelines produced by SIGTTO and published by Witherby Seamanship in 2011
SMTF	Swedish Marine Technology Forum
SMTF procedures	LNG ship-to-ship bunkering procedure published by Swedish Marine Technology Forum in 2010
SOLAS	The International Convention for the Safety of Life at Sea, 1974, and its Protocol of 1988
SO _x	Sulphur Oxides
STS	Ship-to-Ship
TEN-T	Trans-European Transport Network
TPA	Third Party Access
TPS	Terminal-to-ship via Pipeline
TPES	Total Primary Energy Supply
TSO	Transmission System Operator
TTS	Truck-to-Ship
UFL	Upper Flammability Level
VHF	Very High Frequency
WACC	Weighted Average Cost of Capital

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