Rolls-Royce

Rolls Royce: the integrator for environ-shipping

ENA Ecodesign - Ancona, January 21st, 2012

Marco Andreola

Technological and Business Development
LNG fuelled vessels Campaign Manager

Rolls-Royce

World leading supplier addressing four global markets:

Civil Aerospace
- Aero engines
- Helicopter engines

Defence Aerospace
- Aero engines
- Helicopter engines

Marine
- Ship Design
- Equipment systems

Energy
- Gas turbines

39 000 employees

Turnover 2010: 19,4bn. CAD Order book per 31.12.10: 103,3 bn. CAD

Rolls-Royce Marine

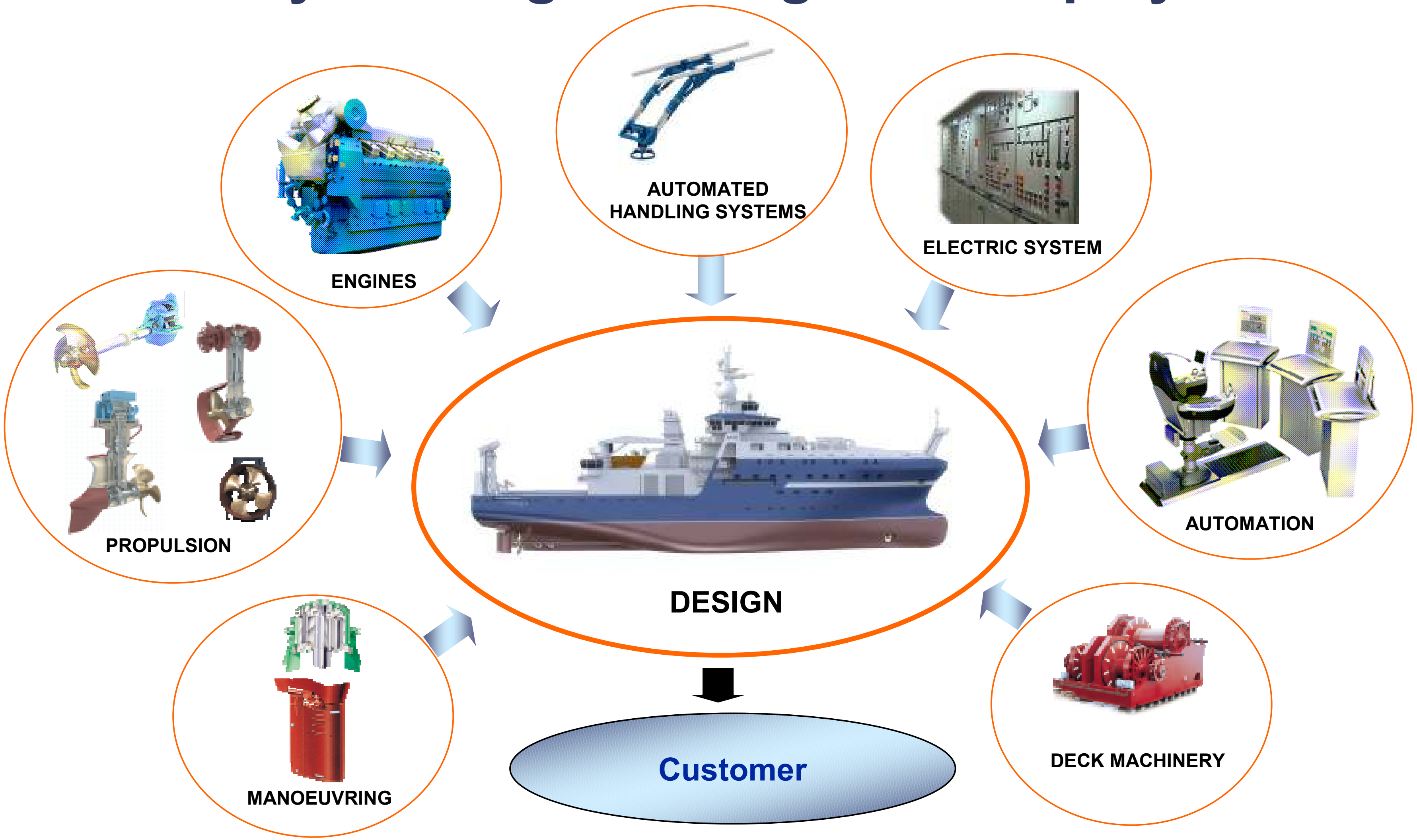
Offshore

Merchant

Naval

- **9000 employees in 34 countries**
- **Over 30.000 vessels with our design and/or equipment**
- **Second largest division in Rolls-Royce**
- **Turnover 2010: 4,5 bn. CAD**
- **Order book 31.12.2010: 5,3 bn. CAD**

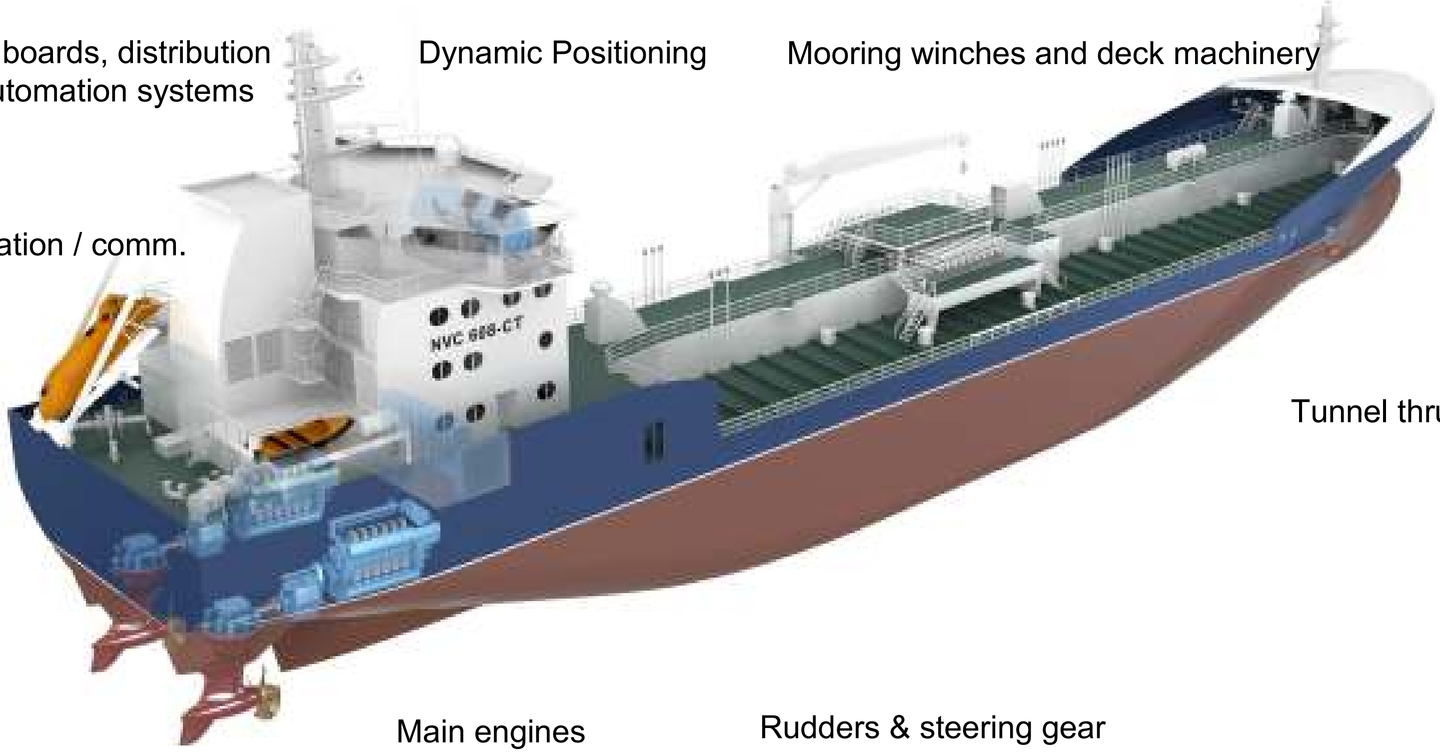
Rolls-Royce design & integrated ship systems



One contact, one supplier, one deal = a safe & cost-effective solution

Integrated system solutions

Project management | **Design & integration** | **Ship control & instrument.** | **Procurement & equipment supply** | **Installation & commissioning** | **Support services**

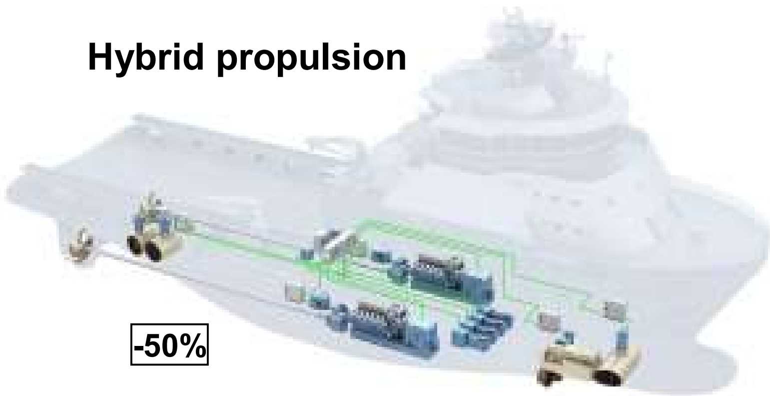


Increasing oil prices and new legislation drive technology
Ways of reducing emissions

