Summary 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)
Observers

Consultants

Reference Group

Association of Danish Transport and Logistic Centres
Aula Europe Spri
Baltic Clean Sea Shipping
Baltic Energy Forum
Baltic Ports Organization
Belgian Federal Public Service Mobility and Transport
Danish Ports
Danish Shipowners’ Association
Danish Society of Naval Architecture and Marine Engineering
Delphis N.V
European Community Shipowners' Associations
Gaz-System
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Keppel Offshore & Marine Europe Technology Centre
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Ministry of Transport, Denmark
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Port of Aarhus
Port of Antwerpen
Port of Dunkerque
Port of Esbjerg
Rolls Royce
Royal Belgian Shipowners' Association
SeaTechnik
Stockholm Ports
Svenskt Marintekniskt Forum
Viking Line
Vopak
Wärtsilä
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. One alternative is natural gas in the form of liquefied natural gas (LNG) as it has environmental and climatic 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 into force. Accordingly, the sulphur content has to be decreased from 1.0 % to 0.1 %, placing the competitiveness of short sea shipping under pressure against land-based transport, particularly road haulage.

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 associated infrastructure for storage and distribution; hence a structure of LNG filling stations must be set up.

The project has focused on these issues and has come up with recommendations that encompass 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 associated with developing such an infrastructure, the actions required to solve these problems and the key stakeholders identified with the role of contributing to the task of overcoming these problems.

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

In the Summary Report, the Executive Summary is followed by a Summary and Recommendations.

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

Copenhagen, May 2012
Executive Summary

Introduction

In order to improve the environment by developing shipping as a green means of transport, regulations from 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 that 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: switch 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 (MGO) 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, distribution, 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 is a number of recommendations that 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 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 to feed into the natural gas grid and cannot be directly used for maritime purposes.

To better address the needs of marine customers, a system of small-scale and medium-scale terminals with feeder ships bringing LNG from the import terminal to these 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 the 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, 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 with regard to 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 terminal-to-ship via 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 MGO alternative. The question of availability of the anticipated required volume of MGO 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, decisions on building a more fine-meshed supply infrastructure are necessary.

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 4.2 million tonnes in 2020 and 7 million tonnes in 2030.\(^2\) It is foreseen that to meet this demand, in the order of 10-12 new 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 generally be based on an average internal rate of return for infrastructure investments below 12% (corresponding to a payback time of approximately 8 years) 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 and medium-scale LNG;
- Off-shore and on-shore safety regulations are harmonized;
- LNG feeder vessels and barges, as well as bunker vessel traffic, etc., should be considered similar to other dangerous cargo movements.

\(^2\) To convert from tonne LNG to cubic meters of LNG, multiply with a factor 2,2.
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;
- Tailor-made 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

Table of Contents

1 Introduction .......................................................................................................................... 10

2 Supply of LNG ...................................................................................................................... 11
   2.1 Status and Plans for the North European LNG Terminals .............................................. 13
   2.2 Bunkering and Delivery to Customers ......................................................................... 14
   2.3 Other Requirements for an LNG Bunkering Port ......................................................... 15

3 Supply Costs of the Different Fuel Alternatives ................................................................. 15
   3.1 Price Developments of LNG Versus Oil-Based Fuel Types ........................................ 15
   3.2 Price of LNG, HFO and MGO at Major European Import Hubs .................................... 16
   3.3 Infrastructure Costs within Northern Europe ............................................................... 16
   3.4 On-Board Delivered Fuel Prices ................................................................................ 19

4 Demand for LNG from Shipping ...................................................................................... 19
   4.1 The Demand for Marine Fuels in the SECA ................................................................. 19
   4.2 Economic and Financial Aspects for the Shipowner ..................................................... 20
   4.3 LNG Demand from Shipping ....................................................................................... 21
   4.4 LNG Demand from Ships Sailing beyond the SECA Region ....................................... 23

5 Land-based LNG Demand ................................................................................................. 23

6 Business Cases for Ports ................................................................................................. 24

7 The Development of an LNG Filling Station Network ................................................... 25
   7.1 Scenarios for Infrastructure Development ................................................................. 25
8 Business Models for Establishment of an LNG Bunkering Infrastructure 28

8.1 Ports and Terminals ....................................................................................................................................... 28
8.2 Financing ...................................................................................................................................................... 30
8.3 Investment Risks and Risk Mitigation ........................................................................................................... 30

9 Safety Aspects and Risk Assessment in the LNG Supply Chain .......... 31

10 Technical and Operational Aspects in the LNG Supply Chain .......... 33

11 The Permit Process ....................................................................................................................................... 34

Recommendations .............................................................................................................................................. 37

Recommendations for Bunkering Solutions ........................................................................................................ 37
Recommendations Regarding Economic and Financial Aspects .......................................................................... 40
Recommendations Regarding Safety Issues ........................................................................................................ 45
Recommendations Regarding the Technical and Operational Aspects ................................................................ 50
Recommendations on the Permit Process ............................................................................................................ 58
1 Introduction

Regulations from 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 that of industries that rely on cost-efficient transportation. 
To illustrate the magnitude of the fuel-usage business, it can be mentioned that, during 2010, ships sailing 
within these sea areas consumed around 12 million tonnes of fuel, 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, 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.
2 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 is construction of 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-scale and medium-scale 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-scale, medium-scale and small-scale terminal/storage facilities](image-url)

In this study, large-scale, medium-scale 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 interrelationship between the different components of the system.
Table 1: Applied definitions of large-scale, medium-scale and small-scale in different activities or aspects

