Maritime Gas Fuel Logistics

Developing LNG as a clean fuel for ships in the Baltic and North Seas

Report from the MAGALOG project
December 2008

Intelligent Energy Europe

The MAGALOG project partners

Baltic Energy Forum e.V., Germany
City of Swinoujscie, Poland
Gasnor AS, Norway *(Co-ordinator)*
Hordaland Olje og Gass, Norway
MARINTEK, Norsk Marinteknisk Forskningsinstitutt AS, Norway
Stadtwerke Lübeck GmbH, Germany

Indirect partners:

Göteborgs Hamn (Port of Gothenburg)
Stockholms Hamnar (Ports of Stockholm)

The MAGALOG project is supported by The Intelligent Energy Executive Agency on behalf of the European Commission.

Intelligent Energy Europe

MAGALOG - The project

MAGALOG - Maritime Gas Fuel Logistics - is a study project undertaken by six parties in Northern Europe during 2007-2008 for the purpose of developing LNG (Liquefied Natural Gas) as a clean fuel for ships.

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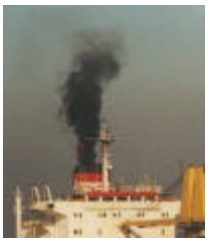
The challenge: Pollution from ships' engine fuels

Pollution with local and regional impacts including health:

- Particulate matter (PM)
- Sulphur oxides (SOx)
- Nitrogen oxides (NOx)
- Volatile organic compounds (VOC)

Climate gas emissions:

- Carbon dioxide (CO_2)
- Methane (CH_4)



Particulate matter (soot).
Photo from IMO.

Onshore pollution have been much reduced in Europe and elsewhere due to tight environmental regulations.

Shipping largely unregulated in the past => Increasing share of pollution

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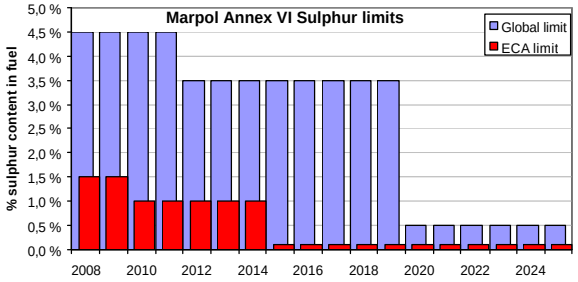
MARPOL: International regulations of pollution from ships

Managed by IMO (International Maritime Organization), under United Nations

Annex VI to MARPOL regulates emissions to air.

October 2008 revision: Tighter future global limits on sulphur; indirect effect on particulate matter

Emission Control Areas (ECAs): Tighter regulations still. Baltic & North Seas



MARPOL limits on sulphur content in marine fuels.

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Baltic & North Seas are the first Emission Control Areas

Tighter limits on emissions than the global MARPOL standards.

Sulphur Emission Control Areas of the Baltic and the North Sea (indicated in shades of blue).

Illustration: Swedish maritime administration.

More waters internationally expected to become ECAs

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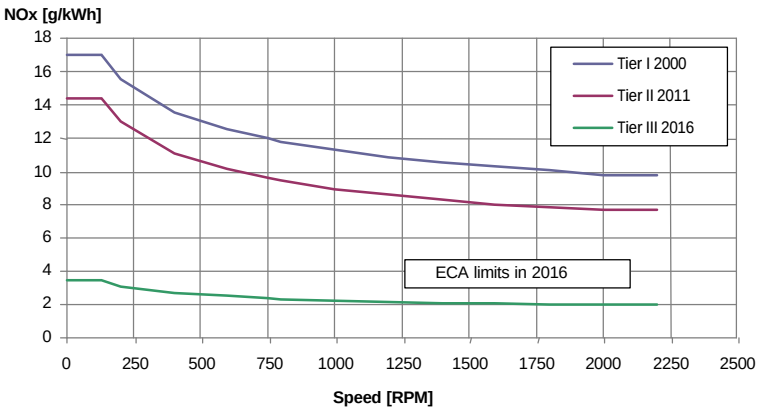
MARPOL: Limitations also on NOx emissions

Defined as function of engine speed



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MARPOL limitations will require much cleaner fuels

Switch to from heavy (residual) bunker oils to distillates widely expected.
LNG (Liquefied Natural Gas) has superior environmental qualities.

