Turning the page in ship propulsion, by switching to LNG

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Gas as fuel for propulsion of ships - status and perspectives

Copenhagen, March 3rd, 2008

Content

- Environmental drivers
- LNG as marine fuel
- DF engines
- LNG cruise ship
- Running on gas in port
- Turning the page in propulsion
  - Example: The next generation ferry

Development driver for ship propulsion

- Environment
  - Emission reduction
    - NO_X emissions
    - SO_X emissions
      - SECA areas
      - EU ports
  - The next step will be climate change
    - Greenhouse gases
      - Focus on CO_2 emissions
    - Particles
- Fuel cost
  - Increasing oil prices

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Greenhouse emission reductions

CO_2 emission reduction:

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

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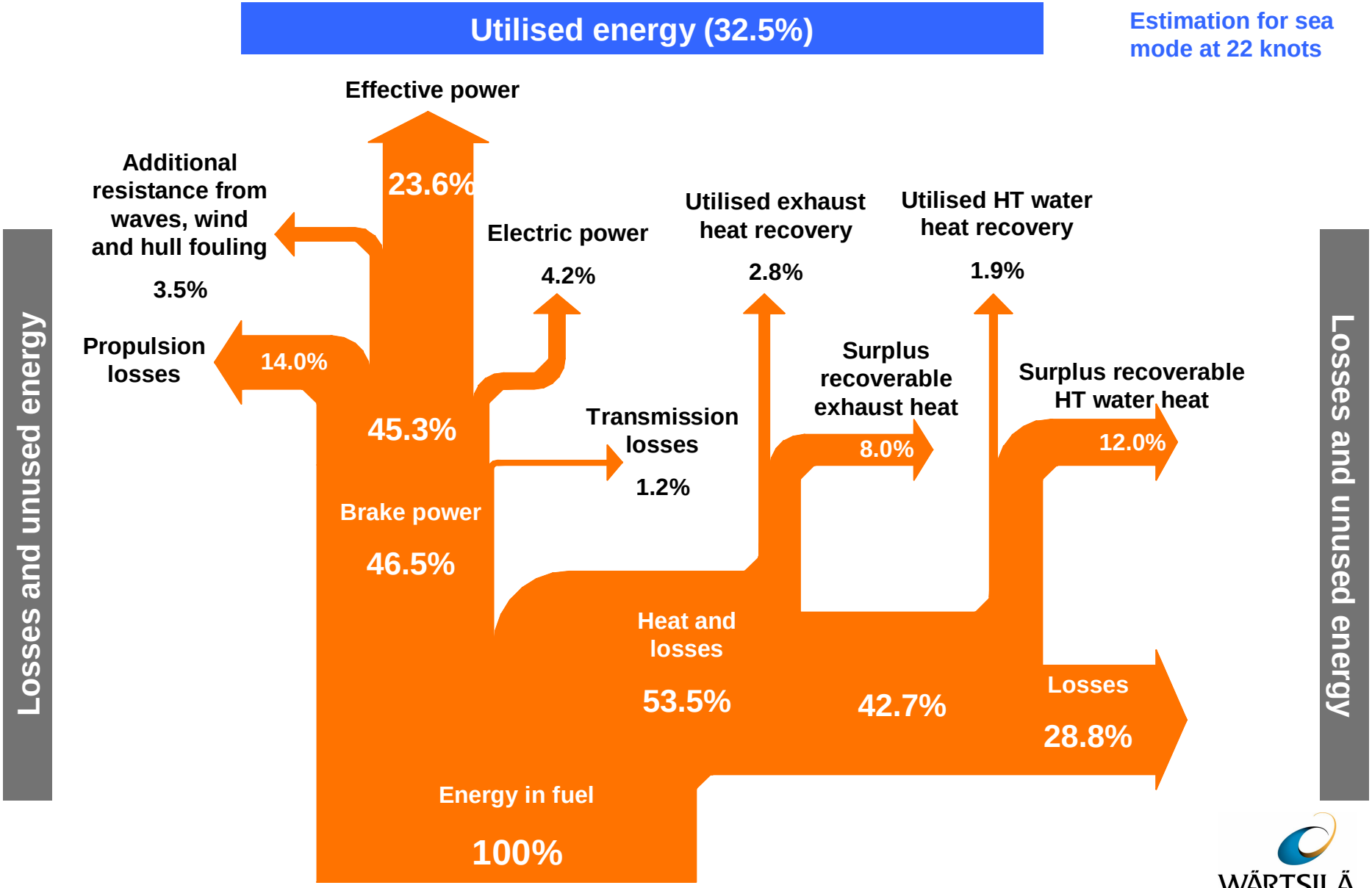
Ferry efficiency



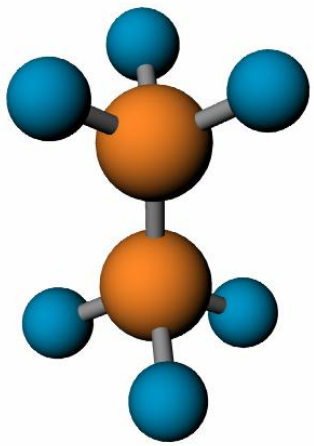
Alternatives to oil

What are the alternatives to oil?

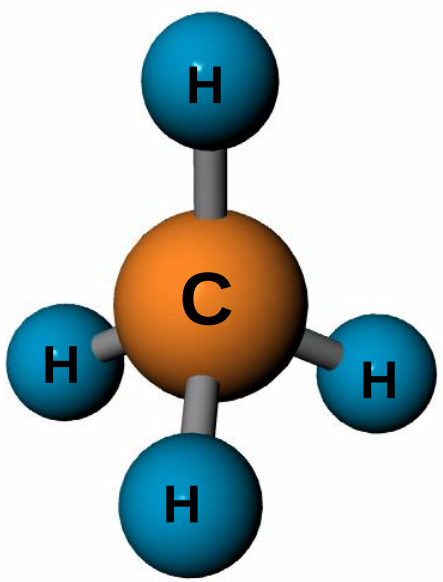
- Biofuel
- Hydrogen
- Synthetic fuels
- **Natural gas**

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



Ethane (C_2H_6)



Methane (CH_4)

Cleaner Exhaust Emissions with LNG

- 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
- Very low particulate emissions
- No visible smoke
- No sludge deposits

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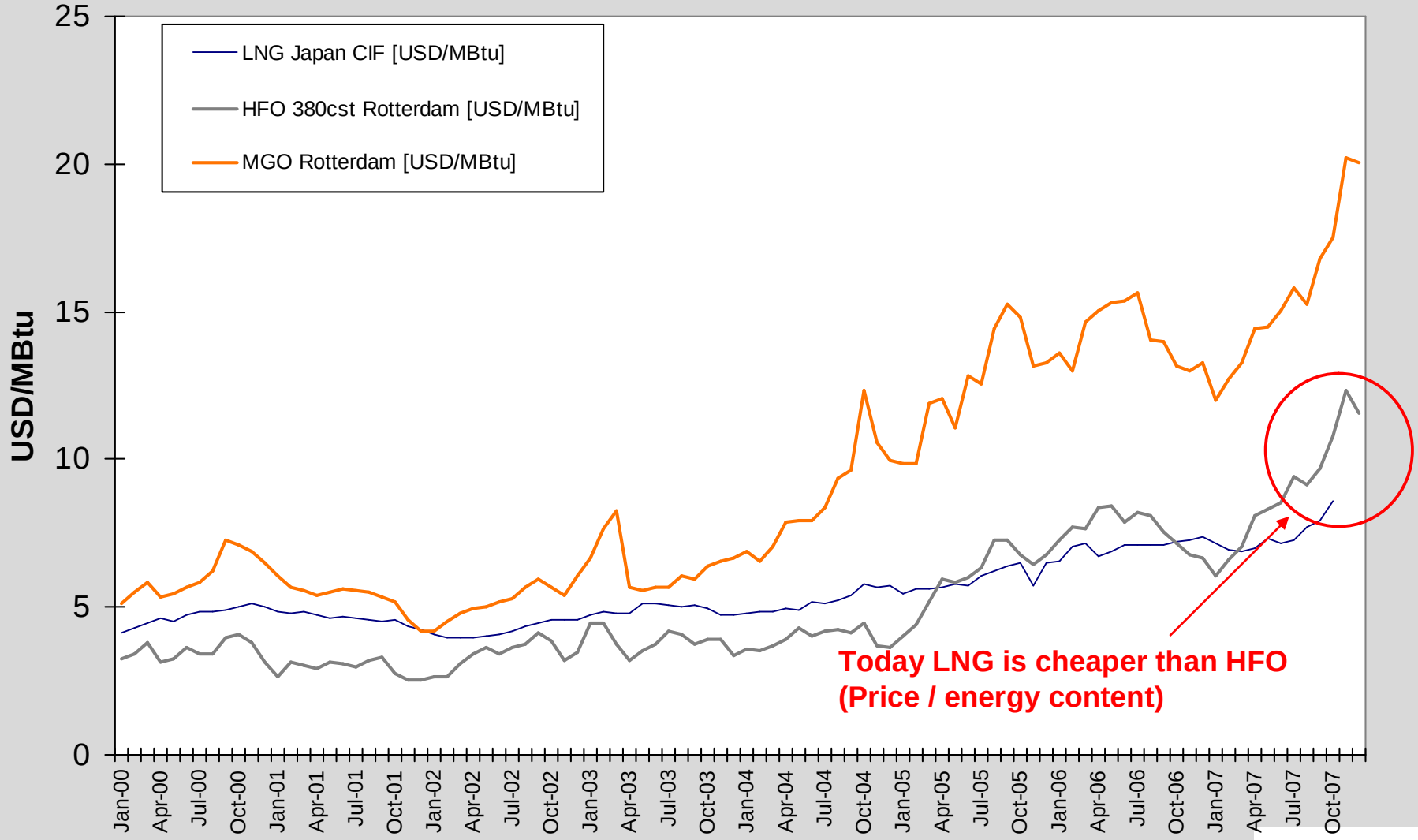
Fuel prices



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

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Dual-fuel engine characteristics

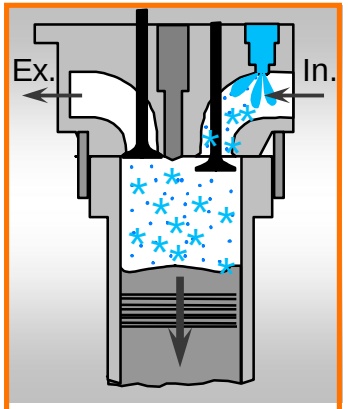
- High efficiency
- Low gas pressure
- Low emissions, due to:
  - High efficiency
  - Clean fuel
  - Lean burn combustion
- Fuel flexibility
  - Gas mode
  - Diesel mode
- Two engine models
  - Wärtsilä 34DF
  - Wärtsilä 50DF

Wärtsilä 6L50DF

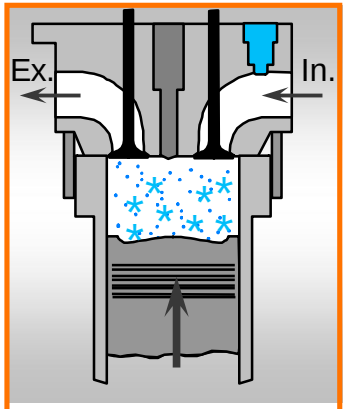
DF Engines - Operating modes

Gas mode:

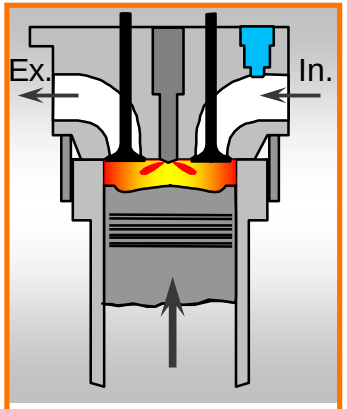
- Otto principle
- Low-pressure gas admission
- Pilot diesel injection



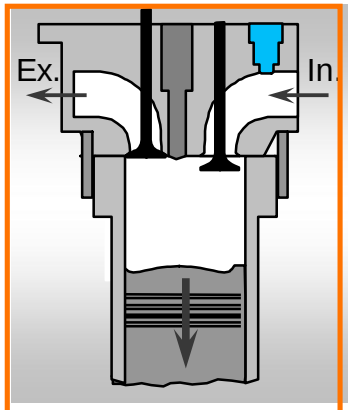
Intake of air and gas



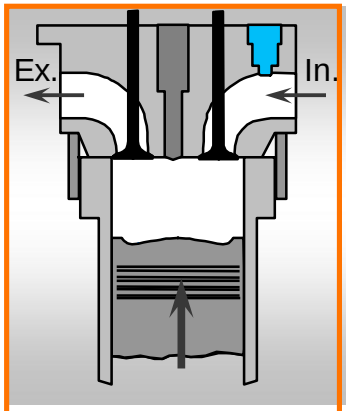
Compression of air and gas



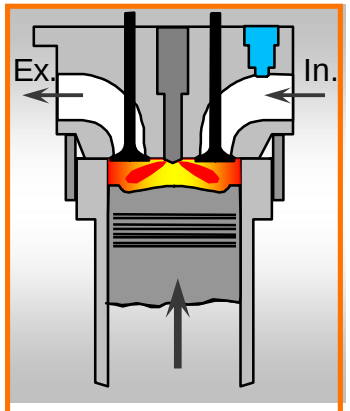
Ignition by pilot diesel fuel



Intake of air



Compression of air



Injection of diesel fuel

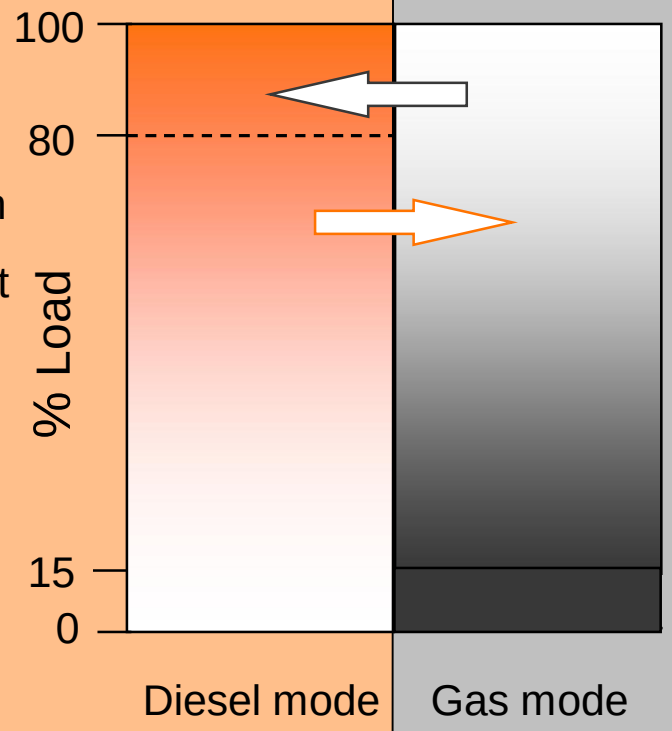
Diesel mode:

- Diesel principle
- Diesel injection

Engine characteristics - Operating mode changes

Diesel mode

- Running on HFO or MDO and MDO pilot fuel injection
- Transfer to gas operation at loads up to 80%
- Pilot fuel injection in operation



Gas mode

- Automatic and instant trip to diesel operation in alarm situations
- Trip to diesel operation on request at any load
- Automatic trip to diesel mode after 3 minutes at engine loads below 15%

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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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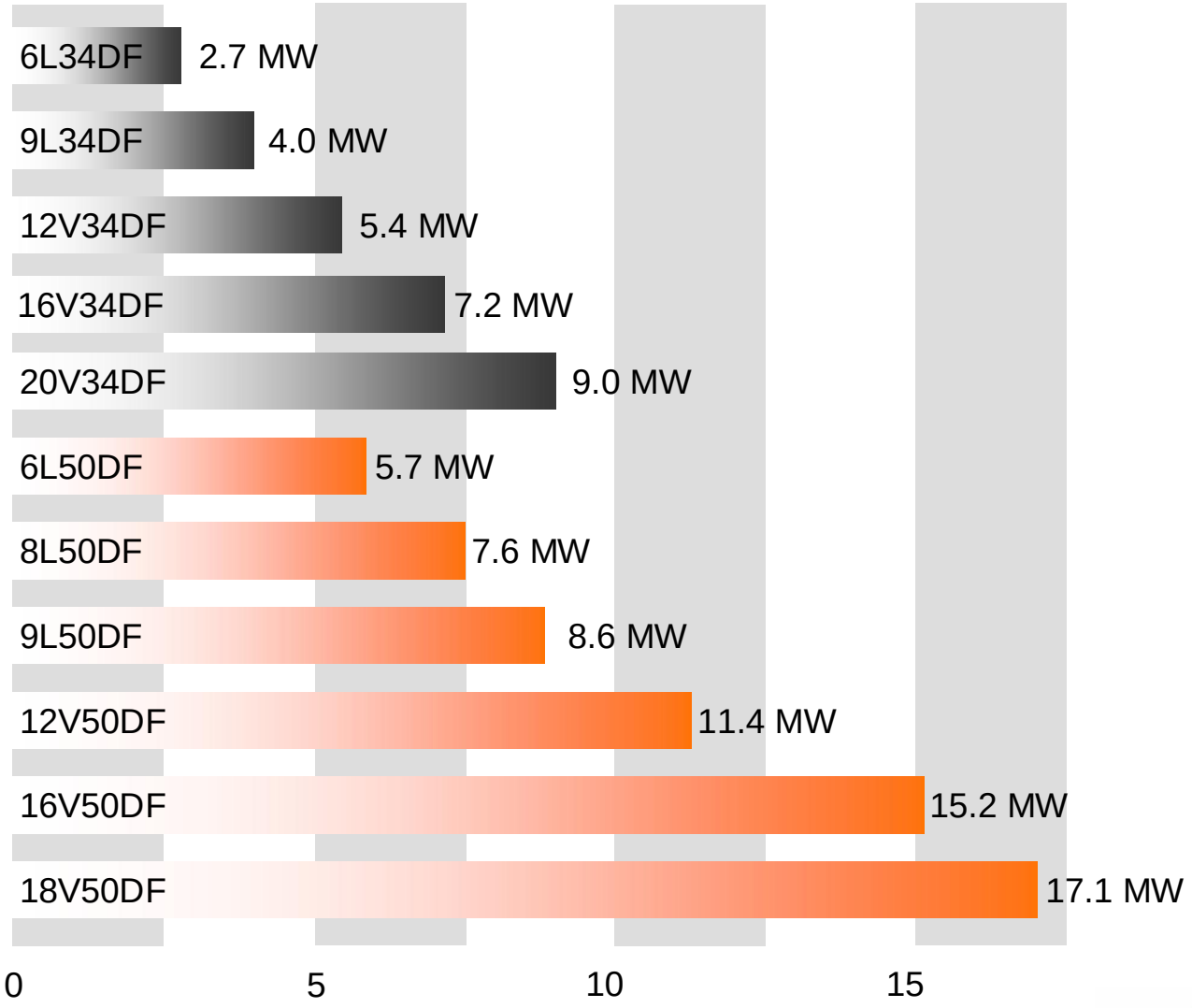
Dual-fuel engine range

WÄRTSILÄ **34DF**

WÄRTSILÄ **50DF**



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Dual-fuel engine references at sea

Petrojarl 1
FPSO
Petrojarl
2x 18V32DF
2x 32’000 running hours

Sendje Ceiba
FPSO
Bergesen
1x 18V32DF
18’000 running hours

Viking Energy
DF-electric offshore supply vessel
Eidesvik
Kleven Verft
4x 6R32DF
4x 19’500 running hours

Stril Pioner
DF-electric offshore supply vessel
Simon Møkster
Kleven Verft
4x 6R32DF
4x 16’500 running hours

Viking tbn (Gass Avant) and hull 30
DF-electric offshore supply vessel
Eidesvik
West Contractors
4x 6R32DF
Ship deliveries 2007 & 2008

Provalys and Gaselys
DF-electric LNG Carrier
Gaz de France
Alstom Chantiers de l’Atlantique
2x 12V50DF + 2x6L50DF
Total 20’000 running hours for 2 ships

Gaz de France energY
DF-electric LNG Carrier
Gaz de France
Alstom Chantiers de l’Atlantique
4x 6L50DF
Total 16’000 running hours

British Emerald
DF-electric LNG Carrier
BP Shipping
Hyundai Heavy Industries
2x 12V50DF + 2x9L50DF
Delivered 2007

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LNG fuelled vessel: PSV Viking Energy & Stril Pioneer

