2011

MAN Diesel & Turbo

„Engineering the Future – since 1758“

MAN Group
Corporate Structure

MAN SE (HQ: Munich / Germany)

Business	**Commercial Vehicles**		**Power Engineering**	
Company	**MAN Truck & Bus** (HQ: Munich / Germany) *Revenues '09: 6.4 bn€*	**MAN Latin America** (HQ: São Paulo/ Brazil) *Revenues '09: 1.4 bn€**	**MAN Diesel & Turbo** (HQ: Augsburg / Germany) *Revenues '09: 3,8 bn€*	**RENK** (76,6%) (HQ: Augsburg / Germany)
				
Investments	**Sinotruk** (25,0% +1 Share), **Scania** (17,4%**)			

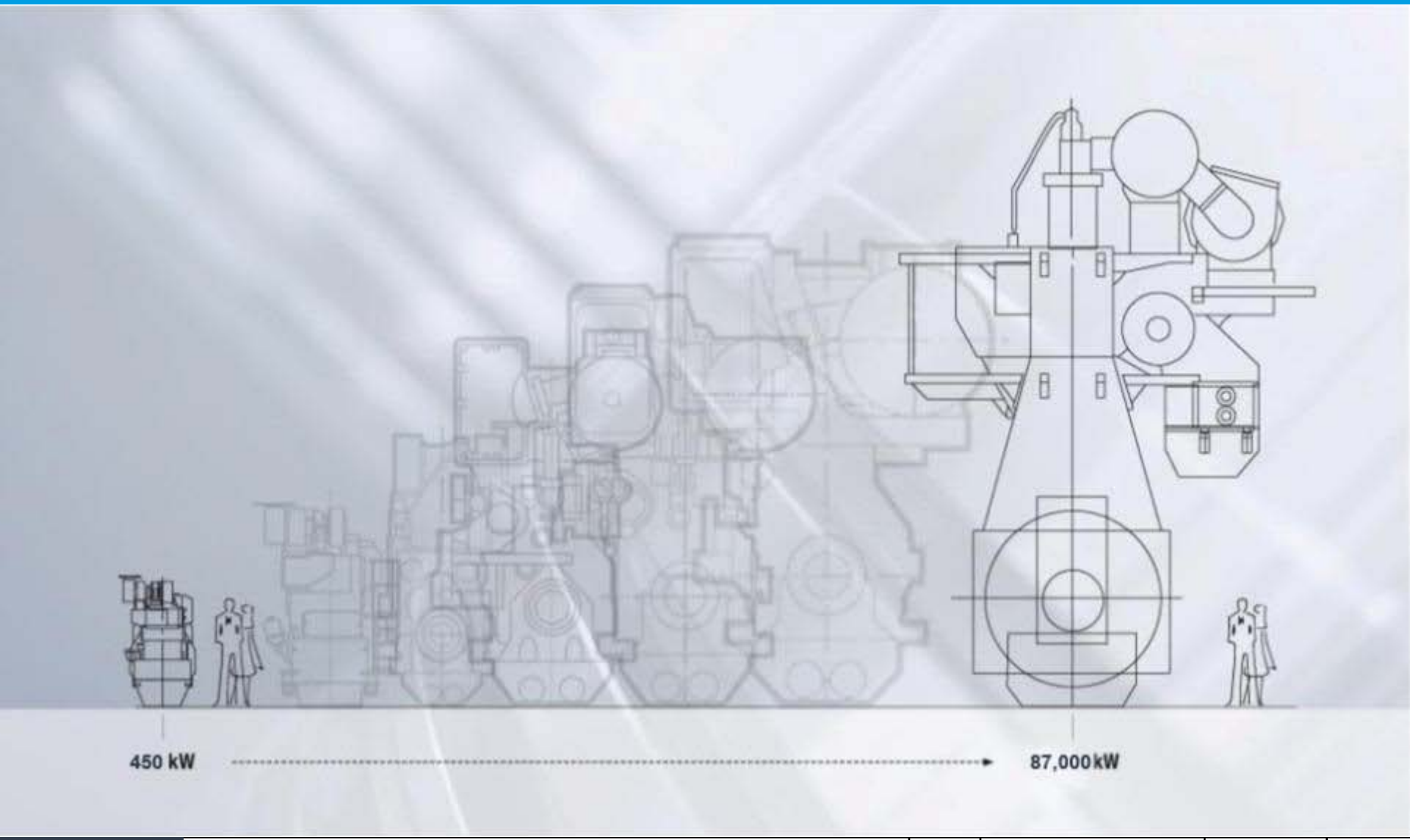
MAN Group 2009: 12.0 bn€ Revenues, 47,700 Employees