Gas powered propulsion

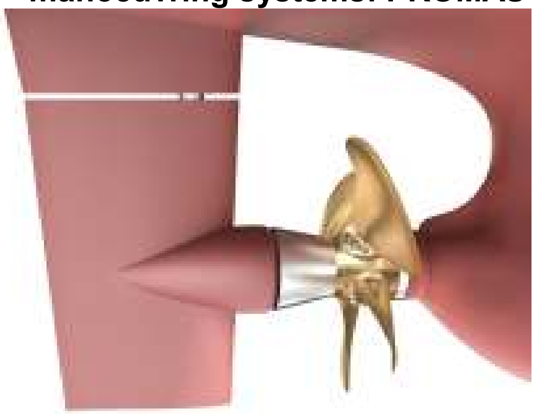
- CO_2 - 23%
- NOx - 92%
- SOx - 100%
- Particulate – 98/100%

Hybrid propulsion



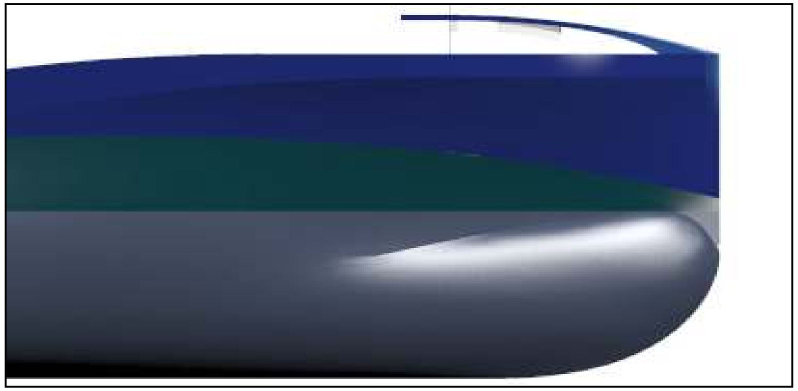
-50%

High efficiency propulsion and manoeuvring systems: PROMAS



up to -8%

Advanced hull forms



Application for patent protection by Rolls-Royce

up to -8%

Rolls-Royce

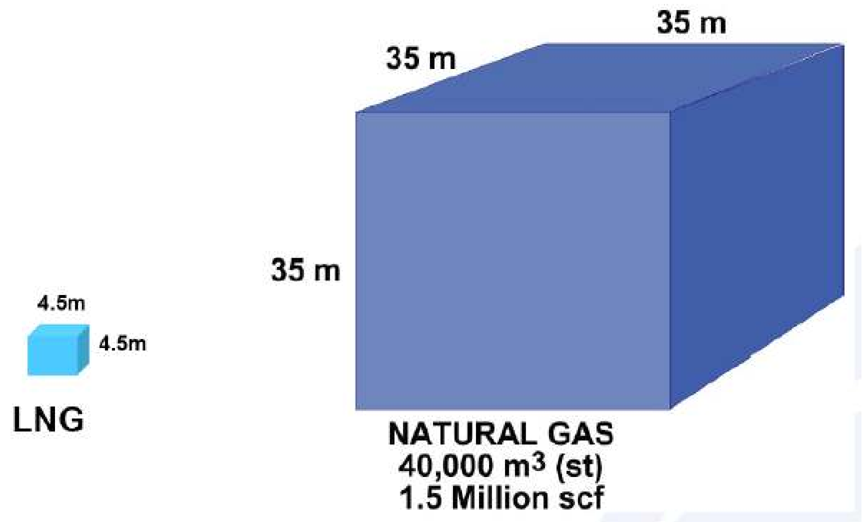
Gas Fuel "only LNG" vessel

Key drivers:

- low cost
- simplicity
- reliability

Natural gas and LNG

- Natural gas is consisting primarily of methane, a typical composition is:
  - Methane 94%
  - Ethane 4.7%
  - Propane 0.8%
  - Butane 0.2%
  - Nitrogen 0.3%
- Natural gas burns more cleanly than all other fossil fuels:

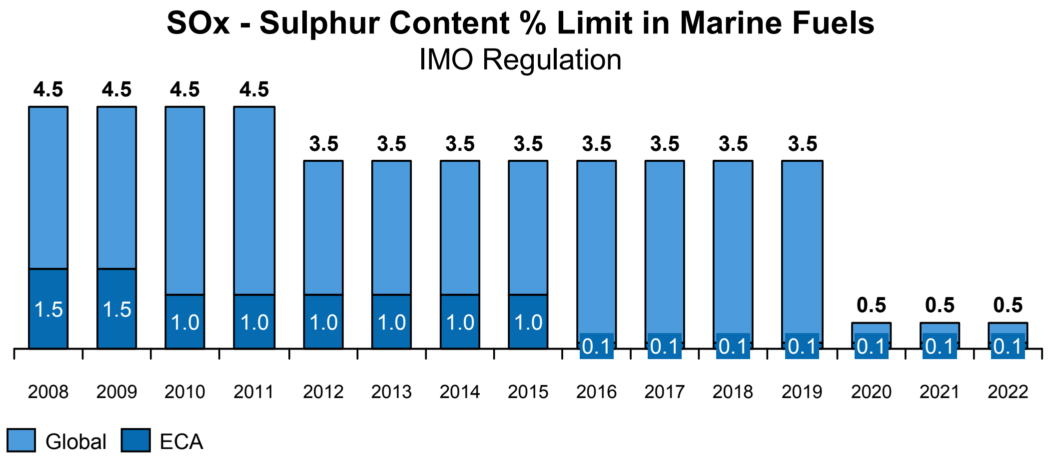


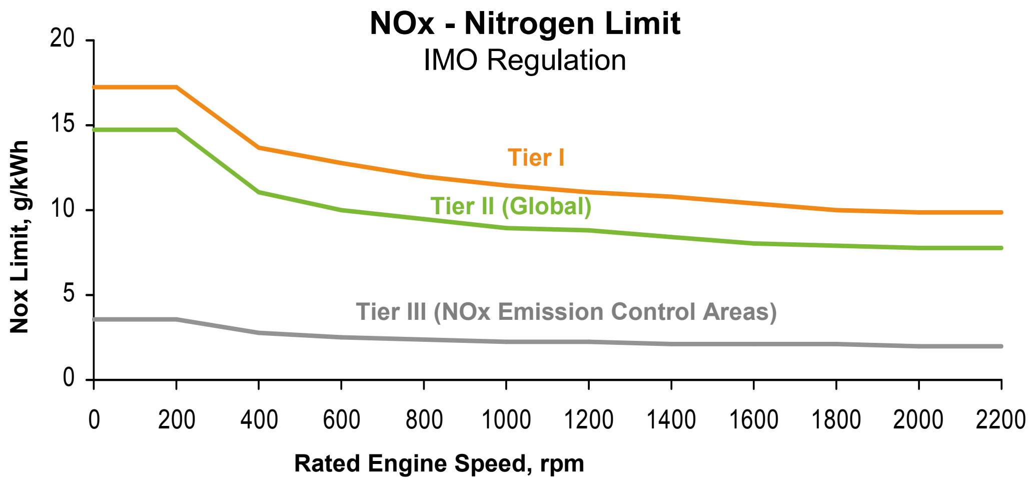
1: 600

Natural gas (LNG) as a marine fuel

- **Emissions**
- Reduce harmful emissions of NOx, SOx, CO2, Particles
- **Costs, operability and maintenance**
- Reduced maintenance, higher TBO
- Remove- or Reduce Ship owners taxes and other fees related to emissions
- Reduced LO consumption
- Reduced Fuel consumption, gas engine more efficient than diesel.
- All HFO installations deleted; Heating system with coils, purifiers, treatment units, service- and setteling tanks.
- **Installation**
- A simpler propulsion set installation / refurbishment
- A simpler propulsion set operability and maintenance