<table>
<thead>
<tr>
<th>Activity/Aspect</th>
<th>Large scale</th>
<th>Medium scale</th>
<th>Small-scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>On shore storage capacity</td>
<td>Import terminal ≥ 100,000 m³</td>
<td>Intermediary terminal 10,000-100,000 m³</td>
<td>Intermediary terminal &lt; 10,000 m³</td>
</tr>
<tr>
<td>Ship size, LNG capacity</td>
<td>LNG carriers 100,000 – 270,000 m³</td>
<td>LNG feeder vessels 10,000-100,000 m³</td>
<td>LNG bunker vessels 1,000-10,000 m³ LNG bunker vessels/barges 200 – 1,000 m³</td>
</tr>
<tr>
<td>Tank trucks</td>
<td></td>
<td></td>
<td>40 – 80 m³</td>
</tr>
</tbody>
</table>
2.1 Status and Plans for the North European LNG Terminals

In Figure 2 below, the map shows existing and planned LNG infrastructure in Northern Europe. Large LNG import terminals exist at present in the United Kingdom, the Netherlands, and Belgium. By 2020, large import terminals are likely to have been established in Northern Europe, in France, Finland, Germany, and Poland. In the United Kingdom additional terminals are expected due to an increased demand. In the Netherlands and Belgium, existing LNG terminals are expected to manage an increase in LNG imports.

Figure 2 Existing and planned production plants and LNG terminals in the SECA

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

4 This refers only to the terminals that are decided to the consultant’s best knowledge in January 2012.
In the Baltic countries, a prime reason for LNG import facilities is to achieve increased diversity of energy supply and hence to provide alternative gas supply routes. For all countries, short sea shipping and its potential LNG demand is a secondary factor.

A number of small-scale 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.

### 2.2 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; ship-to-ship, truck-to-ship and terminal-to-ship via pipeline](image-url)
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 m$^3$. 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 m$^3$ (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 m$^3$ (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).

2.3 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, public communication, environmental and regulatory issues. All the parameters need to be taken into consideration even though bunkering volumes are often the determining factor.

3 Supply Costs of the Different Fuel Alternatives

3.1 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 of two main parts:

- Price of the fuel at the major European import hubs;
- Infrastructure costs
  - The costs of storage;
  - The cost of transhipment between hubs and local port facilities and further to the end-user.
3.2 Price of LNG, HFO and MGO at Major European Import Hubs

In Europe, the LNG price is fixed relative to the price of pipeline gas, which in turn typically follows the lead of competing fuels such as crude oil or other oil products. In the study, price forecast for HFO has been based on crude oil price forecasts from the UK Department for Energy and Climate Change (DECC). This forecast, together with different designed relative price levels for MGO versus HFO and LNG versus HFO respectively form the basis for six different fuel price scenarios.

The price scenarios comprising “Central” and “High” price levels for MGO and “Low”, “Central”, and “High” price levels for HFO are described in Table 2. Tables and figures showing fuel prices are market prices while relative prices are adjusted for their different energy equivalence.

Table 2 Six scenarios’ price levels for MGO and LNG and relative to HFO from an energy content point of view

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

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

3.3 Infrastructure Costs within Northern Europe

In order to get a more comprehensive picture seen from a shipowner’s point of view, infrastructure costs are included when analyzing the future demand of LNG. For the HFO and MGO fuel cases, this report has used a cost of €10/tonne for infrastructure costs. This figure may seem to be low but has been confirmed by different market players.

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

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5 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.
6 The future HFO price is derived by using linear regression analysis (assuming a linear relationship between HFO and crude oil prices).
7 The designed price levels have been estimated after studying historical MGO and LNG prices relative to the HFO price.
Port Case I is defined as a large-scale facility that is incremental to an existing LNG import terminal. Medium-scale and small-scale, Port Case II and Port Case 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 and thereby throughput. 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 3.

<table>
<thead>
<tr>
<th>LNG Port Case</th>
<th>Large-scale Port Case I</th>
<th>Medium-scale Port Case II</th>
<th>Small-scale Port Case III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput (year 2015)</td>
<td>204,000 m³/yr</td>
<td>343,000 m³/yr</td>
<td>52,000 m³/yr</td>
</tr>
<tr>
<td>Throughput (year 2015)</td>
<td>91,000 tonnes/yr</td>
<td>154,300 tonnes/yr</td>
<td>23,300 tonnes/yr</td>
</tr>
<tr>
<td>Tank size</td>
<td>(no separate tank)</td>
<td>20,000 m³</td>
<td>2 x 700 m³</td>
</tr>
<tr>
<td>Tank turnover/year</td>
<td>n/a</td>
<td>20</td>
<td>44</td>
</tr>
<tr>
<td>Installations for import, bunkering and other transfer to end-users</td>
<td>One bunkering berth including one jetty (pier for mooring) and associated equipment</td>
<td>One bunkering berth including one jetty (pier for mooring) and associated equipment</td>
<td>One bunkering berth and associated equipment</td>
</tr>
<tr>
<td></td>
<td>One small scale bunkering vessel, 4 000 m³</td>
<td>Two small scale bunkering vessels, 3 000 m³ and 4 000 m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Two tank trucks, 50 m³ each</td>
<td>One tank truck, 50 m³</td>
<td>One tank truck, 50 m³</td>
</tr>
<tr>
<td></td>
<td>One LNG tank-truck filling station;</td>
<td>One LNG tank-truck filling station;</td>
<td>One LNG tank-truck filling station</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>LNG Port Case</th>
<th>Large-scale Port Case I</th>
<th>Medium-scale Port Case II</th>
<th>Small-scale Port Case III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total initial investment cost [million €]</td>
<td>69</td>
<td>137</td>
<td>15</td>
</tr>
<tr>
<td>- thereof investment in bunker vessels [million €]</td>
<td>32</td>
<td>60</td>
<td>-</td>
</tr>
<tr>
<td>Total operational cost [million €/yr]</td>
<td>10</td>
<td>17</td>
<td>3,0</td>
</tr>
<tr>
<td>- thereof fixed operational costs of bunker vessels [million€/yr]</td>
<td>2</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>- thereof fuel costs for bunker vessels [million€/yr]</td>
<td>0.5</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 5 Infrastructure costs per tonne for the three LNG port cases