** April-December 2009*

*** Voting Rights*

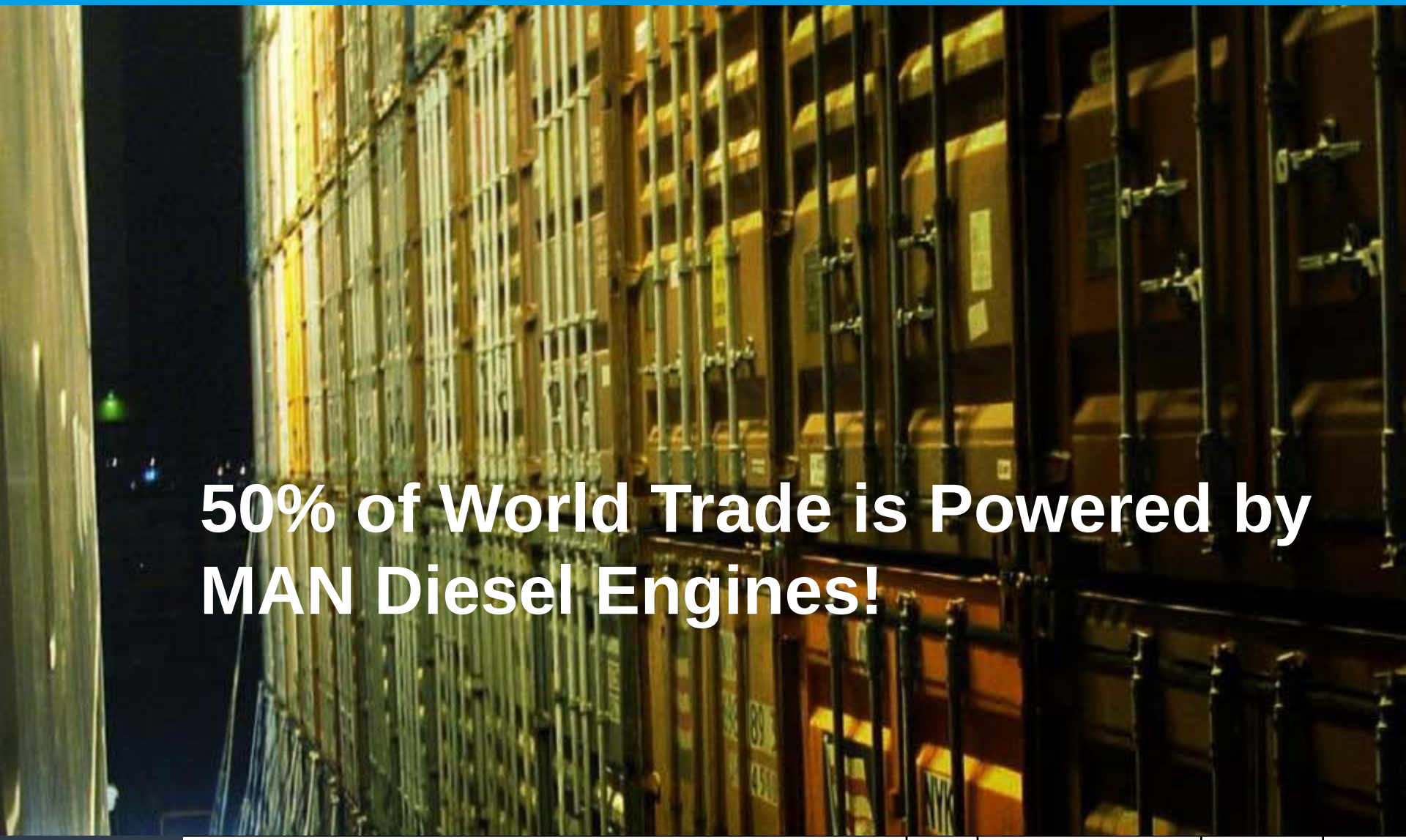
Areas of activity

Diesel Engine range from 450 kW to 87,000 kW



Areas of Activity

MAN Diesel & Turbo in World Trade



LNG on the Spot

Engineering the Future – since 1758

Sulaiman Fahimi

Sales Manager

Marine Medium Speed

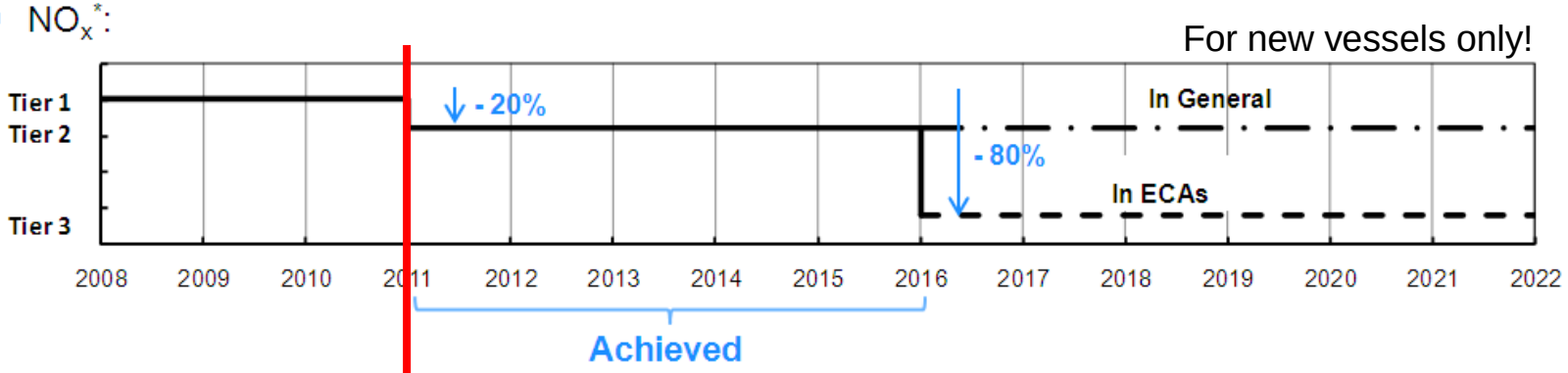
Content

- Motivation for Gas Fuelled Ship
- MAN Dual Fuel Technology
  - Engine Related
  - Tank Related
- Conclusions

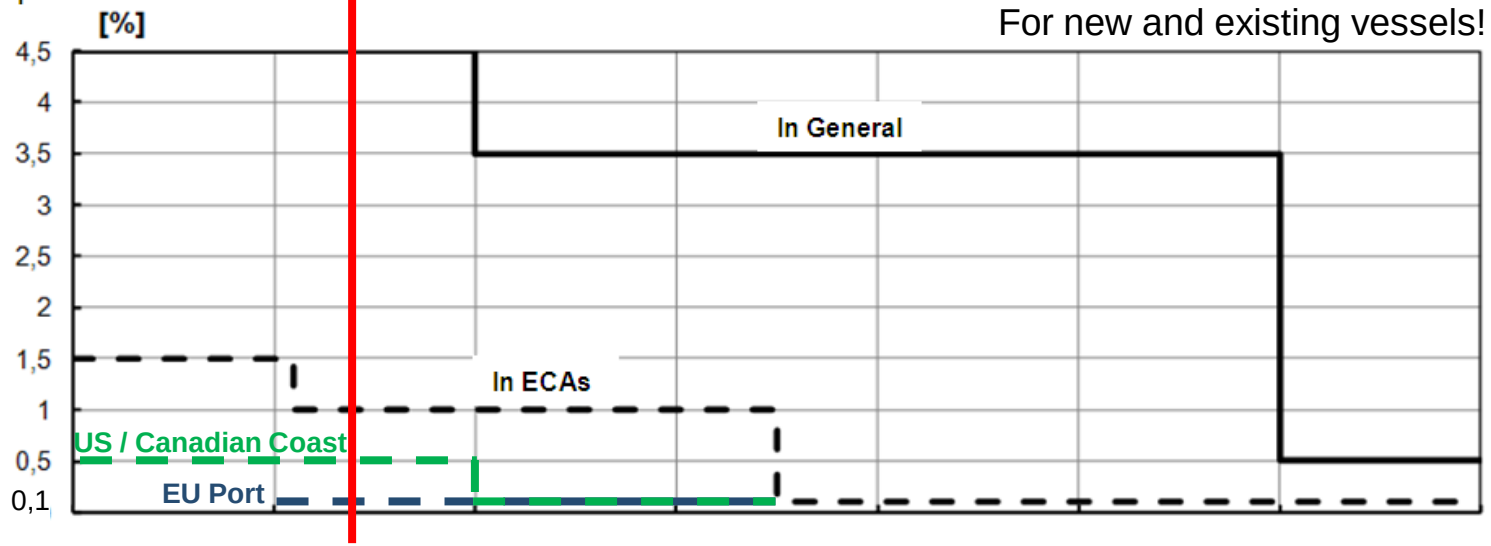
Emission Legislation Marine

IMO NOx and SOx Limits

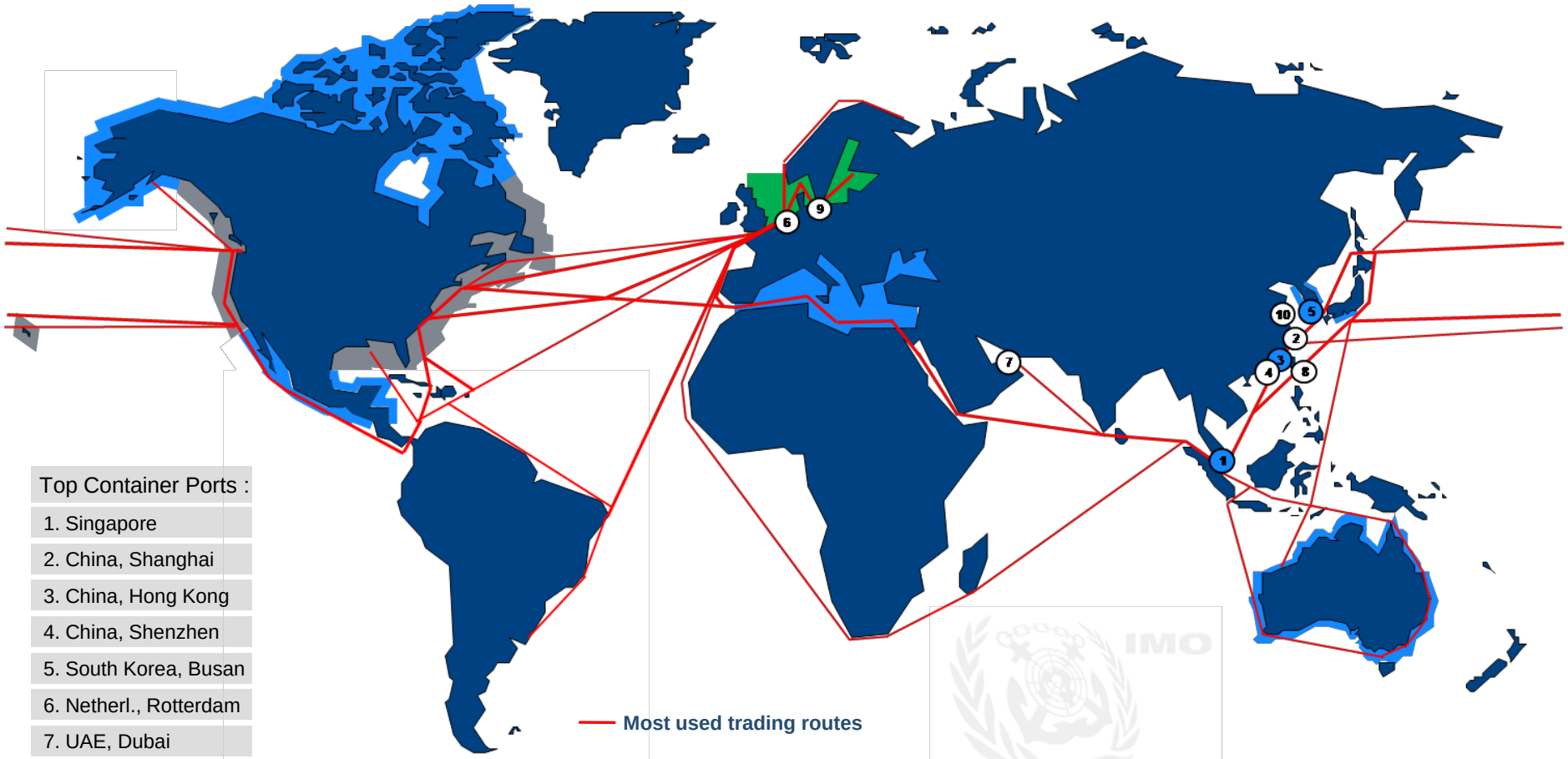
- Mandatory for all new ships to get operation permission
- Future emission guidelines:
  - NO_x^*:



  - Sulphur content:



