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

Date: 2011-10-20

Reference: Danish Maritime Authority
Mogens Schrøder Bech

Baseline Report

ÄF Industry AB
SSPA Sweden AB

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Units

Energy units

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<th>Description</th>
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<tbody>
<tr>
<td>Wh</td>
<td>Watt hour</td>
</tr>
<tr>
<td>kWh</td>
<td>kilo Watt hour (1,000 watt hours) 1kWh = 3.6 MJ</td>
</tr>
<tr>
<td>MWh</td>
<td>Mega Watt hour 1,000,000 watt hours</td>
</tr>
<tr>
<td>MJ</td>
<td>Mega Joule, 1,000,000 Joule, = 1MJ = 0.28kWh</td>
</tr>
<tr>
<td>MBTU</td>
<td>Million British Thermal Unit, 1 MBTU = 293 kWh = 1,055 MJ</td>
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</tbody>
</table>
**Power units**

kW  kilo Watt, 1,000 Watt, 1 kW=1.34 hp =3.6 MJ/h
MW  MegaWatt = 1,000 kW= 1,000,000 W
### List of Abbreviations

<table>
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<th>Description</th>
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<tr>
<td>ADN</td>
<td>International Carriage of Dangerous Goods by Inland Waterways</td>
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<tr>
<td>AIS</td>
<td>Automatic Identification System is a very high frequency (VHF) radio-based system which enables the identification of the name, position, course, speed, draught and cargo of ships</td>
</tr>
<tr>
<td>BLG</td>
<td>Bulk Liquids and Gases</td>
</tr>
<tr>
<td>BOG</td>
<td>Boil-Off Gas</td>
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<tr>
<td>BSR</td>
<td>Baltic Sea Region</td>
</tr>
<tr>
<td>BV</td>
<td>Bureau Veritas</td>
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<tr>
<td>CCNR</td>
<td>Central Commission for Navigation on the Rhine</td>
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<tr>
<td>CEN</td>
<td>European Committee for Standardization</td>
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<tr>
<td>CNG</td>
<td>Compressed Natural Gas</td>
</tr>
<tr>
<td>CO₂</td>
<td>Chemical formula for Carbon dioxide</td>
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<td>DNV</td>
<td>Det Norske Veritas AS</td>
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<td>DMA</td>
<td>Danish Maritime Authority</td>
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<tr>
<td>DME</td>
<td>Di Methyl Ether</td>
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<tr>
<td>ECA</td>
<td>Emission Control Area</td>
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<tr>
<td>ECE</td>
<td>Economic Commission for Europe</td>
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<tr>
<td>ECSA</td>
<td>European Community Shipowners’ Associations</td>
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<tr>
<td>EGCS</td>
<td>Exhaust Gas Cleaning System-SOX</td>
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<tr>
<td>EGR</td>
<td>Exhaust Gas Recirculation</td>
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<tr>
<td>EMEP</td>
<td>European Monitoring and Evaluation Program</td>
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<td>EMSA</td>
<td>European Maritime Safety Agency of the European Commission</td>
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<td>ENOVA</td>
<td>Energy Efficiency Agency</td>
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<tr>
<td>ERS</td>
<td>Emergency Release System</td>
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<td>ESD</td>
<td>Emergency Shut Down</td>
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<td>ETS</td>
<td>European Trading Scheme</td>
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<td>EU</td>
<td>European Union</td>
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<td>EUROGAS</td>
<td>Natural Gas Industry of the European Union</td>
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<tr>
<td>FSRU</td>
<td>Floating Storage and Regasification Unit</td>
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<td>GBS</td>
<td>Gravity-Based Structure</td>
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<td>GHG</td>
<td>Greenhouse Gas</td>
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<tr>
<td>GIIGNL</td>
<td>The International Group of Liquefied Natural Gas Importer</td>
</tr>
<tr>
<td>GL</td>
<td>Germanischer Lloyd SE</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>GT</td>
<td>Gross Tonnage</td>
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<tr>
<td>HELCOM</td>
<td>Helsinki Commission is a Baltic Sea Action Plan</td>
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<tr>
<td>HFO</td>
<td>Heavy Fuel Oil</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation, Air Conditioning</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>IFO</td>
<td>Intermediate fuel oil (IFO 380: viscosity max 380 cSt)</td>
</tr>
<tr>
<td>IHO</td>
<td>International Hydrographic Organization (<a href="http://www.iho-ohi.net">www.iho-ohi.net</a>)</td>
</tr>
<tr>
<td>IKC</td>
<td>In Kind Contributors</td>
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<tr>
<td>IMO</td>
<td>International Maritime Organization (<a href="http://www.imo.org">www.imo.org</a>)</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<tr>
<td>IТОPF</td>
<td>The International Tanker Owners Pollution Federation Limited</td>
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<tr>
<td>LNG</td>
<td>Liquefied Natural Gas</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>LNGRV</td>
<td>Liquid Natural Gas Regasification Vessel</td>
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<tr>
<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
</tr>
<tr>
<td>LSHFO</td>
<td>Low Sulfur Heavy Fuel Oil</td>
</tr>
<tr>
<td>MARIS</td>
<td>Maritime Accident Response Information System of HELCOM has been created to display different existing datasets into a common GIS format and under a single user interface (<a href="http://www.helcom.fi/GIS/maris/en_GB/main/">http://www.helcom.fi/GIS/maris/en_GB/main/</a>)</td>
</tr>
<tr>
<td>MARKIS</td>
<td>Maritime Competence and Innovation Cooperation in the Skagerrak and Kattegat</td>
</tr>
<tr>
<td>MarPol</td>
<td>The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto</td>
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<tr>
<td>MGO</td>
<td>Marine Gas Oil</td>
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<tr>
<td>MoS</td>
<td>Motorways of the Seas</td>
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<tr>
<td>MSC</td>
<td>The Maritime Safety Committee</td>
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<tr>
<td>NGO</td>
<td>Non Government Organization</td>
</tr>
<tr>
<td>NGVA</td>
<td>Natural Gas Vehicle Association Europe</td>
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<tr>
<td>NOx</td>
<td>Nitrogen Oxides</td>
</tr>
<tr>
<td>OCIMF</td>
<td>Oil Companies International Marine Forum</td>
</tr>
<tr>
<td>PM</td>
<td>Particulate matter</td>
</tr>
<tr>
<td>PPP</td>
<td>Public Private Partnerships</td>
</tr>
<tr>
<td>SCR</td>
<td>Selective Catalytic Reduction</td>
</tr>
<tr>
<td>SECA</td>
<td>SOx Emission Control Area describes an area where the adoption of special mandatory measures for SOx emissions from ships is required according to Annex VI of MarPol</td>
</tr>
<tr>
<td>SIGTTO</td>
<td>Society of International Gas Tanker and Terminal Operators</td>
</tr>
<tr>
<td>SOx</td>
<td>Sulphur Oxides</td>
</tr>
<tr>
<td>STS</td>
<td>Ship-to-Ship</td>
</tr>
<tr>
<td>SWOT</td>
<td>Strengths, Weaknesses, Opportunities, Threats</td>
</tr>
<tr>
<td>TEN-T</td>
<td>Trans-European Transport Network</td>
</tr>
<tr>
<td>TEU</td>
<td>Twenty Foot Equivalent Unit</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>VLCC</td>
<td>Very Large Crude Carrier</td>
</tr>
<tr>
<td>VLOC</td>
<td>Very Large Oil Carrier</td>
</tr>
<tr>
<td>VTS</td>
<td>Vessel Traffic Service</td>
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<tr>
<td>WP</td>
<td>Work Package</td>
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Foreword

The Danish Maritime Authority (DMA) has commissioned the present study within the context of the European Union financed TEN-T programme, Motorways of the Seas. The objective of the study is to address aspects of the feasibility in establishing a maritime Liquefied Natural Gas (LNG) infrastructure in the Sulphur Emission Control Area (SECA) covering the Baltic Sea, the North Sea and the English Channel, with surrounding countries. AF (lead) and SSPA are the contracted consultants elaborating the study within the North European Infrastructure Project.

This report presents a baseline study, which was initiated in July 2011 and published in October 2011.

The main activities following after this baseline are analyses of the most relevant investment options for the establishment of an LNG filling station infrastructure in the SECA, covering economic and financial aspects, investment models for stakeholders as public utilities and private operators, technical and operational aspects as well as safety and security aspects.

The study is conducted in close cooperation with various authorities, organisations and companies with an interest in the sector. The study is co-financed by a selection of participants and also receives co-financing from the TEN-T funds.

The participating In Kind Contributors (IKCs) are:

- Port of Zeebrügge;
- Port of Hirtshals;
- Port of Szczecin and Swinoujscie;
- Port of Rotterdam
- Gasnor;
- Gasum;
- Gasunie;
- Energinet.dk;
- Fluxys;
- Germanischer Lloyd SE;
- MAN Diesel & Turbo;
- Lauritzen Kosan A/S.

The IKCs have contributed to valuable information in this report. DNV has as well contributed with input to the baseline report.

Stockholm, October, 2011
The Steering Group members:

- The Flemish Ministry of Mobility and Public Works;
- The Danish Maritime Authority;
- The Finnish Transport Safety Agency;
- The Norwegian Ministry of Trade and Industry;
- The Swedish Maritime Administration;
- The Swedish Gas Association;
- Council of Nordic Ministers
- Szczecin and Swinoujscie Sea Ports Authority;
- Port of Hirtshals;
- Port of Zeebrugge;
- Port of Rotterdam;
- Fluxys:
- Gasnor;
- Gasum;
- Gasunie;
- Germanischer Lloyd SE;
- Energinet.dk;
- MAN Diesel & Turbo;
- Lauritzen Kosan A/S;
- Bureau Veritas;
- Gazprom Global LNG;
- TEN-T EA as observer;
- European Maritime Safety Agency (EMSA) as observer;

The Reference Group members:

- Aula Europe Sprl;
- Baltic Energy Forum e.V.;
- Baltic Ports Organization;
- Baltic Sea Clean Shipping;
- Belgian Federal Public Service Mobility and Transport;
- Danish Ministry of Transport;
- Danish Ports;
- Danish Shipowners’ Association;
- Danish Society of Naval Architecture and Marine Engineering;
- Delphis N.V.;
- European Community Shipowner’s Association;
- Energy Ports;
- FDT – Association of Danish Transport and Logistic centers;
- Port of Dunkerque;
- Közlekedésmérnökök szakértő;
- Keppel Offshore & Marine Europe Technology Center;
- Danish Ministry of Transport;
- Ministry of Infrastructure, Shipping Division, Netherlands;
- Nordic Council of Ministers;
- Oiltanking Copenhagen A/S
- Polskie LNG S.A.
- Ports of Stockholm;
- Port of Aarhus;
- Port of Esbjerg;
- Port of Antwerp;
- FPS Mobility & Transport;
- Swedish Marine Technology Forum;
- Royal Belgian Shipowners’ Association;
- Rolls-Royce;
- Viking Line;
- Vopak LNG Holding B.V.;
- Wärtsilä Ship Power Division;
- Duna-Express;
Executive Summary

Liquefied Natural Gas (LNG) has the potential to become a solution for many ships in the North Sea, the Baltic Sea and the English Channel after January 2015 when maritime fuel sulphur content is restricted to 0.1% by the International Maritime Organisation (IMO). The IMO has imposed this regulation specifically to the above mentioned area, a Sulphur Emission Control Area (SECA). The LNG option relies on the establishment of a maritime LNG infrastructure, including both distribution and bunkering aspects. This Baseline Study aims at setting preconditions for further analyses for the establishment of such an infrastructure.

Ship owners compliance strategies to meet the sulphur regulations in Northern Europe

Shifting from Heavy Fuel Oil (HFO) to LNG is seen as one possible solution for the ships in the SECA to meet the environmental demands, besides for example oil distillates or the use of abatement technologies.

Marine gas engines are proven reliable. LNG as a fuel has the advantages of being cleaner than prevailing fuels and without sulphur. For some two stroke engines, LNG combustion will also require an SCR (Selective Catalytic Reduction) or EGR (Exhaust Gas Recirculation) in order to meet the expected NOx regulations for the SECA (expected to come in force in 2016).

LNG is expected to have a competitive price development in comparison to conventional fuels. On the negative side, the LNG option will impose increased capital investment costs on the ship owner, it will reduce cargo capacity since tank volumes need to be increased and it will rely on the establishment of a new infrastructure.

While a shift to oil distillates, for example Marine Gas Oil (MGO) does not require much capital investment, the fuel is more expensive than HFO and it will not fulfil the expected NOx limitations for the area.

The prime abatement technology option for the removal of sulphur and particulate matters is scrubber technology in combination with either SCR or EGR for NOx cleaning. Abatement technologies will call for capital investment and uncertain costs for e.g. dealing with scrubber waste and reduced cargo capacity.

LNG supply infrastructure and missing links for the maritime sector

Natural gas is becoming more important in Europe, and LNG import is expected to account for a larger share of natural gas supplies. In its liquefied form, natural gas is possible to transport and with this flexibility it becomes a global commodity rather than a regional one. The main demand for LNG in Europe constitutes of the
established natural gas users, i.e. within residential and commercial sector, the energy industry and other industry. The use of LNG is however expected to increase for heavy duty land–based vehicles as well as in the maritime sector, provided that the required filling stations and bunkering facilities will be developed.

The existing LNG infrastructure in North Europe is strongly correlated to extensions of the natural gas network. The main task for the majority of the existing and planned LNG import terminals is to deliver natural gas to the network, implying a possibility to meet gas demand although indigenous resources decline and to improve security of supply through a diversified gas supply. Exemptions from this rule can be seen in Norway, Sweden and Finland where the natural gas network is not well extended.

The total liquefaction capacity in the region is expected to increase from a present 4.8 million tonnes per year to 13.5 million tonne in 2018.

LNG import/receiving terminals within the SECA are few at date, but many are planned. A majority of the terminals, with exception for the terminals in Norway and Sweden, are constructed for large scale LNG vessels. However, jetties for small-scale LNG vessels will be built in the terminals of Zeebrugge and Rotterdam to be in operation in 2014 and the planned terminals of Rostock, Gothenburg and Turku are small-scale, i.e. below 100 000 m$^3$ storage capacity. Fourteen of the Norwegian terminals are organized to supply LNG as fuel for vessels and four of them are used as bunkering stations today. There are also bunkering facilities at Risavika production plant. Furthermore, many of the planned and proposed terminals, e.g. in Swinoujscie, Padilski, Rostock, and Porvoo have plans of establishing small-scale export/bunkering facilities.

In addition to the small-scale land-based terminals, offshore terminals and LNG bunker vessels will be important segments in the future downstream LNG infrastructure within the SECA. Long lead times and high investment costs for land-based terminals have resulted in an increased interest in offshore terminals. There is only one LNG bunker vessel in the SECA region, the Pioneer Knutsen. The lack of bunker vessels is an obstacle for bunkering in e.g. Nynäshamn/Stockholm today (2011) and will most probably be a bottleneck at the terminals and small-scale jetties planned for the coming 3-4 years.

**Maritime LNG demand in Northern Europe**

It is estimated that by 2020, the maritime LNG demand will be 2-4 million tonnes per year in SECA. The shipping activities in the North European SECA can be characterised by two main activities: short sea shipping and international shipping. Basically, all vessel types can be suitable for LNG propulsion. However, with respect to their age distribution and other features, the adoption rate will vary. It is
envisaged that among the earliest adopters will be those having regular traffic calling a limited number of ports, since these can more easily predict their fuel demand per route and constitute “secure” customers for terminal investors.

**Actors and important key aspects of establishing a small-scale maritime LNG infrastructure**

An infrastructure investment in ports, such as land development, surrounding maritime infrastructure and port infrastructure, is often on the part of the government or local community and the port authority. Superstructure investments on the other hand, such as terminals, are normally born by a private partner, although different investment models exist.

Preliminary lessons learned from the terminals that have been established so far in the SECA, suggest that an early and good communication between the involved authorities and the general public is a key prerequisite, as well as to take adequate time for the permit process.

**Important tasks for the feasibility study of an LNG filling station infrastructure in northern Europe**

In order for LNG to become a competitive fuel, more medium and small scale ports need to take initiatives aiming at establishing LNG bunkering facilities. An important task for this project is to oversee the key features for establishing such small scale infrastructure.

A central output from the study is the development of recommendations which take into account safety regulations, technical solutions and standards, operational models, financial and economic aspects as well as recommendations for the permit process for small scale terminals and bunkering facilities in the concerned countries. It is also important to address public awareness and acceptance as well as local rules and regulations.
1 Introduction

Environmental and climate change concerns are influential on transport policies. Emission restrictions have been imposed on transportation within the maritime sector and more is expected. Within the Sulphur Emission Control Area (SECA), which includes the North Sea, the English Channel and the Baltic Sea, recent legislation\(^1\) requires that the sulphur content in fuel oil be reduced to 0.1% by January 2015. Furthermore, from 1\(^{st}\) of January 2016, provided that IMO member states submit a proposal for a Nitrogen Emission Control Area (NECA), there will be a subsequent requirement for reducing nitrogen oxides from new ships.

The options for the shipping industry to meet the new sulphur emission requirements before January 1, 2015, and the possibility of upcoming NO\(_x\) legislations, are few but filled with technical and economical challenges. The options used in this study are\(^2\):

- Using low-sulphur Marine Gasoil (MGO) or Marine Diesel Oil (MDO);
- Installing exhaust scrubbers to meet sulphur limits for ships running on Heavy Fuel Oil (HFO);
- Shifting to LNG as ship fuel.

LNG is methane rich gas cooled to minus 162\(^\circ\)C and it combines the benefits of high energy gas with transportation flexibility of liquids. However, the LNG option relies on the development and establishment of an LNG filling station infrastructure.

The above options for the shipping industry will be studied and presented in more details in this report.

The prime demand for LNG in North Europe is existing natural gas users, i.e. mainly the residential and commercial sector, the energy industry and other industries. Using LNG as a fuel is an interesting and potentially viable solution for the maritime sector, and also for other sectors, such as land-based transportation. However, an introduction of LNG as fuel for short sea shipping in Northern Europe entails both technical and financial challenges.

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\(^1\) IMO (International Maritime Organization
- MARPOL 73/78, Annex 6, regulation 13 and 14

\(^2\) Shifting to alternate fuels such as LPG is also possible, but will not be analyzed in this study. The DME (Dimethyl Ether)/methanol option is under development but will not be further analyzed in this study.
LNG propulsion of ships requires either technical fitting and optimisation of existing vessels or the change for new-built LNG ships.

In Northern Europe, there is an existing LNG infrastructure to meet the current demand. However, there are insufficient solutions for delivering the LNG to ships. For an LNG supply mechanism to emerge that suits the maritime sector, it is important to address and assess critical issues and to formulate recommendations.

Technical, safety and regulatory aspects, aligned by financial and economic analyses, are of particular importance to the various potential investors and their operations. Furthermore, questions related to the permit and consultation processes for the establishing of a LNG supply infrastructure will be crucial, including public awareness. A well functioning permit process will be crucial especially with regards to the short time limit before the sulphur emission limitations are enforced.

This report is a baseline for further assessments of the different aspects of the introduction of LNG as a ship fuel in Northern Europe.

1.1 Objectives
This Work Package, i.e. WP2 Baseline Study, is aimed at describing the current situation of the LNG supply chain, different alternatives for stakeholders such as ship owners, port authorities, and gas suppliers, in order to meet the upcoming regulations. The Baseline Study thus establishes a platform for further analyses on a number of operational options regarding the LNG filling station infrastructure in Northern Europe.

1.2 Methodological Approach and Limitations
The following methodology has been applied throughout the Baseline Study in order to address all issues specified in the Inception Report.

1.2.1 A Comprehensive Literature Review
Stakeholders at regional, national and sub national levels are participating actively in the process of adaptation to the new regulations on sulphur emission reductions. A comprehensive set of studies has supported the process that follows, refer to the reference list. The Baseline Study therefore contains essential observations from EU funded studies as well as from other industry funded studies, referenced throughout the study.
1.2.2 Overview of the Shipping Industry in the SECA

In order to have an overview of the shipping characteristics and estimation of traffic patterns of the area. Automatic Information System (AIS) data has been used to assess the situation in the SECA and has been complemented with publicly available material about the shipping industry in the Baltic Sea[^3]. In Appendix IV. Examples of Vessels Suitable for LNG Propulsion, an overview of the existing ship characteristics is given.

1.2.3 Compliance Strategies to meet SECA Regulations

With the help from MAN Diesel & Turbo, an assessment of different compliance strategies, regarding both technical abatement technologies and alternative fuels was performed.

1.2.4 Mapping and Analysis of Existing LNG Infrastructure

A comprehensive mapping and analysis of the existing and planned infrastructure of LNG in the SECA region has been made. Details of this work are provided in Appendix V. LNG Infrastructure in Northern Europe. Work has been performed with input from Gasnor, Gazprom, Gasum, Fluxys, Gasunie and Energinet.dk.

1.2.5 Review of International Agreements and Regulations

A review of international conventions and agreements, as well as regulations were undertaken in order to identify possible gaps and/or weaknesses. A review of existing regulations and guidelines is presented in Appendix VII. International Conventions, Agreements and Regulations.

1.2.6 Public Awareness and Consultation Process Experiences

Experiences from the IKCs (mainly Energinet.dk, Gasnor, Gasunie, Fluxys, and Gasum) and other stakeholders in relation to public awareness have been assessed through interviews, written report and EIA literature studies in the countries with LNG infrastructure experience. The specific national experiences are presented in Appendix IX National Experiences from Public Awareness and Consultation Processes.

1.2.7 Review of Economic Instruments

There has been specific focus on the economic instruments addressing sulphur and nitrogen oxide emissions, not greenhouse gas emissions nor particulate matters.

1.2.8 Continuous Input from In Kind Contributors

Throughout the study, the consultant has had extensive contact (through start-up meetings, interviews, questionnaires, SWOT analyses and written expert comments)

[^3]: No material covering the North Sea and English Channel in particular exists to the knowledge of the consultant team.
with IKCs. The IKCs have provided expert input and comments to all the chapters in the Baseline Report. The IKCs have also been invited to participate in the Baseline Report review process and have contributed with inputs and comments in that process.

1.3 Limitations to the Study

The focus of the Baseline Report is the following countries; Norway, Finland, Sweden, Denmark, Germany, Poland, Netherlands and Belgium. An overview of the existing LNG and natural gas infrastructure is provided for the remaining SECA bordering countries. In the coming work, information on foreseen LNG infrastructure development for other countries bordering the SECA will be sought (United Kingdom, France, Estonia, Latvia, Lithuania and the part of Russia bordering the Baltic Sea).

The geographical limits of the AIS (Automatic Identification System) data available for the study set boundaries for the analyses made from that material.
2 Background

The shipping characteristics of the Baltic Sea, the North Sea and the English Channel will be introduced in this chapter, forming the basis for the development of TEN-T goals, also a financing part of this study.

2.1 European Maritime-Based Logistics

An efficient intermodal transportation network, integrating land, sea and air transport, is identified as an important aspect of sustainable development of the transport sector in the European Union (EU). One of EU’s goals is to establish a Trans-European Transport network (TEN-T).

Under the umbrella of TEN-T, the concept Motorways of the Seas has been designed in order to expand existing and to introduce new inter-modal maritime logistics chains, shifting cargo traffic from heavily congested land networks to locations with more available spare capacity, i.e. the environmentally-friendly waterways. The potential within rail and inland waterways will also be included in the maritime-based logistics. The sea areas selected to be Motorways of the Seas, including the Baltic Sea and the seas of the Western Europe, are shown in Figure 1 below. Port efficiency and hinterland connection are a vital part of the Motorways of the Sea.

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

Stricter emission requirements, than those globally required, are regulated in specifically designated geographical areas. An Emission Control Area (ECA) can be designated for SO$_x$, PM or NO$_x$, or all three types of emissions from ships. There is an ECA in North America, which includes most of the US and Canadian coasts (addressing NO$_x$ & SO$_x$ emissions) which comes into effect in 2012.

The Baltic Sea, the North Sea and the English Channel are together designated as an ECA for SO$_x$ emissions reductions, or Sulphur Emission Control Area (SECA). The restrictions for the SECA are:

- 1.0% as the maximum allowable sulphur content of bunker fuel (from July 1, 2010);
- 0.1% as the maximum allowable sulphur content of bunker fuel (from January 1, 2015).
These restrictions also can be fulfilled with alternative technologies as LNG and scrubbers.

The geographical scope of this study includes the countries affected by the SECA, namely: the United Kingdom, France, Belgium, the Netherlands, Germany, Denmark, Poland, Latvia, Lithuania, Estonia, Finland, Sweden and Norway (see Figure 2).

2.3 Overview of the Shipping Industry in the SECA

The shipping activities in the Baltic Sea, the North Sea and the English Channel, constituting the SECA, can be characterized in two categories; international shipping and short sea shipping. The major European import hubs are attracting a long haul tonnage both for petroleum products and container goods. The dominating port in the region is Rotterdam, ranking among the three biggest ports in the world together with for example Antwerp, Hamburg, Amsterdam and Bremerhaven. The average rates of transhipment are significant, here understood as goods are reloaded on smaller carriers to be distributed in the area and transferred to the region. Transhipment rates in the biggest ports rank normally from 40 to 20% of the...
goods received. In the Nordic area, Gothenburg is the major hub, and the centre for container and general cargo goods as well as automotive industry shipping.

The distribution of ship types that are principally operating inside the SECA area and are not regularly calling ports outside the area is presented in Figure 3. As illustrated in the figure, bulk carriers, general cargo and tankers are the dominating segments. For further explanations about how AIS-data has been used to calculate the ship type distribution in the SECA, please refer to Appendix VI.

![Figure 3. Ship type distribution in the SECA area based on AIS data analysis.](image)

The vessel fleet in SECA has been significantly modernised during the past 10 years. New orders were ample starting around year 2000. In 2008, when the financial crisis commenced, the orders ceased in numbers. The average age of vessels is approximately 10 years. Figure 4 provides an overview of the ship age distribution in the studied region (based on AIS data).

![Figure 4. Ship age (y-axis) distribution in the SECA area Note: based on AIS data analysis.](image)

For details on the estimated appearance of different ship types in the SECA, please refer to Appendix VI.
The total number of ships principally operating inside the SECA is shown in Figure 5.

![Figure 5. Total numbers of ships in the SECA in 2011](image)

Note: based on AIS data analysis.

The shipping activities in the SECA can, as outlined above, be defined as international and short sea shipping. An overview of the cargo sea routes of the Baltic Sea and North Sea is shown in Figure 6.
For the Baltic Sea, short sea shipping is characterised by vessels trafficking steady routes. This is, for example, evident for RoPax, RoRo and general cargo traffic, which have typically relatively predictable trading patterns and hence port activity, whereas other segments like tanker trading and movements are less foreseeable. In later stages of the feasibility study, similar descriptions will be presented for the North Sea and English Channel.

### 2.4 Environmental Impact of the Shipping Industry

In 2008, air emissions from shipping in the Baltic Sea emitted about 135,000 tonnes sulphur oxides (SO$_x$), 393,000 tonnes nitrous oxides (NO$_x$) and 18.9 million tonnes carbon dioxide CO$_2$. This is the same amount of NO$_x$ and twice the amount of SO$_x$ as the total land-based emissions from Sweden and Denmark combined. Based on the share in the total number of ships, it can be concluded that the share of NO$_x$

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emissions from passenger ships, RoRo ships and tankers in the total NOx emissions is relatively higher than from other ships. The environmental data used here in the baseline presentation has been derived from the Helsinki Commission (HELCOM). There are no plans within this feasibility study to seek or develop such data for the North Sea and the English Channel.

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

- SOX and PM emissions;
- NOX emissions;
- CO2 emissions;
- Chemical release from vessels; and
- Waste generation (solid as well as liquid waste).

Traditionally, focus has been on the shipping sectors’ effect on air emissions and pre-dominantly on local pollution related to NOX, SOX and PM emissions. The introduction of ECAs is an attempt to address this aspect and reduce the environmental footprint of the shipping industry. During the last few years, the focus on shipping’s impact on green house gas emissions has attracted interest from society at large and legislators.

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

The MARPOL 73/78 Convention by the IMO is the main international convention to prevent pollution by ships. Air pollution is regulated in Annex VI (which came into effect in 2005). Furthermore, significant reductions in SOX and NOX from ships globally are required in the amendment of 2008. New fuel quality requirements (from July 2010), Tier II and III NOX emission standards for new engines, as well as Tier I NOX requirements for existing pre-2000 engines were introduced in this document. A revised version of Annex VI came into effect in July 2010.

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

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

9 The IMO emission standards are commonly referred to as Tier I...III standards. The Tier I standards were defined in the 1997 version of Annex VI, while the Tier II/III standards were introduced by Annex VI amendments adopted in 2008.
2.5 Regional Challenges within the SECA

There are environmental as well as health reasons for reducing sulphur and nitrogen emissions in Northern Europe. However, the transition may have other effects as well.

Within the SECA, there are a number of regional differences between the Baltic Sea, the North Sea and the English Channel that influences the preconditions for LNG terminal investments and bunkering business. The maturity of the gas markets within these regions, financial possibilities and market sentiment on LNG, public awareness and acceptance as well as local rules and regulations are a few of these differences.

Despite the differences, a number of remarks published and presented below could be regarded as valid in the whole SECA:

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

- Tier III regulations on NOx emission from new engines from 2016 (in SECA only).
- EEDI (new ships)
- SEEMP (all ships)
- EU Staff working paper on Pollutant Emission Reduction from Maritime Transport and the Sustainable Waterborne Transport Toolbox – suggest several incentives/disincentives to support the development of a cleaner shipping industry in the European Union.

The EU, in their latest publication, Staff working paper on pollutant emission reduction from maritime transport and the sustainable waterborne transport toolbox, states that they are aware of the large investments needed to comply with the IMO regulations on emissions from the shipping industry in the SECA.

The Annex VI - Regulations for the prevention of Air Pollution from Ships - of the International Maritime Organisation (IMO) MARPOL 73/78 Convention, have been incorporated in the EU Directive 2005/33/EC1 amending Directive 1999/32/EC relating to a reduction in the sulphur content of certain liquid fuels and amending Directive 93/12/EEC. There is also a new directive under way, incorporating the 2015 provisions set by IMO.

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10 At date, not all ship types are included in the EEDI. The types of ships that are currently included are: Bulk carrier, Gas carrier, Tanker, Container ship, General cargo ship, Refrigerated cargo carrier, Combination carrier.
The Swedish Maritime Administration, among others, notes that the stricter cap on sulphur emission in the SECA may induce migration of ships and/or a modal shift to land-based transport. The stricter regulations within the SECA boundaries may further reduce global competitiveness for industries in the bordering countries.\textsuperscript{11}

2.6 On-Going Activities

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

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

These projects aim to interact when suitable, and among other activities there is a common meeting arranged\textsuperscript{12}. Much EU funded support is concentrated around the Baltic Sea by providing support to a large number of projects. Several of these projects are conducting studies related to same issues as concerns the current studies. Despite this concentration in the Baltic Sea, there is also a project, Markis, which addresses the North Sea and integrates Kattegat and Skagerak. However, apart from this ongoing study, there appear to be few, if any, collaborative efforts integrating the entire SECA region as such.

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

\textsuperscript{11} Swedish Maritime Administration; Konsekvenser av IMO:s nya regler för svavelhalt i bränsle (Consequences of the New Regulations on Sulphur in Fuels by the IMO).

\textsuperscript{12} Arranged in Gothenburg on October 11, 2011.
3  Compliance Strategies - Technical Possibilities to Fulfil the SECA 2015 Requirements

The shipping industry in the North Sea, the Baltic Sea and the English Channel is facing a number of challenges, and a number of compliance strategies are investigated. In order for ship-owners to comply with the upcoming environmental regulations in the SECA, there are a number of possible alternative strategies, e.g. use of alternative fuels and installing abatement/scrubber technologies.

3.1 Fuel and Propulsion Alternatives

Heavy Fuel Oil (HFO) has been the dominating fuel throughout the global maritime sector in modern time. It will still be allowed in the SECA provided that it meets the applicable sulphur limitations. Otherwise alternative measures are needed. A few options to HFO are presented below. The technical characteristics of the fuels are presented in Appendix II. Fuel Alternatives and Technical Properties. A summary table (Table 4) of the benefits and disadvantages of the fuel alternatives is provided in section 3.5.

In preparation for a comparative investment analysis, each alternative is summarized in Table 1 – Table 3 stating the main required investments and possible savings for new buildings and retrofit.

First, however, some central facts about the prevailing gas engines are presented.

3.1.1 Gas Engine Concepts

Dual Fuel Engines, Four Stroke Otto Engines

Dual fuel engines were first developed for propulsion of LNG carriers in order to make use of the boil off gas. The advantage of the dual fuel engine is the ability to run on either liquid fuel oils or gaseous fuel; i.e. it can run on the same fuel oils as a regular marine diesel engine or on natural gas. While the working principle is based on the Otto cycle when operating on natural gas, the Diesel cycle is the basis for operation on fuel oils. The ignition source is a small amount of fuel oil which is injected and ignited by the compression heat; the burning oil ignites the gas.

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13 This chapter has been written in cooperation with IKC MAN Diesel & Turbo.
Dual Fuel Engines, Two Stroke Diesel Engines
This technology applies high pressure gas injection together with pilot diesel oil, and is suitable for two stroke engines. Like the dual fuel engine, it is the fuel oil that ignites first, and the gas is ignited by the burning fuel oil. This engine can run on fuel oil only or on a mixture of gas and fuel oil. The engine has no or almost no methane slip, but cannot meet Tier III NOx regulation without further countermeasures such as EGR or SCR. For example, Wärtsilä is currently developing the dual fuel principle, as described for four stroke engines, for two stroke low speed engines to meet Tier III.