NOx and Sox ECA and global limits





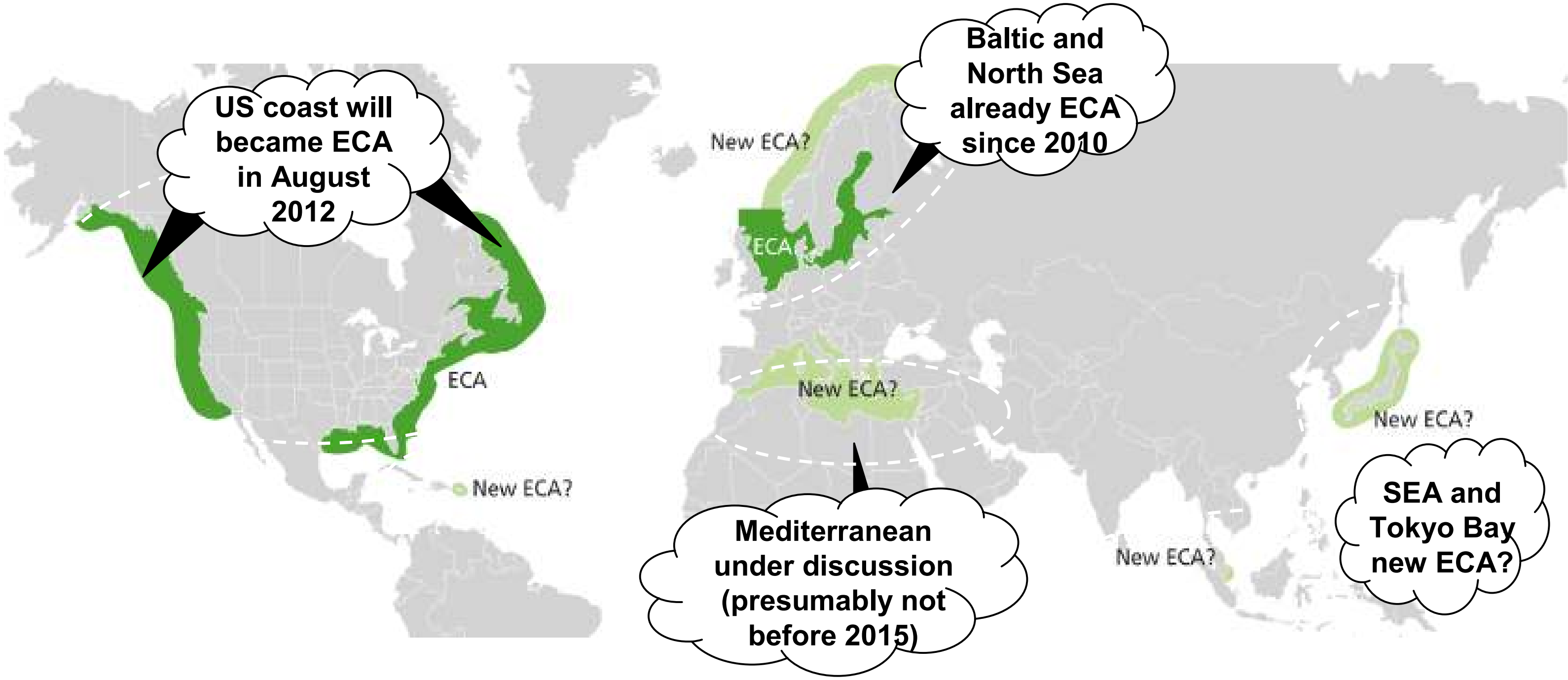
(1) Mexico, Alaska, and Great Lakes, Singapore, Hong Kong, Korea, Australia, Black Sea, Tokyo Bay
Source: Public sources, Booz & Company and Rolls Royce analysis

Comments

- **Currently, Nordics (Baltic Sea and North Sea) is the only ECA** (Emission Control Area)**:**
  - **IMO** agreed to reduce SOx and NOx emissions by controlling the emission content in marine fuels
  - Within ECA's, ship owners need to switch to **cleaner fuels** (e.g., MGO, LNG), or to adopt **alternative technologies** (e.g. scrubber, after treatments)
- **Mediterranean could become an ECA in 2015 (under discussion)**
- **USA coasts will become ECA in August 2012** -- Other regions are under discussion (1)

The Mediterranean sea could also become an ECA soon – a benefit for the development of LNG fuelled shipping

ECA Map



Source: DNV, Rolls Royce and Booz & Company analysis

The gas engines

- **Types: B35:40L6-8-9 & B35:40V12, -16**
- **Bore: 350 mm**
- **Stroke: 400 mm**
- **Power: 420 / 440 kW / cyl**
- **Speed: 500 - 750 rpm**
- **Power range: 2520 - 8750 kWmech**

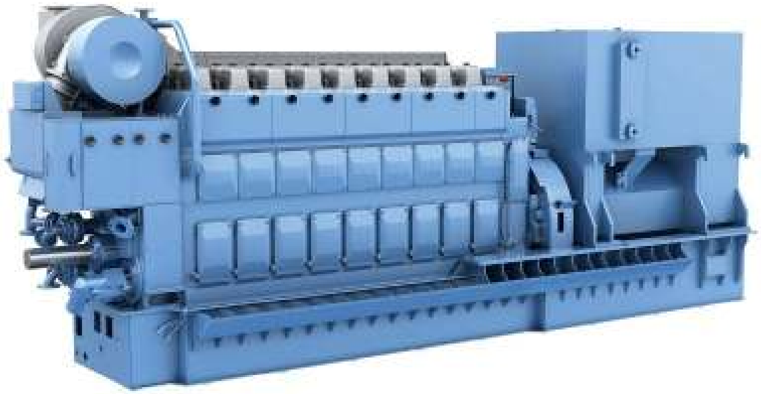
References:

Sea-Cargo, RoRo vessel (2x1xB35:40V12PG)

Torghatten Nord, Gas ferry (2 x 1xB35:40V12PG + 2 x 1 x C26:33L9PG)

The gas engines

- Types: C26:33L6-8-9
- Bore: 260 mm
- Stroke: 330 mm
- Power: max. 244 / 270 kW / cyl
- Speed: 600 – 1000 rpm
- Power range: 1460 – 2430 kWmech



References:

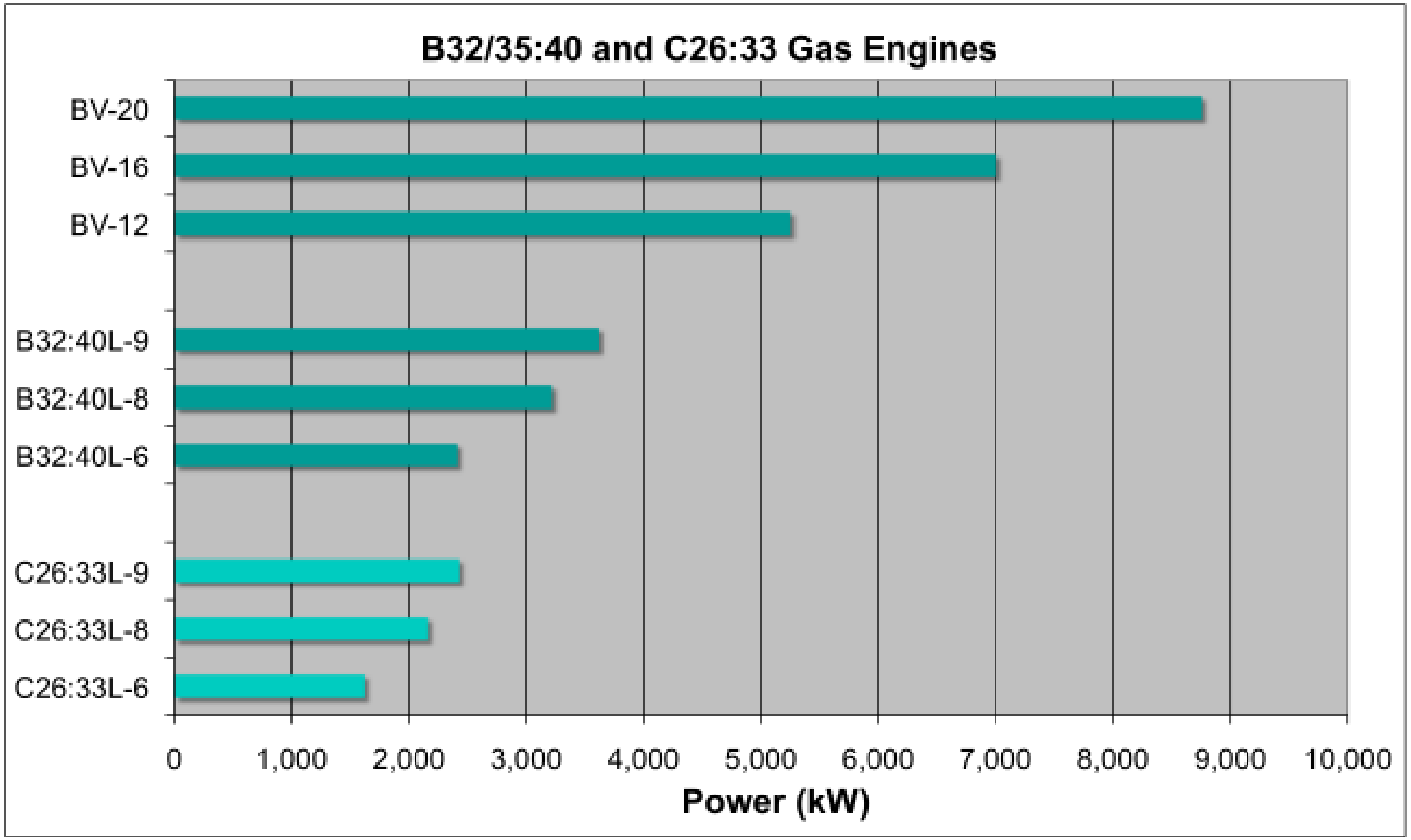
Fjord1 - Gas fuelled ferry (3xC26:33L9AG + 1xC25:33L9ACD)

Island Offshore – UT776CDG PSV (2xC26:33L9AG + 2xC25:33L6ACD)

