WÄRTSILÄ Ship Design

Gas as marine fuels – operational aspects

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Ship Efficiency, by STG
Hamburg, 29.9.2009

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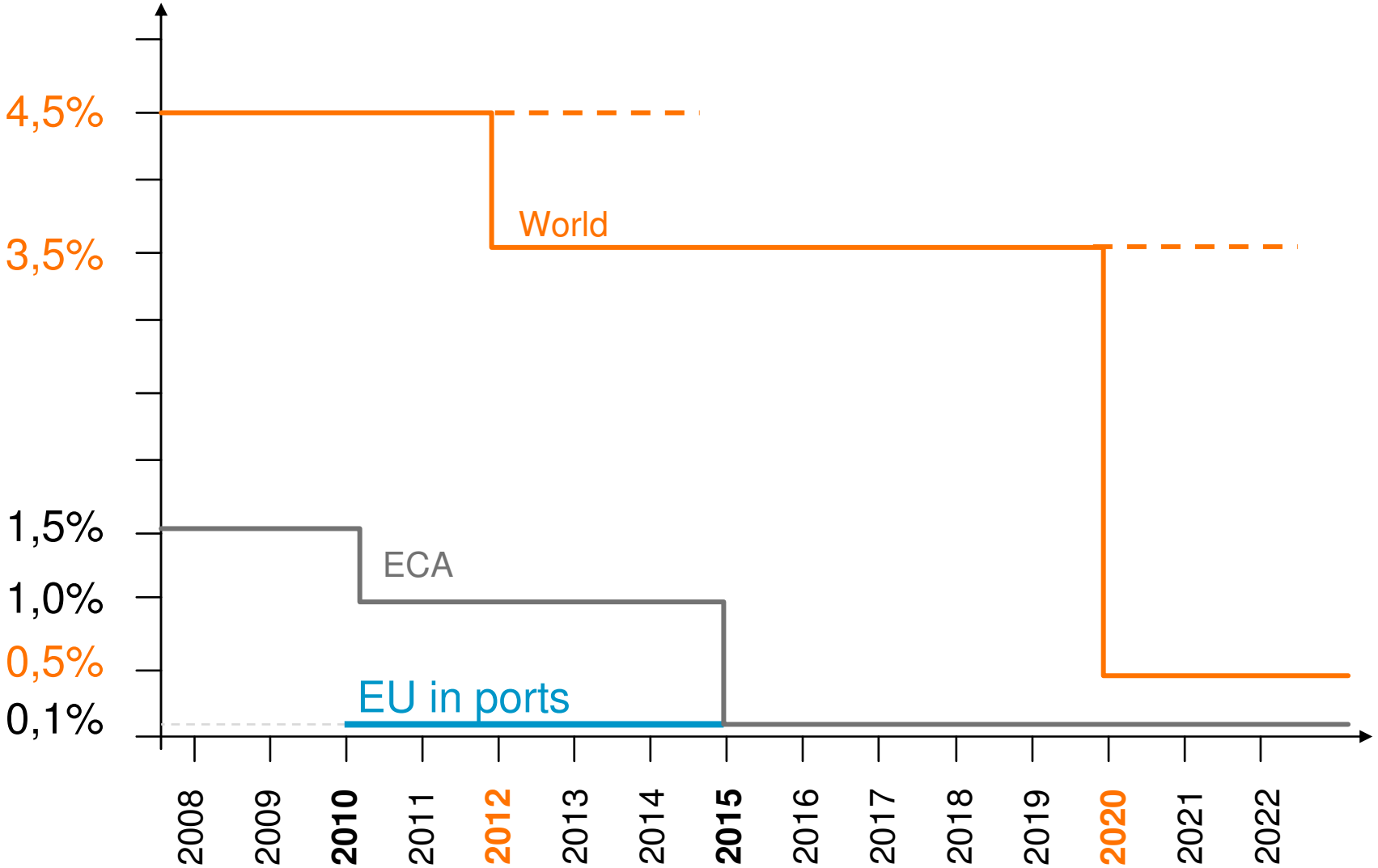
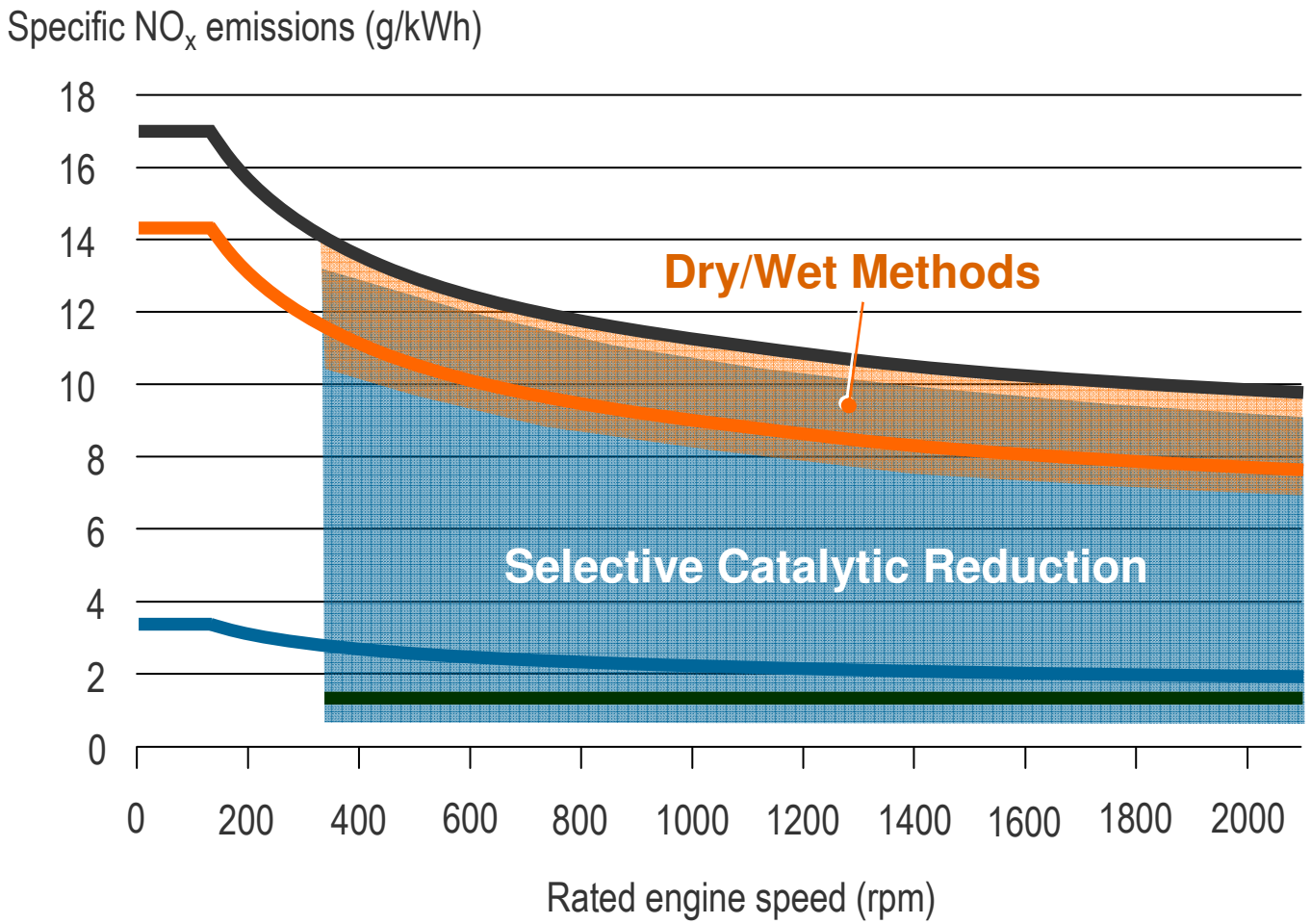
Content

- Drivers
  - Emission legislations
  - Global warming – reduction of CO2 emissions
- LNG as a marine fuel
- LNG fuelled ship references
- Dual fuel engines
- Rules & regulations
- Gas storage and feed system
- Bunkering
- Running on gas in port
- The efficient ferry concept

IMO Sulphur Limits



NO_x reduction – IMO requirements and methods



Tier I (present)
Ships built 2000 onwards
Engines > 130 kW

Retrofit: Ships built 1990 – 2000
Engines > 90 litres/cylinder and > 5000 kW

Tier II (global 2011)
Ships built 2011 onwards
Engines > 130 kW

Tier III (ECAs 2016)
Ships in designated areas, 2016 onwards
Engines > 130 kW

Wärtsilä Dual Fuel Technology

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NOx and sulphur ECA - what are the options?

How to meet the emission limits after 2016 when operating inside SECA (NO_x) areas:

- HFO + Scrubber + SCR
- Distillate fuels + SCR
- Alternative liquid fuels + SCR
- Gaseous fuels
- …?

Greenhouse emission reductions

CO_2 emission reduction:

- Reduce power demand
  - Ship and propulsion design
  - Operation profile
- Improve efficiency
  - Propulsion optimisation
  - Engine technology
  - Waste energy recovery
- Change to alternative fuels
  - Fuels with less carbon

IMO Energy Efficiency Design Index (EEDI)

$$EEDI = \frac{CO_2 \quad from \quad propulsion \quad + CO_2 \quad from \quad Auxiliaries \quad - Efficent \quad use \quad of \quad energy}{fi \cdot Capacity \cdot V_{ref} \cdot f_W}$$

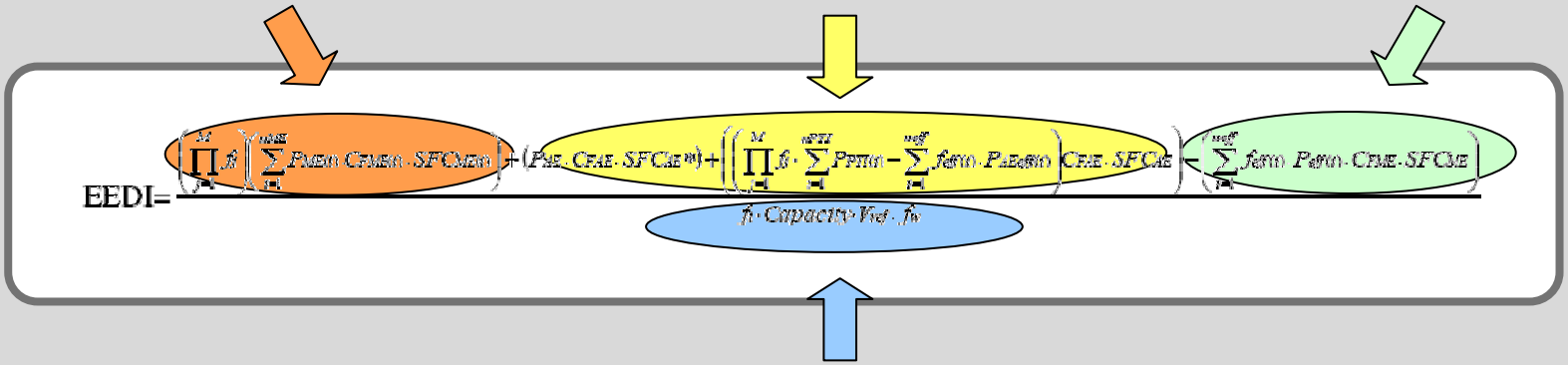
$$EEDI = \frac{\left(\prod_{j=1}^{M} fj\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right) + \left(\left(\prod_{j=1}^{M} fj \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{fi \cdot Capacity \cdot V_{ref} \cdot f_w}$$

EEDI improvement

Reduction of propulsion power
- Speed reduction
- Lower resistance
  - Hull form
  - Reduced friction
- Propulsion efficiency
  - Propulsion concept
  - Propulsor efficiency
- Propulsion machinery efficiency
- **Fuels with less carbon**
  - **LNG**

Reduction of aux power
- Reduce hotel load
  - HVAC
  - Lighting
- Aux machinery efficiency
- **Fuels with less carbon**
  - **LNG**

Clean energy and recovery
- WHR
- Wind power
  - Sails
  - Kite
  - Flettner rotors
- Solar power
- CO2 capturing
- ….



Increase capacity
- Larger ship
- Larger payload

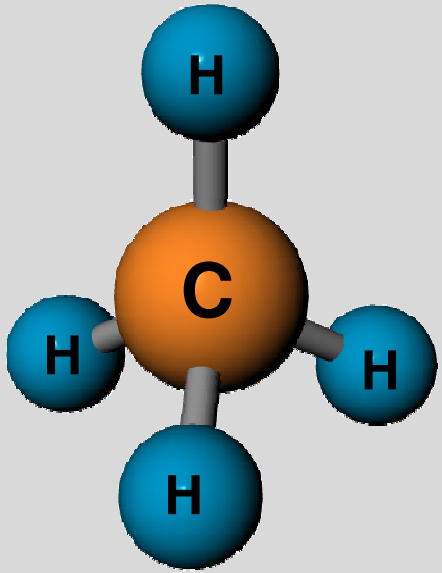
3 thesis - how to meet the emission regulations

How to meet the coming emission regulations:

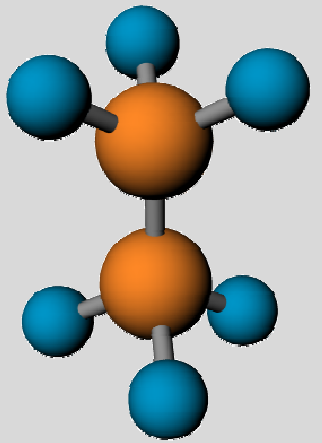
- **Keep it simple** - No complex process plants
- **Keep it clean** - No waste, sludge, soot
- **Keep it cool** - Liquefied gas storage for compact size

What is natural gas?