Single Fuel Gas Engines
Gas engines of the Otto/Miller type with spark ignition allow for the engine to run on gas at the expense of losing the flexibility to also run on fuel oil. The “lean-burn” technology, which was applied on Rolls-Royce marine gas engines, is a way to implement a spark ignition drive line. Instead of a pilot fuel, a rich gas/air mix in a pre-combustion chamber is ignited which forms a strong ignition source for the very
lean mixture in the cylinder. This technology ensures high efficiency and low emissions\textsuperscript{14}.

![Figure 9. Spark ignited gas engine of Wärtsilä design and Rolls Royce design respectively](image)

**Source Wärtsilä & Rolls Royce**

### 3.1.2 LNG

Liquefied Natural Gas (LNG) is Natural Gas (NG) stored as liquid at -162°C. The predominant component is methane with some ethane and small amounts of heavy hydrocarbons. Natural gas can also be mixed with biogas, or replaced entirely by biogas. Due to the low temperature, LNG has to be stored in cryogenic tanks. LNG has a high auto ignition temperature and therefore needs an additional ignition source, i.e. a pilot fuel, to ignite in combustion engines. Natural gas is lighter than air and has a narrow flammability interval. For two stroke engines, the gas injection pressure is around 300 bars and NG is injected in gaseous form. For the Otto cycles, the NG is injected in gaseous form using a low pressure.

LNG storage tanks require more space than traditional fuel oil tanks. This may reduce the cargo capacity, depending on type of vessel, type of fuel tank and potential of adequate location of the LNG tanks on-board, see Appendix III. LNG Storage Tanks. The reduction of cargo space was examined within a GL study of the retrofit from HFO to LNG of the CV Neptun 1200 design. Due to the LNG tank dimensions the container capacity of 1,284 TEU would be reduced by 48 TEU to 1,236 TEU\textsuperscript{15}.

Another example is shown by the first retrofit worldwide of a seagoing vessel, the tanker Bit Viking. The two LNG fuel tanks with a capacity of each 500m\textsuperscript{3} LNG are located on deck with no actual reduction of the cargo capacity. Due to the

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\textsuperscript{14} Rolls-Royce Diesel and Gas Engines

\textsuperscript{15} GL Scholz & Plump
properties of LNG and NG, special requirements for the tanks and the fuel supply system need to be fulfilled.

In order to outline the investment costs that are associated with opting for LNG propulsion, Table 1 below lists the main cost items to be considered for new-builds as well as retrofitting.

Table 1. Liquefied Natural Gas investments

<table>
<thead>
<tr>
<th>New Building</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional investment for gas engine</td>
<td>Investments for gas engine</td>
</tr>
<tr>
<td>LNG fuel gas supply system</td>
<td>LNG fuel gas supply system</td>
</tr>
<tr>
<td>LNG bunkering onboard system</td>
<td>LNG bunkering onboard system</td>
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<tr>
<td>LNG storage tanks</td>
<td>LNG storage tanks</td>
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<tr>
<td>Classification</td>
<td>Classification</td>
</tr>
<tr>
<td>Savings in HFO system?</td>
<td>Hull reinforcements?</td>
</tr>
</tbody>
</table>

Investments needed for retrofit and newbuilds respectively. Source: MAN Diesel & Turbo

3.1.3 Low Sulphur Diesel Oils, Marine Gas Oil (MGO)

Conventional Marine Fuels

Conventional marine fuels used by commercially operating ships are commonly divided into two categories, residual fuel oil and distillates. Residual fuel oil, often referred to as Heavy Fuel Oil (HFO), is the heaviest marine fuel with respect to viscosity and sulphur content. Distillate fuels can be further divided into two categories, Marine Gas Oil (MGO) and Marine Diesel Oil (MDO). When residual fuel oil is blended with distillates, the blend is called Intermediate Fuel Oil (IFO).

HFO with 0.1% sulphur content is possible to produce, however, that will not be done by refineries since they will produce higher priced products, such as MGO, to the same production price. MGO with 0.1% sulphur or less is readily available and share about the same properties as the diesel fuel used for high speed diesel engines. The viscosity of MGO is lower than for MDO or HFO (Figure 10). For operation in two stroke marine diesel engines the viscosity should not be lower than 2cSt at the engine inlet, rather, a viscosity over 3cSt is recommended. Fuel pump wear and other parts of the fuel system may require an even higher viscosity. Fuel cooler requirements are dependent on expected viscosities of distillate fuel.

16 Conversation with Preem refinery, Brofjorden September 2011.
17 centiStokes, a measure of viscosity. 1cSt= 1mm²/s. To compare water viscosity at 20°C is about 1 sCt
18 MAN Diesel and Turbo
If operating on low sulphur fuel oils for a longer term, i.e. more than two weeks duration, a change of lubrication oil quality is recommended. A change from high-sulphur HFO to low-sulphur MGO is recommended at 25-40% engine working load. This is in order to ensure a slow reduction of the temperature in the fuel system when changing from preheated HFO (80-150°C) to cool MGO (max 35°C). During the change, the fuel viscosity should not drop below 2cSt and not exceed 20cSt. The rate of temperature change of the fuel inlet to the fuel pumps must not exceed 2°C/minute.19 These figures are for MAN two stroke engines. However, similar figures can be expected for four stroke medium speed engines and engines of other manufacturers.20

Modern common-rail engines are more tolerant towards low viscosity compared to conventional fuel injection pumps.

In order to outline the investment costs that are associated with opting for MGO propulsion, Table 2 below lists the main cost items to be considered for new-builds as well as retrofitting.

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19 MAN Diesel & Turbo
Table 2. Marine Gas Oil investments

<table>
<thead>
<tr>
<th>New Building</th>
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<tr>
<td>Fuel cooler?</td>
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<table>
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<tr>
<th>Retrofit</th>
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</thead>
<tbody>
<tr>
<td>Fuel cooler?</td>
</tr>
</tbody>
</table>

Savings in HFO fuel systems if operation on solely MGO planned

Investments needed for retrofit and newbuilds respectively. Source: MAN Diesel & Turbo

3.2 Fuels for Propulsion: Pros and Cons

Why choose LNG?
LNG is expected to be available at competitive cost. It is a clean and low-sulphur fuel. The gas engines have been proven to be reliable. Exhaust emissions such as SO\textsubscript{X} and PM are negligible. NO\textsubscript{X} can be reduced by approximately 80 – 90 % for Otto cycle processes, and 10-20% for Diesel cycle processes. LNG contains less carbon than fuel oils, reducing the CO\textsubscript{2} emissions first and foremost from tank to propeller. The environmental drawback for Otto cycle process operation is methane slip in the dual fuel engine. Engine manufacturers are however working on the methane slip problem. Methane is an aggressive greenhouse gas. If including the CO\textsubscript{2} and the methane emissions, LNG can still potentially give a reduction in greenhouse gases emissions compared to fuel oils.\textsuperscript{21} Methane slip is however not a problem for engines operating on gas in the Diesel cycle.

Why choose MGO?
Using MGO gives low sulphur emissions matching the SECA demands. Particulate matter in exhaust gases is also reduced. NO\textsubscript{X} and greenhouse gases will remain at the same level as when using HFO. To comply with NO\textsubscript{X} Tier III SCR or EGR is needed when operating on MGO. MGO does not require extra volume for storage tanks, and retrofitting of the engine is not required. Therefore, using MGO will give small or no investments costs. However, fuel prices are already at a rather high level and are in general believed to continue to rise, to some extent due to limited refinery capacity.

3.3 Abatement Technology Solutions

3.3.1 Exhaust Gas Scrubbers
Abatement technologies, or ‘end of pipe’ solutions, include primarily use of scrubbers for the SO\textsubscript{X} and PM removal in combination with either Selective Catalytic Reduction (SCR) or Exhaust Gas Recirculation (EGR) for NO\textsubscript{X} cleaning. This

\textsuperscript{21} Litehaus, IncentivePartners, DNV, Ramböll Oil and Gas, Natural Gas for Ship Propulsion in Denmark – Possibilities for using LNG and CNG on ferry and cargo routes, 2010
combination is a strong candidate to fulfil the requirements in SECA 2015 and ECA Tier III. MAN Diesel & Turbo claim to be close to fulfilling Tier III by use of EGR technology alone. Once successful, SCR is not needed in order to fulfil Tier III, but future stricter requirements might require SCRs later on. Scrubbers have both benefits and drawbacks - some of these are described below.

Advantages of the scrubber technology are that readily available high sulphur HFO can be used, thereby keeping the fuel costs down. The infrastructure, hence the availability, of HFO is also good and the ship owners do not need to retrofit or replace the engines. Scrubber tests show that the sulphur emissions are reduced to almost zero and a significant reduction of PM in the exhaust gases.

The disadvantages include the required capital investments as well as the wastes produced by the scrubbers. Another disadvantage with the scrubbers is that that share of CO\(_2\) in the exhaust gases is not reduced\(^{22}\). Any scrubbers used to fulfil the SECA requirements must be IMO certified.\(^{23}\) This certification and Port Authorities’ controls increase the administrative paperwork. HFO bunkering might be restricted in many ports in the future, due to the environmental risks related to HFO handling\(^{24}\), which might reduce fuel availability. The infrastructure for scrubber waste deposition in ports is not yet in place and although there are guidelines\(^{25}\), there is no established praxis or regulations in place that regulate the ports responsibility to handle such waste. This may become a service that can be charged for. Scrubbers also occupy space and might reduce cargo capacity.\(^{26}\)

In order to outline the investment costs that are associated with opting for scrubbers, Table 3 below lists the main cost items to be considered for new-builds as well as retrofitting.

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\(^{22}\) According to Alfal Laval Aalborg A/S a scrubber solution implies a net saving in CO\(_2\) in the range of 4 – 5 % as the “CO\(_2\) costs” at the refinery in refining the HFO to MGO has to be added to the ships CO\(_2\) emissions in using MGO instead of HFO. The fuel penalty from running the scrubber has been deducted.

\(^{23}\) MAN Diesel & Turbo

\(^{24}\) Einemo, U., 2010


\(^{26}\) Dry scrubbers occupy more space than wet scrubbers (MAN Diesel & Turbo). On the other hand dry scrubbers have advantages for operators using the exhaust gas heat.
Table 3. Scrubber investments

<table>
<thead>
<tr>
<th>New Building</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scrubber</td>
<td>Scrubber</td>
</tr>
<tr>
<td>SCR and/or EGR (for NO\textsubscript{X})</td>
<td>SCR and/or EGR retrofit (for NO\textsubscript{X})</td>
</tr>
<tr>
<td>Consumables stores</td>
<td>Consumables stores</td>
</tr>
<tr>
<td>Waste store</td>
<td>Waste store</td>
</tr>
<tr>
<td>Waste disposal system</td>
<td>Waste disposal system</td>
</tr>
<tr>
<td>IMO certification</td>
<td>IMO certification</td>
</tr>
<tr>
<td>Classification</td>
<td>Classification</td>
</tr>
</tbody>
</table>

*Investments needed for retrofit and new buildings respectively. Source: MAN Diesel & Turbo*

### 3.3.2 Other Alternatives

Besides low-sulphur fuel oils, exhaust gas cleaning and LNG there are other alternative fuels which are considered within the current development of the IGF Code. These fuels are e.g. LPG, DME/methanol, ethanol and hydrogen and will be allowed after ratification of the IGF Code in 2014.

### 3.4 Fuel Cost Considerations

#### 3.4.1 International Bunker Fuel Prices

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

For Europe, the “standard reference” for crude oil price is the price of Brent blend, which is crude oil extracted from the North Sea. The Brent blend price is obtained from the international petroleum exchange in London and based on future contracts. In Figure 11 below, the correlation between Brent Crude future prices and European marine fuel prices is illustrated. In the figure, marine fuel prices are represented by low-sulphur heavy fuel oil (LSHFO) (price data only runs from the beginning of 2009) and the intermediary fuel oil with a maximum viscosity of 380 cst (IFO 380 cst) (a common blend of Intermediate Fuel Oil is used as a reference). The figure shows the similarity of average prices for LSHFO and IFO 380 cst, as well as the marine fuel prices’ strong correlation with the Brent Crude Future prices in Europe. The price of LSHFO and IFO is steadily about 25-30% below the price of Brent Crude Future and Marine Diesel Oil.
3.4.2 Estimating Future LNG Prices

While the prices for present conventional bunker fuels are relatively transparent in the market-place, the fuel price for LNG is not publicly observable. Currently, a vast majority of LNG imports to Europe are long term contracted with mostly oil-indexed pricing. A smaller portion is flexible LNG and with gas market price indexation.

The future price of LNG for bunkering at a certain terminal is likely to be strongly related to regional natural gas prices with a surcharge for LNG downstream infrastructure and logistics. The regional natural gas prices in the North West Europe region, in turn, are likely to be set by prices in the major North West Europe hubs: NBP (UK), Zeebrugge (B) and TTF (NL), at least for the foreseeable future. In the past 3 - 4 years, the prices of these hubs have been strongly converging.

Prices will also be influenced by those in the United States and Asia given the ease with which LNG can be transported. Furthermore, an increasing use of spot market agreements and the relatively low proportion of the total LNG price related to shipping/transportation contributes to this. The availability of natural gas and LNG today, and in the future in particular, is a strong driving force for LNG as a fuel. Furthermore, future LNG prices will be shaped by major energy market developments and events. Forecasting future LNG prices is therefore difficult, and further elaboration of the LNG price driving forces will be done in close relation to the development and assessment of investment options for the study.
3.5 Comparative Analysis of Compliance Strategies

The major compliance strategies that ships are assumed to adopt include LNG, MGO/MDO or scrubbers, as detailed above. The technical properties of these are presented in Appendix II. Fuel Alternatives and Technical Properties. Table 4 below shows a comparison between the different investment alternatives.

3.5.1 Technology

LNG is a promising fuel with expected good availability and a competitive price, but the investments needed to fuel a ship with LNG are high. Low sulphur fuel oil does not require any major additional investments, but the fuel cost is deemed to be high. This option is therefore best considered for ships which are not worth a retrofit investment and for ships with limited operation within SECA. scrubbers seem to be more suitable for retrofit than an alternative retrofit to gas propulsion.

An LNG powered ship with dual fuel engines will need a fuel oil tank and fuel oil supply system for the pilot oil and the fuel oil operation. In order to gain a broader market share, an LNG filling station is therefore recommended to also be able to supply fuel oil.

3.5.2 Cost

Financial viability of the different investment options considered depends on the capital investment needed as well as fuel and operating costs.

The capital costs for constructing a LNG-fuelled new build are approximately 20% higher than for a traditional ship, depending on the type and size of vessel. However, lower fuel and operating costs mean that the annual machine related costs are less for LNG than for HFO and scrubbers or MDO, as shown in the chart below.

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27 Concerning alternatives that will not be further analysed: Choosing LPG probably provides a simpler fuel system by reducing the investment. LPG is readily available in Northern Europe and the price is, although hard to estimate, likely to be competitive. For DME the fuel availability, and price, is hard to estimate. Those ship owners who know that LPG or DME (methanol) will be available at a competitive price in their ports may consider these alternatives. For LPG or DME/methanol bunkering stations, it will be necessary to provide diesel as well, since dual fuel engines are expected to be the most common alternative for these fuels too.

28 Wärtsilä
The same study concluded that the estimated annual running costs for MDO make it possibly unviable, from an economic point of view, to comply with the ECA regulations (NO\textsubscript{X} Tier III). Also, normal HFO operated vessels will have higher capital cost that today when targeting for low NO\textsubscript{x} and SO\textsubscript{x} emissions.

A study from the Glosten Associates\textsuperscript{29}, as well concludes the LNG option to give lower annual costs than traditional fuels.

On the basis of above a comparison between the different alternatives is presented in Table 4 below and provides the starting point for further analyses of the options. It can be seen that LNG has better environmental features that the other options. On the financial viability, the LNG option demonstrates high investment costs compared to the other options, whereas the operational costs are probably lower.

\textsuperscript{29} The Glosten Associates, 2011, Feasibility for Washington State Ferries. The study is under revision and the figures might be subject to change.
Table 4. Comparing the alternatives; LNG, DME, MGO and HFO

<table>
<thead>
<tr>
<th>Alternative</th>
<th>SO$_x$</th>
<th>NO$_x$</th>
<th>PM</th>
<th>CO$_2$</th>
<th>Cargo capacity</th>
<th>Capital Investments</th>
<th>Operating costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>Restricted</td>
<td>Very high</td>
<td>Low</td>
</tr>
<tr>
<td>MGO</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Not restricted</td>
<td>Low</td>
<td>Very high</td>
</tr>
<tr>
<td>HFO/Scrubber</td>
<td>+</td>
<td>--</td>
<td>+</td>
<td>-</td>
<td>Slightly restricted</td>
<td>High</td>
<td>Medium$^a$</td>
</tr>
</tbody>
</table>

$^a$ very good, + good, – bad, -- very bad

a) Fuel costs remain basically unchanged, a small increase (1-2%) can be expected. Cost for scrubber maintenance and waste handling are yet unknown but may add to the total operating costs.

3.6 Vessels Suitable for LNG Propulsion

A general overview of a number of typical vessel types considered to be suitable for LNG propulsion is given in Appendix IV. Examples of Vessels Suitable for LNG Propulsion. The vessel types are to be seen as examples for each type category taking into consideration that the environmental effects are positive in all cases. Huge variations exist for all categories, in all respects.

One may argue whether all of these vessels are suitable in the ECA or not. In the longer perspective, all of them can be used, however, as with the example of a VLCC, it is likely to take a long time before this can be seen in reality.

Examples of vessels for both North European (short sea) waters as well as for ships operating in international trade are included. Actual numbers and type of vessels depends on several factors such as:

- Rapid technology development in the areas of; engine- and tank systems;
- Supply of LNG;
- Fuel prices;
- Future trading patterns;
- Future environmental regulations;
- Availability of engines and process equipment, as well as maintenance service;
- New build or retrofit vessels;

$^{30}$ Most part of this section is based on a project performed by: SSPA, FKAB, Whitesmoke & SMTF
• The ship owners environmental profile and demands;
• Local regional conditions regarding type of traffic.
4 Inventory of Existing and Planned LNG Infrastructure and Supply Routes

4.1 Overview of the LNG Value Chain

The LNG value chain illustrates the whole process from extraction of natural gas in the gas fields to gas deliveries to the end user. It is normally broken down into six major steps, which are shown in and described below. Upstream LNG infrastructure includes exploration and production, liquefaction, and shipping to receiving terminals. These activities are briefly presented in Appendix V. LNG Infrastructure in Northern Europe that also includes more details on the existing downstream infrastructure in Northern Europe.

![Figure 13. LNG value chain](image)

Upstream infrastructure exists in Northern Europe and in all other major regions in the world. LNG is economically feasible to transport over long distances and has the potential to bring regional gas markets closer together in terms of pricing, thus transforming the gas markets from regional markets to a global market. It is the downstream infrastructure in particular that is interesting for the maritime sector in the SECA.

4.2 Upstream LNG Infrastructure in Northern Europe

4.2.1 Production Plants

There are nine production plants today in Northern Europe, of which five are located in Norway, one in Sköldvik in Finland, and three in the vicinity of St Petersburg in Russia. All production plants, except for Melköya in Norway, are small-scale plants, producing 2 500 to 300 000 ton LNG per year. In Melköya, 4.3 million tonnes of LNG is produced per year. The total liquefaction capacity in the region is 4.8 million tonnes per year. The production capacity is expected to increase within a few years. For example, Gazprom has a new plant under construction in the vicinity of Kaliningrad which will produce 25 000 tonnes of LNG from 2012. Furthermore, proposals of establishing one midscale liquefaction plant...
in Vyborg or Greifswald to 2016 and one small scale plant in Kaliningrad to 2017 are under discussion. The main purpose of these plans will be to supply the maritime sector with LNG. Also, Gazprom has plans of establishing a large scale LNG plant at Shtokman-Teriberka, about 100 kilometers north-east of Murmansk, with a production capacity of 7.5 million tonnes LNG per year. The plant is expected to be in operation in 2017/2018. All in all, the production capacity is expected to increase from 4.8 million tonnes per year to 13.5 million tonnes when the Shtokman-Teriberka plant is in operation. All existing, planned and proposed plants are listed in Table 33, Table 34 and Table 35 in Appendix V. LNG Infrastructure in Northern Europe.

4.2.2 Import/Receiving Terminals
Receiving (or import) terminals import LNG from the production plants, store and redistribute it as gas, mainly to the natural gas network via pipelines and to large gas consumers. However, receiving/import terminals may also be used for distribution to vessels. As a thought scenario, an import terminal for distribution to vessels would generally consist of:

- A terminal facility, where the vessel can be unloaded to storage tanks;
- Facility where loading of smaller vessels can take place, either at the unloading spot or a separately dedicated jetty;
- Storage tanks, usually full containment tanks;
- A re-gasification system, and;
- Auxiliary systems and buildings, for operation and maintenance.

If the terminal is solely dedicated to distribution to vessels, a regasification system is not necessary. The boil-off gas from the storage tanks can be used as fuel for power generation at site or it can be re-liquefied.

Import/receiving terminals exist in Belgium, the Netherlands, United Kingdom, Sweden and Norway. There are more than 40 existing small-scale LNG terminals in Norway, shown in Table 34 in Appendix V. LNG Infrastructure in Northern Europe.

A majority of the terminals has a storage capacity less than 1000 m$^3$, and altogether they account for less than 1% of the total storage capacity in the region. The total LNG storage capacity in the region was approximately 2 million cubic meters in 2011. The storage capacity in Northern Europe is expected to increase quite rapidly. There are plans to establish an additional 16 terminals in Poland, Lithuania, Sweden, Finland, Germany, France and United Kingdom in near future, see Figure 14.

However, it is not likely that every single one of these terminals will be realized as some of the sites are competing for the same gas demand. For example, studies indicate that the gas demand in Eastern Baltic Sea only allows the establishment of
one single large scale storage terminal\textsuperscript{31}, although there are plans of establishing five terminals in the area, one in each country and two in Finland.

Figure 14 below shows the location of existing, planned and proposed LNG terminals and production plants. In tables of Appendix V. LNG Infrastructure in Northern Europe, are listed the details of each LNG facility that is marked out in the map below. It has to be noted that there are discussions going on about establishing LNG terminals at several other locations within the area, among others in Helsingborg, Sundsvall (Sweden), Hirtshals (Denmark), Oslo, Mongstad, Helgelandsbase (Norway) but as these projects has not become official yet, they are not shown in the map or listed in the tables of the Appendix V. LNG Infrastructure in Northern Europe.

\textsuperscript{31} Ramböll, 2009
Today, a majority of the terminals, with exception for the terminals in Norway and Sweden, are constructed for large scale LNG vessels. However, jetties for small-scale LNG vessels will be built in the terminals of Zeebrugge and Rotterdam to be in operation in 2014 and the planned terminals of Rostock, Gothenburg and Turku are small-scale. Fourteen of the Norwegian terminals are organized to supply LNG as fuel for vessels and five of their terminals are used as bunkering stations today. Furthermore, the terminal in Nynäshamn has small-scale LNG export/bunkering facilities and the planned and proposed terminals in Swinoujscie, Padilski, Klaipeda, Rostock, Gothenburg, Turku and Porvoo have plans of establishing small-scale export/bunkering facilities.

### 4.2.3 Technologies for Offshore Terminals

The long lead time and high investment costs for land-based terminals, together with safety concerns and environmental considerations, have recently resulted in an increased interest in offshore re-gasification terminals, so called floating terminals.

- A Floating Storage and Regasification Unit (FSRU) is an LNG carrier with on-board re-gasification capacity. It remains attached to a single point or spread mooring system offshore and receives LNG from other carriers by ship-to-ship transfer. The LNG is stored, re-gasified on demand and exported to shore by a sub-sea pipeline.

- An LNG Regasification Vessel, LNGRV, is a carrier with re-gasification equipment on-board. The carrier docks at a floating buoy and exports its gas to the shore via a sub-sea pipeline. Shipboard re-gasification can take 5 to 7 days before the carrier is depleted and can sail to its next destination or reloaded by Ship-to-Ship transfer from another LNG carrier.

- A Gravity-Based Structure (GBS) is a submersible structure that permanently rests on the sea floor and contains integrated LNG storage tanks and regasification equipment on the topside. It is a robust, yet rather costly, solution and, currently, there are no proposals for GBS projects.

All technologies exist today in real applications. Floating technology exists in small-scale implementation projects as well. For example, Torp LNG has developed examples of how this could be implemented.

### 4.3 Downstream Infrastructure in Northern Europe

The location of existing and a majority of the planned LNG infrastructure are strongly correlated to extensions of the natural gas network. The main task for the majority of existing and planned LNG receiving terminals in Europe is to deliver natural gas to the network and in turn major land-based user categories such as residents, power generation and other industries.
When LNG is used as a fuel for shipping, the value chain is extended with several steps after the LNG import/receiving terminal. The different supply options from the LNG import terminal to the ship are illustrated in Figure 15 and are briefly described in the following text.

4.3.1 Small and Medium Sized LNG Carriers
There are two categories of small and medium sized LNG carriers; LNG bunker vessels and LNG feeder vessels, a vessel size distinction made for convenience in this project. Furthermore, LNG can be transported by barges, which either can be self-propelled or unpowered. It should be noted that no orders for LNG bunker vessels exist today, but there are developed designs. There is only one LNG vessel in the world that can be described as a LNG bunker vessel, the Pioneer Knutsen. However, the Pioneer Knutsen is mainly used as an LNG feeder vessel delivering LNG to very small intermediary terminals along the Norwegian coast. LNG bunker vessels will be an important part of the future LNG filling station infrastructure in Northern Europe. The lack of LNG bunker vessels is an obstacle for bunkering in e.g. Nynäshamn/Stockholm (Sweden) today and will most probably be an obstacle for bunkering of LNG in other terminals and small-scale jetties to be commissioned in the coming 3-4 years.
The purpose of the feeder vessel is, primarily, a regional distribution of LNG. The LNG is loaded from the larger import terminals/liquefaction plants to receivers along the coast line. In the Netherlands, development of an infrastructure for LNG propulsion of barges that travels the inland waterways also is underway. The primary receiver is the LNG intermediate terminals of varying size or larger vessels in need of large quantities of LNG as bunker fuel. The size and main dimensions of an LNG feeder vessel can vary drastically, depending on different market demands, depths and other physical limitations of the ports and bunker sites to be used. Typical cargo capacity for LNG feeder vessel may be approximately 7 000 to 20 000 cubic meters.

There are only slightly more than 20 small-scale LNG vessels in the world. The existing fleet is listed in Table 32 in Appendix V. LNG Infrastructure in Northern Europe. The number of vessels is increasing. Especially the Norgas fleet of LNG carriers can be seen as a vital addition to the small to mid-size LNG fleet in Northern Europe.

4.3.2 Intermediary LNG Terminal
An intermediary LNG terminal can be used if the distance from the LNG import terminal plant to the end user is longer than what is feasible for a bunker vessel or truck to cover (approximately 40-100 nautical miles for a bunker vessel (larger volumes= larger distance) and 350-600 kilometers for a truck). An intermediary terminal may also be needed if it is necessary to bunker at a fast rate and for local bunkering to consumers such as harbor tug, fishing vessels or ferries.

An intermediary terminal can therefore vary considerably in size. In a full-scale application, the terminal in a large port could be as large as 100 000 m$^3$, while an LNG terminal serving small fishing vessels or tugboats through a pipeline at a bunkering quay may have a capacity down to 50 m$^3$.

Many of the existing intermediary terminals are stationary onshore LNG tanks, but LNG containers, which are used for transporting LNG by railway, sea, river or road transport, can also be used for storage of LNG onshore. Furthermore, offshore terminals (see paragraph no 4.2.3) could serve as an intermediary terminal. The offshore terminal could either be a vessel or a barge. In both cases a bunker vessel and small scale LNG fuelled vessels will be able to moor alongside the vessel/barge and bunker LNG. Advantages of offshore terminals are lower investment costs and

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33 Prerequisites for a landbased infrastructure for LNG/LBG in Sweden, ÅF 2011 and telephone interview with Gasum july 2011 and Gazprom sep 2011
34 This kind of solution may also be applied to conventional bunkers, Dimethyl ether (DME), methanol etc
shorter delivery times than stationary tanks. It can also be easier to find a suitable location for an offshore terminal. Finally, a small scale liquefaction plant, could also serve as an intermediate terminal.

The general description of an import terminal for distribution to vessels in 4.2.2 can be applied for onshore intermediary terminals as well. The intermediary LNG terminal may be supplied with LNG by LNG vessels (bunker vessel or feeder vessel), by LNG truck or by a liquefaction plant), which is shown in Figure 15 above. In Appendix V. LNG Infrastructure in Northern Europe more information on existing and planned LNG terminals in Northern Europe is presented.

4.3.3 LNG Trucks
Regional land-based distribution of LNG can be carried out by heavy duty trucks, for example to serve nearby industries, other harbors in the region and transportation within the harbor. LNG trucks are also used for transporting LNG from small scale liquefaction plants (see 4.3.4 below) to customers who are not connected to the gas network. Examples of countries where LNG is distributed by trucks are Norway, Sweden, Finland, Belgium, Germany, the Netherlands, Poland, Spain, Turkey and Russia. LNG terminals with regional distribution of LNG by trucks are equipped with facilities for loading and unloading of trucks. Flexible hoses are used for the transfer of LNG between the truck and the terminal. The truck can carry between 40 to 80 m$^3$ of LNG depending on allowable size of trucks in a specific country. A normal bunkering operation from a semi-trailer takes up to two hours including signing of documents and safety procedures. The pumping time is approximately one hour.

4.3.4 Small-Scale Liquefaction Plants
LNG can also be supplied from small scale liquefaction plants. Examples of small scale production plants are Kollsnes and Karmøy production plants in Norway and the production plants close to St Petersburg in Russia (see Appendix V. LNG Infrastructure in Northern Europe).

Small scale liquefaction plants are advantageous because the capital investments are small. The capital investment for small scale LNG plants is approximately 600-800 EUR/ton LNG$^{35}$. Furthermore, their compact size enables the production of LNG close to the location where it will be used. These plants also make it possible for customers without access to natural gas pipelines to be supplied with natural gas. The LNG is normally transported from these plants to industries and other customers by LNG trucks or by LNG vessels. A disadvantage with small scale plants is that they are not as energy efficient as larger liquefaction plants, which results in higher production costs$^{36}$ and difficulties in competing with LNG deliveries from

$^{35}$ Gasnor, August 2011.
$^{36}$ Trond A Pedersen, Gasnor, August 2011
large-scale plants. The economics of small scale liquefaction plants will be incorporated in the work ahead.

4.3.5 Vessels for LNG Propulsion

End users of LNG can be trucks, industries, power plants and vessels etc. In this chapter, the focus is on vessels for LNG propulsion. Vessels suitable for LNG propulsion are described in Appendix IV. Examples of Vessels Suitable for LNG Propulsion and the gas engine concepts are described in 3.1.1.

There are mainly three bunkering methods for vessels for LNG propulsion today. Bunkering operations are made either from truck, fixed filling lines or bunker vessels/barges. They have different capacities, speed and flexibility. The vessels currently operating on LNG in Norway are either served by dedicated trucks or stationary tanks on the quay with fixed filling lines. Bunkering from barges in port is currently not a conventional technology, but has been discussed as a temporary solution for example in Stockholm. Bunkering from LNG bunkers and LNG feeder vessels will most likely be the main bunkering option in the future, as the operational cost of berthing at a terminal is considered to be too expensive, especially for large vessels. Fixed filling lines may however be a good alternative for bunkering of small-scale vessels and vessels bunkering at dedicated quays, for example ferries.

The LNG on board the vessel will most likely be stored in a pressurized IMO type C tank. The pressurized tank will be able to take care of the increased pressure that will arise during the bunkering operation. The storage tanks on the vessels are further described in Appendix III. LNG Storage Tanks.

The characteristics of LNG lead to different requirements in comparison to conventional oil bunkering. LNG is a cryogenic liquid with a very low flash point at gaseous state. These two properties entail certain requirements for the handling, material of piping and components, ventilation and surrounding equipment on both the receiving vessel and the bunker vessel. However, the safety level of bunkering of LNG must be equal to current HFO bunkering procedures.

4.4 Example of LNG Infrastructure in Norway

Small scale LNG infrastructure and LNG as a bunker fuel has already been introduced in Norway. Important driving forces for the development in Norway are large natural gas reserves in combination with a mountainous landscape, making distribution of natural gas by pipeline expensive. Local and regional distribution of LNG is a flexible option, which makes it possible to increase the numbers of natural gas customers in Norway. Even if the circumstances in Norway differs from the ones in the other SECA countries, the LNG infrastructure in Norway can serve as an
example of how small scale LNG infrastructure could be developed in the SECA region. The text below gives a short description of the LNG infrastructure in Norway.

The LNG distribution system in Norway was developed with industrial customers in mind, but the technology has also made it possible to use LNG as fuel in vessels. Today there are several vessels operating with LNG as fuel in Norway, for example passenger ferries, car ferries, coast guard vessels and LNG feeder vessels.

LNG is produced in five small-scale production plants; see Table 30 in Appendix V. LNG Infrastructure in Northern Europe.

From the production plants LNG is transported either by small-scale LNG carriers or by truck to local storage terminals or bunkering stations. Sometimes LNG is supplied from large LNG carriers to coastal LNG carriers. There are more than 40 small-scale LNG receiving and storage terminals along the coast of Norway. Some of the local terminals are designed for one single industrial user, but most of the terminals are designed as a regional terminal for several customers and/or further distribution by tank lorries. 14 of these terminals are organized to supply LNG as bunker fuel for vessels. The storage capacity varies between 20 m$^3$ to 6 500 m$^3$. A majority of the terminal has a storage capacity less than 1000 m$^3$.