Indicated emissions to air from LNG and liquid petroleum fuels for ships

Emissions related to engine output in kWh. Typical medium speed engines built after year 2000 without exhaust cleaning. Emissions vary with fuel quality and engine type.

Fuel type	SOx (g/kWh)	NOx (g/kWh)	PM (g/kWh)	CO2 (g/kWh)
Residual oil 3.5% sulphur	13	9-12	1,5	580-630
Marine diesel oil, 0,5%S	2	8-11	0,25-0,5	580-630
Gasoil, 0.1% sulphur	0,4	8-11	0,15-0,25	580-630
Natural gas (LNG)	**0**	**2**	**~0**	**430-480**

Source: Marintek

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LNG*: Natural gas in liquid form

Can be stored & transported in tanks rather than pipelines

*LNG: Liquefied Natural Gas

- Cooled to -162ºC
- Stored in highly insulated tanks
- A common way of transporting natural gas in long distance shipping trade
- No less safe than other fuels.

LNG tanker ship arriving at a discharge terminal

Photo: Roar Lindefjeld / StatoilHydro

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LNG is used in Norwegian coastal shipping since 2000

Significant reductions of pollution - Excellent operating and safety record

LNG fuelled coastal car ferry "Bergensfjord" (built 2007)

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LNG as fuel for ships: Feasibility proven in Norway

Applied for an increasing number & variety of ships since 2000

Offshore supply vessels

RoRo-vessels on order

Coast guard vessels (2009 deliveries)

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Technical capabilities developed

Rolls-Royce Bergen KVGS-G4 reciprocating gas engine used in car ferries

LNG bunkering of ferry from tanker truck

Regulations for constructing and operating LNG fuelled ships have been developed by the Norwegian shipping authority. Worldwide adaption by IMO in preparation.

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LNG for ships currently supplied from small production plants in Western Norway

Small scale LNG production plants at Kollsnes, near Bergen, Norway. Annual capacity 120.000 tonnes LNG.

Future LNG supplies likely via large European LNG teminals

Large scale LNG terminals; existing and in construction as of 2008.
(Capacity several million tonnes/year each)

- *Import terminal*
- *Export terminal*

LNG tanker discharging at the Zeebrugge terminal, Belgium.
Photo from Fluxys

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What types of ships are suited to using LNG ?

⇒ In principle, any ship.

⇒ Initial logistical constraints: Focus first on ships in scheduled, stable trade within limited geographical range.

⇒ MAGALOG chose to focus on certain such segments of shipping:

- ✓ RoRo ships (Roll on, roll off)
- ✓ RoPax ships (Rolling cargo and passengers)
- ✓ Super-fast RoPax ships

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The shipping segments considered for LNG

RoRo vessel

RoPax vessel

Super fast RoPax vessel

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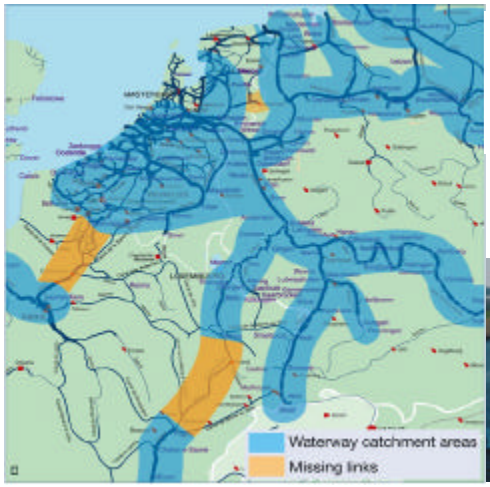
Inland navigation is also potentially suited to LNG as fuel



The Rhine Corridor of European inland waterways.

Map and photo: INE
www.inlandnavigation.org

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The selected shipping segments are large consumers of fuel in Northern Europe

Annual bunker fuel consumption, RoRo and RoPax shipping
Baltic and North Seas. Tonnes, 2007.

	North Sea	Baltic Sea	Total
RoRo ships	557 000	645 000	1 202 000
RoPax and super fast ships	719 000	1 185 000	1 904 000
Total	1 276 000	1 830 000	3 106 000

The fuel consumption in each sea is estimated to represent the fuel burned by ships while sailing on that sea regardless of the voyage port of origin and destination.

