LNG in shipping – Perspectives for regional ports

1 Intro

More and more vessels in the northern European waters are now sailing on liquefied natural gas (LNG), and in a number of European countries there are contracts on many more LNG-powered vessels. The development is mainly caused by new environmental standards on air pollution and CO2 emissions from ships - as well as differences in prices of marine fuel.

The global actions to reduce emissions of greenhouse gasses SOx and NOx in sea transport have led to formation of zones where extra focus is needed. Parts of the Baltics and North Sea have since 2006 been designated as Emission Control Areas (ECA) and Northern Europe and Scandinavia the North Sea and the Baltic Sea will from January 2015 become Sulphur Emission Control Area (SECA). The SECA regulation will imply that the content of sulphur in marine fuels must not exceed at 0.1%.. In 2016 there will be further reductions in the emission of nitrogen oxides (NOx).

The air pollution from ships within the EU area is regulated at a general level by the International Maritime Organization (IMO), the UN maritime organization and the EU regarding the emission standards for the coastal regions.

These environmental standards imply that e.g. owners of ferries on heavy fuel oil (HFO) must invest in exhaust gas cleaning systems or rebuild their motors. The alternative is to shift to fuel with less sulphur e.g. marine gas oil (MGO), but it is more expensive than LNG. Furthermore LNG is considered to be the most cost efficient marine fuel to ensure compliance with future emission requirements.

An alternative to LNG - A"Scrubber"- exhaust gas cleaning system

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Tetraplan A/S
Kronprinsessegade 46 E
1306 København K

Tlf. 33 73 71 00
Fax 33 73 71 01
www.tetraplan.dk

Installation of a "scrubber" can be a technical and as well as cost efficient way of reducing SOx emissions to the requested level on some vessels. "Scrubbers" can clean the exhaust gas and reduces the sulphur oxide content of the exhaust gases by 90 to 95 per cent.
The process is done by drenching the exhaust gas with sea water from spray jets just before the flue. Water and sulphur react to form sulphuric acid, which is neutralised with alkaline components in the sea water. Filters separate particles and oil from the mixture before the cleaned water is given back into the sea.

Therefore there is a growing demand for LNG-powered vessels in Europe. Currently (2014) there are 44 vessels, predominantly ferries, that are LNG-powered and another 34 are in order.

The existing fleet of LNG-powered vessels are dominated by ferries (46%), the rest are platform service vessels, patrol vessels, tugs and other Ro-Pax vessels. A general characteristic for these vessels is that they typically operate in coastal waters or in ECA or SECA zones and therefore are subject to stricter emission standards.

The trend in Europe and worldwide is that more and more ports are investing in LNG-terminals for vessels. This is also a possibility in Denmark. We have a widespread natural gas infrastructure network covering large parts of the country, which makes it possible to setup LNG-terminals for ferries and other vessels in a number of Danish ports

In Denmark the first LNG-powered ferry is expected to go into service in November 2014. Another three LNG-powered vessels are in the order books and a ferry company is considering rebuilding two of their three vessels for LNG operation.

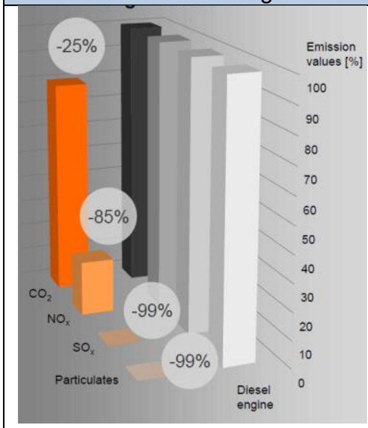
2 Reductions in emissions with LNG propulsion

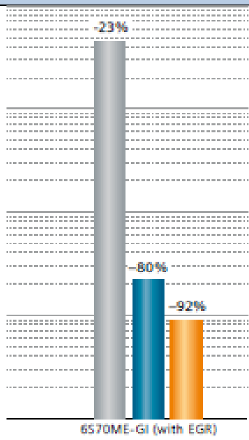
LNG is considered to be the most promising alternative marine fuel. It reduces the harmful emissions significantly and meets all the known emission standards (IMO tier III), without exhaust gas cleaning. The environmental regulations therefore make LNG increasingly competitive to traditional fuels such as Marine Diesel Oil (MDO) and Heavy Fuel Oil (HFO). LNG is also available worldwide at a large scale, and can be distributed to small scale fuel market and the energy efficiency is equal and even better compared to MDO/HFO.