In existing vessels, LNG is stored in cylindrical pressurized IMO type C tanks. Powder-vacuum or multi-layer-vacuum insulation ensure long time storage. The typical storage tanks in a bunkering terminal for vessels have a capacity of 500 to 700 m$^3$ LNG. The capacity can be increased by time by adding new storage tanks.

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37 Trond A Pedersen, Gasnor, aug 2011
38 Marintek, 2008
From the receiving and storage terminal LNG can be transported to fuel bunkering stations. Four of the terminals are used as LNG bunkering stations today, that is Kollsnes production plans, CCB Ågotns Offshore base and Halhjelm ferry quay and Øra. There are also bunkering facilities at Risavika production plant.

For transfer of LNG between the storage and the vessel, insulated piping with a pipe connection or marine loading arm is used. The same pipeline is used for the supply of LNG from a LNG carrier to the terminal and the bunkering of vessel from the terminal. The distance between the terminal and the quay should be as short as possible to minimize boil-off. Boil-off vapours from the onshore LNG storage tank are displaced via the vapour return line to the LNG carrier.

At the locations where there are deliveries of gas from the LNG terminal into a local gas grid or to a nearby gas customer, the terminal includes evaporators for the heating of LNG and conversion to gas. Furthermore, most of the LNG terminals in Norway are equipped with a filling station for LNG road trucks and for regional distribution of LNG to gas customers who are not connected to the local gas network.
5 Analysis of the Potential of LNG as a Maritime Fuel in Northern Europe

The overall aim of the feasibility study will be to analyse possible scenarios for the development of a future LNG bunkering infrastructure in the SCEA. The potential for LNG as a maritime fuel in Northern Europe is a crucial input to the analysis of a feasible filling station infrastructure development. This chapter describes the current bunkering volumes of traditional fuels and estimates the potential transfer to LNG over time and in total for the SECA. A preliminary assessment of what factors will influence the demand and early LNG infrastructure development will as well be presented. These baseline data and order of magnitude calculations give the basis for further analysis of how the infrastructure can be expected to develop based on different scenarios.

Based on present available information on traditional fuel oil bunkering and analysis of AIS statistics from the study area, this chapter presents an estimation of the future potential demand for LNG in the Northern Europe SECA.

For most ports in the area, accurate statistics on bunkering are not available. Contacts with companies providing forecasts on the bunker market confirm that statistics are not readily available and that predictions on the current and future market are based on calculations and assumptions. It was therefore concluded by the project team that analysis of AIS data would likely provide a more reliable source of additional data for the prediction of potential future LNG demand as marine fuel.

Figure 17 below gives an overview of how the analysis is made. As can be seen to the left in the figure, the major input categories to this analysis will be the estimation of future LNG demand and other factors that may influence the feasibility of infrastructure investments, such as synergies with land-based demand. These other factors are discussed in other parts of the baseline report, whereas the maritime demand is elaborated below.

The figure illustrates how the maritime demand of LNG is estimated based on a fraction of the total current bunkering demand for ships that principally operate in the SECA. Based on statistics on recorded AIS-data, the number and type of ships can be determined. This data is then matched with specific ship data, including generalised speed-power and fuel consumption models for the concerned ship types to derive a total LNG demand figure.

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39 Robin Meech, phone and email conversation, 2011
To this, a very rough state of the art pattern of current bunkering in the SECA is presented based on data from AAPA (American Association of Port Authorities).

5.1 Bunkering of Traditional Fuels

Information on the characteristics of today’s bunker market is important for the prediction of the future potential LNG market. The existing major bunker locations usually fulfil at least two of the following criteria:

- A large port with an intense vessel traffic
- High density of traffic transiting in or close to the port or port area
• Vicinity to oil production, shipping and refinery resources

Considering the ports in the table below it is clear that the most of the above criteria are met in the listed main bunkering ports.

The table shows the main bunkering ports/areas in Northern Europe\textsuperscript{40} where conventional bunkering are taking place today.

Table 5. Major bunker ports in Northern Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>Antwerp</td>
</tr>
<tr>
<td>Denmark</td>
<td>Copenhagen</td>
</tr>
<tr>
<td>Denmark</td>
<td>Great Belt</td>
</tr>
<tr>
<td>Estonia</td>
<td>Tallinn</td>
</tr>
<tr>
<td>Germany</td>
<td>Hamburg</td>
</tr>
<tr>
<td>Latvia</td>
<td>Riga</td>
</tr>
<tr>
<td>Lithuania</td>
<td>Klaipeda</td>
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<tr>
<td>Netherlands</td>
<td>Amsterdam</td>
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<tr>
<td>Netherlands</td>
<td>Rotterdam</td>
</tr>
<tr>
<td>Norway</td>
<td>Bergen</td>
</tr>
<tr>
<td>Poland</td>
<td>Gdansk</td>
</tr>
<tr>
<td>Russia</td>
<td>St Petersburg</td>
</tr>
<tr>
<td>Sweden</td>
<td>Gothenburg</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Falmouth</td>
</tr>
</tbody>
</table>

Source: www.bunkerindex.com

As noted above, the criteria for existing large bunker ports/areas show that these often are located in, or close to, large ports. As a reference, the largest ports\textsuperscript{41} in northern Europe are listed below. It is compiled from the top 126 ports of the world in each category TCV (Largest ports in the world calculated on Total Cargo Volume) and CTV (Largest ports in the world rank calculated on Container Traffic Volume).

\textsuperscript{40}http://www.bunkerindex.com/directory/neurope.php
\textsuperscript{41}AAPA, 2009 (American Association of Port Authorities)
Table 6. Large European ports

<table>
<thead>
<tr>
<th>TCV rank</th>
<th>CTV rank</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>10</td>
<td>Rotterdam</td>
</tr>
<tr>
<td>19</td>
<td>14</td>
<td>Antwerp</td>
</tr>
<tr>
<td>27</td>
<td>15</td>
<td>Hamburg</td>
</tr>
<tr>
<td>30</td>
<td>-</td>
<td>Newcastle</td>
</tr>
<tr>
<td>34</td>
<td>-</td>
<td>Amsterdam</td>
</tr>
<tr>
<td>42</td>
<td>-</td>
<td>Primorsk</td>
</tr>
<tr>
<td>45</td>
<td>47</td>
<td>Le Havre</td>
</tr>
<tr>
<td>51</td>
<td>20</td>
<td>Bremen/Bremerhaven</td>
</tr>
<tr>
<td>61</td>
<td>-</td>
<td>Bergen</td>
</tr>
<tr>
<td>69</td>
<td>-</td>
<td>St Petersburg</td>
</tr>
<tr>
<td>-</td>
<td>32</td>
<td>Felixstowe</td>
</tr>
<tr>
<td>84</td>
<td>43</td>
<td>Zeebrügge</td>
</tr>
<tr>
<td>101</td>
<td>72</td>
<td>Southampton</td>
</tr>
<tr>
<td>97</td>
<td>102</td>
<td>Gothenburg</td>
</tr>
<tr>
<td>82</td>
<td>-</td>
<td>London</td>
</tr>
<tr>
<td>96</td>
<td>-</td>
<td>Tees and Hartlepool</td>
</tr>
<tr>
<td>106</td>
<td>-</td>
<td>Wilhelmshaven</td>
</tr>
<tr>
<td>114</td>
<td>-</td>
<td>Tallinn</td>
</tr>
<tr>
<td>126</td>
<td>-</td>
<td>Riga</td>
</tr>
</tbody>
</table>

Source: Extract from AAPA, 2009.

The list of major bunker ports/areas and the list of the largest ports in operation today basically cover the same ports.

Figure 18 below presents estimates on residual fuel demand from 2009\textsuperscript{44} done by Marine and Energy Consulting Limited. It should be noted that the figures shown in most cases are calculated and thus not based on statistical or actual data. Hamburg, Gothenburg and St. Petersburg together with the huge bunkering port Rotterdam are the only Northern European ports found on this world’s top 32 list.

\textsuperscript{42} Largest ports in the world calculated on Total Cargo Volume  
\textsuperscript{43} Largest ports in the world rank calculated on Container Traffic Volume  
\textsuperscript{44} Robin Meech, email and phone conversation, 2011
5.2 Potential Quantities of LNG in Northern Europe by 2020

In order to provide additional data for more accurate calculation on potential LNG fuel demand, recorded AIS statistics from ships principally operating in the SECA have been analysed with respect to frequent departure and arrival routes and types of vessels. The approach of this analysis and its assumptions are described in more detail in Appendix VI. Calculation on Future Potential of LNG Demand in the SECA.

For this base line analysis it is assumed that only new buildings are being considered to use LNG and thus it is assumed that only a few existing vessel will be converted for LNG fuel operation by retrofitting of LNG tanks and engines. For this base line, It is not assumed that a significant portion of the fleet will be converted because of commercial considerations and it is foreseen that the number of sponsored demonstration or pilot vessels will be limited. However, the retrofit option will be reviewed in coming investment analyses, and if motivated, the LNG demand assumptions will be adjusted in accordance with new findings.

5.2.1 Automatic Identification System (AIS) for vessels

Automatic Identification System (AIS) is compulsory for most commercial sea going vessels. This system is installed on board the vessels and transmits for example position, speed, identification and type of vessel to other vessels and to land based stations.
The calculations made here are based on AIS data collected from the whole SECA. The AIS data has been matched to a vessel database to find out more information on all individual ships. An example of matched data is year of build for each specific vessel.

### 5.2.2 Adaptation Rate to LNG

In order to make a calculation of the expected future LNG demand, it is also essential to know the adaptation rate to LNG in newly built vessels. Within this study, an expected adaptation rate (see Figure 19) based on data presented by the GL Baltic study was used. As can be seen in the figure, Ropax, RoRo and cruisers are assumed to have the steepest fuel-shift trend reaching a 70 % LNG portion in 2017, while for other ship types about 50 % of the new buildings in the area are assumed to be LNG fuelled by 2020.

![Figure 19. Gas fuelled ships adoption rate in new-buildings](source: Sames, 2010)

### 5.2.3 The new building rate of ships

The rate of new buildings is generally estimated to correspond to an average of 2% annual growth of the fleet and a replacement rate of 2% of old ships being scrapped and replaced. This gives an annual new building rate of 4% and combined with the expected rate of adaptation to LNG, an expected number of LNG-ships in the SECA area per year is calculated (Figure 20). The new building rate varies in different market areas and for various ship type segments and is difficult to predict accurately. In order to show the impact of a higher or lower new building rates than assumed, three different optional scenarios are also shown.

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45 Sames, 2010
The scenarios are:
- Case A: New build ratio is 4% of entire fleet (assumed basic scenario);
- Case B: New build ratio is 6% of entire fleet;
- Case C: New build ratio is 2% of entire fleet.

![Figure 20. LNG fuelled ships in the SECA area 2014 – 2020](image)

The calculated figures on the growth of the LNG fuelled fleet in the SECA illustrated in the diagrams above, show that about half of all new buildings can be expected be LNG fuelled by 2020 and that the LNG fuelled portion of the total fleet gradually will rise to about 7% by 2020 in the SECA for the basic scenario case A.

### 5.2.4 Estimation of future LNG fuel demand

To estimate the total energy demand for an average ship in each category the power requirement of a ship is approximated by a simplified equation taking into account the ships’ size, speed and distances travelled. By multiplying the power requirement curve with the time spent at different speeds the daily average energy use for each ship category is derived.

The results of the calculations show that, with about 1 000 LNG fuelled vessels included in the basic scenario case, a yearly LNG consumption of 4.3 million tonnes can be expected. The total expected weekly demand in the area is approximately 180 000 m³ including all ships in the English Channel, the North Sea and the Baltic Sea.
In Figure 21, the calculated quantities of LNG demand 2015 and the future development from 2015 to 2020 are shown for the three scenarios.

![Figure 21. LNG demand in SECA area 2015-2020 – tonnes per year](image)

A closer look at LNG demand for specific ship types for 2020 is shown in Figure 22.

![Figure 22. LNG demand 2020 by ship type – tonnes per year](image)
5.3 Future LNG infrastructure development in SECA

Further to what is presented in AAPA statistics, bunkering today is taking place in many other medium size and small ports around Europe. Some small ports with very specific traffic are in need of very special type of bunkering system. Hirtshals and Dover with heavy passenger ferry traffic are examples of such ports. These ports need smaller terminals and bunker solutions to be able to make the transition from conventional fuel to LNG.

AIS-data will be further used to specifically describe a few typical representative ports and their foreseen LNG bunkering customer base, including bunkering volumes and bunkering frequency.

For future LNG bunkering infrastructure development in SECA, the total LNG bunkering volume will be of prime relevance. Other feasibility criteria for ports pioneering on LNG bunkering facilities will include:

- High portion of regular liner shipping, in the initial transition phase before the LNG filling station infrastructure is fully developed, facilities serving specific ferries and liners regularly calling the same port may pioneer the development;
- Other LNG consumers in the area, i.e. in particular synergies with land-based demand;
- Vicinity to LNG import/receiving terminal.

In coming work, these factors will be given further attention, see chapter 11, Way Forward.

5.4 Analysis on the Potential for LNG as a Marine Fuel

For ferries or purpose built vessels, pure LNG/single fuel LNG engines is an option, but as a general rule, most vessels will be fitted with dual fuel engines to be attractive on the second hand market outside the SECA/ECAs and to be able to trade outside the SECA/ECAs at a competitive price. All engine manufacturers that offer dual fuel engines today require diesel as a pilot fuel to ignite the LNG. 0.5-5% of the total bunker volume used is needed for this purpose. It is therefore considered favourable if both LNG and conventional fuel would be available at the locations where LNG filling stations are being built.

According to the calculations above, LNG fuelled vessels would by year 2020 amount to approximately 5-10 % of the ships (Figure 20). If the figures on the estimated demand in Figure 21 are reflected in volume figures for the four identified main North European bunker ports about 2-4 million tonnes of residual fuel would be replaced by LNG. Taking into account that all four ports have a
substantial amount of shipping operating outside the area, the figures probably represent an over estimation of the volumes.

The above calculations for the area as a whole, will be further refined in the next phase of this project, and three examples will be calculated using AIS data and these findings will be used for estimations on required storage capacities and infrastructure needed and thus also be able to include the LNG price estimation for the ship owner.

Many of the large bunker ports are already planning for LNG terminals capable to distribute LNG to customers in the port including bunkering of ships with LNG fuel. In order for LNG to become a competitive fuel, more medium and small scale ports also need to take initiatives aiming at establishment of LNG filling stations for bunkering of ships. For small ports, like the project partner Hirtshals, criteria for successful implementation will be further analyzed in the coming project phases and issues addressing commercial conditions and potential subsidies or other incentives will be discussed.

The above calculations rests on the assumption that liner traffic or vessels returning in regular intervals to one port will use LNG as a fuel, at least in the early stage – much like the current situation in Norway. With an expansion in the number of terminals being built and large terminals building export facilities for smaller LNG vessels, it is likely to see vessels on longer trading routes and possibly even on the spot market using LNG as a fuel before 2020. Thus, most ships in Appendix IV. Examples of Vessels Suitable for LNG Propulsion are suitable for using LNG as a fuel with the exception of VLCCs.
6 LNG in Land-Based Applications

Current use of natural gas in other sectors besides the maritime sector is described in this chapter, as well as possible developments of future use of natural gas within those sectors. The possible synergies between maritime and land-based use of LNG are assessed. The land-based demand of natural gas and specifically of LNG is a strong driving force for the development of LNG terminals. A land-based demand with contracted volumes has been an important part of business cases for terminals up until today. The potential of land-based demand and the possible synergies with the maritime market for LNG will be further assessed as a part of future work.

6.1 Residential and Commercial Sectors

Within Europe, natural gas has been widely used both within the residential and commercial sector, the industrial sector and for power generation for many years. In 2009 the natural gas share of primary energy consumption was 24 percent. The use of natural gas within the residential and commercial sectors is not expected to increase due to a number of reasons;

- Somewhat saturated market in many gas consuming countries;
- Expected slow population growth;
- Low population density sets economical constraints to greater market expansion;
- Increased energy efficiency in buildings.

6.2 Industrial Sector

Within the industrial sector, growth of natural gas consumption has historically been extensive in countries with a developed gas infrastructure. The industry is price sensitive and it is not expected that natural gas will increase its share of energy consumption if gas prices are not competitive in relation to other fuel alternatives. LNG may have an opportunity to expand market shares for natural gas within this sector in countries without a developed natural gas infrastructure such as Sweden and Finland. The synergies between the build-up of an LNG terminal infrastructure and industrial use are evident in the development of LNG terminals in Northern Europe where a majority of the existing and planned terminals have chosen locations close to large energy consuming industries and power plants. For instance, the terminal in Nynäshamn, Sweden is located close to the Nynas refinery and the terminal also serves the town gas grid in Stockholm. As for the planning of terminals in Finland, the developers are looking for locations that offer one or

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46 Eurogas, 2010.
47 Eurogas, 2010_b.
48 ÅF, 2011.
several large industrial energy consumers within a radius of 400 km from the planned terminal location. In Swinoujscie, Poland, the planned terminal location is in the immediate vicinity of a power station and a chemical plant. The economies of scale for LNG terminals drive the aim to find synergies between different users of LNG. On the other hand, in countries with a developed natural gas network, the potential for increased use of natural gas is estimated to be limited (refer to map of natural gas grid in Europe).

6.3 Power Generation

According to Eurogas, the long term outlook for gas demand and supply, the driving factor for increased use of natural gas until 2030 will be power generation. In 2009, one fifth of the electricity in EU27 was produced by natural gas. Due to the incident in Fukushima, Japan\(^{49}\) and the following political decision of Germany to close all nuclear power plants before 2022 it is likely that the use of natural gas will increase. However, the developments are also influenced by several other factors such as:

- The growth rate of electricity consumption;
- Energy policies and other political incentives on EU level and within the individual countries;
- Price developments.

The existing residential, commercial, industrial sectors and power generation facilities are likely to continue to be fed by the existing European natural gas infrastructure via mainly indigenous gas and imported gas by pipeline. LNG will mainly function as a tool for strengthening security of supply, an increasingly important topic on the European agenda. LNG can also function as a means to keep pressure in smaller networks such as the one in Sweden and to allow for peak-shaving.\(^{50,51}\) In 2009, net imports of LNG to EU27 increased significantly, from 13% in 2008 to 19%. Due to declining production in indigenous fields some countries aim to diversify their natural gas imports as this trend will probably continue.

6.4 Transportation

Natural gas as a fuel in land transportation is a well proven, reliable technology that has already entered the market in several countries in Europe. The commercial use is mainly for urban services such as public transportation and garbage collection and there also exists a significant private gas vehicle sector in some European countries.

\(^{49}\) On March 11\(^{th}\), 2011, Japan was struck by an earthquake and a following tsunami that destroyed several nuclear power plants in Fukushima.

\(^{50}\) Lars Frisk, Swedegas. Phone conversation, june 2011.

\(^{51}\) Peak-shaving; cover peak loads in a natural gas network with stored LNG.
The average market share in Europe is 0.4%\textsuperscript{52}. The European Expert Group on Future Transport Fuels estimates that it is possible that CNG/LNG vehicles may have a 5% market share by 2020, with some 15 million vehicles, and increase further in the years towards 2030. Although LNG is first and foremost a technology for heavy duty vehicles with an even and predictable demand for fuel, but LNG also fills an important function as back-up distribution for CNG fuelling stations.

The infrastructure of gas fuelling stations, either served by biogas or natural gas or both, exists or is rapidly expanding in a few countries in Europe like Germany and Sweden. In these countries development is driven by political incentives. Remaining countries surrounding the SECA area, none or few fuelling stations exist and the market is in its infancy. To illustrate the large differences in development in the countries in the SECA, the number of fuelling stations and natural gas vehicles by country is shown in the figures below.

![Figure 23. Gas fuelling stations in European countries](source: www.ngva.org)

Today, most of the vehicles used run on CNG (Compressed Natural Gas) which is fed to fuelling stations from the European gas grid. CNG and CBG (Compressed Biogas) are also used for commercial traffic for public transportation in cities. The interest of LNG as a fuel for land transportation is mainly connected to heavy duty vehicles. The lack of a continuous infrastructure within Europe has limited the spread of gas vehicles. Mercedes have developed an Otto-type engine with an LNG tank to improve the range for gas vehicles. Several companies today, including Hardstaff in the United Kingdom together with Volvo, are developing a Dual Fuel system for heavy duty vehicles\textsuperscript{53}, where the vehicle runs on both diesel and gas\textsuperscript{54}, trying to

\textsuperscript{52} European Expert Group on Future Transport Fuels, 2011.
\textsuperscript{53} Lennart Philgren, Volvo AB, telephone conversation, May 2011.
\textsuperscript{54} Technologies available for both CNG and LNG.
bypass the trouble with the inconsistent gas infrastructure. Volvo in 2011 started to sell Dual Fuel trucks with LNG tanks in Sweden, Norway, United Kingdom and the Netherlands. According to the company, the interest from customers is high. However, there are very few fuelling stations serving LNG in Europe today. For instance, AGA, a Swedish gas company, estimates that many of the future fuelling stations will be LCNG stations with the possibility to fuel both LNG and CNG vehicles.\footnote{ÅF, 2011, Studie av förutsättningar för utbyggnad av landbaserad infrastruktur för flytande naturgas och flytande biogas.}

![Figure 24. Number of natural gas vehicles in different European countries](source: www.ngva.org)

Natural gas propulsion as an alternative to diesel propulsion in railways has been tested and several prototypes have been realised. However, the time horizon for a broad introduction is further away than that for other transport modes and the market potential for LNG within railways are estimated as highly uncertain.\footnote{www.railway-energy.org}

It has to be noted that the consumption of natural gas in transport sector is very small compared to the consumption in other sectors and the total consumption in Europe. Today natural gas vehicles accounts for less than 1\% of the total natural gas demand in EU27 and according to Eurogas long term outlook for gas demand and supply to 2030 natural gas vehicles will stand for about 1\% of the total gas consumption in EU27 in 2030\footnote{Long term outlook for gasd demand and supply 2007-2030, Eurogas}.  

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure24.png}
\caption{Number of natural gas vehicles in different European countries}
\textit{Source: www.ngva.org}
\end{figure}
7 Regulations and Guidelines

7.1 GAP Analysis of Regulations and Guidelines for LNG Bunkering

A GAP methodology consists of defining the present and the desired/targeted state, and hence the gap between them. The aim of this part of the analysis is to find a way to bridge the defined gap regarding regulations and guidelines. The three stages of the analysis are (1) listing of characteristic factors of the present situation, (2) cross listing factors required to achieve future well-functioning infrastructure (in accordance with the objectives of this study), and finally (3) highlighting the gaps that exist and need to be filled.

The first section represents stage one in the GAP analysis and lists presently applied International rules, regulations and standards etc. Thereafter follows the second and third stage. In the second stage, factors required for future development are listed, and as a result, the third stage highlights gaps in rules and regulations that need to be dealt with in order to reach the objectives.

7.2 International Regulations and Guidelines

Organisations, authorities, and also the private sector are investigating possibilities to use LNG as a fuel as a response to IMO:s regulations on sulphur limit in SECAs that will be put into force from January 2015. A potential change in bunker fuel draws closer and this requires rules and regulations to facilitate infrastructure, handling of LNG as a fuel, and the coverage of safety and security issues.

As the shipping industry is international, the regulations and rules are set on an international, global basis. There are many organisations dealing with shipping in different ways, contributing to international shipping development with best practices, accepted standards and regulations. The most relevant worth a mention are:

- The IMO with its MARPOL 73/78 Convention. The International Organization for Standardization (ISO)
- The IMO:s Safety of Life at Sea Convention (SOLAS)
- The Society of International Gas Tanker and Terminal Operators (SIGTTO)
- The International Group of Liquefied Natural Gas Importer (GIIGNL)
- The Oil Companies International Marine Forum (OCIMF)

LNG consuming countries; locally, regionally and globally, are using existing guidelines, rules and regulations regarding transportation of LNG (See Appendix VI. Calculation on Future Potential of LNG Demand in the SECA)
There are rules and regulations regarding equipment for LNG, design and manufacturing of cargo containers and storage facilities for LNG and transportation of dangerous goods that vary depending on national standards. This fact points out the need of international standards to facilitate the use of LNG as bunker fuel on a global level.

Other aspects important to develop are rules and regulations concerning the human factor. Training of ships crews and technicians/personnel handling LNG is essential to maintain safety levels compared to that of bunker fuel today.

In relevant IMO codes, SIGTTO and other standards and rules are presented. Special focus has been put on safety standards and regulations related to bunkering and ship to ship transfer. There is also a relevance to list rules and regulations regarding greenhouse gas emissions, and LNG propulsion for inland waterways.

7.3 Required Factors

The use of LNG as cargo is not new to the shipping industry and there are many guidelines and regulations covering different aspects of LNG handling in the supply chain. The difficulty lies in the fact that most regulations are applicable on large scale LNG installations, and applying these regulations to small-scale installations are not sufficient. Each country with an LNG “presence” also tends to have one or more governmental agencies monitoring, in varying fashion, their own LNG industry.

The safe processing, storage and transportation of LNG is an essential condition for the continued existence, growth and sustenance of the entire industry. Required factors are well functioning infrastructure to enable supply of LNG and ensure fast and safe loading and unloading of the cargo.

Nautical rules and procedures concerning small bunker and feeder ships are a further part of the infrastructure.

Design issues that need to be addressed include the location of fuel tank/tanks on-board the LNG fuelled vessels as well as bunkering equipment. This depends on ship type which adds complications, e.g. SOLAS and IGC95 do not permit gas tanks to be placed below accommodation areas. Another important safety issue that needs to be addressed in order not to affect the time at quay is loading and un-loading passengers and goods while bunkering. The dimension of the tank/tanks is also to be considered since the required volume of LNG is approximately the double that for HFO, which in turn affects bunkering times.
7.4 Identified Gaps

The largest gap in respect to LNG bunkering is the lack of international guides, standards and recommendations in general for small scale LNG. There is a need to work pro-actively to propose international legislation for small-scale use. Uniform global standards regarding the use of LNG as fuel will ensure safe development of the industry which is of essence if investments are to be made.

The use of LNG has to allow for parallel activities such as loading and passenger boarding/disembarking during LNG bunkering operations. Other safety issues include navigational aspects and risk from the passenger traffic.

To be able to use LNG for propulsion of inland barges, European, national and local regulations have to be adjusted. LNG supply chains for inland barges require port regulations and bunkering procedure standards for inland navigation in the same way as shipping in general. Emergency response organisations as well as enforcement officers must be prepared and trained for handling inland ships with LNG on board and regulations. Inland shipping will be closer to the population, hence requiring public awareness of the risk of LNG etc.

7.4.1 Ship Side

The ship itself is well covered through both the IGC 95 Code, the draft IGF Code and ICS rules and IACS guidelines. It can be assumed that this area can fulfil the requirement of being both global and uniform.

7.4.2 Ship to Ship

The draft IGF code contains some issues related to ship to ship bunkering. However, as it has not yet been finalized, it is too soon to draw any conclusions on the outcome. Hence, this is more specifically the largest gap in rules and regulations concerning the LNG small scale industry.

The SIGTTO document Guidelines on Ship to Ship bunkering covers most of the issues including pre-notification and safety zones. These guidelines are not yet global, though the intent of the guidelines is for authorities and other organisations to use them as input to regulation and guideline work concerning LNG bunkering.

Developing guidance for systems and installations for supply of LNG as fuel to ships is an on-going ISO project. When finalized, these guidelines will constitute uniform standards on some of these issues. Only Norway has some work linked to safety when bunkering with passengers onboard. The SIGTTO Guidelines on Ship to Ship bunkering has been developed with these issues in mind. The development, and testing, of the Ship to Ship equipment and procedures need to focus on ensuring the highest degree of safety and reliability.
7.4.3 Ship to Shore

Here, the draft IGF code is applicable although it has to be further developed towards small scale LNG. The SIGTTO guidelines of the industry best practice for ship-shore LNG handling have been developed with large to huge LNG carriers in mind.

ISO 28460:2010 Standard on Petroleum and natural gas industries - Installation and Equipment for Liquefied Natural Gas - Ship-to-Shore interface and port operations contains numerous provisions in relation to this field. But as explained earlier this standard is applicable to gas carriers i.e. bunker vessels and not specifically to gas-fuelled ships so they cannot be assumed to be either uniform or global in this respect even if they can serve as a good basis for such development. This standard targets large scale LNG handling and will not always be applicable to small LNG tankers either.

The ISO 28005-2:2010 standard contains technical specifications that facilitate efficient exchange of electronic information between ships and shore for coastal transit or port calls. It is intended to cover safety and security information requirements related mainly to the relationships between the ship and the port and coastal state authorities.

In EEC countries any shore based storage facility (in a port or elsewhere) for LNG will be subject to SEVESO dependent on upper and lower tier thresholds for LNG\(^{58}\).

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\(^{58}\) DNV, 2011
8 Financial and Economic Instruments

8.1 Economic Instruments

There are various financial and economic instruments in place in order to provide incentives and disincentives for SO\textsubscript{X} and NO\textsubscript{X} emissions reductions in Northern Europe. Some of them, such as the Norwegian NO\textsubscript{X} Fund and Swedish fairway and port differentiation dues, and voluntary agreements such as the Green Award Certification and EIS, are presented in Appendix VIII. Examples of Economic Instruments, as examples.

8.2 Policy measures

In July 2011, the IMO adopted new mandatory mechanisms relating to the energy efficiency of ships, the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) in order to reduce greenhouse gas emissions from ships. These mechanisms are further described in Appendix VIII. Examples of Economic Instruments.

Emission Trading Schemes (ETSs) are also discussed but are not considered to be amongst the most efficient instruments for supporting the maritime sector.\textsuperscript{59} Regarding greenhouse gases (GHG), a GHG Contribution Fee is seen as the most appropriate instrument for reductions within the shipping sector.

8.3 Large Differences between Incentives in Different European Countries

There is considerable variation between Member States in their application of regulations vis-a-vis fiscal and economic instruments\textsuperscript{60}, which in turn may influence the national and regional financial climate for investments. For example, Sweden shows a higher proportion of fiscal and economic based measures while Germany’s measures are predominantly regulatory. France and the UK cite a higher proportion of information and educational based measures.

The Table 7 below shows that about half of the policies and measures specified in Europe are regulatory ones. Moreover, the reduction of SO\textsubscript{X} emissions relies to 20%
of the cases on economic and fiscal instruments and to more than 50% on regulatory measures. NOx emissions, on the other hand, are addressed to a higher extent by economic and fiscal instruments.

Table 7. Types of instrument used to address different NECD pollutants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Type of measure</th>
<th>Economic</th>
<th>Fiscal</th>
<th>Negotiated agreement</th>
<th>Voluntary agreement</th>
<th>Regulatory</th>
<th>Information</th>
<th>Education</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO2</td>
<td></td>
<td>13%</td>
<td>7%</td>
<td>1%</td>
<td>7%</td>
<td>54%</td>
<td>11%</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>NOx</td>
<td></td>
<td>14%</td>
<td>9%</td>
<td>1%</td>
<td>6%</td>
<td>50%</td>
<td>11%</td>
<td>7%</td>
<td>2%</td>
</tr>
</tbody>
</table>


8.4 Financing of Port Investments

Ports can be owned by the public sector, i.e. by the state and/or a municipality as well as by the private sector. The port authorities are vital and have different functions according to the national port “traditions”. Furthermore the authorities are characterized by going through changes. The traditional functions of the port authority are as regulatory authority, rent out land within the port area, catering for infrastructure and facilities and as operators. The everchanging environment in which ports operate has put strong pressure on port authorities, mainly from market actors (ship owners, terminal operators and logistics operators), the government and public society. In the ESPO report on European Port Governance61, four main roles of the port authorities are outlined;

- Landlord;
- Regulator;
- Operator;
- Community manager.

The Landlord function can be considered to be the principal role of the port function of the port authority and also forms the most important governance tool of the port authority, i.e. the ability to contract land to third parties. The increased focus of negative externalities of the port stresses the function of the port authority as Regulator in the fields of environment, safety and security. The Operator function has made way to landlord and regulatory functions. The Community manager function can essentially be described as coordinating functions meant to solve collective problems in and outside the port area such as infrastructure bottlenecks, training and education as well as marketing and promotion. Revenue generation is

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needed to cover a minimum the operating costs of the service, but also investments related to port development if the port authority chooses to adapt such a role. The main revenues of the port authority are income from land and real estate and different kinds of port dues.

The port authority plays an important role as the central stakeholder for investments in port developments such as land development, maritime infrastructure and port infrastructure needed for investments in LNG infrastructure for ports. Other services often provided by the port authority are port utilities and port maintenance. Investments in port superstructure such as terminal tanks, LNG filling station equipment, LNG bunkering solutions are often financed by private investments, but could also be state owned or organized in Public-Private Partnerships.
9 Public Awareness and Consultation Process Experiences

The process of obtaining permission for LNG terminals in most of the countries in the SECA includes both processes with public hearings and the issuance of permits by the local authorities – municipalities and regions. This is partly based on the implementation in the countries of EU-directives on requirements of Environmental Impact Assessment (EIA) and Strategic Environmental Assessment. Also, the need for permits according to safety regulations will involve local authorities and may include processes of public hearings.

At present, the following countries in the SECA have been involved in consultation processes and in acquiring an approval of an EIA for an LNG terminal: Belgium, Finland, the Netherlands, Norway, Sweden and the United Kingdom. Poland has advanced plans to establish a LNG terminal. They all have experience from the topics that the public and local authorities focus on during the consultation process to acquire the permit.

9.1 Experience from Existing LNG Projects in the Region

In order to create a background for giving recommendations for future consultation and permit processes, information on public consultation processes have been gathered and assessed for the different countries with this experience (see above). Information has been gathered through interviews, written contributions and a literature review of the EIA’s. The experiences in each country are reported in Appendix IX National Experiences from Public Awareness and Consultation Processes.

