For hvilke fartøygrupper er LNG aktuelt?

- Teknologisk status og kritiske faktorer
- Dual fuel eller ren gass – fordeler og ulemper

Harald Ellingsen, professor NTNU

Teknologikonferanse 2011

Gass som energibærer i fiskeflåten

13. Oktober 2011, hotell Radisson BLU, Ålesund

Presentation outline

- Background
  - Environmental challenges and emission restrictions at sea
  - Need for alternative fuels (to replace HFO)
- Natural Gas fueled marine engines
- LNG as a solution to environmental challenges in shipping
- Propulsion systems and onboard LNG fuel systems
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- Summary and conclusions

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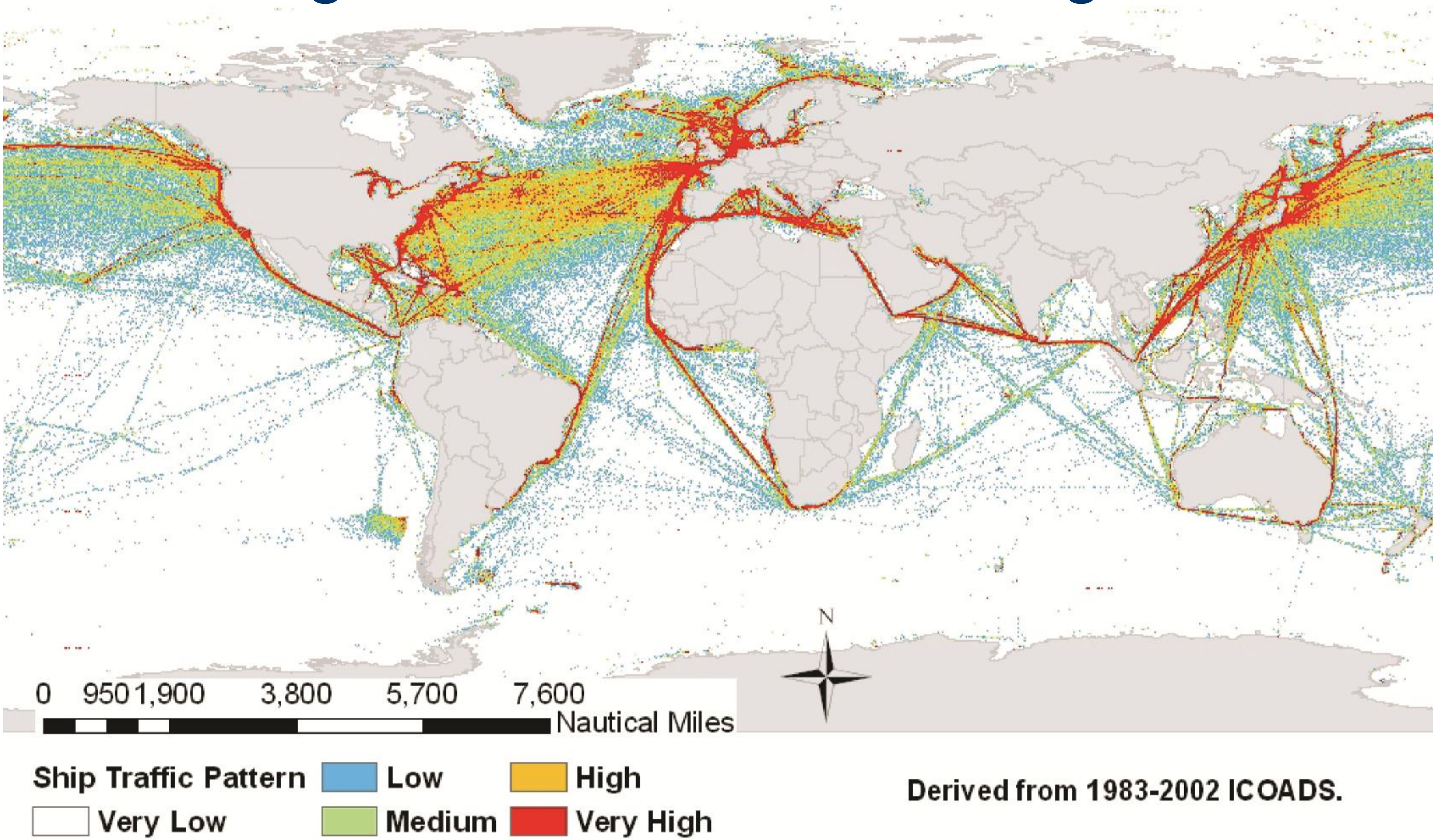
Global shipping – Regional and local challenges

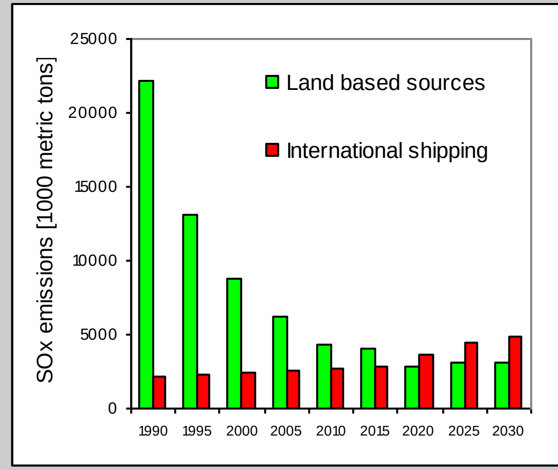


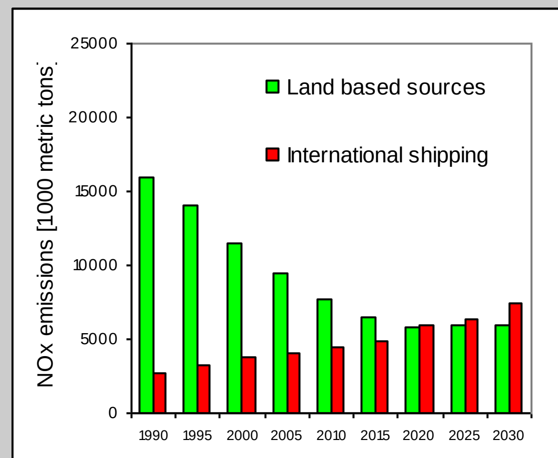
Harmful emissions

Pollutions from ships

- NOx
- SOx
- VOC
- PM
- Micro organism in ballast water
- Oil and chemical spill
- …