<table>
<thead>
<tr>
<th>LNG Port Case</th>
<th>Large-scale Port Case I</th>
<th>Medium-scale Port Case II</th>
<th>Small scale Port Case III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needed income to reach 8 years payback [€/tonne LNG]</td>
<td>136</td>
<td>157</td>
<td>211</td>
</tr>
<tr>
<td>Needed income to reach 10 years payback [€/tonne LNG]</td>
<td>118</td>
<td>137</td>
<td>194</td>
</tr>
<tr>
<td>Needed income to reach 12 years payback [€/tonne LNG]</td>
<td>107</td>
<td>125</td>
<td>183</td>
</tr>
<tr>
<td>Needed income to reach 15 years payback [€/tonne LNG]</td>
<td>95</td>
<td>112</td>
<td>172</td>
</tr>
</tbody>
</table>

As can be seen above, the transshipment and handling costs in the studied cases range from about 118 to 194 €/tonne of LNG assuming a payback time of 10 years. They are heavily dependent of the payback period, the needed investments and furthermore the throughput.

Figure 4 below shows how the infrastructure costs increase with higher IRR\(^8\) on the investment for each of the three LNG port cases.

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

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

---

\(^8\) Internal Rate of Return (IRR) calculations are based on expected life times for terminal equipment, vessels and trucks being 40, 20 and 10 years respectively.
3.4 On-Board Delivered Fuel Prices

With the infrastructure costs assumed above added to the projected price levels shown in Table 2, the price scenarios for the end-user prices are as follows:

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>MGO price level</th>
<th>MGO price €/tonne</th>
<th>LNG price level</th>
<th>LNG price €/tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Low LNG_Central MGO</td>
<td>Central</td>
<td>885</td>
<td>Low</td>
<td>485</td>
</tr>
<tr>
<td>2. Central LNG_Central MGO</td>
<td>Central</td>
<td>885</td>
<td>Central</td>
<td>610</td>
</tr>
<tr>
<td>3. High LNG_Central MGO</td>
<td>Central</td>
<td>885</td>
<td>High</td>
<td>740</td>
</tr>
<tr>
<td>4. Low LNG_High MGO</td>
<td>High</td>
<td>1210</td>
<td>Low</td>
<td>485</td>
</tr>
<tr>
<td>5. Central LNG_High MGO</td>
<td>High</td>
<td>1210</td>
<td>Central</td>
<td>610</td>
</tr>
<tr>
<td>6. High LNG_High MGO</td>
<td>High</td>
<td>1210</td>
<td>High</td>
<td>740</td>
</tr>
</tbody>
</table>

HFO price is in all scenarios assumed to be 530 €/tonne. Relative prices corrected for energy equivalence, see Table 2.

Recommendation

Prices for maritime LNG corresponding to internal rates of return below 12% (corresponding to a payback time of about 8 years) 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)

4 Demand for LNG from Shipping

4.1 The Demand for Marine Fuels in the SECA

A total of 14,000⁹ ships entered the SECA waters in 2010. Of these, 2,200 were confined to the SECA region and an additional 2,700 were present for more than 50% of their time. These ships, during the time they are in the SECA waters consume around 12 million tonnes of fuel¹⁰. Assuming a fleet growth rate of 2%, the use of more than 17 million tonnes can be expected within the SECA in 2030.

---

⁹ 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

¹⁰ The fuel consumption is calculated by IHS Fairplay based on AIS data for actual ships sailing in the SECA with installed power and speed being known factors. Different assumptions regarding individual ship energy consumption over a year may alter this figure. Alternatively, bunker statistics could have been used. However bunker statistics are not available in many ports and the
4.2 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.

The choice will be based on the shipowners’ views on 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 payback 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 investment cost, and the highest operational cost. Hence, MGO has been chosen as a “baseline” to which the other compliance strategies are compared. For a starting point, four ship types are considered\(^\text{11}\), 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 payback 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 and scrubber strategy has generally slightly shorter payback times than any of the LNG options. In Scenario 3 with high LNG prices the difference between the different compliance alternatives is more marked. Retrofitting has slightly longer payback times, however still within range of 2 - 4 years.

Sensitivity analysis of the payback periods for different fuel price ratios has been made for the HFO and the LNG strategies respectively. An example, the situation for one of the type ships – a big RoRo ship, is shown below.

**Uncertainties of these data are considerable. It is for example not possible to differentiate between fuels used within and outside the SECA.**

\(^\text{11}\) RoPax/RoRo vessel, deadweight 4,200 tonnes, estimated consumption 4,000 tonnes LNG per year; Costal tanker/bulk carrier, deadweight 10,000 tonnes, estimated consumption 6,000 tonnes LNG per year; Container ship, deadweight 9,000 tonnes, estimated consumption 6,500 tonnes LNG per year; Big RoRo, estimated consumption 9,800 tonnes LNG/year.
4.3 LNG 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) is used to assess the demand. The fleet is assumed to grow 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, the analysis shows that newer ships can be economically retrofitted to use LNG depending on the price development scenario.

In this study, the demand analysis is further reviewed regarding sensitivity to different factors, primarily the fuel prices. At an LNG price of 610 €/tonne and an MGO price a 885 €/tonne, which represents Scenario 2, (Central LNG-Central MGO), the LNG demand is estimated to an amount 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, illustrated in the figure below.