- An early and good communication between the authorities and the general public is key (Norway and Sweden);
- To perform accurate safety analysis and take adequate time to communicate this to the general public, the neighbours to the installation and the authorities (Norway and Sweden);
- Taking into account safety and environmental concerns throughout the project can help to ease the concerns of local authorities and local politicians (the United Kingdom);
- The company that will build the infrastructure must act in a responsible manner – previous LNG experience is beneficial (Norway and Sweden);
- It is important to openly communicate to the public the advantages of LNG as a fuel, e.g. reduced emissions and reduced engine noise. (the Netherlands);

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62 This chapter has been developed together with Energinet.dk and Gasnor. Interviews have been made with Gasunie, Gasum and Gaz System Poland.
• In general, objections to LNG may be expected in areas where there is much attention on port development (Finland);
• The media in general have little knowledge of LNG and often confuse LNG with LPG (Finland);
• Environmental issues may be seen as positive regarding LNG for shipping (Finland).
10 Conclusions

10.1 LNG Availability in Northern Europe

- Several LNG import and storage facilities are currently being developed and planned in the SECA;
- LNG will be available in quite large quantities in Northern Europe;
- The global LNG market is expected to grow rapidly and LNG prices in different global regions are expected to converge. This implies that LNG prices in Europe are likely to become higher in the future;
- Liquefaction capacity is expected to increase until 2017, mostly in Russia.

10.2 LNG Demand and Infrastructure in Northern Europe

- The main task for the majority of existing and planned LNG import terminals in Europe is to deliver natural gas to the network, which means that a majority is or will be connected to the European gas network. A major explanation to an increased demand of LNG is that the indigenous natural gas resources in northern Europe are in decline;
- The demand for LNG in Northern Europe will increase;
- In order to be a competitive maritime fuel, an efficient LNG supply chain is the key to success. Up until to today, most of the existing and planned terminals are large scale and dedicated to supply natural gas to nearby natural gas networks. There are few export/bunkering facilities today (2011), but many small scale LNG terminals and jetties to be commissioned in the near future;
- LNG bunker vessels, including barges, will be an important part of the future LNG filling station infrastructure in Northern Europe. The lack of LNG bunker vessels is a problem today (2011) e.g. in Nynäshamn/Stockholm, Sweden and will most probably be a bottleneck in other terminals and small-scale jetties to be commissioned in the coming 3-4 years.
- “First movers” for investment in a small-scale LNG infrastructure and bunkering facilities are instrumental for the development of a filling station infrastructure. Early conversions are expected to be ships on fixed routes where the regularity in port calls can facilitate LNG terminal localizations as well as help predict the demanded volumes of LNG;
- 2 million to 4 million ton LNG per year may be handled as a ship fuel from year 2020 within the SECA;
- The political will and other drivers for the small scale LNG bunkering infrastructure differ from country to country.
10.3 **LNG as Fuel from a Ship Owner Perspective**

- LNG is expected to have a competitive price development in comparison to conventional fuels;
- Engine technology for LNG propulsion is well developed and available in the market;
- Dual-fuel engines are viewed as the most flexible solution to allow ship owners to use LNG or fuel oils for ship propulsion;
- Retrofitting ships to LNG is possible. It is also possible to keep the original engine and install scrubbers. Depending on vessel types these options will be more or less financially viable.
- Compared to HFO and MGO, LNG requires larger tanks for storing fuel;
- The LNG option means high initial investment cost;
- The introduction of SECA will most probably have an influence on the second hand market for the existing fleet in that it will be more nished, especially for solutions with solely gas engines (lean burn).

10.4 **Regulations**

- Regulations and standards are missing for small scale LNG infrastructure.
- National and port authorities lack regulations and guidelines for the movement of small-scale LNG ships in ports;
- Operational guidelines and regulations for LNG bunkering are lacking.

10.5 **Permit Processes for LNG terminals**

- Based on a review of the permit process in different countries, plans for interaction and communication with different stakeholders, including involved authorities and the general public are viewed as key prerequisites.
- It is important to commence this process well in time.
11 Way Forward

Based on the findings presented in this Baseline Study, the forthcoming work will be diverted to performing a feasibility study and setting up recommendations. The recommendations will be following a specific format including a title, a description, the benefit and the target group.

The feasibility will be analysed in basically two interlinked parts: the maritime demand and the maritime supply chain infrastructure. There will be “hard” aspects such as technical and operational and “soft” aspects such as regulatory and financial challenges.

One chief facet for this study will be from the ship-owners’ point of view and how can LNG become a vital option for them.

The analysis will include a further assessment of selected compliance strategies from a ship owner perspective. In this perspective, a ship owner will be interested in the price and availability of LNG compared to other options. The price in turn, will be partly dependant on the local infrastructure cost, which is analysed separately.

The ship owners options will be assessed including investment cost calculations, operational cost calculations, required and existing standards and safety aspects to prevail;

Ship owners’ option 1 LNG; being central for this study, the LNG option will be assessed in more detail. Analyses will cover both new built vessels for LNG propulsion and retrofitting of vessels. The LNG price development will be analyzed and in particular the extra cost for the filling station infrastructure development, which is assumed to be covered by the fuel price.

Other possible options for the ship owner that shall be compared to LNG are:

Ship owners’ option 2 same engines – using cleaner fuels; This option mainly considers low sulphur diesel and the expected price development on these fuels. Assumptions on the refinery capacity and fuel availability will be made.

Ship owners’ option 3 same engines - installing scrubbers; This option mainly concerns the additional costs and implications on operations when installing a scrubber. The assessment will need to estimate the availability of scrubbers on the market and also the possible charges that may be linked to waste management.
Another principal perspective for the analysis is the LNG-terminal operator’s and therefore some possible system solutions and operational models for LNG filling stations will be assessed. The assessments will include investment cost calculations, operational cost calculations, required and existing standards to prevail and will also regard relocation of demand. The LNG supply alternatives centre on three various types of bunkering solutions:

- ship to ship at quay or at sea\(^{63}\);
- tank truck to ship;
- and tank to ship.

These three solutions will be assessed and the capital and operation costs will be estimated for some different sizes. Different, existing and possible operational models will be reviewed, including allocation of responsibilities, investments and costs amongst different stakeholders.

Conditions for and definition of scenarios with different levels, or types, of LNG coverage (small-scale, medium scale, and large-scale terminals) in the region, including integration with land-based systems and investment costs will be screened. A few different scenarios for the LNG demand will be assessed together with scenarios for the supply chain design on a regional level.

The business case for different potential LNG suppliers and other stakeholders will be assessed, including the dividing line between ports, public utilities/the state, the energy industry and other private operators from an investment and operational point of view.

Further, an identification of key characteristics of locations for filling stations/bunkering facilities will be made as well as possible connections to inland waterways.

Applicable existing or awaited political regulations and economic instruments on national and EU level will be reviewed. From the different stakeholders’ point of view, economical key figures will be presented.

Lastly, there will be a review of the relevant lessons learned from the consultation process.

\(^{63}\) Including LNG bunker barges.
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**Contacts**
Input from IKC companies has been done on a continuous basis through meetings, phone and e-mail conversations:
Energinet.dk
Fluxys
Gasnor
Gasum
Gasunie
Gazprom
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Port of Zeebrugge
Port of Rotterdam

External contacts
Marine and Energy Consulting Limited, Robin Meech
Rolls-Royce Diesel and Gas Engines
Scholz & Plumb
Swedegas, Lars Frisk, phone conversation, June 2011
Wärtsilä
Appendix I. The Shipping Industry: a Historical Review of Propulsion and Fuelling Changes

This chapter briefly describes the development of marine propulsion and fuelling changes. Rather than looking as far back as propulsion with oars and sail, focus lies on the most common marine engines progressing from steam engines, to diesel fuelled engines, nuclear power, and, finally, natural gas fired engines.

Early Marine Engines
Shipping and maritime progress have been under continuous development since ancient times, from the Egyptian dhows, Roman Triremes and Spanish Galleons to British clipper ships. These are just a few epochs. During the 19th century traditional sailing vessels and steam powered ships remained common across the globe. Sailing vessels continued to dominate in markets where distances were great and coal less plentiful or more expensive. Once reliability concerns regarding steam powered ships were overcome, they were preferred in short sea markets or where fuel was available at competitive prices.

Modern Marine Diesel Engine
During the 20th century development of the steam engine, paddle wheel riverboats, propellers and later on venerable petrol and diesel engines further contributed to maritime propulsion success. Compelling advantages of steam turbines versus reciprocating engines for shipping are: smaller size, lower maintenance, lighter weight and lower vibration.
Tetraethyl lead (TEL) was first blended with gasoline in 1924, increasing octane and giving marine gas engines significantly more horsepower. The only problem was its toxicity why it was prohibited as a fuel in 1986.

Reciprocating diesel engines remain the standard for marine propulsion with development continuing to this day. Diesel engines are manufactured in two stroke and four stroke versions depending upon the vessels’ needs. Since the 1910s they have been used in submarines and ships. The world’s largest diesel engine is currently a Wärtsilä Sulzer RT96-C Common Rail marine diesel of about 108,920 hp (81,220 kW) @ 102 rpm. This turbocharged two-stroke diesel engine is 89 feet long, 44 feet tall, and weighs 2300 tonnes. Two-stroke engines typically offer a more favorable power-to-weight ratio, as well as better fuel economy.

In 1978, during the second oil crisis, gasohol was introduced to cut dependence on foreign oil. But the alcohol/gasoline blend brought significant problems for marine engines. It caused loss of horsepower, even worse it absorbed moisture from the atmosphere which affected fuel filters and carburetors.

**Modern Fuels for Shipping**

Use of natural gas and other manufactured gases in motor vehicles began in the 1910s and continued into the 1930s, though expansion of the crude oil industry after World War II stifled development. However, in the early 1990s when Indmar Marine Inc introduced the first fuel-injected inboard marine engine, pressures to reduce engine emissions launched natural gas engine development in earnest. Designers recognised the opportunity to burn relatively clean burning natural gas in spark ignited engines to reduce emissions. Early efforts focused on vehicular emissions and thus on relatively small engines, and as emission regulations spread to encompass other emitters like power plants, vehicular natural gas engine designs were adapted to larger engines more appropriate for power plants, or ships.
The global LNG short sea trading fleet now comprises 22 ships, of which 21 are currently operating in Norway. Omitting commercial LNG tankers, there are expected to be 28 LNG-powered vessels in service by the end of 2011, including tugs, car and passenger ferries, platform supply vessels, and patrol vessels. While it took nearly a decade to get the first 22 LNG-fuelled ships into operation, the confirmed order book is now almost the same size as the existing fleet, with 17 LNG-powered ships currently under construction or on order (predominantly RoRos, RoPaxes and Platform Service Vehicles) by the following companies: Sea-Cargo, Viking Line, Nordnorsk, Eidesvik Shipping, Olympic Shipping, Fjord1, Torghatten Nord, Island Offshore and DOF ASA.

Summarized, modern ship designers may select from a wide array of marine engine alternatives to meet new vessel requirements. While steam engines are out-dated and civilian nuclear propulsion is too costly and risky for most, conventional steam driven ships remain viable in certain applications. However, more common is the venerable marine diesel proven over the past 100 years, and the rapidly emerging natural gas fired engines now common in stationary applications.
Appendix II. Fuel Alternatives and Technical Properties

The appendix gives additional information on the technical properties of the different fuel alternatives of the study as an input to Chapter on Compliance Strategies - Technical Possibilities to Fulfil the SECA 2015 Requirements. Furthermore, LPG and DME are elaborated as being potential alternative solutions.

Table 8. Technical properties of fuel alternatives

<table>
<thead>
<tr>
<th>Technical properties</th>
<th>HFO</th>
<th>LNG</th>
<th>MGO</th>
<th>LPG</th>
<th>DME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling point [°C]</td>
<td>304-574</td>
<td>-162</td>
<td>171-343</td>
<td>-42-0</td>
<td>-25</td>
</tr>
<tr>
<td>Auto ignition temperature[°C]</td>
<td>262&lt;sup&gt;a)&lt;/sup&gt;</td>
<td>600</td>
<td>250</td>
<td>480-550</td>
<td>230</td>
</tr>
<tr>
<td>Stoichimetric air/fuel ratio, [Wt/Wt]</td>
<td>14.1</td>
<td>16.4</td>
<td>15</td>
<td>15.5</td>
<td>8.9</td>
</tr>
<tr>
<td>Flash point: [°C]</td>
<td>66</td>
<td>-187</td>
<td>62</td>
<td>-104</td>
<td>-41</td>
</tr>
<tr>
<td>Flammability range: [vol%]</td>
<td>-</td>
<td>5.0–13.9</td>
<td>1.4–7.6</td>
<td>2.2–9.5</td>
<td>3.4–27.0</td>
</tr>
<tr>
<td>Lower heating value [kJ/kg]</td>
<td>42 686</td>
<td>46 000</td>
<td>41 348</td>
<td>50 000</td>
<td>27 088</td>
</tr>
</tbody>
</table>

<sup>a)</sup> Fuel Oil No. 4

LPG

Liquefied Petroleum Gas (LPG) comes from refineries and is a mixture of fossil fuel propane and butane. LPG can be used for heating and as a fuel for vehicles. The availability is expected to increase, but not to the same extent as of LNG, as LPG is a by-product from LNG production as well as from petroleum production. LPG operation in engines is very similar to that of LNG. However, LPG contains slightly more energy per volume unit. It can be stored as a liquid in temperatures below -42°C or be pressurized into a liquid. LPG is heavier than air. However, the narrow flammability interval makes the LPG a relatively safe fuel.

The engines for LPG work very similar to LNG engines. For two stroke Diesel engines (gas-diesel) the fuel pressure is higher, around 550 bars, and the LPG is in liquid form<sup>64</sup>.

In order to outline the investment costs that are associated with opting for LPG, Table 9 below lists the main cost items to be considered for new-builds as well as retrofitting.

---

<sup>64</sup> MAN Diesel & Turbo
Table 9. Liquefied Petroleum Gas investments

<table>
<thead>
<tr>
<th>New Building</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional investment for gas</td>
<td>Retrofit</td>
</tr>
<tr>
<td>engine</td>
<td>LPG fuel gas supply system</td>
</tr>
<tr>
<td>LPG fuel gas supply system</td>
<td>LPG fuel gas supply system</td>
</tr>
<tr>
<td>LPG bunkering onboard system</td>
<td>LPG bunkering onboard system</td>
</tr>
<tr>
<td>LPG bunkering onboard system</td>
<td>LPG storage tanks</td>
</tr>
<tr>
<td>LPG storage tanks</td>
<td>Classification</td>
</tr>
<tr>
<td>Classification</td>
<td>Classification</td>
</tr>
<tr>
<td>Savings in HFO system?</td>
<td>Hull reinforcements</td>
</tr>
</tbody>
</table>

Investments needed for retrofit and new building respectively. Source: MAN Diesel & Turbo

DME

Dimethyl Ether (DME) is a gaseous fuel suitable for diesel engines due to the low auto-ignition temperature of about 230°C. A dual fuel engine can run on 100% DME without any need for pilot fuel oil. The engine can also run on fuel oils, thereby retaining the flexibility. DME is not suitable for Otto cycles due to the low ignition temperature.

DME can be made onboard in a process called OBATE from the liquid methanol or stored as liquefied DME on-board. DME or methanol can be made from both fossil and renewable sources.\(^{65}\) Drawbacks with DME are the relatively low energy content and the broad flammability range.

In order to outline the investment costs that are associated with opting for DME, Table 10 below lists the main cost items to be considered for new-builds as well as retrofitting.

\(^{65}\) MAN Diesel & Turbo
Table 10. DME investments

<table>
<thead>
<tr>
<th>New Building</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Retrofit</td>
</tr>
<tr>
<td>Additional investment for gas engine</td>
<td>Gas engine</td>
</tr>
<tr>
<td>Methanol supply system</td>
<td>Methanol supply system</td>
</tr>
<tr>
<td>OBATE</td>
<td>OBATE</td>
</tr>
<tr>
<td>DME supply system including day tank</td>
<td>DME supply system including day tank</td>
</tr>
<tr>
<td>Classification</td>
<td>Classification</td>
</tr>
<tr>
<td>Methanol bunker tanks</td>
<td>Bunker tank to be coated for methanol bunker, or new bunker tank for methanol</td>
</tr>
<tr>
<td>Possibly savings in HFO system</td>
<td></td>
</tr>
</tbody>
</table>

*Investments needed for retrofit and newbuilds respectively. Source: MAN Diesel & Turbo*

**Why choose LPG?**

LPG has some advantages over LNG in requiring a simpler fuel supply system. Fuel availability of larger quantities might be limited but small scale LPG terminals are more common today than small scale LNG terminals. Environmentally similar advantages to LNG can be achieved.

The drawback is mainly on the safety issues as LPG is heavier than air meaning that the possibility of a leakage might be higher.

For LPG, Green House gases are reduced by approximately 7.5% per energy unit and \( \text{NO}_x \) is reduced by approximately 20-25% if compared to HFO.

**Why choose DME?**

DME have similar environmental benefits as LNG, the sulphur emission are almost eliminated and particulate matter close to zero. Green House gases are reduced by approximately 15% and \( \text{NO}_x \) is reduced by approximately 80 – 90%, if compared to HFO.

The fuel supply system is simpler than for LNG and the engine does not need any additional ignition source. It is possible to bunker liquid methanol. However, DME/Methanol is not expected to be available to the same extent as LNG. Another drawback with methanol is that it is poisonous and aggressive to many materials.
Appendix III. LNG Storage Tanks

The storage tank for LNG on the vessel is an area of concern for the ship-owners for many reasons. LNG requires due to the properties of the fuel about two times more volume to provide the same energy as HFO. In addition, the tanks in use today for LNG fuelled vessel are additionally space requiring, and also adds weight. The design of the tanks conveys that about 4 times more space is required for an LNG tank compared to storage of traditional energy carriers. Furthermore, LNG tanks are substantially more cost demanding and estimate to about a third of the added cost for an LNG fuelled vessel.

There are three types of tanks that could be a possibility for LNG fuelled vessels, which are described in the table below.

<table>
<thead>
<tr>
<th>IMO Type Tanks</th>
<th>General Description</th>
<th>Suppliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMO A Type Tank</td>
<td>Full secondary barrier</td>
<td>One supplier</td>
</tr>
<tr>
<td></td>
<td>Full redundancy with respect to ULS and FLS (Safety for IMO tank type A to C is reflected on acceptance criteria for ULS (Ultimate Load Strength) and FLS (Fatigue Load Strength) to give the same safety level for all tank types. Independent with respect to strength and fatigue Maximum pressure, &lt;0,7 bar</td>
<td></td>
</tr>
<tr>
<td>IMO B Type Tank</td>
<td>Partial secondary barrier (support)</td>
<td>Two suppliers</td>
</tr>
<tr>
<td></td>
<td>Partially redundant by FLS, no redundancy for extreme loads Maximum pressure, &lt;0,7 bar</td>
<td></td>
</tr>
<tr>
<td>IMO C Type Tank</td>
<td>No secondary barrier</td>
<td>Handful suppliers or more</td>
</tr>
<tr>
<td></td>
<td>No redundancy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High strength, high tightness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressurized tank, up to 9 bar</td>
<td></td>
</tr>
</tbody>
</table>

Source: DNV. Pictures source: MGI

In addition the membrane tank could be an alternative. This type of tank is today used for LNG carriers but not allowed currently for LNG fuelled vessels. Current application of LNG as fuel for ships all have IMO C type tanks installed.
The various tanks concepts all have their pros and cons and different segment in the shipping industry have different characteristics that will lead to tank choices based on space availability, sailing pattern etc. It is not the target of this analysis to evaluate various tank alternatives, but bunkering solutions needs to be developed that can cater for the tank concepts outlined above and also for membrane tanks. This will convey a holistic and all encompassing solution for bunkering independent of vessel configuration and design.
Appendix IV. Examples of Vessels Suitable for LNG Propulsion

Note that bunkering positions are mentioned as what will be the normal case for one ship type, but exemptions from this will occur.

RoPax / RoRo Vessels

![Figure 25. RoPax vessel](Source, DNV, 2011)

Table 12. RoPax RoRo Vessel properties

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>165 m</td>
</tr>
<tr>
<td>Estimated main engine power</td>
<td>2 x 2,700 kW</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>24 m</td>
</tr>
<tr>
<td>Estimated bunkering volume</td>
<td>65-125 m $^3$LNG</td>
</tr>
<tr>
<td>Deadweight</td>
<td>4.200 tonnes</td>
</tr>
<tr>
<td>Bunkering Frequency</td>
<td>2-3 days</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>1-2 hours</td>
</tr>
<tr>
<td>LNG volume/year (and vessel)</td>
<td>16500$^3$</td>
</tr>
<tr>
<td></td>
<td>7,500 tonnes</td>
</tr>
</tbody>
</table>

Available bunkering positions: At quay by dedicated bunker vessel
Bunker stations on both sides of vessel

Parallel activities:
Embarkment / disembarkment of passengers on quay side
Loading/unloading of vehicles
Oil bunkering
Stores loading

Notes
As these types of vessels often are a combined passenger/cargo vessels they handle both passengers as well as rolling cargoes such as trailers, trucks and cars. The berth is often made in city ports hence this type of vessel is suitable for improving environmental status in coastal areas. Also, because the routes are clearly defined, the amount of fuel to bunker is easy to estimate making it possible to optimize fuel tanks.

Issues to be considered are:
- Short bunkering time;
- Passengers embarking / disembarking at the same time as bunkering;
- The engines may be either dual-fuel type or pure gas type;
• Use LNG cryogenic properties in HVAC process.

Bunkering of a RoPax or RoRo vessel will most likely be done by a type of bunkering barge/vessel (STS). A ship of this type has dedicated berths along their routes therefore the possibility of a fixed bunkering system could be feasible. It should be noted that special safety precautions are necessary since parallel activities such as cargo and passenger handling is likely to be performed simultaneously during bunkering operations. STS bunkering solutions have some benefits since the bunkering can be carried out on the opposite side of cargo handling which reduces risks of interference between the cargo handling and the bunkering operation.

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Type of vessel</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCAT</td>
<td>Australia</td>
<td>High-speed catamaran ferry</td>
<td>2012</td>
</tr>
<tr>
<td>Torghatten Nord</td>
<td>Norway</td>
<td>Express ferries</td>
<td>2012 (first)</td>
</tr>
<tr>
<td>Viking Line</td>
<td>Sweden</td>
<td>Cruise ferry</td>
<td>2013</td>
</tr>
</tbody>
</table>

Although these vessels are more costly, the environmental profile can be a strong reason for longer pay-off time compared to other ship types.

**Port Tug Boats**

![Figure 26. Tug boat](https://example.com/tug-boat.png)

**Source:** DNV 2011.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>Estimated main engine power</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>Estimated bunkering volume</td>
</tr>
<tr>
<td>Deadweight</td>
<td>Bunkering Frequency</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>LNG volume/year (and vessel)</td>
</tr>
</tbody>
</table>
Available bunkering positions: At land based terminal, by dedicated bunker vessel or truck
Parallel activities: Preparations for next tow operation
Oil bunkering
Stores loading

Notes
Usual operations in coastal and port areas make it possible to bunker while staying in the port vicinity.

Points to be considered are:
- Placement and size of LNG tank due to limited space;
- The large variations in load of main engine. Discussions around best solution i.e. single or dual fuel engines;
- Availability of LNG close to normal operations area/home port.

Since the tugboat is either operating in, or nearby, the home port it is frequently possible to design the vessels with limited LNG tank capacity, which implies high bunkering frequency in rather small batches. Tank truck or an intermediate tank/pipeline solution would often be most effective. Since the harbor tug is maneuverable and small, there is no disadvantage in using a special bunkering berth for those operations.

At the time of writing, there are no known orders for tug boats with LNG propulsion. However some manufacturers, like Wärtsilä, have developed a concept design for this type of vessel.

Coastal Tankers/Chemical tankers/Bulk Carriers

Figure 27. Bulk carrier
Source: DNV, 2011

Figure 28. Dual fuel Retrofit of Chemical Tanker BIT VIKING
Table 15. Coastal Tankers/Bulk Carriers properties

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>125-180 m</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>20-27 m</td>
</tr>
<tr>
<td>Deadweight</td>
<td>10,000-25,000 tonnes</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>8-12 hours</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Available bunkering positions: At quay by dedicated bunker vessel
Parallel activities: Loading/unloading of cargo
                   Oil bunkering
                   Stores loading

Notes
Operations over short and medium distances are most common. As each bunker moment will require 500 – 1,000 m³ LNG a bunker vessel would probably be the most practicable and effective bunker solution for these kinds of vessels.

Points to be considered are:
- Range requirements;
- Trading pattern;
- The requirements for parallel activities such as cargo handling;
- Placement of LNG tank(s).

The coastal tankers may also be retrofitted since the tanks preferably are located on open deck to avoid limitations in cargo capacity. The available space on deck is however often very limited for bulk carriers.

The Bit Viking is still in conversion and will be running with a dual-fuel engine. Both tanks are located on open deck to avoid limitations in cargo capacity. The seatrial is proposed for October 2011.

Table 16. Example of orders with LNG propulsion

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Type of vessel</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSK Shipping</td>
<td>Norway</td>
<td>General cargo vessel</td>
<td>2012</td>
</tr>
<tr>
<td>Tarbit Shipping</td>
<td>Sweden</td>
<td>Chemical Tanker <em>Bit Viking</em> (Retrofit)</td>
<td>2011</td>
</tr>
</tbody>
</table>
Container Ship (700-800 TEU)

![Figure 29. Container ship](image)
Source: DNV, 2011

Table 17. Container ship properties

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>135 m</td>
</tr>
<tr>
<td>Estimated main engine power</td>
<td>8,000 kW</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>20 m</td>
</tr>
<tr>
<td>Estimated bunkering volume</td>
<td>500-700 m³ LNG</td>
</tr>
<tr>
<td>Deadweight</td>
<td>9,000 tonnes</td>
</tr>
<tr>
<td>Bunkering Frequency</td>
<td>Every 10 days</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>6-12 hours</td>
</tr>
<tr>
<td>LNG volume/year (and vessel)</td>
<td>10,200-25,000 m³ LNG (4,600-11,200 tonnes)</td>
</tr>
</tbody>
</table>

Available bunkering positions: At quay by dedicated bunker vessel
Parallel activities: Loading / unloading of cargo
Oil bunkering
Stores loading

Notes
Shipping along coast lines and for short sea routes motivates this type of vessel. Although, mainly fuel price will affect decisions on LNG propulsion.

Fixed timetables contribute to regular port visits but due to cargo, different berths in the container port. Depending on container capacity of the vessel, turnaround times while in port could be a bottleneck for the bunker operation. A bunker vessel solution is the most likely solution regarding flexibility and capacity reasons.

Points to be considered are:
- Short bunkering time due to short turnaround time in port;
- The requirements for parallel activities such as cargo handling;
- Range requirements;
- Trading pattern;
- Placement of LNG tank(s) preferably on open deck, but cargo space can be considered.

One option could be using a number of LNG tanks placed in containers instead of fixed storage tanks. The bunkering process would then consist of replacing empty tank containers
during loading/unloading of cargo, hence solving the problem with the location of tanks. However, this limits the load carrying capacity.

This type of vessel has substantial auxiliary power engines which can be interesting to run on LNG.

**Table 18. Example of orders for a Container vessel with LNG auxiliary power**

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Type of vessel</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stefan Patjens</td>
<td>Germany</td>
<td>5,000 TEU Containership (retrofit)</td>
<td>On hold</td>
</tr>
</tbody>
</table>

There are also a number of concept designs developed for this type of vessel, like DNV with their Quantum design and GL with their retrofit CV Neptun 1200 design.

**LNG Feeder Vessels**

**Figure 30. LNG Feeder Vessel**

*Source: DNV, 2011*

**Table 19. LNG Feeder Vessel properties**

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>Estimated main engine power 5,200 kW</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>Estimated bunkering volume 16,500 m³ LNG (app. 500 m³ LNG for propulsion)</td>
</tr>
<tr>
<td>Deadweight</td>
<td>Bunkering Frequency Every 14 days</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>LNG volume/year (and vessel) 13,500 m³ LNG (6,100 tonnes)</td>
</tr>
</tbody>
</table>

Available bunkering positions: Cargo bunkering from land based LNG distribution central or by Ship-To-Ship (STS) transfer from LNG tanker.

Parallel activities: Oil bunkering
Stores loading
Notes
Economic reasons are high for LNG feeder vessels because they can use the cargo as fuel which will make the installation less expensive and space consuming.

Points to be considered are:
- Vapour return system at STS transfer;
- System should be designed to use the Boil-Off Gas (BOG);
- Heat recovery system to reduce the environmental footprint further.

An LNG feeder vessel can be owned and operated directly by the LNG fuel supplier or by another company and chartered to the LNG fuel supplier. The purpose is to supply LNG from larger land based distribution centrals or LNG tankers to land based consumers or storage facilities for further distribution. There are no suitable vessels available for retrofitting today. Expectations are new builds.

The reasons for using LNG as fuel in this case is motivated by not having separate fuel tanks for propulsion, for handling boil off gas and reduction of emissions. There is no need for any supply contract since the vessels fuel supply need is already ensured by using the cargo.

LNG Bunker Vessels

Table 20. LNG Bunker Vessel properties

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>70 m</td>
</tr>
<tr>
<td>Estimated main engine power</td>
<td>2 x 700 kW</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>12 m</td>
</tr>
<tr>
<td>Estimated bunkering volume</td>
<td>800 m³ LNG (app. 40-60 m³ LNG for propulsion)</td>
</tr>
<tr>
<td>Deadweight</td>
<td>850 tonnes</td>
</tr>
<tr>
<td>Bunkering Frequency</td>
<td>3-5 days</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>3-5 hours</td>
</tr>
<tr>
<td>LNG volume/year (and vessel)</td>
<td>4,200 m³ LNG (1,900 tonnes)</td>
</tr>
</tbody>
</table>

Available bunkering positions: Cargo bunkering from land based LNG distribution central or by STS transfer from LNG feeder.
Parallel activities: Bunkering of marine gas or diesel oil (MGO or MDO)
Notes
Same as for LNG feeder vessel above.

Points to be considered are:
- Vapour return system at STS transfer;
- System should be designed to use the Boil-Off Gas (BOG);
- Heat recovery system to reduce the environmental footprint further;
- The engine could be dual-fuel type or pure gas type.

An LNG bunker vessel can be owned and operated directly by the LNG fuel supplier or by another company and chartered to the LNG fuel supplier with the purpose to supply LNG from land based distribution centrals, or LNG tankers, to ships with LNG propulsion.

At the time of writing, there are no known orders for Bunker vessels with LNG propulsion, but there are developed concept designs available.

Naval/Coast Guard Vessels

![Coast Guard Vessel](source: DNV)

Table 21. Naval/Coast Guard Vessel properties

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>93,2 m</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>16,6 m</td>
</tr>
<tr>
<td>Deadweight</td>
<td>4,000 tonnes</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>3-5 hours</td>
</tr>
<tr>
<td>Bunkering Frequency</td>
<td>LNG volume/year (and vessel)</td>
</tr>
</tbody>
</table>

| Deadweight       | 4,000 tonnes                                       |
| Approx length    | 93,2 m                                             |
| Approx breadth   | 16,6 m                                             |
| Deadweight       | 4,000 tonnes                                       |
| Available bunkering time | 3-5 hours                  |
| Bunkering Frequency | LNG volume/year (and vessel)                      |

| Estimated main engine power | 2,500 kW Gas (+ 4,000 kW Diesel) |
| Estimated bunkering volume | 250 m³ LNG |

<table>
<thead>
<tr>
<th>Bunkering Frequency</th>
<th>Every 21 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG volume/year (and vessel)</td>
<td>3,250 m³ LNG (1,450 tonnes)</td>
</tr>
</tbody>
</table>

Available bunkering positions: From land based LNG terminal or by truck due to the nature of the ship and consequent routes.

Parallel activities: Bunkering of marine gas or diesel oil (MGO or MDO)

Stores loading
Notes
This type of vessel often operates in a coastal environment. Depending on bunker capacity and volumes needed at each bunkering occasion the alternatives are supplying bunker fuel from a LNG intermediate tank or by trucks. Even STS operations could be performed for these kinds of vessels at anchorages and/or at sea.

Points to be considered are:
- Trading patterns;
- Range requirements;
- Availability in states of emergency;
- Availability of LNG close to normal operations area/home port;
- LNG tank placement;
- The engines could be dual-fuel type or pure gas type.

Normally these vessels are owned and operated by the navy or government, but the coast guards vessels can in some cases be owned and operated by a management company. The main purpose of these vessels is to patrol the coastline, facilitate inspections and increase availability for search/rescue operations. They will in the future most likely be new builds, replacing older ships.
At the time of writing, there are no known further orders, but three Coast Guard vessels with LNG propulsion in operation:

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Type of vessel</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remoy Management</td>
<td>Norway</td>
<td>Coast Guard Ship</td>
<td>2009</td>
</tr>
<tr>
<td>Remoy Management</td>
<td>Norway</td>
<td>Coast Guard Ship</td>
<td>2010</td>
</tr>
<tr>
<td>Remoy Management</td>
<td>Norway</td>
<td>Coast Guard Ship</td>
<td>2010</td>
</tr>
</tbody>
</table>

Offshore Supply Vessels

![Offshore Supply Vessel](image_url)

Figure 33. Offshore Supply Vessel
Source: DNV, 2011
Table 23. Offshore supply vessel properties

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>95 m</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>20 m</td>
</tr>
<tr>
<td>Deadweight</td>
<td>2,900 tonnes</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>8-12 hours</td>
</tr>
<tr>
<td>Deadweight</td>
<td>2,900 tonnes</td>
</tr>
<tr>
<td>Estimated main engine power</td>
<td>2,000 kW</td>
</tr>
<tr>
<td>Estimated bunkering volume</td>
<td>235 m$^3$ LNG</td>
</tr>
<tr>
<td>Bunkering Frequency</td>
<td>16-18 days</td>
</tr>
<tr>
<td>LNG volume/year (and vessel)</td>
<td>4,170 m$^3$ LNG (1,870 tonnes)</td>
</tr>
</tbody>
</table>

Available bunkering positions: From land based LNG terminal or by truck, due to the nature of the ship and consequent routes.