PSV Viking Energy / Stril pioner

Owners:	Eidesvik AS
	Mökster Shipping
Builder:	Kleven Verft

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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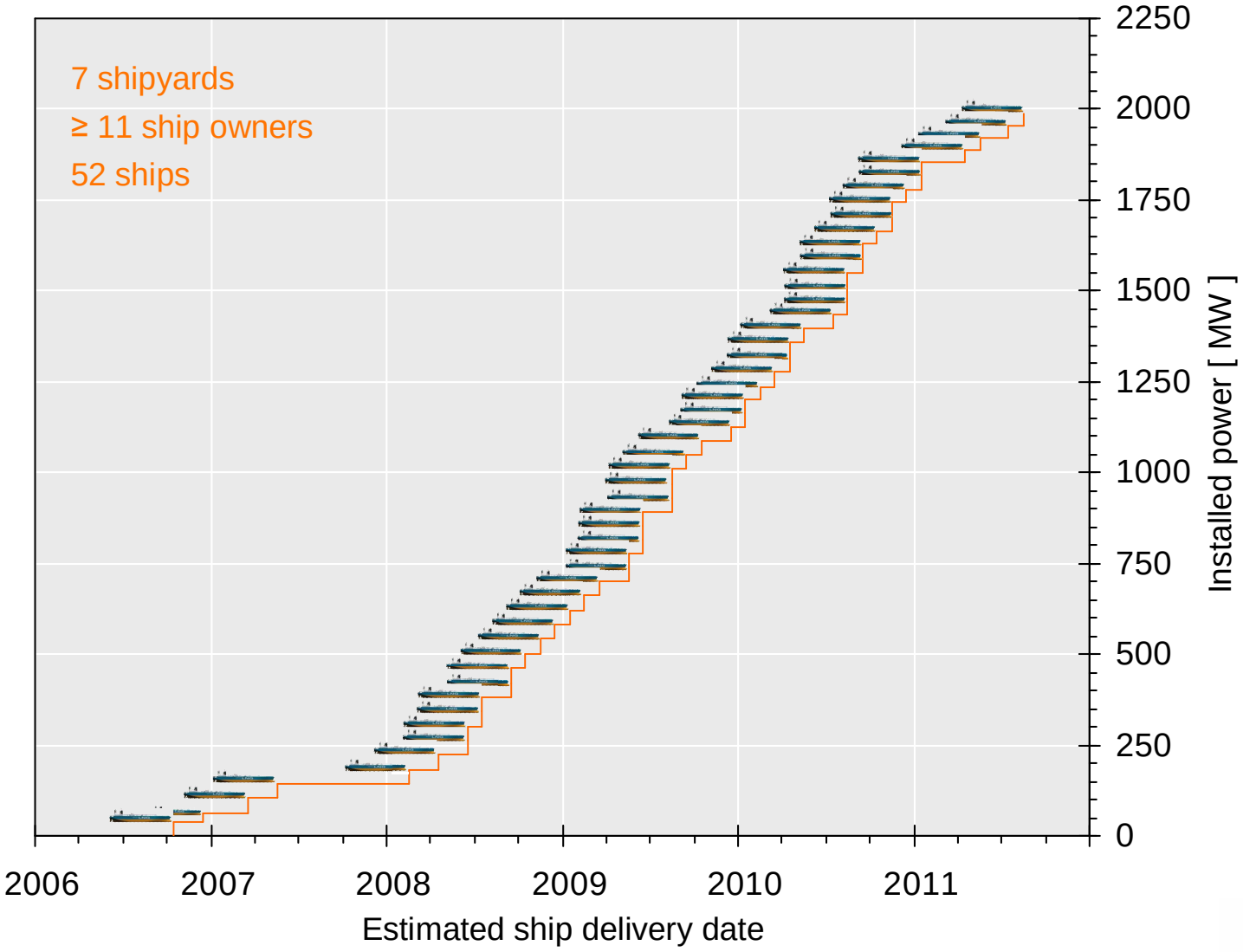
Dual-fuel-electric LNG carrier deliveries



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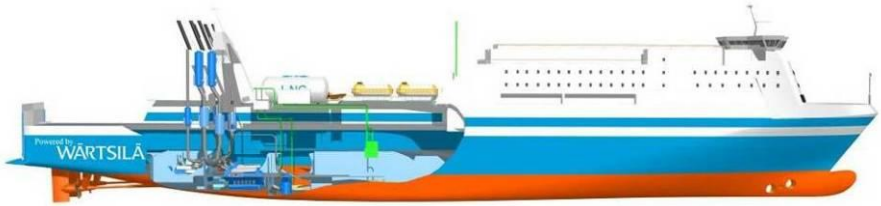
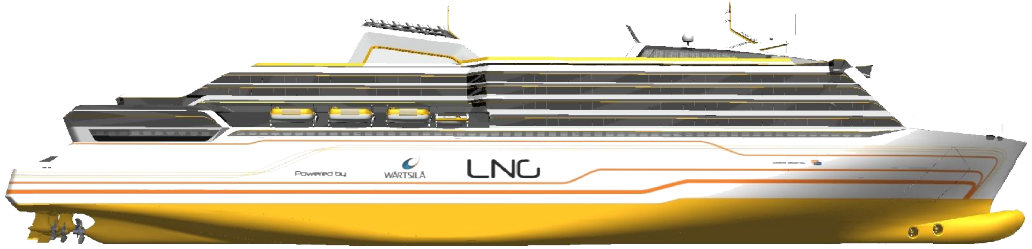
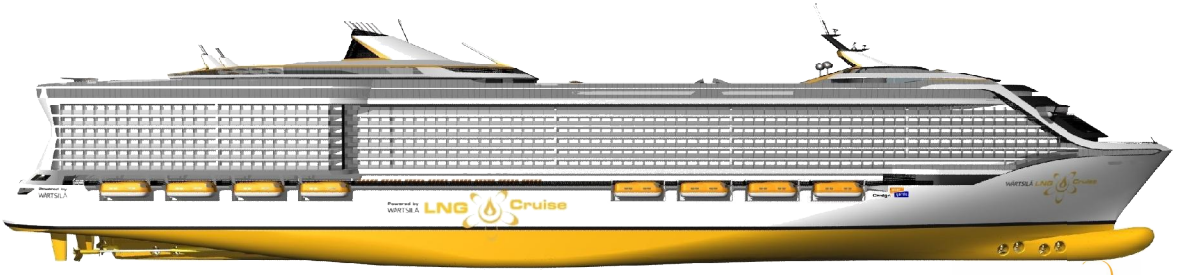
LNG development projects

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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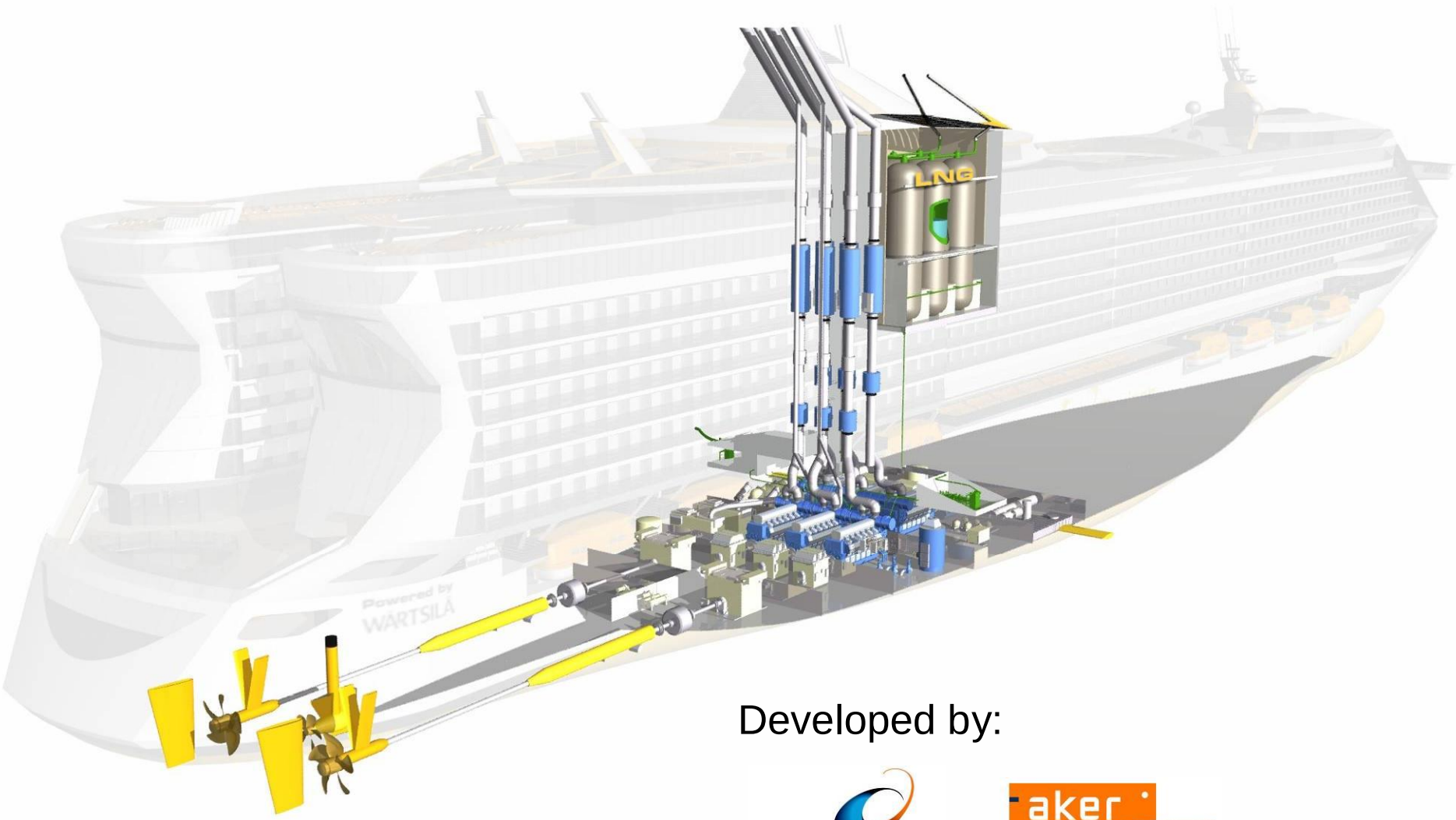
LNG cruise ship
125 000 gt

LNG Cruise Ship concept



Developed by:

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aker yards.

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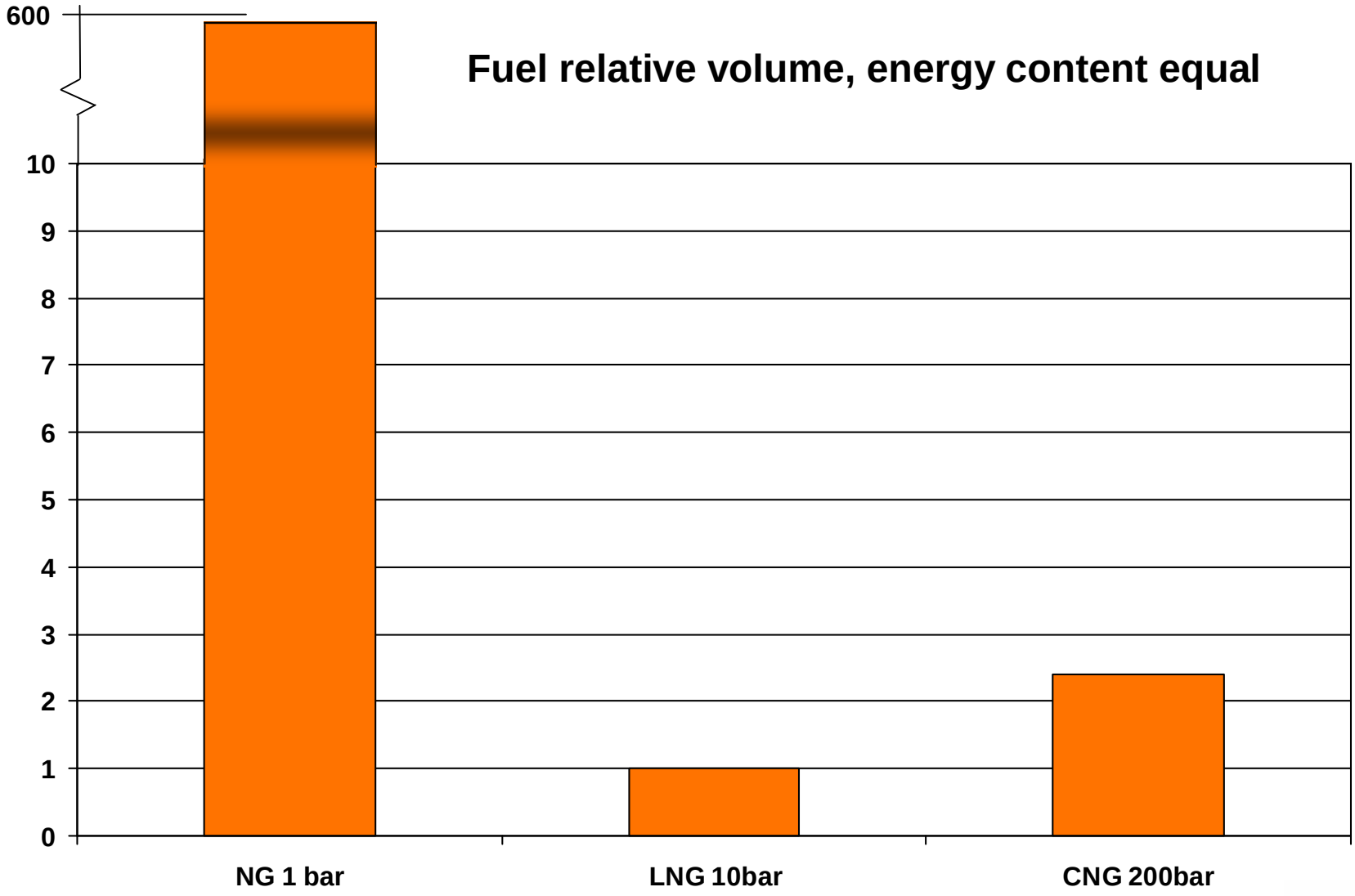
Main particulars

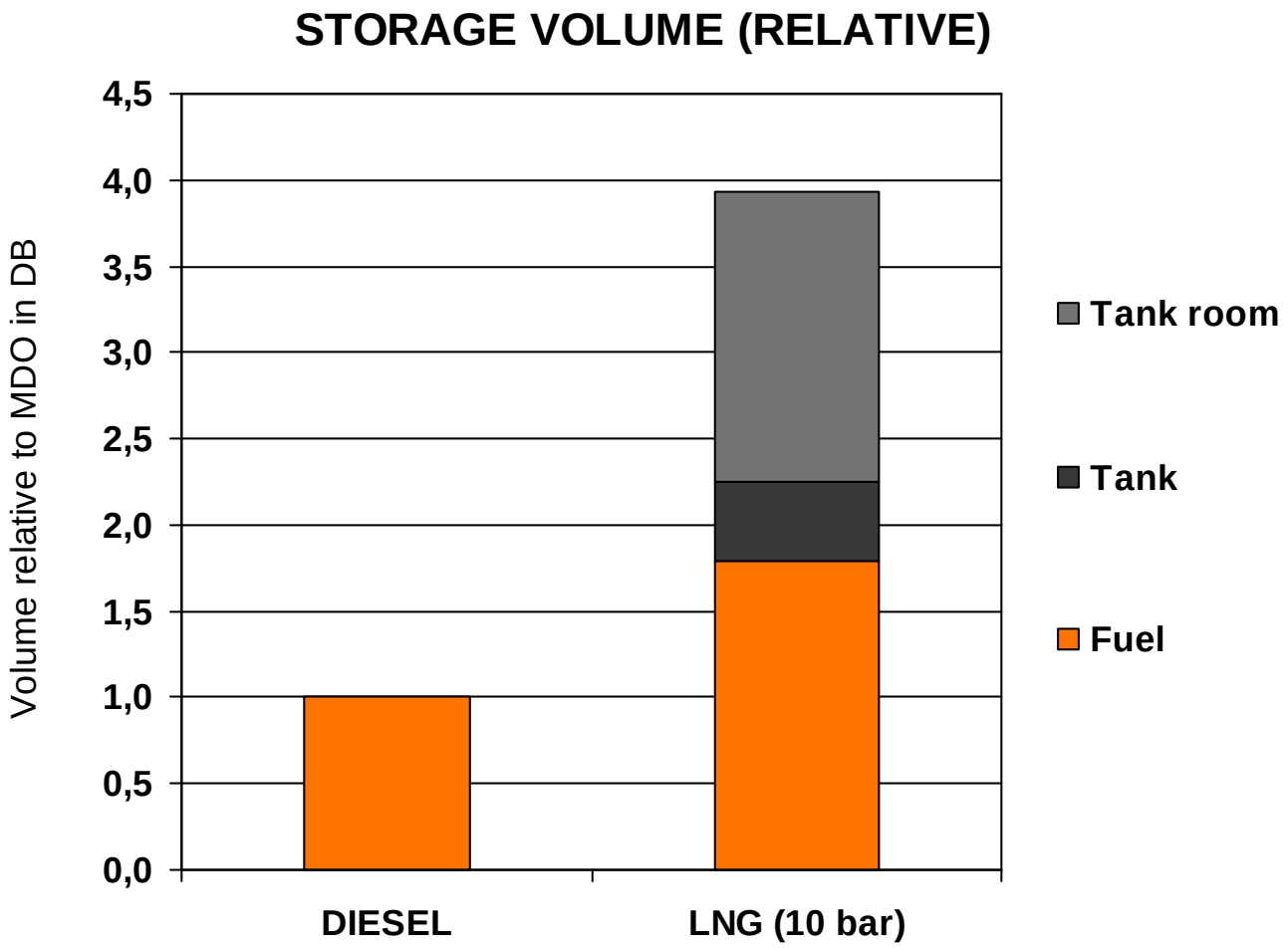
Main Particulars

– Gross tonnage	125 000	GT
– Length over all	310	m
– Length, bp	295	m
– Breadth	40	m
– Draught, design	8.6	m
– Deadweight	10 000	ton
– Service speed, max	21.0	knots
– Lower beds	2 780	pcs
– Pax cabins	1 390	pcs

Why bunker has to be in liquid form (LNG)