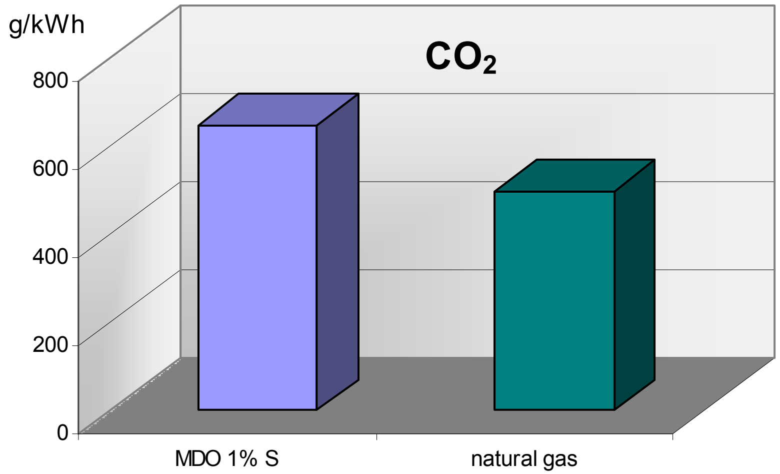
Fjord1 Gas fuelled ferry (1xC25:33L9AG retrofit)

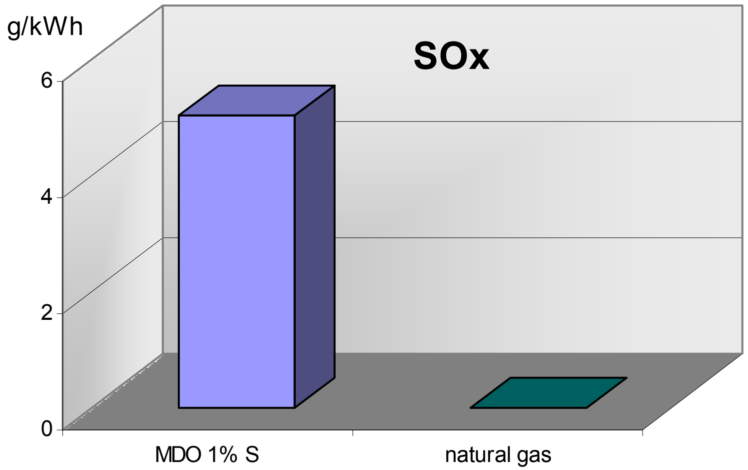
NSK Shipping - Bulk carrier (1xC26:33L6PG)