![Payback time for shipowners as a function of price ratios LNG/MGO and HFO/MGO at ship](image-url)

**Figure 5 Payback time for shipowners as a function of price ratios LNG/MGO and HFO/MGO at ship**
Example big RoRo, estimated consumption 9,800 tonnes per year. Source: AF internal analysis 2012.
Figure 6 LNG demand from retrofits and new-builds using central LNG and MGO price levels, described in Scenario 2

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 relative difference between the three scenarios 1, 2 and 3 with low, central, and high estimated LNG prices and MGO prices at the central level. The other three scenarios (Scenario 4 to 6) result in quite similar demand development as Scenario 1, 2, and 3. Figure 7 clearly expresses the impact of the LNG price level for a market take-off in 2015.

Figure 7 Three scenarios of LNG demand with MGO prices at the central level
Scenario 1 – low level LNG price, Scenario 2 – central level LNG price and Scenario 3 – high level LNG price.
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 liner 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.

4.4 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. The amount of fuel provided from the ports of the SECA is about three times higher than the amount of fuel used in the 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 the SECA. If IMO regulations will be introduced reducing the sulphur dioxide emissions throughout the world\(^{12}\) 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.

5 Land-based LNG Demand

Natural gas and LNG are likely to continue to play a key role in the EU’s energy-mix in the coming decades. The total gas consumption in the SECA is forecasted to remain at today’s level in the period up to 2020. The total demand of LNG in the 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.

While the predominant part of the land-based demand of LNG is believed to come from countries with an established gas grid, it is expected that the demand from small-scale and medium-scale installations also will grow. This demand will be complementary in countries with established gas grids but will offer opportunities in areas currently not served by national gas networks, most notably Sweden and Finland. A small-scale infrastructure serving both marine and land-based customers has already developed in Norway.

The main land-based customers for small-scale and medium-scale terminals are first and foremost industrial applications such as for example steel manufacturers or paper mills, either in the vicinity of the terminal or served by LNG truckloads. Other potential demand from land-based customers would include LNG for truck and car gas filling stations, on railways, local service vehicles such as refuse collection and buses as well as vehicles within the port itself, and local district heating peak load services. In specific cases there will be demand from vessels serving inland waterways.

For the establishment of an LNG infrastructure for marine purposes, the complementary sales to land-based customers while relatively small in total terms could in cases of smaller ports be critical to achieve reasonable payback times.

\(^{12}\) It is planned that by 2020, the sulphur content of fuel will be limited to 0.5% throughout the world.
6 Business Cases for Ports

In the report, critical properties that are factoring in the decision for a port’s suitability for establishment of an LNG terminal are accounted for. Also included is an 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 are presented in Figure 8 below. The diagrams there show the required throughputs to get specific Internal Rate of Return (IRR) at each of the studied port cases between 3 % and 20 % under Scenario 2.

![Figure 8](image)

**Figure 8** Break-even annual throughput of LNG for the port cases at different internal rates of return (IRR)

Table 3 in Section 3.3 shows typical throughputs for bunkering at typical terminal installations. Individual port/terminal 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 year 2015 in our example port cases they would need additional demand equal to 88,000 tonnes, 150,000 tonnes and 27,000 tonnes respectively to achieve a 12 % IRR equivalent to an 8-year payback time.

In all the example cases, there is a requirement of about doubled throughput compared to projected year 2015. The potential for this increase comes from:

1. Further volumes for bunkering. It is estimated that the general demand for LNG for bunkering will increase around 100 % up to 2020 and a further 75 % up to 2030 (Scenario 2, Central fuel prices).
2. Volumes to land-based demand (as discussed in former section).

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 be developed for specific investment projects. Port authorities, potential investors in terminals, ship owners, 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, ship owners, 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)

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### 7 The Development of an LNG Filling Station Network

The potential for LNG supply from large-scale, medium-scale and small-scale terminals has been examined and so have the shipping and land-based LNG demands. 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 challenges here are that sufficient number of filling stations need to exist to provide an adequate network of bunkering terminals and at the same time, sufficient demand needs to materialise to ensure the financial viability of individual terminals.

#### 7.1 Scenarios for Infrastructure Development

In the Full Report (Chapter 9) estimations on the LNG volume to be sold in different sub-regions of the SECA are provided in order to forecast the geographical allocation of the demand. In the same chapter there is also a model to estimate the spread.

From the analysis of the 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. In order to estimate what supply structure is suitable from a logistic point of view in 2015, it is interesting to regard the tank sizes of ships. A small portion of ships will have LNG tanks less than 200 m³ and will need regular fuelling, most suitably with tank truck. However, as can be seen in Table 7, the majority (between 66 and 87 %) of ships confined to different sub-regions have tanks between 100 and 3,000 m³. Liner shipping is the category of ships that is suitable for a terminal-to-ship via pipeline bunkering solution. However, these ships can also be bunkered directly from a ship.