Prognoses from EC

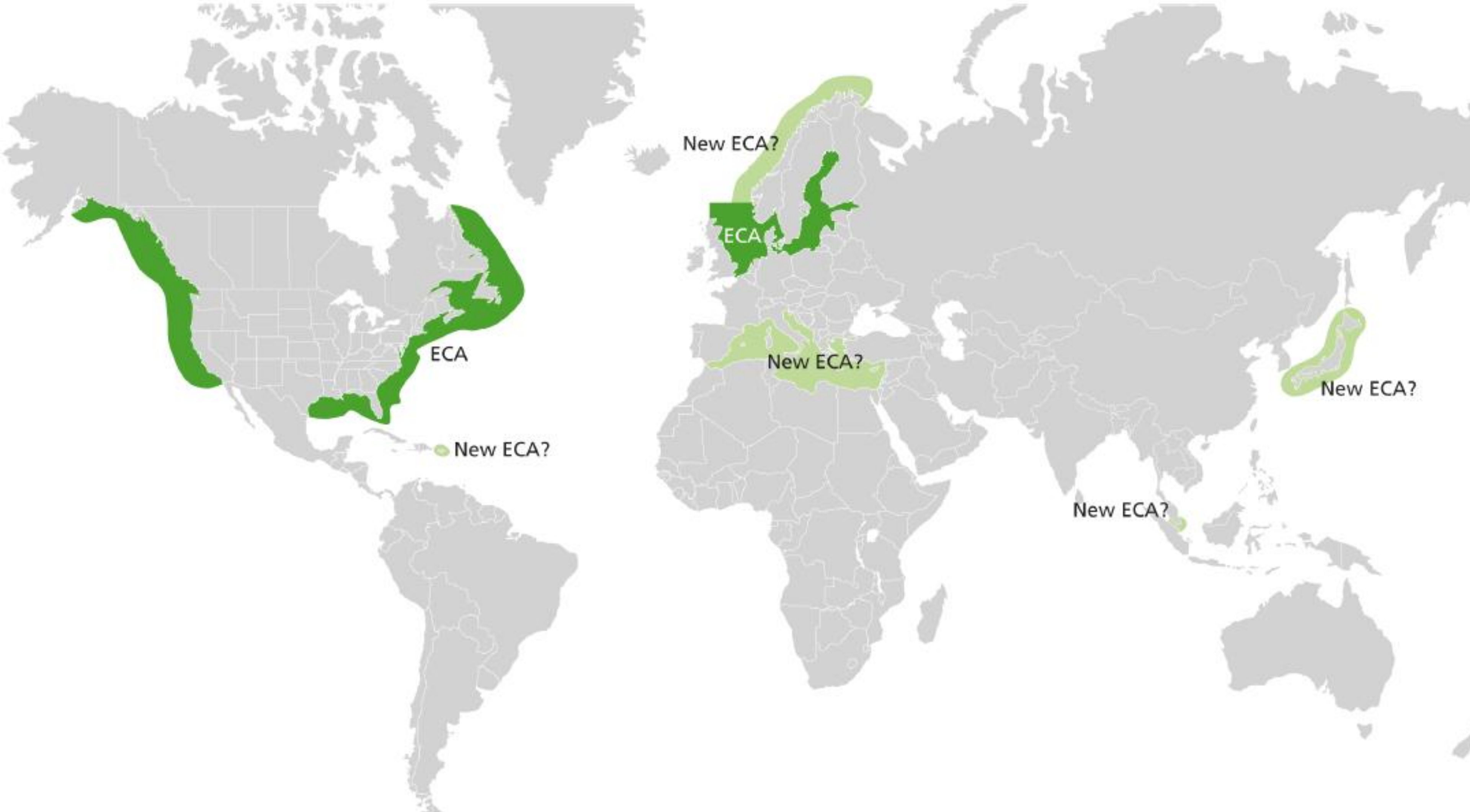




Harmful emissions to air is a major challenge

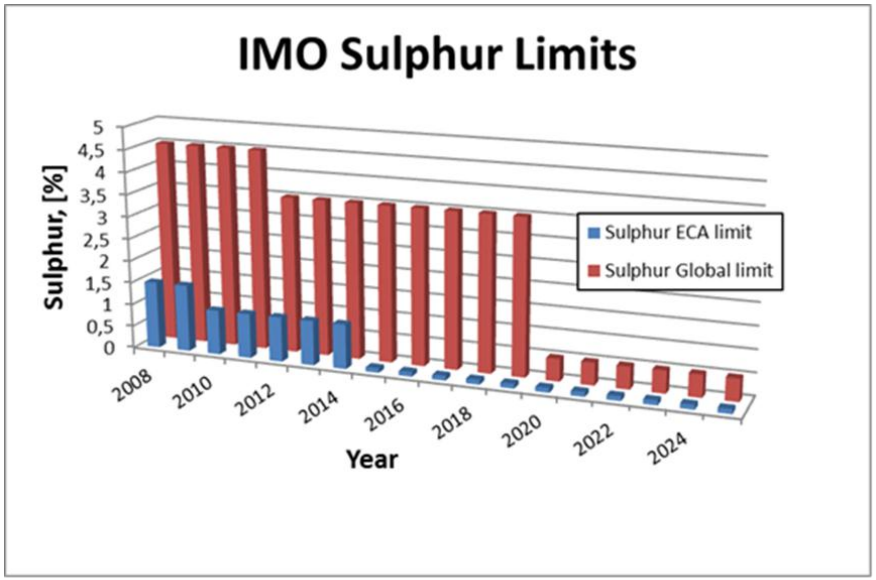
New stricter limitation on sulphur and NOx agreed in IMO

Emission Control Areas (ECA)



IMO MARPOL Annex VI - SOx emission limits

Stricter IMO limitation on SOx



Global sulphur limitations

- Global cap from 4,5% to 3,5% effective from 1. January 2012
- Global cap from 3,5% to 0,5% effective from 1. January 2020

SECA (Sulphur Emission Control Area) limitations*

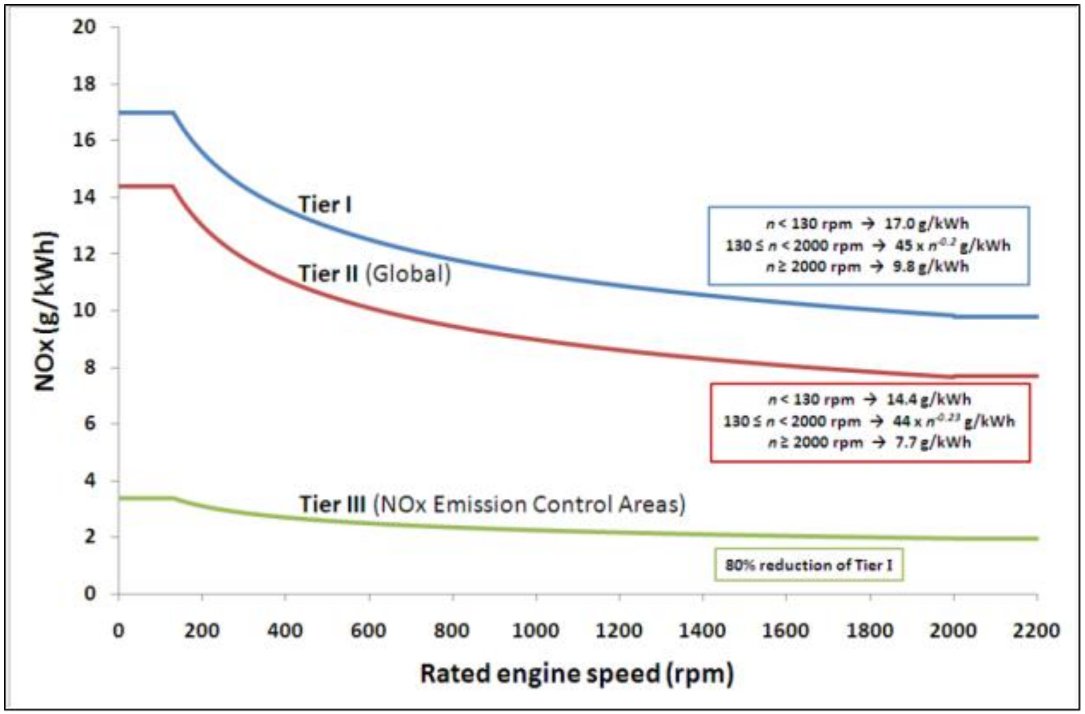
- New sulphur limit from 1,5% to 1,0 % effective from 1. March 2010
- New sulphur limit from 1,0% to 0,1 % effective from 1. January 2015

PM (Particulate Matter) regulated indirectly by the sulphur reduction

*(SECA=ECA)

IMO requirements to prevent pollution from ships

IMO MARPOL Annex VI - NOx emission limits



Global NOx limitations

- Tier II ⇒ 20% reduction of Tier I limit for new ships after 1. January 2011

Emission Control Area (ECA)

From 1. January 2016

- NOx Tier III ⇒ 80% reduction from Tier I limit (new ships)