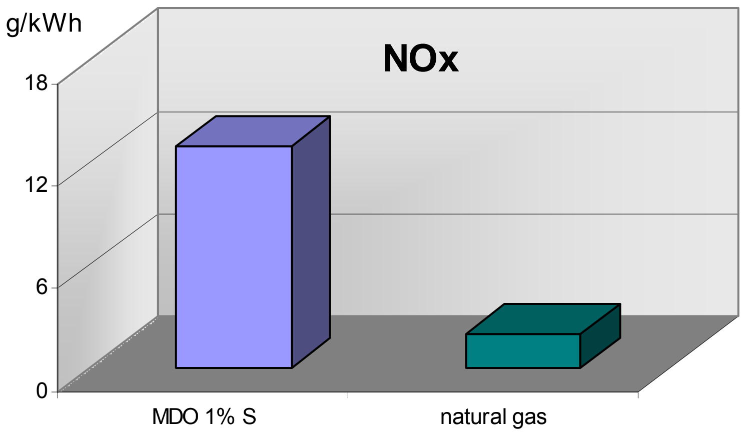
Power range Bergen gas engines

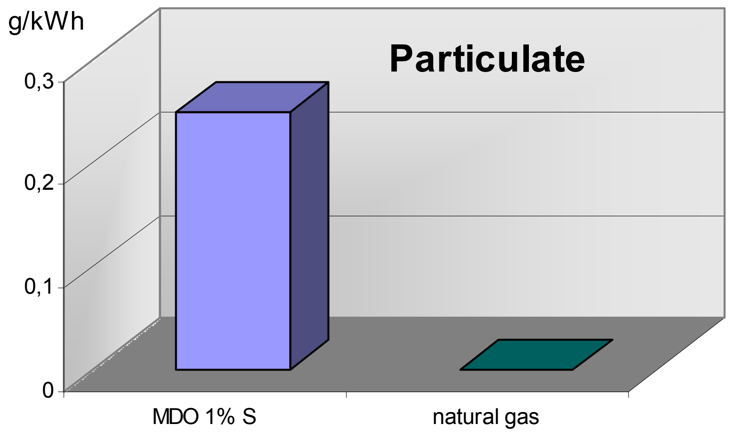


Bergen engines: MDO vs. Natural gas emissions

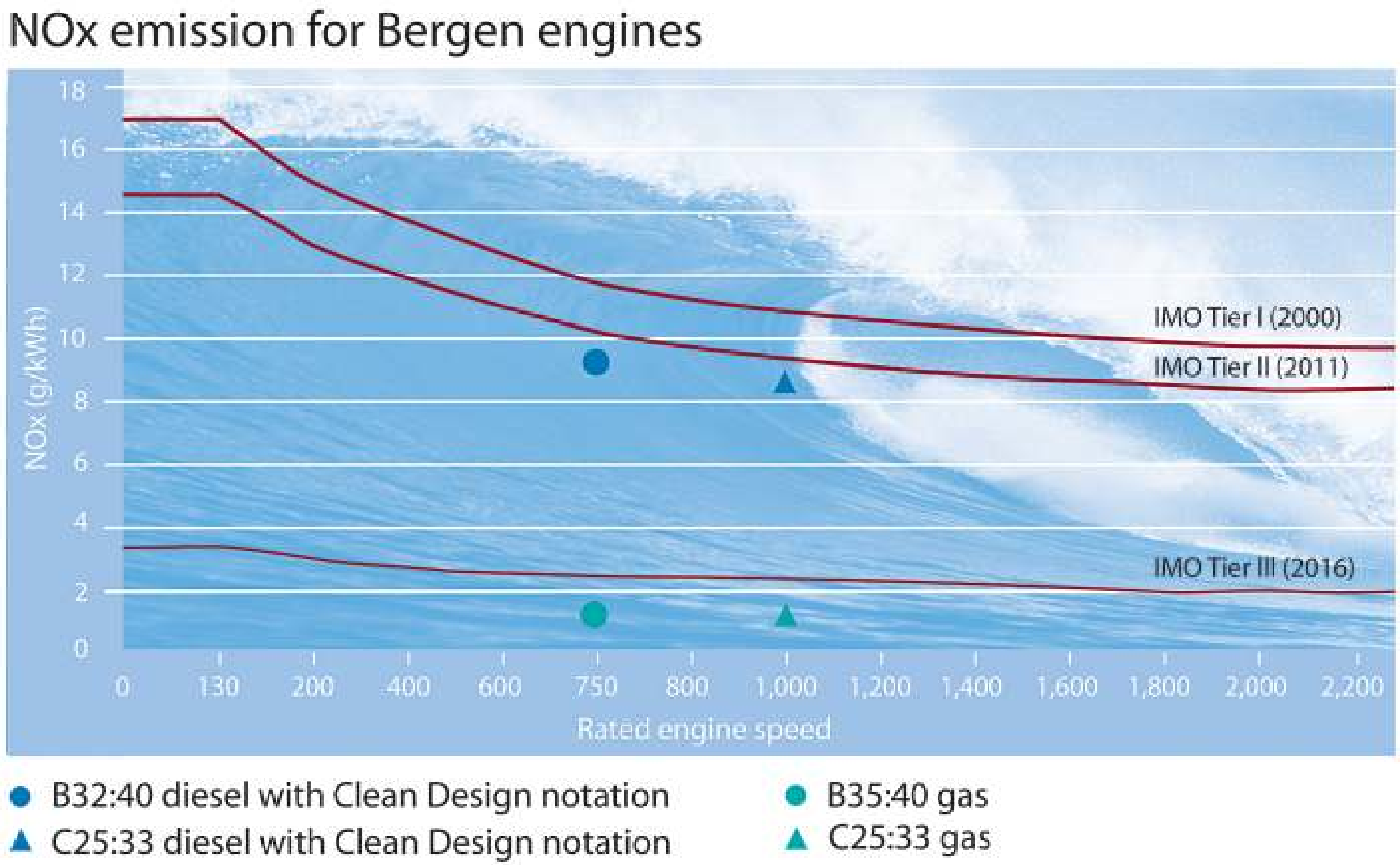








NOx IMO emission limits



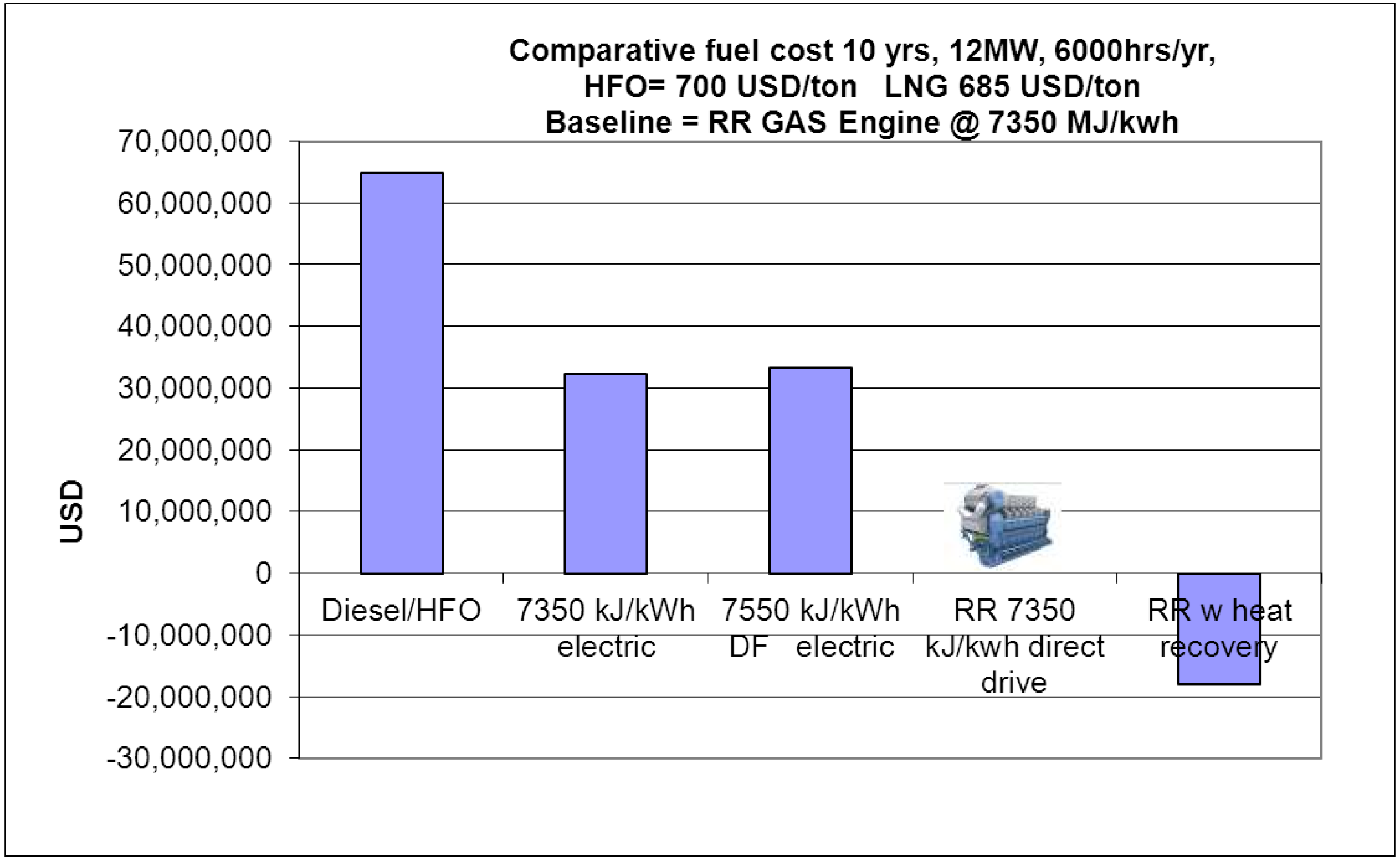
Rolls-Royce

Rolls-Royce gas propulsion system and ship design

- Direct drive – reduce the electric plant to half size and save propulsion electric losses and save <u>10% fuel/CO_2</u>
- Gas engine performance vs Dual Fuel estimated to save at more than <u>8% fuel/CO_2</u>
- Hybrid electric system save about <u>5% fuel/CO_2</u>
- The PROMAS / CPP plant will save up to <u>8% fuel/CO_2</u>
- Advanced hull form up to <u>8% fuel/CO_2</u>

To achieve the most economic and green concept work with Rolls-Royce gas engine systems

The fuel cost benefit



With the above assumption – close to 10MUSD fuel gain over HFO !

Heavy fuel oil

Insert filename

Dual fuel system

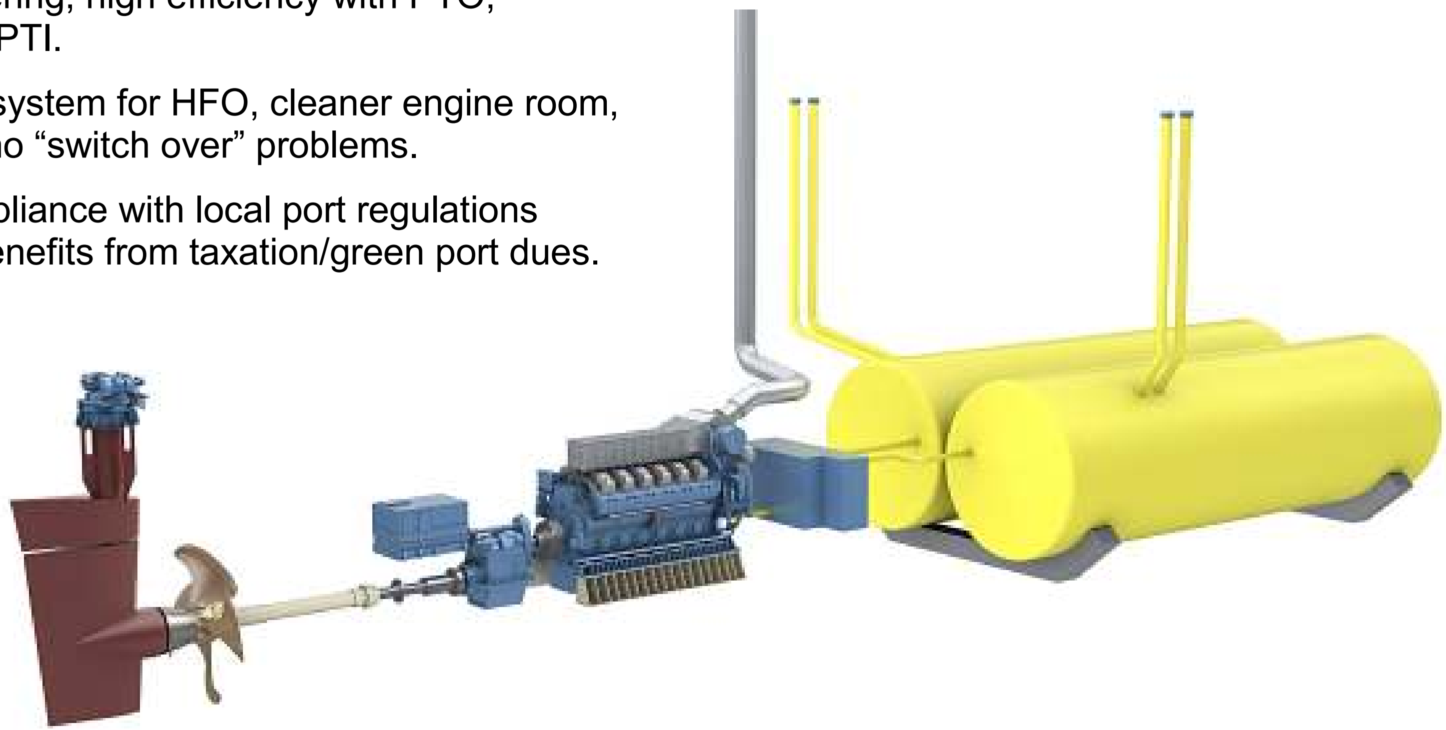
Natural gas

Insert filename

LNG fuelled propulsion system

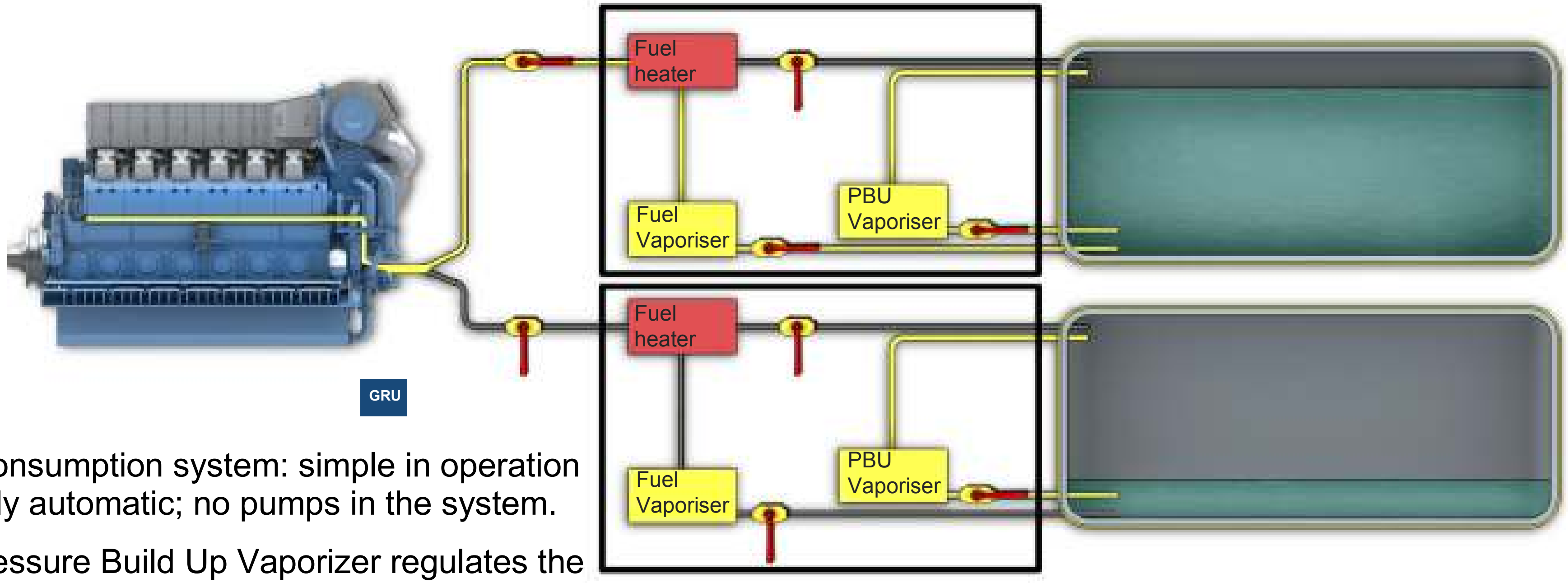
Operational benefits with LNG, single fuel main engine, MDO back up gensets

- One stop bunkering, high efficiency with PTO, redundancy by PTI.
- No purification system for HFO, cleaner engine room, less waste oil, no “switch over” problems.
- Long-term compliance with local port regulations and potential benefits from taxation/green port dues.