The reductions in emissions compared to HFO are substantial. CO2 emissions are reduced 23-30%. The reductions in NOX emissions are 80-86% and SOX reductions are 92-100%. And there is almost no emission of particulate matter (PM), due to the composition of LNG.

Figure 1 shows examples of the reduction in harmful emissions for 3 different marine engines, 2 dual-fuel and 1 lean burn gas engine. The percentage reduction is compared to a traditional engine propelled by HFO.

Figure 1: Savings in CO2, NOx, SOx and PM from two dual fuelde and one gas engine compared to a traditional HFO engine.





Wärsilä dual-fuel engine	Man Marine dual-fuel engine	Rolls–Royce Bergen lean burn gas engine
• *25% lower CO2* • *85% lower NOX* • *99% lower SOX* • *99% lower PM*	• *23% lower CO2* • *80% lower NOX* • *92% lower SOX* • *Very low PM*	• *30% lower CO2* • *86% lower NOX* • *100% lower SOX* • *98% lower PM*

The fuel MGO is already available with a sulphur content below 0,1% and will be an easy substitute for HFO and MDO. The SECA rules will however increase the demand of MDO and it is suggested that prices will increase of almost 50 %

3 Future LNG vessels[1]

The existing fleet of LNG vessel as of march 2014 is 48. 42 of the vessels are based in Norway, one in Sweden, one in Finland and the last four outside Europe.

There are 53 new LNG vessels confirmed in the order books (March 2014) and they are expected to be delivered between 2014 and 2018. Out of these vessels are 34 Europe based and 23 of these will be based in Norway. The 34 vessels will almost double the European fleet of LNG vessels in the years to come.

The distribution of the 53 new vessels on vessel types is shown in table 1.

Table 1: Types of vessels in the order book

Vessel type	Number	Distribution [%]
Platform supply vessel (PSV)	14	26
Car/passenger ferry	8	15
Container Ship	8	15
Ro-Ro	6	11

[1] Source: Notat LNG-drevne skibe i EU-landene, Dansk Gasteknisk Center a/s, 2014

Liquid Ethylene Gas (LEG) carrier	3	6
Car carrier	2	4
Chemical tanker	2	4
Gas carrier	2	4
General Cargo	2	4
Bulkship	1	2
Icebreaker	1	2
Product tanker	1	2
RoPax	1	2
Tug	1	2
Patrol vessel	1	2
Total	**53**	**100**

4 LNG bunker volumes and energy density

LNG require up to 2.5 / 3 times as much space as MDO for the same amount of energy on board. But forthcoming installations of prismatic and membrane type tanks for LNG as bunker, will lower the volumetric ratio down to 2 times. Table 2 illustrates the volumes and energy density of MDO and LNG.

Table 2: LNG volume and density

Fuel[2]	**LHV (MJ/Kg)**	**Density (Kg/m3)**	**Energy density (MJ/m3)**
MDO	42,7	900	38.430
LNG	54,7	442	24.177
LNG/MDO energy density ratio (same volume) 1,6			

5 Cost of using LNG for propulsion of vessels

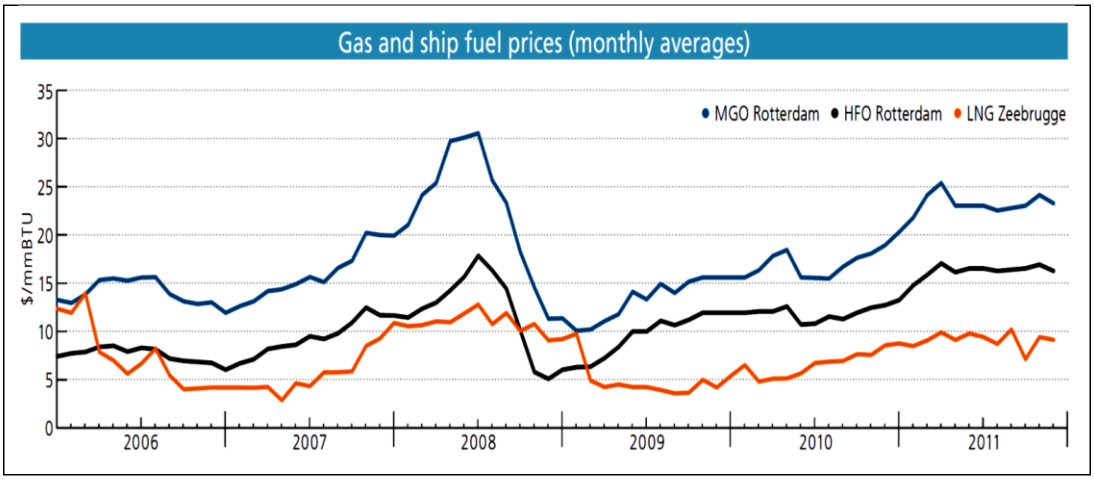
Cost of LNG[3]

