4 stroke engines and systems for gas powered vessels

Rome 20.01.2011 – The use of LNG as fuel for propulsion on board of merchant ships

P. Baan Wartsila

This is Wärtsilä

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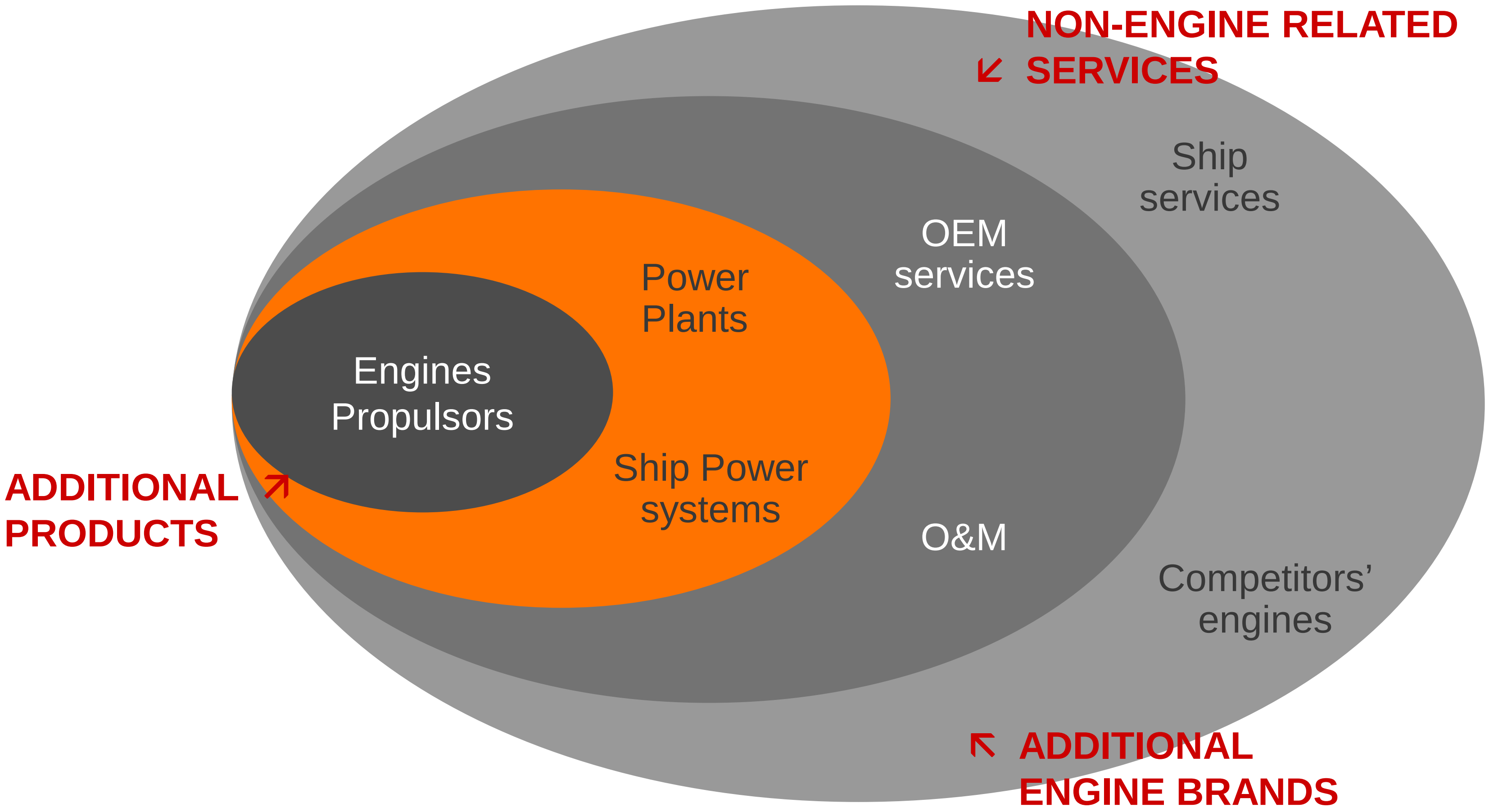
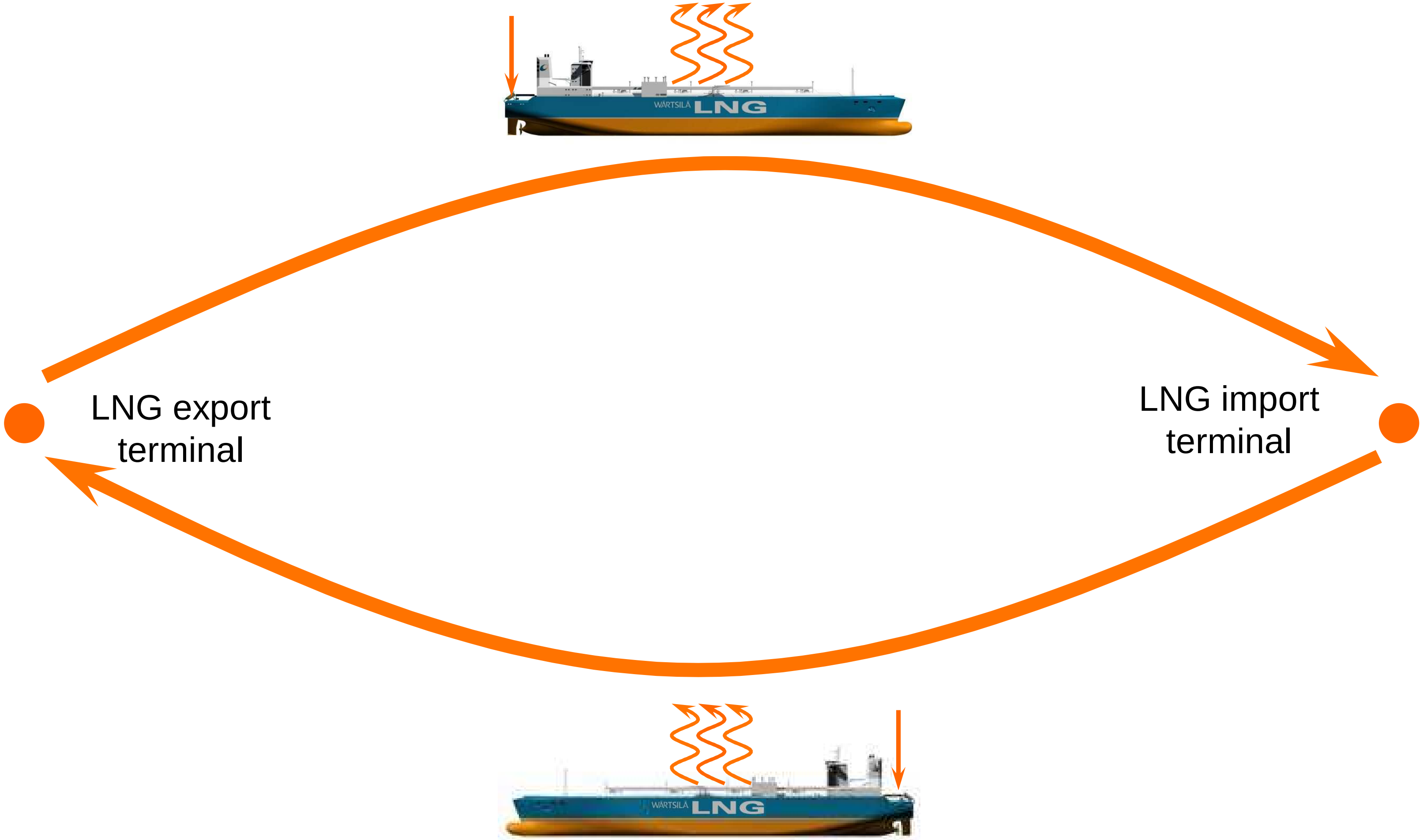
Our offering