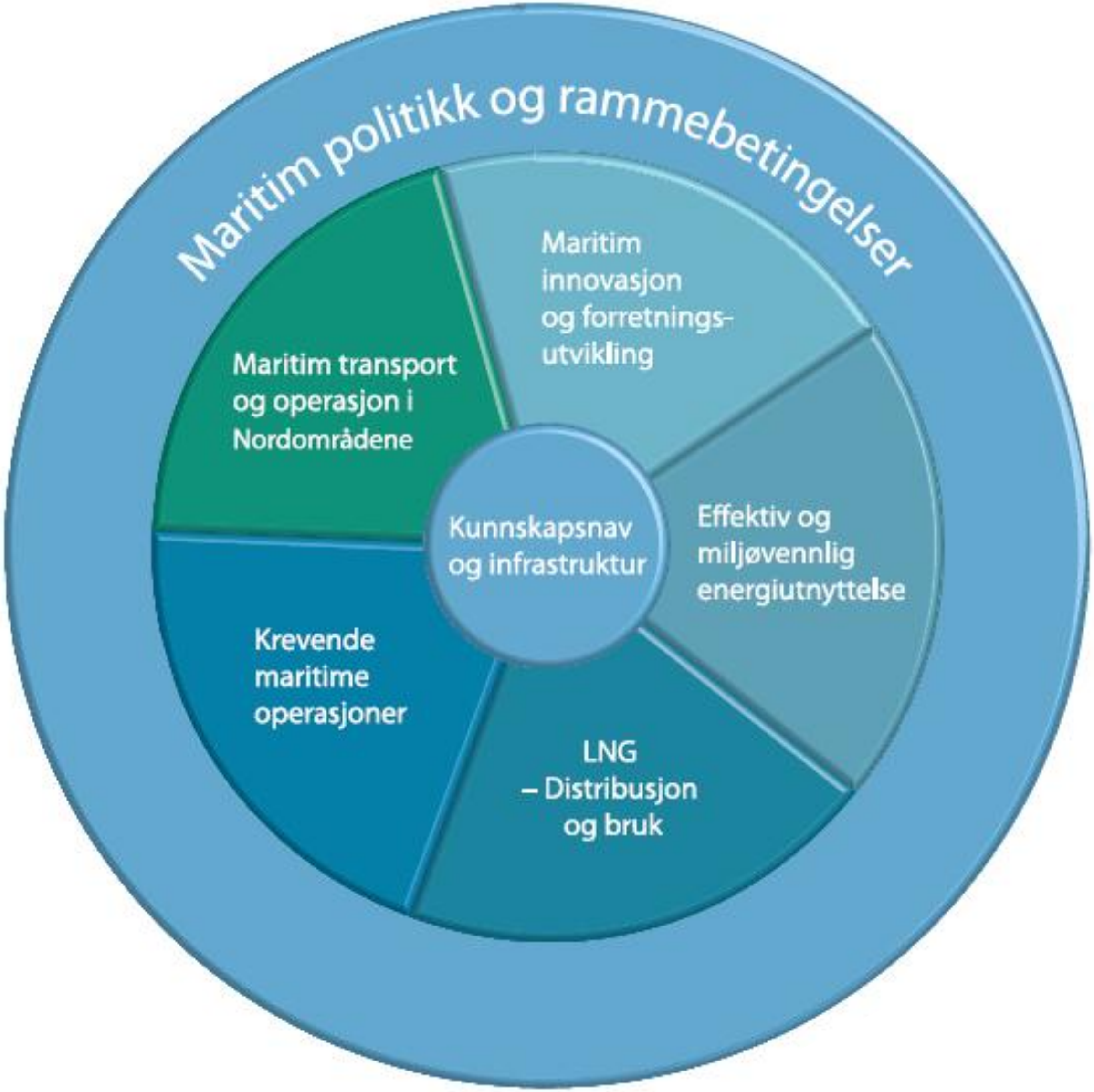
MARITIM 21

En helhetlig maritim forsknings- og innovasjonsstrategi for det 21. århundre

NÆRINGS- OG HANDELSDEPARTEMENTET

MARUT
maritim utvikling

Prioriterte innsatsområder



LNG – distribusjon og bruk

Mål for 2020

- 30 % av norsk nærskipsflåte er gassdrevet
- Kompetanse og erfaring på LNG utvikling, drift og distribusjon som egen eksportvare

Anbefalinger

- Aktiv formidling og økt allmennkunnskap om LNG
- Identifisere markeder som er best egnet til LNG som drivstoff.
- Påvirke internasjonalt regelverk som ivaretar sikkerhet og miljø
- Spesifikt forskningsprogram innen LNG som drivstoff:

LNG – distribusjon og bruk

Forskningsområder

- LNG hoved- og hjelpemaskineri
- LNG bunkringssystem, også skip-skip
- Lagring av LNG ombord på skip
- Transport og distribusjon av LNG
- Storskala demonstrasjonsprosjekt som dekker hele LNG kjeden

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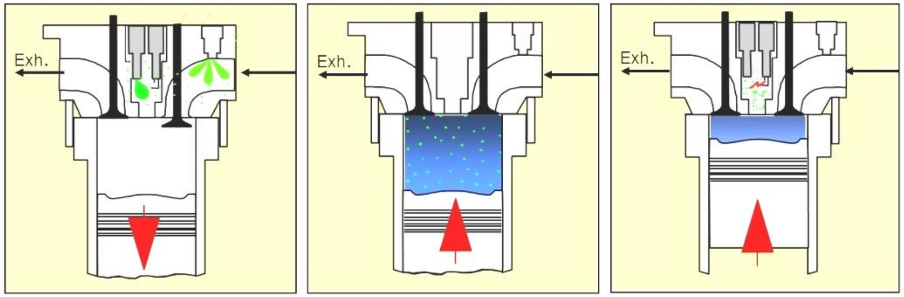
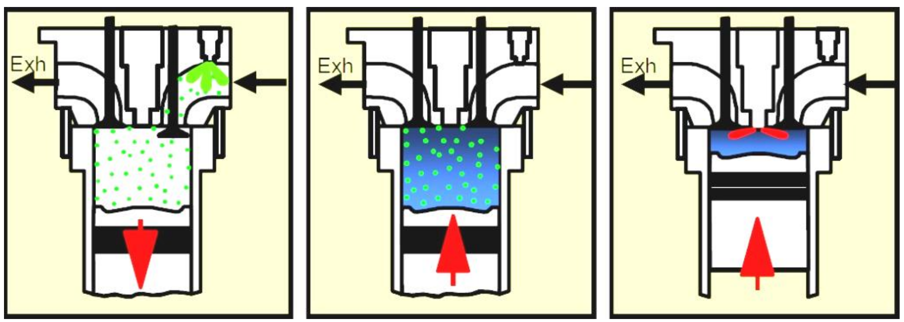
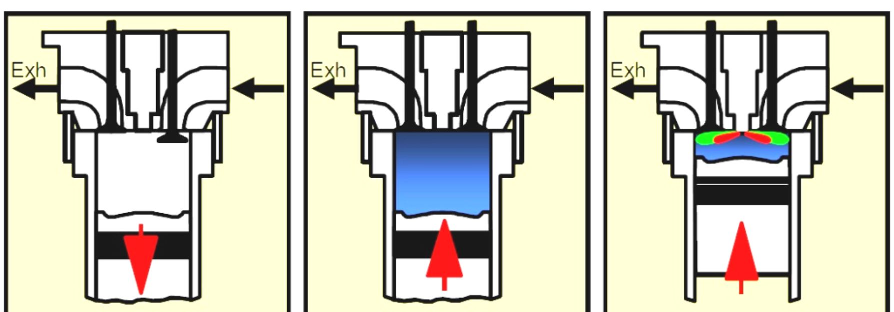
Gas fuelled marine engine concepts



LEAN BURN SPARK IGNITED ENGINE (LBSI)



DUAL FUEL GAS ENGINE (DF) – PILOT DIESEL IGNITION

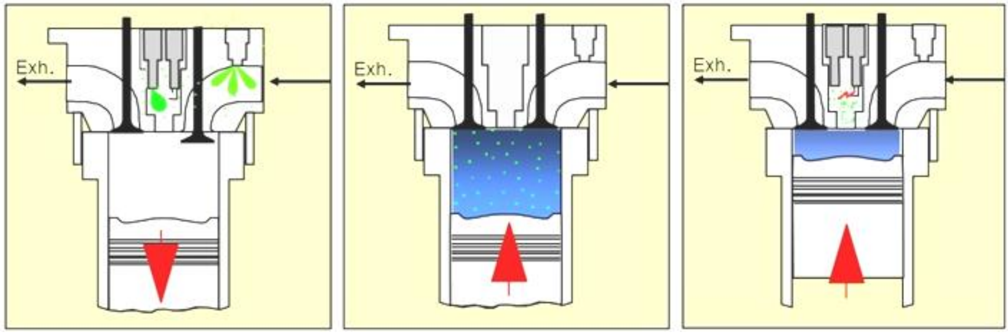


High pressure gas injection - “Gas Diesel engine” –(GD)