Parallel activities: Oil bunkering

Notes
As offshore supply vessels can be dedicated to many different tasks the volumes and frequencies of bunker operations can differ a lot. Although they are often hired on contracts that make them operate in the same geographic location, and this fact would ease the bunkering operations.

Points to be considered are:
- Range requirements;
- Availability of LNG close to normal operations area/home port;
- Tank placement.

The owner will most likely focus on price and supply of LNG together with the environmental regulations regarding emissions. The environmental profile can be a strong reason to use LNG as fuel.

Table 24. Example of orders for supply vessels with LNG propulsion in operation

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Type of vessel</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eidesvik</td>
<td>Norway</td>
<td>Supply / Cargo vessel</td>
<td>2003</td>
</tr>
<tr>
<td>Eidesvik</td>
<td>Norway</td>
<td>Supply vessel</td>
<td>2007</td>
</tr>
<tr>
<td>Eidesvik</td>
<td>Norway</td>
<td>Supply vessel (+ fuel cell)</td>
<td>2009</td>
</tr>
<tr>
<td>Eidesvik</td>
<td>Norway</td>
<td>Platform supply vessel</td>
<td>2012</td>
</tr>
<tr>
<td>Island Offshore</td>
<td>Norway</td>
<td>Platform supply vessel</td>
<td>2012</td>
</tr>
<tr>
<td>Island Offshore</td>
<td>Norway</td>
<td>Platform supply vessel</td>
<td>2012</td>
</tr>
</tbody>
</table>
### Short Trip Passenger/Car Ferries

**Table 25. Short Trip Passenger/Car Ferry properties**

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>Estimated main engine power</td>
</tr>
<tr>
<td>50 m</td>
<td>640 kW Gas + 840 kW MDO</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>Estimated bunkering volume</td>
</tr>
<tr>
<td>12 m</td>
<td>100-150 m³ LNG</td>
</tr>
<tr>
<td>Deadweight</td>
<td>Bunkering Frequency</td>
</tr>
<tr>
<td>1,125 tonnes</td>
<td>7-9 days</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>LNG volume/year (and vessel)</td>
</tr>
<tr>
<td>2 hours</td>
<td>1,340 m³ LNG (600 tonnes)</td>
</tr>
</tbody>
</table>

Available bunkering positions: From land based LNG distribution terminal, truck or by dedicated bunker vessel.

Parallel activities: Oil and supply bunkering
Passengers embarking and disembarking

**Notes**

Operations in harbors and coastal environments make these smaller passenger vessels optimal, in combination with the relative low quantity of LNG bunker fuel required per bunker operation, for LNG propulsion. A smaller LNG intermediate tank or a LNG tank truck would probably be the most suitable bunkering solution.

Points to be considered are:
- Available bunkering time;
- The requirements for parallel activities such as cargo and passenger handling;
- Availability of LNG close to normal operations area/home port;
- LNG Bunker procedure;
- The engines can be dual-fuel type or separate gas + diesel engines.

Emission regulations and company profiles will probably be the main reasons to use LNG as fuel.

**Table 26. Example of ferries with LNG propulsion in operation**

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Type of vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fjord1</td>
<td>Norway</td>
<td>Car / Passenger ferry</td>
</tr>
<tr>
<td>Tide</td>
<td>Norway</td>
<td>Passenger ferry</td>
</tr>
</tbody>
</table>

---

ÅF & SSPA PROJECT TEAM

109 (181) Baseline Report Appendix
Fishing Vessels

Figure 34. Fishing Vessel
Source: DNV, 2011

Table 27. Fishing Vessel properties

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>70 m</td>
</tr>
<tr>
<td></td>
<td>Estimated main engine power</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>15 m</td>
</tr>
<tr>
<td></td>
<td>Estimated bunkering volume</td>
</tr>
<tr>
<td>Deadweight</td>
<td>1,200 tonnes</td>
</tr>
<tr>
<td></td>
<td>Bunkering Frequency</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>10-12 hours</td>
</tr>
<tr>
<td></td>
<td>LNG volume/year (and vessel)</td>
</tr>
</tbody>
</table>

Available bunkering positions: From land based LNG terminal or by bunker vessel.
Parallel activities: Cargo unloading, Oil bunkering

Notes
As fishing vessels usually have long sea passages the frequency of bunkering is low. Depending on what facilities they utilize in the harbor for landing their cargo the best solutions ought to be a pipeline/intermediate tank solution or bunkering via a bunker vessel. For smaller fishing vessels tank trucks are probably the most suitable solution.

Points to be considered are:
- The range requirements;
- Availability of LNG close to normal operations area/home port;
- Tank placement;
- Using LNG as cooling media for cargo storage.

These vessels will most likely be new builds, but some cases may promote retrofitting. One interesting aspect is whether the cold LNG can be used for cooling or freezing the cargo in connection with using it as fuel. This could lower the total power consumption which further enhances economic reasons for investments.

At the time of writing, there are no known fishing vessels with LNG propulsion in operation or on order. According to DNV first order for LNG powered fishing vessel will be placed soon.
Very Large Crude Carriers, VLCC

Figure 35. Very Large Crude Carrier (VLCC)
Source: DNV, 2011

Table 28. Very Large Crude Carrier (VLCC) properties

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>334 m</td>
</tr>
<tr>
<td>Estimated main engine power</td>
<td>25,500 kW</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>58 m</td>
</tr>
<tr>
<td>Estimated bunkering volume</td>
<td>6,000 m³ LNG</td>
</tr>
<tr>
<td>Deadweight</td>
<td>300,000 tonnes</td>
</tr>
<tr>
<td>Bunkering Frequency</td>
<td>35-40 days</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>12-24 hours</td>
</tr>
<tr>
<td>LNG volume/year (and vessel)</td>
<td>62,500 m³ LNG (28,150 tonnes)</td>
</tr>
</tbody>
</table>

Available bunkering positions: From land based LNG terminal or by bunker vessel.
Parallel activities: Oil bunkering

Notes
Depending on how the VLCC is operated the ports of call could vary and bunkering with vessel is the most likely solution due to the large volumes.

Points to be considered are:
- Range requirements;
- Trading pattern;
- Availability of LNG close to normal operations area;
- Tank placement;
- The engine will probably be two stroke type;
- Hull shaped LNG tank types to be considered.

At the time of writing there is no VLCC with LNG propulsion in operation, but DNV has a newly released concept design called Triality which also deals with ballast water and cargo vapour handling.
**Cruise Vessels**

![Figure 36. Figure Design of a gas fuelled cruise vessel (GasPax-Project)](source: Meyer Yard)

**Table 29. Cruise vessel properties**

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx length</td>
<td>238 m</td>
</tr>
<tr>
<td>Estimated main engine power</td>
<td>12,000 kW</td>
</tr>
<tr>
<td>Approx breadth</td>
<td>32 m</td>
</tr>
<tr>
<td>Estimated bunkering volume</td>
<td>2,000 m$^3$ LNG</td>
</tr>
<tr>
<td>Deadweight</td>
<td>63,000 tonnes</td>
</tr>
<tr>
<td>Bunkering Frequency</td>
<td>14 - 21 days</td>
</tr>
<tr>
<td>Available bunkering time</td>
<td>8 hours</td>
</tr>
<tr>
<td>LNG volume/year (and vessel)</td>
<td>50,000 m$^3$ LNG (21,100 tonnes)</td>
</tr>
</tbody>
</table>

Available bunkering positions: At quay by dedicated bunker vessel
Parallel activities: Passengers on board/bordring
Oil bunkering
Loading / Unloading of cargo and supplies

**Notes**
The GasPax project is funded by the german government and lead by the Meyer yard. Aim of the project is the development of gas fuelled ships designs considering the economic and safety principals.

**Other Vessel Types**
There are a number of other vessel types that can be considered for future LNG propulsion.

The following list shows some examples:

- Ore Carriers, VLOC;
- Large Containerships;
- Dredgers;
- Large Tankers;
- Large Bulk Carriers;
- Car Transport Carrier.
Appendix V. LNG Infrastructure in Northern Europe

This appendix gives an introduction to the general upstream infrastructure worldwide, including a list of the current LNG vessels in the world. Furthermore an overview of the LNG supply to Northern Europe is presented including details on the existing and planned LNG facilities.

Upstream Infrastructure

Exploration and Production
The first segment in the LNG value chain is exploration and production. Exploration and production activities range from prospect generation to actual drilling and extraction. The process includes as well the mobilization of financial capital to support drilling.

LNG Liquefaction Plants
In the LNG liquefaction plant, gas is received from gas via pipelines (“raw gas”). The gas is liquefied and stored as LNG. During liquefaction, contaminants found in produced natural gas are removed to avoid freezing up and damaging equipment when the gas is cooled to LNG temperature (-162 °C) and to meet pipeline specifications at the delivery point. The liquefaction process entails cooling the clean feed gas by using refrigerants. The liquefaction plant may consist of several parallel units, so called trains. The LNG is finally stored in storage tanks and can be loaded and shipped for further use and transportation.

Table 30. Existing LNG production plants in the SECA

<table>
<thead>
<tr>
<th>Country</th>
<th>Site</th>
<th>Operator</th>
<th>Liquefaction capacity, 1000 tonnes of LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>Snøhvit, Melkøya</td>
<td>Statoil Hydro</td>
<td>4 300</td>
</tr>
<tr>
<td>Norway</td>
<td>Tjeldbergodden</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Norway</td>
<td>Kollsnes</td>
<td>Gasnor</td>
<td>120</td>
</tr>
<tr>
<td>Norway</td>
<td>Karmøy</td>
<td>Gasnor</td>
<td>20</td>
</tr>
<tr>
<td>Norway</td>
<td>Risavika</td>
<td>Nordic LNG</td>
<td>300</td>
</tr>
<tr>
<td>Finland</td>
<td>Sköldvik</td>
<td>Gasum</td>
<td>20</td>
</tr>
<tr>
<td>Russia</td>
<td>St. Petersburg I</td>
<td>Gazprom</td>
<td>7,5</td>
</tr>
<tr>
<td>Russia</td>
<td>St. Peterburg II</td>
<td>Gazprom</td>
<td>5</td>
</tr>
<tr>
<td>Russia</td>
<td>St. Petersburg III</td>
<td>Gazprom</td>
<td>2,5</td>
</tr>
</tbody>
</table>

Source: Gasnor, and Gazprom
Table 31. Planned and proposed production plants in the SECA

<table>
<thead>
<tr>
<th>Country</th>
<th>Site</th>
<th>Operator</th>
<th>Capacity</th>
<th>Start-up</th>
<th>Planned/proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>Kaliningrad I</td>
<td>Gazprom</td>
<td>25</td>
<td>2012</td>
<td>Planned</td>
</tr>
<tr>
<td>Russia</td>
<td>Vyborg/Grefswald</td>
<td>Gazprom</td>
<td>1 000</td>
<td>2016</td>
<td>Proposed</td>
</tr>
<tr>
<td>Russia</td>
<td>Kaliningrad II</td>
<td>Gazprom</td>
<td>200</td>
<td>2017</td>
<td>Proposed</td>
</tr>
<tr>
<td>Russia</td>
<td>Shtokman-Teriberka</td>
<td>Gazprom</td>
<td>7 500</td>
<td>2017</td>
<td>Planned</td>
</tr>
</tbody>
</table>

Source: Gasnor, and Gazprom

LNG Shipping

LNG is shipped in LNG carriers from the liquefaction plants to large LNG receiving terminals. LNG tankers are double-hulled vessels specially designed and insulated to prevent leakage or rupture in an accident. The LNG is stored in a special containment system within the inner hull where it is kept at atmospheric pressure and cryogenic temperature. Typical LNG carriers have a loading capacity from 145,000 to more than 200,000 m³ of LNG. A large part (53%) of the LNG carriers has been built from the year 2005 and onwards, which shows a rapid expansion of the LNG market. As many of the new built vessels are large vessels with a loading capacity larger than 200,000 m³, the average size of LNG vessels has increased in recent years. There are only about 20 small- and medium sized LNG vessels in the world today, which are shown in the table below.
### Table 32. Small and medium sized LNG vessels in the world

<table>
<thead>
<tr>
<th>Name of Ship</th>
<th>Built</th>
<th>Tank capacity (Dead weight)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>TELLIER</td>
<td>Jan-74</td>
<td>21 301</td>
<td>In service</td>
</tr>
<tr>
<td>AMAN BINTULU</td>
<td>Oct-93</td>
<td>11 001</td>
<td>In service</td>
</tr>
<tr>
<td>SURYA AKI</td>
<td>Feb-96</td>
<td>11 612</td>
<td>In service</td>
</tr>
<tr>
<td>AMAN SENDAI</td>
<td>May-97</td>
<td>10 957</td>
<td>In service</td>
</tr>
<tr>
<td>AMAN HAKATA</td>
<td>Nov-98</td>
<td>10 951</td>
<td>In service</td>
</tr>
<tr>
<td>SURYA SATUMA</td>
<td>Oct-00</td>
<td>12 493</td>
<td>In service</td>
</tr>
<tr>
<td>SHINJU MARU NO. 1</td>
<td>Jul-03</td>
<td>1 781</td>
<td>In service</td>
</tr>
<tr>
<td>PIONEER KNUTSEN</td>
<td>Mar-04</td>
<td>817</td>
<td>In service</td>
</tr>
<tr>
<td>NORTH PIONEER</td>
<td>Nov-05</td>
<td>1 938</td>
<td>In service</td>
</tr>
<tr>
<td>SUN ARROWS</td>
<td>Nov-07</td>
<td>11 142</td>
<td>In service</td>
</tr>
<tr>
<td>SHINJU MARU NO. 2</td>
<td>Oct-08</td>
<td>1 781</td>
<td>In service</td>
</tr>
<tr>
<td>KAKUREI MARU</td>
<td>Nov-08</td>
<td>1 801</td>
<td>In service</td>
</tr>
<tr>
<td>CORAL METHANE</td>
<td>Apr-09</td>
<td>6 150</td>
<td>In service</td>
</tr>
<tr>
<td>NORGAS INNOVATION</td>
<td>Jan-10</td>
<td>10 630</td>
<td>In service</td>
</tr>
<tr>
<td>NORGAR CREATION</td>
<td>Jul-10</td>
<td>10 429</td>
<td></td>
</tr>
<tr>
<td>NORGAS INVENTION</td>
<td>Jan-11</td>
<td>10 441</td>
<td>In service</td>
</tr>
<tr>
<td>NORGAS UNIKUM</td>
<td>Jun-11</td>
<td>12 210</td>
<td>In service</td>
</tr>
<tr>
<td>NORGAS CONCEPTION</td>
<td>Aug-11</td>
<td>10 500</td>
<td>Being built</td>
</tr>
<tr>
<td>MEYER WERFT 665</td>
<td>Dec-12</td>
<td>8 000</td>
<td>Ordered</td>
</tr>
<tr>
<td>DINGHENG JIANGSU 2007-003</td>
<td>Feb-12</td>
<td>12 600</td>
<td>Ordered</td>
</tr>
<tr>
<td>DINGHENG JIANGSU 2007-004</td>
<td>Jun-12</td>
<td>12 600</td>
<td>Ordered</td>
</tr>
<tr>
<td>NORGAS VISION</td>
<td>Aug-11</td>
<td>12 600</td>
<td>Ordered</td>
</tr>
</tbody>
</table>

### LNG Infrastructure in Northern Europe

The European LNG market is expected to grow quite rapidly, as the region looks to expand its use of gas within its broader aim for increased energy diversity and use of less carbon-intensive fuels. The IEA estimates that natural gas demand in Europe will grow steadily from 544 bcm in 2007 to 651 bcm in 2030, with this demand primarily increasing as a result of growth in natural gas use by the power generation sector. \[66\]

At the same time, gas production in Europe is expected to decline (from 294 bcm in 2007 to 222 bcm in 2030)\[67\]. Whilst Norway will step up gas production from two major fields, the Netherlands’ Groningen field and the UK’s continental shelf are approaching maturity, with extraction becoming increasingly costly and difficult. Given these trends, the IEA expects

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\[66\] IEA, 2009.
\[67\] ibid
that natural gas imports will need to increase significantly, from 250 bcm in 2007 to 428 bcm in 2030\textsuperscript{68}.

This significant increase in gas supply is likely to come from a range of areas. Firstly, a substantial increase in the volume of gas supplied along major pipeline routes into Europe (including Norway, Russia and Algeria) is expected. Potential new supplies from the Middle East could materialize and similarly, new supply routes from the Caspian region into Europe are likely to become operational. Some of the gas imported into Europe will also be imported in LNG form, particularly from Qatar, Nigeria, and Trinidad and Tobago. The key LNG import routes are shown Figure 37 below, with projected import costs indicated (in US$\text{/MBTU}).

![Key gas supply routes in Europe with projected import costs in US$\text{/MBTU}. Source: IEA 2009](image)

Parts of Europe (Spain, Portugal, Italy and France) have traditionally been LNG importers, with the first imports arriving from Algeria in the 1960s. In recent years, whilst imports of LNG from Algeria have remained dominant, significant volumes have also been imported from Egypt, Qatar, Nigeria, Trinidad and Tobago, and other states.\textsuperscript{69}

The volumes of imported LNG detailed in Figure 38 below arrive at Europe’s various import terminal facilities, which are distributed within seven countries (Belgium, France, Greece, Italy, Spain, Turkey and the United Kingdom). The volumes of imported LNG to Europe have more than doubled since 2001.

\textsuperscript{68} ibid
\textsuperscript{69} IEA, 2010
Natural Gas Network and the Connection with the LNG Market
The extension of the natural gas network varies between the SECA countries. In Finland and Sweden the gas networks are only extended in the south parts, in Norway there are some small local gas networks, supplying local industrial customers and local buses, while United Kingdom, Belgium, Netherlands, Germany, Denmark, Poland have extensive distribution networks. The East Baltic Countries, i.e. Finland, Estonia, Lithuania and Latvia are the only four EU member states which remain isolated from the present integrated EU gas transmission system.\(^{70}\)

The location of existing and a majority of the planned LNG infrastructure are strongly correlated to extensions of the natural gas network. The main task for the majority of existing and planned LNG import terminals in Europe is to deliver natural gas to the network. LNG importation implies a possibility for the countries in northern Europe to meet the gas demand, in times when the indigenous natural gas resources in northern Europe are in decline, to improve the security of supply and to diversify the gas supply. For the countries in East Baltic Sea region, all of whom today are dependent on gas supply from Russia, diversified supply is a prioritized question and there is a strong political will of establishing LNG terminals in all the Baltic countries.

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\(^{70}\) Ramböll, 2009
The LNG terminals in Norway, Nynäshamn (Sweden) and the planned terminal in Turku (in Finland) and Lysekil (Sweden) are exemptions from locating the terminals close to the natural gas network. Establishing of these terminals imply a possibility of supplying industrial customers and the transport sector with natural gas in areas where there are no gas network.

The development of the gas network will have an influence on the LNG infrastructure and vice versa. Large investments in pipelines may dampen the need for LNG import, while suspended investments in pipelines open for LNG import. For example, the suspension of Skanled, a planned gas offshore pipeline connecting Norway to Sweden and Denmark, raises uncertainty about Norwegian gas supply to EU and the Baltic Sea and implies a need to ensure possibilities of import of gas from outside the region, which means import of LNG.

On the other hand, investments in pipelines are necessary to be able to integrate the gas markets in the Baltic countries and Finland with the European gas network. Integration of the gas networks will have a number of advantages for the market, including easier access to the system for gas suppliers and shippers. Furthermore, integration of markets results in converging of gas prices, which increases the incentives for investment and makes diversification of gas supplies increasingly economically viable for the Baltic countries and Finland. This increases the economic viability of LNG imports (as well as other pipeline imports) considerably.

Figure 39. The European natural gas grid 2010
Existing and planned LNG facilities in Northern Europe

The map shows the location of the LNG facility and the tables in the Appendix gives detailed information of each facility. The existing terminals in Norway are shown in a separate table due to the large number of terminals.

It must be noticed that there are ongoing discussions about establishing LNG terminals at several other locations within the area, among others in Helsingborg, Sundsvall (Sweden), Hirtshals (Denmark), Oslo, Mongstad, Helgelandsbase (Norway) but as these projects has not become official yet, they are not listed in the table.

Figure 40. Existing, planned and proposed LNG terminals and productions plants
Source: Gas Infrastructure Europe, 2011, Gasnor, Gazprom. Note: Gazprom’s proposed production plants will be either in Vyborg or Greifswald.
Table 33. Existing LNG terminals in Europe 2011

<table>
<thead>
<tr>
<th>Nr on map</th>
<th>Country</th>
<th>Name of terminal</th>
<th>Storage capacity (1000 m³ LNG)</th>
<th>Nr of tanks</th>
<th>Regasification (bcm/y NG)</th>
<th>Operator</th>
<th>Source of import</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belgium</td>
<td>Zeebrügge</td>
<td>2011: 380</td>
<td></td>
<td>4</td>
<td>9.0 Fluxyx LNG</td>
<td>Qatar, Egypt, Norway, Trinidad&amp;Tobago, Nigeria</td>
</tr>
<tr>
<td>2</td>
<td>The Netherlands</td>
<td>Gate terminal, Rotterdam</td>
<td>2014/15: 720</td>
<td>2014: 3</td>
<td>12 Gasunie, Vopak</td>
<td>(Start up in sep 2011)</td>
<td>Algeria, Egypt, Qatar, Trinidad&amp;Tobago, Norway, Australia</td>
</tr>
<tr>
<td>3</td>
<td>United Kingdom</td>
<td>Isle of Grain</td>
<td>1 000</td>
<td>7</td>
<td>19.5 Grain LNG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>South Hook</td>
<td></td>
<td>775</td>
<td>5</td>
<td>21.00 South Hook LNG Terminal LNG Ltd</td>
<td>Qatar</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Dragon</td>
<td></td>
<td>320</td>
<td>2</td>
<td>6.00 Dragon LNG</td>
<td>Various</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Teesside</td>
<td></td>
<td>-</td>
<td>-</td>
<td>4.60 Excelerate Energy</td>
<td>Trinidad&amp;Tobago</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Sweden</td>
<td>Nynäshamn</td>
<td>20</td>
<td>1</td>
<td>0.18 AGA</td>
<td>Norway</td>
<td></td>
</tr>
</tbody>
</table>

Source: Gas Infrastructure Europe, 2011
<table>
<thead>
<tr>
<th>Nr on Map</th>
<th>Location</th>
<th>Operator</th>
<th>Storage capacity (thousand m$^3$ of LNG)</th>
<th>Nr on Map</th>
<th>Location</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Fredrikstad</td>
<td>Nordic LNG</td>
<td>6 500</td>
<td>29</td>
<td>Halhjem</td>
<td>Gasnor</td>
</tr>
<tr>
<td>9</td>
<td>Sarpsborg</td>
<td>Skagerak Naturgass</td>
<td>117</td>
<td>30</td>
<td>Bergen</td>
<td>Gasnor</td>
</tr>
<tr>
<td>10</td>
<td>Askim</td>
<td>Nordic LNG</td>
<td>250</td>
<td>31</td>
<td>Bergen</td>
<td>Gasnor</td>
</tr>
<tr>
<td>11</td>
<td>Oslo</td>
<td>Hafslund</td>
<td>500</td>
<td>32</td>
<td>Bergen</td>
<td>Gasnor</td>
</tr>
<tr>
<td>12</td>
<td>Tønsberg</td>
<td>Skagerak Naturgass</td>
<td>105</td>
<td>33</td>
<td>Bergen</td>
<td>Gasnor</td>
</tr>
<tr>
<td>13</td>
<td>Skien</td>
<td>Skagerak Naturgass</td>
<td>125</td>
<td>34</td>
<td>CCB</td>
<td>Gasnor</td>
</tr>
<tr>
<td>14</td>
<td>Bamle</td>
<td>Skagerak Naturgass</td>
<td>78</td>
<td>35</td>
<td>Bergen</td>
<td>Gasnor</td>
</tr>
<tr>
<td>15</td>
<td>Porsgrunn</td>
<td>Skagerak Naturgass</td>
<td>850</td>
<td>36</td>
<td>Høyanger</td>
<td>Gasnor</td>
</tr>
<tr>
<td>16</td>
<td>Risør</td>
<td>Skagerak Naturgass</td>
<td>78</td>
<td>37</td>
<td>Florø</td>
<td>Gasnor</td>
</tr>
<tr>
<td>17</td>
<td>Vennesla</td>
<td>Skagerak Naturgass</td>
<td>250</td>
<td>38</td>
<td>Florø</td>
<td>Saga Fjordbase</td>
</tr>
<tr>
<td>18</td>
<td>Lista</td>
<td>Gasnor</td>
<td>1 250</td>
<td>39</td>
<td>Nordfjordeid</td>
<td>Gasnor</td>
</tr>
<tr>
<td>19</td>
<td>Sirevåg</td>
<td>Gasnor</td>
<td>78</td>
<td>40</td>
<td>Vedde</td>
<td>Naturgass Møre</td>
</tr>
<tr>
<td>20</td>
<td>Sokndal</td>
<td>Gasnor</td>
<td>250</td>
<td>41</td>
<td>Ålesund</td>
<td>Naturgass Møre</td>
</tr>
<tr>
<td>21</td>
<td>Vigrestad</td>
<td>Gasnor</td>
<td>25</td>
<td>42</td>
<td>Brattvåg</td>
<td>Naturgass Møre</td>
</tr>
<tr>
<td>22</td>
<td>Nærø</td>
<td>Gasnor</td>
<td>21</td>
<td>43</td>
<td>Tresfjord</td>
<td>Naturgass Møre</td>
</tr>
<tr>
<td>23</td>
<td>Bryne</td>
<td>Gasnor</td>
<td>21</td>
<td>44</td>
<td>Sunndalsøra</td>
<td>Gasnor</td>
</tr>
<tr>
<td>24</td>
<td>Oltedal</td>
<td>Gasnor</td>
<td>78</td>
<td>45</td>
<td>Trondheim</td>
<td>Gasnor</td>
</tr>
<tr>
<td>25</td>
<td>Aksdal</td>
<td>Gasnor</td>
<td>21</td>
<td>46</td>
<td>Malvik</td>
<td>Gasnor</td>
</tr>
<tr>
<td>26</td>
<td>Stord</td>
<td>SKL Naturgass</td>
<td>105</td>
<td>47</td>
<td>Ålesund</td>
<td>Naturgass Møre</td>
</tr>
<tr>
<td>27</td>
<td>Husnes</td>
<td>Gasnor</td>
<td>250</td>
<td>48</td>
<td>Mosjøen</td>
<td>Gasnor</td>
</tr>
<tr>
<td>28</td>
<td>Odda</td>
<td>Gasnor</td>
<td>250</td>
<td>49</td>
<td>Bodø</td>
<td>Barents Naturgass</td>
</tr>
</tbody>
</table>

*Source: Gasnor 2011*
Table 35. Planned and proposed terminals in northern Europe

<table>
<thead>
<tr>
<th>No in map</th>
<th>Country</th>
<th>Location</th>
<th>Planned/proposed</th>
<th>Start-up</th>
<th>Storage capacity (thousand m³ of LNG)</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>United Kingdom</td>
<td>Anglesey, Almchw offshore</td>
<td>Proposed</td>
<td>-</td>
<td>-</td>
<td>Canatxx</td>
</tr>
<tr>
<td>52</td>
<td>United Kingdom</td>
<td>Port-Meridian (FSRU)</td>
<td>Proposed</td>
<td>2013+</td>
<td>-</td>
<td>Hoegh LNG</td>
</tr>
<tr>
<td>53</td>
<td>United Kingdom</td>
<td>Gateway LNG</td>
<td>Proposed</td>
<td>-</td>
<td>-</td>
<td>Stag Energy</td>
</tr>
<tr>
<td>54</td>
<td>United Kingdom</td>
<td>Teesside Middlesbrough</td>
<td>Proposed</td>
<td>-</td>
<td>-</td>
<td>Norsea Pipeline Ltd</td>
</tr>
<tr>
<td>55</td>
<td>United Kingdom</td>
<td>Canvey Island</td>
<td>Proposed</td>
<td>2014+</td>
<td>240</td>
<td>Calor Gas</td>
</tr>
<tr>
<td>56</td>
<td>France</td>
<td>Dunkerque</td>
<td>Planned</td>
<td>2014</td>
<td>380-570</td>
<td>Dunkerque LNG/EdF/Total/Fluxys</td>
</tr>
<tr>
<td>57</td>
<td>Germany</td>
<td>Wilmershafen</td>
<td>Proposed</td>
<td>-</td>
<td>-</td>
<td>DTFG (E.ON)</td>
</tr>
<tr>
<td>58</td>
<td>Germany</td>
<td>Wilmershafen</td>
<td>Proposed</td>
<td>-</td>
<td>-</td>
<td>RWE, Excelerate</td>
</tr>
<tr>
<td>59</td>
<td>Germany</td>
<td>Rostock</td>
<td>Proposed</td>
<td>Small-scale</td>
<td>Vopak, Gasunie, Gasunie, VNG</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Sweden</td>
<td>Lysekil</td>
<td>Planned</td>
<td>-</td>
<td>-</td>
<td>Nordic LNG, Preem</td>
</tr>
<tr>
<td>61</td>
<td>Sweden</td>
<td>Göteborg</td>
<td>Proposed</td>
<td>2013</td>
<td>10</td>
<td>Göteborg Energi</td>
</tr>
<tr>
<td>62</td>
<td>Poland</td>
<td>Swinoujscie</td>
<td>Planned</td>
<td>2014</td>
<td>320</td>
<td>Polski LNG</td>
</tr>
<tr>
<td>63</td>
<td>Lithuania</td>
<td>Klaipeda</td>
<td>Proposed</td>
<td>2014</td>
<td>-</td>
<td>Klaipeda nafta</td>
</tr>
<tr>
<td>64</td>
<td>Latvia</td>
<td>Ventspils/Riga</td>
<td>Proposed</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>65</td>
<td>Estonia</td>
<td>Padilski</td>
<td>Proposed</td>
<td>2015</td>
<td>-</td>
<td>Balti Gas</td>
</tr>
<tr>
<td>66</td>
<td>Finland</td>
<td>Åbo/Turku</td>
<td>Proposed</td>
<td>2015</td>
<td>20</td>
<td>Gasum</td>
</tr>
<tr>
<td>67</td>
<td>Finland</td>
<td>Porvoo</td>
<td>Proposed</td>
<td>2017</td>
<td>150-300</td>
<td>Gasum</td>
</tr>
</tbody>
</table>

Note: Planned terminals is terminals where investment decisions have been taken. Source: Gas Infrastructure Europe 2011.
Appendix VI. Calculation on Future Potential of LNG Demand in the SECA

Current situation of vessels operating in the SECA
The calculations made here are based on AIS data collected from the whole SECA. AIS data is obtained from vesseltracker.com. Data was collected for the periods:

- 11/2 to 11/3 2011
- 11/6 to 7/7 2011

The periods are assumed to be representative for summer and winter conditions respectively and have been extrapolated for estimation of representative full year data. Based on recorded IMO numbers, the AIS data was matched to a vessel database with the aim to obtain additional information on individual ships such as year built and more detailed ships dimensions.

Calculations
The type of ship is indicated in the AIS-message, where the ships are divided into different categories according to type of ship and length. The ship type corresponds to the AIS-message “ship type” and the length categories are divided into 50 m intervals, see Table 36. The following data was derived for each category:

- Number of ships;
- Time per day spent at different speeds;
- Average design speed;
- Average installed power.
Table 36. Ship groups and the total number of ship route registrations analysed in each group

<table>
<thead>
<tr>
<th>Type</th>
<th>Length</th>
<th>0-50</th>
<th>50-100</th>
<th>100-150</th>
<th>150-200</th>
<th>200-250</th>
<th>250-300</th>
<th>300-350</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>WIG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High speed craft</td>
<td>1 312</td>
<td>613</td>
<td>179</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Passenger ship</td>
<td>4 998</td>
<td>4 538</td>
<td>2 834</td>
<td>5 593</td>
<td>1 703</td>
<td>573</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Cargo ship</td>
<td>1 718</td>
<td>44 032</td>
<td>28 243</td>
<td>14 744</td>
<td>5 505</td>
<td>2 348</td>
<td>2 139</td>
<td></td>
</tr>
<tr>
<td>Tanker</td>
<td>756</td>
<td>10 158</td>
<td>14 441</td>
<td>6 820</td>
<td>3 250</td>
<td>1 857</td>
<td>266</td>
<td></td>
</tr>
<tr>
<td>Other types</td>
<td>2 897</td>
<td>4 950</td>
<td>853</td>
<td>304</td>
<td>113</td>
<td>6</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Fishing</td>
<td>3 001</td>
<td>1 404</td>
<td>97</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Towing</td>
<td>831</td>
<td>80</td>
<td>49</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Towing size &gt; 200x25m</td>
<td>806</td>
<td>127</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Dredging or underwater op.</td>
<td>1 476</td>
<td>3 648</td>
<td>1 191</td>
<td>175</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Engaged in diving operations</td>
<td>294</td>
<td>207</td>
<td>125</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Engaged in military operations</td>
<td>68</td>
<td>217</td>
<td>95</td>
<td>63</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sailing</td>
<td>538</td>
<td>423</td>
<td>90</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pleasure craft</td>
<td>145</td>
<td>284</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Pilot vessel</td>
<td>488</td>
<td>406</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Search and Rescue</td>
<td>757</td>
<td>807</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Tug</td>
<td>18 390</td>
<td>1 473</td>
<td>211</td>
<td>87</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Port Tender</td>
<td>95</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Vessel w. anti-pollution facilities</td>
<td>140</td>
<td>177</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Law enforcement vessel</td>
<td>1 451</td>
<td>772</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Medical transport</td>
<td>3 241</td>
<td>3 908</td>
<td>1 363</td>
<td>720</td>
<td>494</td>
<td>71</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

The AIS data was then used to estimate the average energy consumption for an average ship during an average day for each ship category and length interval.
Calculation of energy demand for ships in Northern Europe based on AIS data

In order to estimate the total energy consumption for an average ship of each category, the power demand of a ship is approximated according to the following simple equation\(^1\).

\[ P_{actual} = \left( \frac{V_{actual}}{V_{design}} \right)^3 + 0.2 \frac{P_{design}}{1.2} \]

Where \( V_{actual} \) and \( P_{actual} \) are the momentary speed and power use. \( V_{design} \) and \( P_{design} \) are the design speed and installed power of the ship.