Emission Control Areas – ECA-Trend by IMO (04/2010)



Top Container Ports :

1. Singapore
2. China, Shanghai
3. China, Hong Kong
4. China, Shenzhen
5. South Korea, Busan
6. Netherl., Rotterdam
7. UAE, Dubai
8. Taiwan, Kaohsiung
9. Germany, Hamburg
10. China, Qingdao

existing ECAs: Baltic Sea, North Sea

adopted ECAs: Coasts of USA, Hawaii and Canada (08/2011)

discussed ECAs: Coasts of Mexico, Coasts of Alaska and Great Lakes, Singapore, Hong Kong, South Korea, Australia, Black Sea, Mediterranean Sea (2014), Tokyo Bay (in 2015)

Towards a Greener Future

Portfolio of Solutions

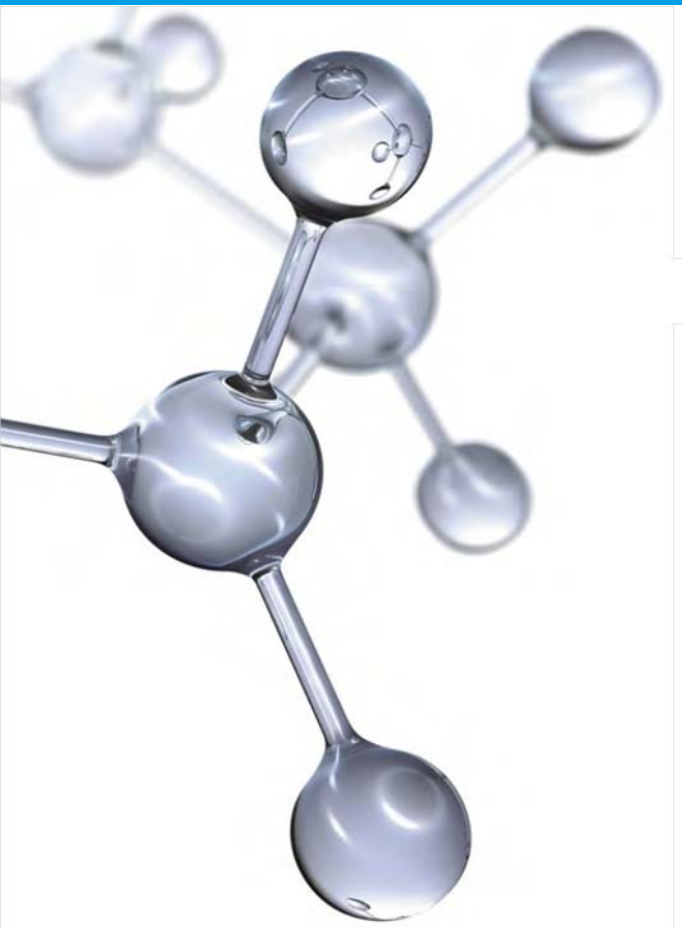
NO_x	SO_x
SCR	MGO
EGR*	DryEGCS
	Wet Scrubber

4-Stroke Dual Fuel in Gas Mode

2-Stroke Dual Fuel in Gas Mode
+
EGR* or SCR

*In case of using high sulphur fuel a Scrubber system would be necessary for the EGR system

Natural Gas
Characteristics



- Natural gas typical with 80% methane (CH4)
  LNG typical with 95% methane (CH4)
  Rest: Ethane, Propane, Butane and Nitrogen
- Colorless, odorless, non-toxic, non-carcinogenic
- In liquid form ~1/600 volume of natural gas
  and ~45% the density of water
- Vapors are ~50% density of air under normal atmos-
  pheric conditions (propane/butane heavier than air)
- Flammable range: approx. 5 – 15vol-% in the air
- Ignition temperature: 600°C

Natural Gas as Fuel

Benefits & Challenges with 4-Stroke DF Engines

- Benefits:
  - No additional measures to reach NO_x and SO_x-limits
  - Reduced PM and CO_2 emissions
  - Safe and redundant operation
  - Waste heat recovery possible

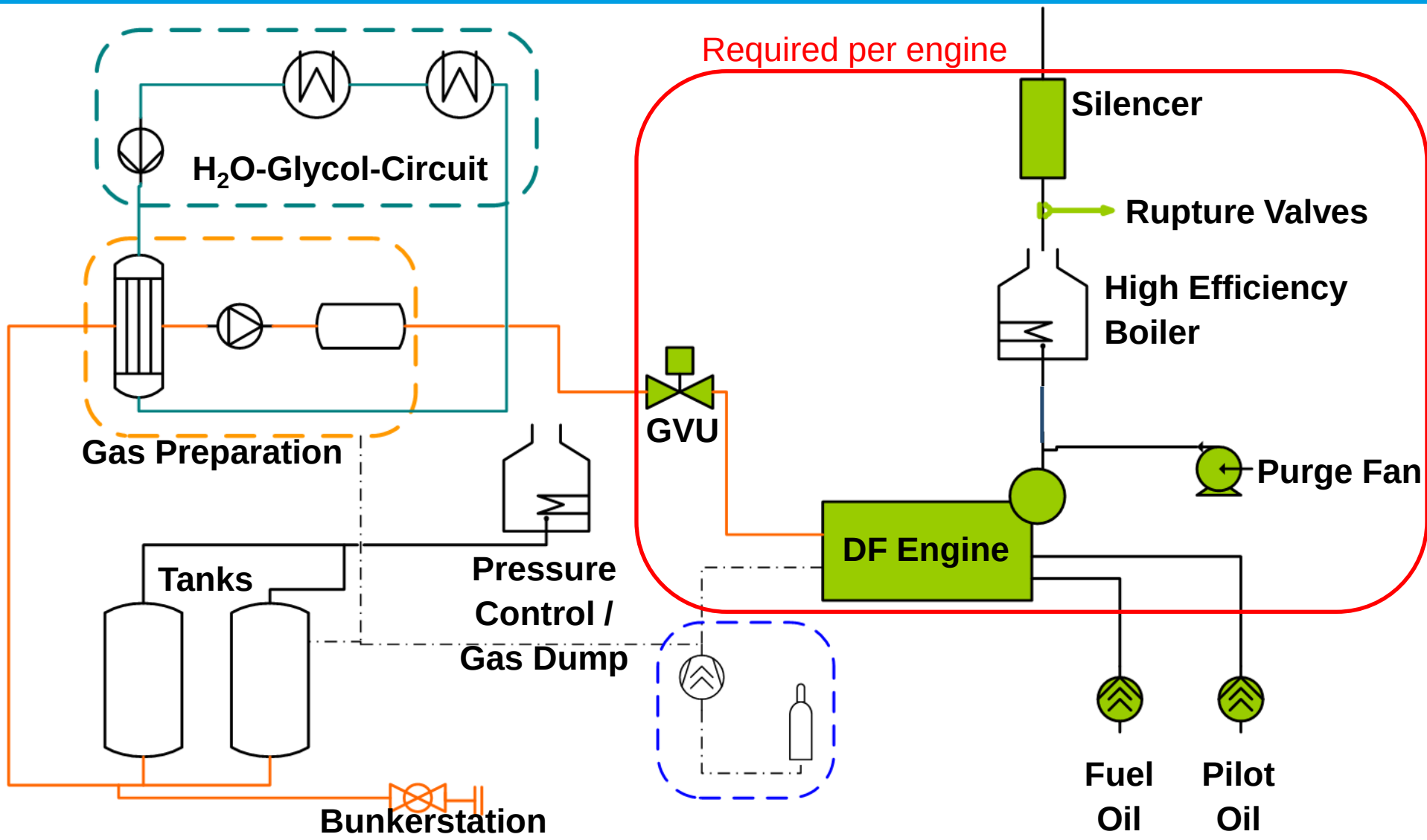
- Challenges:
  - Installation of storage equipment
  - Regulations not finally settled
  - Infrastructure and refuelling

Content

- Motivation for Gas Fuelled Ship
- MAN Dual Fuel Technology
  - Engine Related
  - Tank Related
- Conclusions

Gas-Fuelled Ships (not LNGC)