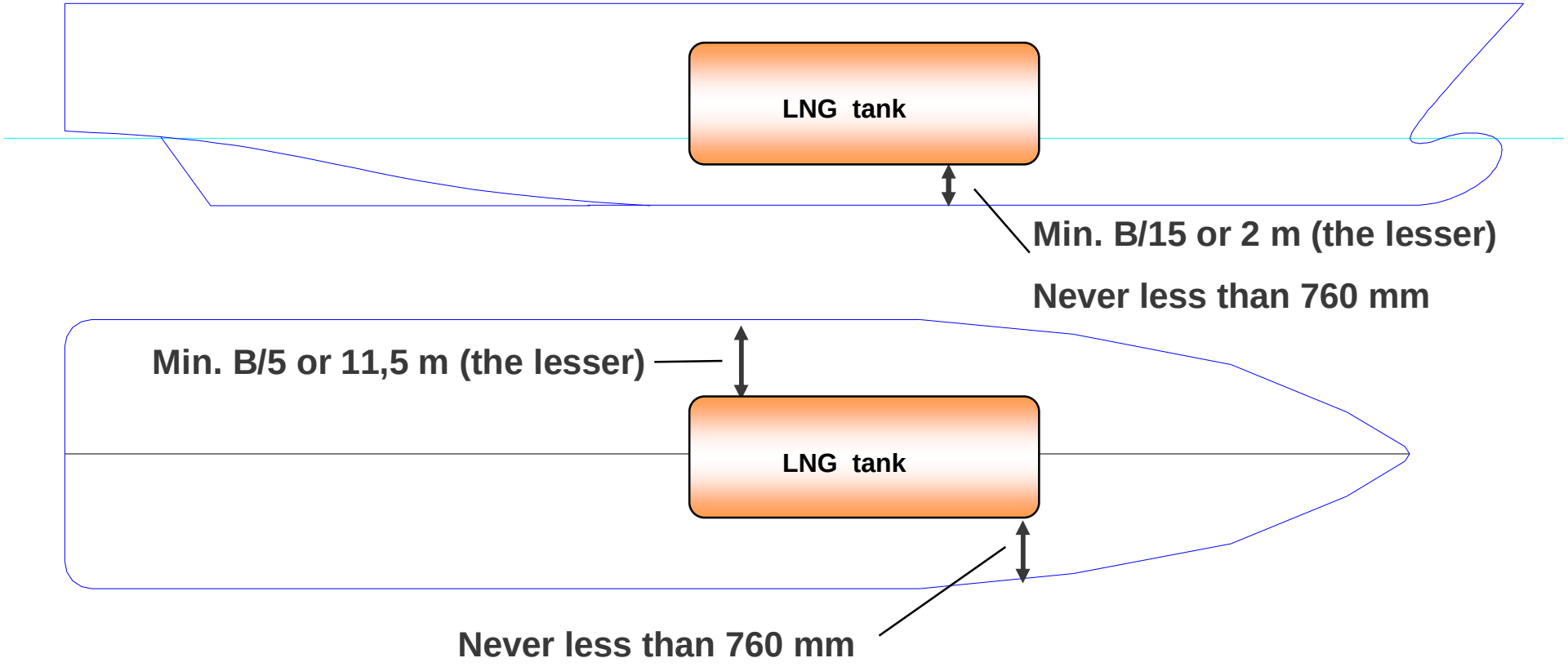
LNG tank – space demand



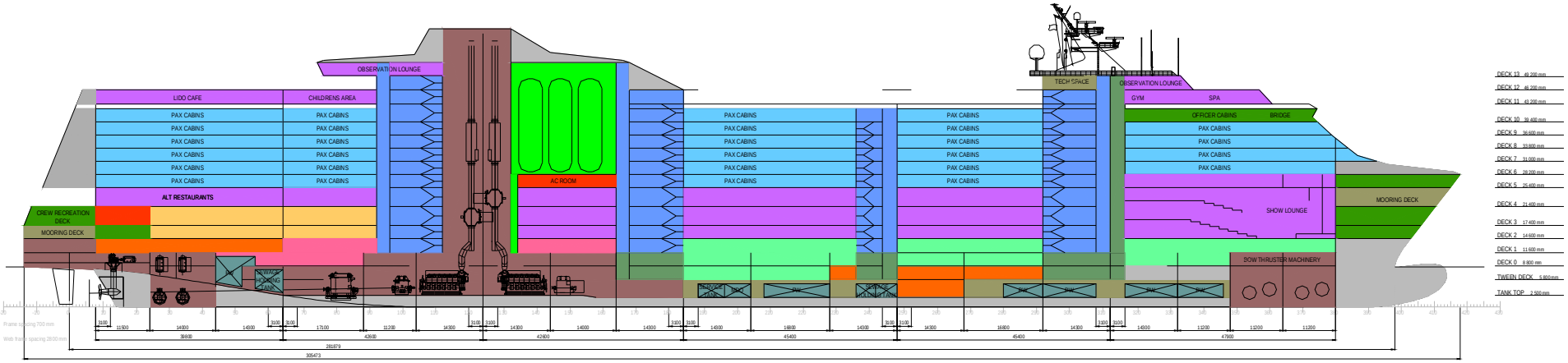
Energy content equal

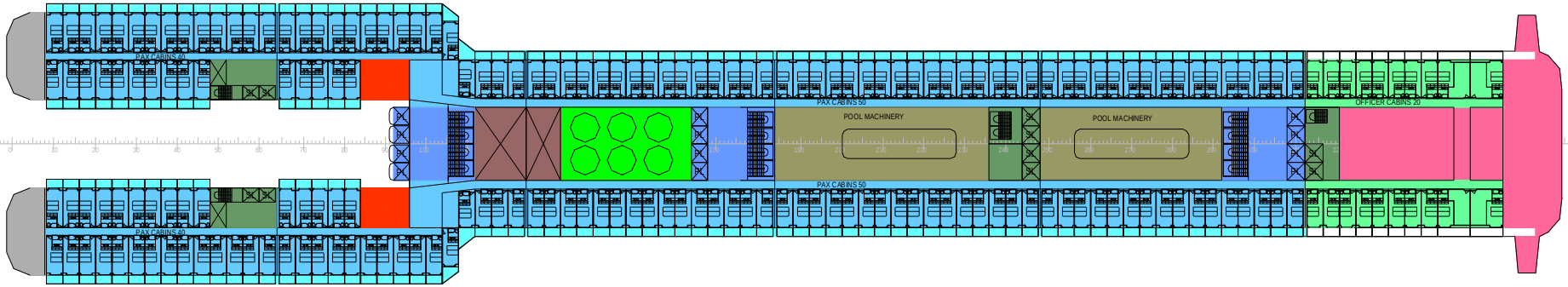
LNG storage location

Gas storage below deck



General arrangement





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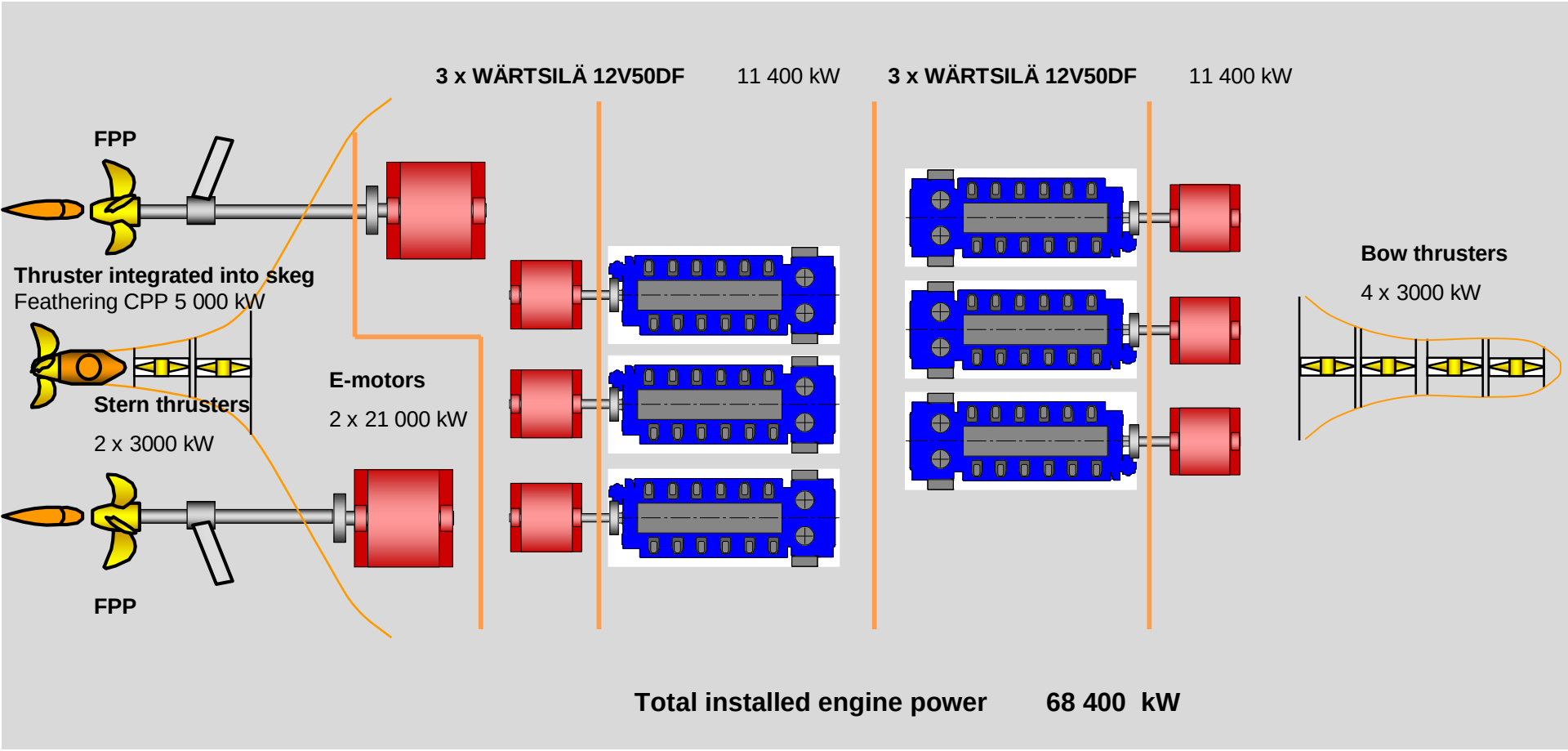
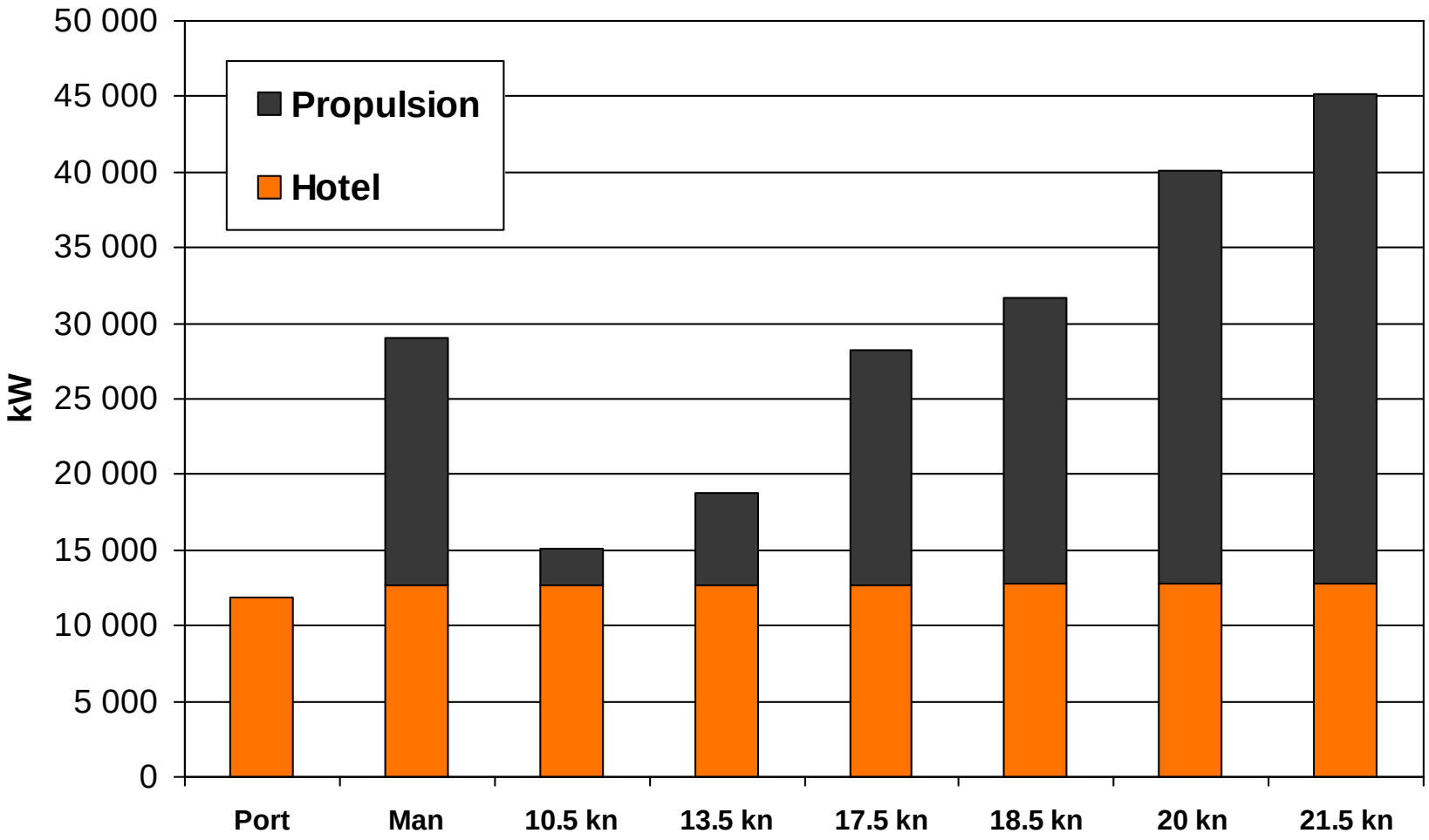
DF-electric machinery



Power requirement – total plant



Safety philosophy

- LNG is a very safe fuel for passenger vessels
  - LNG will not ignite (too cold)
  - Dfficult to ignite NG
    - NG can be ignited in a very narrow fuel / air ratio range (5-15%)
  - No build up of gas in bottom of ship
  - A possible NG leak will disperse upwards (lighter than air)

- Machinery concepts adds safety
  - Gas detection – automatic gas supply shut off
  - Double wall pipes
  - Never any large quantities of NG in engine rooms
  - LNG stored is special tanks in separate compartments

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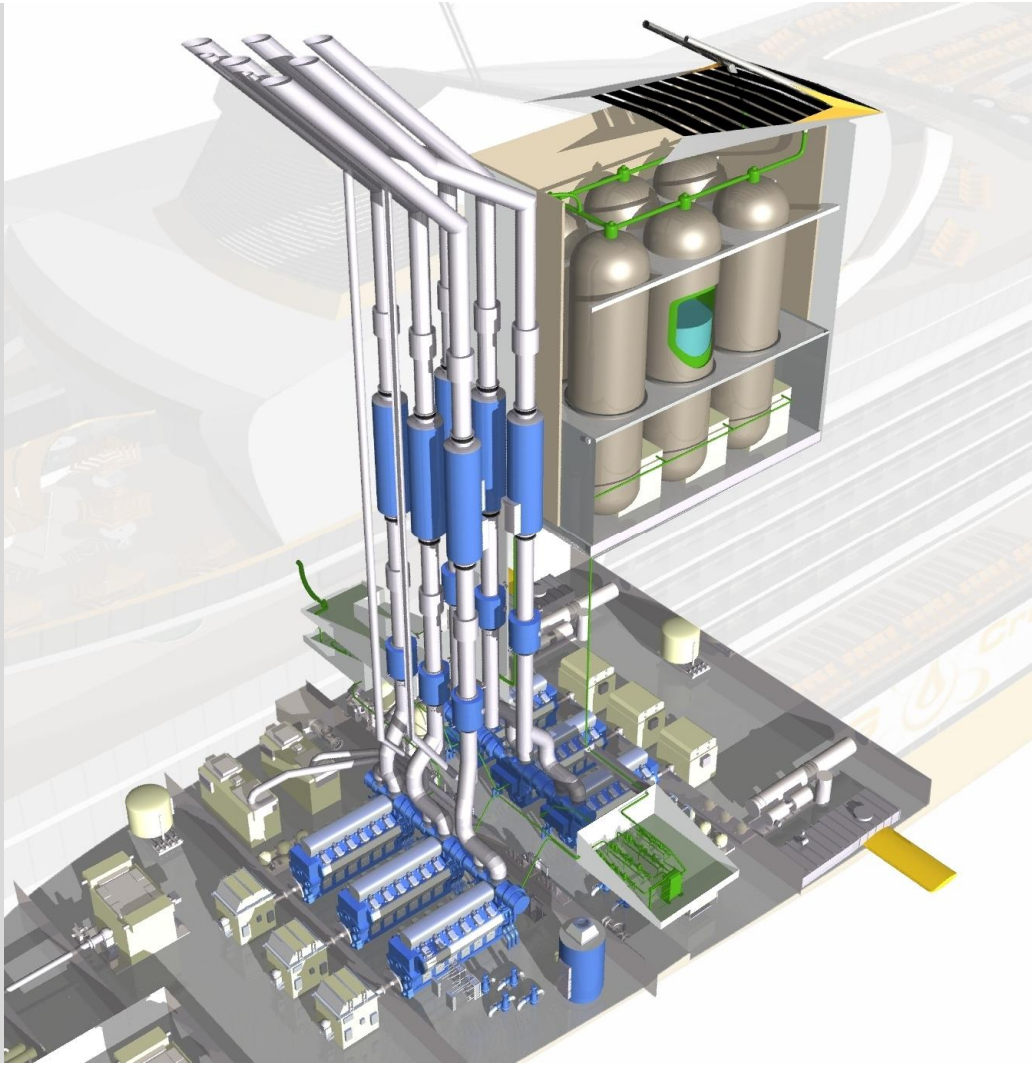
LNG tanks – Location

- Rule requirements
  - From side: B/5
  - From bottom: B/15 or 2 m (the lesser)

- Novel location in cruise ships
  - In centre line casing
  - Free ventilation to open air
  - Fire insulated space
  - “Drip tray” below tanks capable of containing the fuel of an entire tank



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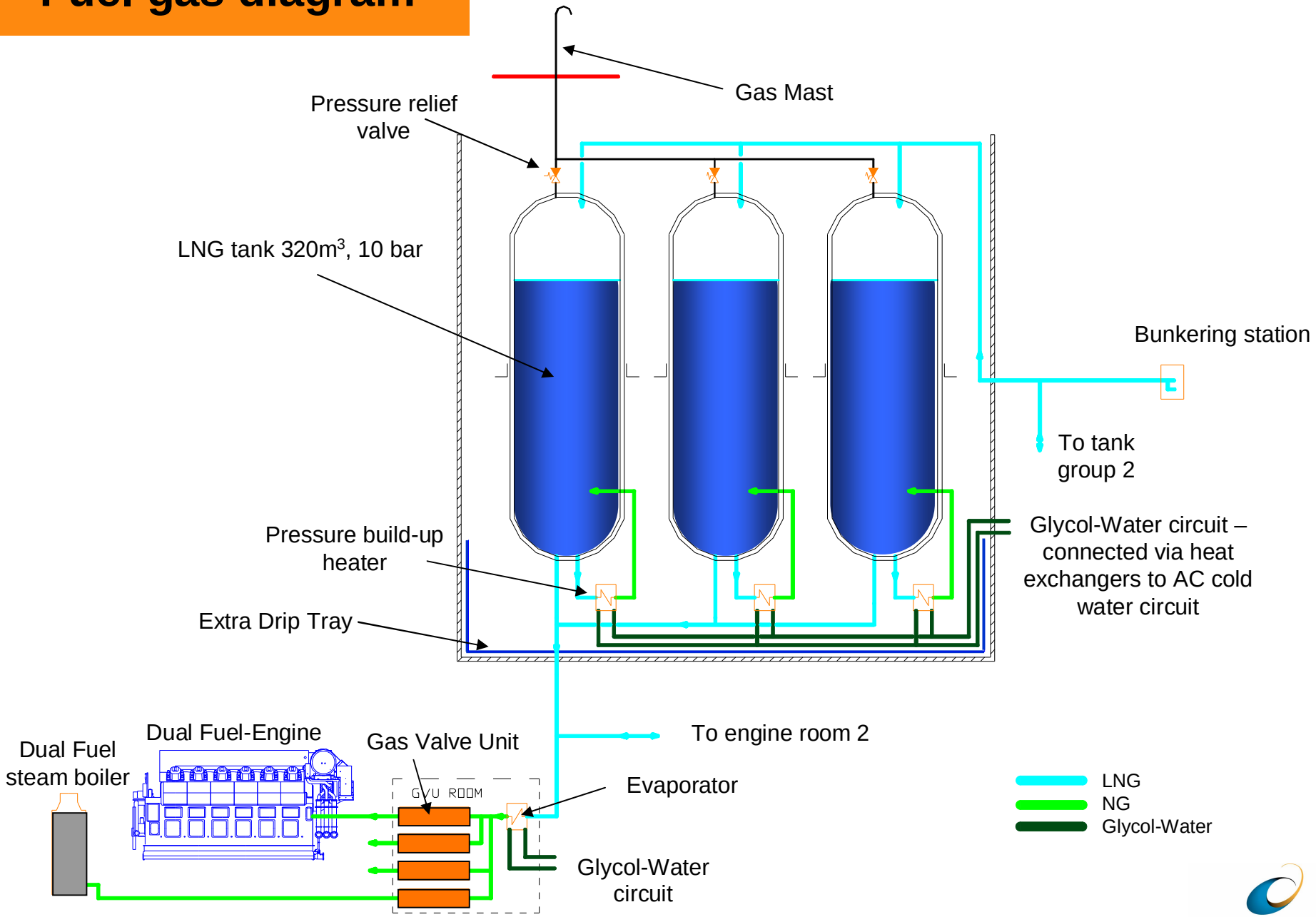
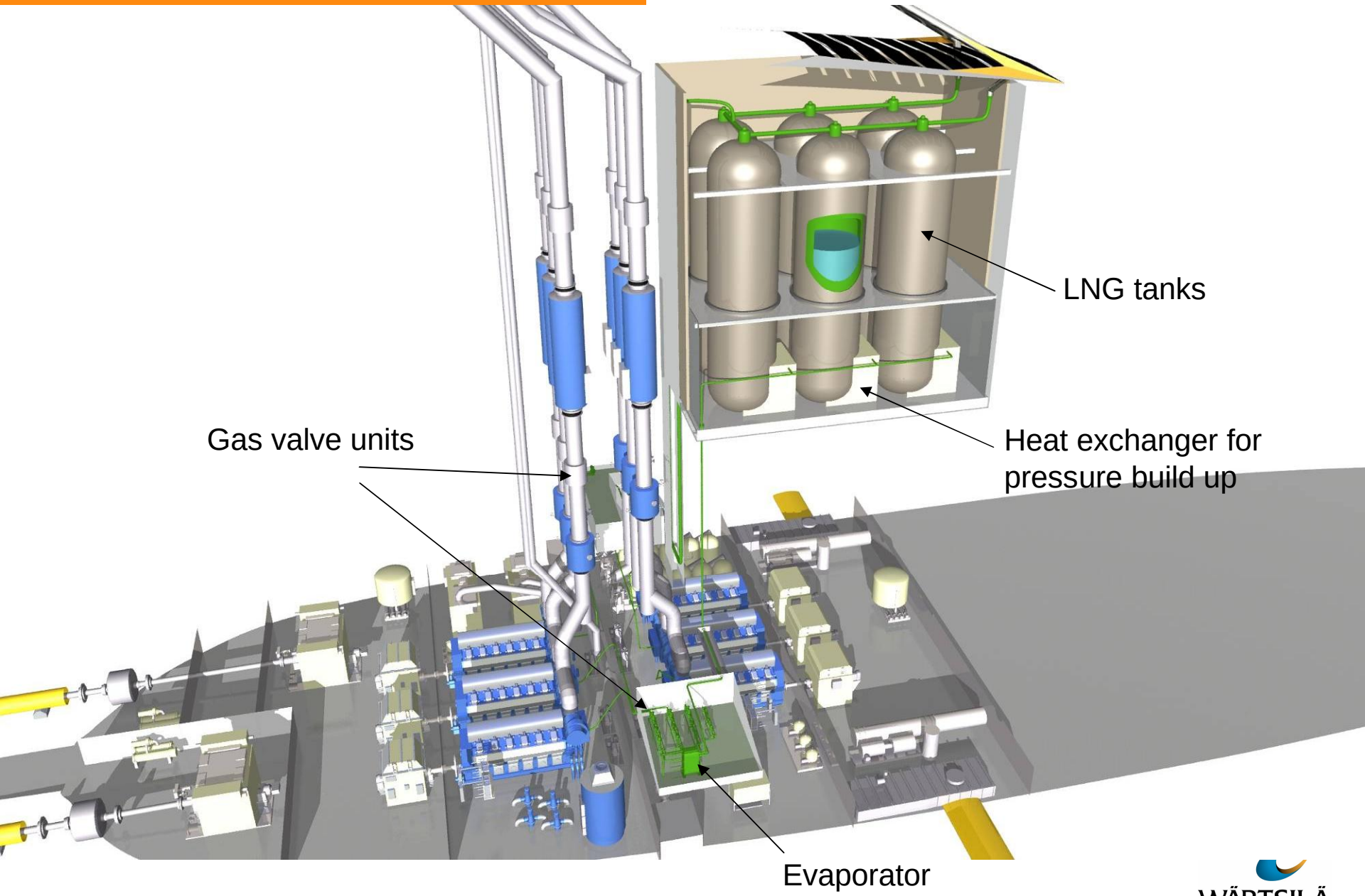
Fuel gas diagram