LNG fuelled propulsion system

No moving equipments in the vaporisation and heating processes



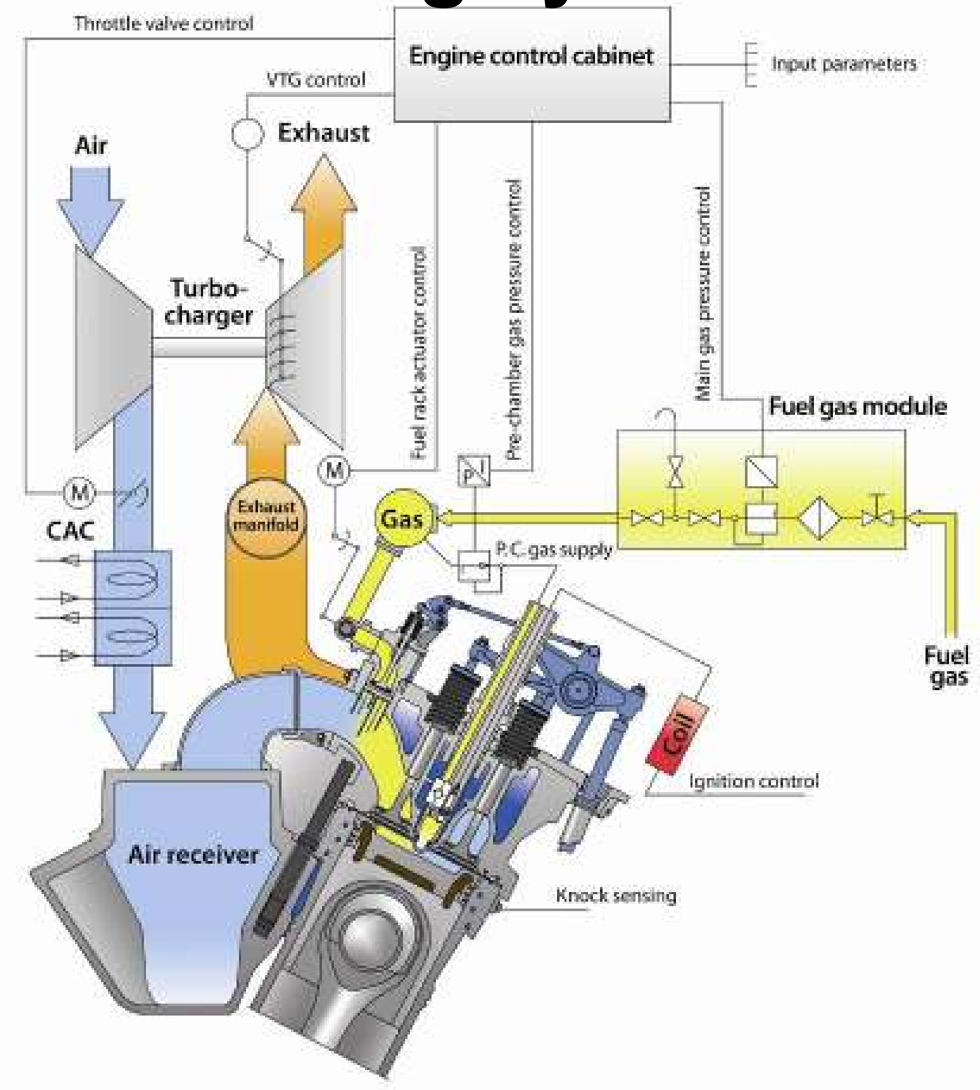
Fuel consumption system: simple in operation and fully automatic; no pumps in the system.

The Pressure Build Up Vaporizer regulates the pressure in the tank which is driving the LNG to the Fuel Vaporizer. LNG is vaporized to NG which goes to the Fuel Heater. The heater takes the NG to the temperature level required before entering the GRU-Gas Regulating Unit

Tank room arrangement

Bergen Gas Engines: feeding system

- **The Fuel Gas Module controls the gas flow to the engine based on engine load control system.**
- **The Variable Turbo Geometry (VTG) gives the Optimum response at all engine load points**



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LNG bunker volumes

FUEL	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			

Specific fuel consumtion of Bergen gas engines vs. MDO engines (@ MCR):

- Bergen MDO engines: 7770 KJ/KWh
- Bergen gas engines: 7500 KJ/KWh

LNG bunker volumes

• Considering the existing “C” type (pressure vessels) cilindrical LNG storage tanks

• Considering the additional available space due to absence of conventional fuels installations: heating system with coils, purifiers, treatment units, bunkering, service- and settling tanks

• Considering tanks insulations, additional bulkheads, access trunks, vents, etc.

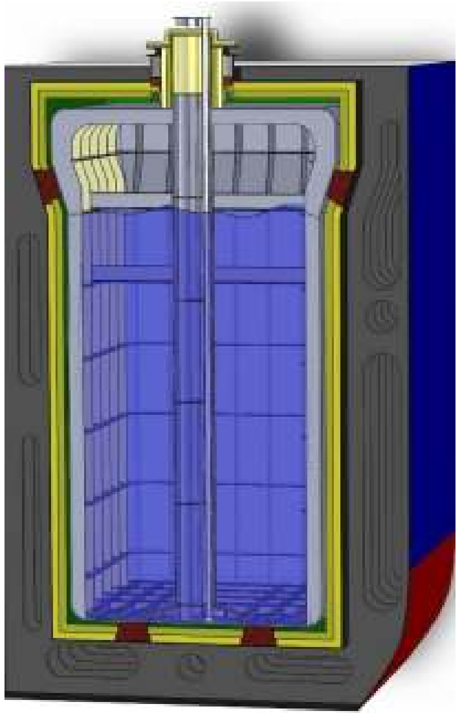
• LNG could require up to 2.5 / 3.5 times as much space as MDO for the same amount of energy onboard.

• The forthcoming installations of prismatic and membrane type tanks for LNG as bunker will lower the volumetric ratio down to 2 times.

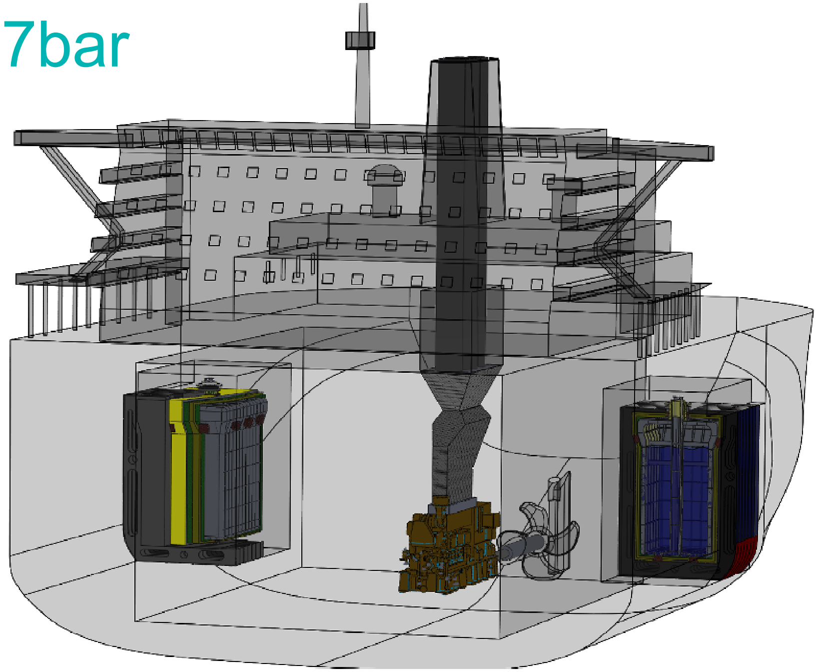
LNG bunker volumes

A-tank operating mock up in Bergen, NO.