LNG is expected to be less costly than marine gas oil (MGO) which will be required to be used within the ECAs if no other technical measures are implemented to reduce the SOx emissions. Current low LNG prices in Europe and the USA suggest that a price – based on energy content – below heavy fuel oil (HFO) seems possible, even when taking into account the small-scale distribution of LNG. Figure 2 shows the development in prices for MGO, HFO and LNG

Figure 2: Development in prices for MGO, HFO and LNG

[2] The use of LNG as fuel for propulsion on board merchant ships, Presentation by Rolls- Royce

[3] Germanisher Lloyd: Costs and benefits of LNG as ship fuel for container vessels - Key results from a GL and MAN joint study



Additional capital cost related to LNG fuel

Compared to vessels fuelled by HFO or MDO there are some additional costs to LNG fuelled vessels. These costs are related to engine, fuel system and the arrangement and structure on the vessel. Table 3 shows the additional costs for 3 different vessel types.

Table 3: costs for 3 different vessel types

Additional cost factor[4]	**Car ferry (5MW / 250m3 LNG)**	**Platform supply vessel (PSV) (8 MW / 200 m3LNG)**	**Ro-Ro (5 MW / 450m3LNG)**
Engines	~3%	~3%	~2%
Fuel system	~4-5%	~2-3%	~5-8%
Arrangement and structure	~2-3%	~3-6%	~2-5%
Total	**~10%**	**~8-12%**	**~9-15%**

The payback period is highly dependent on the ship value and the operating profile. The payback period for new building/retrofitting of our ongoing projects and operating ships is in the range of 2.5 to 5 years5.

The lower energy density and asset specificity to LNG carriers imply that LNG will have higher transportation costs than other fuels. This increase in LNG transportation costs will mainly have impact on prices when LNG needs to be transported for long distances. The increasing LNG propelled vessels for the future means that there will be a large demand on production. It has been suggested that the LNG production might in 2016 through 2018 be too low to meet the demand from the new vessels.

[4] LNG-Fuelled Engines and Fuel Systems for Medium-speed Engines in Maritime Applications, Presentation by Dag Stenersen, MARINTEK
[5] The use of LNG as fuel for propulsion on board merchant ships, Presentation by Rolls- Royce

6 Perspectives for regional ports

LNG as marine fuel will in the near future expand in areas around the English Channel, the North Sea and the Baltic Sea, due to stricter emission standards.

The first vessels to use LNG are ferries, platform service vessels and patrol vessels, but also smaller tankers and cargo vessels for short sea shipping are in order now.

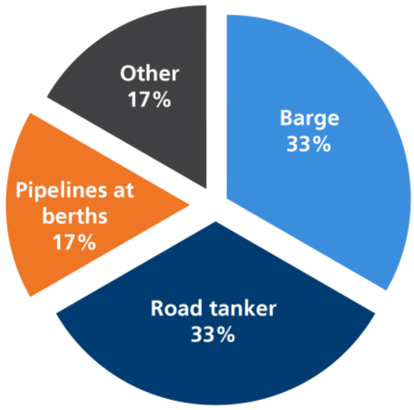
This implies that ports in these waters must invest in LNG bunkering facilities in order to accommodate the LNG powered vessels. At the moment there are only few regional ports with LNG bunkering facilities, and it could be an advantage to invest in LNG bunkering facilities now and start to attract the LNG powered vessels. That will give a head start and offset the competition from other regional ports.

Lloyd's Register's LNG Bunkering Infrastructural Survey 2014

The survey indicates that LNG bunkering is likely to develop fast as global ports get ready for shipping's gas fuelled future.

The survey provides insight into the future of LNG bunkering world-wide as short sea demand grows and the possibility of expansion into bunkering for deep sea emerges.

Therefore lack of infrastructure will not stop Ports delivering gas as bunkering fuel!