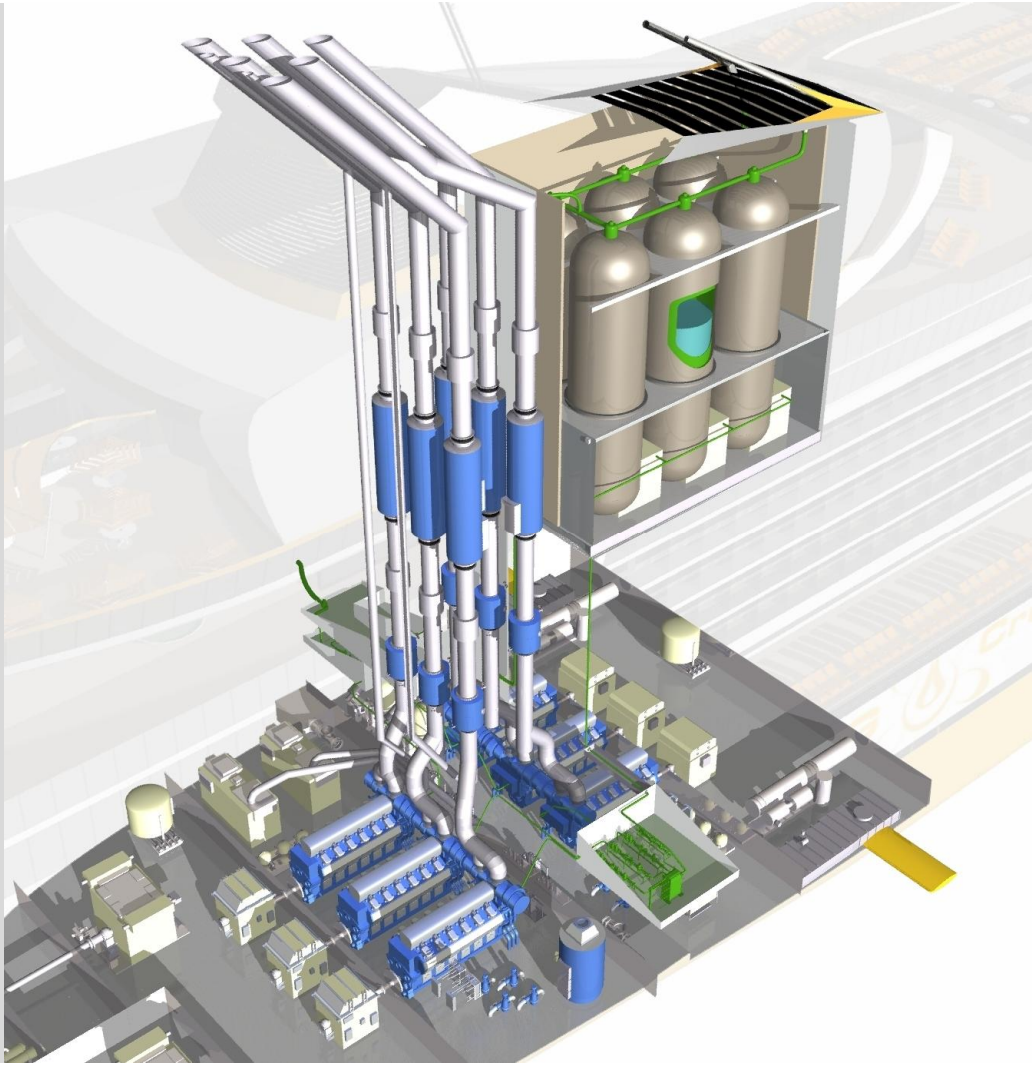


Gas system components



LNG tanks – Capacity

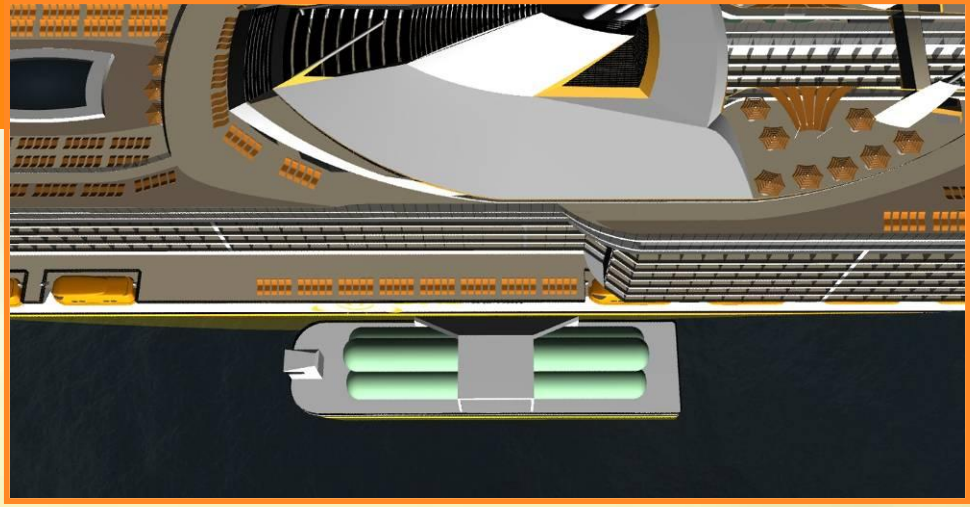
- Daily LNG consumption:
  - 100 ton
  - 220 m^3
- Capacity for 7 day cruise:
  - 1 560 m^3 consumption
  - 20% margin
  - filling ratio 95%
  - **<u>2 000 m^3 tank volume</u>**
- Back-up and extended range is covered with **MDO**



Bunkering

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

LNG bunkering from barge



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LNG in Europe

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LNG in Caribbean and Alaska

- Import terminal
- Export terminal

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LNG in Asia Pacific

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Fuel prices

	USD/ton	EUR/ton	USD/MBtu
LSHFO	460	312	12.0
MDO	720	490	17.8
MGO	790	537	19.5
LNG	470	317	10.0

Source: www.bunkerworld.com (Rotterdam 29.1.2008), LNG price estimated

1 EUR = 1.47 USD

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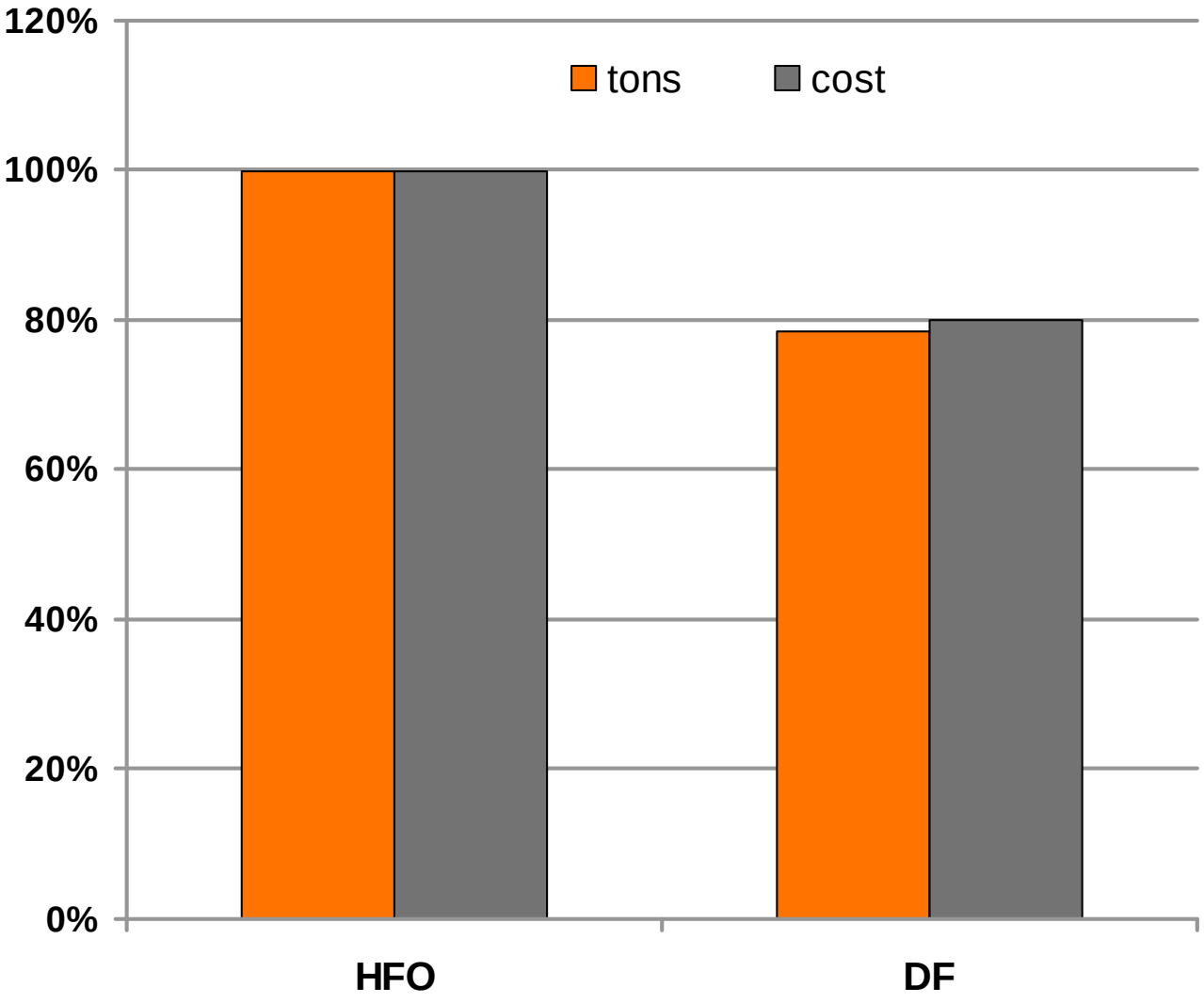
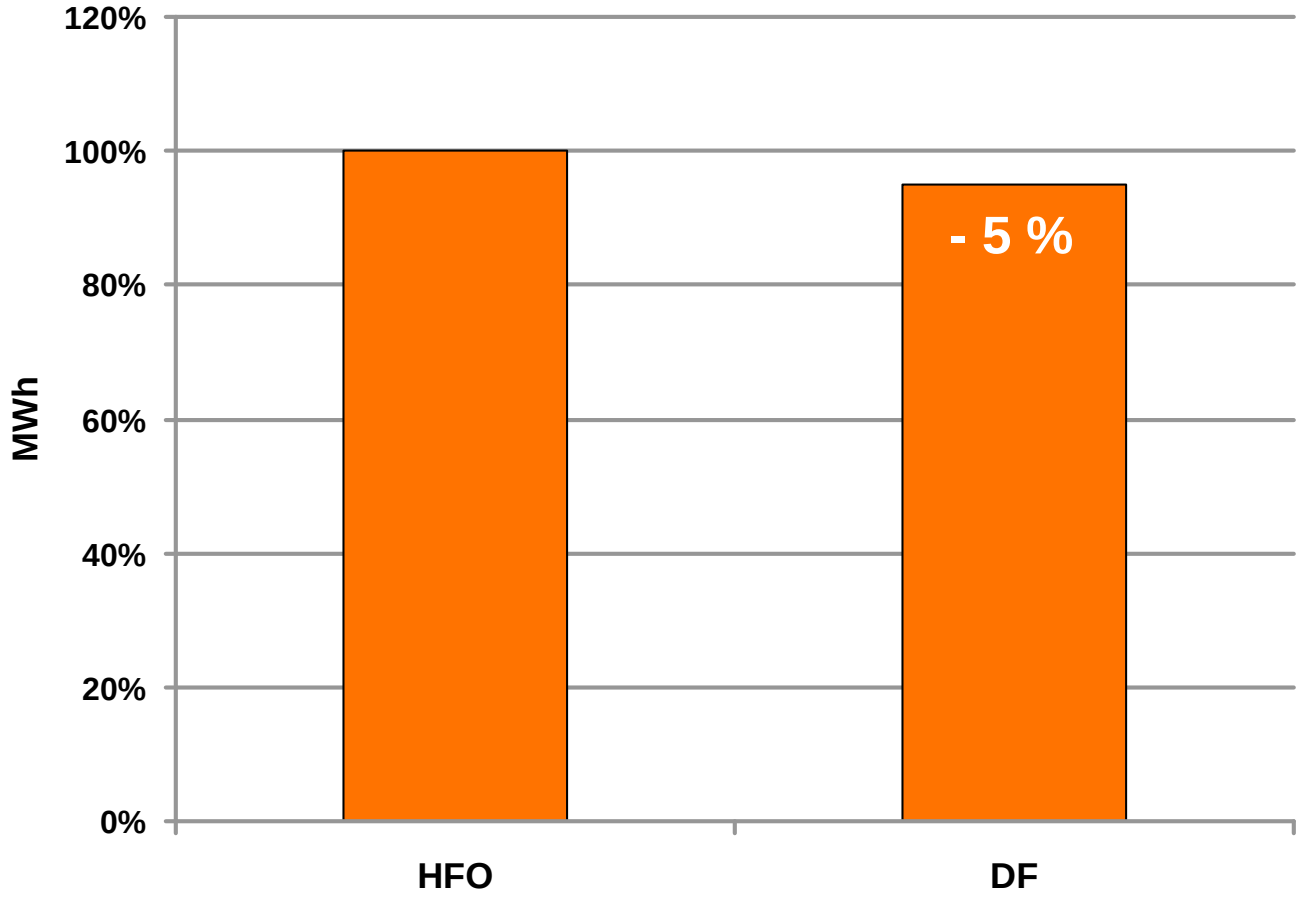
Fuel consumption and cost



Assumed fuel prices:

LSHFO	312	€/ton
	(460	USD/ton)
MDO	490	€/ton
	(720	USD/ton)
LNG	317	€/ton
	(10.0	USD/MBtu)

Energy consumption

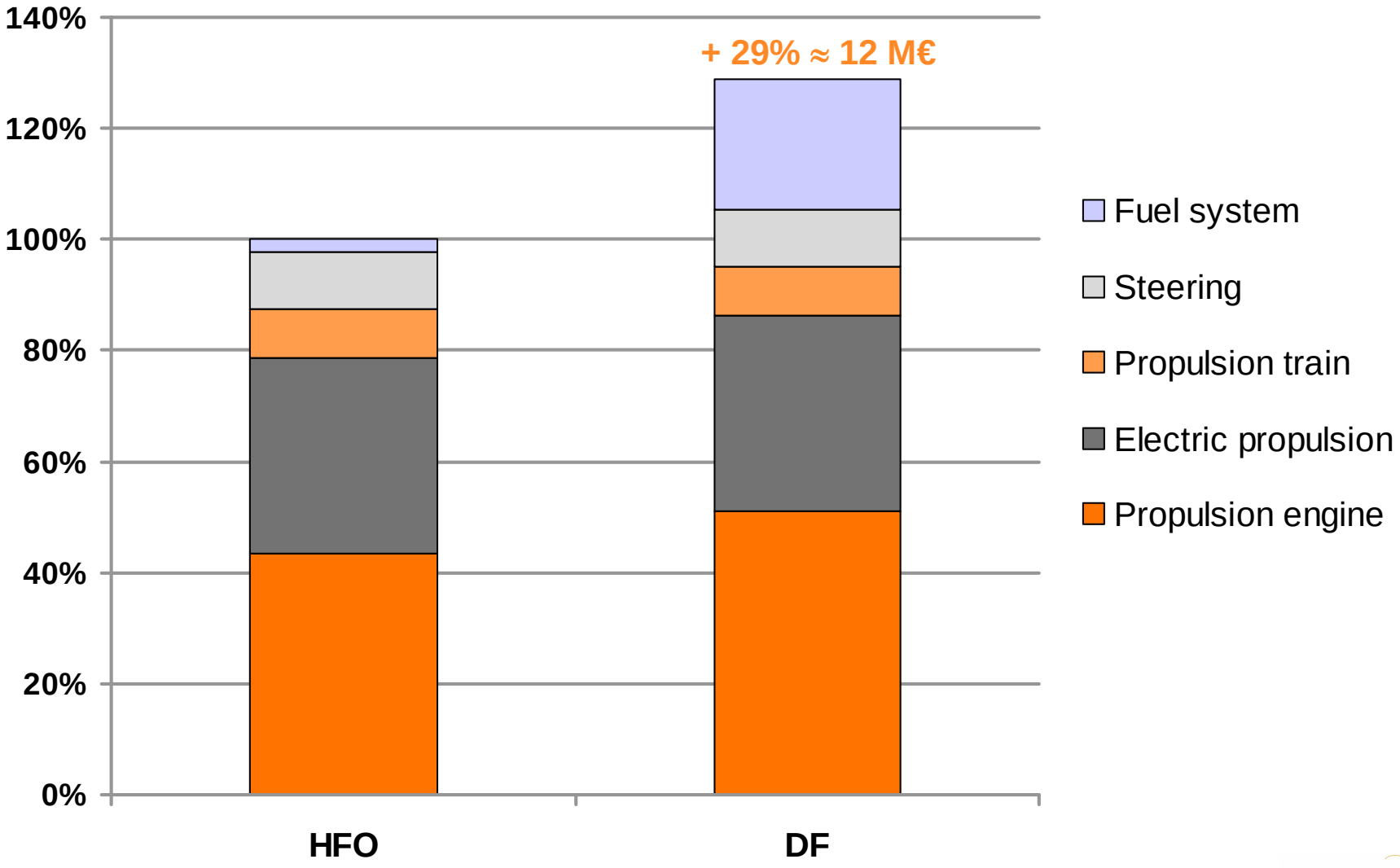


Energy consumption is lower for DF thanks to:

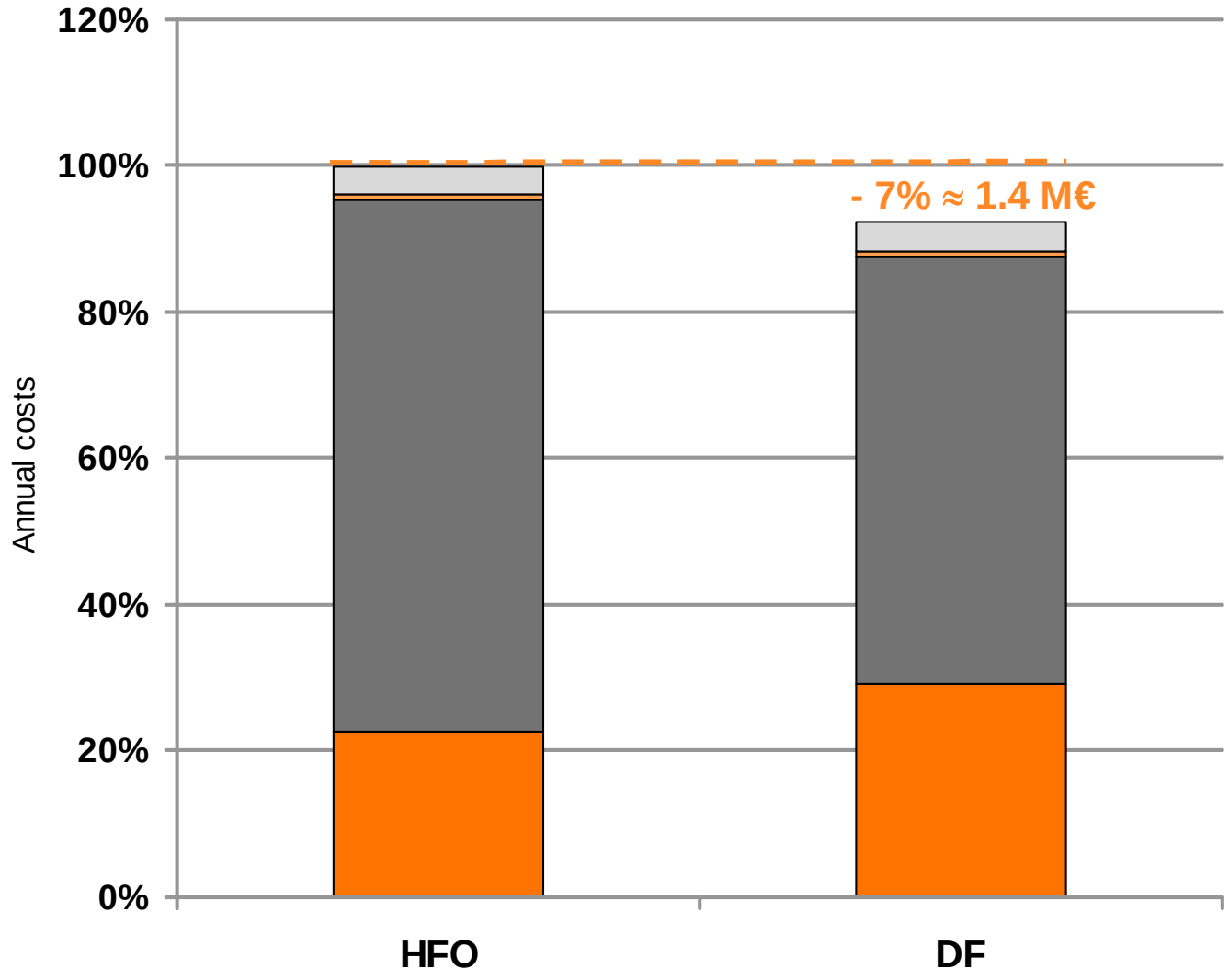
- Lower heat demand (no HFO)