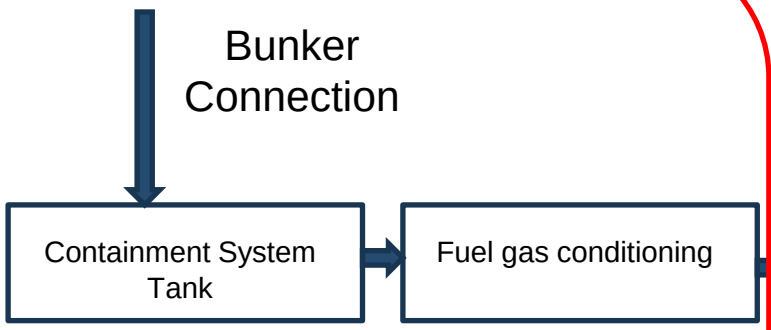
System Design



Split of Scopes MDT / Tank Supplier

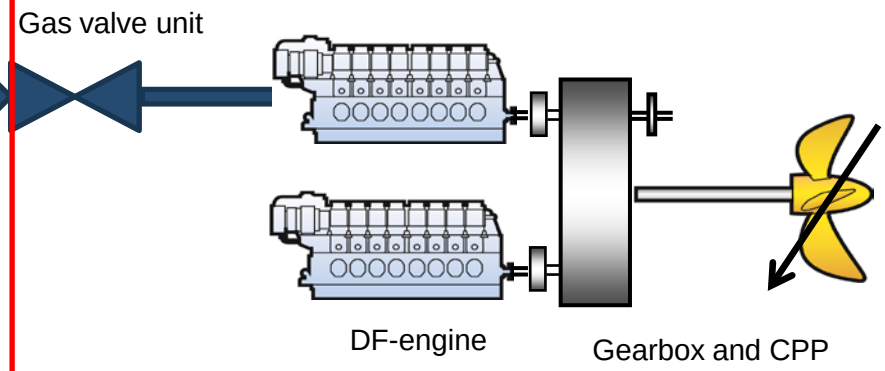
Tank supplier scope:
LNG storage & supply system

MDT scope:
Engine & supply system (e.g. gas valve unit)
+ gearbox and propeller (if applied)



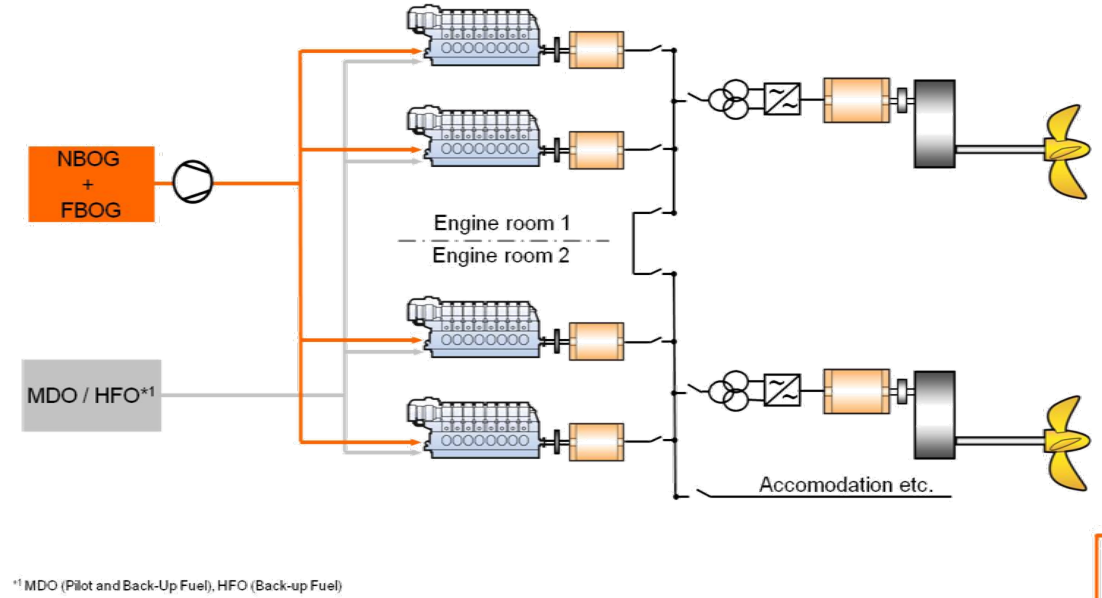
Auxiliary systems:

- water-glycol heating system
- inert gas system
- vent / ventilation
- valve remote operation
- safety systems



Example RoPax Ferry

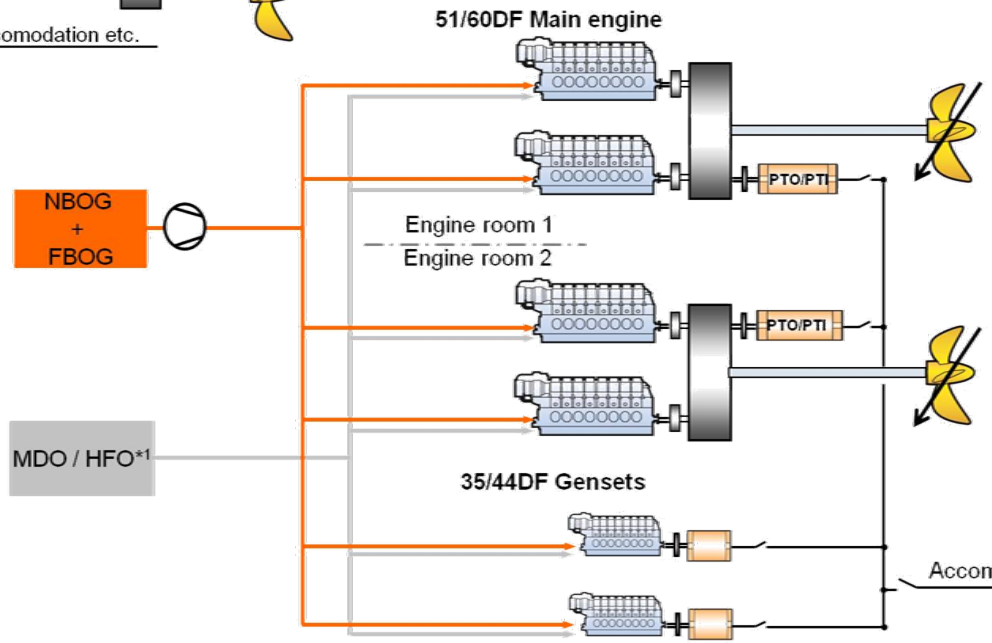
4-Stroke Dual Fuel Propulsion Solutions



*1 MDO (Pilot and Back-Up Fuel), HFO (Back-up Fuel)

4-Stroke Dual Fuel Diesel Electric

4-Stroke Dual Fuel Diesel Mechanic



*1 MDO (Pilot and Back-Up Fuel), HFO (Back-up Fuel)

51/60DF

Technical Data			
Number of Cylinder	L	6, 7, 8, 9	
	V	12, 14, 16, 18	
Speed	r/min	500	514
mep	bar	19.05	19.05
Cylinder Output	kW/cyl.	975	1000
Bore / Stroke	mm	510 / 600	
Power Range	kW	5,850 – 18,000	
SFOC @ 100% MCR	g/kWh	188	
SFGC @ 100% MCR	kJ/kWh	7,430	
SLOC	g/kWh	0.5	

Notes:

Consumption at ISO conditions, with engine driven pumps (LO, HT, LT) and 5% tolerance

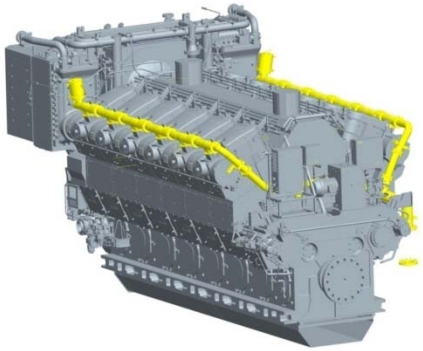
SFOC with MDO or HFO

SFGC including pilot fuel and with LHV_{min} of 28,000 kJ/m³

Above figures are preliminary

51/60DF
Operation Modes

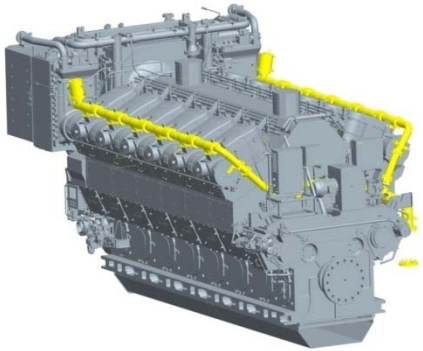
Gas mode



⇦ **99%** **Gas admission valve**
Natural gas
(vaporized LNG)

⇐ **< 1%** **Pilot fuel nozzle**
MDO (DMA, DMB)