- Natural gas is mostly methane (CH_4)
- Methane contains the highest amount of energy per unit of carbon of any fossil fuel
  - Carbon to hydrogen ratio 1 / 4 (gasoline: 1 / 2,25)
  - Lower CO_2 emissions
- Natural gas is:
  - A very safe fuel
  - Non-toxic
  - Lighter than air



Methane (CH_4)



Ethane (C_2H_6)

Cleaner Exhaust Emissions with LNG

- 25-30% lower CO_2
  - Thanks to low carbon to hydrogen ratio of fuel
- 85% lower NO_X
  - Lean burn concept (high air-fuel ratio)
- No SO_X emissions
  - Sulphur is removed from fuel when liquefied
- >90% lower particulate emissions
- No visible smoke
- No sludge deposits

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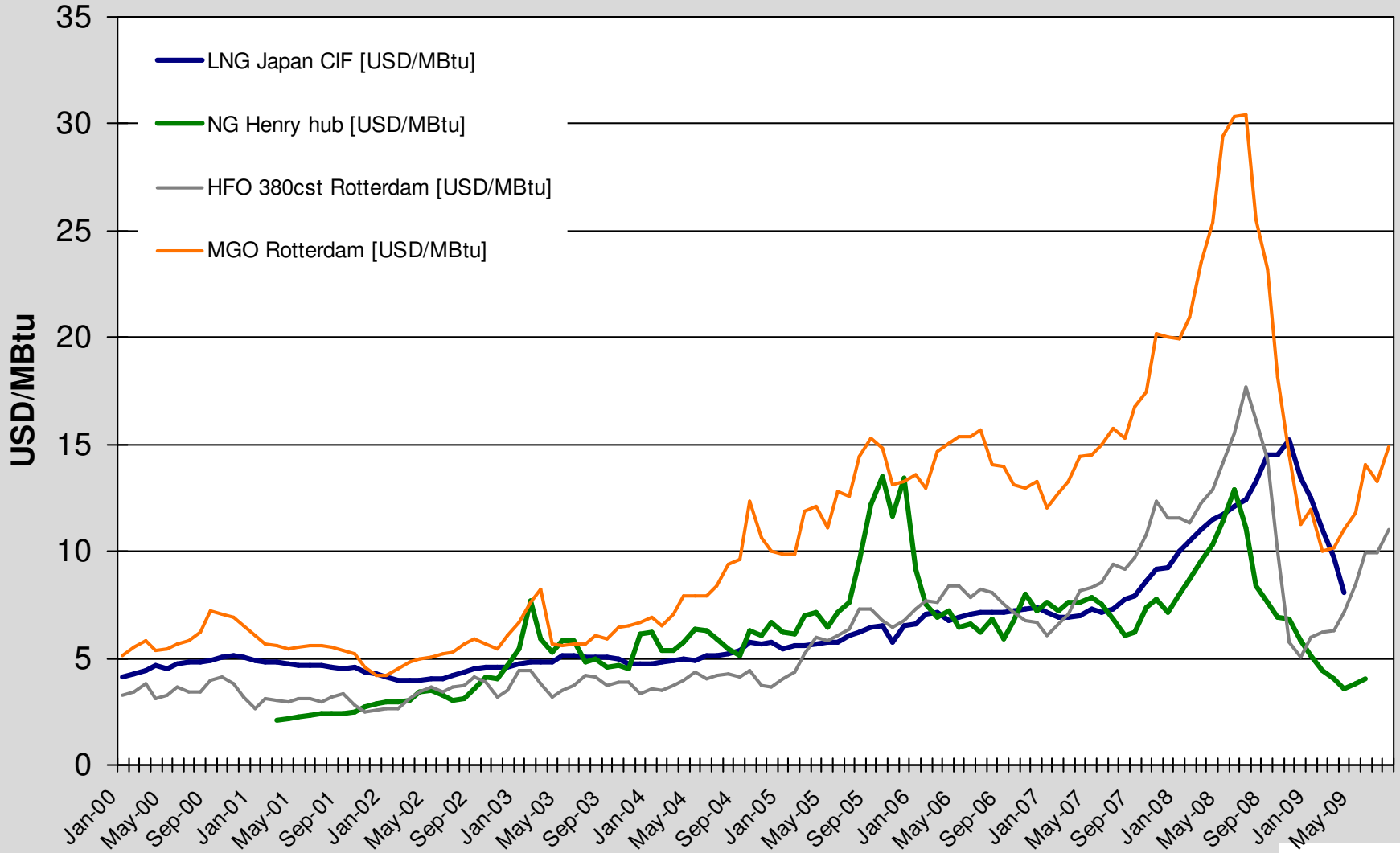
Fuel prices



Sources: www.lngoneworld.com, www.bunkerworld.com, LR Fairplay

LNG fuelled ship references

LNG fuelled ships* in operation




Ship name	Ship type	Owner	Year built	Installed power
Glutra	Ferry	Fjord1 (NO)	2000	2 700 kW
Viking Energy	PSV	Eidesvik (NO)	2003	8 080 kW
Stril Pioneer	PSV	Simon Mokster (NO)	2003	8 080 kW
Bergensfjord	Ferry	Fjord1 (NO)	2006	12 370 kW
Fanafjord	Ferry	Fjord1 (NO)	2007	12 370 kW
Raunefjord	Ferry	Fjord1 (NO)	2007	12 370 kW
Stavangerfjord	Ferry	Fjord1 (NO)	2007	5 300 kW
Mastrafjord	Ferry	Fjord1 (NO)	2007	5 300 kW
Viking Queen	PSV	Eidesvik (NO)	2008	8 080 kW
Viking Lady	PSV	Eidesvik (NO)	2008	8 080 kW

* Other than LNG Carriers

LNG fuelled vessel: PSV Viking Energy & Stril Pioneer

Viking Energy / Stril pioner (2003)

Owners: Eidesvik AS
Mökster Shipping
Builder: Kleven Verft
Designer: Vik-Sandvik
(Wärtsilä Ship Design)
Main particulars:

- Gross 4000 GT
- Length 94,9 m
- Beam 20,4 m
- Speed 17,2 knots
- LNG tank 220 m^3
- 4 x Wärtsilä 6L32DF gensets
- Power 4 x 2020 kW
  Total 8080 kW

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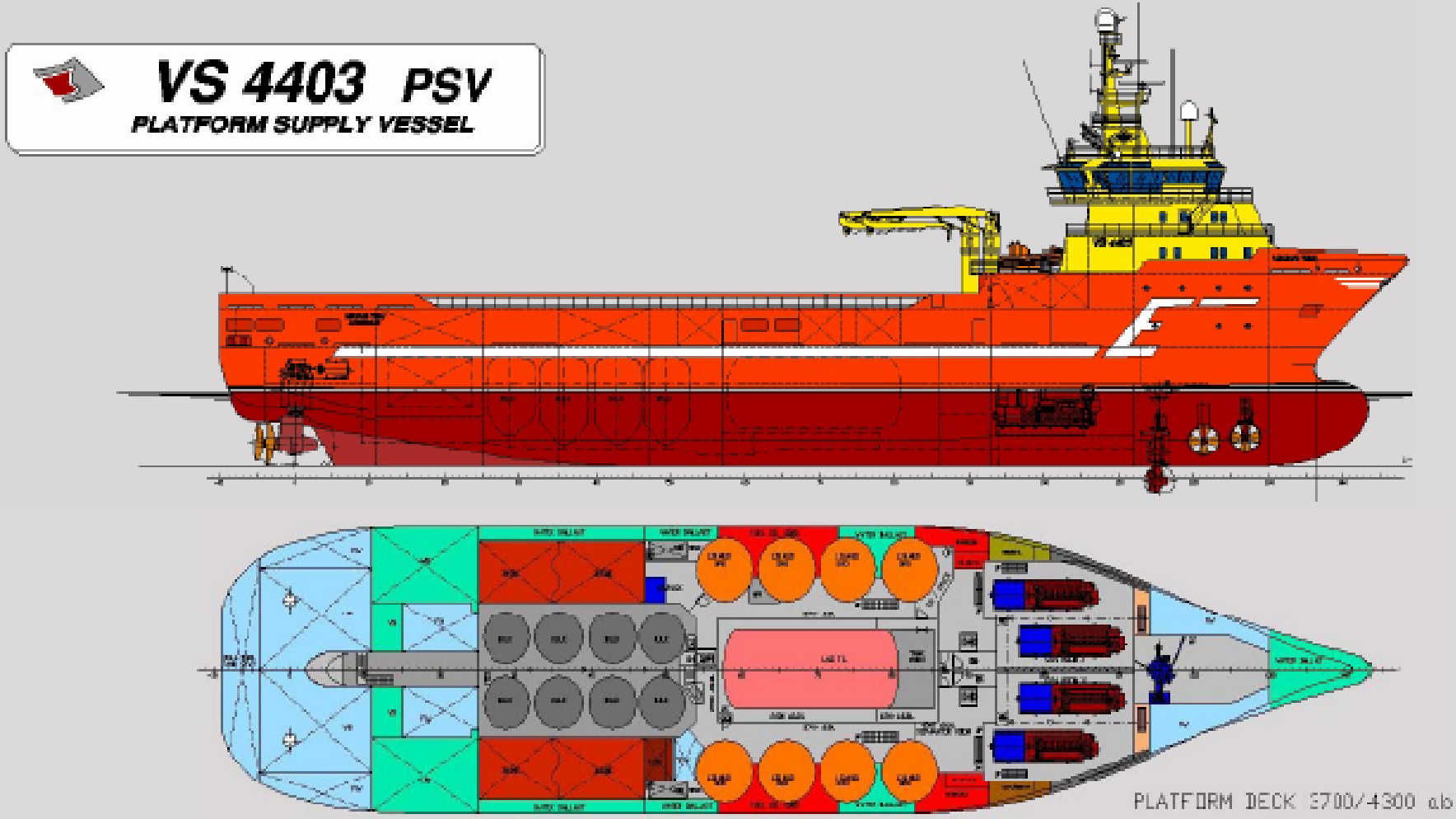
LNG fuelled vessel: PSV Viking Energy & Stril Pioneer



LNG fuelled vessel: PSV Viking Queen & Viking Lady

Viking Queen / Viking Lady (2008)

Owners:	Eidesvik AS
Designer:	Vik-Sandvik (Wärtsilä Ship Design)

Main particulars:

– Gross	5 934	GT
– Length	92,2	m
– Beam	21	m
– LNG tank	220	m^3
– 4 x Wärtsilä 6L32DF gensets		
– Power	4 x 2020	kW
– Total	8080	kW

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LNG fuelled vessel: PSV Viking Queen & Viking Lady

LNG fuelled ships on order

- 3 different small ferries
- 3 coast guard vessels
  - Gas and diesel engines
- LNG supply vessel
- RoRo vessel for Sea-Cargo

DF engines for LNG carriers

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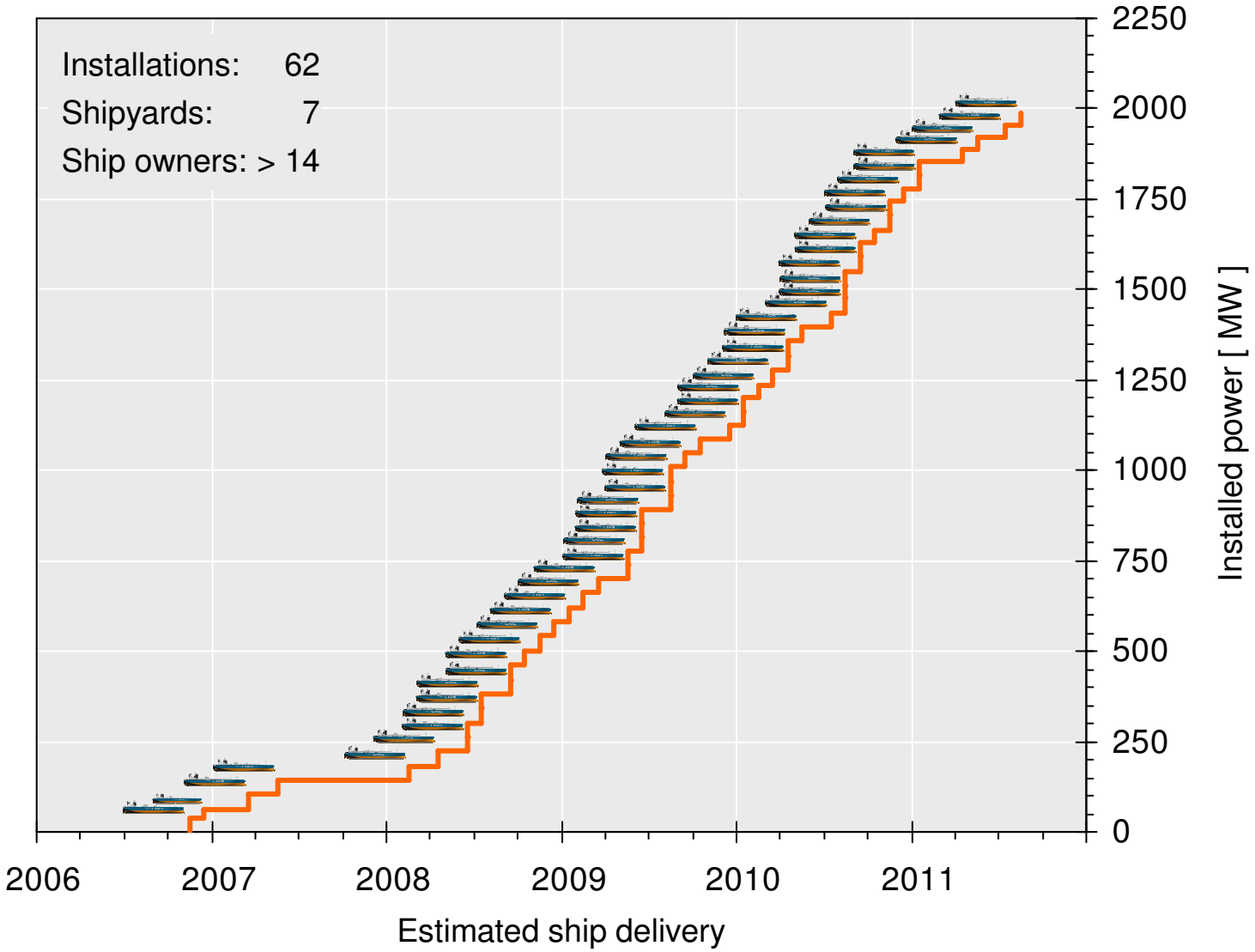
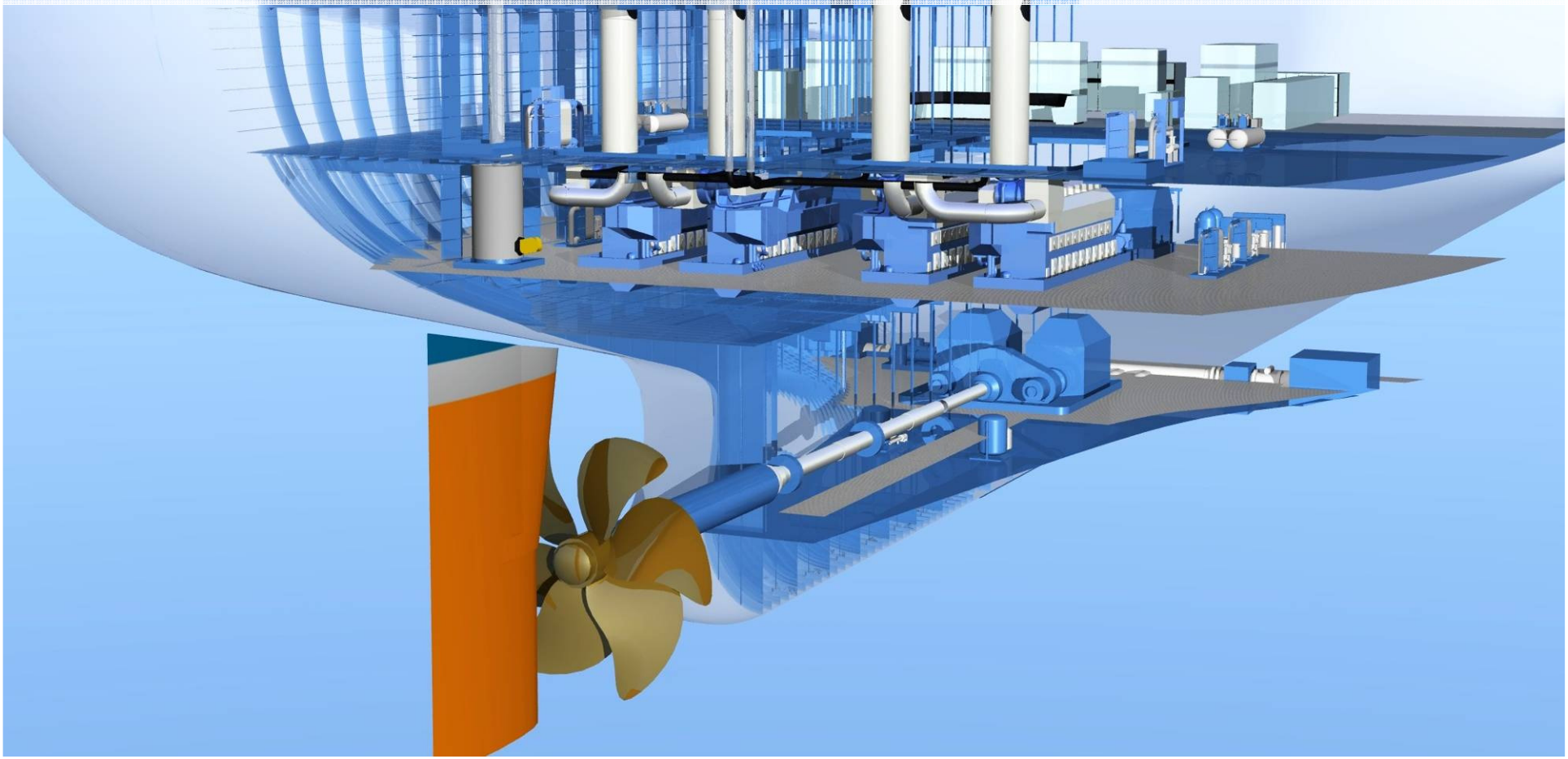
Dual-fuel-electric LNG carriers