Bunkering on A-tank and on Membrane tanks (prismatic tanks, hull shaped) will also be available



Hull integrated A-tank
Pressure-less – 0,7bar



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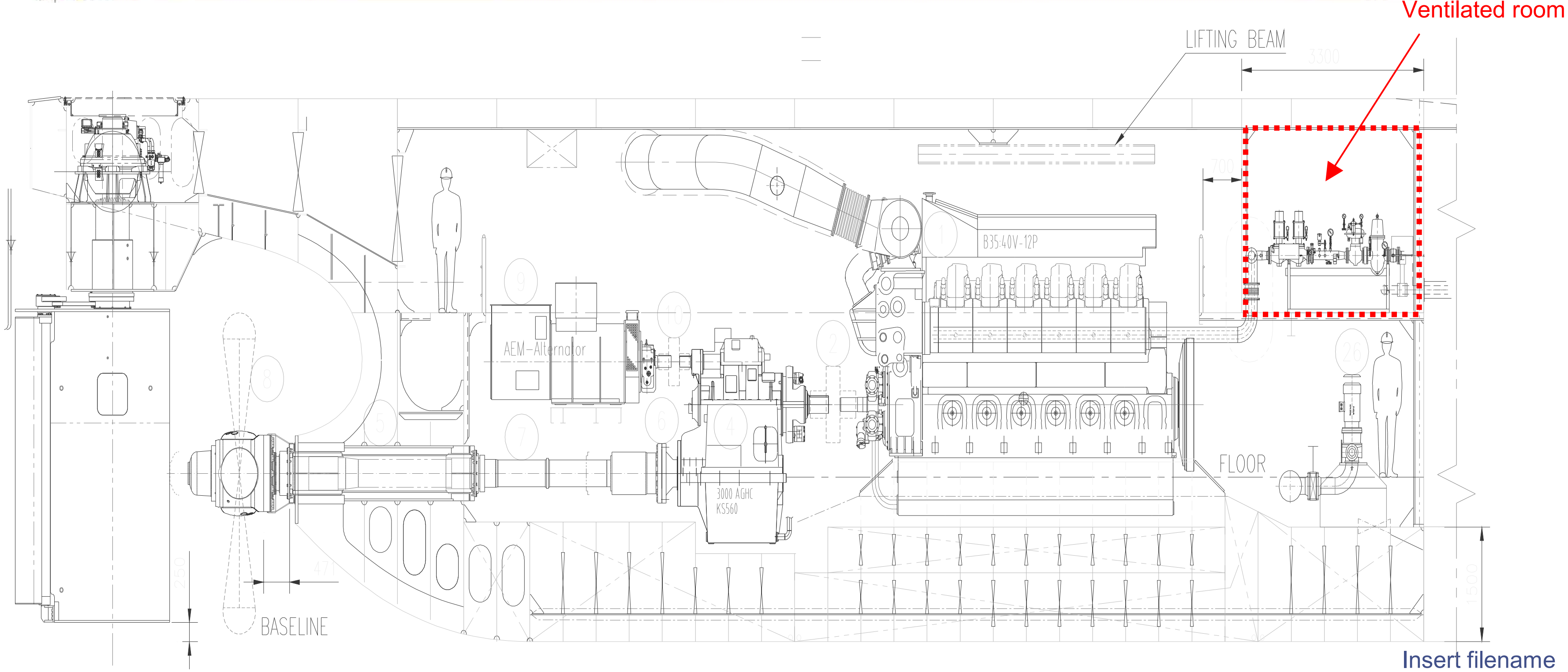
Inherently Safe Installation of engine



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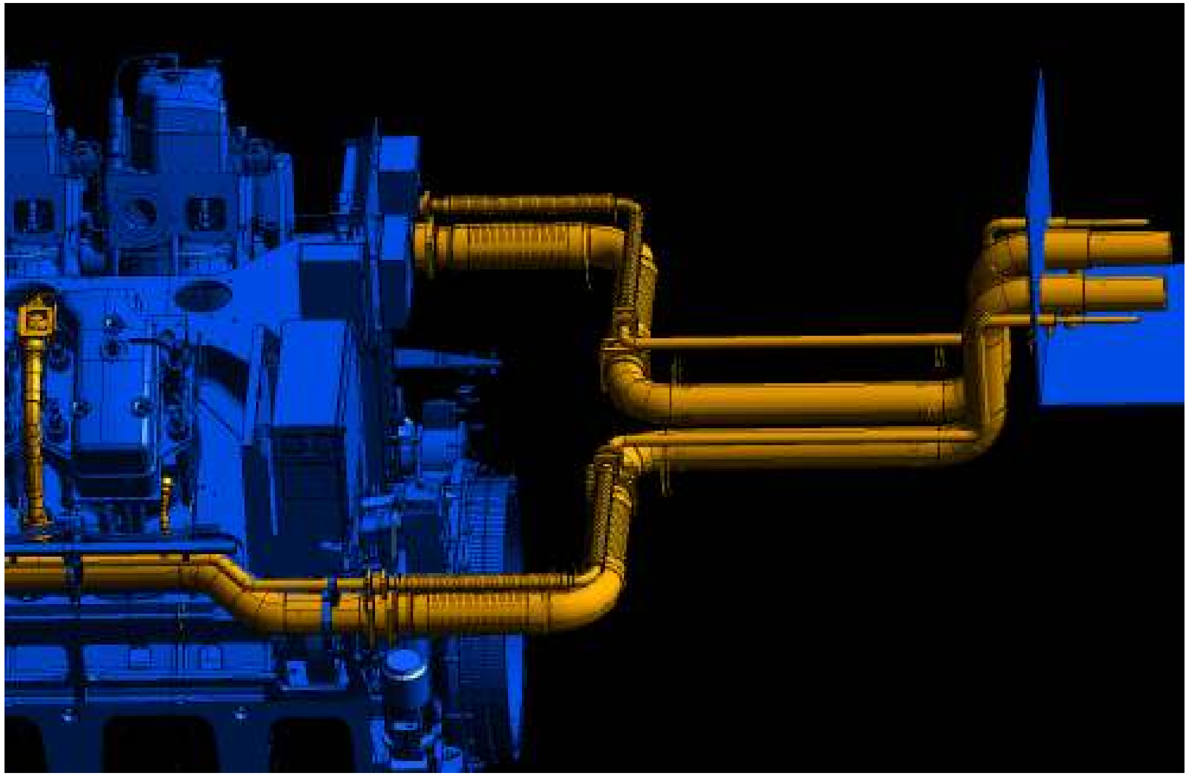
Gas Engines: marine installation

- **Double walled piping on main gas supply and pre-chamber gas for Inherently Safe Installation**

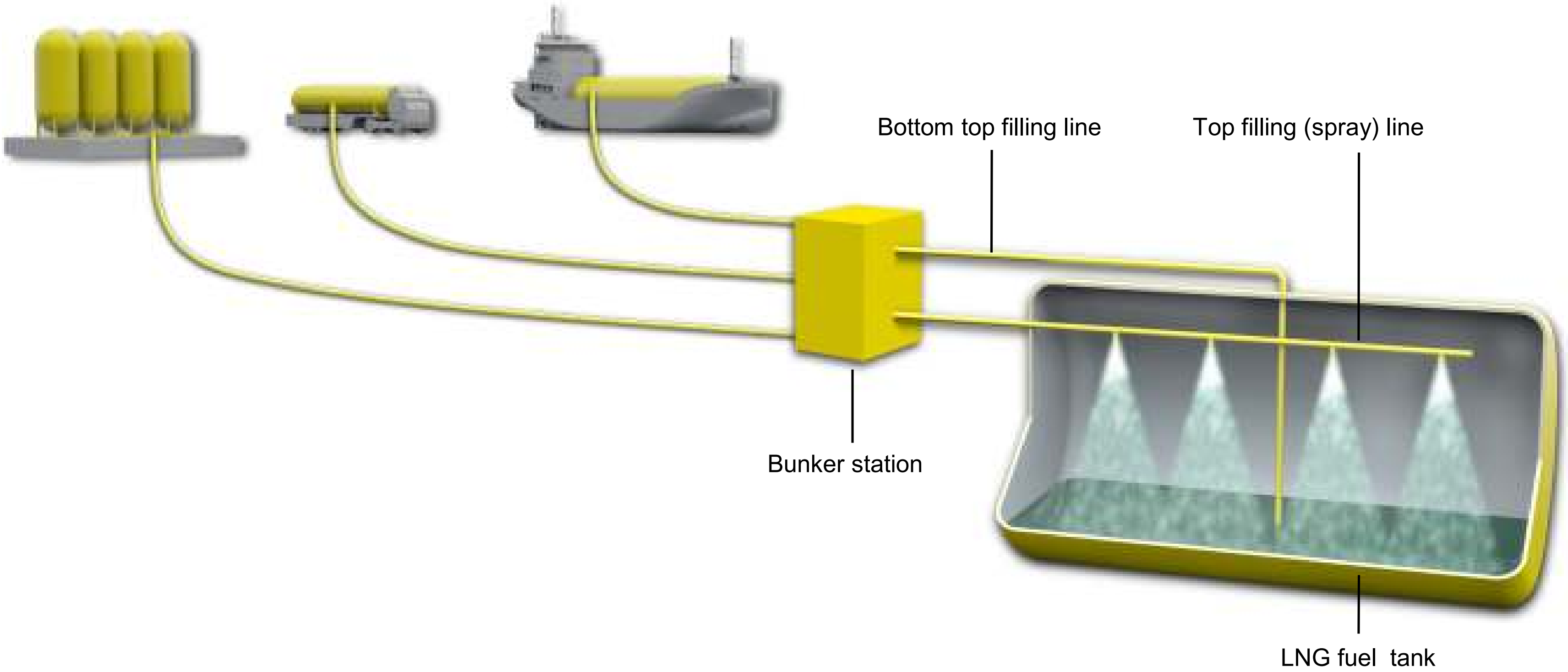


LNG supply chain for marine bunkering

- LNG can be supplied by:
  - Land based stations
  - Tank trucks
  - Coastal tankers
  - Bunker barges
  - Floating bunkering stations

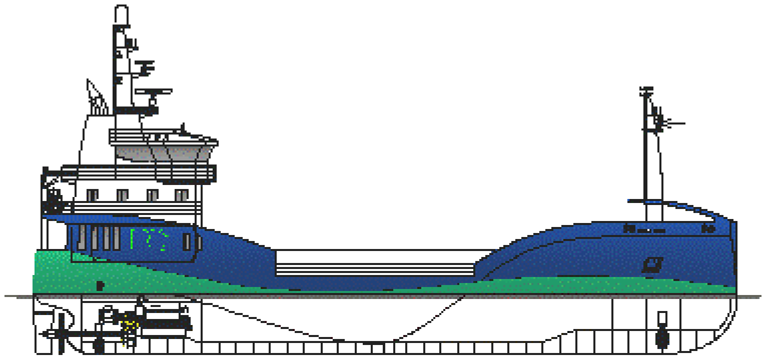
LNG bunkering

Liquefied Natural Gas (LNG) is bunkered by pressure from land based stations, tanker trucks, coastal tankers or bunker barges.