… we are seeking growth beyond the organic growth



NG for shipping, the start

Natural Boil-Off Gas (N-BOG), Forced Boil-Off Gas (F-BOG),
Heavy Fuel Oil (HFO) and / or Marine Diesel Oil (MDO)

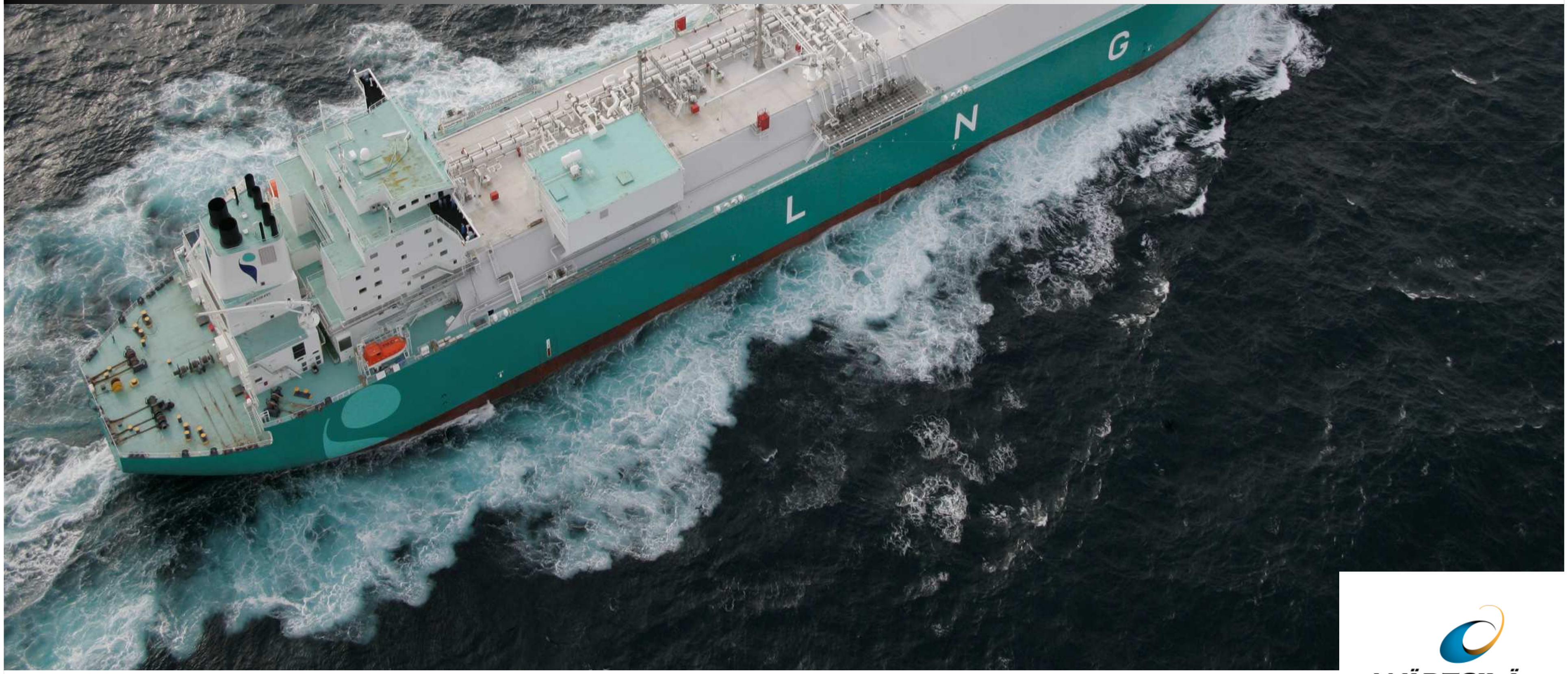


Natural Boil-Off Gas (N-BOG), Forced Boil-Off Gas (F-BOG),
Heavy Fuel Oil (HFO) and / or Marine Diesel Oil (MDO)