Spark Ignited Lean Burn gas engine (LBSI)

- Single fuel LNG, low pressure gas supply (4-5 bar)
- High energy efficiency at high load, higher than the corresponding diesel engine
- Low emissions, meets IMO tire III
- GHG reduction potential in the range of 20-25% ref. to HFO (incl. methane)

- Challenge on methane slip, minimized by design and combustion process control
- Sensitive to gas quality (Methane Number)
- Not suitable for retrofit of existing engines



Rolls-Royce C26:33L9

Operating characteristics (Lean Burn gas engine)

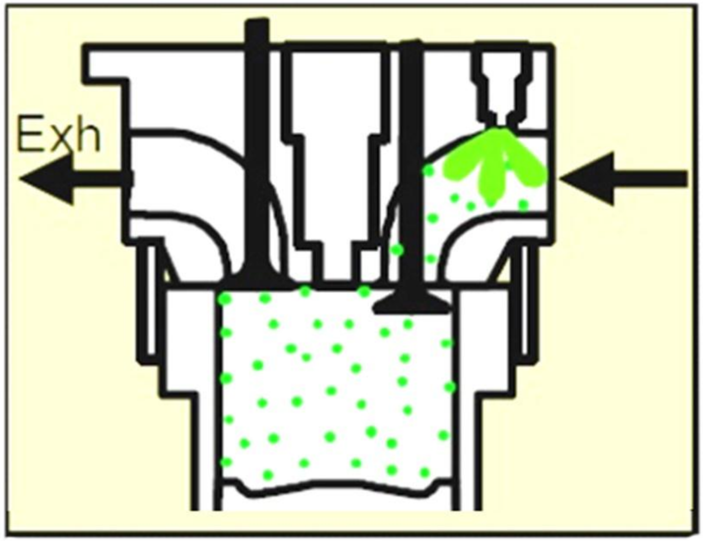
- S. I. lean-burn gas engines can take load pick up in the same range as the diesel engine counterpart
- The S.I. Lean-burn gas engines can run with fixed speed or variable speed, meaning generator load or propeller load.
- The energy efficiency can be in the same range as the diesel engine counterpart at the same time as the emissions (NOx) are kept low over the whole load range

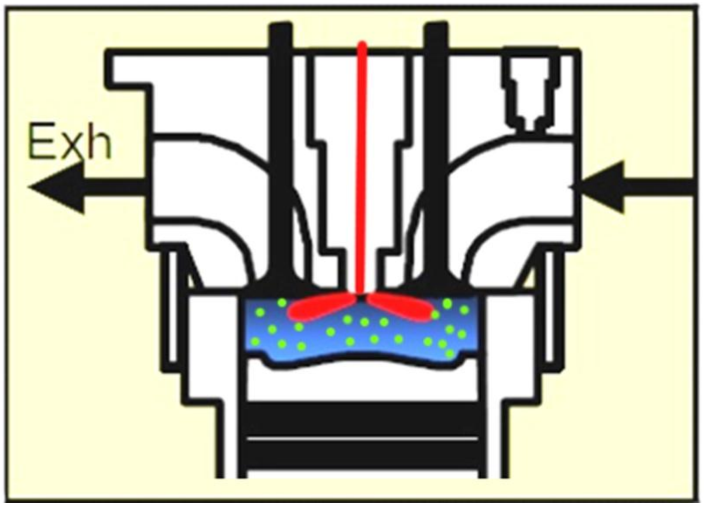

"Bergensfjord" In service January 2007
BERGENSFJORD
Fjord1
Fylkesbaatane

Dual-Fuel engine (DF)

- Dual fuel capability (NG or MDO)
- Low gas pressure supply (4-5 bar)
- High energy efficiency at high load
- Low emissions, meets IMO tire III
- Flexibility in fuel mix
- GHG reduction potential in the range of 20-25% ref. to HFO (reduction is dependent on level of methane slip)

- Challenge on methane slip, limited possibility to combustion process control
- Sensitive to gas quality (Methane Number)
- Possible for conversion of existing engines (extensive rebuilding)





Wärtsilä 6L50DF

Micro Pilot Dual Fuel concept
Ship application

- Flexibility in fuel
- Diesel oil as back up fuel in natural gas operation
- Switch to pure diesel oil operation at low load (switch point: 15% engine load)
- Manoeuvring in diesel oil mode

Gas fuelled ships (LNG)

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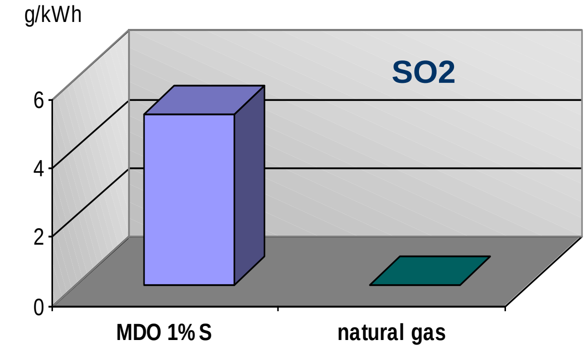
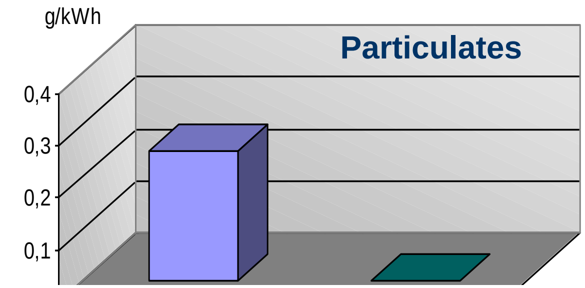
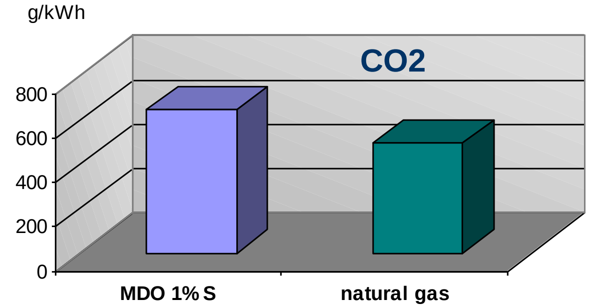
Exhaust emission - Natural gas vs MDO

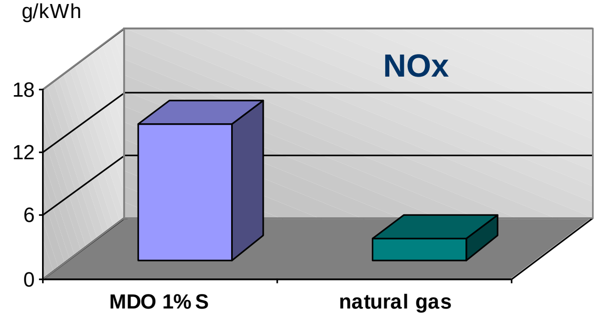
- Sulphur emission is eliminated
- Particulate matters is close to zero
- CO_2 is reduced by 26%
  Due to unburned methane the net reduction of greenhouse gases are in the range of 0% -15% for sailing ships today
- NOx is reduced by 80-90%

Source: Rolls-Royce Marine









Climate impact, methane slip

- Lean burn gas engines emit un-burned hydrocarbons (methane) from the engine exhaust which is a GHG
- This is related to low flame temperatures when burning a lean gas/air mixture, which keeps NOx emissions low but tends to create quenching zones. Un-combusted gas from these quenching zones ends up as hydrocarbons (mainly methane) in the exhaust.

- Net GHG reduction potential with **best available technology** is 15-20% with LNG versus MDO operation, (including CO2 and methane).