- Lower electrical power demand (AC)

Machinery investment cost



Annual machinery related costs



Maintenance costs

Lub oil costs

Fuel oil costs

Annual capital costs

Assumed fuel prices:

LSHFO	312	€/ton
	(460	USD/ton)
MDO	490	€/ton
	(720	USD/ton)
LNG	317	€/ton
	(10.0	USD/MBtu)

Capital cost assumptions:

Interest	6	%
Time	15	years

Maintenance cost:

Calculation period	15	years

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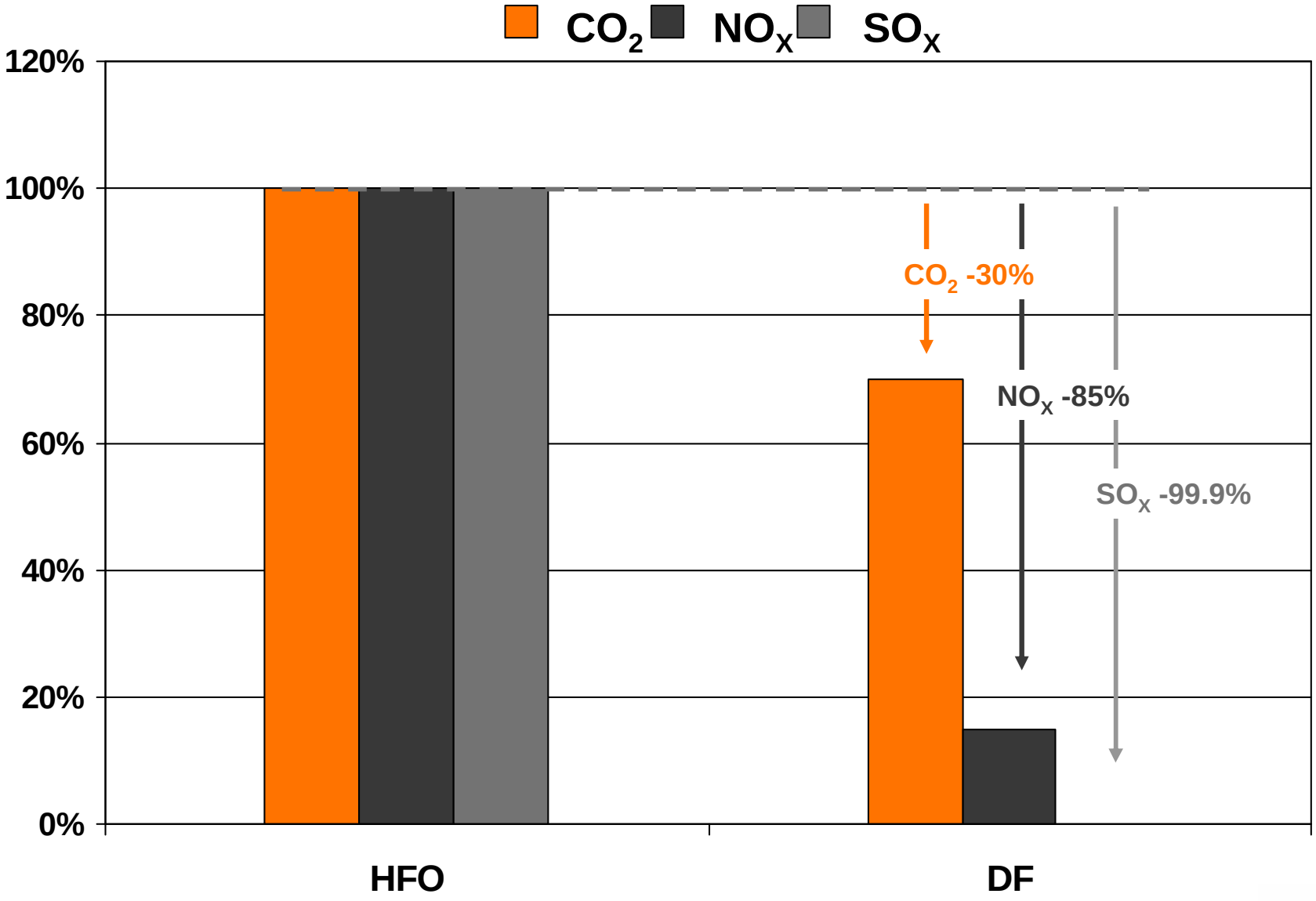
Emissions



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LNG challenges

Challenges:

– Space for tank locations	Alternative locations New tank types
– Cost	
• Investment	Design for actual use
• Operation	LNG price can be competitive
– Rules	DNV and LR rules Draft IMO rules
– Availability of LNG	Gas suppliers are interested

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Running on gas in port

Why ports are going for shore power?

- Environmental 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)
- Noise pollution

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Shore power

Shore power features

- No **local** exhaust emissions

- Expensive comp. to HFO gensets
- Not available in all ports
- Voltages and frequencies are not standardised
- Connectors are not standardised for high voltages
- Limitations of local power-distribution network
- Risk for power loss during changeover

Alternatives to shore power

- HFO + Exhaust gas treatment
  - SCR → NO_X
  - Seawater Scrubbers → SO_x (and Particles)
- MGO
  - Only meets the regulation for sulphur content
  - Does not comply with the demands in certain ports
- LNG

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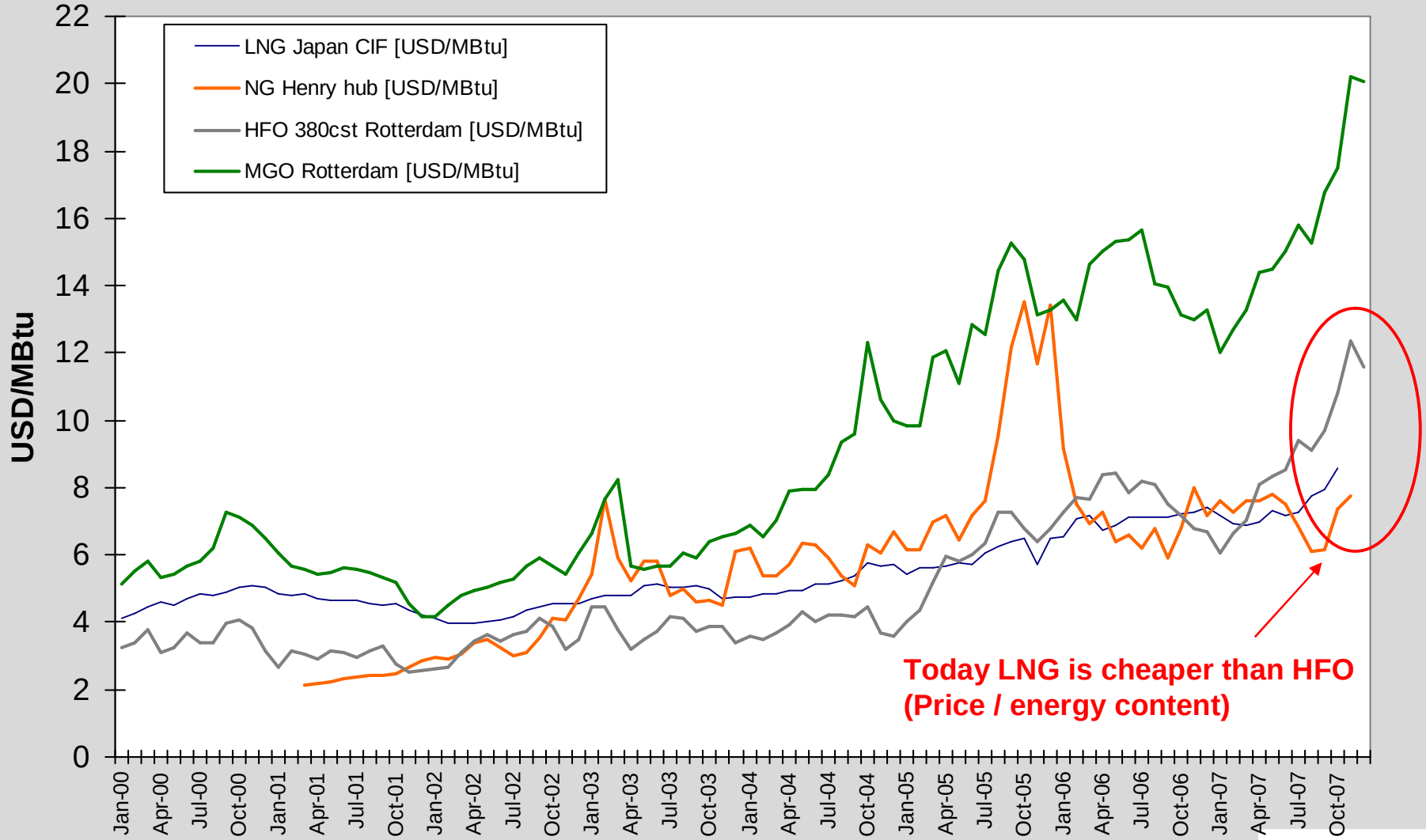
Fuel prices



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

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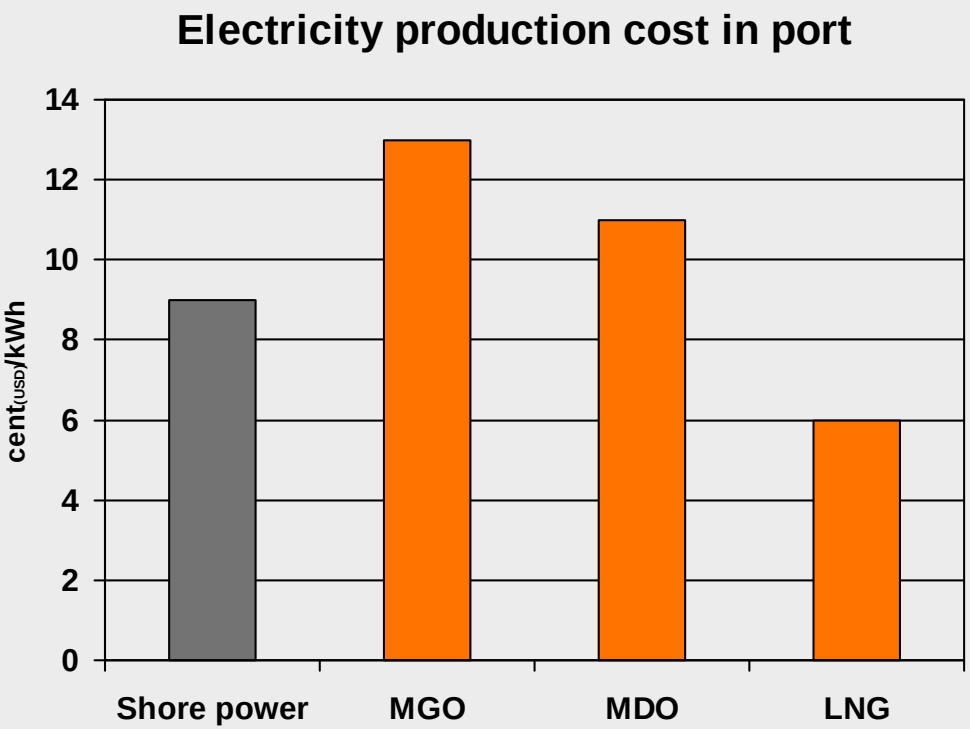
NG in port philosophy

- 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

→ **Simple system**

LNG auxiliary power in port for cruise vessels

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



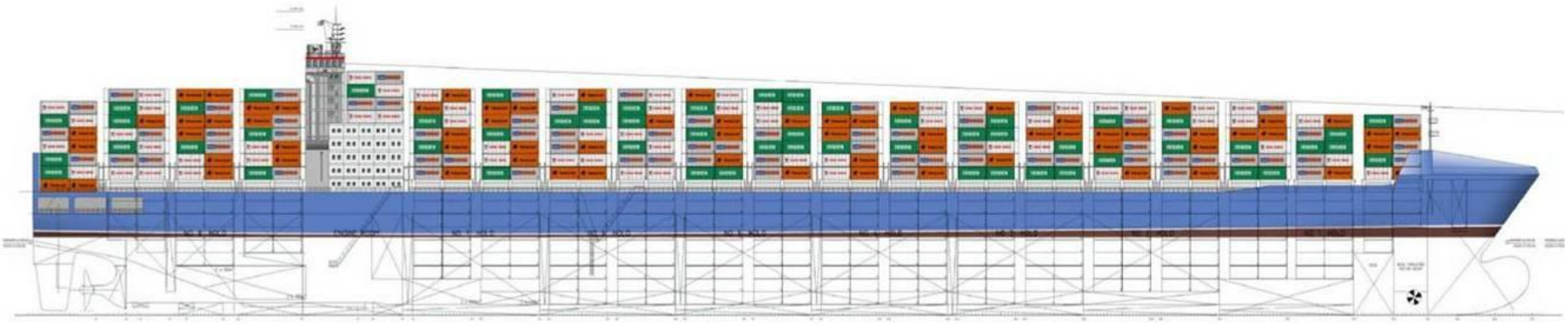
Case study – SCHIFFKO CV 7300

Case study – Reference vessel

SCHIFFKO CV 7300

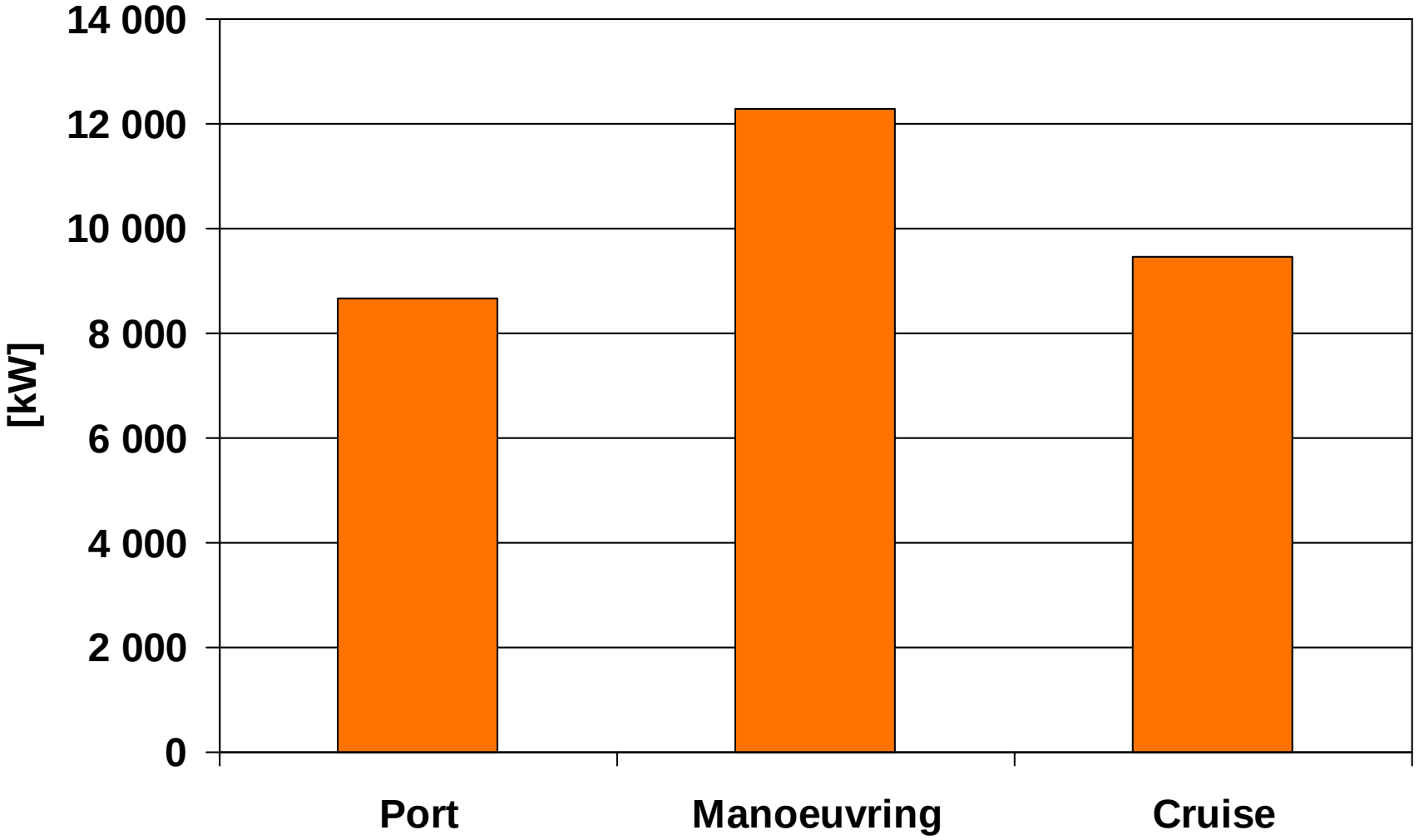
Length over all	322.34	m
Breadth	40.00	m
Draught	14.00	m
Deadweight	84 500	ton

Main engine	Wärtsilä 11RT-flex96C	
Propulsion power	62 920	kW
Speed (trial)	25.5	kn
Cargo capacity	7 300	TEU
Reefer plugs	1 300	FEU

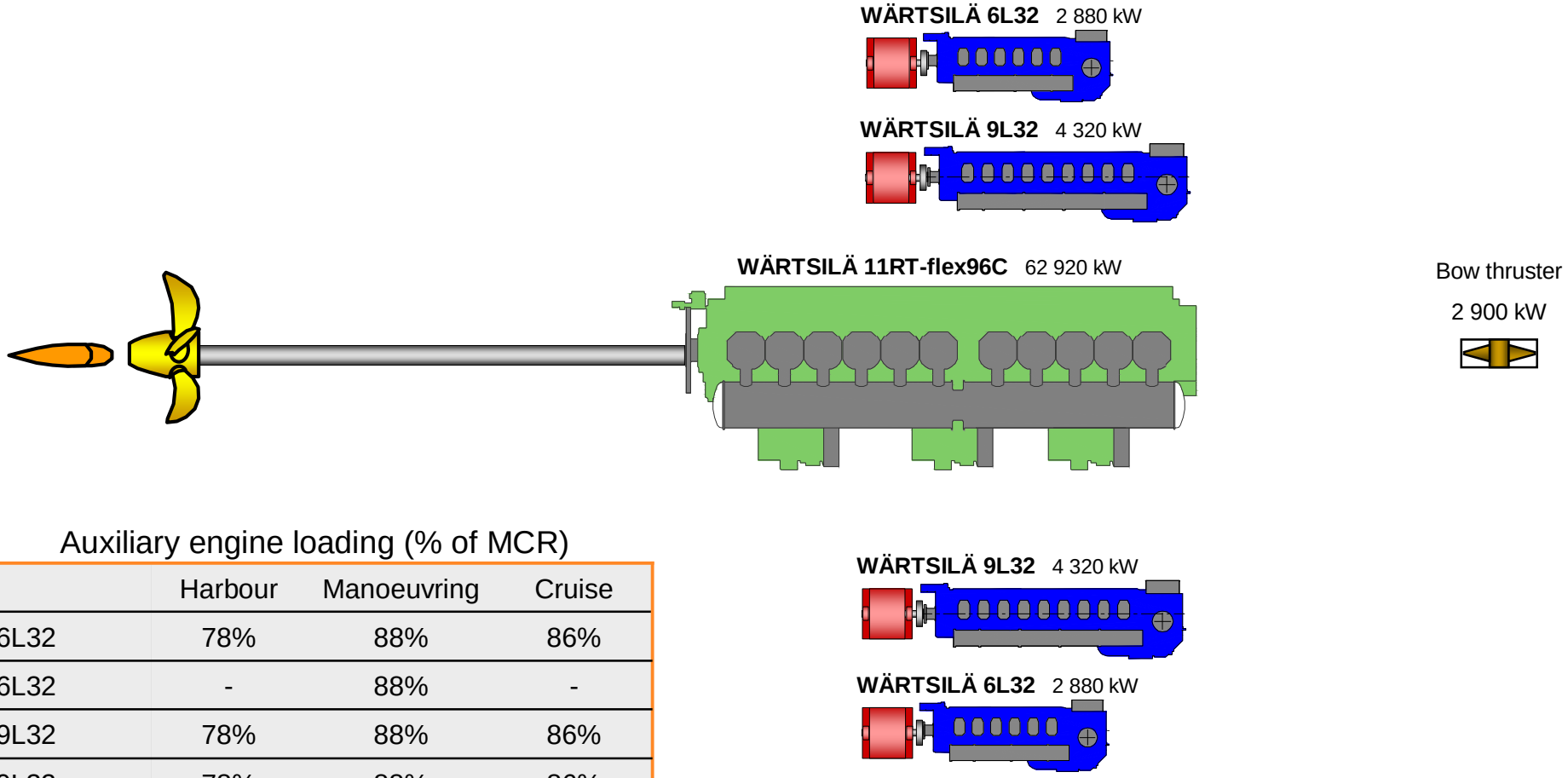


SCHIFFKO CV 7300

Electrical load



Machinery – Diesel (reference)