The LNG Carrier Segment

Gaz de France – Suez “Provalys”
The first LNG Carrier with Wärtsilä Dual-Fuel engines

Delivered in November 2006
Total running hours cumulated ~ 70’000



Dual-Fuel engines - References

Dual Fuel sold or running

LNG carriers
62 installations
230 engines
> 600’000 running hours

Power plant
28 installations
84 engines
>640 000 running hours

Offshore
7 installations
22 engines
>226 000 running hours

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Environmental challenge

NO_x	SO_x	PM	CO_2
Acid rains Ozone depletion	Acid rains	Harming humans and animals	Greenhouse gas
Tier II (2011) Tier III (2016)	3.5% (2012) ECA 0.1% (2015)	Along with SOx reduction	Under evaluation by IMO → EEDI

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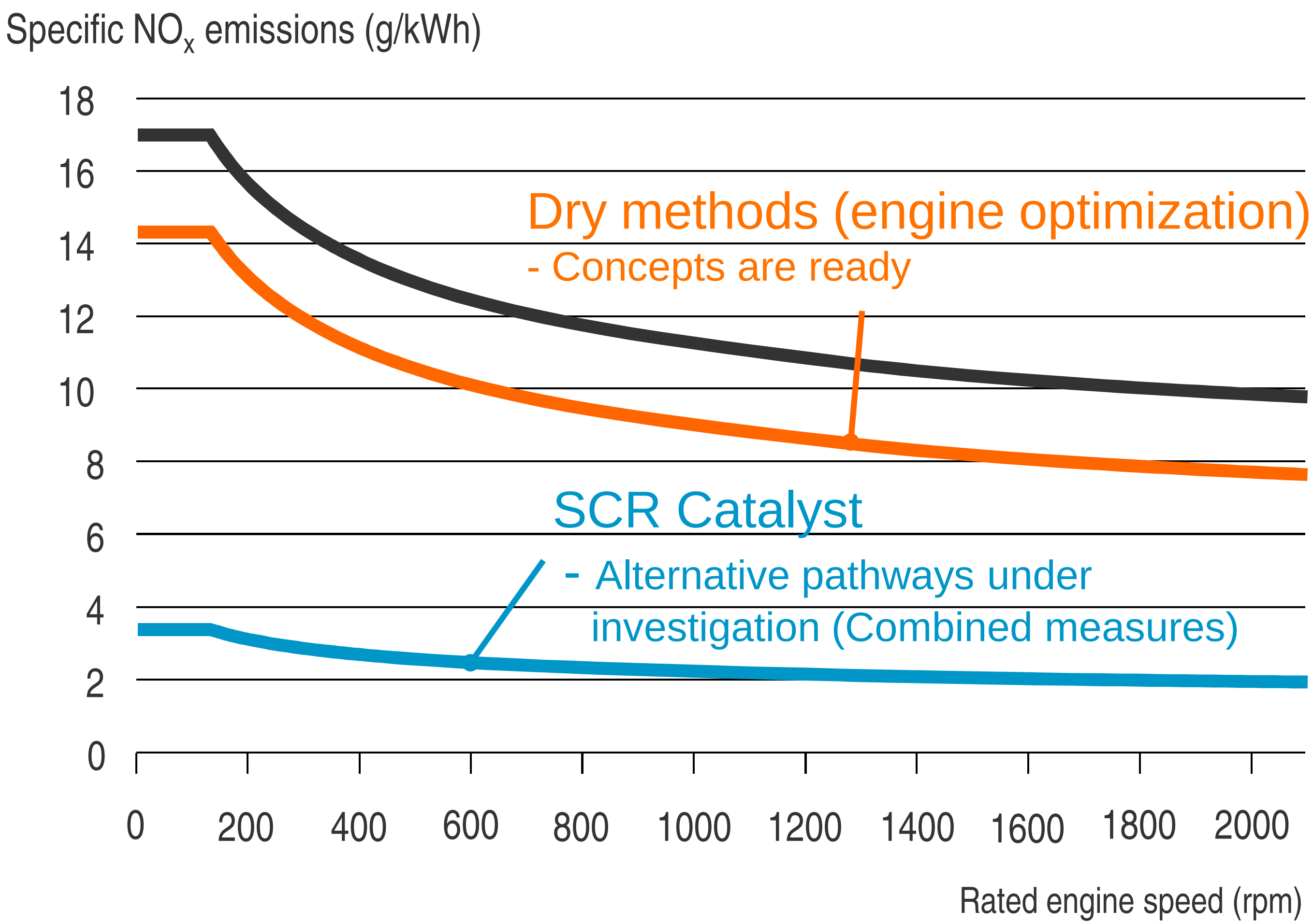
NO_x reduction – IMO requirements and methods



Tier I (present)
Ships built 2000 onwards
Engines > 130 kW
Retrofit: Ships built 1990 – 2000
Engines > 90 litres/cylinder and > 5000 kW
Wärtsilä: RTA, W46, W64