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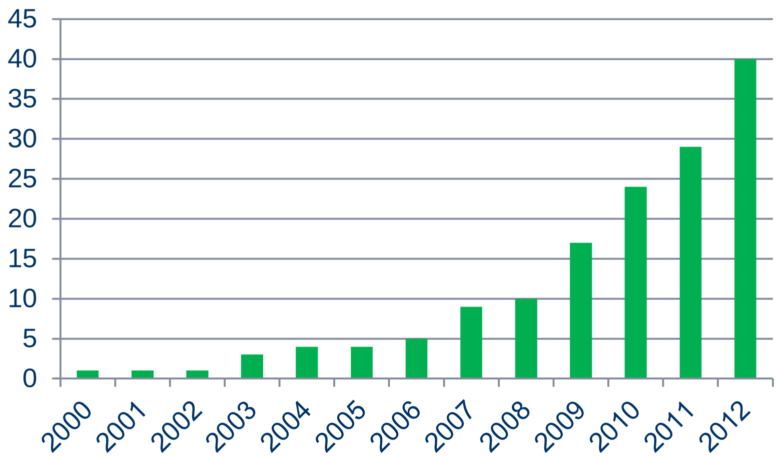
LNG powered ship design

26 LNG propelled ships in operation:

- Ferries (15)
- Offshore support vessels (5)
- Coast guard vessels (3)
- Product tanker (1)
- LNG tanker (2)

15 LNG propelled ships under construction

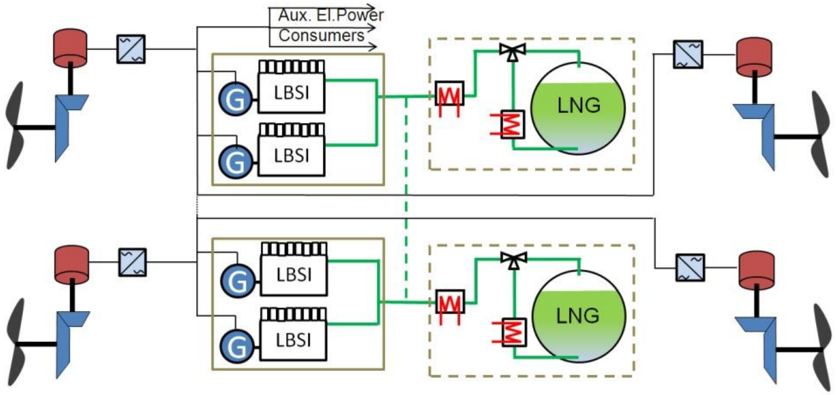
More than 40 LNG fuelled ships by 2012

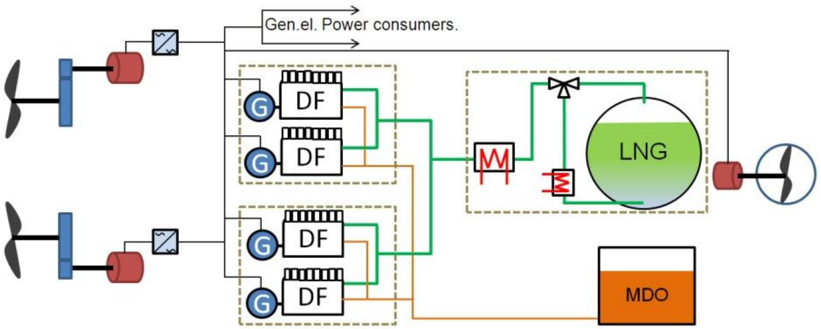


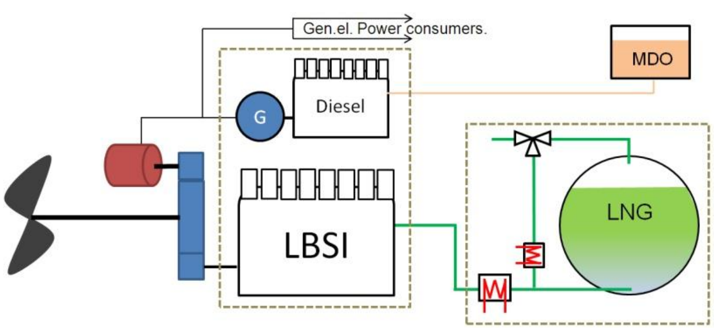
Fiskefartøy på forprosjektstadiet

- Flere prosjekt 2005-2006 (Innovasjon Norge, FHF, Forskningsrådet)
  - Skipsteknisk
  - Wärtsilä
  - GasNor
  - Lie-gruppen
  - Ivan Ulsund
  - Midøy Fiskeriselskap
  - Roaldsnes
  - SB Verksted
  - SINTEF Fiskeri og havbruk/MARINTEK
- Søknad om nye prosjekt hos NOx-fondet i dag

Propulsion system arrangements and fuel systems







Electric drive vs mechanical drive

All the LNG fuelled ships in operation are using electric drive

Development or adaptation of mechanical drive for ship application is a necessity for a cost efficient solution

Impact on ship design

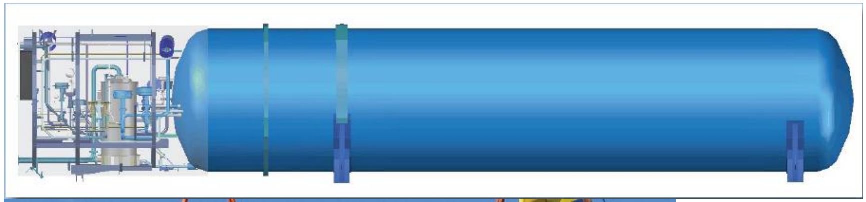
- Fuel storage and distribution
- Fuel bunkering and operational issues
- Machinery systems and arrangement
- Rules and regulations and safety issues

Impact on ship design, cont.

Fuel storage and distribution, fuel bunkering

- Gas storage tank and piping according to IMO guidelines for gas fuelled ships, and classification rules

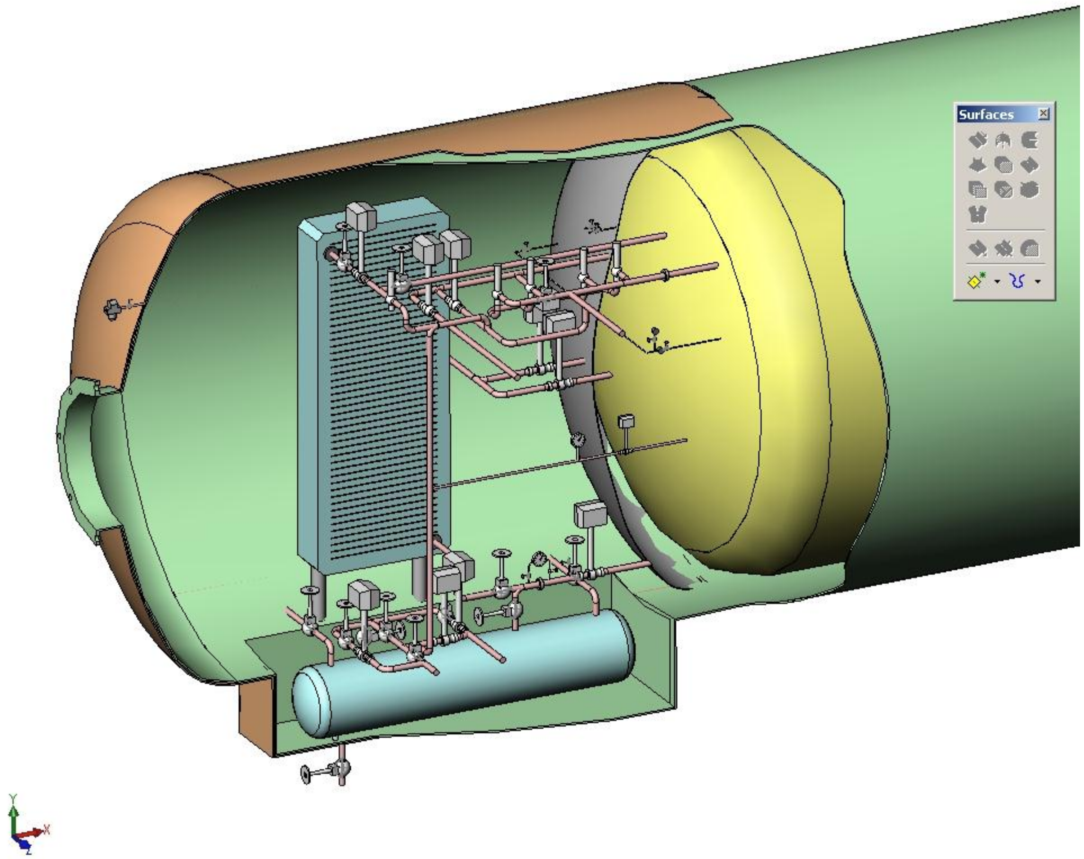
- The LNG Fuel System includes:
  - One or two LNG Fuel Tanks.
  - A Vaporizer unit for vaporization of the LNG to gaseous natural gas.
  - A Pressure build up unit for regulation of tank pressure.
  - Bunker station with filling and vapour return connection.
  - Piping for bunkering and delivery of natural gas to the engines.