DF-electric machinery

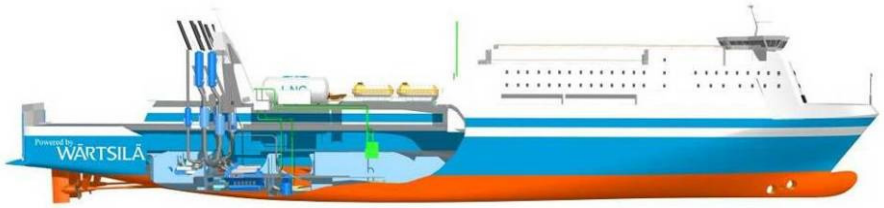
Dual Fuel electric machinery has become the leading new machinery solution for LNG carriers

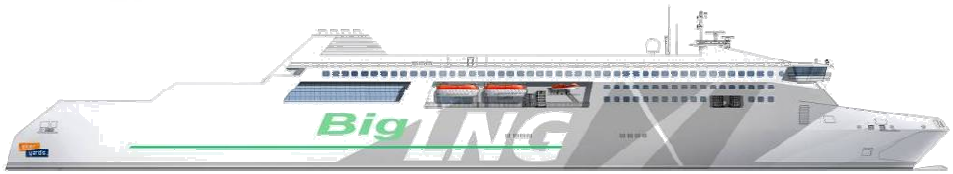


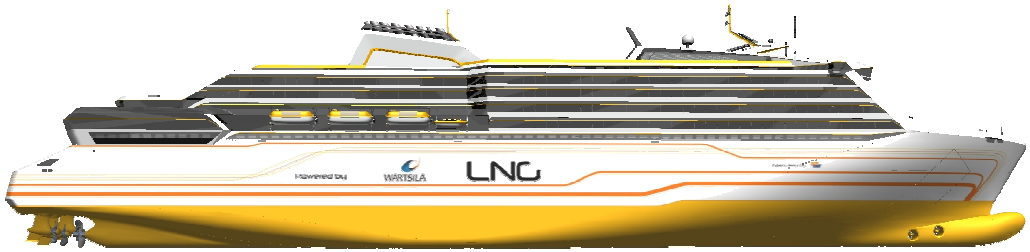
LNG fuelled passenger vessel concepts

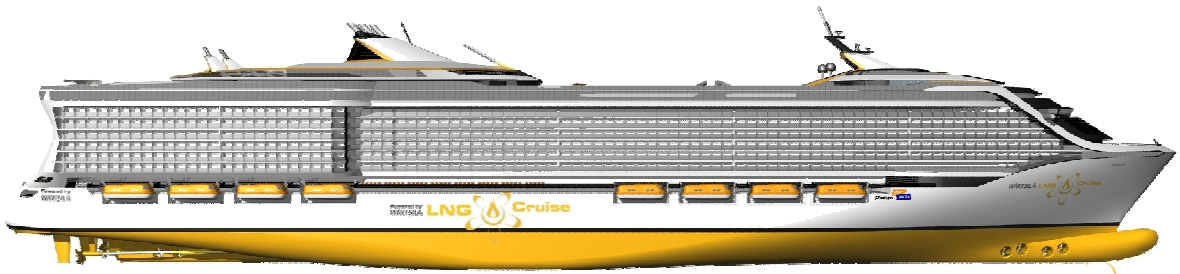
Wärtsilä is actively developing solutions for LNG fuelled passenger vessel:

- 10 000 gt Cruise Ferry
- 30 000 gt RoPax
- BIG LNG
- 65 000 gt PaxCar Ferry
- 125 000 gt Cruise ship









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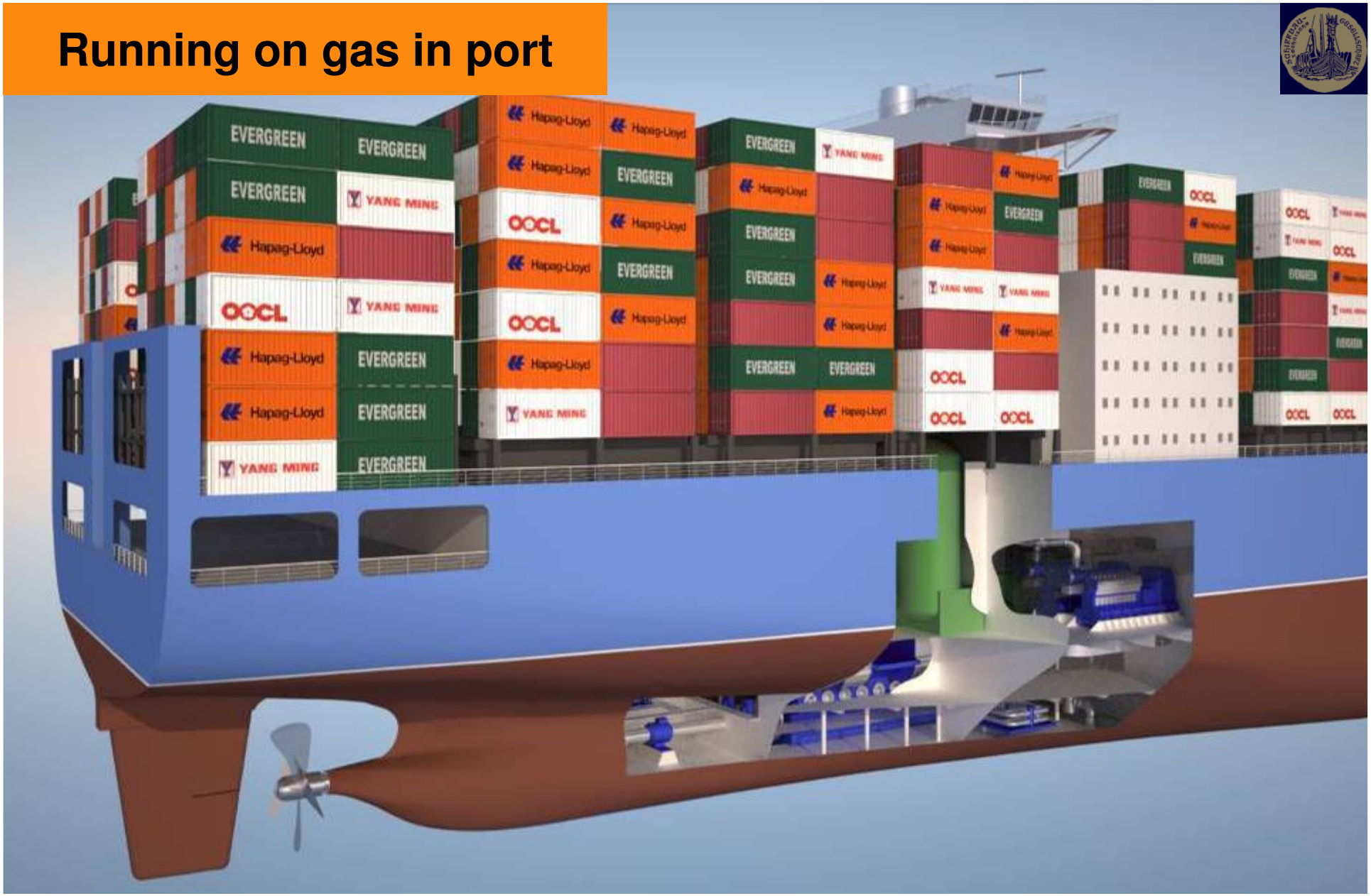
Running on gas in port



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LNG for tugs and inland vessels

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Gas Engines

Gas engine technologies

Gas-diesel (GD) engines:

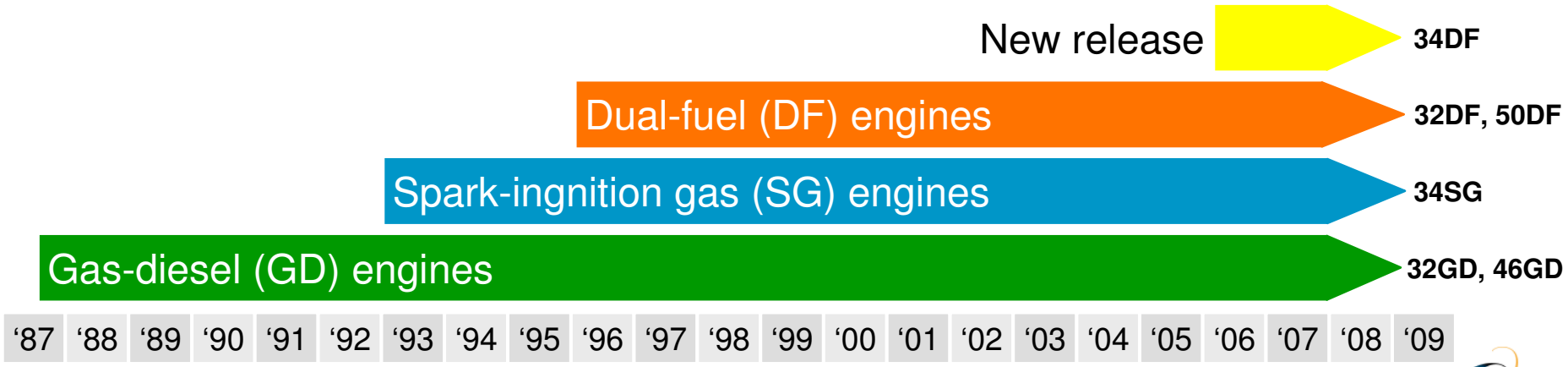
- Runs on various gas / diesel mixtures or alternatively on diesel.
- Combustion of gas, diesel and air mixture in Diesel cycle.
- High-pressure gas injection.

Spark-ignition gas (SG) engines:

- Runs only on gas.
- Combustion of gas and air mixture in Otto cycle, triggered by spark plug ignition.
- Low-pressure gas admission.

Dual-fuel (DF) engines:

- Runs on gas with 1% diesel (gas mode) or alternatively on diesel (diesel mode).
- Combustion of gas and air mixture in Otto cycle, triggered by pilot diesel injection (gas mode), or alternatively combustion of diesel and air mixture in Diesel cycle (diesel mode).
- Low-pressure gas admission.

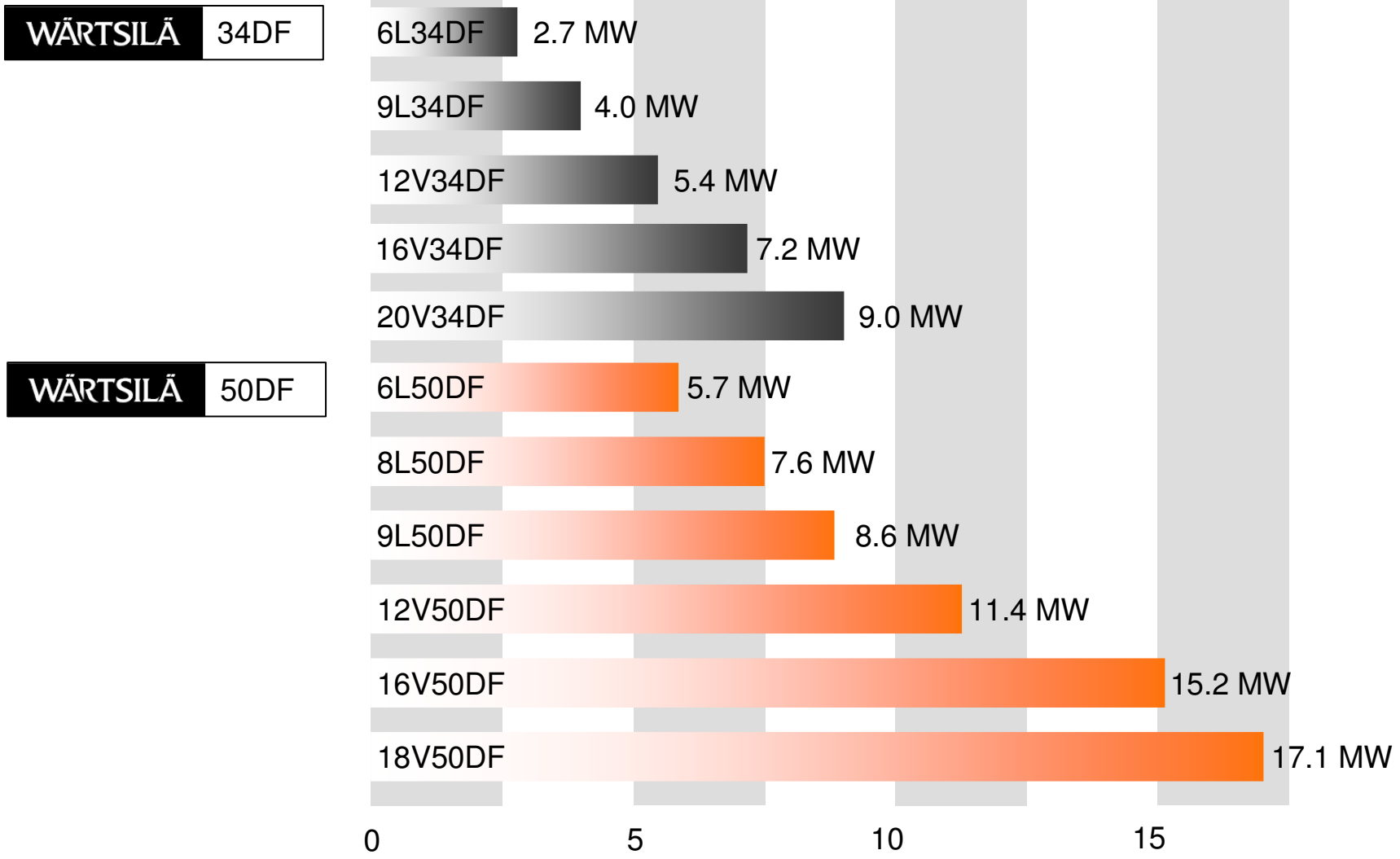


Dual-fuel engine characteristics

- High efficiency
- Low gas pressure
- Low emissions, due to:
  - High efficiency
  - Clean fuel
  - Lean burn combustion
- Fuel flexibility
  - Gas mode
  - Diesel mode
- Two engine models
  - Wärtsilä 34DF
  - Wärtsilä 50DF