The proportion of terminal-to-ship via pipeline versus ship-to-ship bunkering will influence the overall design of an appropriate supply structure. If bunker ships are ample they can meet a big share of the LNG demand. If terminals with customised terminal-to-ship via pipeline bunkering are widespread, the market for bunker vessels will be more limited. In the case illustrated in Table 7 below, the share of ship-to-ship bunkering as well as terminal-to-ship via pipeline bunkering is assumed to be 50 %. Liner ships crossing the different sub-regions would in most cases have tanks sized above 200 cubic meters, implying that ship-to-ship bunkering would be the most suitable solution. The liner shipping traffic crossing different sub-regions is not included in the demand calculations for the different sub-regions described in Table 7.
Table 7 The maritime LNG demand confined to different sub-regions of the SECA and its most suitable bunkering solution (2015)

<table>
<thead>
<tr>
<th>SECA sub-region</th>
<th>LNG tank size for ships confined to the region</th>
<th>Share [% m$^3$]</th>
<th>Most suitable bunkering solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>The English Channel</td>
<td>&lt; 100 m$^3$</td>
<td>4 %</td>
<td>Tank truck-to-ship, TTS</td>
</tr>
<tr>
<td></td>
<td>100 m$^3$ &lt; tank &lt; 3,000 m$^3$</td>
<td>66 %</td>
<td>Bunkering vessel ship-to-ship, STS, or terminal-to-ship via pipeline, TPS</td>
</tr>
<tr>
<td></td>
<td>3,000 m$^3$ &lt; tank &lt; 10,000 m$^3$</td>
<td>30 %</td>
<td>Ship-to-ship, STS</td>
</tr>
<tr>
<td>The North Sea</td>
<td>&lt; 100 m$^3$</td>
<td>6 %</td>
<td>Tank truck-to-ship, TTS</td>
</tr>
<tr>
<td></td>
<td>100 m$^3$ &lt; tank &lt; 3,000 m$^3$</td>
<td>82 %</td>
<td>Bunkering vessel ship-to-ship, STS, or terminal-to-ship via pipeline, TPS</td>
</tr>
<tr>
<td></td>
<td>3,000 m$^3$ &lt; tank &lt; 10,000 m$^3$</td>
<td>12 %</td>
<td>Ship-to-ship, STS</td>
</tr>
<tr>
<td>Skagerrak/Kattegat</td>
<td>&lt; 100 m$^3$</td>
<td>2 %</td>
<td>Tank truck-to-ship, TTS</td>
</tr>
<tr>
<td></td>
<td>100 m$^3$ &lt; tank &lt; 3,000 m$^3$</td>
<td>87 %</td>
<td>Bunkering vessel ship-to-ship, STS, or terminal-to-ship via pipeline, TPS</td>
</tr>
<tr>
<td></td>
<td>3,000 m$^3$ &lt; tank &lt; 10,000 m$^3$</td>
<td>11 %</td>
<td>Ship-to-ship, STS</td>
</tr>
<tr>
<td>The Baltic Sea</td>
<td>&lt; 100 m$^3$</td>
<td>2 %</td>
<td>Tank truck-to-ship, TTS</td>
</tr>
<tr>
<td></td>
<td>100 m$^3$ &lt; tank &lt; 3,000 m$^3$</td>
<td>87 %</td>
<td>Bunkering vessel ship-to-ship, STS, or terminal-to-ship via pipeline, TPS</td>
</tr>
<tr>
<td></td>
<td>3,000 m$^3$ &lt; tank &lt; 10,000 m$^3$</td>
<td>12 %</td>
<td>Ship-to-ship, STS</td>
</tr>
</tbody>
</table>

Tramp shipping and linear shipping that is not confined to sub-regions but that sail in the SECA add up to the overall maritime demand\(^{13}\). These typically have tanks larger than 1000 m$^3$ and therefore ship-to-ship bunkering is the most suitable solution. The geographic demand scenarios in the analysis further include a projected land-based LNG demand. For countries with a gas grid, it is assumed that this demand will 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 (proportional by storage capacity). First and foremost land-based demand in non-grid countries will come from industrial applications, backup for gas fuelling stations and peak-load services for district heating and electricity production. The land-based demand is further described in Appendix 6 in the Full Report. Together, the demand from the maritime side and the land side add up to a 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-scale and small-scale demand in different scenarios. It can be evaluated if the investments in supply will be feasible or not given their assumed throughput and specified LNG price. For the maritime demand development, as specified in Scenario 2 (Central LNG_Central MGO) above and together with the

\(^{13}\) 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.
projected land-based demand per country, it is found that a possible and feasible infrastructure development
can be as presented in Table 8 below. It is based on the assumption that all the existing and decided LNG
terminals in the area (in total 14) have invested in incremental equipment to be able to bunker ships of the
sizes sailing in the SECA, refer to the Port Case I, and that additional small-scale and medium-scale
terminals will be required.

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

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maritime demand to be supplied by small-scale and medium-scale terminals, vessels, and trucks [tonnes]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,590,000</td>
<td>3,630,000</td>
<td>6,212,780</td>
<td></td>
</tr>
<tr>
<td><strong>Number of terminals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium-size terminal – Port Case II</td>
<td>7</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Small-size terminal – Port Case III</td>
<td>13</td>
<td>23</td>
<td>38</td>
</tr>
<tr>
<td><strong>Number of bunker vessels</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bunker vessel - 1,000 m³</td>
<td>9</td>
<td>19</td>
<td>28</td>
</tr>
<tr>
<td>Bunker vessel - 3,000 m³</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Bunker vessel - 4,000 m³</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bunker vessel - 10,000 m³</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Number of trucks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck - 50 m³</td>
<td>5</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

The above is a minimum if seen from a logistic point of view, in addition to the incremental investments in
existing terminals including large vessels (feeder vessels and large bunker vessels). The logistic point of
view implies that the LNG infrastructure is used in an optimal way across the different owners, ports,
operators etc. However, in the port cases when seen from an individual point of view, all ports will have at
least one LNG tank truck. 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. Tank trucks will most probably be important in Sweden and Norway where there is no
national grid and yet an LNG demand already in 2015. On the other hand, many foreseen customers are local
industries or local small distribution grids, so pipeline solutions may as well be important in these countries.

It can also be shown 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 costs can be
maintained at a lower level. The example in the above table refers to 50 % of the medium-sized ships being
bunkered via TPS (terminal-to-ship via pipeline) throughout the period. The investment costs for the
structure, including the incremental investments required in existing and planned ports, vessels in these as
well as the estimated number of small and medium-scale ports (plus vessels and trucks in these) would
amount to approximately 1.2 billion Euros in 2015.