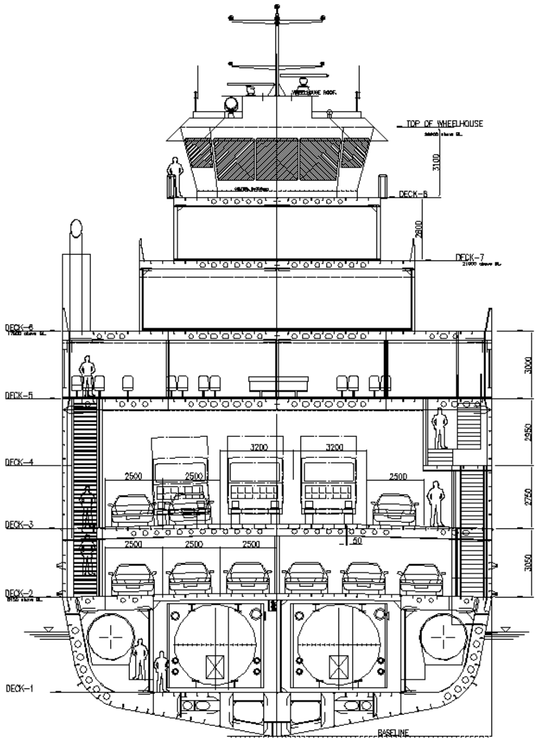


Ref.: Linde Cryo

LNG storage vacuum isolated pressure tank

Outer tank as secondary barrier (low temperature material)
Integrated cold box extension of the outer tank



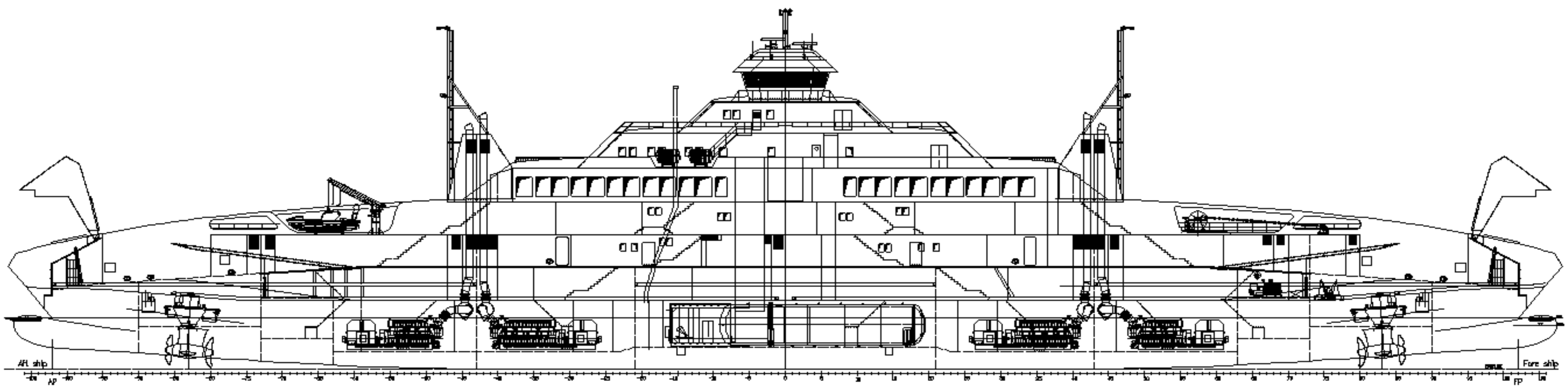


MID SECTION
(SEEN FROM AFT)

LNG ferry Bergensfjord

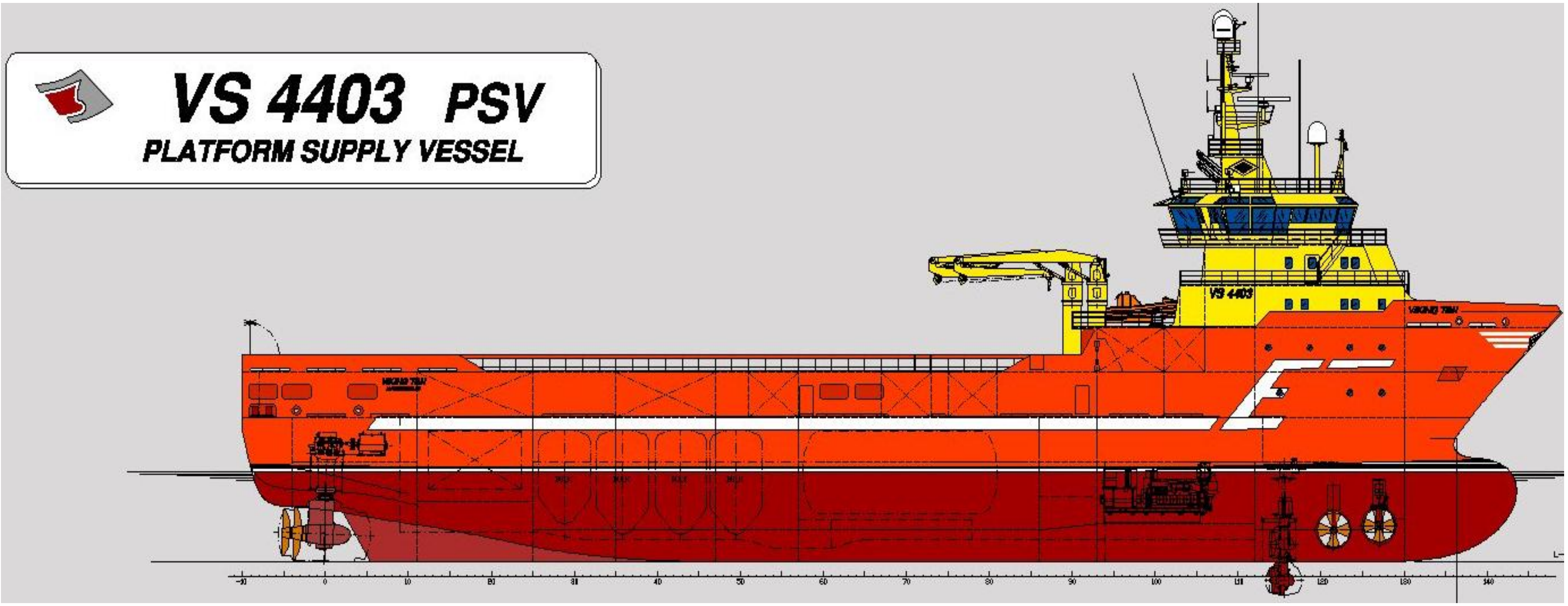
Main dimensions and capacities:

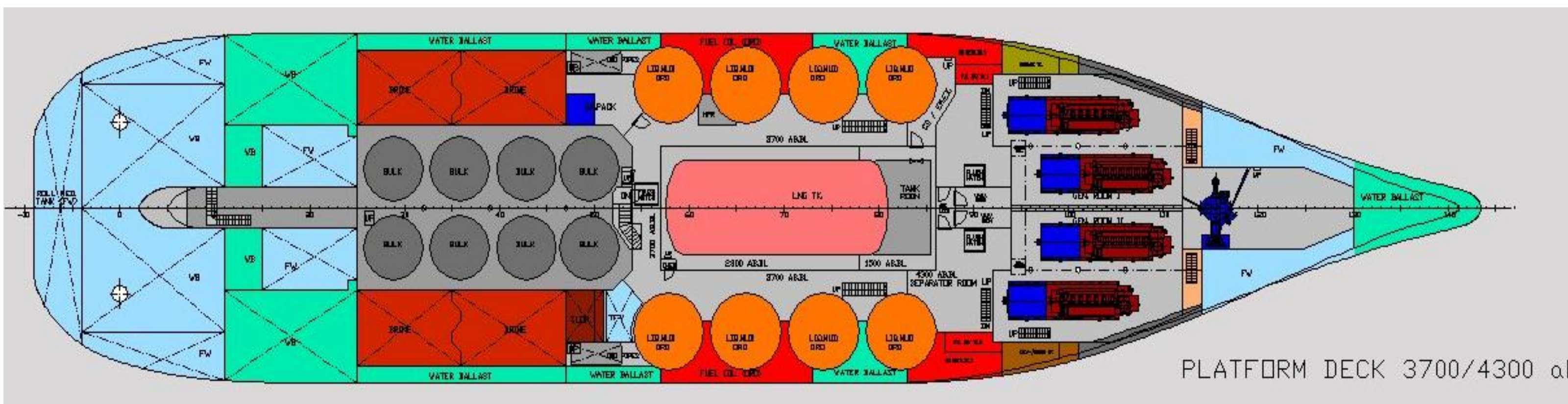
- Overall length 130 m
- Breath 19 m
- Draught max 4, 6 m
- Cars (pcu) 212
- Passengers 590
- Service speed 21 knots
- LNG storage: 2 x 125 m^3 LNG

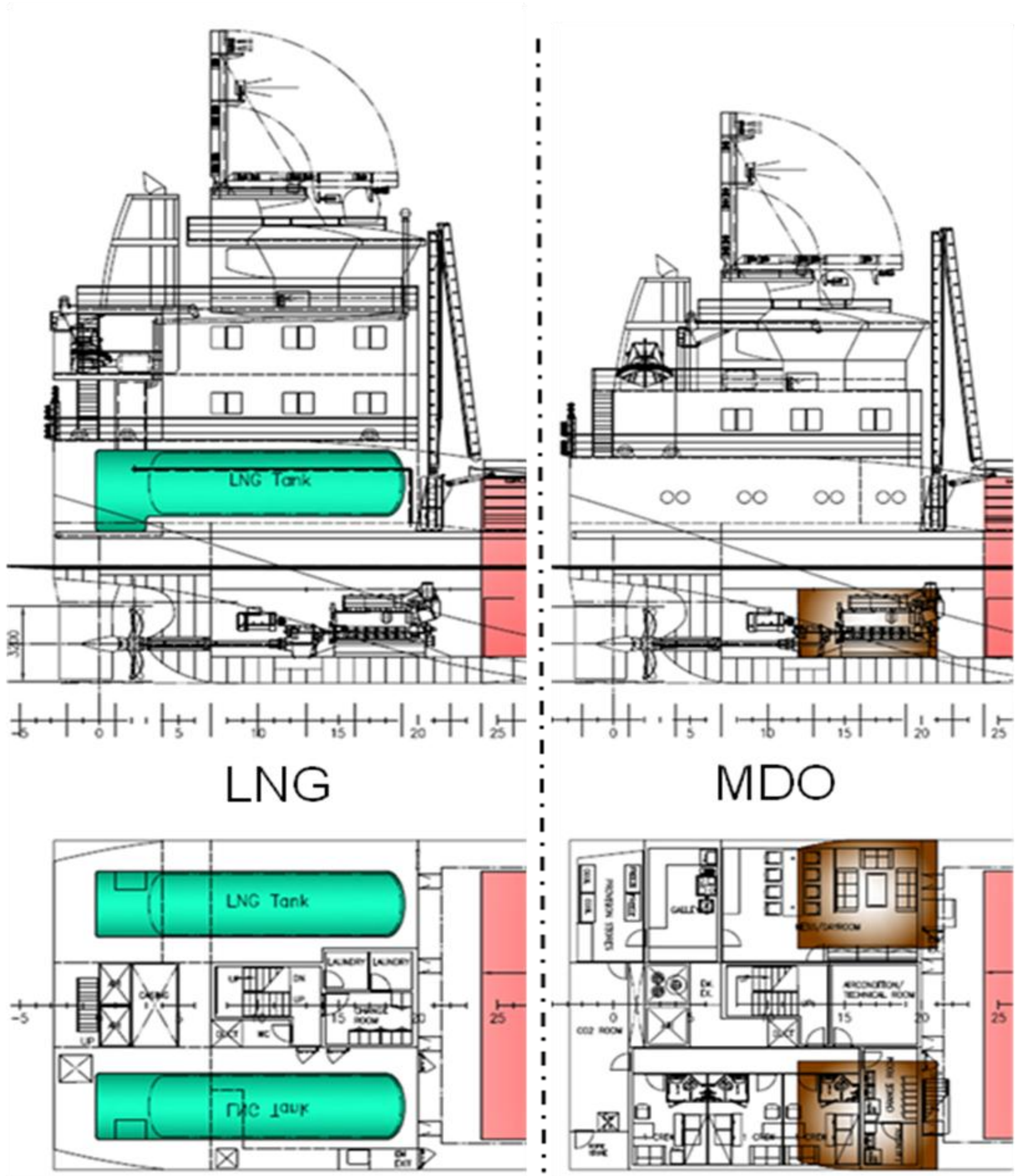


Engines and LNG tank arrangement

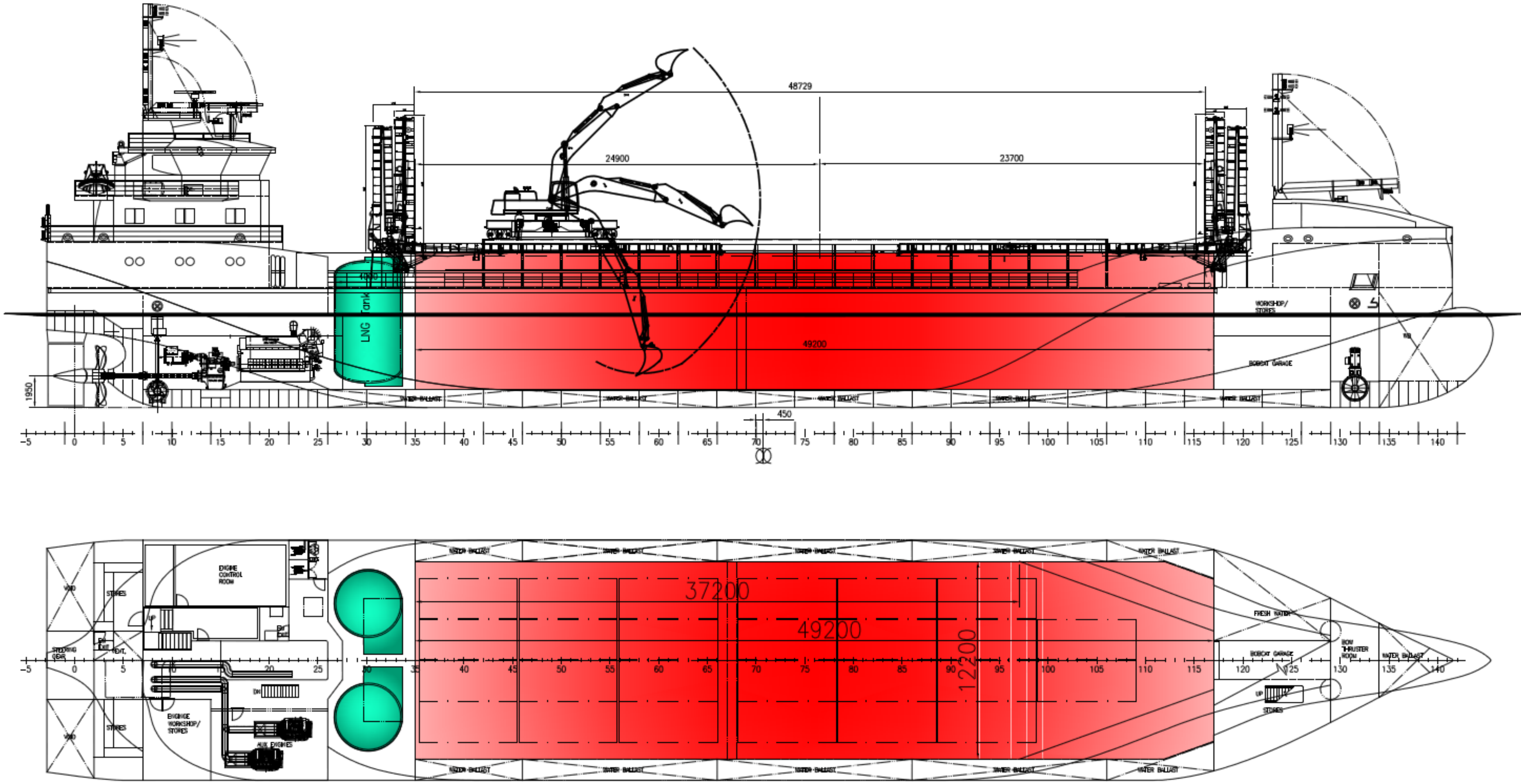
4 Generator sets: Wärtsilä 6x32 DF, LNG storage 240 m^3