Trend in fuel consumption quantity: ~ Stable.
(Increasing cargo volume offset by increasing efficiency)

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LNG provides a large potential for reduced emissions from ships' fuel

Tonnes per year reduction	SOx	NOx	PM	GHG *)
LNG vs conventional bunker fuel	215 000	140 000	25 000	1 million

Indicated reductions of air emissions resulting from full conversion of RoRo, RoPax and super fast vessels to LNG in the Baltic and North Seas.

****) GHG: Greenhouse gases expressed in tonnes CO2 equivalent***

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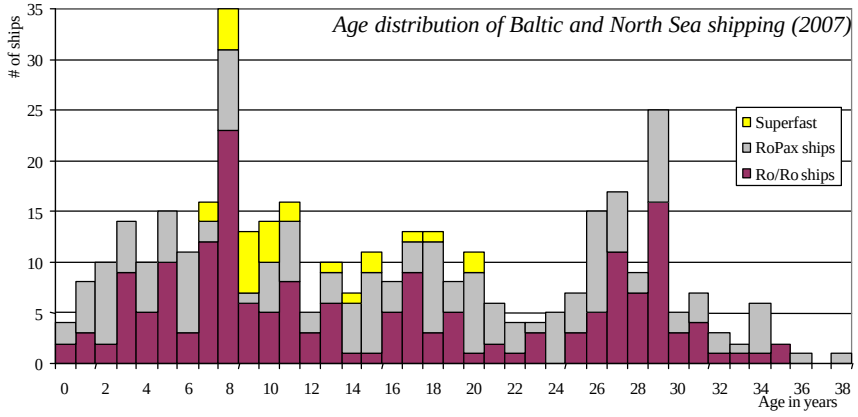
Fleet age distribution determines potential rate of introduction for LNG



Normal service life of ships in Europe: ~ 30 years
Converting existing ships to LNG fuel not likely to be common

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Making LNG available: The required supply arrangements

1. LNG sourcing

Small scale production or from large terminals

2. Transport to bunkering port *by ship or truck*

3. Bunkering terminal

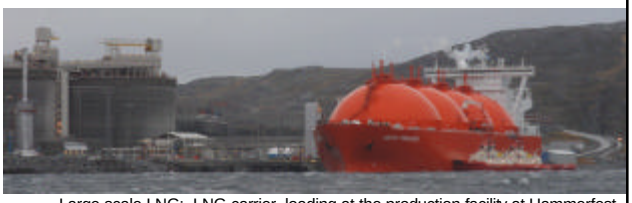
4. Bunkering operation *from line, barge or truck*

LNG sourcing: Small or large scale

Present LNG sourcing:
Small scale production in Norway.
Suited to limited volumes, short range

Small scale LNG: Gasnor's LNG plant at Kollsnes, Norway (120.000 tonnes/year capacity)

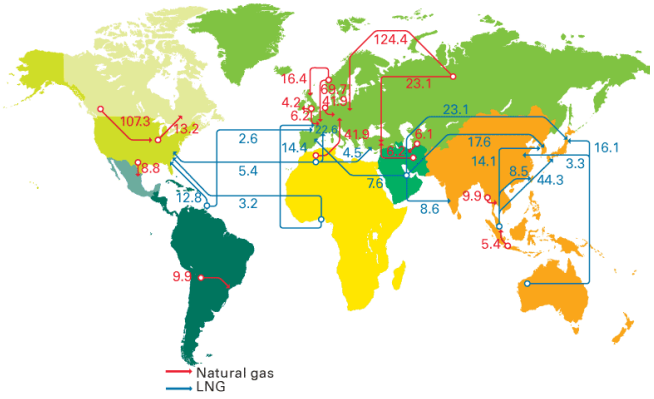
Future LNG sourcing:
Large export or import terminals.
Part of the global LNG trade.
More cost effective with large volumes



Large scale LNG: LNG carrier loading at the production facility at Hammerfest, Norway (4.1 million tonnes/year capacity). *Photo: StatoilHydro*

LNG is a globally traded commodity

Large volumes can be obtained if required



Major trade movements of natural gas, 2007.

Billion cubic metres.