Diesel mode

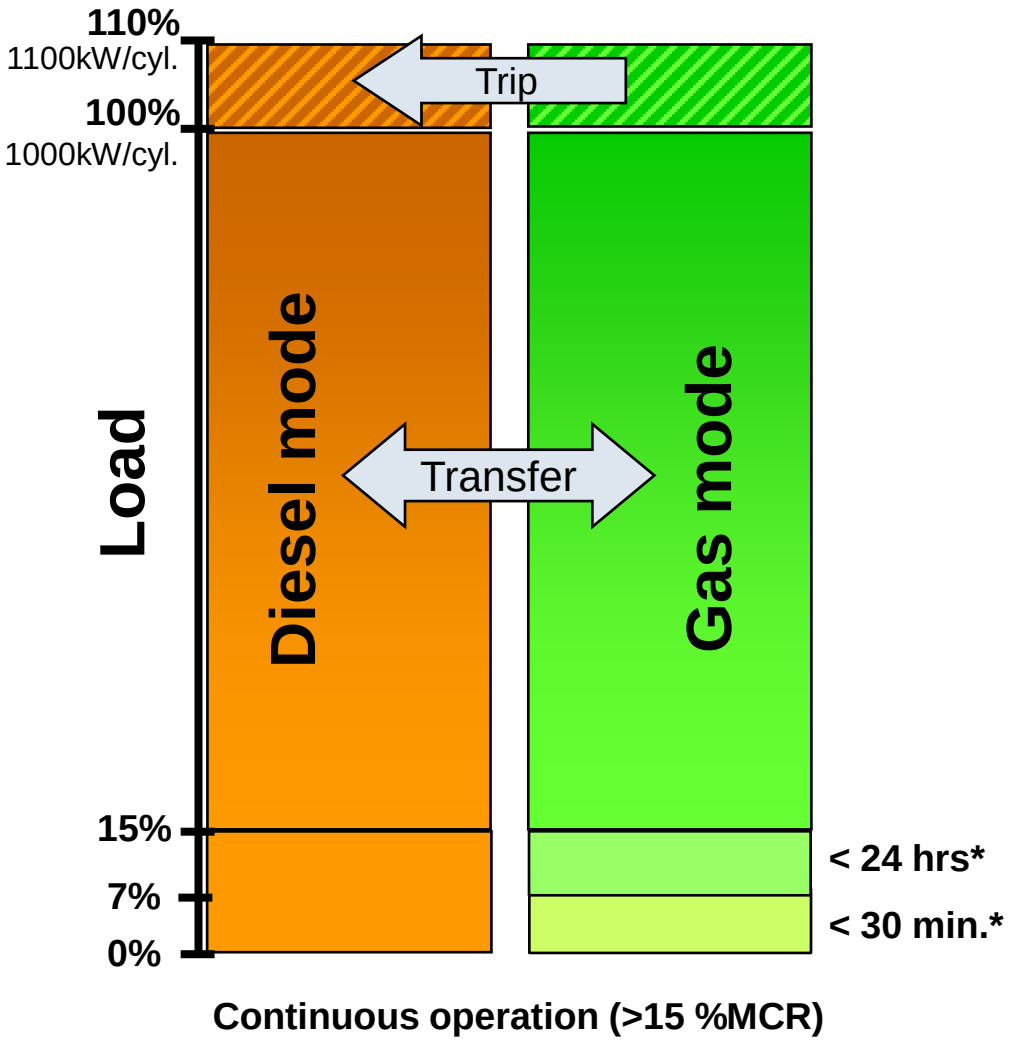


⇦ **99%** **Main fuel nozzle**
MDO (DMA, DMB)
HFO

⇐ **< 1%** **Pilot fuel nozzle**
MDO (DMA, DMB)

51/60DF

Transfer Diesel / Gas Operation (@514 rpm)



* with VTA Option

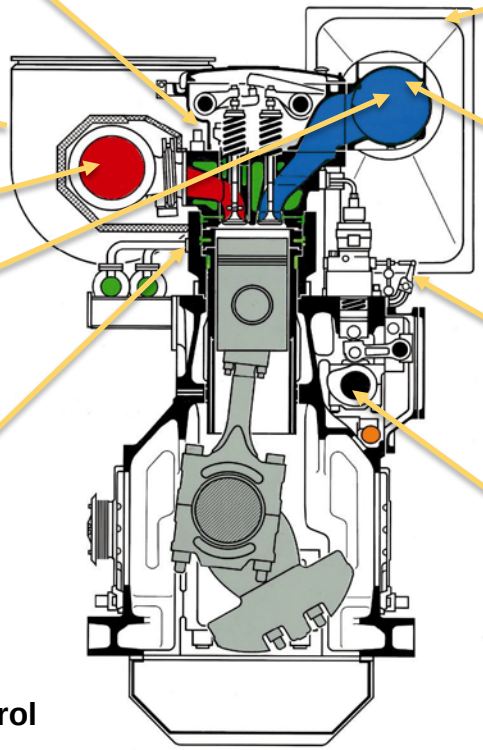
From 48/60B Parent Engine to 51/60DF

Additional Components

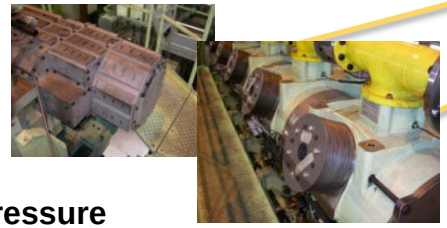
Elec. Common-Rail Pump

Pilot fuel injector for Common-Rail

Air / fuel ratio control flap



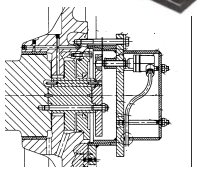
Elec. Gas valve



Pressure Relief valve

Elec. actuator

Knocking Sensor/Control



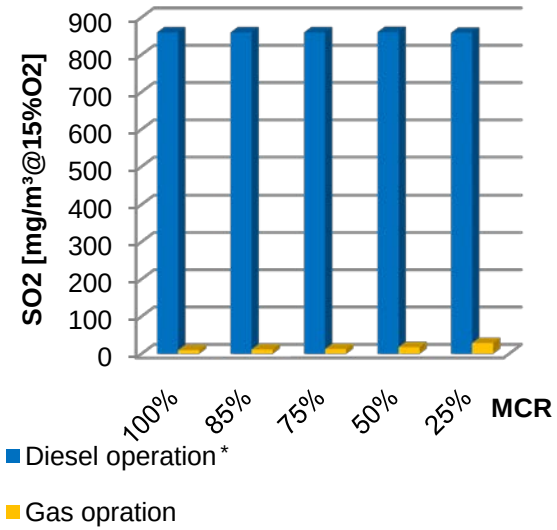
Phase Pick Up

L-type engine

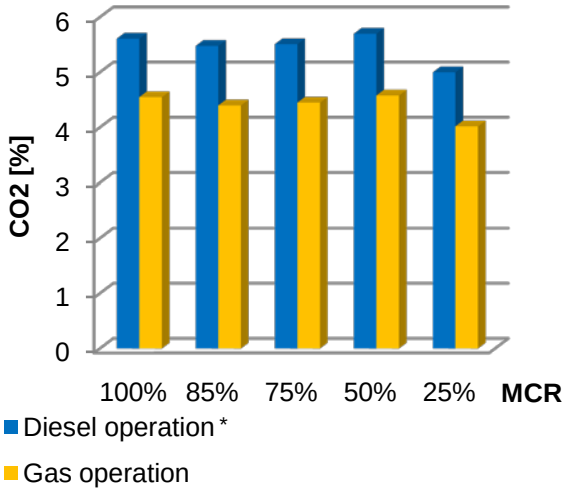
➡ 48/60 engines can be retrofitted to a 51/60DF engine

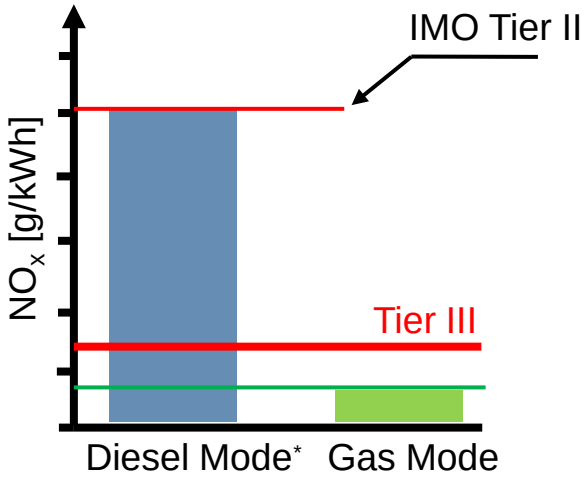
Advantages of Gaseous Fuels
Emissions

SO_x-Reduction



CO_2-Reduction





- CO_2 reduction – 20%
- SO_2 reduction – 99%
- NO_x: already IMO Tier III compliant in Gas mode!