Wärtsilä 6L50DF

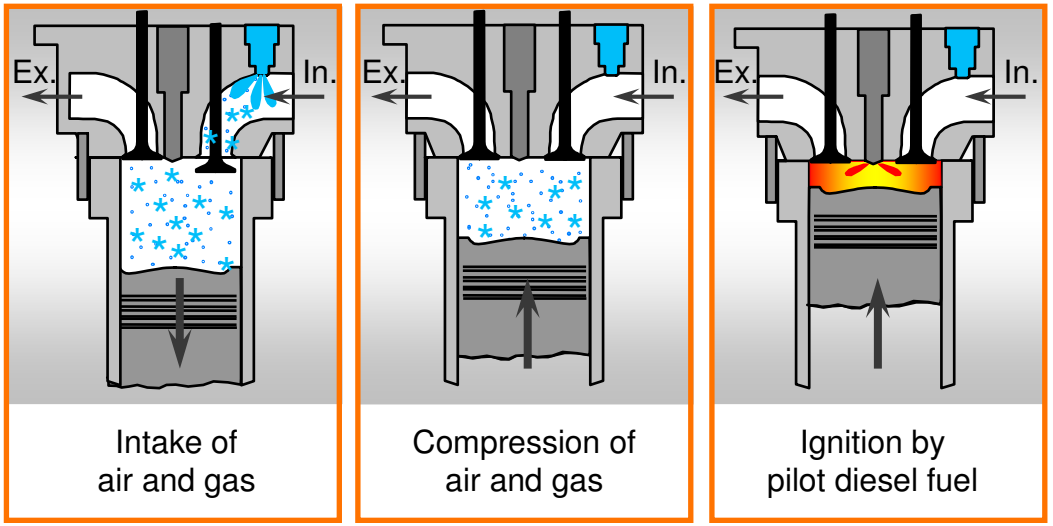
Dual-fuel engine parameters

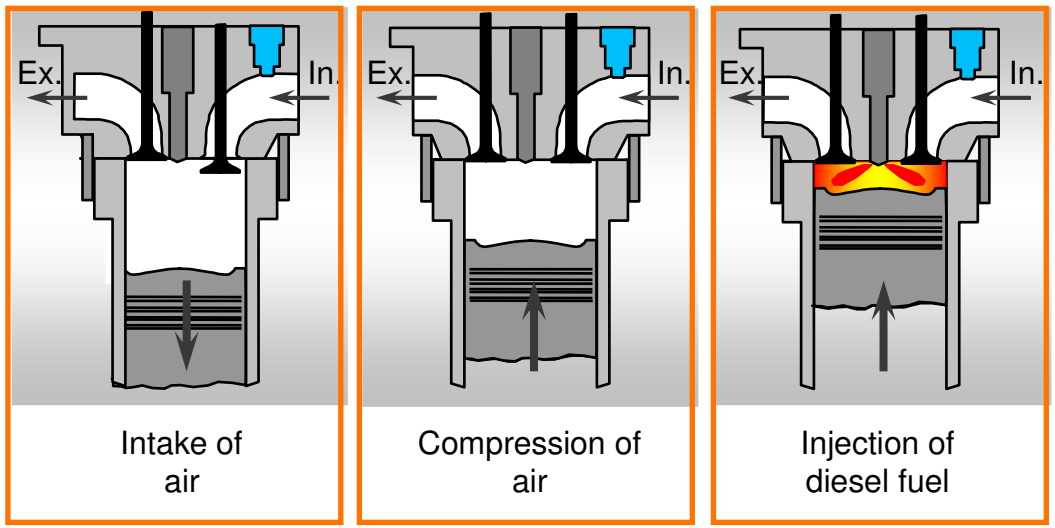


DF Engines - Operating modes

Gas mode:

- Otto principle
- Low-pressure gas admission
- Pilot diesel injection





Diesel mode:

- Diesel principle
- Diesel injection

DF – concept benefits

- Reliability
- Efficiency
- Low gas pressure
- Fuel flexibility
  - MDO as a backup
  - HFO as option
- System configuration
  - Single storage tank is allowed
  - Single engine installations allowed

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Rules and regulations

LNG – regulatory bodies

- Maritime regulations for gas fuelled ships
  - Classification societies
    - DNV
    - LR
  - Flag states
    - Today only the Norwegian Maritime Directorate has got rules available
  - IMO
    - Interim guidelines under development (to be ready in 2009)
  - International Gas Carrier (IGC) code

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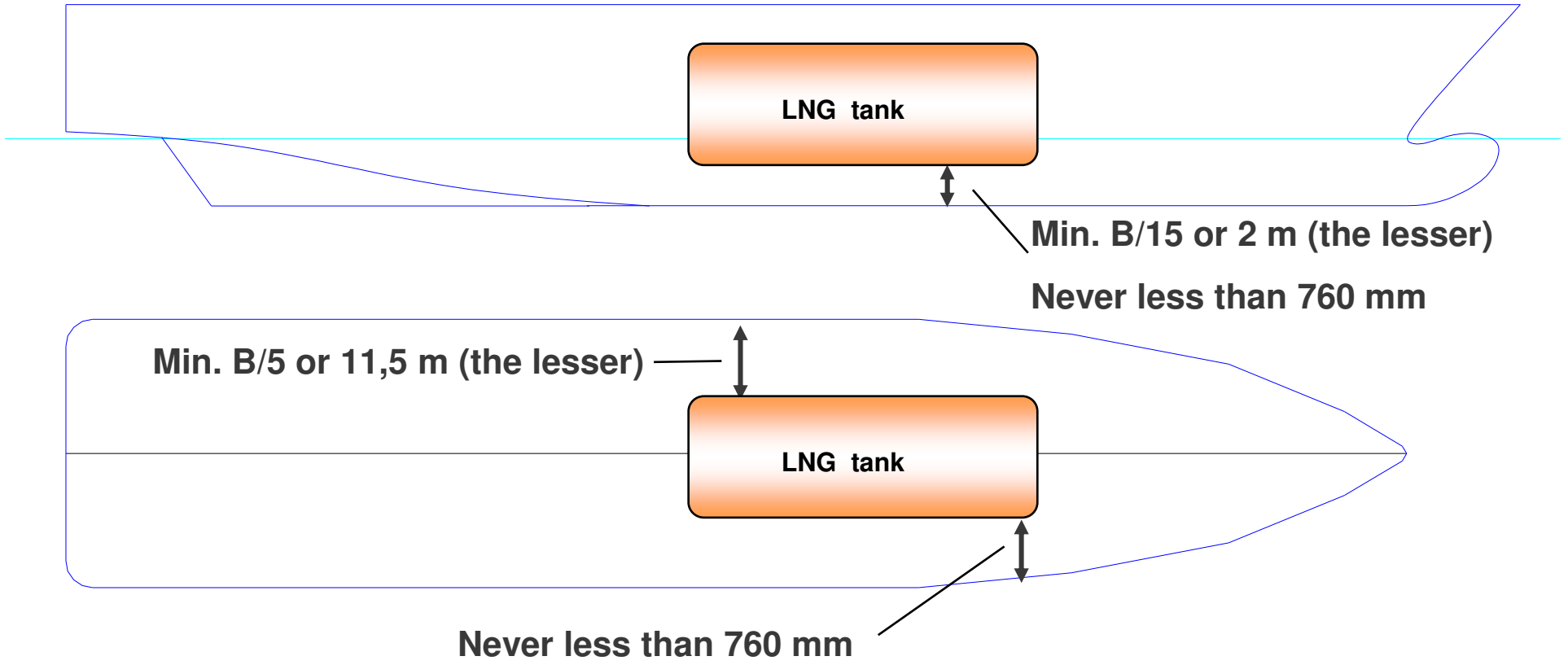
LNG storage location

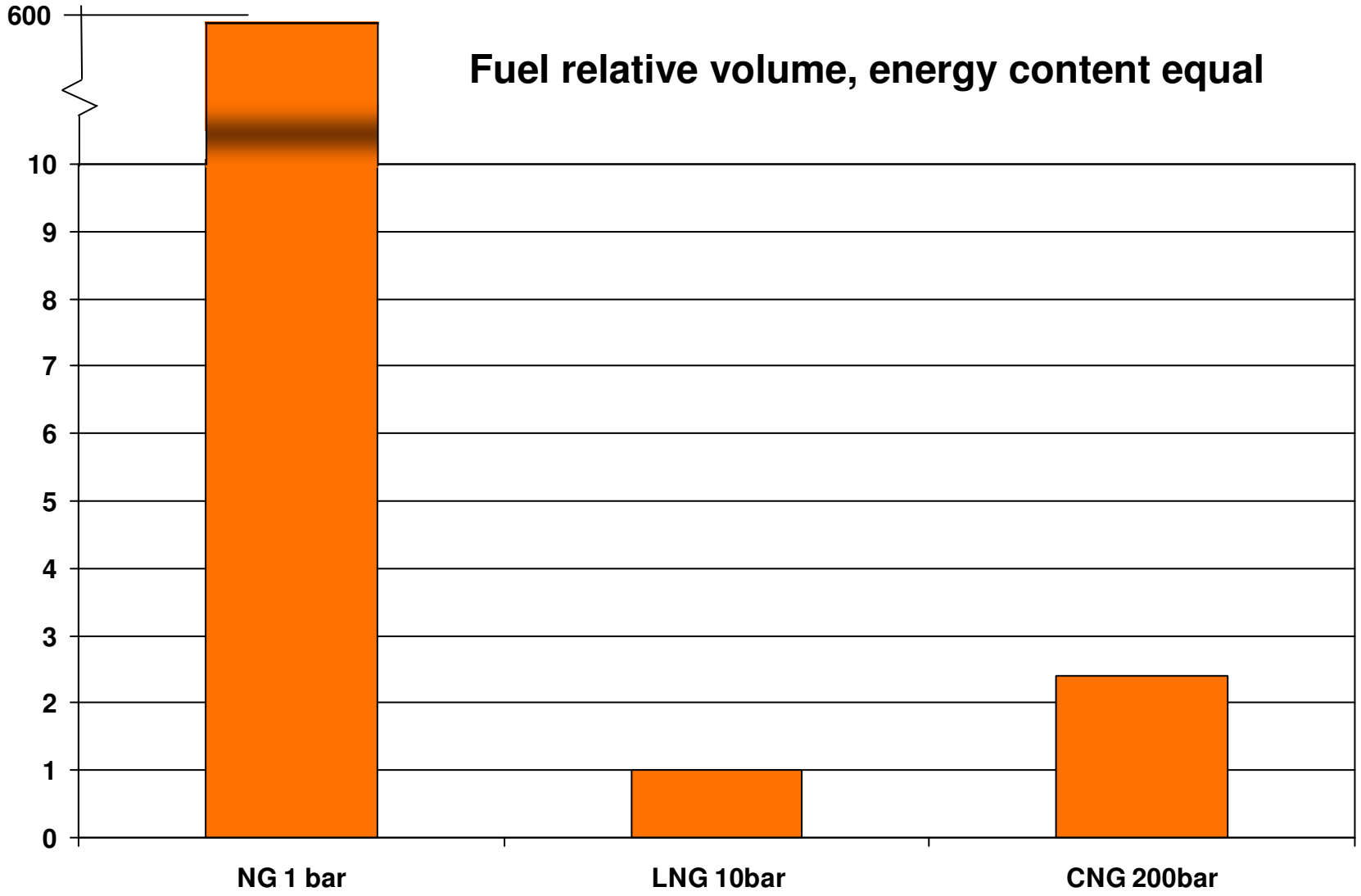
Gas storage below deck



LNG storage

Keep it cool

Why bunker has to be in liquid form (LNG)



Keep it cool

- Cylindrical pressure vessel
- Vacuum insulated
- Approved for passenger vessels
- C-TYPE

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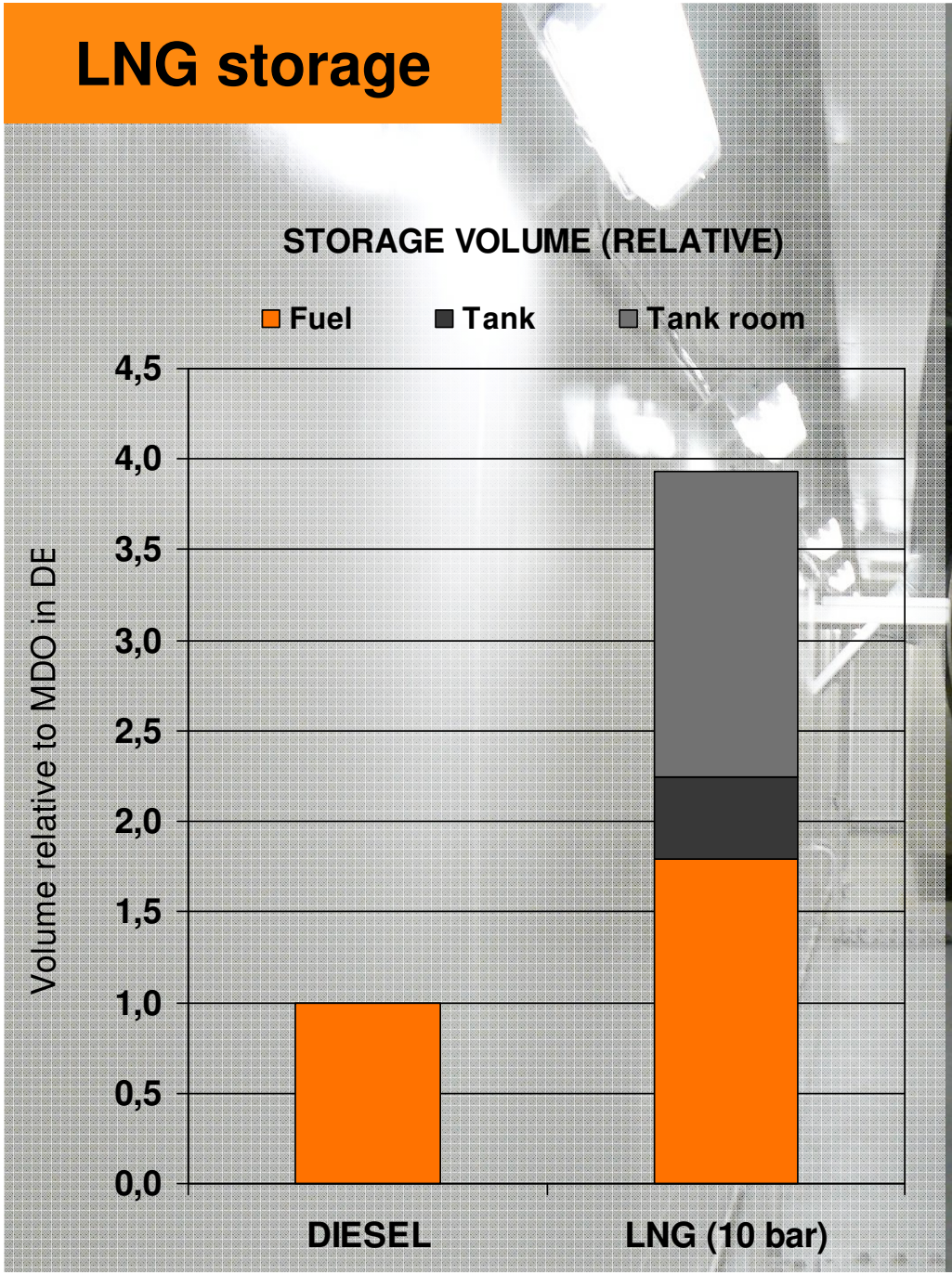
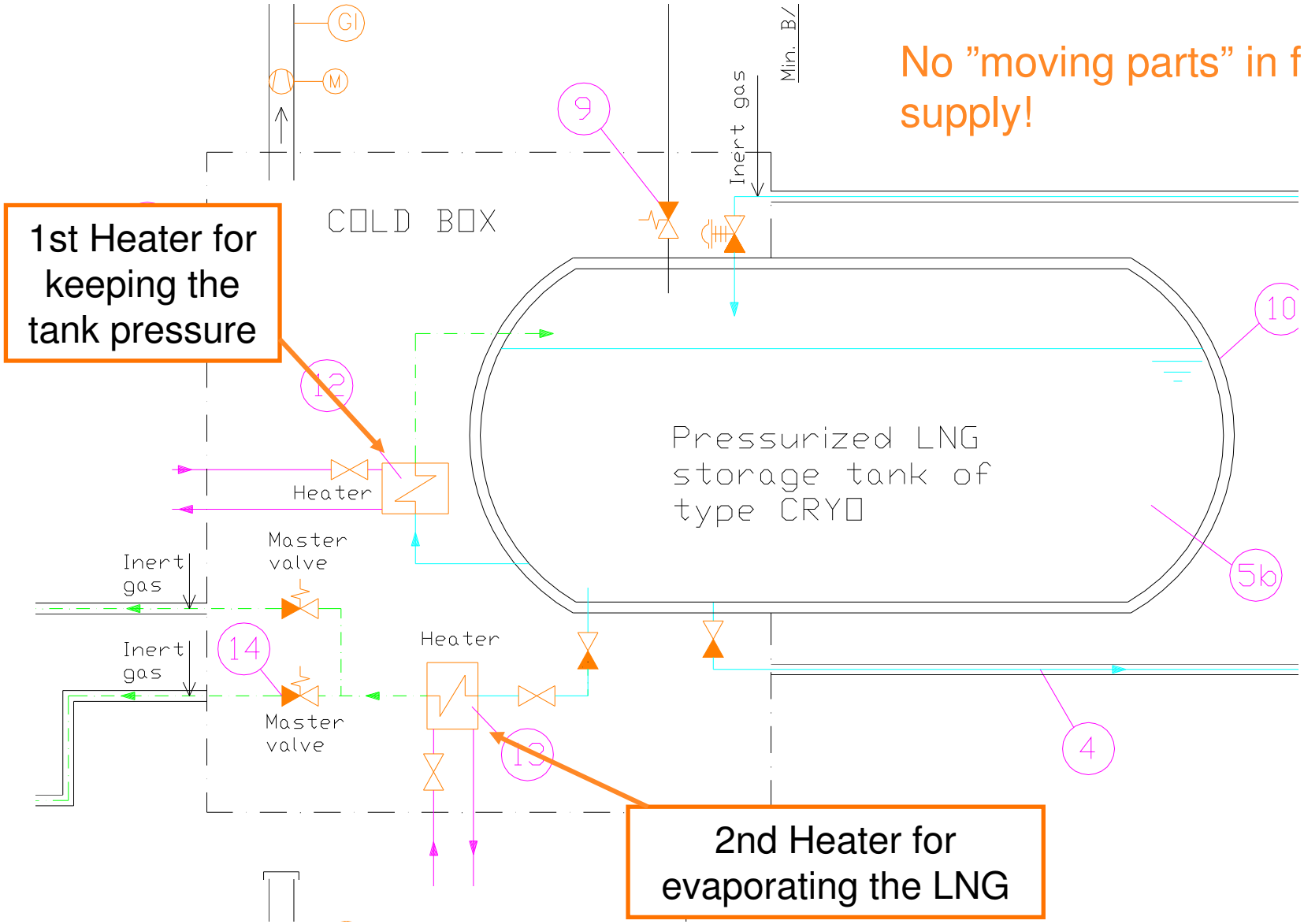
LNG storage


STORAGE VOLUME (RELATIVE)
Fuel
Tank
Tank room
Volume relative to MDO in DE
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
DIESEL
LNG (10 bar)

LNG system

Keep it simple

LNG system (C-type)



No ”moving parts” in fuel supply!