Source: BP

Fuelling the entire Baltic+North Sea RoRo and RoPax fleet would require 5% of European annual LNG imports.

Small scale LNG: 3 Norwegian production sites

And another, 300.000 t/y plant from 2010

Small LNG production plants in Norway.

- Tjeldbergodden: 15.000 tonnes/year (StatoilHydro)
  Truck loading only
- Kollsnes: 80.000+40.000 tonnes/year (Gasnor)
  Ship+truck loading
- Karmøy: 20.000 tonnes/year (Gasnor)
  Truck loading only

In construction - operational 2010:

- Risavika: 300.000 ronnes/year (Skangass)
  Ship+truck loading

Small scale LNG supplied to ships, industries, general onshore uses.
Distribution by ship & truck to small terminals.

Obtaining the gas: Feedstock cost

⇒ LNG supplier must procure gas,
either as feedstock for small scale LNG production
or as LNG from a large terminal.

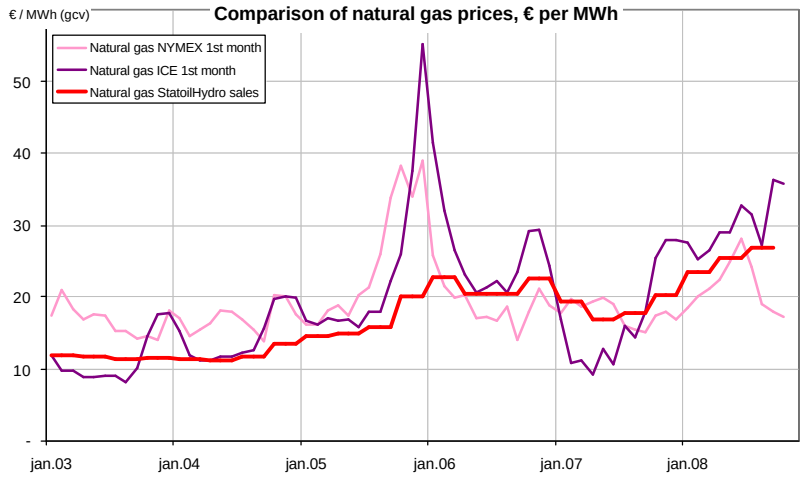
⇒ Cost of gas must ultimately be recovered in LNG supply price to customer.

⇒ Cost of gas (market price) varies broadly with price of crude oil and refined petroleum products.

⇒ Long term supply contracting is common and appropriate.

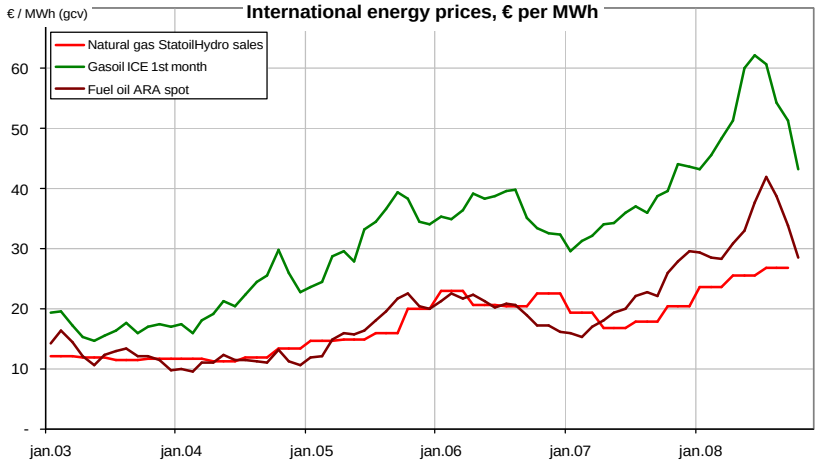
Some market prices for natural gas are observable in public

NYMEX and ICE are for futures trading. StatoilHydro average price mostly reflects long term trade.