By multiplying the power requirement curve with the time spent at different speeds the daily average energy consumption for each ship category is derived, see Table 37.

\(^1\) From: A modelling system for the exhaust emissions of marine traffic and its application in the Baltic Sea area. Jalkanen (et al)
Table 37. Average energy use per day per ship by ship type and length [MWh]. (0 indications in the table reflects type/length intervals where no ship operations were registered)

<table>
<thead>
<tr>
<th>Type/Length</th>
<th>0-50 m</th>
<th>50-100 m</th>
<th>100-150 m</th>
<th>150-200 m</th>
<th>200-250 m</th>
<th>250-300 m</th>
<th>300-350 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIG</td>
<td>2</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High speed craft</td>
<td>13</td>
<td>120</td>
<td>201</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Passenger ship</td>
<td>3</td>
<td>13</td>
<td>92</td>
<td>180</td>
<td>308</td>
<td>451</td>
<td>282</td>
</tr>
<tr>
<td>Cargo ship</td>
<td>23</td>
<td>13</td>
<td>32</td>
<td>76</td>
<td>115</td>
<td>185</td>
<td>270</td>
</tr>
<tr>
<td>Tanker</td>
<td>2</td>
<td>11</td>
<td>28</td>
<td>60</td>
<td>84</td>
<td>115</td>
<td>117</td>
</tr>
<tr>
<td>Other types</td>
<td>4</td>
<td>16</td>
<td>54</td>
<td>90</td>
<td>102</td>
<td>18</td>
<td>256</td>
</tr>
<tr>
<td>Fishing</td>
<td>3</td>
<td>9</td>
<td>27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Towing</td>
<td>7</td>
<td>29</td>
<td>0</td>
<td>29</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Towing size exceeds 200x25m</td>
<td>6</td>
<td>25</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Engaged in dredging or underwater operations</td>
<td>2</td>
<td>10</td>
<td>51</td>
<td>88</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Engaged in diving operations</td>
<td>3</td>
<td>14</td>
<td>22</td>
<td>79</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Engaged in military operations</td>
<td>4</td>
<td>11</td>
<td>31</td>
<td>55</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sailing</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pleasure craft</td>
<td>4</td>
<td>13</td>
<td>44</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pilot vessel</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Search and Rescue</td>
<td>4</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tug</td>
<td>9</td>
<td>21</td>
<td>59</td>
<td>26</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Port Tender</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vessel with anti-pollution facilities</td>
<td>4</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Law enforcement vessel</td>
<td>5</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medical transport</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ships according to resolution 18 (MOB-83)</td>
<td>3</td>
<td>27</td>
<td>97</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Analysis of the potential of LNG as a fuel in northern Europe

Composition of the fleet of ships in the Northern Europe SECA

The analysis on the potential of LNG as a fuel in northern Europe is specifically addressing the ship population that principally is operating inside the SECA area and including ships that are not regularly calling ports outside the area. The fleet of ships operating only within the SECA area has been identified from the AIS data and all vessels that crossed (exit or entry) the border of the area during the two months’ registration period were excluded from the SECA area fleet. The registered number of unique vessels only operating within the SECA area during the analysed AIS registration period is considered to reflect a representative composition and population of ships that are operating and bunkerling within the SECA area, see Figure 41. The ships are categorized by the ship type number given in their AIS-messages.

Figure 41. The SECA area fleet of ships – Number of unique vessels per category only operating within the SECA area. Based on statistics from AIS registrations during two months of 2011.
Age distribution of the fleet of ships in the Northern Europe SECA

The age distribution of the ship population operating principally within the SECA is shown in the Figure below. These data can be used for prediction of an expected phase out rate of old vessels.

![Figure 42. Age distribution of the ships in SECA 2011](image)

Note: Number of vessels launched 1940 – 2010.

New building of vessels

In order to analyse the total growth of the fleet operating in the area, the total number of ships being built each year in the world has been analysed and visualised in the figure below.

![Figure 43. New built vessels per year](image)
It is assumed in the calculations, that until 2020 there will be no or very few commercially driven conversions of existing ships to LNG propulsion. Thus the rate of new built vessels can be used as a basis for calculating the number of vessels expected to use LNG. The assumption that the number of conversion projects and retrofitting of LNG propulsion system will be very marginal is confirmed by Germanischer Lloyd (GL) \(^{72}\).

Since it is possible to use ordinary fuel outside of the SECA region and to switch to low sulphur fuel when entering the area it is moreover assumed that only ships that generally stay in the area will be motivated to use LNG as fuel. Ships that cross the borders of the area are therefore disregarded in the analysis.

**Adoption rate of LNG for new building vessel projects**

In order to make a calculation of the expected future LNG demand, it is also essential to know the adoption rate of LNG for the new built vessels. Within this study, the adoption rate (see Figure 44) made by the GL Baltic study (Sames, 2010) was used.

---

**Figure 44. Gas fuel adoption rate in new buildings**

Source: GL

---

\(^{72}\) Sames, 2010
Calculations are based on:

- 2% annual average growth of fleet
- Old ships corresponding to 2% of the fleet are phased out, scrapped and replaced.

By combining the expected rates of new building vessels and rate of adoption to LNG an expected number of LNG fueled ships in the SECA area per year can be calculated, see Figure 45.

The figures represent rough estimations based on various assumptions. In order to illustrate potential impact of the uncertainties in the results, two optional new building rates are introduced in the graph in addition to the assumed basic scenario. The following scenarios are included in the figure:

- Case A: New build ratio is 4% of entire fleet (base scenario)
- Case B: New build ratio is 6% of entire fleet
- Case C: New build ratio is 2% of entire fleet

![Figure 45. New buildings and LNG fuelled ships in the SECA area 2014 - 2020](image)

The following conversion factors are used to derive the expected overall LNG potential:

- The energy content of LNG: 13.7 kWh/kg which means that the energy content of 73 ton LNG corresponds to 1 GWh.
• Assuming an average efficiency of 45% for ship engines, the engines will have a specific fuel consumption of 162 ton/GWh.

The result
In Table 38, the results are calculated for all ships in the English Chanel, North Sea and Baltic Sea. Close to 1,000 LNG fuelled vessels are included in the standard case generating an annual consumption of 4.3 million tonnes of LNG. This figure represents the entire area addressed by the study.

If the figure is recalculated to a weekly volume demand in the area, it corresponds to approximately 180,000 m$^3$.

<table>
<thead>
<tr>
<th>Case</th>
<th>Number of LNG fuelled-ships by 2020</th>
<th>Yearly energy consumption of LNG-ships 2020 [GWh]</th>
<th>Yearly LNG consumption [ton]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (4%)</td>
<td>967</td>
<td>26,000</td>
<td>4,300,000</td>
</tr>
<tr>
<td>B (6%)</td>
<td>1,450</td>
<td>39,000</td>
<td>6,400,000</td>
</tr>
<tr>
<td>C (2%)</td>
<td>483</td>
<td>13,000</td>
<td>2,100,000</td>
</tr>
</tbody>
</table>

In Figure 46, the calculated quantities and the future development from 2015 to 2020 are shown for the three optional scenario cases.

Figure 46. LNG demand in SECA area 2015-2020 – tonnes of LNG per year

Using the same categories as in Figure 44, the results can be compared to the results in the GL Baltic study (Sames, 2010). The result per ship category is shown in
Figure 47. These categories are the four largest categories found in the SECA (see Figure 41) and represent a majority of the ships.
Appendix VII. International Conventions, Agreements and Regulations

As the shipping industry is international regulations, rules and standards are set on an international basis. Here the relevant IMO codes, SIGTTO, and other standards and rules will be identified and listed. Special focus will be put on safety standards and regulations related to bunkering and ship to ship transfer. Variations and gaps, if found, will be listed here.

The review will not only cover areas within the ECA, but will also address Russia since it is relevant to the supply of gas and LNG. The methodology will be to gather published documentation from established sources as well as experiences from IKCs. The assessment will include a ‘gap’ analysis in order to analyse possible inconsistencies, differences and potential problems together with a handful of selected IKCs.

Introduction
The following chapter presents a brief description of the international authorities and organisations that have developed rules, regulations and guidelines concerning LNG handling in different forms. It also gives a short introduction to the most relevant rules published by each authority or organisation.

The rules, regulations and guidelines are regulating not only the design of LNG vessels but also construction, operation and maintenance of LNG facilities and carriers. When it comes to the handling of LNG as cargo, rules and regulations have been developed over a period of years but dealing with the handling of LNG as bunker fuel, rules are still under development.

Table 39. Overview of International Organisations and Authorities

<table>
<thead>
<tr>
<th>Full name</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The International Maritime Organization</td>
<td>IMO</td>
</tr>
<tr>
<td>The Society if International Gas Tanker and Terminal Operators</td>
<td>SIGTTO</td>
</tr>
<tr>
<td>The International Group of Liquefied Natural Gas Importer</td>
<td>GIIGNL</td>
</tr>
<tr>
<td>The Oil Companies International Marine Forum</td>
<td>OCIMF</td>
</tr>
<tr>
<td>The International Chamber of Shipping</td>
<td>ICS</td>
</tr>
<tr>
<td>The International Association of Classification Societies</td>
<td>IACS</td>
</tr>
<tr>
<td>The International Organization for Standardization</td>
<td>ISO</td>
</tr>
<tr>
<td>The International Association of Ports and Harbours</td>
<td>IAPH</td>
</tr>
<tr>
<td>The International Navigation Association</td>
<td>PIANC</td>
</tr>
<tr>
<td>The International Association of Marine Aids to Navigation and Lighthouse Authorities</td>
<td>IALA</td>
</tr>
</tbody>
</table>
Organisations

The International Maritime Organization – IMO

Background
The international shipping community early identified that the best way of improving safety at sea was by developing international regulations followed by all shipping nations. From the mid-19th century and onwards a number of such treaties were adopted. During the first part of the 20th century several countries proposed that a permanent international organization should be established to promote maritime safety more effectively. The initiative resulted in the International Maritime Organization, IMO.

Present organisation
With headquarters in London, Great Britain, IMO is today the United Nations specialized agency in relations to shipping, responsible for the safety and security of shipping and the prevention of marine pollution by ships. With 169 member states and three associate members the IMO is a powerful organization developing international regulations that are followed by all shipping nations. The IMO is managed by a permanent secretariat of employees who are representative of the member countries.

MARPOL 73/78
Climate changes due to greenhouse gases from emissions are a global concern. The largest international convention covering preventative measures regarding pollution of marine environments by ships are collected under MARPOL73/78. The convention was approved by IMO in 1973 but was updated in 1978 with a protocol due to several tanker accidents, hence the name MARPOL 73/78. As a whole the convention is an instrument referred to as The International Convention for the Prevention of Marine Pollution from Ships, 1973, modified through the protocol from 1978. The major aim of the convention is to preserve all marine environments and eliminate pollution from oil spills and other dangerous substances related to shipping. All emissions are to be minimized, both from operational activities and accidental causes.

Since it entered into force in 1983 the convention has been updated continuously by amendments to cover every aspect of international shipping.

Six annexes are included in the convention. Annex I – VI, where every annex contains detailed rules and guidelines regarding specific areas. Marine environments shall be protected from oil spills, chemicals (transported both in bulk and packaged form), sewage and disposals from ships. The convention also lists rules regarding inspection of ships.

Annex I – Regulations for the prevention of pollution by oil – incorporates various amendments regarding ship-generated pollution of marine environments by oil and applies to all oil tankers of 150 GT and above, and every other ship of 400 GT and above. It also contains requirements for survey and issuance of international oil pollution prevention certificates and regulations related to control of discharge of oil from machinery and cargo spaces, ballast tank arrangements and locations, double hull requirements etc. It separates the construction and equipment provisions from the operational requirements and clearly makes distinctions between new ships and existing ones.
Annex II – Regulations for the control of pollution by NO\textsubscript{X}
ious liquid substances in bulk - includes details of discharge criteria and measures for the
control of pollution by noxious liquid substances carried in bulk. Residue discharges are only allowed at certain reception
facilities.

Annex III – Regulations for the prevention of pollution by harmful substances carried by sea
in packaged form – contains general requirements on detailed standards for packaging,
marking, labeling, documentation etc. by harmful substances.

Annex IV – Regulations for the prevention by sewage from ships – lists requirements to
control pollution of the seas by sewage.

Annex V – Regulations for the prevention by garbage from ships – deals with different types
of garbage and disposals thereof (e.g. distance from land). The annex prohibits dumping of
any form of plastic into the sea.

Annex VI – Regulations for the prevention of air pollution from ships
This was approved in 1997. The regulations collected here set limits on sulphur and nitrogen
oxide from ship emissions together with particulate matter, even more stringent standards
in emission control areas.

The Annex was adopted in 2005 and has been applied by 53 member states, representing
82% of the global fleet. The regulations are expected to have a significant positive impact on
the atmospheric environment and human health foremost in coastal areas and port cities.
This Annex is the reason for the expanded resources put into alternative energy solutions for
ships, and several global project are running in co-operation with harbors, authorities and
shipping companies.

Goals and objectives intended with annex IV is to, primarily, lower the sulphur content in
bunker fuel globally to 3,5%, a decrease of the global cap today at 4,5% . Stricter
requirements will applied from 2012 that progressively lowers the content to 0,5% from
2020 (subject to a consultation process which will be reviewed in 2018).

Provisions allowing for special emission control areas to be established with more stringent
controls on sulphur (SECA) are also included in this annex. In SECAs, the sulphur content of
bunker fuel used may not exceed 1,5%. Alternatively, ships must fit an exhaust gas cleaning
system, e.g. Scrubber technology, or any other technological method to limit sulphur oxide
emissions. The Nordic Sea, Baltic Sea and English Channel are designated SECAs.

The annex prohibits emissions of ozone depleting substances (halons and chlorofluorcarbons) and also limits emissions of nitrogen oxides from diesel engines.
EEDI (Energy Efficiency Design Index)
The EEDI is developed by the International Maritime Organization’s (IMO:s) Marine Environment Protection Committee (MEPC) with the purpose to create stronger incentives for further fuel improvements in fuel consumption of new ships. The purpose with EDDI is to establish a minimum energy efficiency requirement for new ships depending on ship type and size. The EEDI provides a specific figure, expressed in grams of CO2 per ship’s capacity mile. A lower value means a more energy efficient ship design and as long as the minimum energy efficiency level is attend, the choice of what technologies to use in ship design are the stakeholders responsibility. The EEDI is mandatory.

SEEMP (Ship Energy Efficiency Management Plan)
The SEEMP is a management tool, which seeks to improve a vessel or ship’s energy efficiency through four steps: planning, implementation, monitoring and self evaluation and improvement. The SSMP is intended to assist a company in managing the ongoing environmental performance of their ships, through continuous work with theses four steps over time. The SEEMP is a mandatory measure to reduce air pollution from all ships.

The Society of International Gas Tanker and Terminal Operators – SIGTTO
Background
In 1978 a number of prominent companies in the shipping industry, recognizing a common interest, set out to establish a framework of standards and best practice for the then emerging liquefied natural gas (LNG) businesses. Realizing no established industry body fully encompassed the scope of their shared interests they resolved to create one specifically for that purpose. Hence, SIGTTO was formed as an international organisation through which all industry participants might share experiences, address common problems and derive agreed criteria for best practices and acceptable standards. Formed originally with 13 members, the Society has continued to grow and now has more than 150 members. Collectively, SIGTTO’s membership represents nearly all the world’s LNG businesses and more than half of the global liquefied petroleum gas (LPG) business.

Present organisation
Today SIGTTO is a non-profit making international organisation, formed to promote high operating standards and best practices in gas tankers and terminals throughout the world. It provides technical advice and support to its members and represents their collective interests in technical and operational matters.

Loss of confidence in the industry in one part of the world will undermine confidence elsewhere and threaten the reputation of the industry as a whole. This, SIGTTO actively seeks to avoid. The Society remains engaged in its original purpose: to specify and promote

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73 Description of the package of technical and operational reduction measures for ships agreed by MEPC 59, www.imo.org
high standards and best practices among all industry members throughout the world, and hence to maintain confidence in the safety of the liquefied gas industries and maintain their acceptance, by society at large, as responsible industrial partners. The Society does not seek to promote the sectional interests of any of its members, nor will it compromise technical standards to secure commercial advantage for any one party.

The SIGTTO guidelines are focused on large scale LNG transfer from LNG carriers, both for transfer to terminal and for Ship to Ship LNG transfer. Though these guidelines are for large scale LNG, many of the aspects could be used within the LNG bunkering ship to ship project.

**The International Group of Liquefied Natural Gas Importer – GIIGNL**

**Background**

GIIGNL was founded soon after the birth of the LNG industry by the then small group of companies importing LNG to share information to facilitate the development of LNG imports and support the growth of the LNG industry. Beginning with 19 member companies in 1971, GIIGNL has grown to 54 Full and 13 Associate members from 20 different countries around the world (Asia, Europe and the Americas).

In line with the development of the LNG industry, the membership is now composed of infrastructure companies, gas and power companies and most of the major oil companies active in the import of LNG.

**Present organisation**

GIIGNL provides its members with overviews of the general economic condition of the LNG industry and current, state-of-the art LNG technology, operations and best practices. This information enhances facility operations, diversifies contractual techniques, and supports industry positions with international agencies. To this end, GIIGNL members share information about commercial and technical developments in LNG, including safety incidents at member facilities. Activities of shared interest to GIIGNL members include: LNG purchasing, importing, processing, transportation, handling, re-gasification and uses of LNG around the world.

**The Oil Companies International Marine Forum – OCIMF**

**Background**

In 1970, as a result after the “Torrey Canyon” OCIMF was founded. It consists of a voluntary association of oil companies having an interest in the shipment and handling of crude oil and oil products. Governments had reacted to this incident by debating the development of international conventions and national legislation and the oil industry sought to play its part by making its professional expertise available and its views known to governmental and inter-governmental bodies. The role of OCIMF has broadened over the intervening period. Most recently the organisation has contributed to the EU discussion on tanker safety and the draft EU Directive on Environmental Liability, and has provided support to the EU and IMO debate on the accelerated phasing out of single-hull tankers and on the carriage of heavy grades of oil.
Present organisation
OCIMF’s mission is to be the foremost authority on the safe and environmentally responsible operation of oil tankers and terminals, promoting continuous improvement in standards of design and operation. The current membership of OCIMF comprises 84 companies worldwide. OCIMF has produced approximate 50 guidelines concerning the handling of oil and gas, which of many have been taken as industry standards in their particular field.

The work of OCIMF is carried out through the Committees, Sub-Committees, Forums, work groups and task forces composed of members' representatives and assisted by the Secretariat.

The International Chamber of Shipping – ICS
ICS is a voluntary organization of national ship owners’ associations. Established in 1921, it represents more than half the world merchant tonnage. ICS acts in some different interests of shipping such as: marine safety, ship design and construction, pollution prevention and maritime law.

The International Association of Classification Societies – IACS
IACS is a gathering of 12 classification societies, organisations that establish and apply technical standards in relation to the design, construction and survey of marine related facilities including ships and offshore structures. It implies a process of verifying standards against a set of requirements which then are laid down in rules. The aim is to verify that the required rule standard is built in, observed and maintained. Classification societies also maintain significant research departments that contribute towards the on-going development of appropriate, advanced technical standards.

IACS is a non-governmental organisation who is allowed to develop guidance’s for IMO. In other words, the IACS has consultative status with IMO, and remains the only non-governmental organisation with observer status, able to develop and apply rules. The quality of the rules is written in the International Convention for the Safety of Life at Sea (SOLAS). IACS makes a contribution to maritime safety and regulation through technical support, compliance verification and research and development. A range of documents exist to help promote consistency throughout the member societies.

The International Organization for Standardization – ISO
The International Organization for Standardization, widely known as ISO, is standard-setting body on an international level composed of representatives from various national standards organisations. Founded on February 23, 1947, the organisation promulgates worldwide proprietary industrial and commercial standards.

It has its headquarters in Geneva, Switzerland. While ISO defines itself as a non-governmental organisation its ability to set standards that often become law, either through treaties or national standards, makes it more powerful than most non-governmental organisations. In practice, ISO acts as a consortium with strong links to governments.

ISO's main products are the International Standards, but it also publishes Technical Reports, Technical Specifications, Publicly Available Specifications, Technical Corrigenda and Guides.
International Association of Ports and Harbors – IAPH
On November 7th 1955, some 100 delegates from 38 ports and maritime organizations in 14 countries gathered in Los Angeles to announce the creation of the International Association of Ports and Harbours (IAPH). It marked its 50th Anniversary (Golden Jubilee) in 2005. Over the past five decades, IAPH has developed into a global alliance of ports, representing today some 230 ports in about 90 countries. The member ports together handle well over 60% of the world's sea-borne trade and nearly 80% of the world container traffic. It is a non-profit-making and non-governmental organisation (NGO) headquartered in Tokyo, Japan.

IAPH's principle objective is to develop and foster good relations and cooperation among all ports and harbours in the world by proving a forum to exchange opinions and share experiences on the latest trends of port management and operations. IAPH strives to emphasize and promote the fact that ports form a vital link in the waterborne transportation and play such a vital role in today's global economy.

The founding fathers of the IAPH believed five decades ago that ports could contribute to create a more peaceful world by helping world trade grow and develop, as explicitly shown in their motto, "World Peace Through World Trade — World Trade Through World Ports". As contained in its Constitution, IAPH is committed to promoting the world peace and the welfare of mankind as its ultimate goal.

The International Navigation Association – PIANC
PIANC is the global organisation providing guidance for sustainable waterborne transport infrastructure for ports and waterways. Professionals around the world join forces to provide expert advice on cost-effective, reliable and sustainable infrastructure to facilitate the growth of waterborne transport. Established in 1885, PIANC continues to be the leading partner for government and private sector in the design, development and maintenance of ports, waterways and coastal areas.

As a non-political and non-profit organisation, PIANC brings together the best international experts on technical, economic and environmental issues pertaining to waterborne transport infrastructure. Members include national governments and public authorities, corporations and interested individuals. Providing expert guidance and technical advice PIANC provides guidance to public and private partners through high-quality technical reports. Their international working groups develop regular technical updates on pressing global issues to benefits members on shared best practices.

International Association of Marine Aids to Navigation and Lighthouse Authorities – IALA
IALA is a non-profit, non-governmental international technical association. Established in 1957, it gathers marine aids to navigation authorities, manufacturers and consultants from all parts of the world and offers them the opportunity to compare their experiences and achievements. IALA’s aim is to harmonize aids to navigation worldwide and to ensure that the movements of vessels are safe, expeditious, cost effective and harmless to the environment.
The National Fire Protection Association – NFPA

Background
This international nonprofit organisation was established in 1896 with the mission to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training and education.

Present organisation
Today NFPA is the world’s leading advocate of fire prevention and an authoritative source on public safety. The organisation develops, publishes and disseminates more than 300 consensus codes and standards intended to minimize the possibility and effects of fire and other risks.

International Electrotechnical Comission – IEC
Founded in 1906, the IEC is the world’s leading organisation for the preparation and publication of International Standards for all electrical, electronic and related technologies. These are known collectively as “electrotechnology”. IEC provides a platform to companies, industries and governments for meeting, discussing and developing the International Standards they require.

Laws, Codes and Standards
The following section is a collection of the most important rules and regulations, published by authorities and well established organisations, mentioned in the previous section, which will affect the distribution system for LNG for ships.

The International Maritime Organization – IMO
IMO, as one of the oldest international organisations governing the marine industry, has published several of the most important rules and regulations. The IMO webpage is a valuable source of further information.

- International Convention for the Safety of Life at Sea (SOLAS), 1974
The International Convention for the Safety of Life at Sea (SOLAS) is an international maritime safety treaty. The SOLAS Convention in its successive form is generally regarded as the most important of all international treaties concerning the safety of merchant ships. SOLAS requires flag States to ensure that their ships comply with minimum safety standards in construction, equipment and operation. It includes articles setting out general obligations etc. followed by an annex divided into twelve chapters.

Following the terrorist events on 11 September 2001, IMO agreed to develop security measures applicable to ships and port facilities. These security measures have been included as amendments to the Safety of Life at Sea Convention, 1974 (SOLAS Convention).
• Standards regarding special training requirements for personnel on certain types of ships (STCW Chapter V)
The International Convention on Standards of Training, Certification and Watch keeping for Seafarers, 1978 (STCW78) was amended at a conference held in London 1995. Chapter V of the STCW Conventions governs Standards regarding special training requirements for personnel on certain types of ships, including LNG vessels.

• Convention on the International Regulations for Preventing Collisions at Sea (COLREG)
The COLREG includes 38 rules divided into five sections: Part A - General; Part B - Steering and Sailing; Part C - Lights and Shapes; Part D - Sound and Light signals; and Part E - Exemptions. There are also four Annexes containing technical requirements concerning lights and shapes and their positioning; sound signalling appliances; additional signals for fishing vessels when operating in close proximity, and international distress signals.

• International Convention for the Prevention of Pollution from Ships, (1973 as modified by the Protocol of 1978) (MARPOL 73/78)
The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. MARPOL was adopted on 2 November 1973 by IMO and covers pollution by oil, chemicals, and harmful substances in packaged form, sewage and garbage.

• International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (The IGC93 code)
The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk IGC93 applies to all kind of gas carriers. The IGC93 Code provides an international standard for the safe carriage by sea of liquefied gases (and other substances listed in the Code) in bulk. To minimize risks to ships involved in such carriage, to their crews and to the environment, the Code prescribes the design and constructional standards of such ships and the equipment they should carry, with regard to the nature of the products involved. A new version of the IGC93 code is under development within IMO. It is set to be presented by IMO during 2012.

• IGC95 - Rules for the bunker ship
The IGC95 is classifying the vessels carrying gas into four different standards; type IG, IIG, IIPG and IIIG (the notations Type 1G/Type 2G/Type 2PG/ Type 3G are also used). As for vessels carrying liquid natural gas, they are required to be constructed with double bottom and double hull. This will class them to be type IIIG vessels. The IMO IGC95 Code is the international regulation for gas carriers and will therefore be valid for the bunker ship carrying bunker fuel.
• IMO IGF International Code of Safety for Ships using Gases or other Low Flashpoint Fuels - Resolution MSC 285(86)

There is of today no formal IMO rule in force concerning gas fuelled vessels other than vessels covered in the IGC93 code (see above). Such code will not be available earlier than 2014. Today there is an interim guideline, not yet finalized, formally titled Resolution MSC 285(86). Published by IMO in 2009 the resolution is used is in all on-going projects concerning gas fuelled vessel. The guidelines indicate arrangement and installation of LNG fuelled machinery to achieve an equivalent level of safety, reliability and dependability compared to conventional oil fuelled machinery.

The IGF code is applicable for the receiving vessel, the ship using LNG as bunker fuel. Hopefully the content of this work could support the IMO via the IGF working group called Bulk Liquid Gases (BLG), with information and solutions in order to implement bunkering LNG in the future IGF Code. With international standards regarding ship to ship bunkering, systems can be more effectively enforced and the LNG fuel supply logistics can be more widely spread.

• International Maritime Dangerous Goods Code (IMDG Code)

The development of the IMDG Code dates back to the 1960 Safety of Life at Sea Conference, which recommended that Governments should adopt a uniform international code for the transport of dangerous goods by sea to supplement the regulations contained in the 1960 SOLAS Convention. The IMDG Code was developed as a uniform international code for the transport of dangerous goods by sea covering such matters as packing, container traffic and stowage, with particular reference to the segregation of incompatible substances.

The Society of International Gas Tanker and Terminal Operators – SIGTTO

Below is a collection of the most important rules and regulations published by SIGTTO (et al) that will affect the distribution system for LNG for ships.

• A Guide to Contingency Planning for Marine Terminals Handling Liquefied Gases in Bulk

A book that specifically relates to the safe storage and transfer of liquefied gases at marine terminals. It can also be adapted for use at any terminal that handles hazardous substances in bulk. The book provides terminal management with guidance on contingency planning, including the identification and control of potential hazards, the control of incidents and review periods. (1989, ISBN 0948691816)

• Accident Prevention - The Use of Hoses and Hard-Arms at Marine Terminals Handling Liquefied Gas - 2nd edition (Information Paper No.4)

Data obtained from independent sources and enhanced by a SIGTTO membership questionnaire has enabled this review of accidents at gas jetties and highlights the safe way many liquefied gases are handled. Recommendations for terminal management guidance provide information on jetty equipment.
• **Ship to Ship Transfer Guide Liquefied Gases (SIGGTO)**

Ship to Ship (STS) transfer of liquefied gases at sea, in this case mainly LPG. This guide will be of use in the event of emergency lightening operations, providing checklists for each stage of the operation. This guide aims to familiarise ship's Masters, ship and barge operators and charterers/traders with the general principles of liquefied gas transfer operations. It may also be of assistance to vessels in distress that need to undertake emergency lightening operations. The second edition has been extensively rewritten and contains check-lists for the various stages of the operation, such as pre-fixture information, before operations commence, before run-in and mooring, before cargo transfer and before unmooring.

• **Guideline ship to ship transfer for LNG ships**

This is the newest publication from SIGTTO, published early 2011, offering guidance to the Masters and operators of vessels undertaking side-by-side ship to ship transfer operations of LNG. The guidance applies to LNG carriers at anchor, alongside a shore jetty or while underway. They are also useful for reference when establishing rules and procedures for transfer operations between seagoing ships and LNG regasification vessels (LNGRV) or LNG floating storage and offloading vessels (FSOs) in inshore waters. This edition does however not review intellectual property position relating to the transfer process or equipment used in it. It does not cover the bunkering process, but can be seen as guidance when producing guidelines for bunkering of LNG.

• **Guide to Contingency Planning for the Gas Carriers alongside and Within Port Limits**

This book helps the port authority, operating liquefied gas terminals, to develop or review their planning to minimize the possibility of accidents. It can also help to controlling the consequences of accidents that might occur while a gas tanker is within the port limits.

• **Site Selection & Design (IP no. 14) for LNG Ports & Jetties**

This is a guide to the minimum design criteria for port developers. Bearing in mind the high consequential risks of a serious accident in the LNG trade, this publication has been prepared for port developers as a guide to the minimum design criteria when a port is built or altered to accommodate LNG carriers.

• **LNG Shipping, Suggested Competency Standards**

With the rapid expansion of the LNG fleet now in progress this paper provides up-to-date guidance on the minimum standards to which Officers should be trained and reference to the knowledge that underpins it. This book is an essential companion to anyone serving on an LNG Vessel or any operator who has LNG vessels within their fleet.

• **Recommendations for Manifolds for Refrigerated Liquefied Gas Carriers**

The recommendations within this book are provided in an attempt to introduce conformity in manifold arrangements of Liquefied Gas Carriers other than LNG carriers. They are
complimentary to the OCIMF/SIGTTO Recommendations for Manifolds for Refrigerated Liquefied Gas Carriers (LNG).

• **The SIGTTO Recommendations and Guidelines for Linked Ship/Shore Emergency Shutdown**
  Proposals are presented for a standardised link to connect ship and terminal emergency shutdown (ESD) systems that are designed to communicate and initiate ESD of cargo transfer as safely and as quickly as possible. This will reduce hazards from pressure surge in an ESD of loading, discharge or ship to ship transfer. An intrinsically safe (IS) electrical link system that has received approval, in principle, from a number of certification and regulatory authorities worldwide, is described.

• **Jetty Maintenance and Inspection Guide**
  This publication provides guidance on the effective maintenance of critical items of equipment on both oil and liquefied gas terminal jetties. The document is providing information on the basic function, failure, inspection, maintenance and repair of all of the key equipment items and systems. The publication reflects both proactive and reactive maintenance philosophies.

• **Liquefied Gas Fire Hazard Management**
  It covers a broad spectrum of the liquefied gas industry, including large refrigerated and smaller pressurised storage terminals, ships, cylinder filling plant and road and rail tanker loading racks. The book has been compiled for operational staff, such as plant supervisors and ships' officers, who are involved in the handling of flammable liquefied gases. It will also be of benefit to fire officers and emergency planners who have liquefied gas installations within their jurisdiction, or experience regular road or rail car traffic involving these products in their area. This publication has been compiled to provide readers with an insight into the design and operation of liquefied gas installations and the equipment essential to the safe and efficient functioning of such installations.

• **LNG Operations in Port Areas**
  This document draws on the collective experience of the SIGTTO membership to provide guidance to best practice in managing gas shipping operations within ports. The publication also carries a useful profile of the risks associated with gas operations.

• **Liquefied Gas Handling Principles on Ships and in Terminals**
  Safety in Liquefied Gas Marine Transportation and Terminal Operations", or "The Guide to Self-Assessment" as this CD ROM based system is colloquially known, is an Excel based management tool. It allows ship and terminal operators to assess, in house, the effectiveness of their operational standards and emergency procedures and their capability to manage risk. By completing this assessment on a regular basis trends can be plotted and areas requiring improvement readily identified and corrected.
• **Safety in Liquefied Gas Marine Transportation and Terminal Operations**

Safety in Liquefied Gas Marine Transportation and Terminal Operations", or "The Guide to Self-Assessment" as this CD ROM based system is colloquially known, is an Excel based management tool. It allows ship and terminal operators to assess, in-house, the effectiveness of their operational standards and emergency procedures and their capability to manage risk. By completing this assessment on a regular basis trends can be plotted and areas requiring improvement readily identified and corrected.