1st Heater for keeping the tank pressure

2nd Heater for evaporating the LNG

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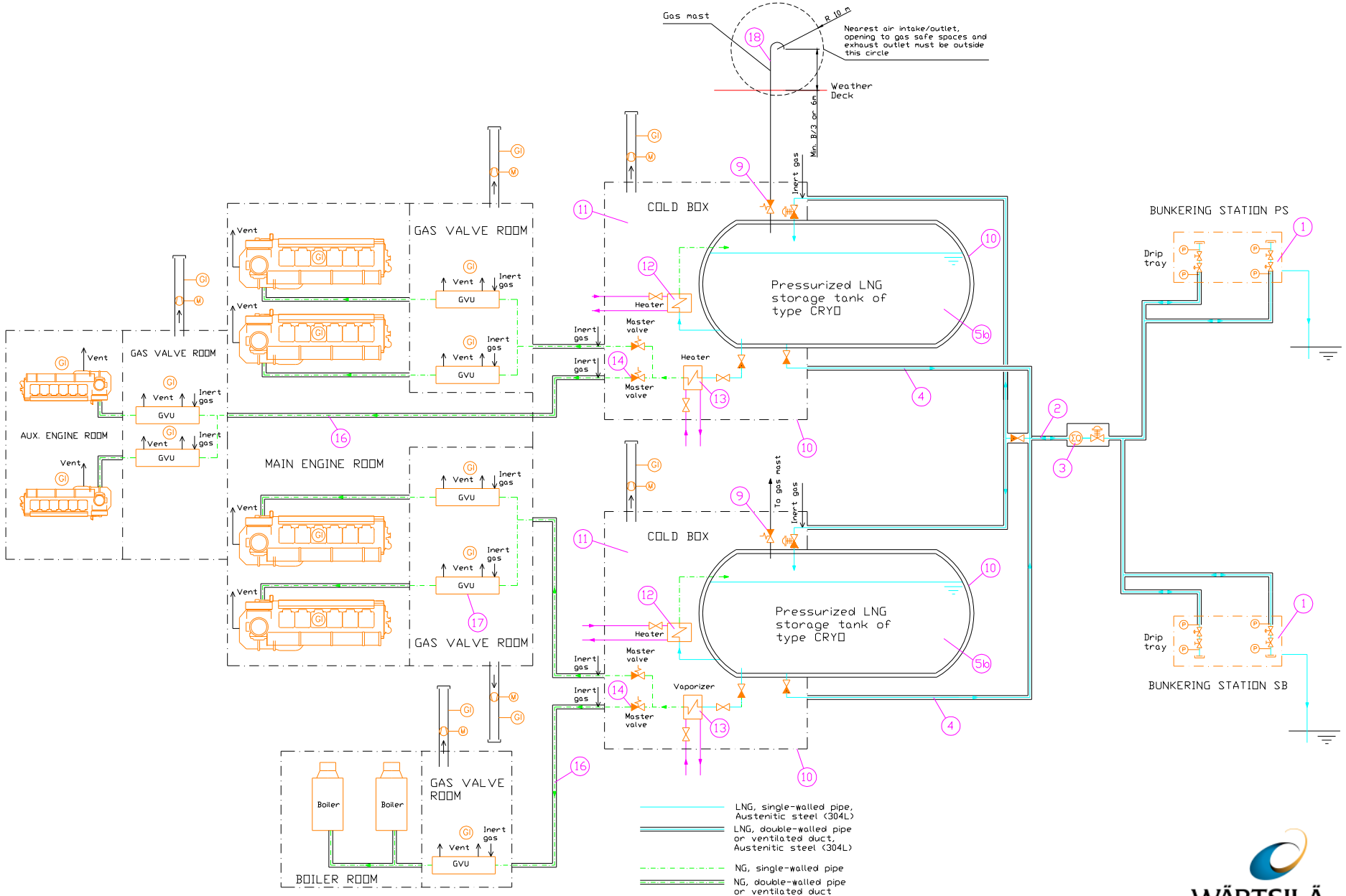
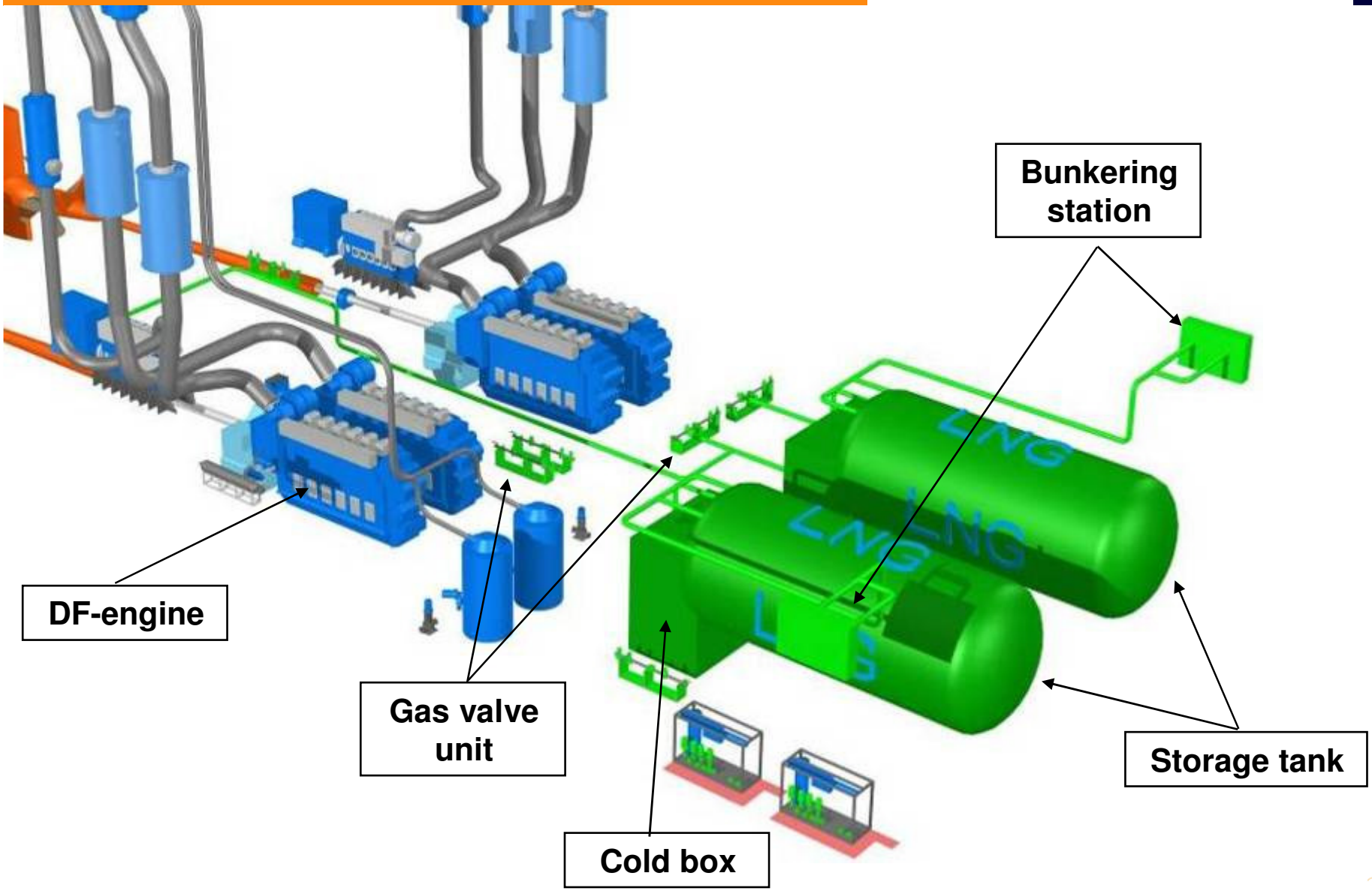
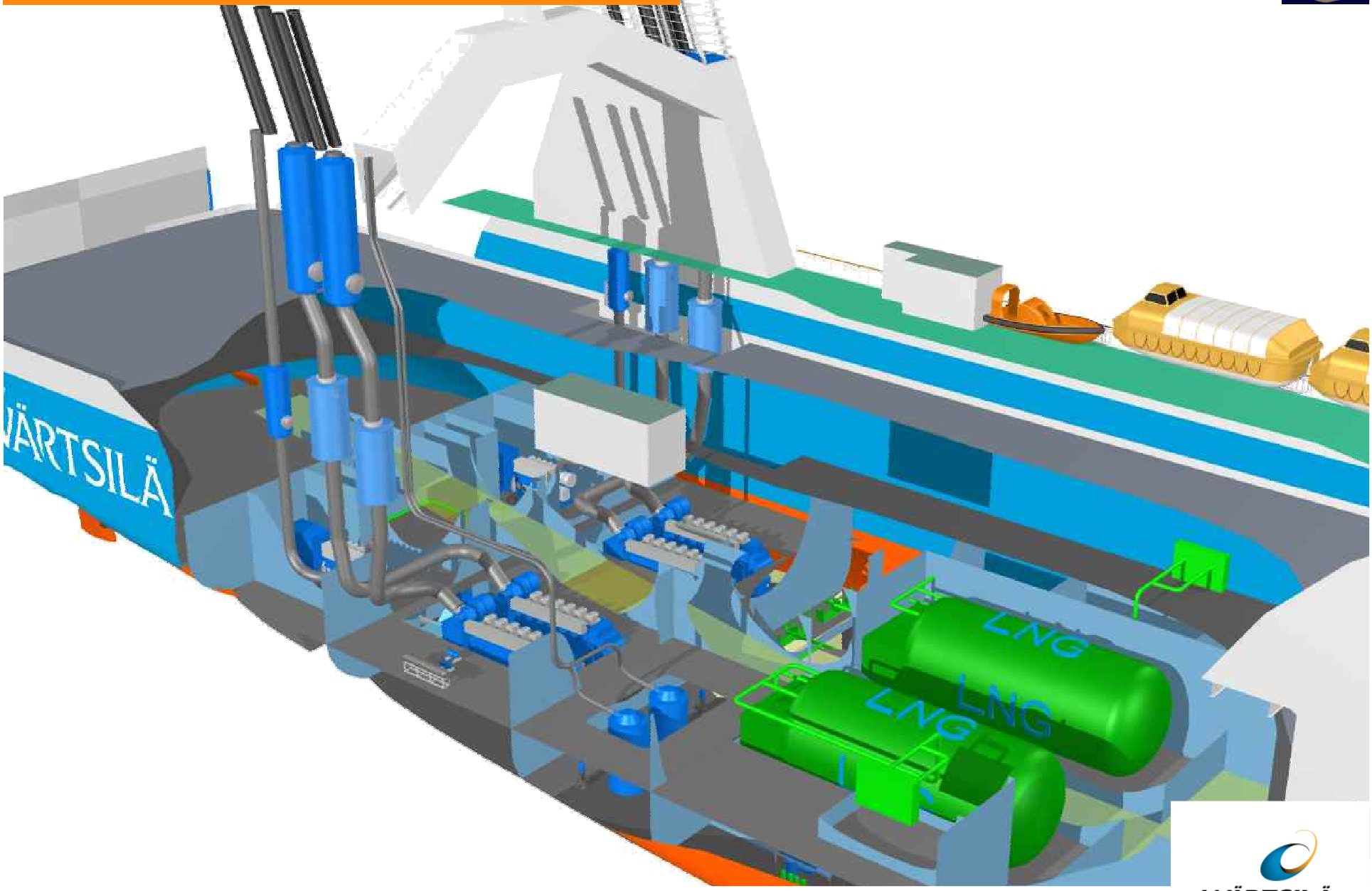
LNG system (C-type)



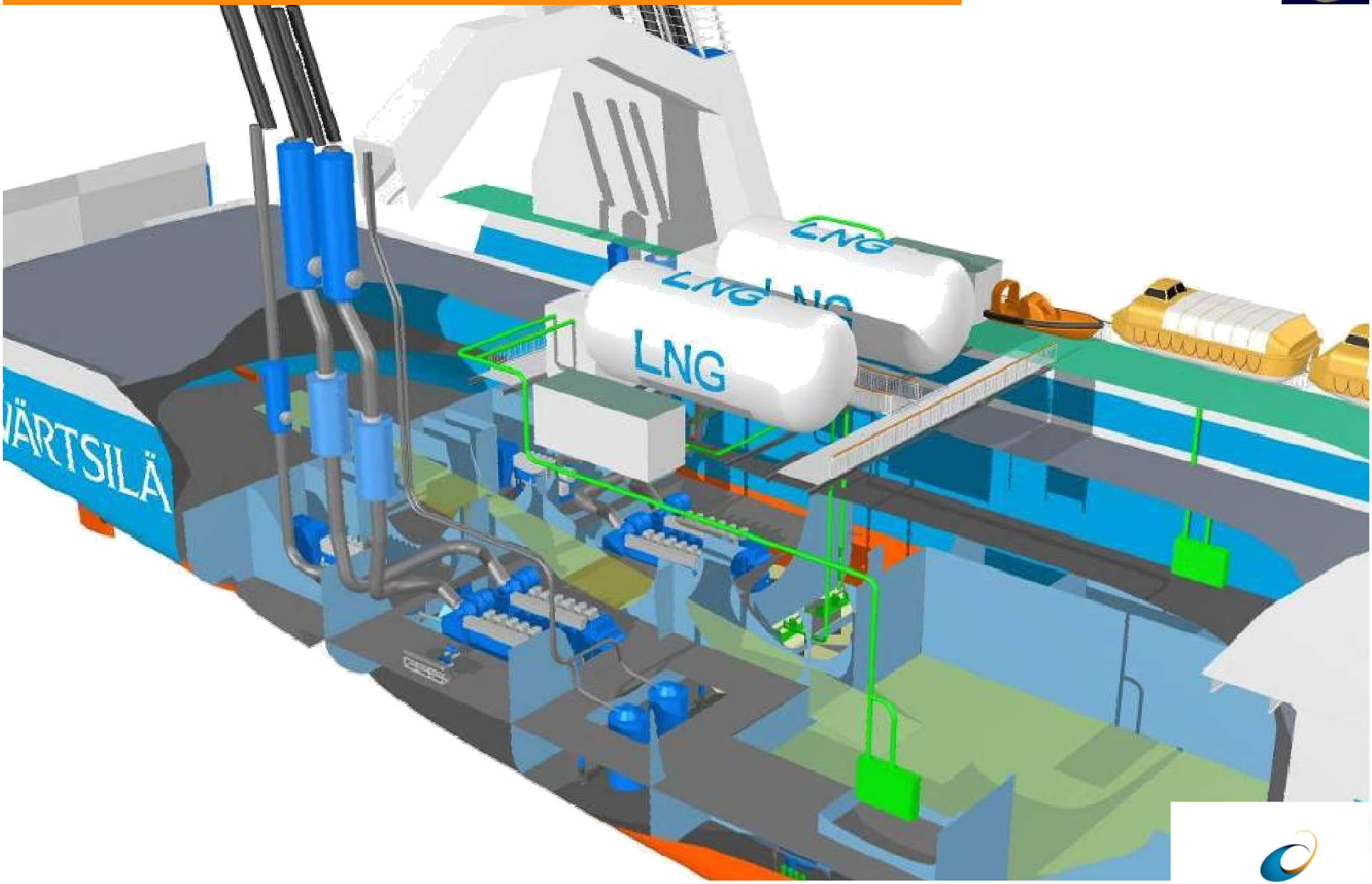
Main Components (C-type tanks)