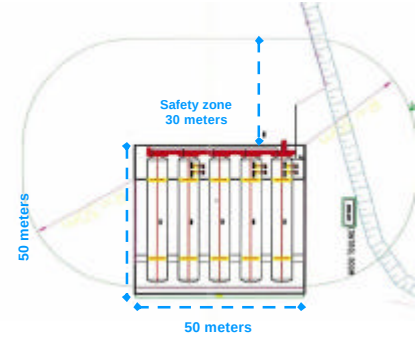
Natural gas in bulk trade is usually cheaper than oil

Significant transport & distribution costs must be added



A proposed lay-out for LNG tank farm of a terminal

Shown here with pressurised removable tanks.
Larger atmospheric, stationary tanks can also be considered depending on local conditions.

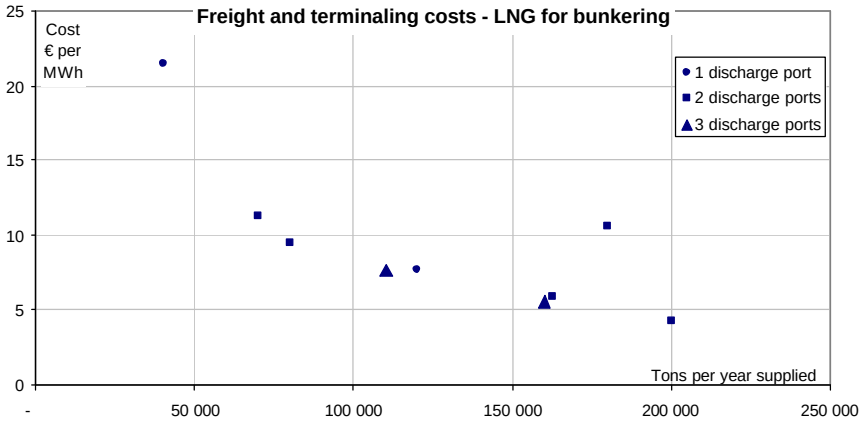


Standard terminal lay-out with five 700m3 storage tanks.

An existing terminal with similar tank configuration. Vertical structures at the back/right are evaporators to regasify the LNG. (Mosjøen, Norway)

A terminal can serve LNG for bunkering as well as supplying local needs by pipeline.

LNG freight and terminalling costs highly dependent on volumes and port locations



Each spot reflects MAGALOG's model estimation of optimal freight + terminalling costs for the indicated quantity at one or several discharge ports in the Baltic or North Sea.

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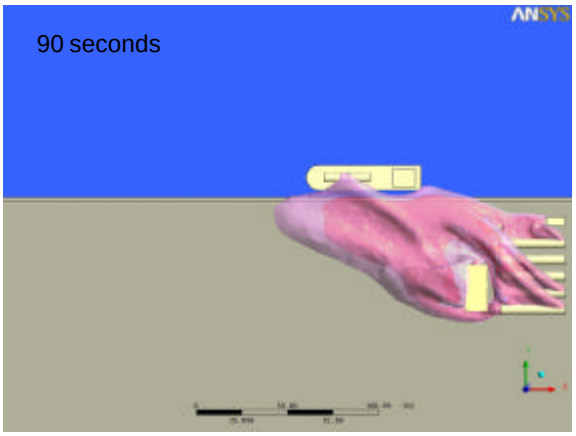
LNG leakage simulation

⇒ A 4000 kg leak shown to dissipate within 200 seconds under certain conditions.
⇒ LNG evaporates to natural gas (mainly methane); lighter than air at > -110ºC
⇒ LNG (natural gas) is harder to ignite than most liquid fuels
⇒ Safe design & operational standards are well established



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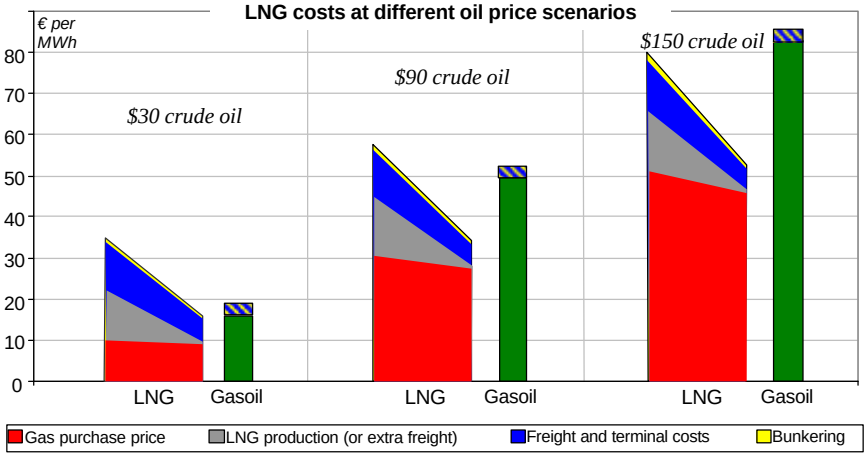
LNG can be cost competitive against distillates for ships