* With MDO (S≤2,0%)

35/44DF

Technical Data			
Number of Cylinder	L	6, 7, 8, 9, 10	
	V	12, 14, 16, 18, 20	
Speed	r/min	720	750
mep	bar	20.1	20.0
Cylinder Output	kW/cyl.	510	530
Bore / Stroke	mm	350 / 440	
Power Range	kW	3,060 – 10,600	
SFOC @ 100% MCR	g/kWh	187	
SFGC @ 100% MCR	kJ/kWh	7,700	
SLOC	g/kWh	0.5	

Notes:

Consumption at ISO conditions, with engine driven pumps (LO, HT, LT) and 5% tolerance

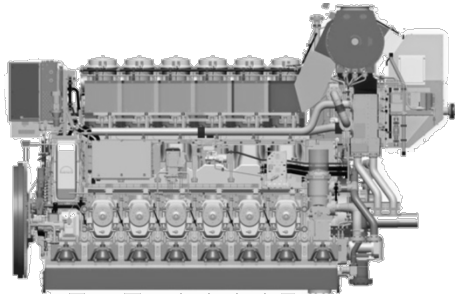
SFOC with MDO or HFO

SFGC including pilot fuel and with LHV_{min} of 28,000 kJ/m³

Above figures are preliminary

35/44DF
Operation Modes

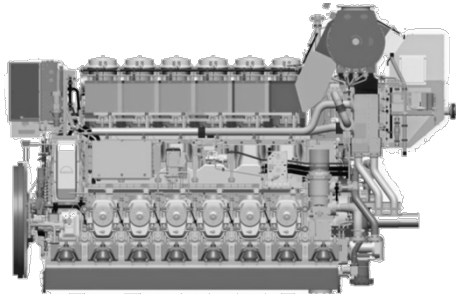
Gas mode



⇦ **99%** **Gas admission valve**
Natural gas
(vaporized LNG)

⇐ **< 1%** **Pilot fuel nozzle**
MDO (DMA)

Diesel mode

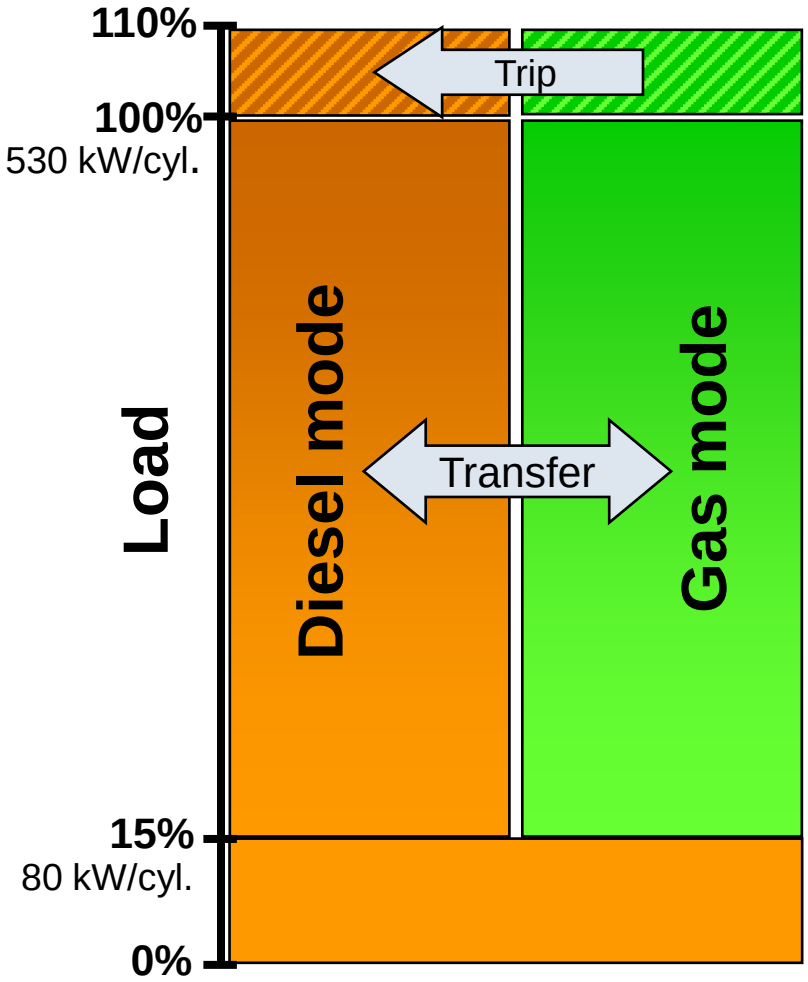


⇦ **99%** **Main fuel nozzle**
MDO (DMA, DMB)
HFO

⇐ **< 1%** **Pilot fuel nozzle**
MDO (DMA)

35/44DF

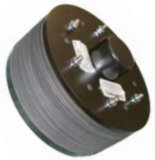
Transfer Diesel / Gas Operation (@750rpm)



Continuous operation (>15 %MCR)

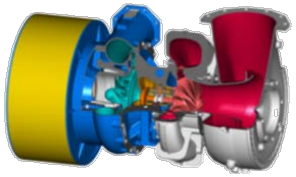
35/44DF Engine Design

Using proven technologies



- Pressure relief valve for safe design

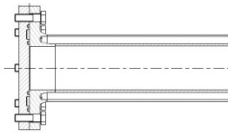
- Flexible, intelligent Pilot fuel oil injection (CR-system)



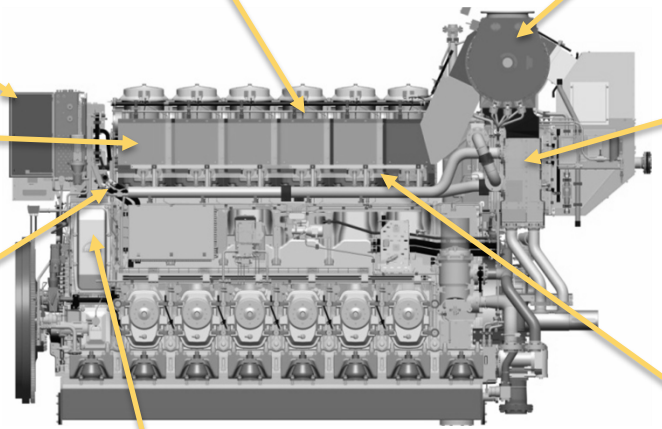
- High efficiency turbocharging

- Flexible, intelligent Fuel gas control

- Air/fuel ratio control system



- Double wall fuel gas piping for safe design



- $SaCoS_{one}$
- Knocking detection control system

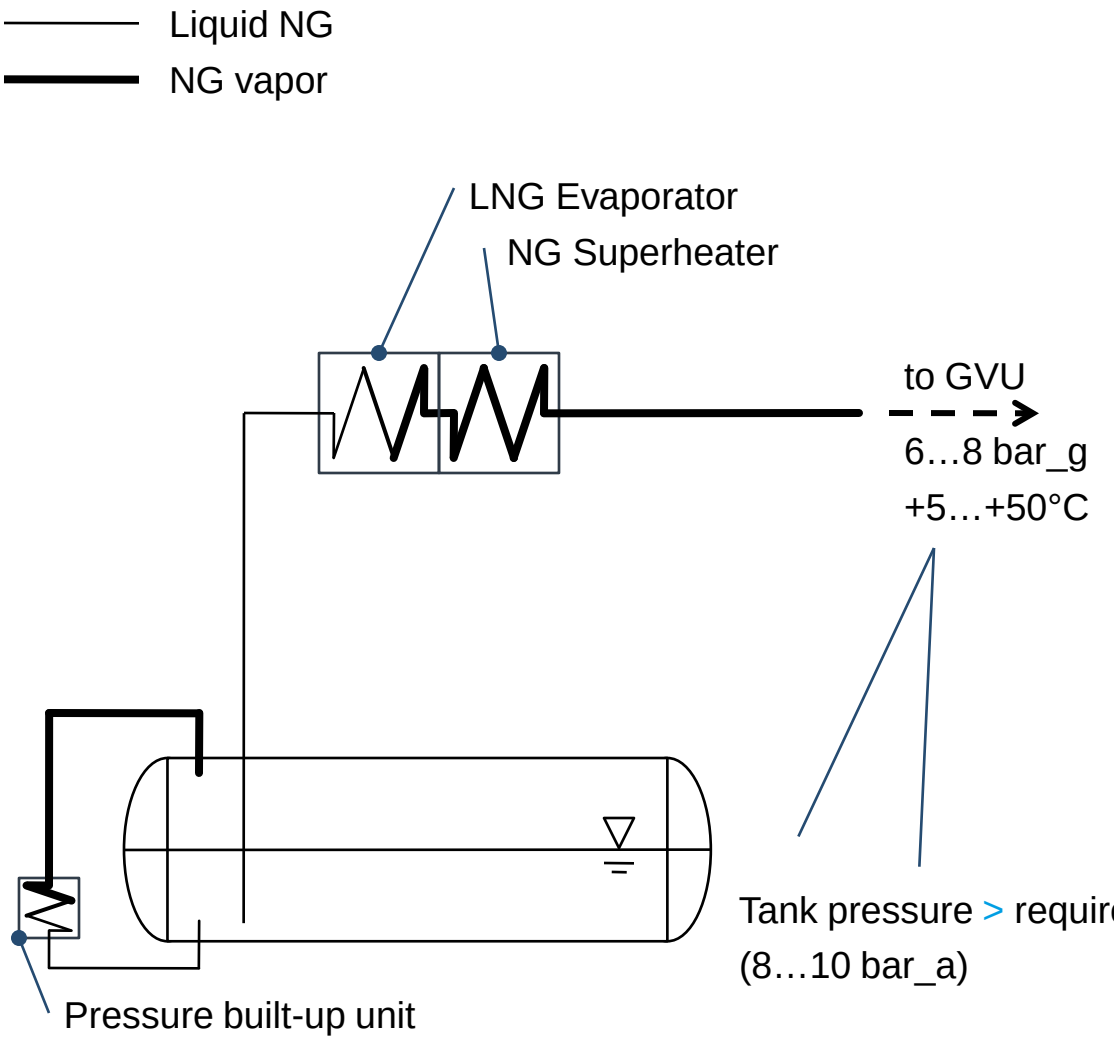
- Flexible, intelligent Main fuel oil injection (CR-system)