C-type tanks – below deck



C-type tanks - Alternative arrangement



LNG tank location

The LNG tanks are located on the upper deck behind the superstructure

- Located outside
  - Good ventilation
- No ventilation casing needed trough accommodation
- Vent pipe for tanks still needed
- Visible location for good PR

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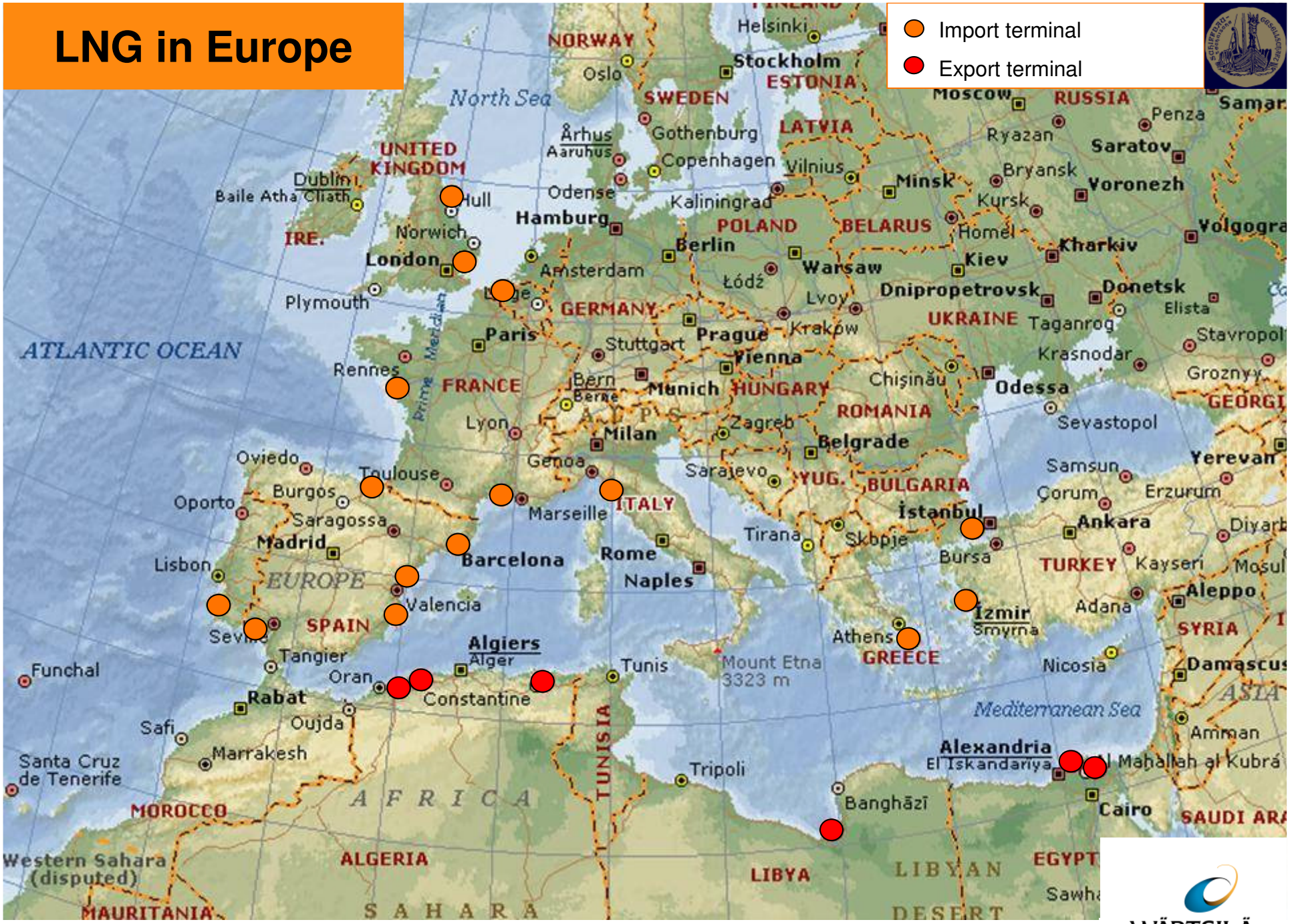
Bunkering

LNG in Europe



Bunkering

- LNG Terminal
- Tanker truck
- Tanker ship / barge
- Land based storage tank

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LNG bunkering

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Bunker station in port

Gas storage tanks

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Running on gas in port

Why ports are going for shore power?

- Public pressure
- Emissions from ships (auxiliary engines running on HFO)
  - SO_X
  - NO_X
  - Particles
- Many ports are close to urban areas
  - Port emissions drifts straight to populated areas (ship funnels are lower compared to land based power plants)

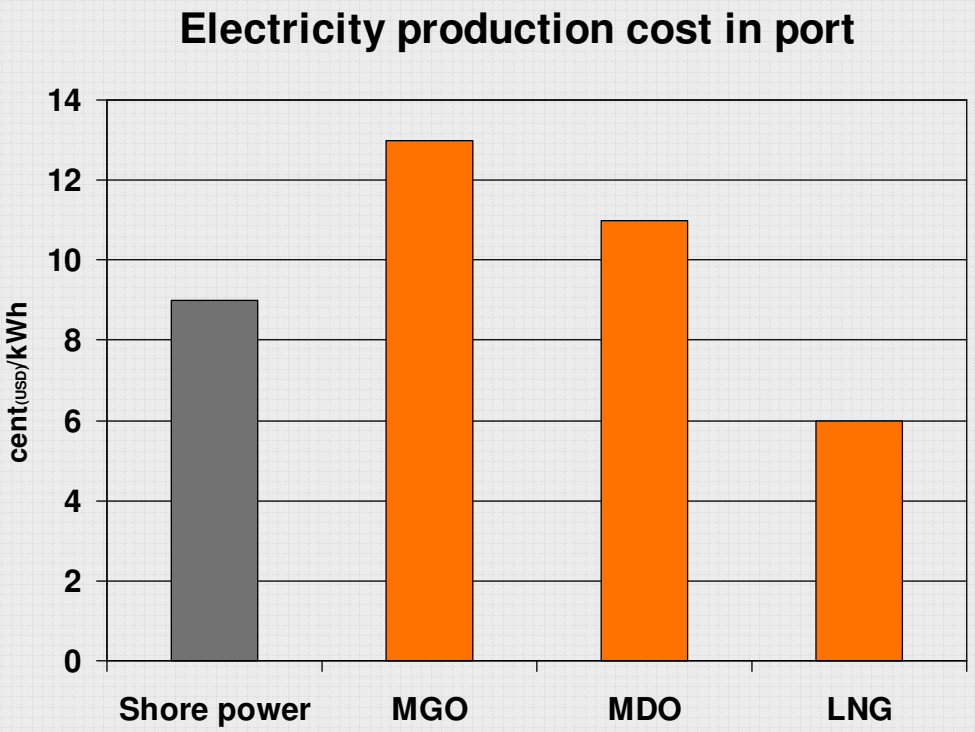
NG in port philosophy

- One engine is of DF-type
- In port vessel is connected to gas pipe network
  or
- Is connected to a shore based LNG storage tank / LNG truck
- At sea, the DF-engine can run on HFO as a gensets among others
- No gas / LNG storage on board needed

→ **Low investment costs**

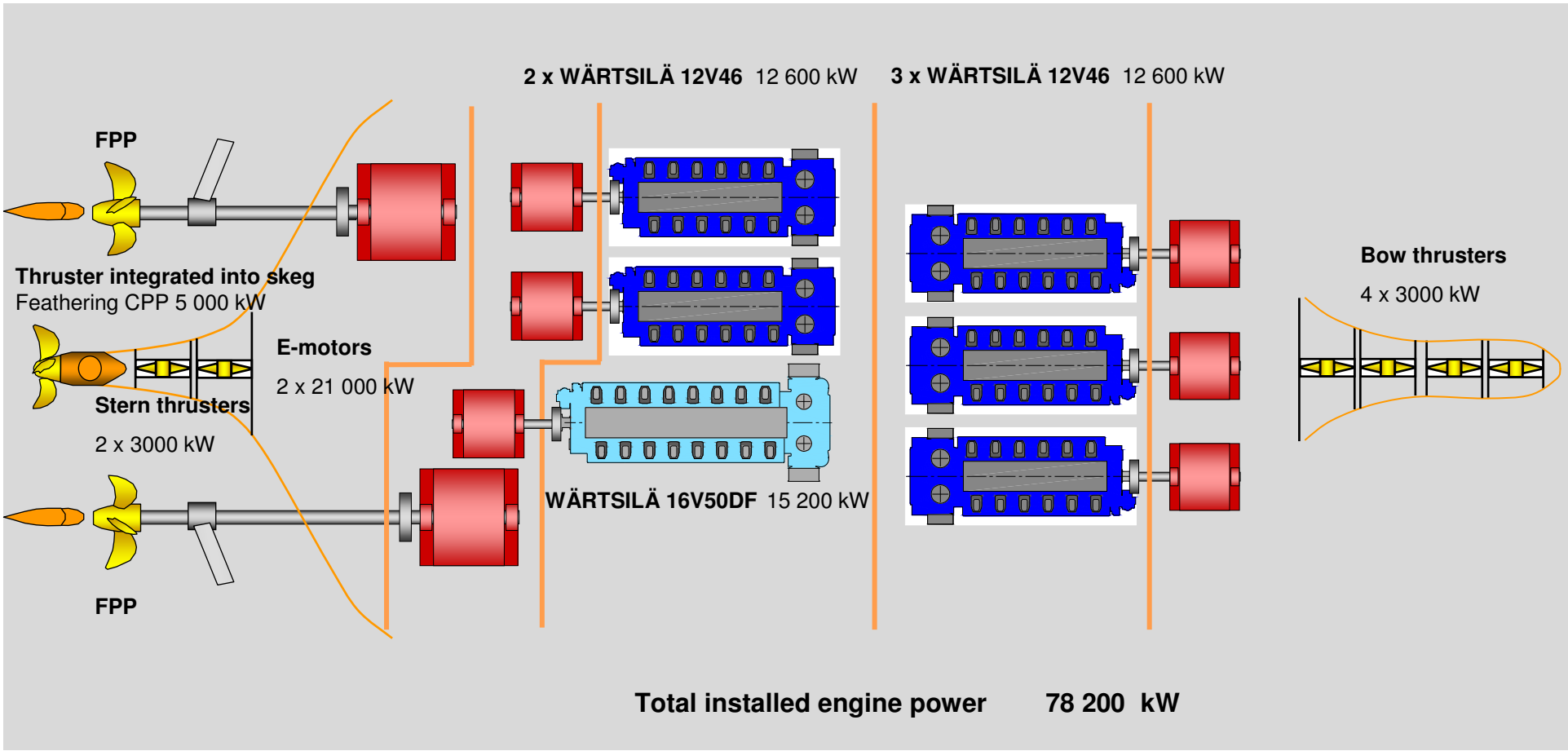
LNG auxiliary power in port for cruise vessels

- LNG auxiliary power for cruise vessels
  - Significant reduction of local emissions
  - Economically feasible
  - Technology is available