• **Liquefied Petroleum Gas Sampling Procedures**

In the liquefied gas shipping industry, cargo sampling is a common requirement as part of the normal quality control or custody transfer standards. It is accepted within the industry that the risks associated with taking liquefied gas samples are minimal - provided that proper procedures established on both ship and shore are carried out by trained personnel familiar with the operation and that they use fully compatible equipment that is suitable for the task in hand. This pocket book represents the updated recommendations for this activity.

• **Guidelines for Hazard Analysis as an Aid to Management of Safe Operations**

This book assists gas tanker and terminal operators in their aim for continuous improvement in the management of safe operations by providing guidelines for hazard analysis.

• **Alleviation of Excessive Surge Pressures on ESD**

This paper provides practical guidance to operators, designers and engineers, of both liquefied gas ship and terminal loading and unloading systems, by enabling them to recognise the potential hazard of surge pressure.

• **A Contingency Planning and Crew Response Guide for Gas Carrier Damage at Sea and in Port Approaches**

This guide addresses the aspects of contingency planning that are relevant to the liquefied gas carrier and provides recommended crew responses to emergency situations that cause ship damage. While not an exhaustive guide to all conditions, it will be found to be applicable to the majority of accident situations.

• **Training of Terminal Staff Involved in Loading & Discharging Carriers**

This is the standard for the training of jetty personnel to the level required by IMO for seagoing staff. It addresses training in a modern format in accordance with a technique known as Functional Analysis and contains a description on how to train jetty personnel on LNG terminals.
The International Group of Liquefied Natural Gas Importer - GIIGNL - LNG Custody Transfer Handbook
This document gives descriptions of the measurement methods and equipment used by the LNG industry and recommended practice for the methodology to be specified in LNG sales and purchase agreements. The third edition (2010) has been completely updated, in particular to take into account the new ISO standards and the latest accepted measurement technology.

The Oil Companies International Marine Forum – OCIMF
The most important rules and regulations published by OCIMF (et al)

- **Ship to Ship Transfer Guide (petroleum) 4th edition**
The guide is aimed at providing advice for masters, marine superintendents and others responsible for planning Ship-to-Ship transfer operations. It is primarily directed to the transfer of crude oil and petroleum products between ocean-going ships. However these guidelines can provide a base for applications using LNG in the future. Although intended for operations taking place at sea, and therefore often beyond normal port services, it will also be of relevance in inshore waters or within harbour limits, although in such cases, special regard will have to be taken of local regulations. The guide does not refer directly to situations in pilotage waters where one ship maybe brought alongside another that is already berthed at a jetty. (4th Edition July 2005).

- **Design and Construction Specification for Marine Loading Arms**
Loading arms are increasingly being purchased for special applications that require accurate and thorough specification and considerable engineering assessment. The uniqueness of each loading arm application is reflected in the variability and complexity of operating envelopes, products transferred simultaneous service requirements, manifold spacing, jetty and piping layouts, arm styles, environmental loadings, auxiliary hardware etc. All these variables need to be considered during the design basis stage and be accurately presented in the final loading arm specification. This book, which draws on the OCIMF member's experiences, will provide support to the terminal as it considers all of these variables. (3rd Edition, 1999, ISBN 9781856090711).

- **International Safety Guide for Oil Tankers & Terminals, ISGOTT**
This is the definitive Guide to the safe carriage and handling of crude oil and petroleum products on tankers and at terminals. ISGOTT was first published in 1978. In producing this Fifth Edition, the content has been reviewed by ICS and OCIMF, together with the International Association of Ports and Harbours (IAPH), to ensure that it continues to reflect current best practice and legislation.

This edition also takes in to account recent changes in recommended operating procedures, particularly those prompted by the introduction of the International Safety Management (ISM) Code, which became mandatory for tankers on 1st July 1998.
The Guide provides operational advice and assistance including guidance on, and examples of, certain aspects of tanker and terminal operations and how they may be managed. It is NOT a definitive description of how tanker and terminal operations are conducted.

It is a general industry recommendation that a copy of ISGOTT is kept and used on-board every tanker and in every terminal so that there is a consistent approach to operational procedures and shared responsibilities for operations at the ship/shore interface. (5th Edition, 2006, ISBN 9781856092913).

- **Mooring Equipment Guidelines**
  The OCIMF first published 'Mooring Equipment Guidelines' in 1992 and this third edition provides a major revision and update to the original content to reflect changes in ship and terminal design, operating practices and advances in technology. These guidelines cover the minimum recommended OCIMF mooring requirements.

  The shipping industry has always been concerned with safe mooring practices. A fundamental aspect of this concern entails the development of mooring systems which are adequate for the intended service, with maximum integration of standards across the range of ship types and sizes.

  Although numerous standards, guidelines and recommendations concerning mooring practices, mooring fittings and mooring equipment exist it is often incomplete. For example, the number of hawsers and their breaking strength may be recommended without any advice on mooring winch pulling force or brake holding capacity. These guidelines are intended to provide an extensive overview of the requirements for safe mooring from both a ship and terminal perspective embrace the full spectrum of issues from the calculation of a ship’s restraint requirements, the selection of rope and fitting types to the retirement criteria for mooring lines. (3rd Edition, 2008)

**The International Chamber of Shipping - ICS - Ship/Shore checklist and guideline**

Approved by IMO this ship/shore safety checklist is for use by ship and terminal operators, incorporating guidance on completion and an example loading/unloading plan.

**The International Association of Classification Societies – IACS**

- **Unified Requirement M59: Control and Safety Systems for Dual Fuel Diesel Engines**
  This document lists, in addition to the requirements for oil firing diesel engines by the Classification Societies, and the requirements contained in the IGC\textsubscript{93} Code and IGC\textsubscript{95} Code, requirements that are to be applied to dual-fuel diesel engines. Can be used for classification and certification of an LNG fuelled ship.

- **1974/rev. 4 2011 – Liquefied Gas Cargo and Process Piping**
  Contains a listing of requirements to be applied to liquefied gas cargo and process piping including cargo gas piping and exhaust lines of safety valves or similar piping.
The International Organization for Standardization – ISO
The following section is a collection of the most important rules and regulations published by ISO that will affect the distribution system for LNG for ships.

- **Refrigerated light hydrocarbon fluids — General requirements for automatic level gauges (ISO 18132:2008)**
  This is a standard listing general requirement for the specification, installation and testing of level gauges used in the measurement of liquid levels on board ships carrying refrigerated light hydrocarbon fluids at close to atmospheric pressure (mainly LNG/LPG). It also establishes the general requirements for calibration/verification testing of automatic level gauges (ALG) used for refrigerated light hydrocarbon fluids, i.e., LNG and LPG, stored in bulk storage tanks on shore at pressures close to atmosphere. This part of ISO 18132 is not applicable to pressurized shore tanks.

- **Installation and Equipment for Liquefied Natural Gas – Ship to shore interface and Port Operations (ISO 28460:2010)**
  Most important for the LNG industry is this standard, ISO 28460:2010. It specifies the requirements for ship, terminal and port service providers to ensure the safe transit of an LNG carrier through the port area and the safe and efficient transfer of its cargo. It is applicable to: Pilotage and vessel traffic services (VTS); Tug and mooring boat operators; Terminal operators; Ship operators; Suppliers of bunkers, lubricants and stores and other providers of services whilst the LNG carrier is moored alongside the terminal. It applies only to conventional onshore LNG terminals and to the handling of LNGC’s in international trade. However, it can provide guidance for offshore and coastal operations.

  This standard specifies the procedure to be used for obtaining samples of unrefrigerated liquefied petroleum gases (LPG). It is suitable for sampling from bulk containers, to provide samples for laboratory testing of products covered by ISO 9162 (Specifications of Liquefied Petroleum Gases). It is applicable for the provision of samples for compositional analysis by ISO 7941 (Commercial Propane and Butane).

- **Pressure Relieving and Depressurising Systems (ISO 23251:2006)**
  A guide that applies to pressure-relieving and vapour depressurising systems intended for use primarily in oil refineries, although it is also applicable to petrochemical facilities, gas plants, liquefied natural gas (LNG) facilities, and oil and gas production facilities. This International Standard specifies requirements and gives guidelines for examining the principal causes of overpressure; determining individual relieving rates; and selecting and designing disposal systems, including such component parts as piping, vessels, flares, and vent stacks. This International Standard does not apply to direct-fired steam boilers.
• **Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries (ISO 13709:2003)**

Requirements specified for centrifugal pumps, including pumps running in reverse as hydraulic power recovery turbines, for use in petroleum, petrochemical, and gas industry process services. It does not cover seal less pumps. ISO 13709 is applicable to overhung pumps, between-bearings pumps, and vertically-suspended pumps. Clause 8 applies to specific types of pumps. All other clauses of this Standard apply to all pump types. This Standard is Technically Equivalent to the API 610.

• **Pipeline Transportation Systems – Pipeline Valves (ISO 14313:2007)**

Specifies pipeline valves and more specifically requirements thereof. It also provides recommendations for the design, manufacturing, testing and documentation of ball, check, gate and plug valves for application in pipeline systems meeting ISO 13623 (design, materials, construction etc. of pipeline systems), or similar requirements for the petroleum and natural gas industries. This Specification is not applicable to subsea pipeline valves, as they are covered by a separate Specification (API Spec 6DSS). This Specification is not for application to valves for pressure ratings exceeding PN 420 (Class 2 500). This edition of API Specification 6D is the identical national adoption of ISO 14313:2007.

• **Security Management Systems for the Supply Chain (ISO 28005-2:2010)**

This document contains technical specifications that facilitate efficient exchange of electronic information between ships and shore for coastal transit or port calls. It is intended to cover safety and security information requirements related mainly to the relationships between the ship and the port and coastal state authorities.

• **Natural Gas/Measurement of Properties (ISO 15970:2008)**

Collection of requirements and procedures for the measurement of the properties of natural gas that are used mainly for volume calculation and volume conversion: density at reference and at operating conditions, pressure, temperature and compression factor.

• **Greenhouse gases (ISO 14064:2006)**

A group of standards specifying the quantification, reporting, monitoring validation and verification of greenhouse gas, published in 2006. The standards aim to reduce greenhouse gas emissions and support emissions trading via an integrated set of tools for management programs, and to provide clarity and consistency between those reporting greenhouse gas emissions and stakeholders.

The standard as a whole gives specification with guidance at the organisation level and project level for quantification and reporting of greenhouse gas emissions and removals, reductions or removal enhancements and validates and verifies greenhouse gas assertions. Implementing the ISO 16064 is intended to achieve benefits regarding promotion of consistency, transparency and credibility in greenhouse gas quantification, monitoring, reporting and verification. The standard also enables organisations to identify and manage greenhouse gas related liabilities, assets and risks and at the same time facilitates the trade of greenhouse gas allowances or credits.
International Association of Ports and Harbors - IAPH - Guidelines for Port Planning and Design
IAPH has compiled best practices and experiences gained by their member ports. It is one of the basic guides to the world port community.

The International Navigation Association – PIANC
The following section is a collection of the most important rules and regulations published by PIANC that will affect the distribution system for LNG for ships.

- **Dangerous Goods in Ports**
  This is a guide for when deciding upon port design in ports where large quantities of dangerous substances are to be handled and stored. Also port operators have usage of it since dangerous goods are handled and stored in many different ways all over the world. The aim if the guide is to indicate preventative measures and/or safety distances for the safe transport, handling and storing of dangerous goods. This with regard to harbour activities, to housing-, industrial- and other areas/activities (Marcom report of WG 35, 2000).

- **Approach Channels, a Guide for Design**
  The design of an approach channel encompasses a number of disciplines including ship handling and maritime engineering in order to design waterways to a desired level of navigability and safety. This requires the assessment of a number of key elements, including vessel size and behaviour, human factors in ship handling and effects of the physical environment. This report covers in detail the process to assess and design a safe waterway (Volume 2, Joint Working Group PIANC and IAPH PTC2 report of WG 30 – Final report 1997 – PIANC).

- **Under keel clearance for large ships in maritime fairways with hard bottom**
  Since port construction and maintenance dredging is costly, using maximum vessel draught when transiting harbour channels tends to minimize cargo transportation cost. Thus an economic trade-off has to be made between allowable draught and the dredged water depth in the navigable port area. In addition, safety considerations require that the maximum draught allowed be controlled to avoid vessel grounding.

  For a vessel to safely transit a port area she must have adequate clearance under the keel. In the design and operation of ships, as well as in the design and maintenance of ports, the required under keel clearance (U.K.C.), the term used to define the distance between the ship's bottom and the channel bed, becomes an important economic and safety consideration (PIANC, 1985).

- **Guidelines for the Design of Fender Systems**
  These guidelines are written for a wide audience including governments, port authorities, private consulting practices, planning agencies, universities and suppliers. Its purpose is to allow designers and suppliers to have a common ground to plan and design.
It contains new approaches to fender design with appendices to help and inform. The document also gives guidance on types of fenders, fender systems and layouts, mooring devices and ropes, mooring system layouts for commercial vessels, and recommendations as to their suitability for various applications and locations. The guidelines are intended principally for use in respect of commercial installations by experienced engineers (PIANC, 2002, ISBN 2872231250).

- **Seismic Design Guidelines for Port Structure**

The occurrence of a large earthquake near a major city may be a rare event but its societal and economic impact can be so devastating that it is a matter of national interest. In order to mitigate hazards and losses due to earthquakes, seismic design methodologies have been developed and implemented in design practice in many regions since the early twentieth century, often in the form of codes and standards. Most of these methodologies are based on a force-balance approach, in which structures are designed to resist a prescribed level of seismic force specified as a fraction of gravity. These methodologies have contributed to the acceptable seismic performance of port structures, particularly when the earthquake motions are more or less within the prescribed design level. Earthquake disasters, however, have continued to occur. These disasters are caused either by strong earthquake motions, often in the near field of seismic source areas, or by moderate earthquake motions in the regions where the damage due to ground failures has not been anticipated or considered in the seismic design.

The objectives of the seismic design guidelines for port structures presented in this report are to address the limitations present in conventional design, and establish the framework for a new design approach. The expected users of the guidelines are design engineers, port authorities, and specialists in earthquake engineering. The applicability of the guidelines will reflect regional standards of practice. If a region has no seismic codes or standards for designing port structures, the guidelines may be used as a basis to develop a new seismic design methodology, or codes applicable to that particular region. If a region has already developed seismic codes, standards, or established design practice, then the guidelines may be used to supplement these design and analysis procedures. It is not the intent of the authors to claim that these guidelines should be used instead of the existing codes or standards or established design practice in the region of interest. It is anticipated, however, that the guidelines will, with continual modification and upgrading, be recognized as a new and useful basis for mitigating seismic disasters in port areas. It is hoped that the guidelines may eventually be accepted worldwide as recommended seismic design provisions. (PIANC, 2001)

**International Association of Marine Aids to Navigation and Lighthouse Authorities - (IALA)**

The following section is a collection of the most important rules and regulations published by IALA that will affect the distribution system for LNG for ships.
Aids to Navigation Guide (Navguide)
The IALA NAVGUIDE will be of interest and assistance to all organisations and individuals who either provide Aids to Navigation or are associated with their use. This fifth edition of the Guide has elevated the document to a new level and is a testimony to the continuous improvement initiatives undertaken by the IALA Operations Committee. This work is a tribute to people already very busy in their own organisations worldwide who are happy to share their expertise with other members of the international maritime community (5th Edition, 2006).

VTS Manual
The 2008 edition of the IALA VTS Manual, prepared by the IALA VTS Committee, updates the guidance and advice provided in previous editions to assist authorities considering the implementation of a new Vessel Traffic Service or the upgrading of an existing one (4th Edition, 2008).

The National Fire Protection Association – NFPA

NFPA 59A: Production, Storage and Handling of Liquefied Natural Gas
This standard has been used for LNG plant design in countries throughout the world for many years. Spacing requirements sets out guidance for siting, layout, equipment fabrication and installation, construction and operation of LNG facilities, and includes provisions for spill containment and measures to protect persons and property from potential hazards arising from accidental releases. The NFPA standard is intended to be applied to the design, location, construction and operation of any installation that produces, stores or handles LNG. Design specifications and construction, testing, commissioning and operation procedures are set down for LNG storage tanks, process equipment, piping systems and marine transfer facilities, with references to the specific standards, codes and recommended practices which should be used. This document is also used worldwide as the final word on site selection, design, construction, and fire protection for LNG plants.

NFPA 30: Flammable and Combustible Liquids Code
Adopted by most states and enforceable under OSHA, this code presents the latest and most complete guidance on the safe storage, handling, and use of these volatile substances. It provides the criteria needed to design facilities for better protection, comply with sprinkler requirements, and use safe operating practices.

NFPA 59A: Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants
This code shall apply to the design, construction, location, installation, operation, and maintenance of refrigerated and non-refrigerated utility gas plants. Coverage of liquefied petroleum gas systems at utility gas plants shall extend to the point where LP-Gas or a mixture of LP-Gas and air is introduced into the utility distribution system.
**NFPA 77: Static Electricity**
In addition to being a danger to individuals and an operating problem in industry, static electricity is often the ignition source for an ignitable mixture. The latest, best practices are outlined in this document to help guard against fires and explosions given clear guidelines for the assessment of ignition potential and protocols for fire prevention.

**NFPA 307: Construction and Fire Protection at Marine Terminals, Piers and Wharves**
The 2011 edition addresses safety issues based on industry best practices and provides state-of-the-art general principles for construction and fire protection in these types of structures. It is essential for architects, building contractors, owners, and code officials, especially since special use piers and wharf structures that differ in design and construction from cargo handling piers require special considerations based on the type and function of the structure.

**NFPA 497A/B: Classification of Class I/II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas**
This practice applies to those locations where flammable gases or vapors, flammable liquids, or combustible liquids are processed or handled; and where their release into the atmosphere may result in their ignition by electrical systems or equipment.

**International Electrotechnical Commission – IEC**

**Electrical installations in ships – Tankers – Special features (IEC 60092-502:1999)**
This international standard deals with the electrical installations in tankers carrying liquids which are flammable, either inherently, or due to their reaction with other substances, or flammable liquefied gases (5th edition).

**Electrical installations in ships - Ships carrying specific dangerous goods and materials hazardous only in bulk (IEC 60092-506:2003)**
This part of IEC 60092 is applicable to the electrical installations on the following types of ships and cargo spaces; ships and cargo spaces not specifically designed for the carriage of freight containers but intended for the carriage of dangerous goods in packaged form including goods in freight containers and portable tanks; purpose-built container ships and cargo spaces intended for the carriage of dangerous goods in freight containers and portable tanks; ro/ro ships and ro/ro cargo spaces intended for the carriage of dangerous goods; ships and cargo spaces intended for the carriage of solid dangerous goods in bulk and materials hazardous only in bulk (MHB); ships and cargo spaces intended for the carriage of dangerous goods, other than liquids and gases in bulk, in shipborne barges (2nd edition).
• Functional safety - Safety instrumented systems for the process industry sector (EN 61511:2004)

A standard that gives requirements for the specification, design, installation, operation and maintenance of a safety instrumented system, so that it can be confidently entrusted to place and/or maintain the process in a safe state. The contents of the corrigendum of November 2004 have been included in this copy.

The Regional/National Perspective

Europe

European Committe for Standardisation – CEN

Founded in 1961, CEN is a non-profit organisation whose mission is to foster the European economy in global trading, the welfare of European citizens and the environment by providing an efficient infrastructure to interested parties for the development, maintenance and distribution of coherent sets of standards and specifications. Consisting of 30 national members, the organisation works towards developing European Standards (ENs) in various sectors to build a European internal market for goods and services and to position Europe in the global economy. Some of the standards are voluntary, whereas other standards such as harmonized standards have been made effectively mandatory under EU law. CEN is officially recognised as a European standards body by the European Union; the other official European standards bodies are the European Committee for Electro technical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). Examples of mandatory standards are those for materials and products used in construction and listed under the Construction Products Directive. The CE mark is a declaration by the manufacturer that a product complies with the respective EU directive and hence the harmonized standard(s) referenced by the directive(s). Below is a list of rules and guidelines from the European Committee for Standardization.

Table 40. Overview of applicable European rules and regulations

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• Installations and equipment for liquefied natural gas - General characteristics of liquefied natural gas (EN1160:1996)

Listed in this document are characteristics of liquefied natural gas and the cryogenic materials used in the LNG industry. It also contains health and safety matters and is intended
to act as a reference document when designing or operating facilities for LNG, and also as a reference for the implementation of other standards of CEN/TC 282 - Installations and equipment for liquefied natural gas.

- **Installations and equipment for liquefied natural gas - Testing of foam concentrates designed for generation of medium and high expansion foam and of extinguishing powders used on liquefied natural gas fires (EN 12065:1997).**
  This is a standard that specifies the tests that needs to be carried out in order to assess the suitability of foam concentrates used to produce medium and high expansion foam and fire extinguishing powder when used alone or in combination on liquefied natural gas fires.

- **Installations and equipment for liquefied natural gas - Testing of insulating linings for liquefied natural gas impounding areas (EN 12066:1997)**
  Specifies the tests to be carried out in order to assess the suitability of insulating linings used in LNG impounding areas.

- **Installations and equipment for LNG - Suitability testing of gaskets designed for flanged joints used on LNG piping (EN 12308:1998)**
  This European Standard specifies the tests carried out in order to assess the suitability of gaskets designed for flanged joints used on LNG pipes.

- **Industrial valves - Isolating valves for LNG - Specification for suitability and appropriate verification tests (EN 12567:2000)**
  This European Standard specifies the general performance requirements of isolating valves (gate valves, globe valves, plug and ball valves and butterfly valves) used in the production, storage, transmission (by pipeline, rail, road or sea) of Liquefied Natural Gas (LNG). LNG filling valves for vehicle refuelling systems are excluded from the scope of this standard.

- **Installations and equipment for liquefied natural gas - Suitability testing of LNG sampling systems (EN 12838:2000)**
  This standard specifies the tests to be carried out in order to assess the suitability of LNG sampling systems designed to determine the composition of Liquefied Natural Gas, in combination with an analytical device such as a chromatograph.

- **Installation and Equipment for LNG - Design of Onshore Installations with a Storage capacity between 5t and 200t (EN 13645:2001)**
  This standard specifies requirements for the design and construction of onshore stationary liquefied natural gas (LNG) installations with a total storage capacity between 5 t and 200 t.
• Thermoplastic multi-layer (non-vulcanized) hoses and hose assemblies for the transfer of liquid petroleum gas and liquefied natural gas – Specification (EN 13766:2003).
This European Standard specifies requirements for two types of thermoplastic multi-layer (non-vulcanized) hoses and hose assemblies for carrying liquefied petroleum gas and liquefied natural gas. It specifies sizes from 25 mm to 250 mm, working pressures from 10.5 bar to 20 bar and operating temperatures from -200°C to +45°C.

• Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and -165°C (EN 14620:2006)
This standard originates from a British Standard: Flatbottomed, vertical, cylindrical storage tanks for low temperature service” and contains specification for the design and construction of single, double and full containment metal tanks for the storage of liquefied gas at temperatures down to -165°C.

• Installation and Equipment for LNG - Design of Onshore Installations (EN 1473:2007)
This European Standard is a guideline for the design, construction and operation of all onshore liquefied natural gas (LNG) installations including those for the liquefaction, storage, vaporization, transfer and handling of LNG. This European Standard is valid for the following plant types: - LNG export installations (plant), between the designated gas inlet boundary limit, and the ship manifold; - LNG receiving installations (plant), between the ship manifold and the designated gas outlet boundary limit; - peak-shaving plants, between designated gas inlet and outlet boundary limits. Satellite plants are excluded from this European Standard.

• Installation and Equipment for LNG - Design and testing of LNG loading arms (EN 1474:2008)
This Standard specifies the design, material selection, minimum safety requirements and inspection and testing procedures for liquefied natural gas (LNG) transfer between ship and shore. Although the requirements for remote control power systems are covered, the standard does not include all the details for the design and fabrication of standard parts and fittings associated with loading/unloading arms. The content of this standard is supplementary to local or national standards and regulations and is additional to the requirements of EN 1532.

• Installation and Equipment for LNG - Shore to ship Interface (EN 1532:1997)
Recommendations and requirements for the terminal and on board the ship can be found in this document to ensure the safe transfer of LNG at receiving and exporting terminals. It is applicable to the ship/shore LNG transfer systems including: - shore to ship connections; - all safety aspects of transfer operations; - any other operations that occur while the ship is moored on the jetty.
European Directives

• **Directive 1999/32/EC**
  This is a directive relating to a reduction of the sulphur content of certain liquid fuels. Proposal for an amendment of this directive will align it with the latest IMO provisions on sulphur content of marine fuels and also increase the adaptability on alternative methods according to IMO. Once adopted by the European Parliament and the Council, this will render the Directive 1999/32/EC more readable and legally clear and contribute to the achievement of the EU better regulation strategy.

• **Seveso**
  The aim of the Seveso Directive is to prevent major-accident hazards involving dangerous substances in establishments (including hazards due to management factors). If accidents continue to occur, the directive also aims at the limitation of consequence of such accidents both out of environmental and health aspects. This is applicable for both industrial operations and storage of dangerous chemicals in three levels of proportionate controls in practice, with larger quantities requiring more controls. Holding a quantity of dangerous substances less than the lower threshold levels given in the Directive are not covered by this legislation. Also, larger quantities than which are above the upper threshold contained in the directive, will be covered by all the requirements contained within the directive. Not covered by the directive are areas concerning nuclear safety, the transport of dangerous substances and intermediate temporary storage outside establishments and the transport of dangerous substances by pipelines.

The directive contains general and specific obligations on both operators and the Member States’ authorities. All operators of establishments coming under the scope of the directive need to send a notification to the authority in charge and to establish a major accident prevention policy. In addition, operators of handling larger quantities need to establish a safety report, a safety management system and an emergency plan. The directive applies to issues regarding internal emergency plans, land-based planning and inspections to increase consistency.
United Nations Economic Commission for Europe - UN/ECE

The UN/ECE has published a recommendation to regulate the transportation of dangerous goods by inland waterways. The European agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN) done at Geneva on 26 May 2000 under the auspices of the United Nations Economic Commission for Europe (UNECE) and the Central Commission for Navigation on the Rhine (CCNR) entered into force on 29 February 2008. ADN consists of a main legal text and annexed Regulations with the objectives to:

- ensure a high level of safety of international carriage of dangerous goods by inland waterways
- contribute effectively to the protection of the environment, by preventing any pollution resulting from accidents or incidents during such carriage
- facilitate transport operations and promoting international trade in dangerous goods.

The Regulations annexed to the ADN contain provisions concerning dangerous substances and articles, provisions concerning their carriage in packages and in bulk on board inland navigation vessels or tank vessels, as well as provisions concerning the construction and operation of such vessels. They also address requirements and procedures for inspections, the issue of certificates of approval, recognition of classification societies, monitoring, and training and examination of experts.

Norway

Although Norway is a pioneer in LNG as fuel for ships, with around 20 vessels in operation, they do not have any special seaside or shore side regulations for LNG bunkering yet. Interim regulations are used at the moment. Recently the Norwegian Maritime Directorate started lobbying for applying rules and regulation used for other gaseous cargoes and dangerous goods to transporting liquefied natural gas. In practice this means the limit of passengers allowed on ferries transporting liquefied natural gas today can be disregarded.

- Agreement on Dangerous Goods by Road/Regulations concerning the International Transport of Dangerous Goods by Rail (ADR/RID)

Regulations on land based transportation of dangerous goods mentions in paragraph 1.1.4.5.1: When transporting by any other mean than road/railroad, national and international regulations are applicable during that part of the transport.

- NO. 1481 Dangerous Cargo onboard Norwegian Vessels

Regulations on dangerous goods transported by ship include one chapter (2, part B) titled Transport of packaged, dangerous goods with RoRo-vessels in Norwegian infrastructure flows.

- NO. 664 Cargo Ships with Natural Gas fuelled internal combustion engines

This Regulation applies to Norwegian cargo ships: with an internal combustion engine installation fuelled by LNG, a gas plant in which the pressure does not exceed 10 bars and arrangement for dual fuel or gas-only operation and where the principle of ESD-protected gas engine-rooms is applied. The Regulation may, insofar as it is appropriate and for matters
not regulated by any international body of rules, also be made applicable to LNG carriers where the cargo is used as bunker fuel.

- **NO. 1218 Construction and Operation of Passenger Ship driven with Natural Gas**
  This regulation and its appendices apply to Norwegian-registered, gas-fuelled passenger ships built on the date of or after the entry into force of this Regulation (9th Sep 2005). It also complies to ships that are converted to gas-fuelled passenger ships. For gas-related matters that are not regulated in this regulation, classified ships are covered by DNV rules currently in force for gas-fuelled engine installations (or equivalent rules of other recognized classification societies). Unclassified ships shall comply with DNV rules.

**Sweden**

There are currently no specific laws, regulations or guidelines in Sweden regarding LNG bunkering. Such are currently under development. There are acts, laws and regulations in force today that are applicable.

- **Shore side legislation issued by MSB, the Swedish Civil Contingencies Agency:**

  **Civil Protection Act (2003:778)** - The objective of this act is the provision of equal, satisfactory and comprehensive civil protection for the whole country – with consideration given to local conditions – for life, health, property and the environment against all types of incident, accident, emergency, crisis and disaster.

  **Flammables and Explosives Act (2010:1011)** - This act deals with the handling and import of flammables and explosives, the aim being to prevent and limit loss of life, injury, and damage to the environment and property as a result of fire or explosion.

  **Transport of Dangerous Goods Act (2006:263)** - The objective of this act is to prevent and limit injury to people and damage to the environment and property as a result of the transport of dangerous goods or unauthorized processes.

  **Technical Conformity Assessment Act (1992:1119)** - This act regulates bodies registered in connection with the assessment of compliance with EU legal requirements. For the MSB this refers to bodies that assess and certify in the field of the transport of dangerous goods.

  **Act on municipal and county council measures prior to and during extra-ordinary events in peacetime and during periods of heightened alert (2006:544)** - The aim is to reduce vulnerabilities during operations and to maintain a good capacity for handling crises in peacetime; and thereby also attain a fundamental capacity for civil defence during periods of heightened alert.

  **Emergency Management and Heightened Alert Ordinance (2006:942)** - The aim of the stipulations of this ordinance is to ensure that government authorities through their operation reduce societal vulnerabilities and maintain a good capacity for dealing with their tasks during peacetime and periods of heightened alert.
• Rules and Regulations by the Government Administration of Transport.

Laws:
- The Act (2006:263) on carriage of dangerous goods
- The Ship Safety Act (2003:364)
- The Act (1980:424) on prevention of pollution from ships

Ordinances:
- The Ordinance (2006:311) on carriage of dangerous goods
- The Ship Safety Ordinance (2003:438)
- The Ordinance (1980:789) on prevention of pollution from ships

Regulations:
- The Swedish Transport Agency's regulations (TSFS 2009:91) on maritime transport of dangerous goods in packaged form (IMDG Code)

Other regulations:
- The Swedish Transport Agency's decree and regulations (SJÖFS 1991:8) and general recommendations on carriage of dangerous goods in ports

Germany

Until recently there has not been a particular regulatory framework for LNG handling in Germany. Instead regulations for gaseous fuels are in place. The most important of these regulations are the BlmSch Gesetz (Federal Pollution law) and the Blmsch Verordnung (Federal Pollution regulation). If a stakeholder should invest in a LNG terminal, it first needs to apply under the Blmsch Verordnung, and then an authority would have to take over responsibility and coordinate between up to 14 different other authorities.

Belgium

Based on regulation for large scale LNG import terminals, ISO and CEN standards are in use. EN1473, EN 1474, SIGTTO guidelines, OCIMF guidelines are applicable and legislation for land based installations are covered by SEVESO directive and transposition in national and regional legislation, the Belgian Gas Act.

All LNG projects with important changes, require an External Safety Report, Environmental Impact Assessment report, Environmental Permit, Gas Transport Permit and Building Permit. Important changes are discussed within the Interministerial Working Group safety aspects Zeebrügge, giving advice to the permitting authorities.

Marine LNG activities in the Zeebrügge area and harbor are also analysed in the Interministerial Working Group. LNG sailing procedures with specific safety procedures applicable in the Zeebrügge area and harbor, are published by the MRCC (Maintenance Rescue and Control Centre)

Asia

In Asia, specific standards have been developed for each area. The codes and regulations specific to LNG import facilities include Gas Industry law and Electricity Power Industry law. Most countries however apply NFPA and EN rules and regulations.

Japan

With its proximity to Korea, Japan's structure is good to know, especially when considering building up routes for ships that use LNG as a fuel that pass between Japan and Korea.
• **The Japan Gas Association (JGA)**

  One of the missions of JGA, an organisation consisting of city gas utilities, is to research the development of technical standards. JGA provides several recommended practices also used in other Asian countries. There are recommended practices for:
  
  - LNG In-ground Storage (JGA-107-RPIS)
  - LNG Aboveground Storage (JGA-108-RPAS)
  - LNG Facilities (JGA-102)
  - Safety and Security in Gas Production Facilities (JGA-103).

  These recommended practices have been developed using references from JIS (Japanese Industrial Standards) and API codes, among others. JGA-107-RPIS was developed by and is unique to Japan.

• **Japanese Ministry of Economy, Trade and Industry (METI)**

  The Ministry of Economy, Trade and Industry or METI, is a ministry of the Government of Japan. It was created by the 2001 Central Government Reform when the Ministry of International Trade and Industry merged with agencies from other ministries related to economic activities, such as the Economic Planning Agency. METI enforces the Gas Utility Industry Law, the Electricity Utility Industry Law and the High Pressure Gas Regulation Law. LNG terminal siting and operation must comply with one of these laws.