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

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

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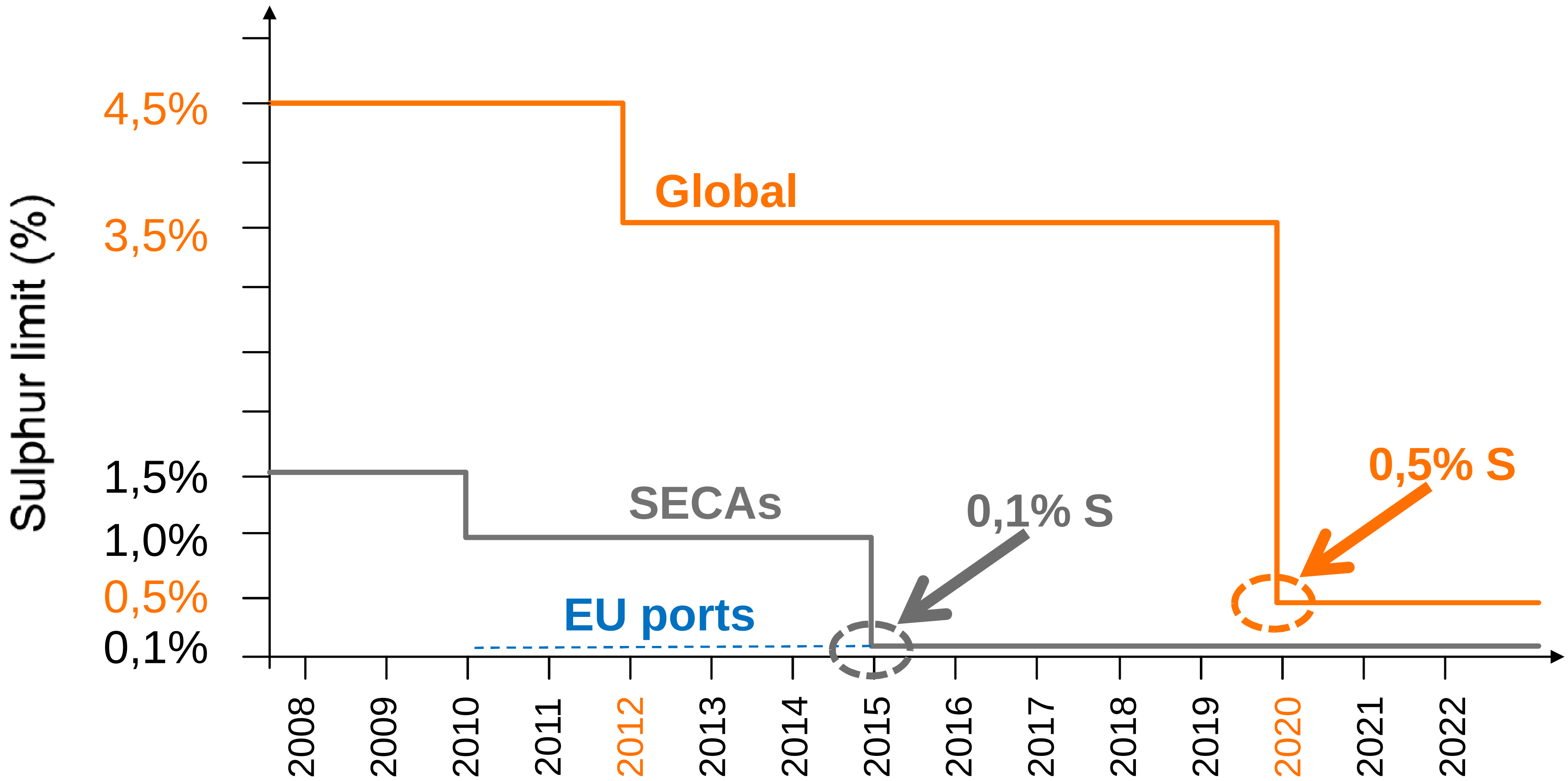
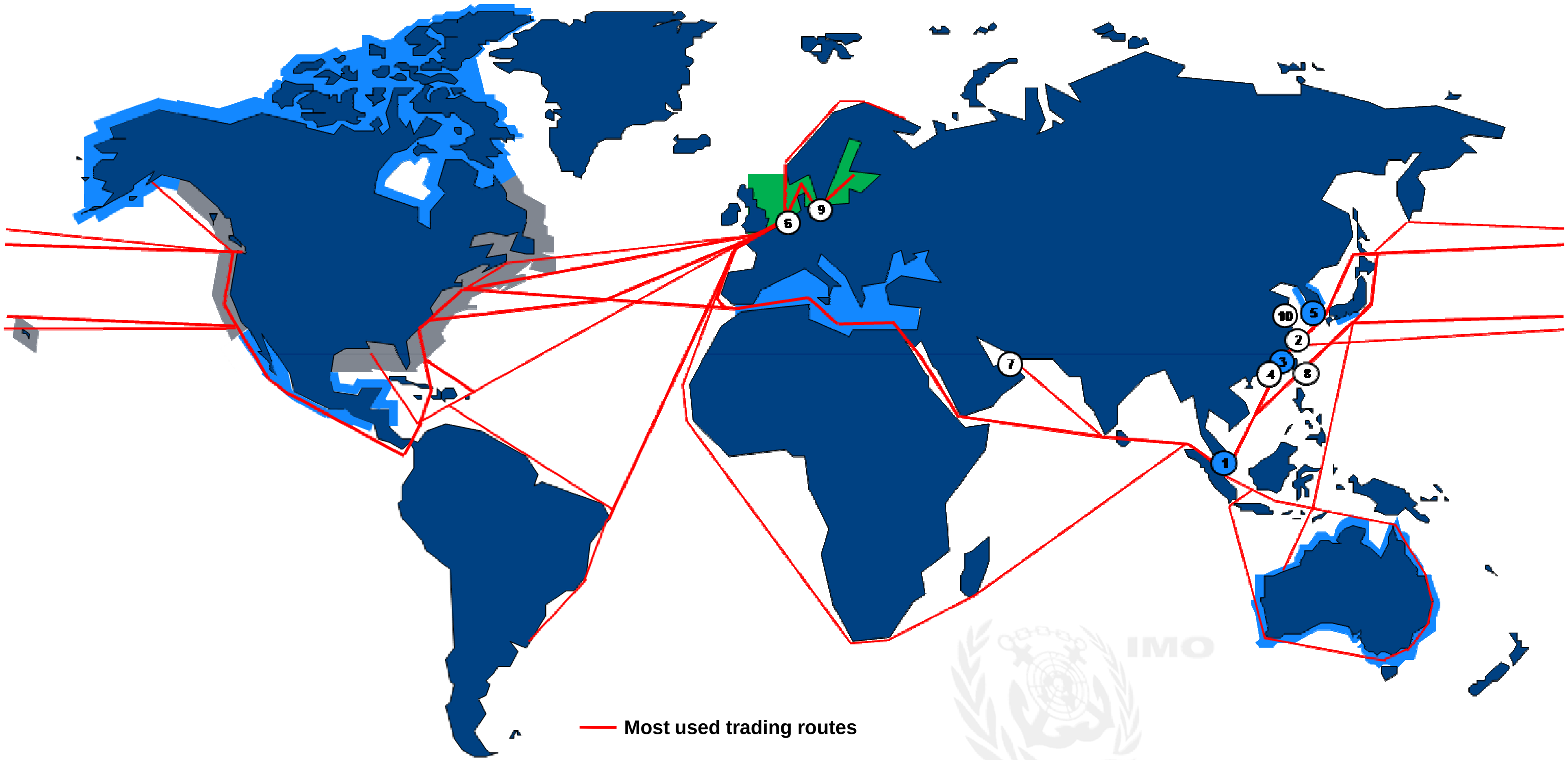
SOx and Particulate reduction - IMO requirements on fuel sulphur content