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 (the
Baltic Sea, the North Sea, and the English Channel) of the SECA 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.
**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-scale and medium-scale LNG infrastructure in the form of 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)

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**8 Business Models for Establishment of an LNG Bunkering Infrastructure**

**8.1 Ports and Terminals**

There are many different models of port and terminal operation and ownership across the region. In Table 9 below, typical providers of the major components in the LNG bunkering supply chain are listed.

In Chapter 10 of the report, legal, operational, and financial models (or business models) for six different ports are reviewed. The ports are Zeebrugge, Hirtshals, Szczecin/Swinoujsci, 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. The choice of business model will be dictated by local circumstances.
Table 9 Provision of the major components in the LNG bunkering supply chain

<table>
<thead>
<tr>
<th>Component</th>
<th>Provider/ Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port external structure (external breakwaters, sea locks, etc.)</td>
<td>National Government or Port Authority</td>
</tr>
<tr>
<td>Port internal structure (internal quays, jetties, and locks, shared access routes)</td>
<td>Port Authority</td>
</tr>
<tr>
<td>Land for siting of storage and terminals</td>
<td>Port Authority</td>
</tr>
<tr>
<td>Jetties, quays serving the LNG storage, both loading and unloading</td>
<td>Port Authority or Terminal Owner/ Operator</td>
</tr>
<tr>
<td>LNG terminal and storage</td>
<td>Terminal Owner/ Operator</td>
</tr>
<tr>
<td>Feeder vessels and barges</td>
<td>Bunkering Service Providers</td>
</tr>
<tr>
<td>Bunker vessels</td>
<td>Bunkering Service Providers</td>
</tr>
<tr>
<td>Tank trucks</td>
<td>Terminal Owner/ Operator</td>
</tr>
<tr>
<td>Berths</td>
<td>Port Authority or Terminal Owner/ Operator</td>
</tr>
<tr>
<td>Anchorages</td>
<td>Port Authority</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Provider/ Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port external structure (external breakwaters, sea locks etc)</td>
<td>National Government or Port Authority</td>
</tr>
<tr>
<td>Port internal structure (internal quays, jetties and locks, shared access routes)</td>
<td>Port Authority</td>
</tr>
<tr>
<td>Land for siting of storage and terminals</td>
<td>Port Authority</td>
</tr>
<tr>
<td>Jetties/ quays serving the LNG storage, both loading and unloading</td>
<td>Port Authority or Terminal Owner/ Operator</td>
</tr>
<tr>
<td>LNG terminal and storage</td>
<td>Terminal Owner/ Operator</td>
</tr>
<tr>
<td>Feeder vessels and barges</td>
<td>Bunkering Service Providers</td>
</tr>
<tr>
<td>Tank trucks</td>
<td>Terminal Owner/ Operator</td>
</tr>
<tr>
<td>Berths</td>
<td>Port Authority or Terminal Owner/ Operator</td>
</tr>
<tr>
<td>Anchorages</td>
<td>Port Authority</td>
</tr>
</tbody>
</table>
8.2 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. Contributing factors for materializing the development under these circumstances are mainly:

- Public; through public early stage investments or financing support, for example public utilities;
- Contractual; mainly through binding agreements regarding supply and consumption of LNG between terminal owners and ship owners respectively;
- Incremental; where part of needed infrastructure already exists additional investments can be limited and/or made step-wise;
- Merchanting, based on regular feasibility study and risk analysis for a proposed project.

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

8.3 Investment Risks and Risk Mitigation

Investors, be they from the public or private sector, will face investment risks. The study has analyzed 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 10. There are also institutional issues such as taxation, contract models, and technology schemes.
Table 10 Financial risks and risk mitigation

<table>
<thead>
<tr>
<th>Risk</th>
<th>Description</th>
<th>Risk Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Project is not built to time, cost and/or performance specification</td>
<td>Engineering, Procurement and Construction (EPC)(^\text{14}) contract for construction or ship mounted temporary solutions</td>
</tr>
<tr>
<td>Volume</td>
<td>Demand from customers does not materialize</td>
<td>Contracts with “lead” maritime and other customers’ temporary solutions</td>
</tr>
<tr>
<td>Supply</td>
<td>LNG cannot be procured to meet demand</td>
<td>Back-to-back contracts(^\text{15}) with shipowners/ importers</td>
</tr>
<tr>
<td>Gas quality</td>
<td>LNG does not meet customers’ specifications</td>
<td>Back-to-back contracts with shipowners/ importers</td>
</tr>
<tr>
<td>LNG Selling Price</td>
<td>LNG cannot be sold at a price to cover costs</td>
<td>Long term contract(^\text{16}), indexed to HFO/ MGO</td>
</tr>
<tr>
<td>LNG Cost Price</td>
<td>LNG cannot be procured at a competitive price</td>
<td>Long term supply contract, indexed to HFO/ MGO</td>
</tr>
<tr>
<td>Operating risk</td>
<td>Terminal cannot be operated and maintained properly</td>
<td>O &amp; M contract(^\text{17})</td>
</tr>
</tbody>
</table>

9 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-scale 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 with regard to small-scale LNG bunkering operations. For reasons of clarity and uniformity, it is important that national and international regulators are specific concerning rules applicable for different installation sizes.

\(^{14}\) EPC is a contract for engineering, procurement and construction that transfers all the cost and performance risks of constructing a plant to a contractor.

\(^{15}\) Back-to-back contracts are 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.

\(^{16}\) Long-term contract in this context means a contract whose duration matches or exceeds any financing used in the project, typically 12-20 years.