LNG Tank
LNG
MDO
LNG Tank

Nyfrakt - Bulk 90 m
LNG arrangement



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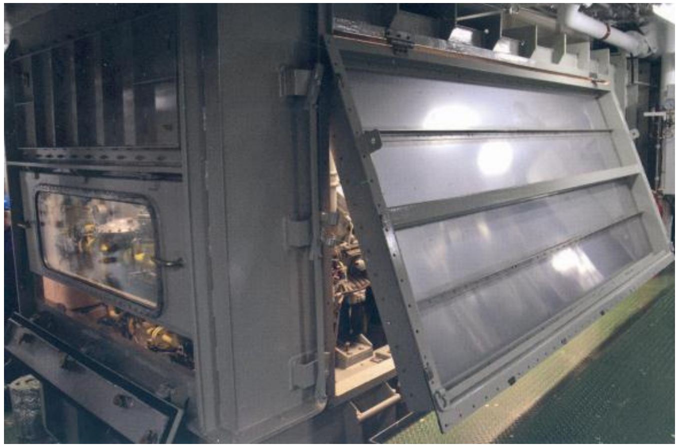
Rules and regulations - Gas fuelled ships

Latest IMO Interim guidelines for gas fuelled ships - 2009

Allows for different engine room arrangements:

- **ESD (Emergency Shut Down) protected engine room**
  - Minimum two separate engine rooms
  - Redundant systems
  - Increased ventilation
  - Gas detection
  - Minimum of ignition sources



- **Inherently safe engine room**
  - Ventilated double piping to engine
  - No other special requirements for the engine room

New IMO code in progress:

International code for gas fuelled ships – IGF - 2014

Capital cost related to LNG fuel

Additional cost factor	Car ferry (5 MW/ 250m^{3}LNG)	Platform supply vessel (PSV) (8 MW / 200 m^{3}LNG)	Ro-Ro (5 MW / 450m^{3}LNG)
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%

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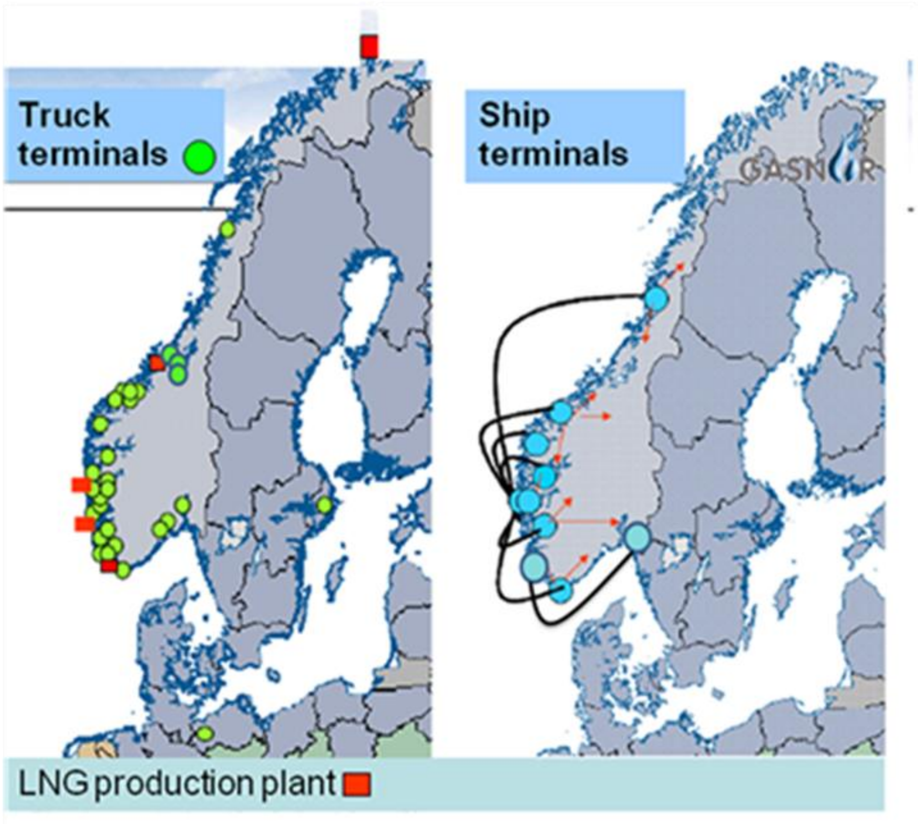
LNG in short sea shipping in Norway today



Source: Gasnor

Covering the long coast of Norway

- LNG source
  - Base load LNG supplied to receiving terminals
  - 4 Small scale LNG production plants10'-300' ton / year
  - Total capacity 450' t/year
- LNG distribution
  - Coastal tankers
  - Trucks
- Regional terminals
  - ~40 terminals in operation
  - 100m^3 - 6500m^3 LNG storage capacity

R&D challenges

- Engines and systems
  - Part load efficiency optimization
  - Methane slip reduction
  - Fuel gas quality
  - Cost reduction
- Fuel handling and storage
  - Better storage tank solutions (space and cost)
  - Improved fuel handling systems – bunkering logistics
  - Simpler and more robust fuel system design without reducing safety (space and cost)

Commercial challenge:

Cost elements – need more actors in the market…

Oppsummering og konklusjon

- LNG antas å være det mest lovende alternative maritime drivstoff
- Skadelige utslipp til luft reduseres drastisk, møter nye IMO-krav
- LNG tilgjengelighet bedret og under forbedring
- Tilgjengelig teknologi for medium speed, 2 takter saktegående teknologi under utvikling
- Energieffektivitet lik eller bedre sammenlignet med MDO/HFO
- Metan en utfordring
- Fortsatt behov for bedring av:
  - tilgjengelighet av LNG,
  - lagring om bord og
  - lastesystemer mht kostnader og plassbehov
- Betydelig økte investeringskostnader (typisk 8-15%) som må rettferdiggjøres gjennom reduserte utslipp og driftskostnader

Aktuelt for fiskeflåten?

- Tilgjengelig teknologi
- Kostnader avgjørende, men må sammenlignes med løsninger med tilsvarende ytelse i forhold til regelkrav (Svovel/NOx)
- Mest aktuelt for flåtegrupper med mange driftsdøgn og relativt høyt energiforbruk
- Dual fuel gir større fleksibilitet i forhold til valg av drivstoff
- Valg avhengig av driftsprofil og tilgjengelighet av gass

NOx < 2 g/kWh
SOx ~ 0
PM ~ 0

Takk for oppmerksomheten!