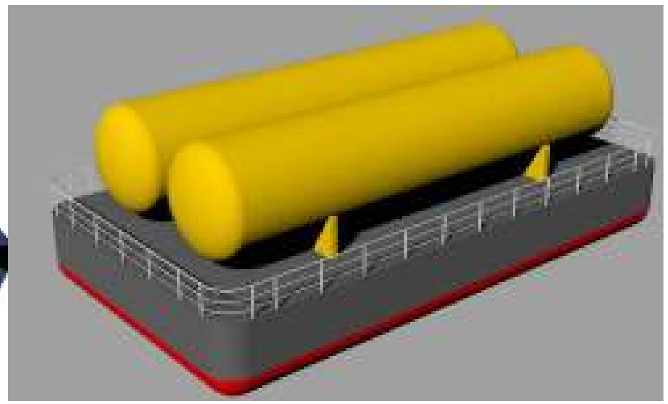


Forthcoming means for LNG bunkering operations:

- **Dedicated bunkering vessels**



- **Bunker barges w pusher tugs**



Coastal trading LNG carriers loading at a large import terminal

Insert filename

The bunkering terminal @ Halhjem 1000 m3 storage capacity

filename

LNG storage for ferries @ Halhjem

Delivery - Bunkering

LNG fuelled vessels payback period; availability and cost of LNG for bunkering

- The payback period is highly dependent on the ship value and the operating profile.

- Payback period for new building / retrofitting of our ongoing projects and operating ships is in the range of 2.5 to 5 years.

- LNG is currently available in many European Countries, including Italy. Most of the operating LNG fuelled ships are still bunkering LNG from trucks. Some bunkering facilities are equipped with satellite storage tanks (a few hundreds of cu.m. each)

- The ex ship LNG price in Italy will vary according to the traded volume and the LNG supply chian scenario, in an expected range of 450 / 600 €/ton.

Drivers for LNG shipping

1. LNG price ex ship / differential price LS distillates vs. LNG

2. Availability of LNG / LNG infrastructures, i.e.: terminals equipped with small scale facilities / LNG storage facilities / established LNG transportation by road / sea / railway, planned bunkering facilities in harbour areas, etc.

3. Favorable shipping scenarios in terms of ship type, routing, installed power, range, operating profile.

4. Availability of multi – end users in the proximity of attractive shipping scenarios, i.e.: domestic / industrial users potentially interested in LNG / NG small mid scale trading and distribution. This scenario could favorably lower OPEX and CAPEX of the LNG supply chain and its infrastructures (satellite LNG tanks, LNG feeders bunker vessels, transportation by roads / trucks, etc.), thus sharing costs with the shipping players.

5. In some of the European Countries ECAs requirements are not always the "main economic driver"

Optimising propeller eff. e.g. PROMAS

- **11-12% Improvement for retrofit (ref. Carnival Glory)**

After

Before

Crowley, Glosten & Rolls Royce:
2 tug boats 90-foot hybrid, 72.5 tonnes bollard pull

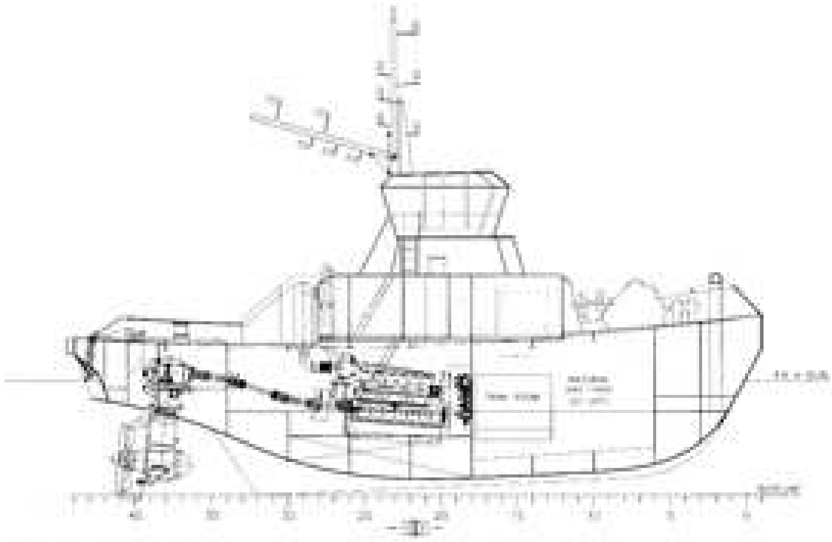


Figure 3: Inboard profile

Photo courtesy Crowley Maritime

Rolls-royce selected due to Engine response time and low emissions

Fjord 1; Ferry 6

INTEGRATOR: The Rolls-Royce Gas engine technology

Propulsion system; Gas engines and AZP

Estimated fuel reduction 25-30%,compared to first 5 ships (7% from engine)

NSK Fish Feeder ship(Bulk)

INTEGRATOR: The Rolls-Royce Gas engine technology

Resulting in a complete system delivery:

Propulsion system; Gas engine-Gear box – propeller - LNG tank ACON-HSG system

Torghatten Ferry Company; 4 ferries at Remontowa

INTEGRATOR: The Rolls-Royce Gas engine technology

Resulting in a complete system delivery:

Propulsion system; Gas engine - Gear box – propeller - LNG tank ACON-HSG system

MF TRESFJORD

Nor Lines – powered by Natural Gas

First Environship concept order. New bow shape, gas propulsion system, Promas propulsion system, which combined will increase fuel efficiency by up to 18 %,

- Length 112 m
- Deadweight 5000 t
- Design Speed 14,3 knots
- Flexible Cargo Handling

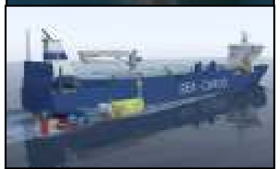
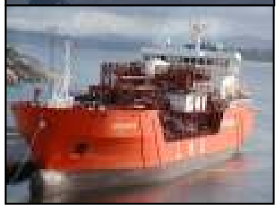
Winner of “Next Generation Ship Award” at Nor-Shipping 2011

Environship design will reduce the overall CO_2 emissions by more than 40 % compared to similar conventional vessels.

Rolls Royce Gas engines References





Fjord1 - “Bergensfjord” (2 x KVGS-12G4 + 2 x KVGS-16G4)
Fjord1 - “Fanafjord” (2 x KVGS-12G4 + 2 x KVGS-16G4)
Fjord1 - “Raunefjord” (2 x KVGS-12G4 + 2 x KVGS-16G4)
Fjord1 - “Mastrafjord” (2 x KVGS-12G4)
Fjord1 - “Stavangerfjord” (2 x KVGS-12G4)
Fjord1 - “Tresfjord” (1 x C26:33L9AG + 1 x BRM-6 (diesel)) – conversion
Fjord1 - “6th ferry” (3 x C26:33L9AG + 1 x C25:33L9LACD

Island Offshore #1(UT776 CDG) @ 2 x C26:33L9AG + 2 x C25:33L6A CD & propulsion
Island Offshore #2(UT776 CDG) @ 2 x C26:33L9AG + 2 x C25:33L6A CD & propulsion

Torghatten “ferry 1” (1 x C26:33L9PG)
Torghatten “ferry 2” (1 x C26:33L9PG)
Torghatten “ferry 3” (1 x B35:40V12PG)
Torghatten “ferry 4” (1 x B35:40V12PG)

NSK Shipping (1 x C26:33L6PG)

Sea Cargo “vessel 1” (1 x B35:40V12PG) hull 357
Sea Cargo “vessel 2” (1 x B35:40V12PG) hull 358

Norlines #1 TBN NVC design, 1xBL35:40L9PG & propulsion
Norlines #2 TBN NVC design, 1xBL35:40L9PG & propulsion

Coral Methane 2 x KVGB-12G4 + 2 x B32:40L8A (MFO/HFO)

Buksér og Berging AS 65 t bollar pull, 2 US35 thrusters, 2 x C6 mech prop + PTO for hydraulic equipments 1 , 1 80 cu.m. LNG tank and 2 cold boxes

Rolls-Royce

Thank you for your attention

For further information please contact:

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LNG fuelled vessels – Campaign Manager Europe

Technological and business development

Rolls Royce

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