What type of bunkering facilities are currently provided/do you plan to provide in your Port for gas fuelled shipping?

LNG bunkering infrastructure

The infrastructure for LNG bunkering is usually costly. Continuous development and improvement means that new alternatives arise; some are less costly, some more permanent and some more sustainable:

- Land based LNG bunkering tank feed by LNG from an LNG bunkering vessel
- Land based LNG bunkering tank feed by trucks with LNG tanks
- Land based LNG bunkering tank feed by LNG production facility e.g. Cryobox, based on natural gas from the natural gas pipelines
- Land based LNG bunkering tank feed by LNG production facility based on gas from a natural gas bunker vessel
- LNG bunkering directly from trucks with LNG tanks

- LNG bunkering directly from LNG bunker barge
- LNG bunkering directly from coastal tankers
- LNG bunkering directly from floating bunkering stations

Cryobox LNG production	***Cryobox*** *is an example of a small scale LNG production facility that allows production close to the users.*
	*The Cryobox can e.g. compress natural gas from pipeline to LNG, for use as marine fuel.* *It is a modular system with plants and tanks:* • *small production plants that are scalable* • *easy and fast installation* • *easy to maintain and operate* • *can be relocated*

Port of Hirtshals - LNG bunkering facility

The Norwegian ferry company Fjord Line establishes together with Liquiline the first commercial LNG bunker facility in Denmark at Port of Hirtshals.

In the initial phase the terminal will have an on-site storage tank with a gross volume of 500m3 and a bunkering solution - having a bunkering capacity of up to 400m3 of LNG per hour. This will enable Fjord Line to bunker its ships within two hours. The ship bunkering terminal is expected to be operational in fourth quarter of 2014

Next phase will be to increase the capacity 20-fold and get an optimal flexibility in bunkering of the Fjord Line ferries, and also be a real player in the LNG bunker market in Scandinavia.

The geographical location of the Port of Hirtshals will offer shipping an option to bunker LNG without major deviations from the route north of Denmark between the North and Baltic Seas. In this way, the port will be attractive for future fleets of LNG-powered vessels. This could also lead the way for new LNG related services at the Port of Hirsthals.

7 Perspectives for services and sub-contractors in the regional ports

Among regional ports there is a large competition and strive for diversification into new business areas. As it appears there might be a potential for several ports to investigate whether their port is appropriate for investing in LNG facilities. Several LNG facilities are targeting a small scale production and handling and might therefore be suitable for regional ports.

A development towards a focus on LNG might give regional ports a first mover advantage that might further develop a business sector around LNG facilities. This could for instance be service providers maintaining the LNG equipment or research and development activities from larger companies. Furthermore, a LNG focus might enable some regional ports to attract LNG propelled vessels. This gives additional port activity and might bring further turnover to the port and region.

It is not predicted that retrofitting from e.g. HFO to LNG will be a large activity that can lead to additional activity at smaller Danish shipyards. As the technology is today, it is generally not economic viable to retrofit vessels to LNG. The new demand for LNG fuel will therefore mainly be from new build vessels.

8 Why LNG?

- LNG is considered to be the most promising alternative marine fuel
- Using LNG as ship fuel – harmful emissions are reduced significantly
- LNG is available worldwide at a large scale, and can be further distributed to small scale fuel market
- Proven engine technologies are available for medium speed natural gas engines, and under development for slow 2-stroke engines
- Energy efficiency is equal and even better compared to MDO/HFO
- LNG fuelled engines are environmental friendly, and meet all the known emission standards (IMO tier III), without exhaust gas cleaning
- Engine R&D are related to part load efficiency, methane slip and gas composition(Methane number)
- LNG is still in an early phase and new technologies will most likely develop and offer even more sustainable alternatives for the future

9 Drivers for supplying LNG at Ports[6]

- Competition – Other competitive bunkering ports along the trade route
- Pricing – Pricing of LNG fuel comparable to alternative fuel options
- Location – Location of the port relative to an ECA
- Traffic – Number of ship calls at the port
- Infrastructure – Provision of infrastructure and facilities for LNG bunkering
- LNG Demand – Demand from ship owners or suppliers for LNG bunkering
- Public opinion – Retain / develop a positive public perception of the port
- Port Significance – Retain / attain the status of the port as a major bunker port

[6] Source: Lloyd's Register LNG Bunkering Infrastructure Survey 2014