⇒ High oil prices tend to make LNG more competitive
⇒ Scale & efficiency of supply system should improve LNG competitiveness over time



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The MAGALOG Project conducted studies of 5 ports as candidates for LNG bunkering

Future LNG bunkering port: BERGEN (Norway)

Photo: Bergen Tourist Board / Jan M. Lilleb ø

LNG bunkering already established at perimeter locations of the port district (Ferries, offshore supply vessels).

Potential for RoRo bunkering of LNG

Bunkering planned at central port location

RoPax segment in decline.

Large cruise vessel destination causing air pollution (photo)

Future LNG bunkering port: GOTHENBURG (Sweden)

Large exporter of cars & other manufactures.

Receives large, intercontinental container vessel.

20 regular RoRo & RoPax vessels

Local ferries etc also possible users of LNG

Suitable LNG terminal location identified at outer perimeter of port

Image: Gothenburg's outer port. This part of the port includes a car terminal, container terminal, RoRo terminal and 2 nearby oil terminals. *Photo from Port of Göteborg*

Future LNG bunkering port: LÜBECK (Germany)

Skandinavienkai at Travemünde, near the Trave river mouth. It is the busiest among several ports on the river between Travemünde and Lübeck (upstream).

Port area covering Lübeck (20km upriver) to Travemünde (on coast).

Major German import/export harbour; paper from Scandinavia is a major commodity.

36 RoRo and RoPax ships identified to call regularly.

Increasing trends towards RoRo (trailer) traffic.

Alternative LNG terminal locations identified; evaluations continued by MAGALOG partners.

Back-up city gas supply is a potential added benefit of LNG

Future LNG bunkering port: Swinoujscie (Poland)

RoPax and RoRo vessels at Swinoujscie ferry terminal, near the Swina river mouth.
The port of Szczecin is located 60 km upriver.

Photo: www.port.szczecin.pl

Swinoujscie is located on the Baltic coast; joint port administration with Szczecin (upriver).

7 identified regular RoRo and RoPax vessels; increasing cargo trend. Also several scheduled container feeders.

Local ferries may be candidates for LNG use.

Large LNG import terminal planned at Swinoujscie, may facilitate logistics.

2 alternative locations for small bunkering terminal identified.

Future LNG bunkering port: STOCKHOLM (Sweden)

Redevelopments are planned at the central Värtan port (above) and for new RoRo/container facilities at Nynäshamn (below)

Photo and illustration: Stockholms Hamnar

Port administration covers central Stockholm, Nynäshamn (60km South) and Kappelskär (90km North)

29 regular RoRo and RoPax vessels (mainly RoPax across the Baltic)

Major expansion for RoRo and containers planned at Nynäshamn

LNG import terminal also planned at Nynäshamn

City interest in increasing biogas use as local transport fuel; may be supported by LNG availability

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1. Solutions for LNG bunkering for ships are identified and prepared in all targeted ports.
2. In Gothenburg, Stockholm and Lübeck, initial users are identified as well as bunkering locations.
3. Swinoujscie may offer future supply of LNG from the planned large scale LNG import terminal.
4. In Bergen LNG bunkering is in operation, and has room to expand.
5. In the Baltic and North Sea new IMO limits of SOx and NOx emissions from 2016 will make LNG as bunker fuel highly relevant and probably competitive, particularly with high oil prices and when LNG use has reached a substantial volume.

Continued ...

MAGALOG Project Summary

... Continued

6. The long term potential for LNG as bunker fuel for RoRo and RoPax shipping in the region is around 3 million tons per year.
7. Technical solutions are available and demonstrated.
8. A degree of supportive public involvement is likely to be needed, particularly for the establishment of suitable LNG terminals at bunkering ports.
9. LNG-fuelled ships are the strongest available tool for reducing air pollution in the Baltic Sea and the North Sea.