- **ALL vessels (new buildings and existing fleet) have to meet compliance**
- **SOx scrubbers are allowed as an alternative!**

Emission Control Areas

Proliferation of ECA areas is expected in the next future



existing ECAs: Baltic Sea, North Sea

planned ECAs: Coasts of USA, Hawaii and Canada

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

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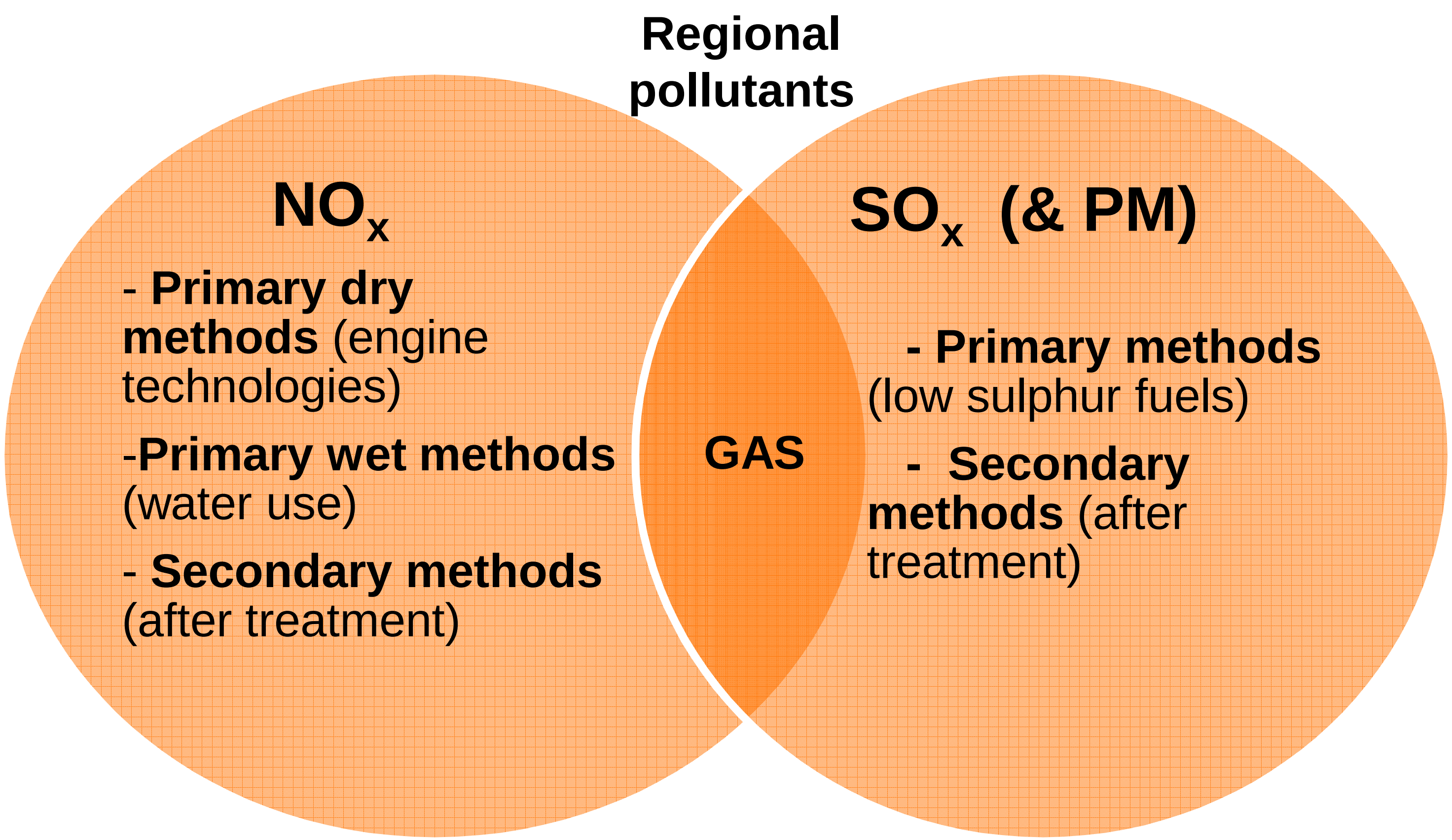
New regulations: how to meet compliance?

Greenhouse gases (GHG) ↔ global warming caused by human activities



Mapping of fuels

Sulphur emission regulations impact the choice of fuel
The choice of fuel is not a simple one!