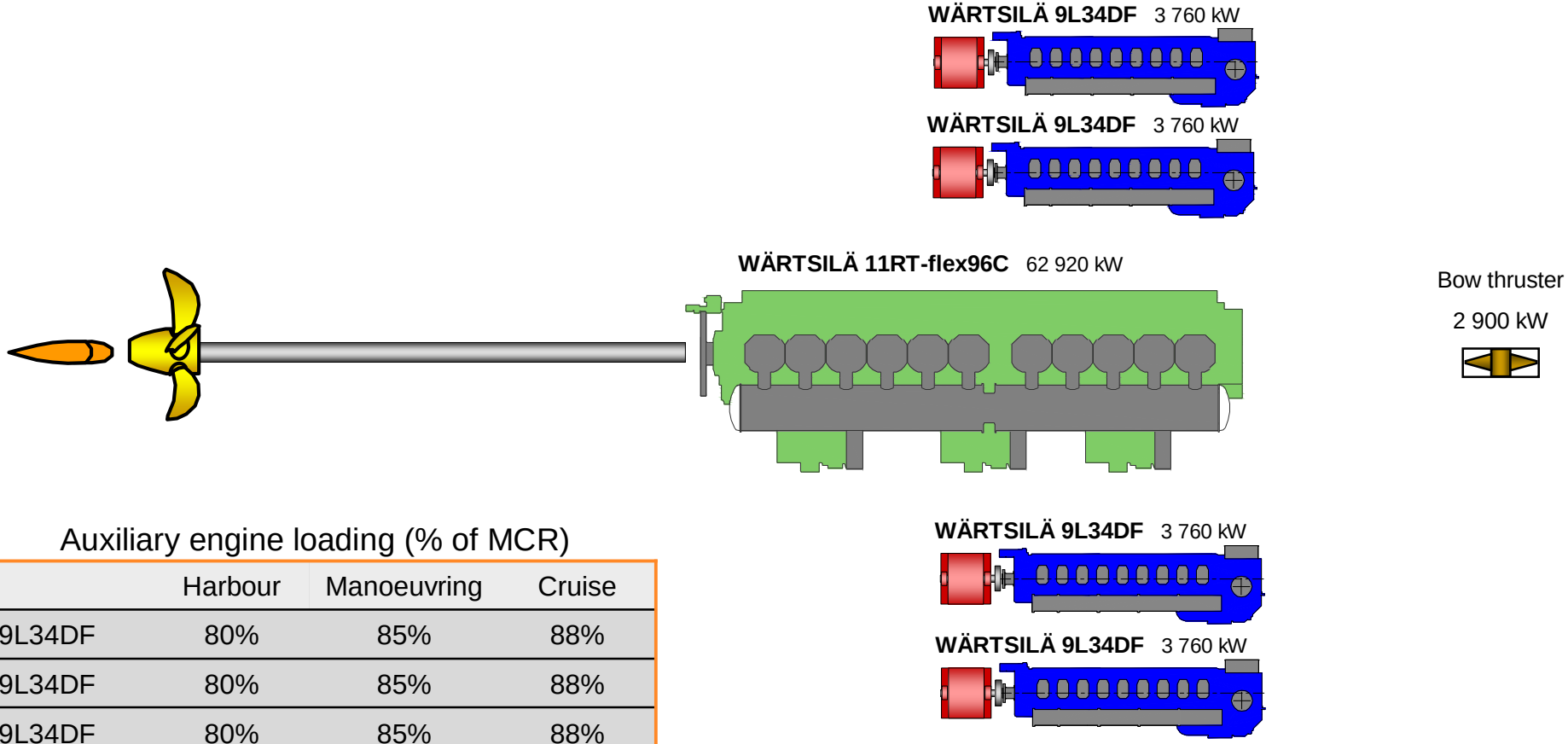


Auxiliary engine loading (% of MCR)

	Harbour	Manoeuvring	Cruise
6L32	78%	88%	86%
6L32	-	88%	-
9L32	78%	88%	86%
9L32	78%	88%	86%

Installed auxiliary power: 14 400 kW

Machinery – DF

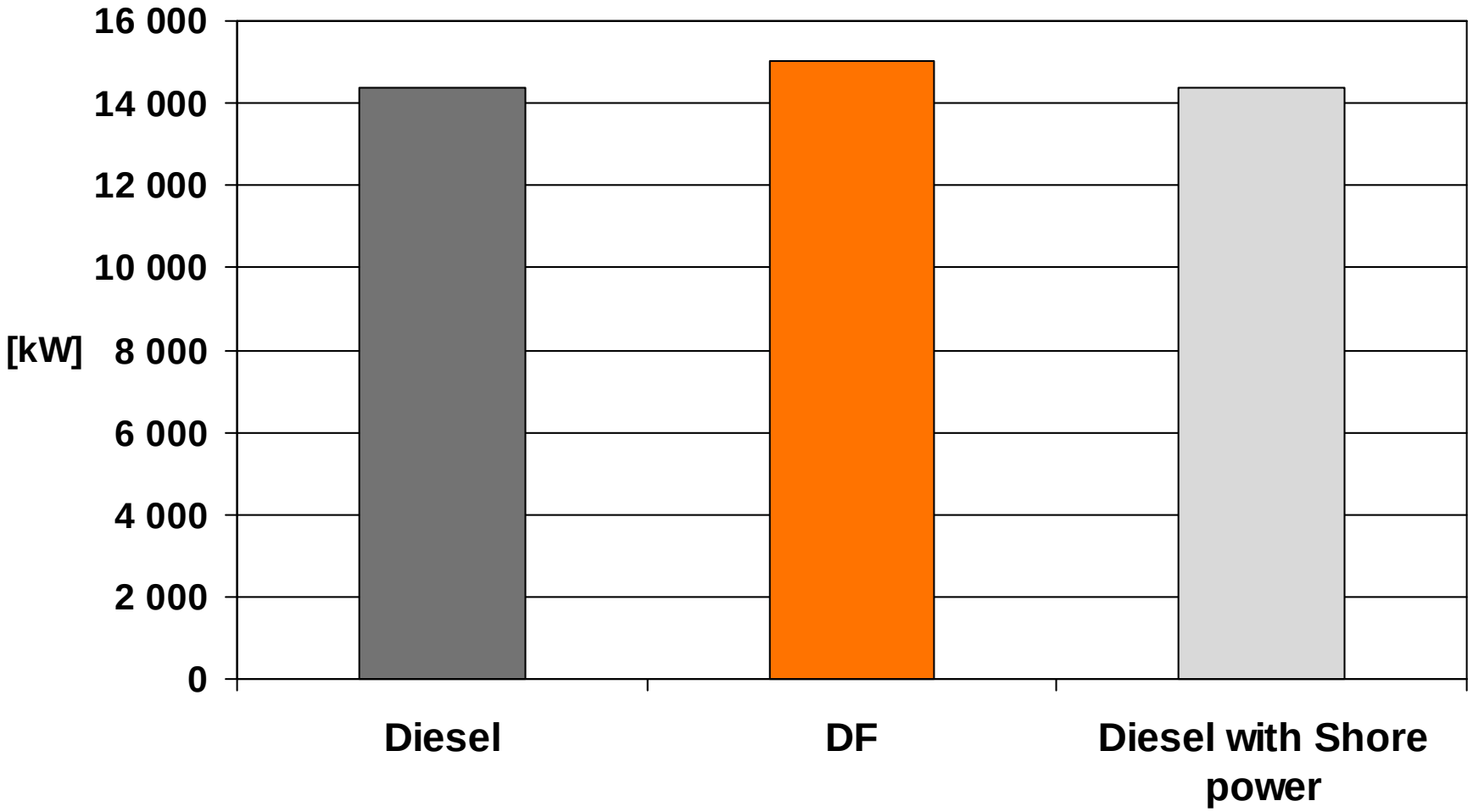


Auxiliary engine loading (% of MCR)

	Harbour	Manoeuvring	Cruise
9L34DF	80%	85%	88%
9L34DF	80%	85%	88%
9L34DF	80%	85%	88%
9L34DF	-	85%	-

Installed auxiliary power: 15 040 kW

Installed Auxiliary engine power



Operation route

Los Angeles – Oakland – Dalian – Busan – Nagoya – Yokohama – Los Angeles

WÄRTSILÄ

Operating in US west coast

24 NM zone:
- clean fuel* is to be used in aux engines

* Sulphur content < 0.5%, after 2010 < 0.1%

WÄRTSILÄ

LNG consumption according to op. profile

OP MODE	LNG consumption ton/h	Running hours per roundtrip hours	Consumption per roundtrip tons
Loading & Unloading	1.5	138	207.0
Manoeuvring	2.1	6	12.6
Slow with clean*	1.6	10	16.0
			236

↓

523 m^3

* Only in US West Coast (2 port calls)

2 x 190 m3 fixed tanks → 380 m3 → bunkering 2 (1.4) times per roundtrip

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LNG consumption – only in US west coast

OP MODE	LNG consumption ton/h	Port calls Los Angeles and Oakland hours	tons
Loading & Unloading	1.5	58	87.0
Manoeuvring	2.1	2	4.2
Slow with clean	1.6	10	16.0
			108

↓

240 m^3

40ft LNG containers

www.gas-logistics.no

a' 31.5 m^3 → 8 units

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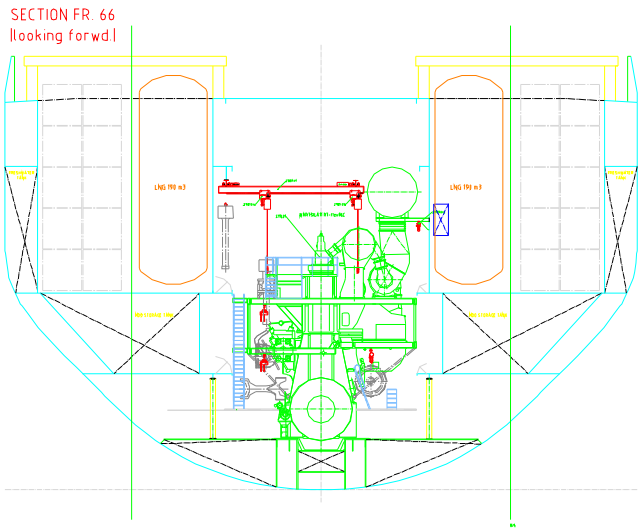
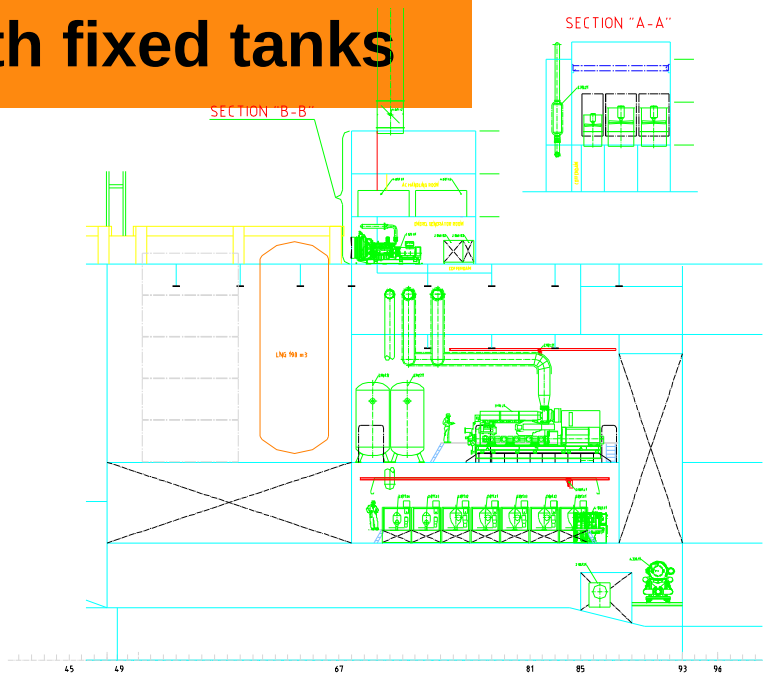
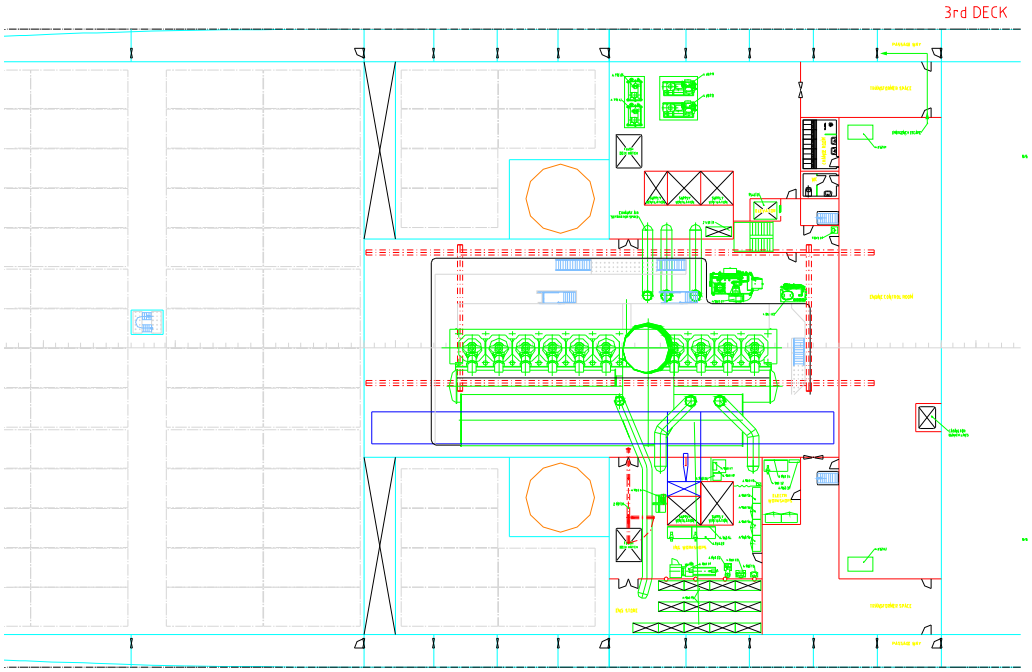
LNG tank arrangement with fixed tanks







- 2 x 190 m³ vertical tanks
- Total capacity: 380 m³
- Cargo capacity: - 20 TEU

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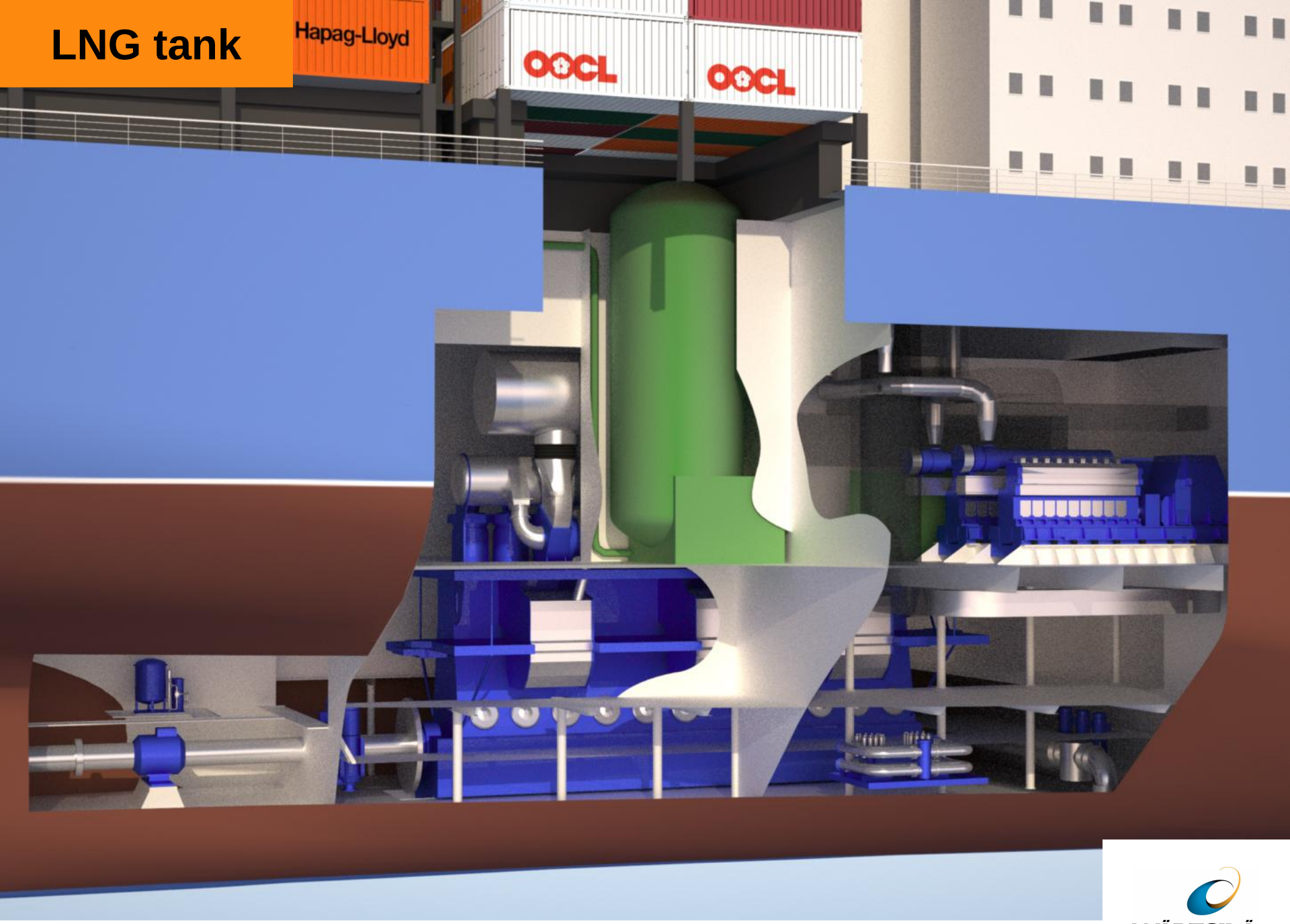
LNG tank

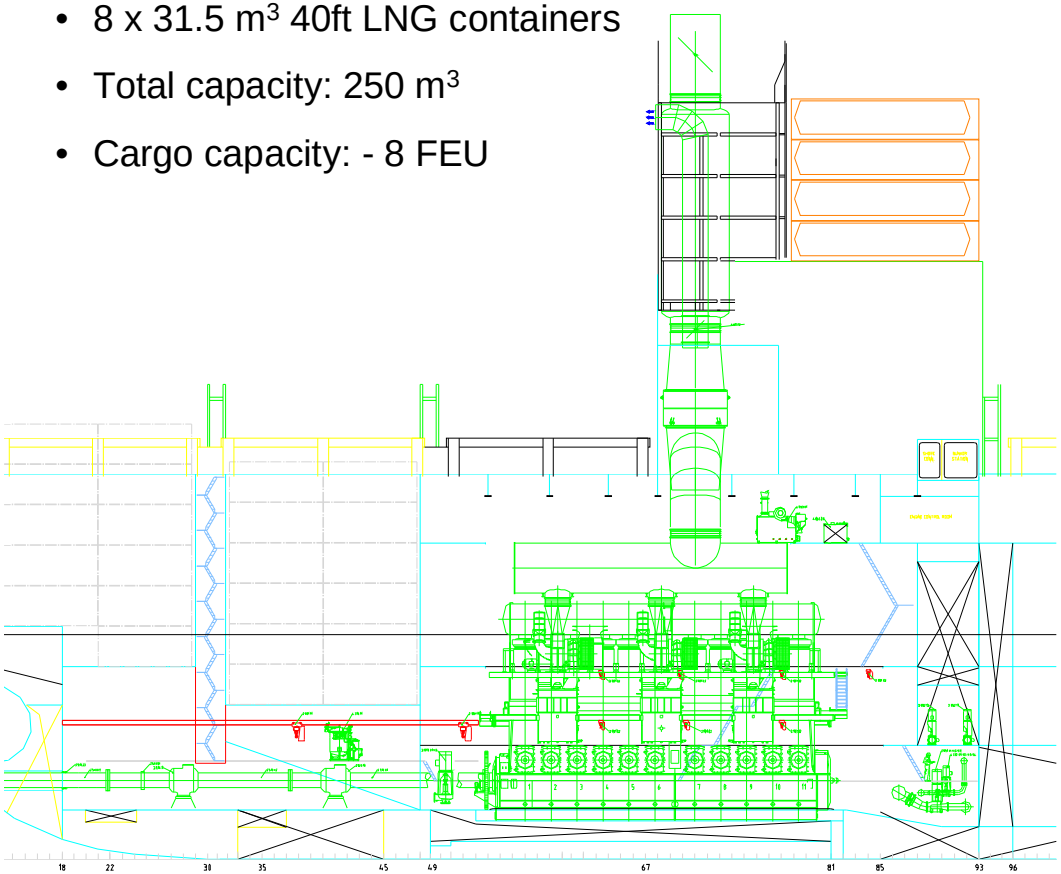


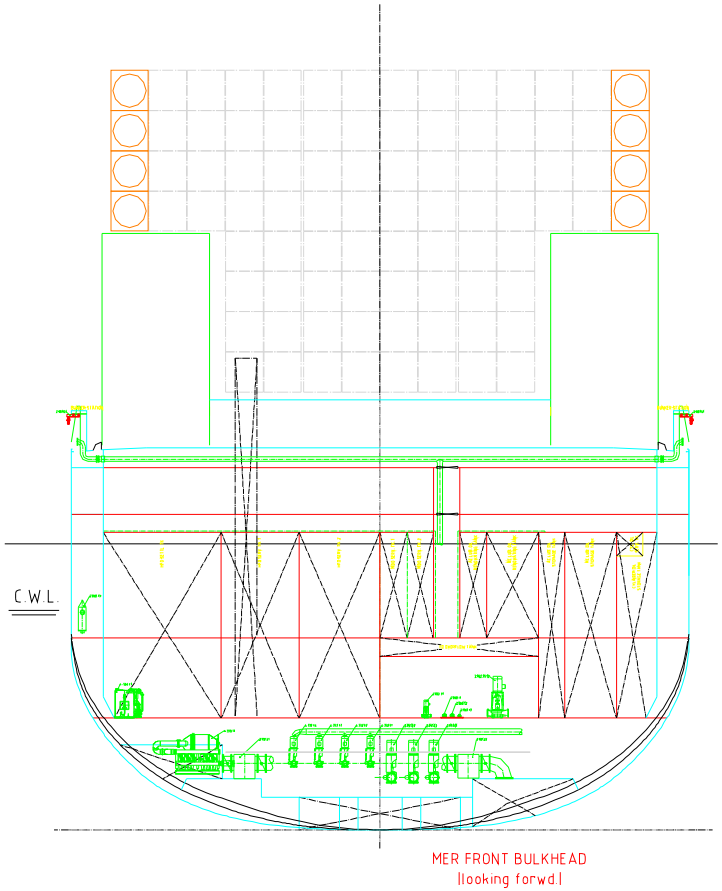
LNG tank

WÄRTSILÄ

Tank arrangement with containers

- 8 x 31.5 m^3 40ft LNG containers
- Total capacity: 250 m^3
- Cargo capacity: - 8 FEU