Content

- Motivation for Gas Fuelled Ship
- MAN Dual Fuel Technology
  - Engine Related
  - Tank Related
- Conclusions

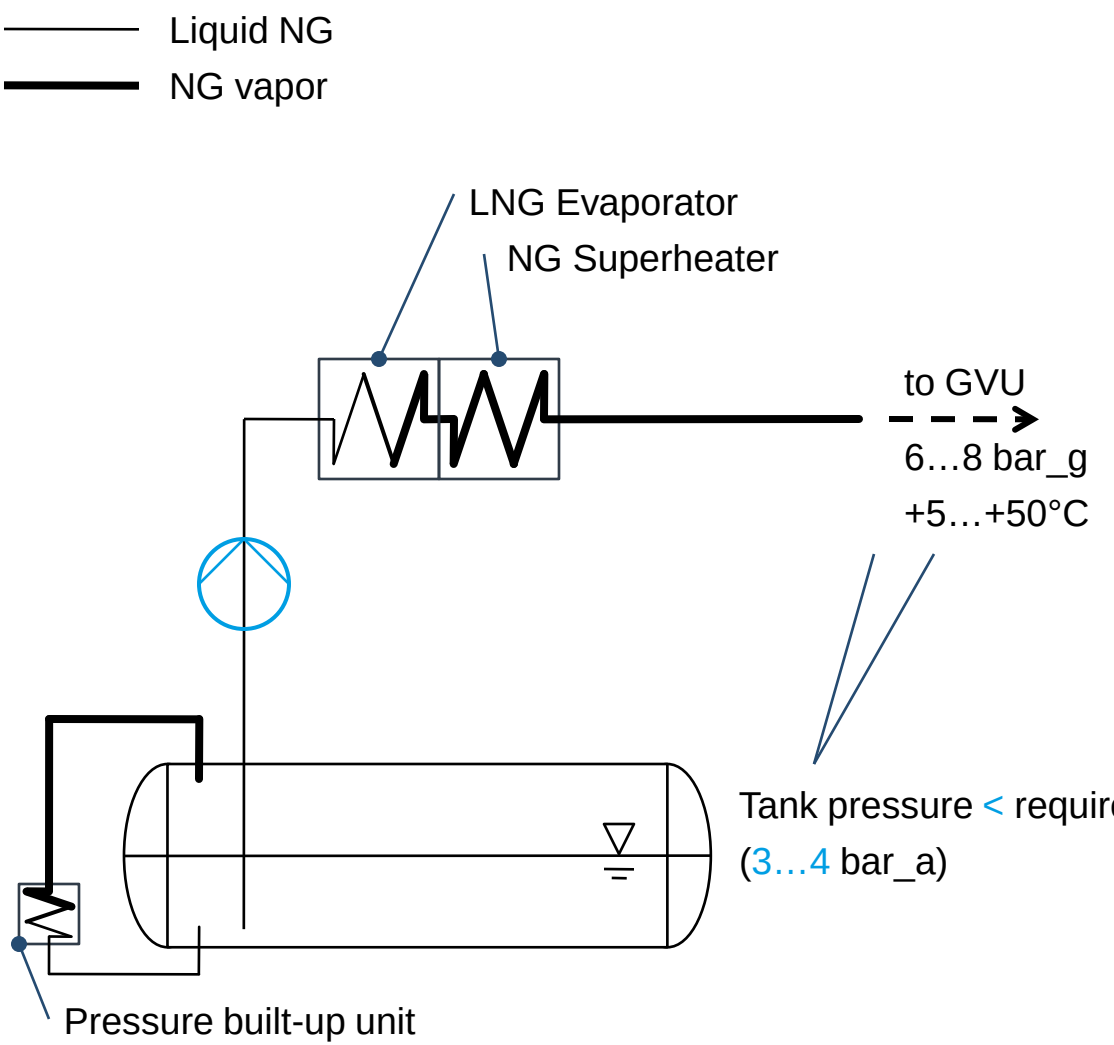
Tank System Designs

1. High Pressure @ 10 bara



- Tank contains full pressure for operation
- Insulated tanks (vacuum or foam)
- No additional pumps needed
- Easy to handle
- High specific weight and invest
- Only cylindrical shaped
- For small applications (<400m³ storage)

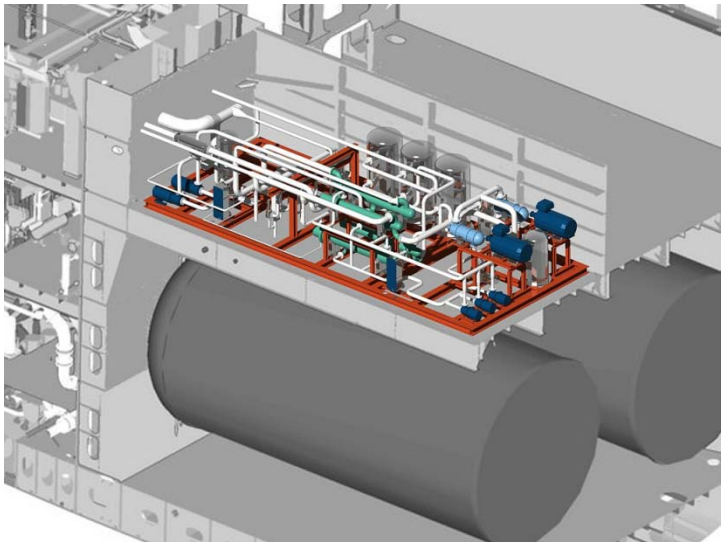
Tank System Designs
2. Medium Pressure @ 4 bara

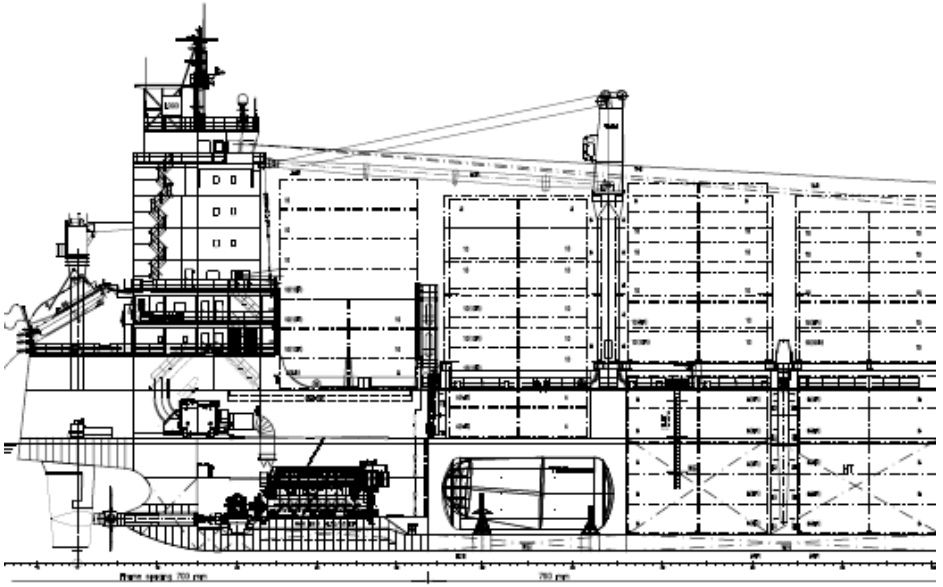


- Tank operates on lower pressures → lower specific weight and invest
- Conventional isolated tanks
- Cylindrical and conical designs possible → better space efficiency
- Additional pumps required
- Proven in small gas tankers
- For mid-size applications