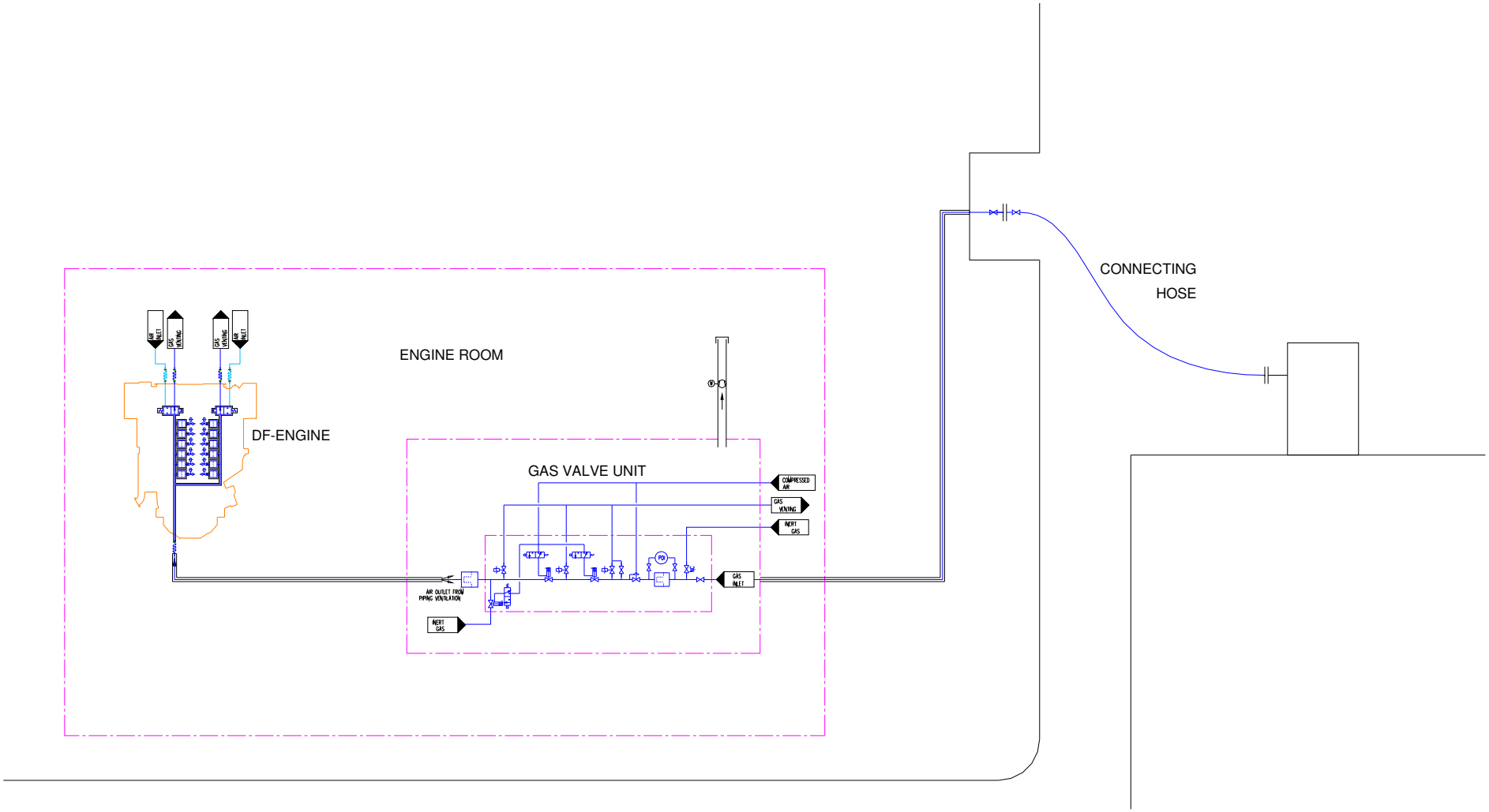


Case study:
Running on gas in port -
125 000 gt cruise ship

DE – DFE machinery

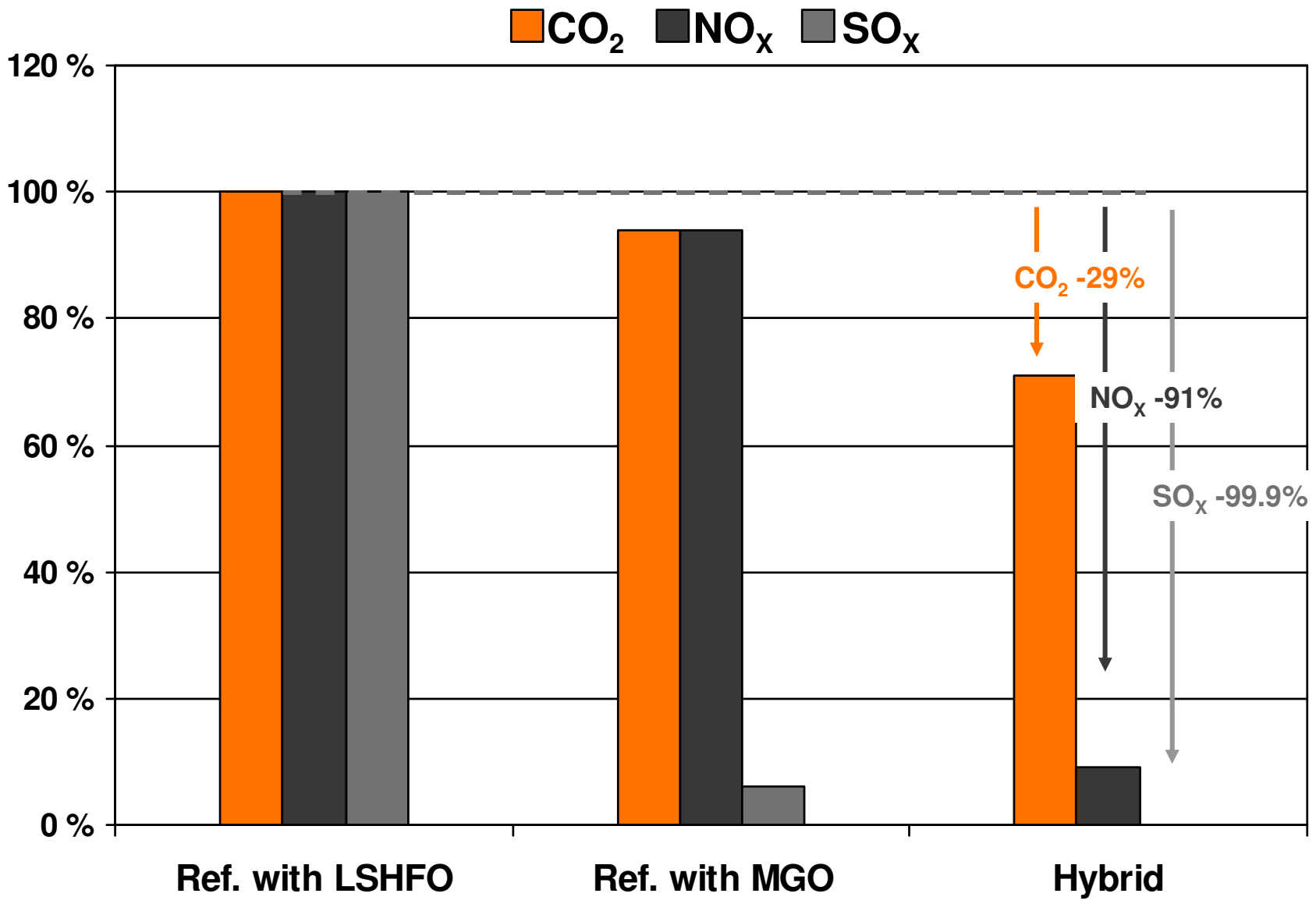


Gas feed system

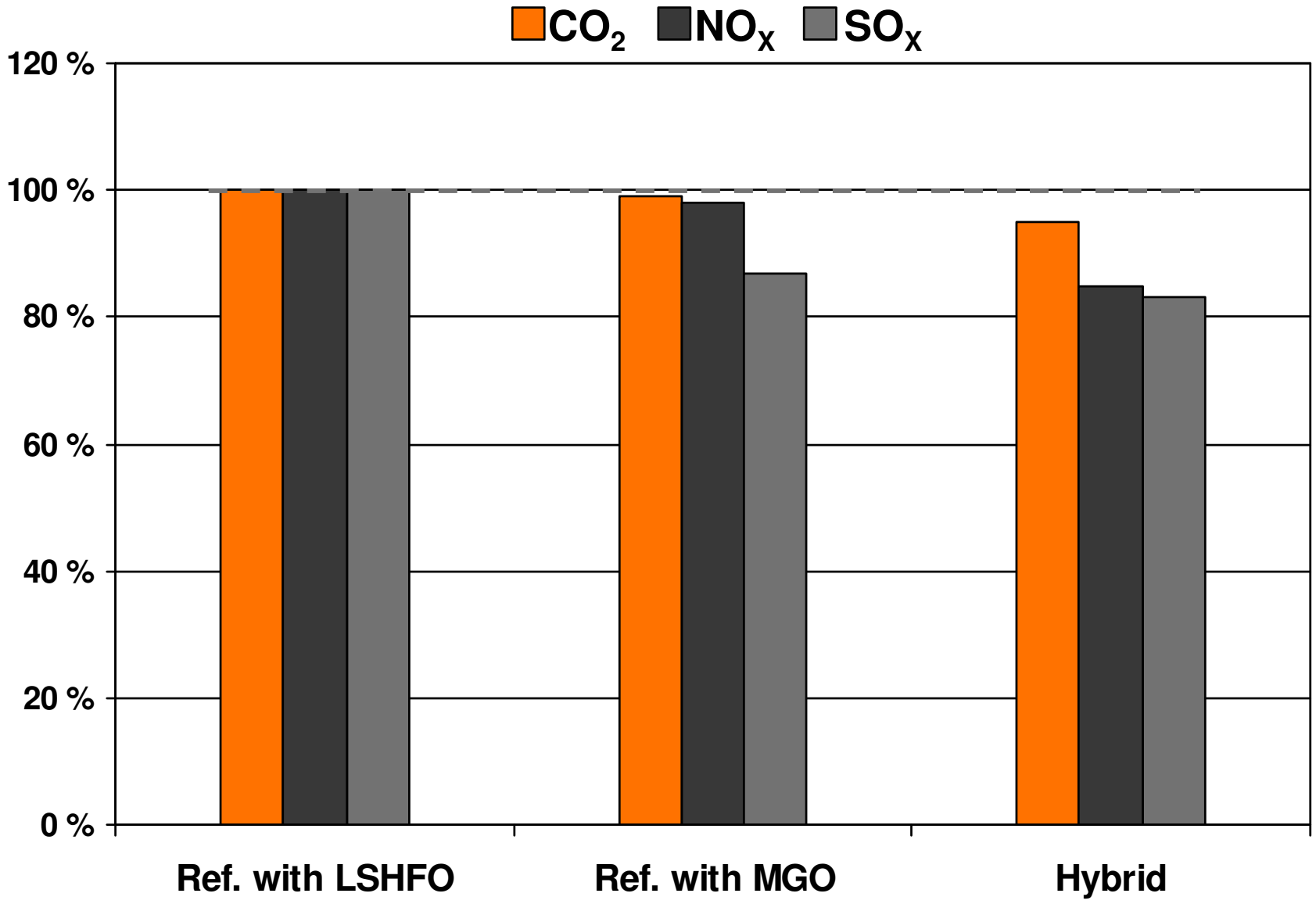


Gas Valve Unit (GVU)