• **Law concerning the Securing of Safety and the Optimization of Transaction of Liquefied Petroleum Gas**

  (Co-administered by Agency for Natural Resources and Energy, and Nuclear Industrial Safety Agency)

• **Gas Business Act**

  The purpose of this Act is to protect the interests of gas users and achieve the sound development of Gas Businesses by coordinating the operation of Gas Businesses, and to ensure public safety and prevent pollution by regulating the construction, maintenance and operation of Gas Facilities as well as the manufacture and sale of Gas Equipment.

• **Maritime Safety Agency (Harbour Master) and the Japanese Coast Guard**

  The Japan Coast Guard, formerly the Maritime Safety Agency, is the Japanese coast guard. Comprising about 12,000 personnel, it is under the oversight of the Ministry of Land, Infrastructure, Transport and Tourism, and is responsible for the protection the coast-lines of Japan. It was founded in 1948. The duty of the JCG is to ensure security and safety at sea.

• **Japanese Harbour Regulation Act** - For all harbour related issues in Japan.

**China**

The Chinese LNG industry is currently using the international codes NFPA 59A, EN 1473 and NFPA 30. Terminals incorporate some additional Chinese codes and standards, but these are largely limited to equipment and building specifications.
India
India has its own high-level code, OISD2 STANDARD 194 – Storage & Handling of LNG, which is primarily based on the NFPA 59A-standard. Elements are also taken from CEN LNG standards, such as EN1473, and American API.

Korea
Korean Gas (KOGAS) mainly uses international standards, as well as some Korean Industrial Standards. Organisations provide and share overviews of state-of-the-art technologies, best practices and high standards to support the development of the LNG industry. In addition to the codes and standards, the regulations of onshore plants, and the classification of LNG carriers, a number of international organisations exist to ensure a high level of safety.

United States of America
United States of America has many current acts, regulations and standards. Many of these also work internationally as industry best practices.

- **American Petroleum Institute (API)**
  API is an American National Standards Institute (ANSI), an accredited standards developing organisation, operating with approved standards development procedures and undergoing regular audits of its processes. API produces standards, recommended practices, specifications, codes and technical publications, reports and studies that cover each segment of the industry. API standards promote the use of safe, interchangeable equipment and operations through the use of proven, sound engineering practices as well as help reduce regulatory compliance costs, and in conjunction with API’s Quality Programs, many of these standards form the basis of API certification programs.

- **API Std 620: Recommended Rules for Design and Construction of Large, Welded, Low-Pressure Storage Tanks**
  This standard covers large, field-assembled storage tanks that contain petroleum intermediates (gases or vapors) and finished products, as well as other liquid products commonly handled and stored by the various branches of the industry. The rules presented in this standard cannot cover all details of design and construction because of the variety of tank sizes and shapes that may be constructed.

- **API RP 520: Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries**
  Part 1 applies to the sizing and selection of pressure relief devices used in refineries and related industries for equipment that has a maximum allowable working pressure of 15 psig (103 kPag) or greater. The pressure relief devices covered in this standard are intended to protect unfired pressure vessels and related equipment against overpressure from operating and fire contingencies. This standard includes basic definitions and information about the operational characteristics and applications of various pressure relief devices. It also includes sizing procedures and methods based on steady state flow of Newtonian fluids. Atmospheric and low-pressure storage tanks covered in API 2000 and pressure vessels used for the transportation of products in bulk or shipping containers are not within the scope of this standard. See API 521 for information about appropriate ways of reducing pressure and...
restricting heat input. The rules for overpressure protection of fired vessels are provided in ASME Section I and ASME B31.1, and are not within the scope of this standard.

Part 2 covers the methods of installation for pressure relief devices for equipment that has a maximum allowable working pressure (MAWP) of 15 psig (1.03 bar g) or greater. Pressure relief valves or rupture disks may be used independently or in combination with each other to provide the required protection against excessive pressure accumulation. The term “pressure relief valve” includes safety relief valves used in either compressible or incompressible fluid service, and relief valves used in incompressible fluid service. Covers gas, vapour, steam, and incompressible fluid service.

• **API Std 617: Axial and Centrifugal Compressors and Expander Compressors for Petroleum, Chemical and Gas Industry Services.**
  Covers the minimum requirements for axial and centrifugal compressors used in petroleum, chemical, and gas industry services that handle air or gas, including process gear mounted. Does not apply to fans or blowers that develop less than 34 kPa (5 psi) pressure rise above atmospheric pressure; these are covered by API Standard 673. This standard also does not apply to packaged, integrally-geared centrifugal air compressors, which are covered by API Standard 672.

• **API Std 619: Rotary Type Positive Displacement Compressors for Petroleum, Chemical and Gas Industry Services.**
  This standard covers the minimum requirements for dry and flooded helical lobe rotary compressors used for vacuum or pressure or both in petroleum, chemical, and gas industry services. It is primarily intended for compressors that are in special purpose applications, and does not cover portable air compressors, liquid ring compressors and vane-type compressors. This edition also includes a new Inspector’s Checklist and new schematics for general purpose and typical oil systems. Related to ISO10440:2007.

• **API RP 2003: Protection Against Ignitions Arising Out of Static, Lightning and Stray Currents**
  This recommended practice presents the current state of knowledge and technology in the fields of static electricity, lightning, and stray currents applicable to the prevention of hydrocarbon ignition in the petroleum industry and is based on both scientific research and practical experience. Furthermore, the principles discussed in this recommended practice are applicable to other operations where ignitable liquids and gases are handled.

• **API Std 2510: Design and Construction of Liquefied Petroleum Gas (LPG) Installations**
  Provides minimum requirements for the design and construction of installations for the storage and handling of LPG at marine and pipeline terminals, natural gas processing plants, refineries, petrochemical plants, and tank farms. This standard covers storage vessels, loading and unloading systems, piping and related equipment.
• **API RP 521: Guide for Pressure-Relieving and Depressuring Systems**
Guidelines are provided for examining principal causes of overpressure; determining individual relieving rates; and selecting and designing disposal systems, including such component parts as vessels, flares, and vent stacks. Suggested solutions to the immediate design and economic and safety problems involved in pressure relieving discharge systems are presented. Related to ISO 23251.

• **US Department of Transportation Pipeline and Hazardous Materials Safety Administration – PHMSA**
PHMSA works to protect the American public and the environment by ensuring the safe and secure movement of hazardous materials to industry and consumers by all transportation modes, including the national pipeline grid. The creation of PHMSA provides the Department a modal administration focused solely on its pipeline and hazardous materials transportation programs. Through PHMSA, the Department develops and enforces regulations for the safe, reliable, and environmentally sound operation of 2.3 million mile national pipeline transportation systems and the nearly 1 million daily shipments of hazardous materials by land, sea, and air.

• **49 CFR Part 193: Liquefied Natural Gas Facilities**
Federal safety standards which are applicable to LNG import terminals and storage facilities.

• **US Federal Energy Regulatory Commission (FERC)**
FERC is the United States federal agency with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, and oil pipeline rates. FERC also reviews and authorizes liquefied natural gas (LNG) terminals, interstate natural gas pipelines and non-federal hydropower projects.

• **18 CFR Part 153. Applications for authorization to construct, operate, or modify facilities used for the export or import of natural gas.**

• **US Coast Guard, Department of Homeland Security**
The United States Coast Guard (USCG) is a branch of the United States Armed Forces and one of the seven U.S. uniformed services. The Coast Guard is a maritime, military, multi-mission service unique among the military branches for having a maritime law enforcement mission (with jurisdiction in both domestic and international waters) and a federal regulatory agency mission as part of its mission set. It operates under the Department of Homeland Security during peacetime, and can be transferred to the Department of the Navy by the President or Congress during time of war. USCG within DHS exercises regulatory authority over LNG facilities which affect the safety of port areas and navigable waterways. The USCG also establishes review criteria for evaluating a proposed deepwater port.
• **33 CFR Part 127. Waterfront Facilities Handling Liquefied Natural Gas and Liquefied Hazardous Gas**

A prime regulation governing the marine portion of an LNG terminal. Individual terminals operate under site-specific USCG Operating Plans (OPLANS). The OPLANS require pre-arrival boarding and inspection including ship certificates, crew licenses, safety equipment, ship condition, ship’s log and procedures. The USCG can deny entry to any US port or terminal at their discretion.

• **33 CFR Parts 148 -150. Regulations applicable to deepwater ports**

Prescribes regulations for the licensing, construction, design, equipment, and operation of deepwater ports.

• **33 CFR Part 156. Oil and hazardous material transfer operations**

This standard is applicable for transfer of oil or hazardous material on the navigable waters or contiguous zone of the United States to, from, or within each vessel with a capacity of 250 barrels or more. It does not apply to transfer operations within a public vessel. A subpart also applies to each vessel to be lightered and each service vessel engaged in a lightering operation in the marine environment beyond the baseline from which the territorial sea is measured when the oil or hazardous material lightered is destined for a port or place subject to the jurisdiction of the U.S. This subpart does not apply to lightering operations involving public vessels, or to the dedicated response vessels and vessels of opportunity.

• **46 CFR Part 154. Safety Standards for Self-Propelled Vessels Carrying Bulk Liquefied Gases**

The purpose of this part is to prescribe rules for new and existing gas vessels, moreover, this part applies to each self-propelled vessel that has on board bulk liquefied gases as cargo, cargo residue or vapour.

• **AGA**

The American Gas Association (AGA), founded in 1918, is an American trade organisation representing natural gas supply companies and others with an interest in manufacture of gas appliances and the production of gas.

• **AGA Report No. 3 - Orifice Metering of Natural Gas**

After years of on-going tests and data collection, the American Gas Association (AGA) collaborated with the American Petroleum Institute in preparing a revised version of AGA Report No. 3, Part 2, which is used as a reference standard for measurement of natural gas and other related hydrocarbon fluids by orifice meters.

The revised report (also known as API MPMS Chapter 14 Section 3 Part 2 and GPA 8185-00), was published in April 2000. Some of the effects of installation on measurement that were previously assumed as "measurement uncertainty" were identified as bias error while some are still recognized as measurement uncertainty.
The most critical use of meters is at points where custody of the gas changes hands. Thus, the meter becomes a cash register, and it is this financial aspect of metering that drives efforts to perfect the system. One reason for promoting awareness of the revised AGA Report is to make gas sellers and buyers know that there are possibilities of bias error that could be rectified by conforming to the recommendations in AGA 3. AGA Report No. 3 also contains information on Fuel Gas Energy Metering and Measurement of Gas by Turbine Meters.

- **ASME - American Society of Mechanical Engineers**
  ASME helps the global engineering community develop solutions to real world challenges. Founded in 1880 as the American Society of Mechanical Engineers, ASME is a not-for-profit professional organization that enables collaboration, knowledge sharing and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. ASME codes and standards, publications, conferences, continuing education and professional development programs provide a foundation for advancing technical knowledge and a safer world.

- **ASME B31.3 - Process Piping**
  Rules for the Process Piping Code Section B31.3 have been developed considering piping typically found in petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants; and related processing plants and terminals. This Code prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping. This Code applies to piping for all fluids.

**Applicable Rules and Guidelines for bunkering operations of LNG**

There are currently no rules and regulations available specifically for bunkering of LNG. Of the previously mentioned rules and guidelines there are a few that can be used in the development of procedures and new regulations. Many of the documents referred to are made with large scale LNG handling in mind. LNG bunkering, being small scale LNG handling, will use a different approach in some of these cases.

Some bunker scenarios will include transfer of both LNG and diesel oil from one ship to another. Therefore the SIGTTO as well as the OCIMF guidelines need to be accounted before and under an LNG bunkering operation. Another thing to take in to account is where the bunker operation is to take place. The rules and regulations can differ depending on if the bunker operation will be done from a quay (pipeline) to ship, truck to ship or ship to ship. Still this is included in national rules and regulations as no international regulations are stated as for today.

If the bunker operation will take place in a harbour area, at anchor or alongside a quay, a special permit from the harbour authorities are probably needed before any bunker operation can take place. There are certain regulations to consider during bunkering operations. Regulatory framework consists of national regulations for the shipside (if any),
port regulations and national regulation for the port side. Local authorities and the responsible port need to permit LNG bunkering at the chosen location.

**Ship to Ship**

Most important in respect of LNG bunkering ship to ship, is the all new **SIGTTO LNG ship – to – ship transfer guidelines**. As ship to ship bunkering of LNG is a form of LNG transfer, these guidelines have to be considered for bunker operations as well. Special consideration should be given the **Liquefied Gas Handling Principles on Ships and in Terminals** as being the industry best practice for Ship-shore LNG handling. In developing new rules for ship to ship bunkering, the need to come as close to ship-shore rules/best practice as possible, is necessary. However, the SIGTTO guidelines are focused on large scale LNG transfer on board LNG carriers, both for transfer to terminal and for ship to ship LNG transfer. Many of the aspects could be used within different LNG bunkering ship to ship projects. Today, in Scandinavia, the Classification Societies and authorities are using these guidelines when producing rules and regulations for LNG bunkering ship to ship. This document will be a very good starting point in producing new rules and regulations as well as procedures. It covers all parts of a ship to ship bunkering. Small scale LNG transfer, as LNG bunkering ship to ship is, cannot directly use large scale rules.

To some extent **Ship to Ship Transfer Guide Liquefied Gases (SIGGTO95)** may be used. However this is mainly focused on LPG and on emergency procedures.

The **IGF guidelines**, the rules and regulations for vessels using LNG as bunker fuel, are at present under construction and will be finalized during 2012 as planned. IMO via the IGF working group called BLG (Bulk Liquid Gases), provide and develop information and solutions in order to implement bunkering in the future IGF Code. With international standards about ship to ship bunkering, systems can be more effectively enforced and the LNG fuel supply logistics can be more widely spread.

As mentioned above, SIGTTO (together with OCIMF and ICS) have issued the **Ship to Ship Transfer Guide Liquefied Gases** that at present is focused on large scale LNG transfers as cargo. They will forthcoming issue a Ship to Ship LNG Transfer guide concentrating on bunkering operations. These guidelines are still just at draft version.

The all new **ISO 28460-2010** can be used. In the scope of the ISO standard it is stated: “**This International Standard applies only to conventional onshore liquefied natural gas (LNG) terminals and to the handling of LNGC’s in international trade. However, it can provide guidance for offshore and coastal operations.**”

**Training of ship crews**

The nature of LNG transfer ship to ship calls for special considerations where the SIGTTO manual, **Training of Terminal Staff Involved in Loading & Discharging Carriers**, is useful. The following may be considered to be applied to ship’s crews doing ship to ship transfer of LNG:

- **Suggested Competency Standards (SIGTTO)**
- **Training of Terminal Staff Involved in Loading and Discharging Gas Carriers (SIGTTO)**
Standards regarding special training requirements for personal on certain types of ships (IMO, STCW Chapter V)

A Contingency Planning and Crew Response Guide for Gas Carrier Damage at Sea and in Port Approaches (SIGTTO / ICS / OCIMF)

Standard for the Production, Storage, and Handling of LNG (NFPA 59A). It includes a chapter on training of personnel involved with LNG

Safety in Liquefied Gas Marine Transportation and Terminal Operations

Technical

For ships and marine operations IMO is the main regulatory body. International Convention for the Safety of Life at Sea (SOLAS) is the main convention on which to rely on. Specifically for LNG ships there is the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (The IGC93 code). This code is applicable to designing and building an LNG bunker vessel or coastal LNG tanker. For Gas fuelled ships IMO has developed the interim guidelines for gas fuelled ships approved by IMO (IGF). These Guidelines are in force and the final version is believed to be in line with these interim guidelines.

Developed by OCIMF, the Design and Construction Specification for Marine Loading Arms may be used, even though it is expected that LNG bunkering ship to ship will most probably use hoses, not loading arms. As a background material, this is valuable. The same goes for International Safety Guide for Oil Tankers & Terminals, ISGOTT. It is a general industry recommendation that a copy of ISGOTT is kept and used on board every tanker and in every terminal so that there is a consistent approach to operational procedures and shared responsibilities for operations at the ship/shore interface.

Mooring of the LNG bunker vessel alongside the LNG fuelled ship is an essential part of the bunkering operation. The Mooring Equipment guidelines are used all around the world as a guideline and industry best practice, not only for tankers. When developing plans, calculations and recommendation regarding mooring of the ships, these guidelines should be used.

Fender systems are a vital element for the safety of the bunkering of LNG ship to ship. PIANC has developed their Guidelines for the Design of Fender Systems that can be applied here.

Dangerous Goods in Ports (PIANC) a guide for designers and operators of ports where large quantities of dangerous substances are to be handled and stored is a valuable input in this context as well.

If the LNG bunkering ship to ship is going to an anchorage or in a new location, Approach Channels, a Guide for Design is a good place to start looking.

IAPH Guidelines for Port Planning and Design is a valuable source of information as is PIANCs Under keel clearance for large ships in maritime fairways with hard bottom.

Other applicable documents

Installation and Equipment for LNG - Shore to ship Interface by the European committee gives recommendations and requirements for the terminal and on board the ship to ensure
the safe transfer of LNG at receiving and exporting terminals. As said above, in developing new rules for ship to ship bunkering, parallels close to ship-shore rules/best practice as necessary. However, it must be noted that these guidelines are written with large to huge LNG carriers in mind. Small scale LNG transfer, as LNG bunkering ship to ship is, cannot directly use large scale rules.
Appendix VIII. Examples of Economic Instruments

This appendix gives some examples of economic instruments in place in order to provide incentives and disincentives for SO\(_x\) and NO\(_x\) emission reductions and for energy efficiency measures.

Environmentally Differentiated Fairway and Port Dues in Sweden

Early on, Sweden introduced schemes which provided financial incentives to buy low-sulphur fuel and invest in technologies in order to reduce emissions of nitrogen oxides. The Swedish Maritime Administration, The Swedish Port and Stevedores Association and the Swedish Ship-owners’ Association were early movers on agreeing on economic instruments to promote SO\(_x\) and NO\(_x\) emissions reductions to be applied in the fairways as well as in ports.

Differentiated Fairway Dues

These dues applied in Swedish waters have two parts: one related to the gross tonnage of the ship and one based on the amount of cargo. Only the first one is differentiated according to the environmental criteria. The system was introduced back in 1998, as the fees were substantially higher for sulphur emitting ships and considerable rebates were given to those operating with lower SO\(_x\) and NO\(_x\) emissions.

If the emission at 75 percent engine load is above 12 g/kWh, no NO\(_x\) discount is given. Below this level the discount increases continuously down to a level of 2 g/kWh, where the discount amounts to Euro 0.18 per GT. This means that a ferry or general cargo vessel that runs on low-sulphur bunker oil and applies the most far reaching means for reducing NO\(_x\) emissions enjoys a total discount of 0.28 Euro per GT.

From 1998, the Swedish Maritime Administration designed another economic instrument to encourage the installation of Selective Catalytic Reduction (SCR). Installations made before 1 January 2000 would be reimbursed up to 40% of the investment cost. This was in fact a government subsidy for promoting such investments in both Swedish and foreign vessels calling on Swedish ports.

Differentiated Port Dues

Various Swedish ports have introduced environmentally differentiated harbor dues in order to encourage emissions reductions. As each port is an autonomous entity, which needs to optimize its revenues in competition with other ports, they don't have the same options of providing subsidies as does the Swedish Maritime Administration – see above. For the Swedish ports, therefore, there is a balancing act of providing an incentive with is in addition to – and which complements – the fairway dues. The table below shows some dues in Swedish ports in 1999. It shows the principles of giving discounts and penalties.
Table 41. Discounts and penalties on fuels

<table>
<thead>
<tr>
<th>Port of Gothenburg</th>
<th>Discount</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port of Helsingborg</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Port of Malmo</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Port of Stockholm</td>
<td>0.10</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Selected Swedish ports in October 1999, SEK per GT Source: Kågeson, 1999

The following are incentives and penalties for NO\textsubscript{X} emissions in some Swedish ports:

Table 42. Discounts and penalties for NO\textsubscript{X} emissions

<table>
<thead>
<tr>
<th>Selected ports</th>
<th>Discounts</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port of Gothenburg</td>
<td>&lt; 2 g/kWh</td>
<td>0.20 0.10 0.05</td>
</tr>
<tr>
<td>Port of Helsingborg</td>
<td>0.10 0.06- 0.09 0.05</td>
<td></td>
</tr>
<tr>
<td>Port of Malmo</td>
<td>0.15 0.15 0.05</td>
<td></td>
</tr>
<tr>
<td>Port of Stockholm</td>
<td>0.20 0.15 0.05 0.10</td>
<td></td>
</tr>
</tbody>
</table>

Selected Swedish ports in October 1999, SEK per GT Source: Kågeson, 1999

**Green Award Certification**

The Green Award Certification scheme started as an initiative of the Port of Rotterdam and has now developed into a global certification system that gives certified ships discounts on port dues. In line with Corporate Social Responsibility (CSR) it contributes with a better image of the ship and the shipping company and further subscribes to continuous improvement. In order to be certified the ship must comply with international and national law and regulations.\textsuperscript{75}

**ESI (Environmental Ship Index)**

The Environmental Ship Index (ESI) measures a ship’s emissions based on the amount of nitrogen oxide (NO\textsubscript{X}), sulphur oxides (SO\textsubscript{X}), as well as of Particulate Matter (PM) it releases. ESI is used as a good indication of the environmental performance of ocean going vessels or ships.

Ports discuss and consider to provide an incentive, thereby rewarding ships when they comply or meet lower than current International Maritime Organization emission standards. Although this is a completely voluntary program, ports hope that the incentives will motivate the global port community to assume its role in improving the environment.

\textsuperscript{75} Green Award Foundation, www.greenaward.org
**NOx Fund in Norway**

The Norwegian policy makers in the gas sector generally make reference to the Convention on Long Range Transboundary Pollution and the Gothenburg Protocol which address measures to abate acidification, eutrophication and ground level ozone addressing sulphur, nitrogen oxides, particulate matter and Volatile Organic Compounds (VOCs) emissions.

In 2007, a NOx tax was introduced in Norway, amounting to about 2 Euro per kilo NOx emitted. The tax did however not sufficiently help achieve the goals: decreased NOx emissions.

As a complementary initiative, an Environmental Agreement was signed for the NOx Fund between 14 business organizations and the Ministry of Environment. Actors emitting NOx in Norway can now choose, either to pay the 2 Euro levy, or to become members of the fund and pay only about 25 % of the tax levy for non members. The agreement was signed on 14th of May 2008 to span between the years 2008-2010. In 2011 this agreement was extended to last up to 2017. The NOx Fund levies a tax for emissions of nitrogen oxides (NOx) during the production of energy - from the following energy sources 76:

- a) propulsion machinery with a total installed capacity of over 750 kW,
- b) motors, boilers and turbines with a total installed capacity of more than 10 MW,
- c) flares on offshore installations and on facilities on land.

By registering in the Business Sector’s NOx Fund a company may benefit from a reduced rate per kg of NOx. Being a member further means you can apply for monetary support for investments that decrease the NOx emissions in Norway. A member can get up to 75 % of the investments for such measures.

The NOx Fund provides support for NOx reductions to the following areas 77:

- New buildings and retrofitting gas propulsion;
- Filling stations for gas;
- New and promising NOx reducing measures;
- Catalytic reduction with the use of urea;
- Battery-powered propulsion of car and passenger ferries;
- Gas in land based industry;
- Engine modifications and retrofitting;
- Other NOx reducing measures

Costs and effects of measures taken have to be documented by the companies and verified by DNV.

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76 Directorate of Customs and Excise: Excise Dirty on Emissions of NOx 2011, Circular no. 14/2011 S

77 Næringslivets Hovedorganisasjon (NHO), web page
Appendix IX National Experiences from Public Awareness and Consultation Processes

Below follows the views and experiences of work with public awareness issues in the countries within the SECA area with experience from establishing LNG terminal infrastructures. The material has been gathered through interviews, written comments and a literature review of EIAs.

Belgium
Project: LNG terminal in the Port of Zeebrugge

When the LNG Terminal Zeebrugge was constructed in the 1980's, a lot of concern was raised about the safety of LNG. For the construction, an Interministerial Working Group was formed, and determined the procedures and rules to be respected.

In time, people got used to the presence of the LNG Terminal. On a periodic basis, neighbors and public can visit the terminal, and get informed about the safety rules, procedures, measures etc.

When developing new projects, such as construction of the 4th LNG tank, the Open Rack Vaporiser or the Second Jetty, few questions are raised by the public on the safety of the projects, or LNG in general. The authorities on the other hand, remain very demanding on respect of stringent rules and measures, as well as thorough safety studies.

On the other hand, industries and authorities see the environmental benefits of the use of natural gas in general, and of LNG as fuel for shipping in particular. The Flemish authorities and harbors certainly try to promote the use of LNG as fuel for shipping.

Despite the general acceptance of the LNG Terminal in Zeebrugge, the move to small LNG ships, LNG bunkering, ships filling on LNG will require acceptance by the authorities, based upon proven procedures, codes and standards etc.

Finland
Project: Porvoo LNG plant

Main experience from public awareness and concerns
People are positive to both natural and bio gas as such but the large majority does not know what LNG is. The safety levels must be very high as there are a lot of people circulating close to the filling station (thousands around ferries). Norway has shown us that it is possible to safely handle LNG.

The experience from public consultations is that it is generally positive. We stressed the environmental advantage and how it would be good for the Baltic Sea.
Main experience concerning media attention
LNG is still a rather exotic phenomenon. The papers wrote a lot about Viking Line when they discussed the construction of the new LNG ferry. The reactions were mostly positive as it created job opportunities in Turku.

Interests of politicians
The Finnish government has given Viking Line financial support for the “environmental and innovative” LNG project.

Conclusion and recommendation
Finland has years of experience from a small LNG production plant in Porvoo which has been in operation since 1996. The plant is located in a refinery area and there has been no problems concerning public awareness.

A number of LNG projects are on the way in Finland Poorvoo, Åbo, Turku – some are still in the initial planning phase – and thereby have no experience with public awareness.

One could reason that EU should do something similar to motivate for such investments. EU could also give some support to the countries within the ECA as the shipping cost will be higher there in the beginning compared to e.g. the Mediterranean Sea.

Netherlands
Project: LNG terminal in the Port of Rotterdam

Main experience from public awareness and concerns
The public consultations that have been made so far have only considered large scale LNG import and only inside industrial or harbour areas (Gate terminal).

The general public in the Netherlands is very used to gas, since the country already for over fifty years is a large gas producer and exporter. Over 99% of the households are connected to the gas grid.

There is still work to be done in the area of Gas/LNG as transportation fuel. The benefits of using LNG, e.g. as an environmentally friendly fuel, must be communicated to the public. There isn’t a strong public opinion against LNG today. There are already busses powered by compressed natural gas, and more and more passenger vehicles are using (bio)CNG as fuel. At the moment there are already some trucks using LNG as fuel and there is one LNG fuel station, but more to come.

Main experience concerning media attention
Thusfar it is rather quiet in the press.

Involvement of local authorities
Gasunie has strong support from the government and the local authorities today.
Interests of local politicians
Discussions have started regarding how to tax LNG as a truck fuel. LNG in the Netherlands is currently taxed as LPG not as diesel.

Norway
Projects: Lista, Kollsnes, Mosjøen

Main experience from public awareness and concerns
The public often has questions based on their feelings. In general most of the public do not know that different gases have different properties and characteristics. Their general opinion is that gas may explode. In the following the most common questions are listed:

- Is an explosion possible?
- What happens if the gas leaks?
- An LNG - terminal is a good idea but why place it in my backyard?
- Is there not any better location?
- Is there a lot of noise from the terminal?

The experience is that when the public gets to know the properties and the characteristics of LNG their concerns are reduced. Especially the information that LNG warmer than minus 100 degrees is lighter than air and will rise to the atmosphere is important.

Main experience concerning media attention
The media is often positive to LNG because they already know about the environmental benefits in the shipping traffic. Note that in Norway the information of the establishment of the LNG-terminal usually comes after the information that the ship owner has ordered a new ship and the pollution will decrease.

Involvement of local authorities
In Norway the local authorities are involved in giving the building permits and the permit to store and handle dangerous goods. The local authorities usually get a lot of support from the national DSB authority for the dangerous goods permit.

Interests of local politicians
Local politicians are usually positive. They are basically engaged with the following questions:

- Reduce emissions;
- Expand the use of natural gas in Norway (many politicians think that it is wrong to export all the gas and not to use the “clean” energy in Norway. Only 1% of the gas from the North Sea is used in Norway;
- Employment.
Poland
Project: LNG terminal in Swinoujscie

Main experience from public awareness and concerns
During the planning process several meetings were held with the public to inform and to answer questions that the public might have. Most questions were regarding
- LNG plant safety;
- Construction jobs and business opportunities;
- Public health and safety;
- Construction nuisance;
- Impacts on beaches and tourism;
- Fishing, wildlife and environment;
- Overall economic support.

Main experience concerning media attention
All meetings held with the public during the planning stages have been covered by the press.

Involvement of local authorities
The Maritime Office in Szczecin is part in the project as a “sponsor” and is responsible for the construction of the new breakwater.
The Municipality in Swinoujscie is positive to the project that will give around 50 – 60 million PLN annual tax revenues excluding tax revenues from employees on the site. The land designated for the LNG terminal was transferred from the municipality to Ploskie LNG (the terminal operator) in 2009 for the long-term use for the terminal.

Interests of politicians
The LNG terminal project in Swinoujscie is seen as a project of strategic importance for Poland and therefore of high importance for the politicians. The plant has been designated a project of strategic importance and been part of larger development project for the harbour. As such the focus has been on the positive consequences for the area(Poland);
The new breakwater that is to be constructed will be completely financed by the state budget. The building and extending of the LNG infrastructure is in accordance with the Energy Policy of Poland until 2030. In the document Energy Policy of Poland until 2030 (adopted by the Council of Ministers on 10 November 2009) the following primary directions of Polish energy policy are set up:
- To improve energy efficiency;
- To enhance security of fuel and energy supplies;
- To diversify the electricity generation structure by introducing nuclear energy;
- To develop the use of renewable energy sources, including biofuels;
- To develop competitive fuel and energy markets;
- To reduce the environmental impact of the power industry
Sweden
Project: Nynäshamn, Stockholm and Gothenburg

Main experience from public awareness and concerns
The main experience from public awareness and concerns are mostly the same as seen in Norway. The public often has questions based on their feelings. In general most of the public do not know that different gases have different properties and character. Their general opinion is that gas may explode. The most common questions are listed below:

• Is explosion possible?
• What happens if the gas leaks?
• An LNG-terminal is good but why place it in my backyard?
• Is there not any better location?
• Is there a lot of noise from the terminal?
• Why fossil fuel?
• Will the LNG terminal be at terror goal?

When the public gets known with the properties and the characteristics of LNG their concerns are reduced. Especially the information that LNG warmer that minus 100 degrees is lighter than air and will rise to the atmosphere is important.

Main experience concerning media attention
The media is often positive to LNG because they already know about the environmental benefits for the ship traffic. Note that information of the establishment of the LNG-terminal usually comes after the information that the ship owner has ordered a new ship and the pollution will decrease. This was the situation of Stockholm when it was clear that the new Viking Line ferry was ordered.

Involvement of local authorities
The local authorities are involved in giving the building permit and the permit to store and handle dangerous goods. The local authorities usually get a lot of support from the national MSB authority for the dangerous goods permit and the Environmental permit.

Interests of local politicians
Local politicians are basically engaged with the following questions:

• Reduce emissions, but why fossil fuels?
• Safety
• Business development – ie. Will the harbour be more attractive?
• Employment

The United Kingdom
Project: Grain LNG

Main experience from public awareness and concerns
The site of the new facility was converted and enlarged from an existing LNG storage facility to an importation terminal. The area also had a history of petrochemicals since 1950 and the local community therefore were more used to having such plant in the vicinity.
Notwithstanding this Grain LNG have actively informed the local community since 2003 when the construction work began.

**Main experience concerning media attention**
There has generally been positive recognision due to both the declining of the UK continental shelf gas and the lower CO$_2$ impact of gas compared to other carbon based fuels. We have contended with objections from a very small minority using a variety of different media e.g Facebook, internet campaigns etc in a manner that is not consistent with the formal channels that have dealt with majority views.

**Involvement of local authorities**
Planning permission has been needed to construct the site and Medway council have been a positive partner in this process albeit looking to National Grid to be a responsible partner in the construction and operation of the site. As other local heavy industry has shut down we have found the local council supportive of the £1 billion investment made by National Grid.

**Interests of local politicians**
Energy ministers, local members of parliament down to the community council have all been important stakeholders in agreeing what was built on site. Both the local authorities and the politicians have been generally positive recognising the economic benefits the business brings directly or indirectly to the region. Safety and environmental concerns were taken into account throughout the development of the project, that helped to allay their concerns.

**Conclusions and recommendations**
In interviews with the different stakeholders, the following conclusions and recommendations were collected:

- Early and good communications with authorities and public (Norway and Sweden);
- Perform accurate safety analysis – take good time to communicate with public, neighbours and authorities (Norway and Sweden);
- Taking into account safety and environmental concerns throughout the project can help to allay the concerns of local authorities and local politicians (United Kingdom);
- The company to built the infrastructure must behave serious – experience is an advantage (Norway and Sweden);
- The plant has been designated a project of strategic importance and been part of larger development project for the harbour. As such the focus has been on the positive consequences for the area (Poland);
- Important to openly communicate with the public on the advantages of LNG as a fuel. Less emissions, less engine noise etc (Netherlands);
- Generally speaking resistance can be expected in areas where there is a lot of attention in general on harbour development (Finland);
- The media in general have little knowledge of LNG and often confuse LNG and LPG (Finland);
- Environmental issues may be seen as positive regarding LNG for shipping (Finland).