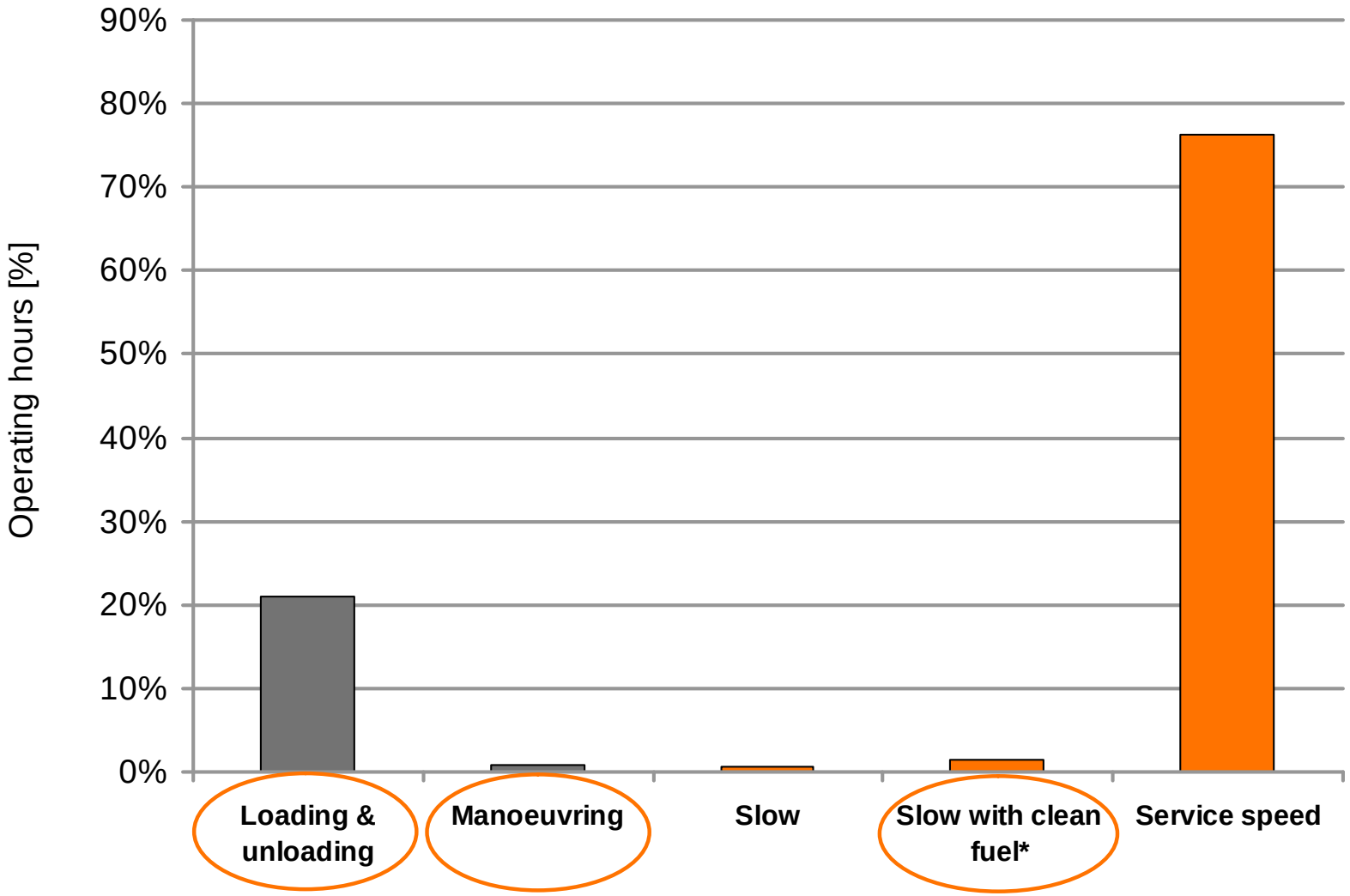




Fuel prices

	USD/ton	EUR/ton	USD/MBtu
HFO	350	259	9.1
MDO	600	444	14.8
MGO	700	519	17.3
LNG	336	249	7.2

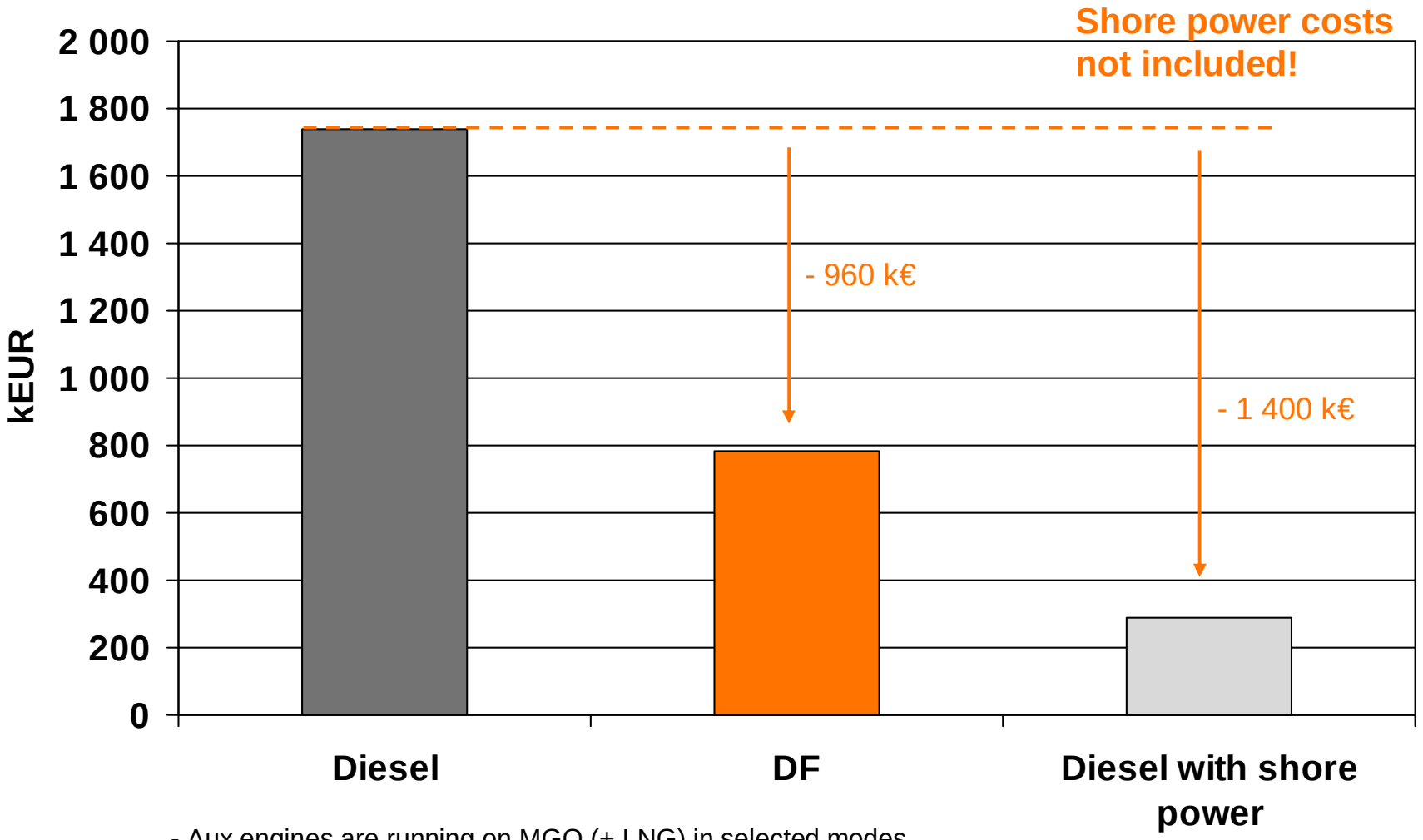
Operating profile



Clean fuel is to be used in aux engines in these modes

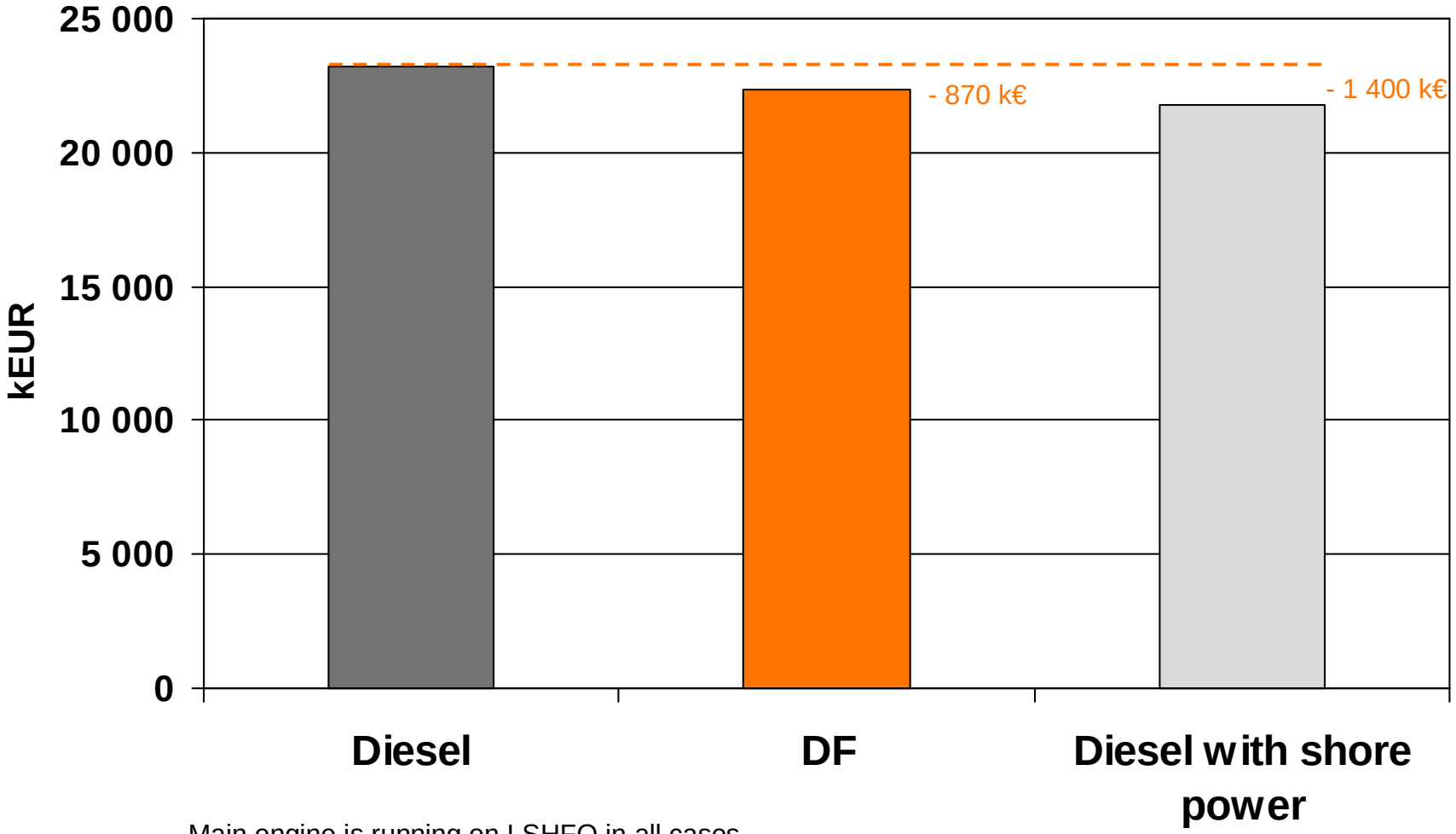
* Closer than 24NM from coastline, US west coast only

Annual fuel cost of aux engines in selected modes



- Aux engines are running on MGO (+ LNG) in selected modes

Total annual fuel cost (ME +AE)



- Main engine is running on LSHFO in all cases
- Aux engines are running on MGO (+ LNG) in selected modes
- Aux engines are running on HFO at sea

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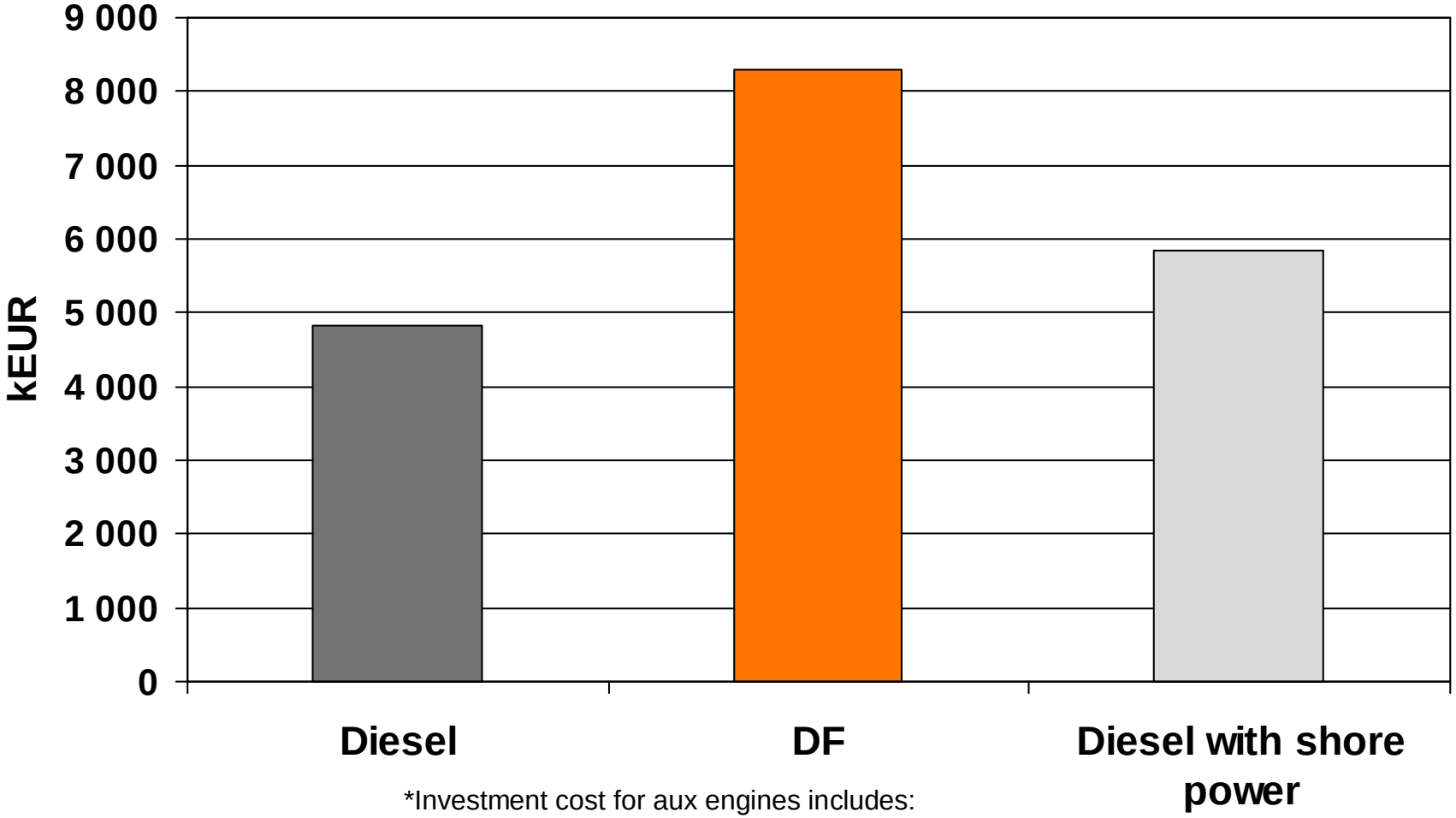
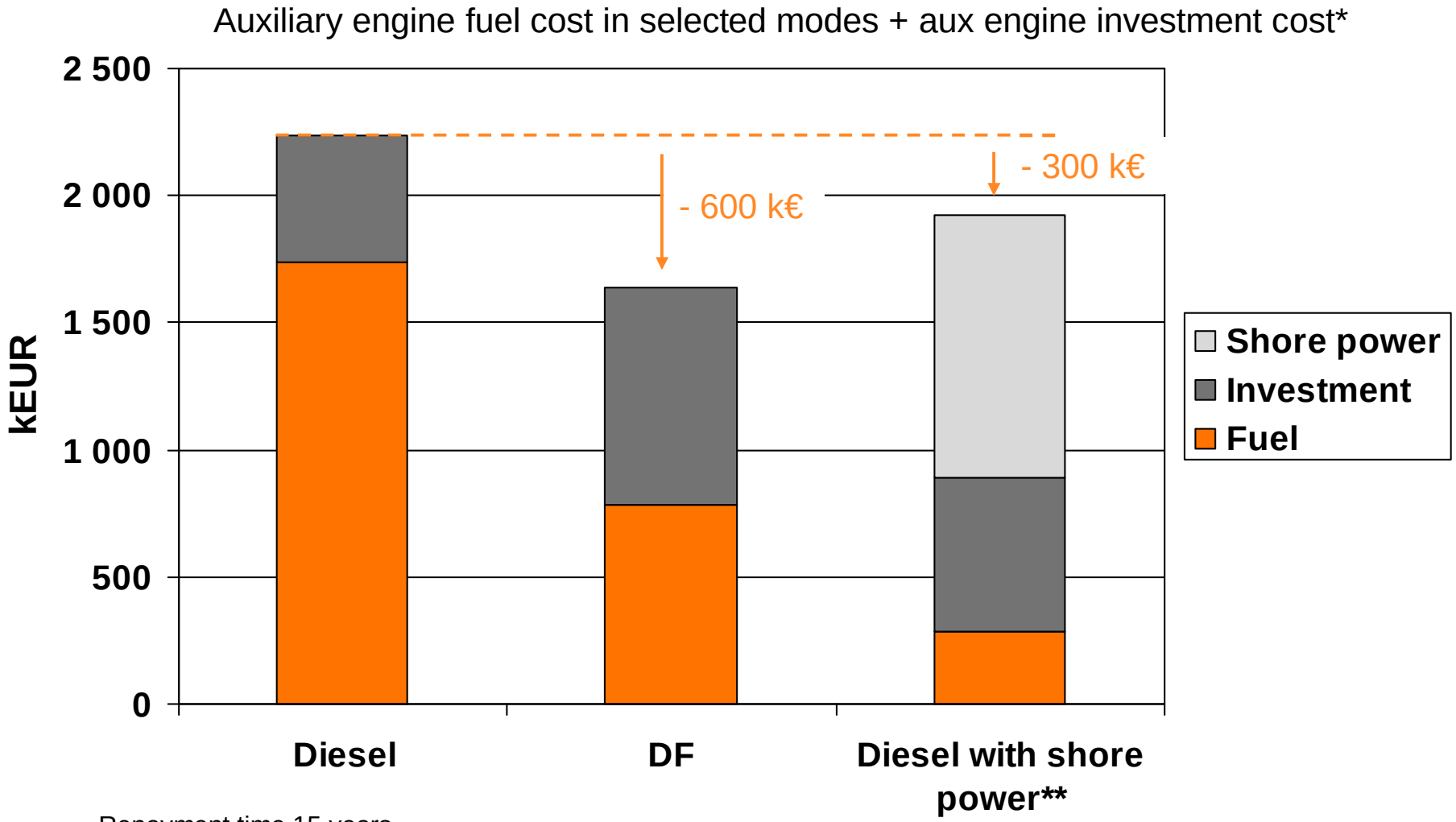
Auxiliary engines investment cost*



*Investment cost for aux engines includes:

- Engines + Generators
- LNG system
- Shore power connection

Annual cost in selected modes



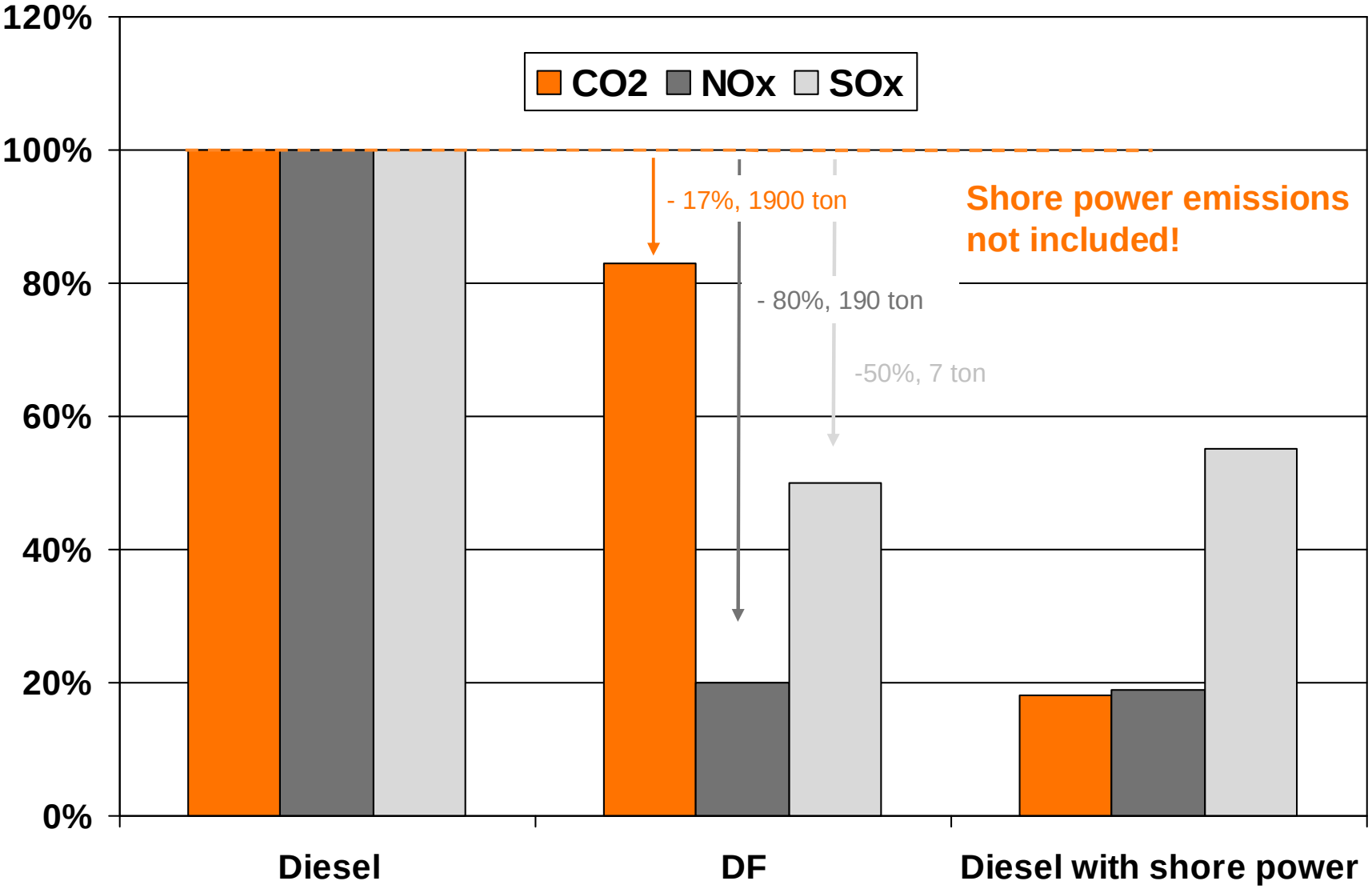
Repayment time 15 years
Interest rate 6%

*Investment cost for aux engines includes:

- Engines + Generators
- LNG system
- Shore power connection

** Shore power 0.09 USD / kWh

Exhaust emissions – selected modes



Includes Aux and Main engine emissions in selected modes (ME: LSHFO, AE: MGO)

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Summary

- LNG is a economical solution for generating auxiliary power in port conditions
- DF concept is not dependent on port facilities
- The emissions are significantly lower compared to use of MGO
- The higher investment cost of LNG system + DF engines is paid back in 4 years

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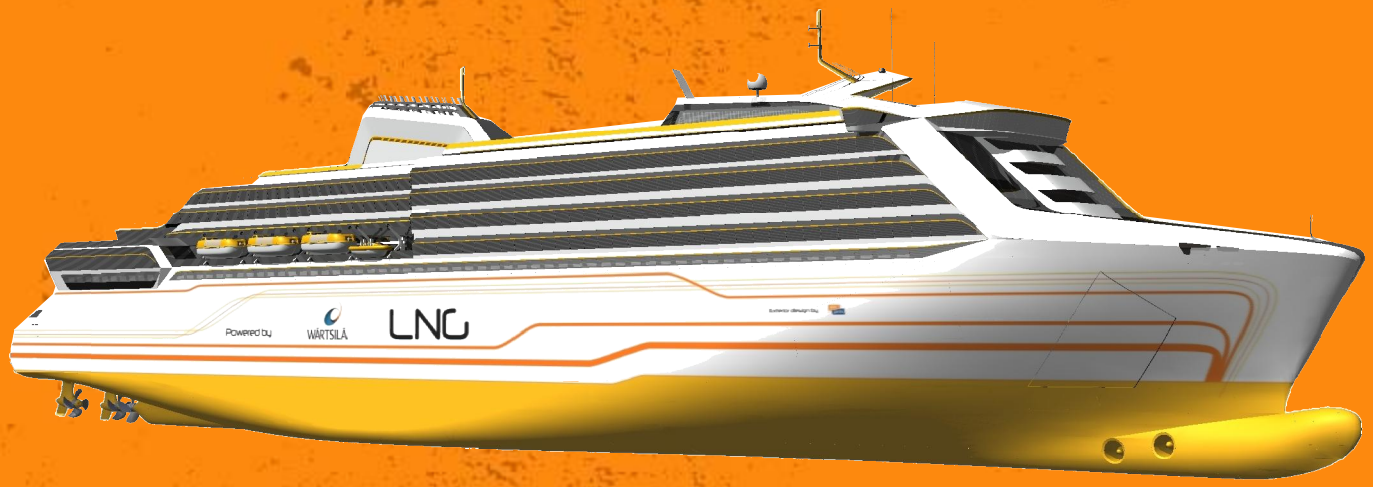

Turning the page in ship propulsion

Example: The Next Generation Ferry

Ferry vision

- Design target
  - High efficiency
    - Novel propulsion solutions
    - Large cargo capacity – economy of scale
    - Fast turnaround in port
      - Efficient cargo handling
      - Excellent manoeuvring
  - Environmentally sound
  - New amenities for demanding passengers

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Main particulars

– Gross tonnage	65 000	GT
– Length over all	225	m
– Length, bp	210	m
– Breadth	34	m
– Draught, design	7	m
– Deadweight	8 500	tons
– Service speed	23	knots
– Beds	1 800	pcs
– Pax cabins	600	pcs
– Lane meters	3 250	m

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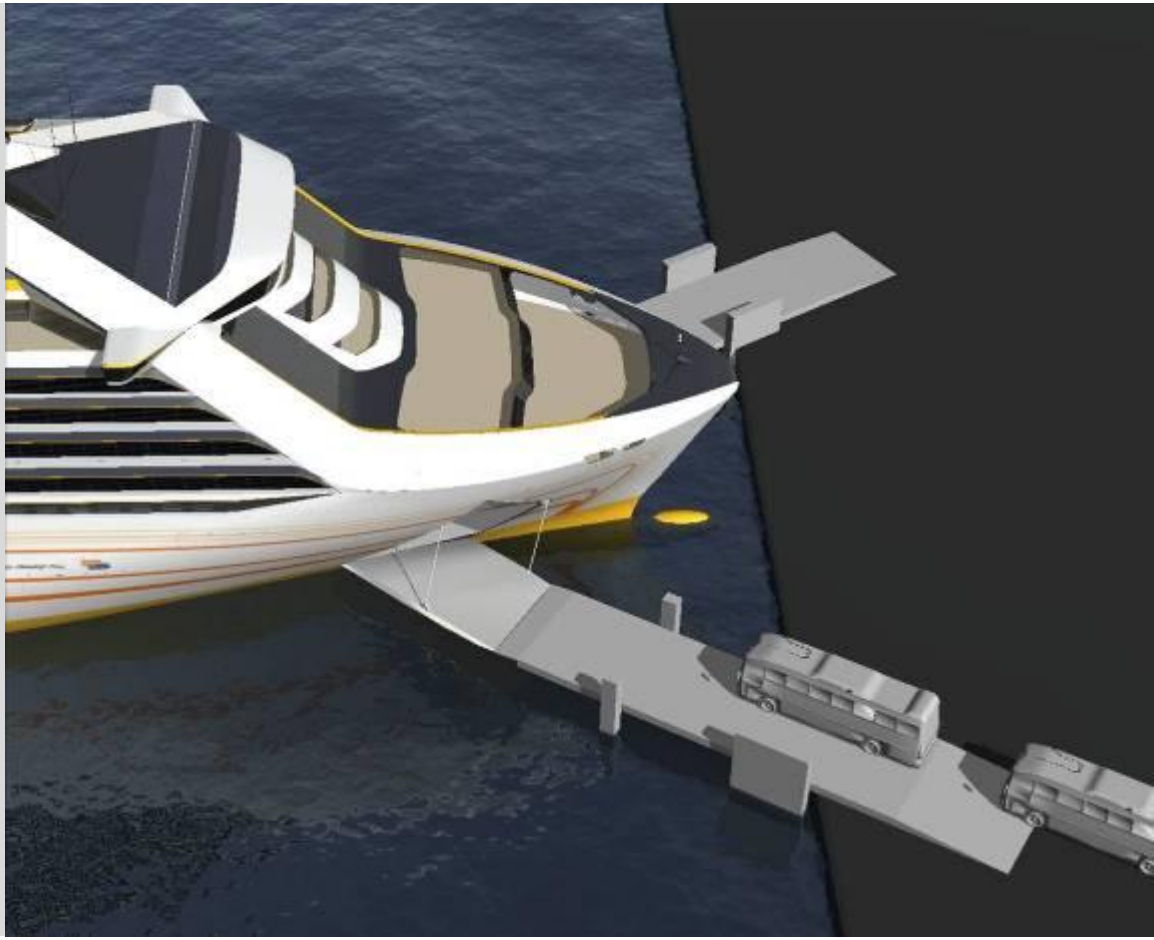
Efficient cargo handling

- Large cargo capacity
- Two extra wide cargo decks
  - 10 lanes
  - No lower cargo hold
- No lower hold
- Two level loading from twin level link spans in port
- Drive trough loading
- New bow door arrangement

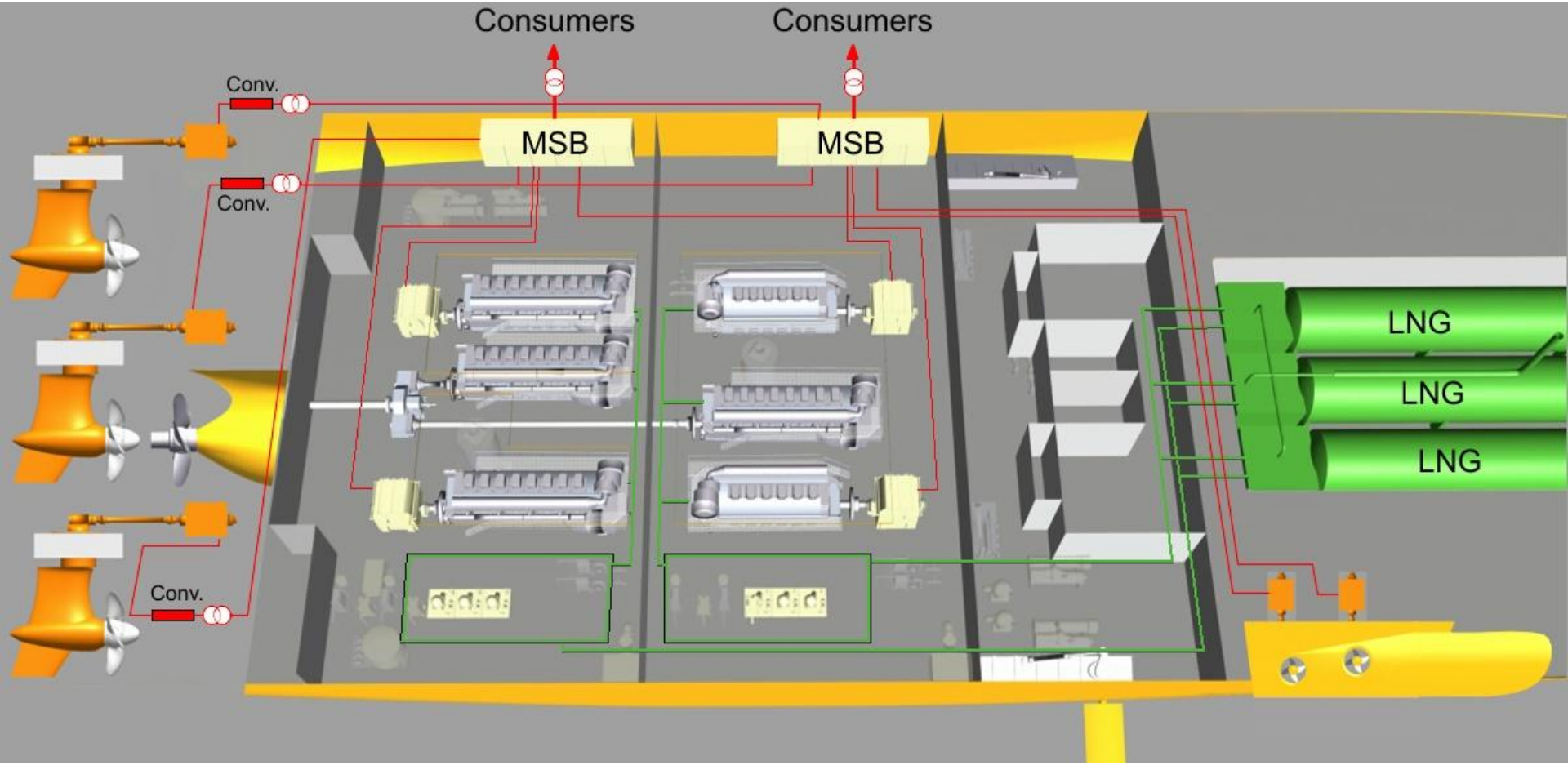


Passenger facilities

New amenities for demanding passengers

- Indoor two level street - city atmosphere
- Coffee shops, ice cream stands, news and internet cafes
- Outlet shopping malls

Machinery



Propulsion:		
3 x pulling thrusters	3 x 5 500	kW
CPP, centre shaft lines	15 200	kW
TOTAL	**31 700**	**kW**

Engine power:		
2 x 8L50DF genset	2 x 7 600	kW
2 x 6L50DF genset	2 x 5 700	kW
2 x 8L50DF mechanical	2 x 7 600	kW
TOTAL	**41 800**	**kW**

Bow thrusters:		
2 x Bow thrusters	2 x 2 500	kW
TOTAL	**5 000**	**kW**

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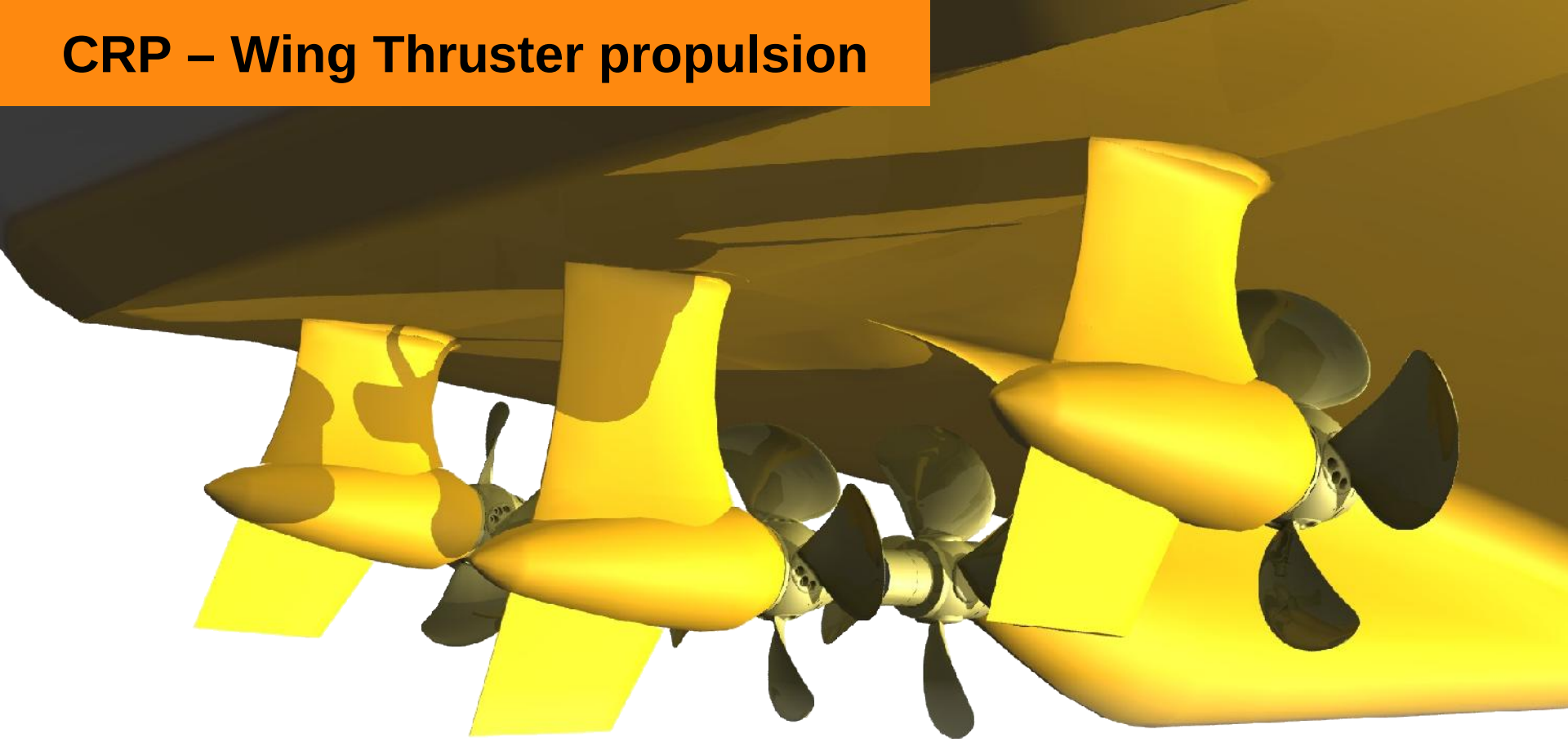
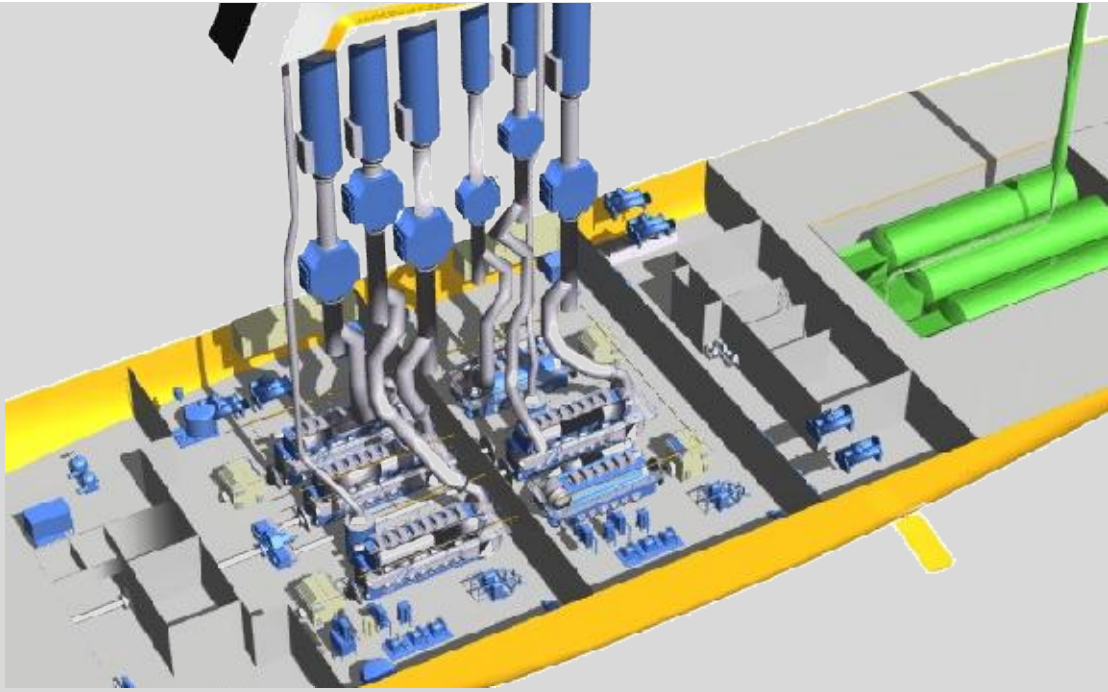
CRP – Wing Thruster propulsion



Combined CRP and Wing Thruster propulsion

- High efficiency
- Excellent manoeuvring
- Possibility to use low power thrusters (reliability)
- Redundancy

Machinery design



- Environmentally sound
  - LNG
- Best efficiency
  - CRP + Wing Thrusters
  - LNG
- Excellent manoeuvring
  - Three steerable thrusters
- Ultimate flexibility
  - **CODFEM** – Combined Dual Fuel Electric and Mechanical machinery
  - Electric operation at low speeds – good efficiency at part load
  - Mechanical booster – low transmission losses

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The Future Ferry

THE NEXT GENERATION FERRY – AVAILABLE TODAY!

Conclusions

LNG is an attractive fuel for the passenger vessels of the future

- **The emissions can be significantly reduced**
- **The technology needed is available and well proven**
- **Economically promising**

CRUSING ON GAS INTO A CLEANER FUTURE