	HSFO	Distillates (MDO - MGO)	Natural Gas	Biofuels*
+	• **Cost** • Availability	• **Low emissions** • No treatment on board	• **Very low emissions** • High efficiency (LHV) • Low ship operating costs	• **Low SOx and CO2 emissions**
—	• **Requires scrubber in SECA** • Treatment on board	• **Price** • Long term availability • Viscosity issues	• **Availability / logistics** • Space on board	• **Price** • Availability • Not sustainable from food crops

* Includes raw vegetable oils, biodiesel, synthetic fuels (BTL)

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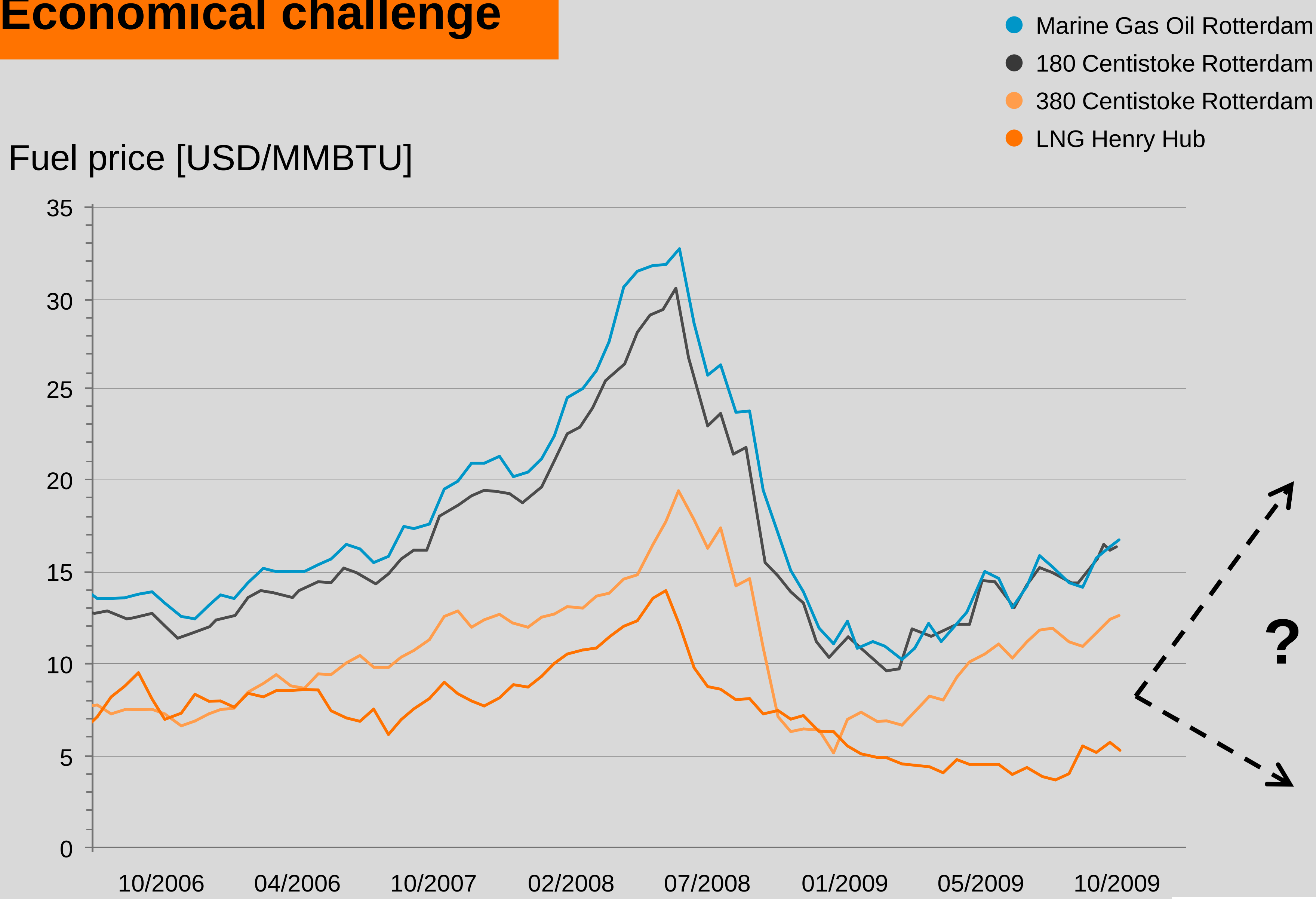
Economical challenge



Source: bunkerworld.com; LNG OneWorld.com

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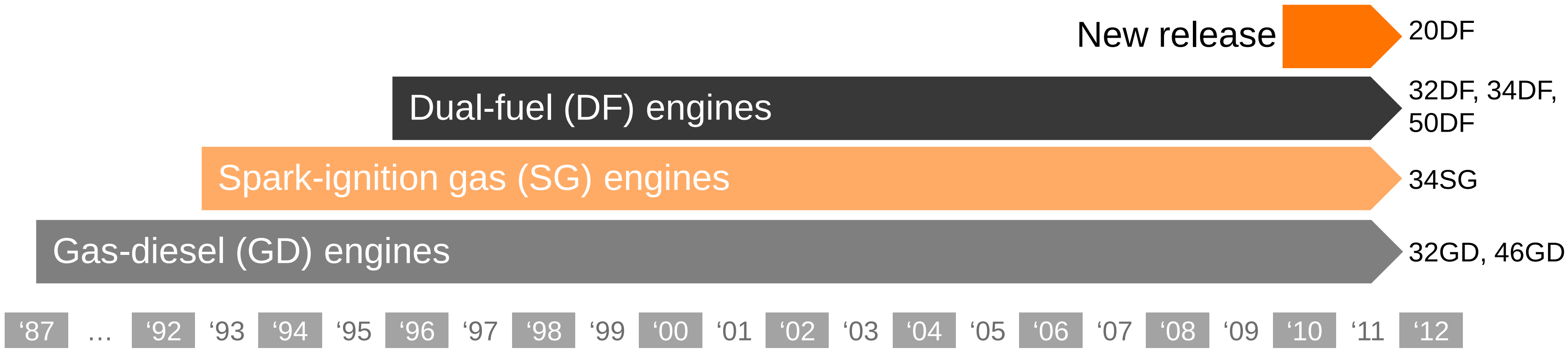
Gas engine technologies experience