\(^{17}\) 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.
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 presently applied in large-scale LNG import terminals 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 well-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 terminal-to-ship via pipeline.
**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)

Experience from ports where LNG bunkering and traffic with LNG bunker vessels take place or are planned, shows that existing regulative framework and standards for transportation of dangerous cargo is considered to ensure basic safety requirements and that there is no need to introduce specific new port by-laws or national regulations to regulate the traffic with LNG bunker vessels/barges. 18

**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 new special requirements for LNG bunker vessel traffic. (Recommendation no. 11)

## 10 Technical and Operational Aspects in the LNG Supply Chain

Bunker operations create safety issues for example on separation distances from other activities in the port area. 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 (STS) transfer is an important operation in a maritime bunkering infrastructure. However, compared to existing LNG handling, STS bunkering is a new type of operation and is the main area for ongoing studies and projects. The STS bunkering 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 refer to the safety zones to which non-authorized people have restricted access.

Truck-to-ship (TTS) bunkering is by definition a relatively small operation and the truck driver normally has a large responsibility. There are established operational procedures for loading and discharging of LNG

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18 The ISO 28460:2010 standard includes some specific requirements to ensure a safe transit of an LNG carrier through a port. The standard, which primarily is addressing large LNG carriers, has been reviewed within this study and some modifications are proposed to make the standard applicable also for small and medium-sized LNG feeder vessels and LNG bunker vessels/barges. Proposed modifications will harmonise the safety requirements for traffic with LNG bunker vessels/barges with existing requirements applied for traffic with other dangerous cargo, including conventional bunker vessel traffic, and it is therefore not necessary to introduce new regulations.
trucks today and 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 in which no unauthorized personnel, traffic or activities are allowed. 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.

**Recommendaion**

It is recommended to develop guidelines specifically devoted to LNG bunkering. The working group within the International Standardizations Organization (ISO) currently developing guidelines for LNG bunkering may well do this. (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)

## 11 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 the 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.

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ISO TC 67/Working Group 10
One of the findings is that a major reason for a long permit process 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 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.

**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 (SIRTTO) 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. Introduction at the national level is recommended. (Recommendation no. 19)
Recommendations for Bunkering Solutions

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 m³. 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 20,000 m³ are suitable for these operations. If the volumes are larger than 10,000 m³, an 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 100 m³ or larger.

Who:
- Terminal operators, large and medium-sized terminals;
- Port authorities;
- Bunker vessel operators.

When:
In the planning and investment phases for terminal facilities and LNG bunker vessels.
### Recommendation no. 1b regarding bunkering solutions; tank truck-to-ship (TTS)

**Why:**

Tank truck investments are for many manageable and they provide flexible solutions for bunkering of receiving vessels with small LNG bunker volumes. The truck capacity varies between 40 to 80 m$^3$ of LNG. LNG bunker volumes of approximately 200 m$^3$ 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.

**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 m$^3$.

**Who:**

- Terminal operators, all sizes;
- Port authorities;
- Tank truck operators.

**When:**

In the planning and investment phase for terminal facilities and tank trucks.
**Recommendation no. 1c regarding bunkering solutions; terminal-to-ship via pipeline (TPS)**

**Why:**

The terminal-to-ship via 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 problematic 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, 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.
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 ship owner’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, corresponding to a payback time of approximately 8 years. 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, such as the European Investment Bank, as the main arm backed by EU and Member State initiatives.

When:
Until 2020.
**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. Support could also be directed toward market-based issues. Regarding LNG procurement; the LNG market is characterised by long-term contracts with thin liquidity.

**What:**

It is recommended that business cases or plans be 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.

Further study is recommended on institutional issues such as technology procurement schemes, examining for example to which extent the design of the LNG market proves a constraint to the development of medium and small terminals. Also, the development of model contracts, where shipowners may contract with filling stations and either shipowners or filling stations could contract with LNG shippers or importers for LNG supplies could assist all parties of the supply chain.

**Who:**

Port authorities, potential investors in terminals, LNG providers, shipowners and other stakeholders.

**When:**

EU calls regarding business case studies have already been issued and further are expected.
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 liner traffic, fishing boats’ stations or other regular traffic, which in turn are connected to other ports. Furthermore demand from other nonmaritime 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, shipowners 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, shipowners, local communities, permit authorities, LNG providers and other stakeholders. Relevant EU and/or national authorities must support the work.

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.
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 m$^3$ (4 million tonnes) 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. Institutional issues such as taxation, contract models, and technology procurement schemes are important for an early development and it is envisaged that countries bordering the SECA cooperate and share information.

Some important measures for early market introduction are suggested in Recommendation no 2, 3 and 4.

Who:
EU and national authorities, ports, LNG suppliers, LNG providers, and end-users.

When:
Work has already started but it can be made even better as from today.
**Recommendation no. 6 regarding the need of bunkering vessels/barges - a floating infrastructure**

**Why:**

There is a need for floating small and medium LNG infrastructures in the form of bunker vessels and bunker barges.

Medium-sized LNG feeder vessels (> 10,000 m³) are already on the market and more are ordered. Therefore, these are expected to be able to cover the initial introduction of LNG as marine fuel. In addition however, bunker vessels/barges (< 10,000 m³) are needed to supply LNG to vessels. Today, with the exception of Pioneer Knudsen, no LNG bunker vessel or barge exists.

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, payback 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.
Recommendations Regarding Safety Issues

Recommendation no. 7: Define what is 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 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 up to 10,000 m$^3$, and bunkering pipe/hose diameters of Ø < 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.
**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.
**Recommendation no. 9 regarding the routines for accident and incident reporting systems for LNG bunkering**

**Why:**

Accident statistics on LNG bunkering today are 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. Currently it is difficult to extract and analyse accident data specifically related to bunkering accidents from the established maritime casualty databases 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.
**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 considerably 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.
**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 new 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 as well as potential risks associated with the projected LNG feeder and bunker vessel traffic and to compare it with the present bunker vessel traffic in the port.