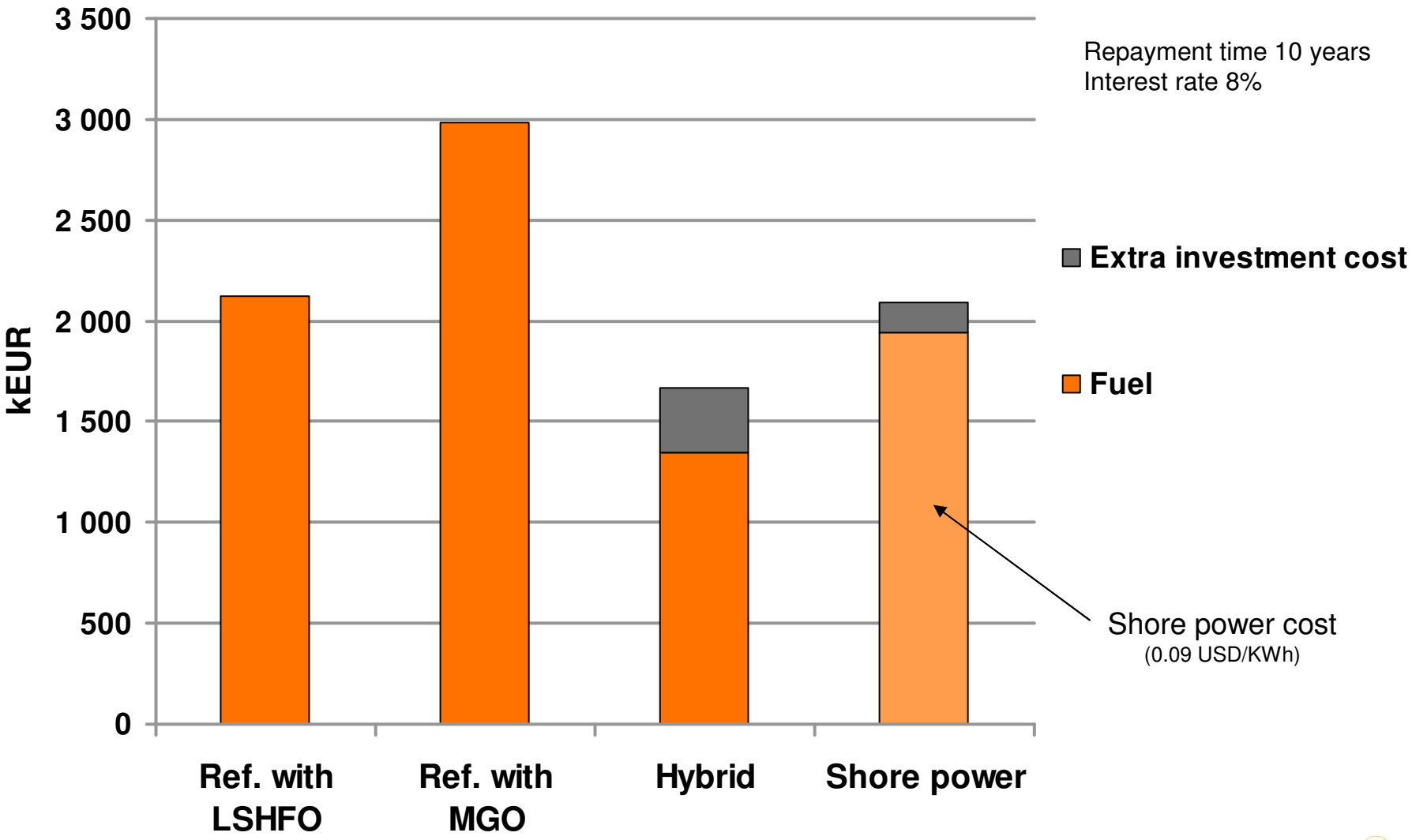
Emissions in port



Annual total emissions



Annual cost in port



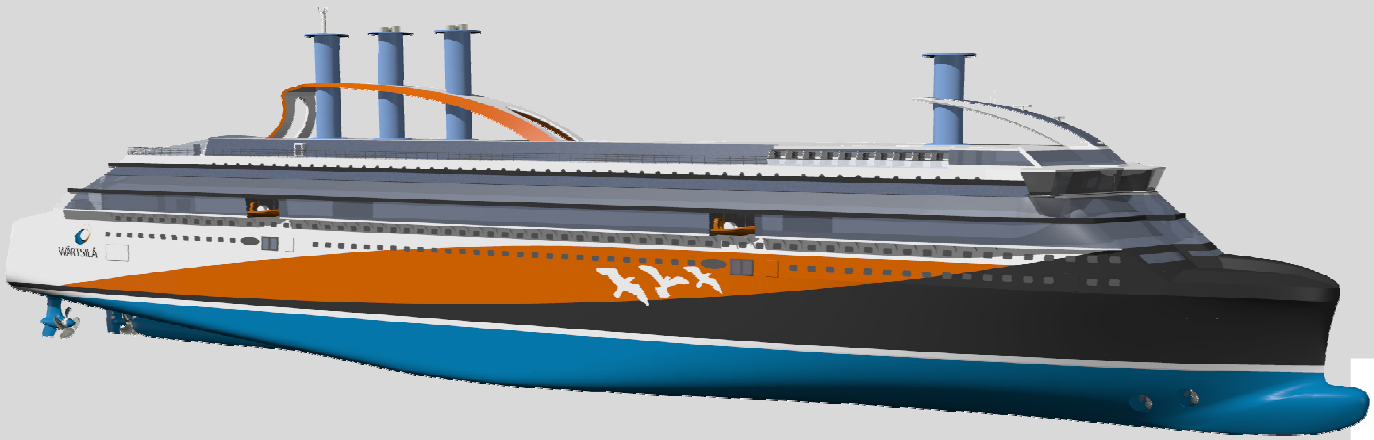
The Efficient Cruise Ferry

The efficient cruise ferry

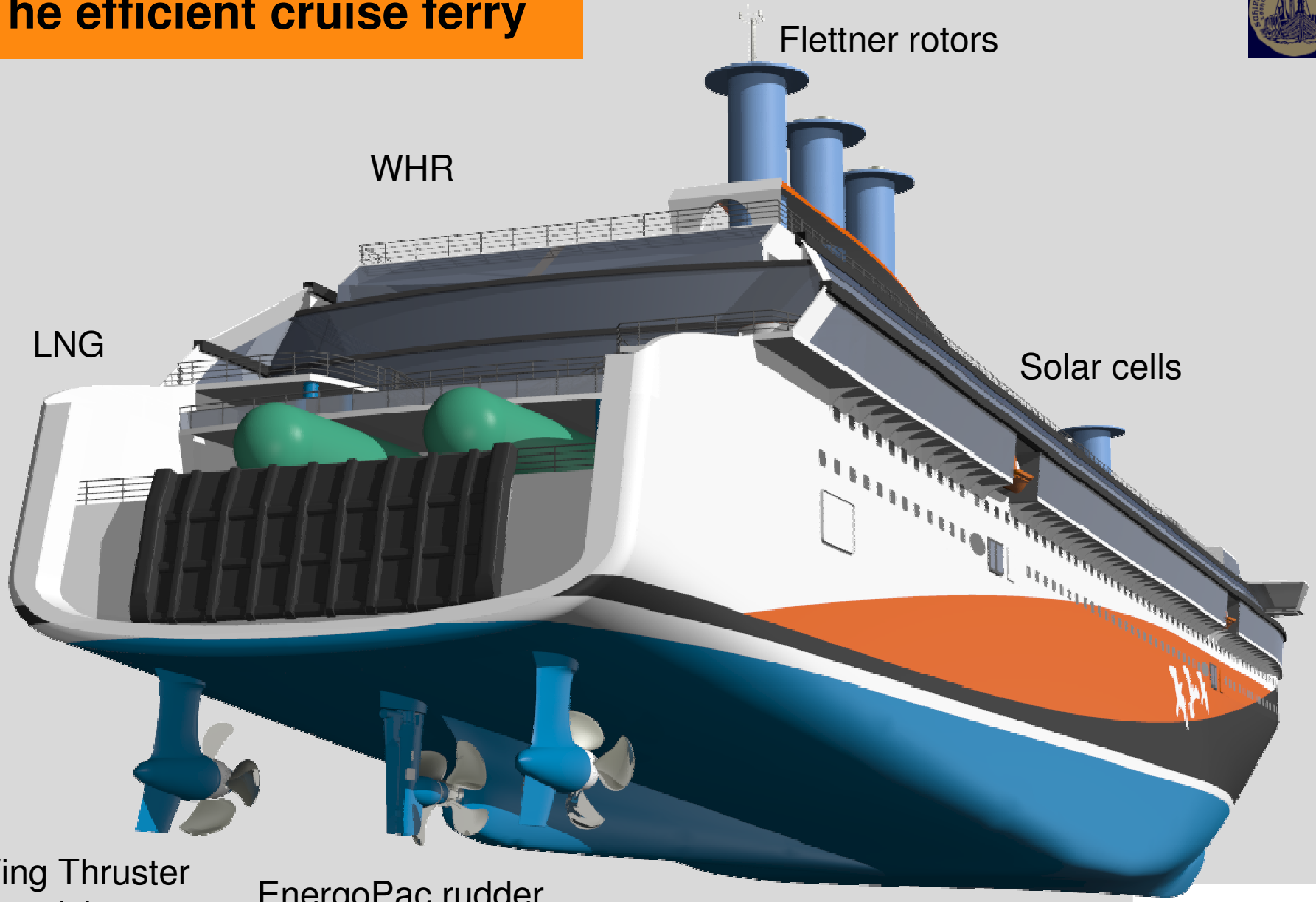
The efficient cruise ferry

Main dimensions

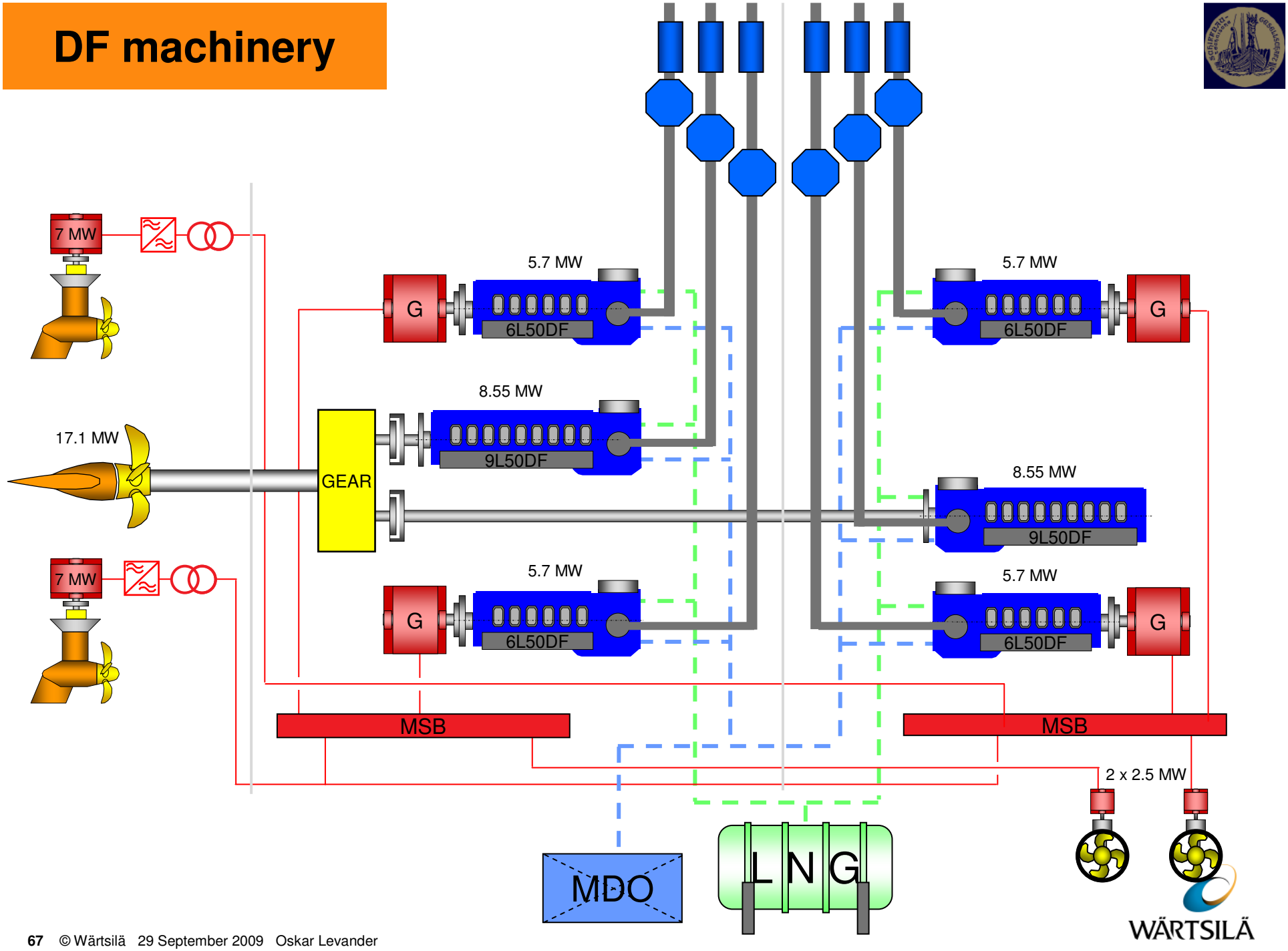
Gross tonnage	58 000	GT	Pax capacity	2 800	pcs
Length, oa	225	m	Pax cabins	750	pcs
Breadth	31.2	m	Crew cabins	180	pcs
Draught, design	6.8	m			
Deadweight	5 000	tons	Lane meters	1 400	m
Service speed	24	knots	Lane meters, cars	850	m



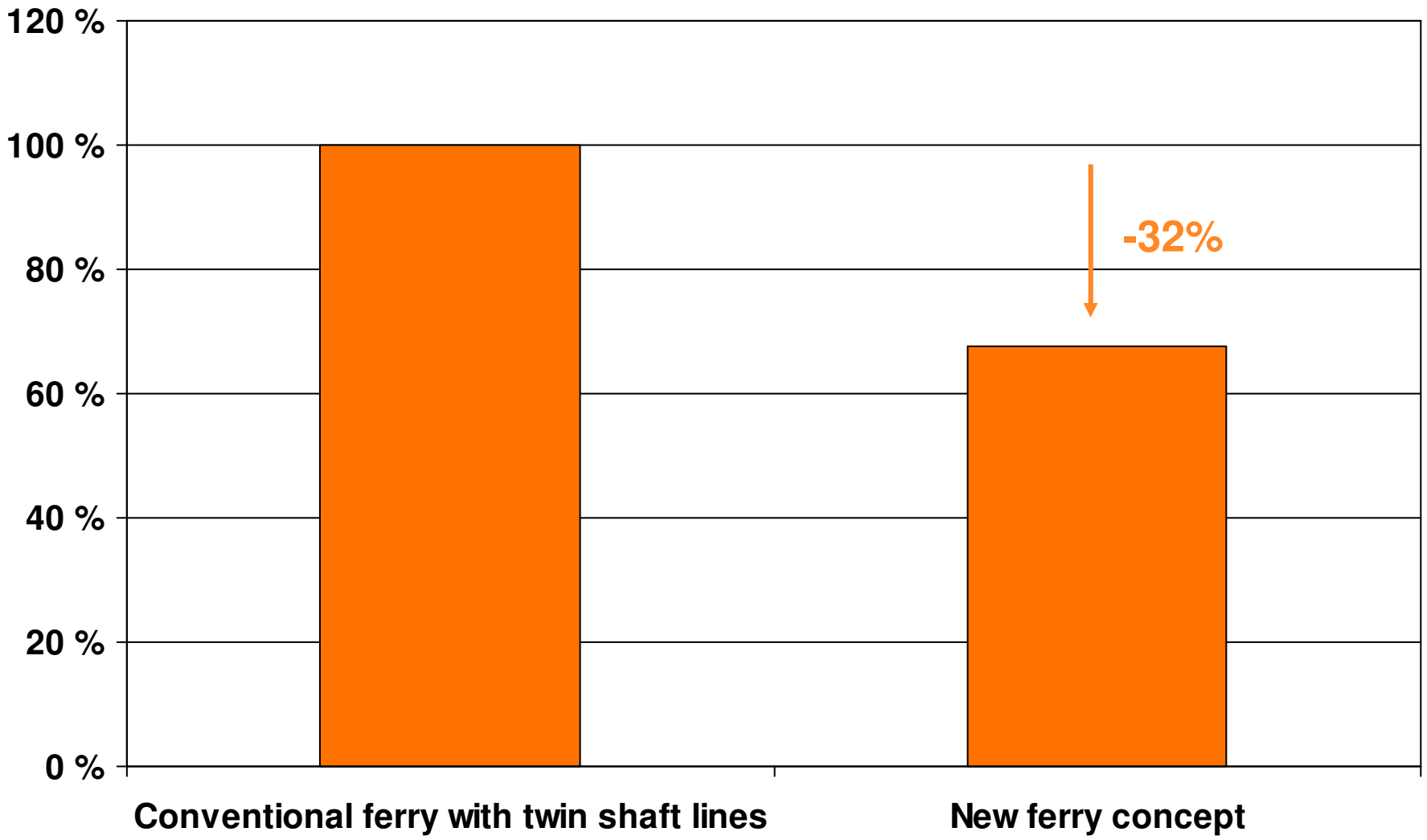
The efficient cruise ferry



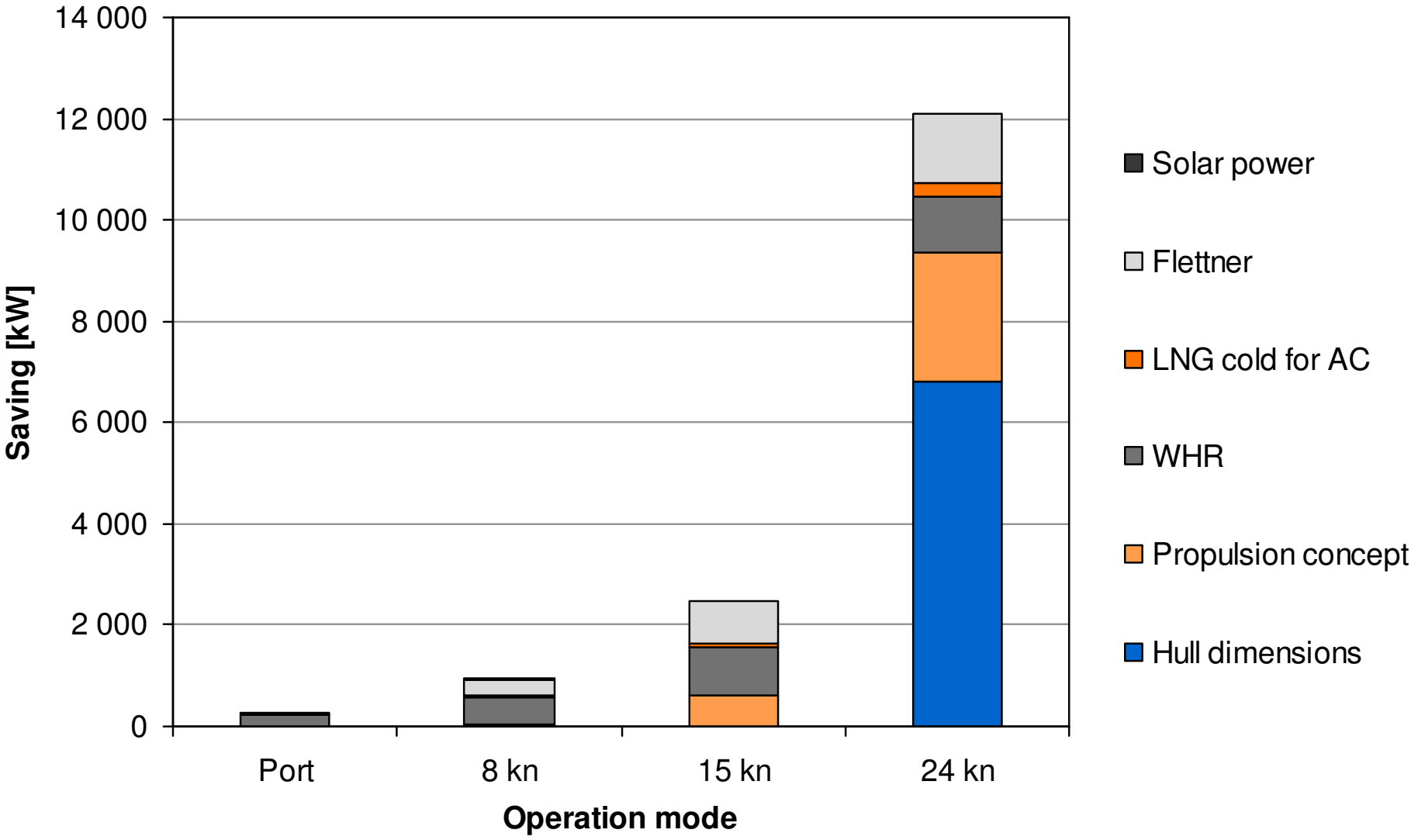
DF machinery



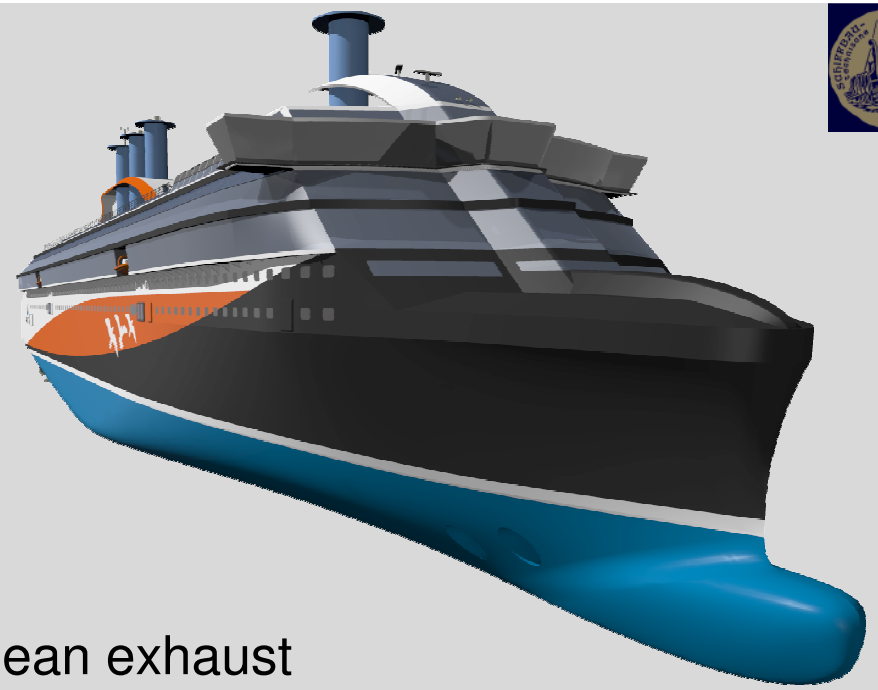
Ship efficiency – total annual energy consumption



Energy savings



Conclusions



- LNG offers great advantages
  - Significantly lower emissions – clean exhaust
  - A simple way to meet all currently known emission regulations
  - Improved efficiency
- Better availability of LNG bunkering would aid the introduction of the clean fuel in ships
- New designs are needed to meet the demand of the future

WÄRTSILÄ

Experienced design partner – Wärtsilä Ship Design

CRUSING ON GAS INTO A CLEANER FUTURE