Examples
Container Feeder Vessel

- 1300 TEU Container Feeder Vessel
- 3 x 300 cbm LNG tank
- Fuel gas supply system including gas compressors to allow for very high LNG-fuel bunkering rate

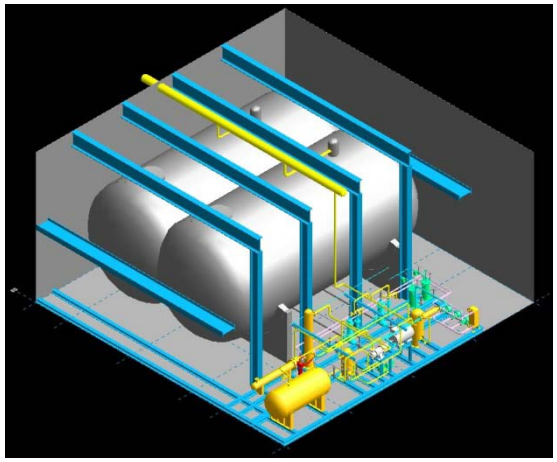


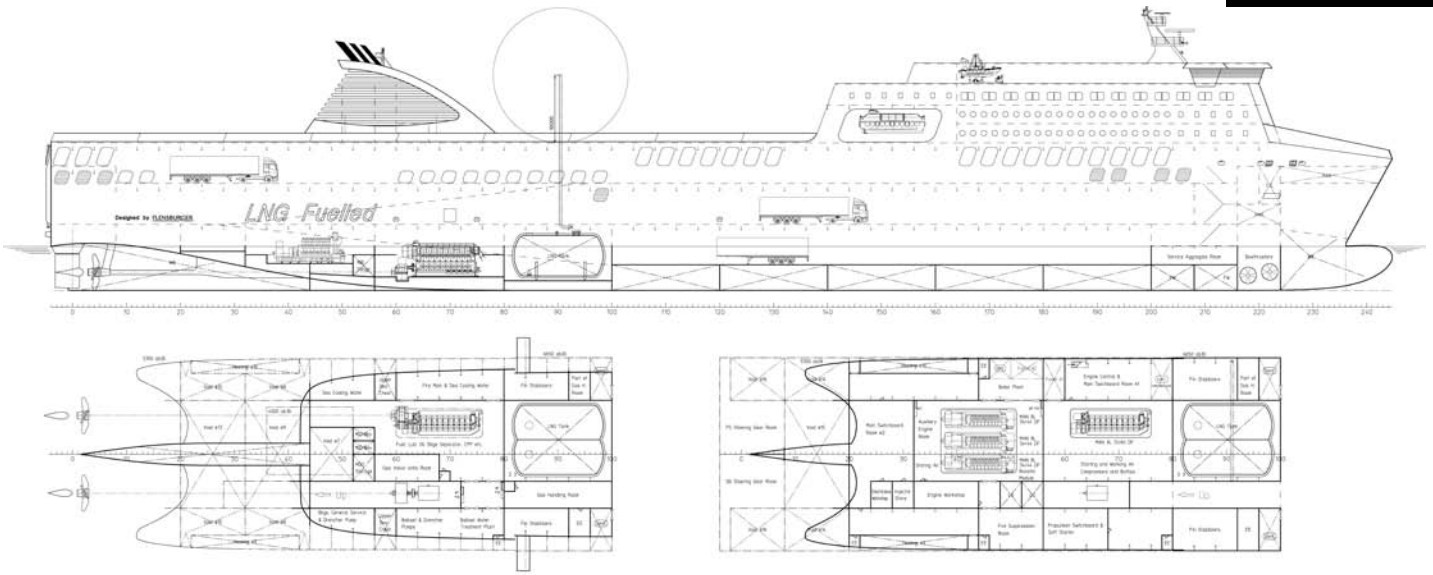


Source: Neptun Stahlkonstruktions GmbH

Examples
RoPax Vessel

- RoPax Vessel Design
- One 600 cbm bi-lobe design LNG tank
- Fuel gas supply system with gas compressors

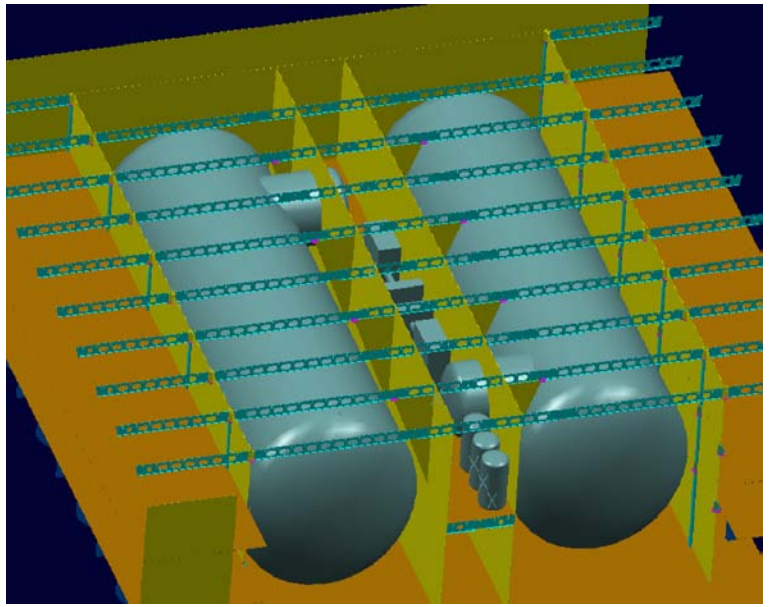


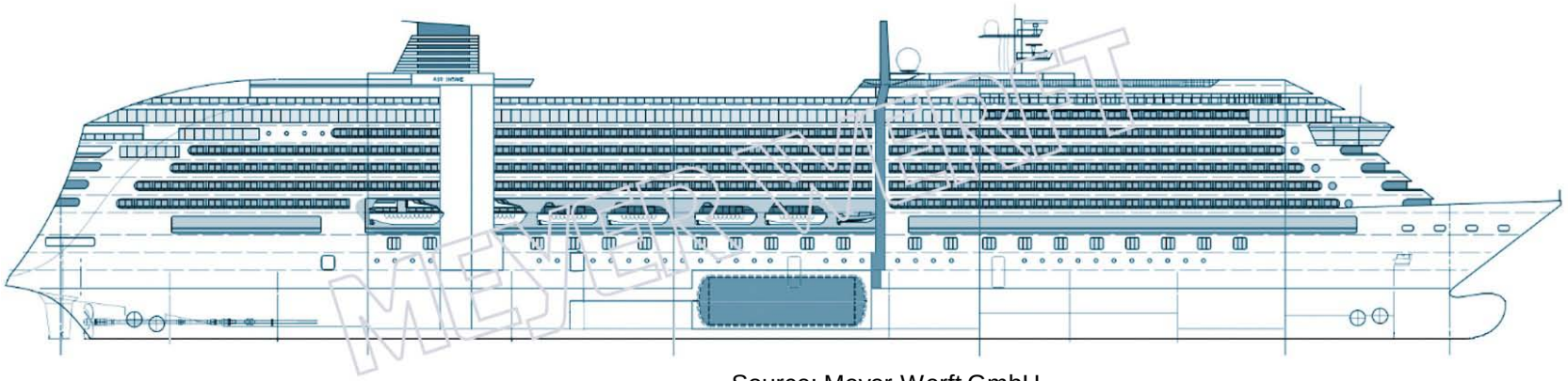


Source: Flensburger Schiffbau GmbH & Co KG

Examples
Cruise Vessel

- Cruise ship Design
- Two cylindrical LNG tanks
- Fuel gas supply system with gas compressors





Source: Meyer Werft GmbH

Content

- Motivation for Gas Fuelled Ship
- MAN Dual Fuel Technology
  - Engine Related
  - Tank Related
- Conclusions

Gas Fuelled Vessel

What does this mean for you?

- **Engine related**: size-wise similar to “mono-fuel” diesel engine, enhanced demand for electronics (e.g. pilot fuel, knocking control), double walled pipes, gas valve unit, further components related to gas mode etc.
- **Engine room related:** Safety concept for gas safe engine room mandatory (including ventilation system, gas detection system etc.)
- **Plant related:** LNG containment system, Fuel gas conditioning system etc. in addition to liquid fuel containment and conditioning system

Conclusions

- LNG has been shipped in LNGC around the globe for half a century without any major incident
- LNG can play a major role as a future fuel for shipping due to its ecological and economical advantages
- Technical solutions for LNG fuelled vessels are available today
- Dual-fuel engine propulsion system allow highest flexibility to choose the best fuel for each situation
- Challenge:
  - Availability of LNG fuel infrastructure

Thank You For Your Attention

Engineering the Future

– since 1758.