**What:**

Consider LNG feeder vessels and barges as well as bunker vessel traffic similar to other dangerous cargo fuel vessel traffic and avoid introduction of new 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.
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 code (The International Code for Gas Fuelled vessels which is under development by IMO) and IGC code (International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk) do 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 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 11 in the Full Report. However, standardization work takes a long time and interim bunkering guidelines are needed to facilitate the deployment of LNG without jeopardizing the safety issue, and the maritime administrations have to work together to develop these. Furthermore, intermediary solutions must be aligned with the ISO standardization work.

Due to the developments in the Nordic countries, with Fjord Line and Viking Line ferries being built, an expert working group on bunkering has been assigned by the Nordic Directors for Safety at Sea. This is recommended as a practical way of setting up interim guidelines and it could be considered to expand this work with other countries as well. Furthermore, the SMTF (Swedish Maritime Technology Forum) findings on LNG bunkering procedures can be used in this work.
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<th>Who:</th>
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<tr>
<td>• Port authorities and national authorities;</td>
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<tr>
<td>• ISO TC 67/WG 10 and IGF.</td>
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<th>When:</th>
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<td>• Effective immediately: For a case-by-case study with FSA studies;</td>
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Recommendation no. 13 regarding the use of an Emergency Shutdown System (ESD) and communication system

<table>
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<th>Why:</th>
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<tr>
<td>The function 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. There is a need for an ESD to minimize risks and reduce the size of safety zones thus enabling LNG operations even during cargo and passenger handling.</td>
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<td>It is recommended to use an Emergency Shutdown System (ESD) and communications connection based on the SIGTTO electric link system when loading, discharging, and bunkering LNG for all LNG-fuelled vessels, LNG bunker/feeder/barges, and small-scale LNG terminals as well as tank trucks.</td>
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<td>It is recommended that the system for bunkering operations be designed in a way that enables immediate detection of leakage and failures, both on the bunkering and on the receiving side. It is also recommended that the system be capable of rapidly closing ESD valves, 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. Implementation of a data and telephone link, as suggested by SIGGTO, is recommended 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.</td>
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The SIGGTO link should be used in LNG bunkering:

- Ship-to-ship;
- Truck-to-ship;
- Terminal-to-ship-via pipeline.

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<tr>
<td>- National Authorities;</td>
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<tr>
<td>- ISO TC 67/WG 10;</td>
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<tr>
<td>- IMF IGF Working Group.</td>
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</tbody>
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20 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;
Recommendation no. 14 regarding the use of Emergency Release Systems (ERS) during LNG bunkering

Why:

An Emergency Release System (ERS) 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. A need for such ERS has been identified. 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-to-ship via pipeline.

Who:

- National Authorities;
- ISO TC 67/WG 10;
- IMF IGF Working Group.

When:

- Effective immediately: For a case-by-case study with FSA (Formal Safety Assessment);
Recommendation no. 15a regarding the need for review of training of crew onboard small and medium-scale vessels carrying LNG as cargo

Why:

A potential problem for LNG to take a larger share of the market for maritime fuels is the need for well-trained crew. Today, the crew of an LNG bunkering/feeder vessel (ocean-going) would need the same competence as the crew of a large IGC tanker, a competence which few people have and which takes a 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 and medium-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 Maritime Competence and Innovation Cooperation in the Skagerrak and Kattegat (MARKIS) project;
- Training institutions.

When:

As soon as possible.
**Recommendation no. 15b regarding the need for establishing training of personnel on-board LNG-fuelled vessels and in small and medium-scale LNG terminals on handling of LNG**

**Why:**

It is considered very important that the involved operators, both on-board vessels and in small and medium scale LNG 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 on-board LNG-fuelled vessels handling LNG and for workers in small-scale and medium-scale terminals.

**What:**

In general, it is recommended that the training requirements for all actors in the LNG supply 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 are anticipated as a result of 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 supply chain and operations

#### Why:

The main objective of introducing LNG as an alternative ship fuel in the SECA is to reduce the sulphur emissions but it also offers a reduction of greenhouse gas (GHG) emissions by reducing the CO$_2$ 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 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 bunkering infrastructure.
# 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 investment 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 low awareness, Environmental Impact Assessment of LNG.

To increase public acceptance, better communication is needed. According to the EIA Directive (Article 2(2)) the general public 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 plan 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 location options;
- 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 neighbours 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 increase the awareness 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.
**Recommendation no. 18 regarding guidelines on siting of small-scale 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-scale and medium-scale LNG terminals with land-based filling as well as bunkering services must be located close to their customers in the port in order to be competitive. Such requirements may create conflicts with safety aspects. The development of guidelines on the siting of intermediary small-sized and medium-sized LNG terminals, LNG tank truck filling stations and LNG bunker stations is therefore considered to be an urgent matter.

Terminals and filling stations handling $> 50$ tonnes ($> 110 \text{ m}^3$) 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-sized 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 may also be interested in facilitating safe and competitive siting of intermediate small-scale and medium-scale terminals with bunkering services and land-based LNG filling stations.

**What:**

Develop guidelines on siting of small-scale 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 to note that the development of new guidelines must not be referenced as a reason for delaying of pending applications and 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 for long processes is that there are two or more permit processes required and two or more authorities involved in many countries in the SECA. The process could be shortened by integration of these processes into one single process at the national level. However, this “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, at least to some extent, as soon as possible to be able to establish an LNG infrastructure in 2015.