Gas-diesel (GD) engines:	Spark-ignition gas (SG) engines:	Dual-fuel (DF) engines:
• Runs on various gas / diesel mixtures or alternatively on diesel.	• Runs only on gas.	• Runs on gas with 1% diesel (gas mode) or alternatively on diesel (diesel mode).
• Combustion of gas, diesel and air mixture in Diesel cycle.	• Combustion of gas and air mixture in Otto cycle, triggered by spark plug ignition.	• 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).
• High-pressure gas injection.	• Low-pressure gas admission.	• Low-pressure gas admission.



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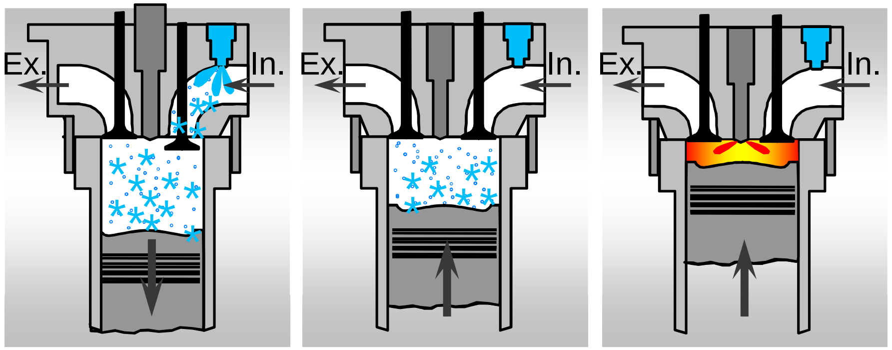
Dual-Fuel advantages

Main advantages of the Dual-Fuel 4-stroke engine compared to SG:

- DF never totally misfires at low engine load thanks to diesel process of the pilot fuel combustion

Gas mode – DF:

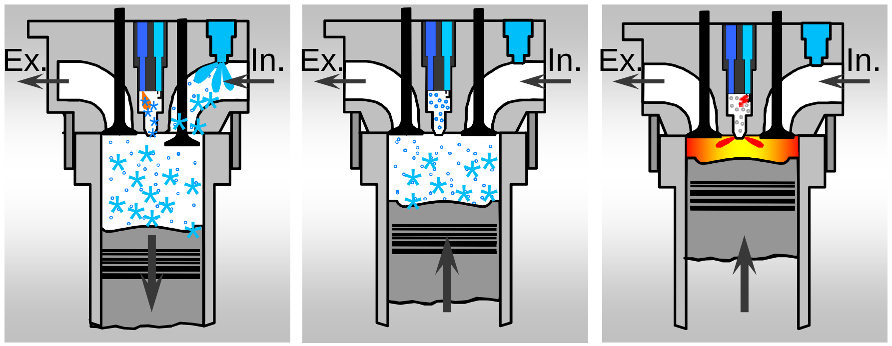
- Otto principle
- Low-pressure gas admission
- Pilot diesel injection



Intake of air and gas | Compression of air and gas | Ignition by pilot diesel fuel

Gas mode – SG:

- Otto principle
- Low-pressure gas admission
- Pilot gas injection to prechamber and ignition by spark plug



Intake of air and gas | Compression of air and gas | Ignition by spark plug

“Pure gas” engine claimed arguments

Main advantages of the spark ignited gas engine (SG) compared to Dual-Fuel 4-stroke engine

- “Clean” Gas engine, i.e. no liquid fuel in the SG engines
  - Liquid however needed onboard for auxiliary/emergency gensets
- Optimized engine performance for certain gas quality/property due to single fuel optimisation

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Dual-Fuel advantages

Main advantages of the Dual-Fuel 4-stroke engine compared to SG:

- Multi-fuel operation capability (HFO, LFO, LNG, LBF)
- Operation capability on liquid fuel outside ECA-area (incl HFO)
- Single gas storage. SG solution would require following for redundancy:
  - Double gas storage and fuel supply systems, independent from each other (class requirement), or
  - PTI/"Take me home" device needed in single main engine "Gas only" application
- Freedom to re-route the vessel
  - Independent of gas bunkering terminals
- A disturbance in gas mode leads to an automatic and instant switch-over to diesel mode without loss of engine power and speed

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Dual-Fuel advantages

Main advantages of the Dual-Fuel 4-stroke engine compared to SG:

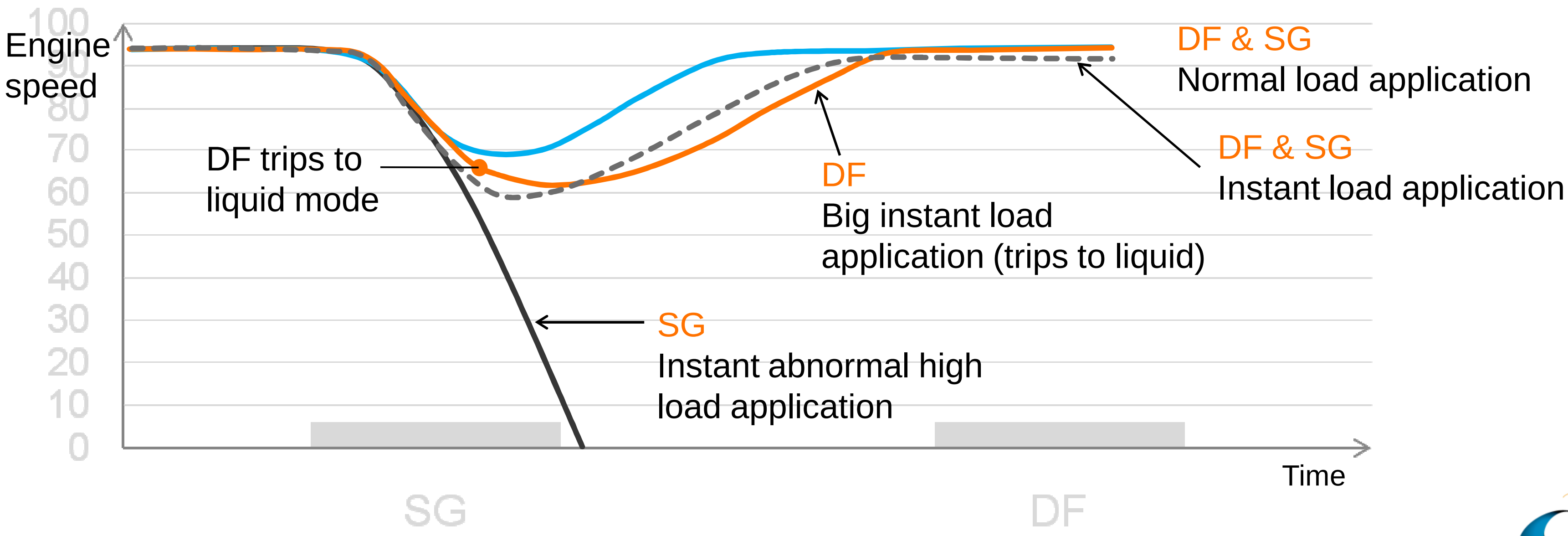
- Freedom to re-route the vessel
  - Independent of gas bunkering terminals
- A disturbance in gas mode leads to an automatic and instant switch-over to diesel mode without loss of engine power and speed
- In case of leakage in a gas supply pipe making shutdown of the gas supply necessary
  - A secondary independent gas fuel supply needed in “gas only” installations
  - Back-up diesel fuel generators required in “gas only” installations

Dual-Fuel advantages

Main advantages of the Dual-Fuel 4-stroke engine compared to SG:

- Simple mechanical propulsion application
  - Full power available in both fuel operation modes
- Load application capability
  - Load application capability is equal between dual-fuel and SG
  - Dual-fuel can trip to liquid in case instant abnormal high load / unload requirement (no shut-down)

→ **Improves safety**



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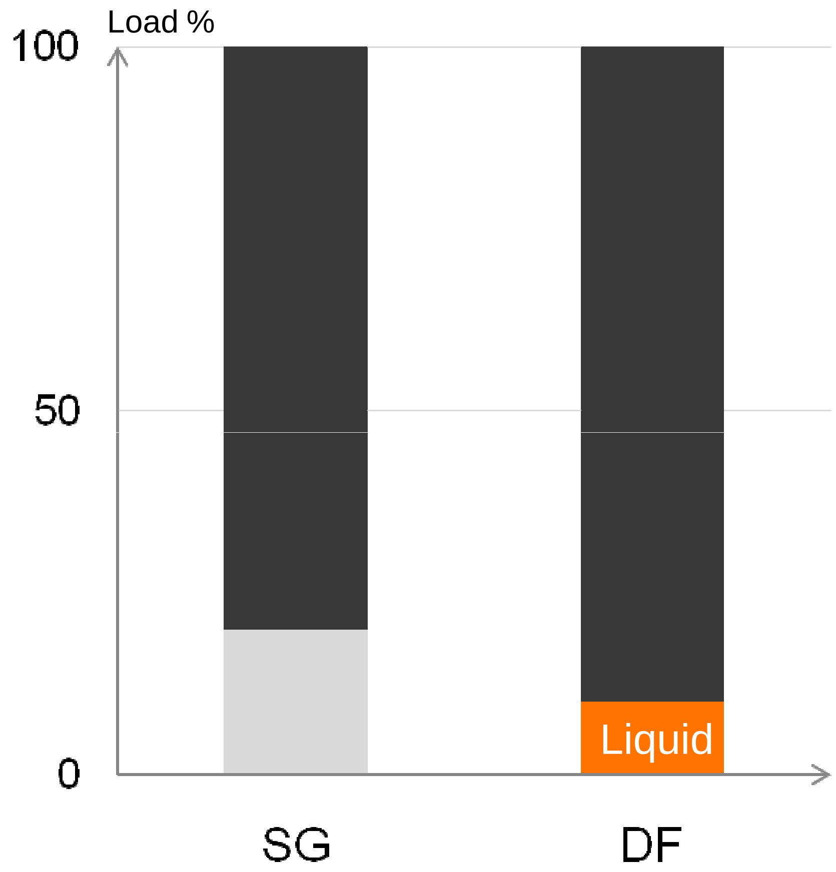
Dual-Fuel advantages

Main advantages of the Dual-Fuel 4-stroke engine compared to SG:

- Same low load / idling limitation as in diesel engine (under validation)
  - Dual-fuel engine is capable running on <10% MCR (2bar BMEP) in gas mode
- No secondary NOx exhaust gas purification needed in gas operation mode



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Dual-Fuel advantages

Main advantages of the Dual-Fuel 4-stroke engine compared to SG:

- Service interval
  - Dual-fuel normal time between overhaul is 6’000hrs (injection nozzle)
  - SG normal time between overhaul is 1’000 - 2’000hrs (spark plugs)

Conclusion technology selection

DUAL-FUEL MACHINERY brings:

Safety

Redundancy

Flexibility

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What is natural gas?

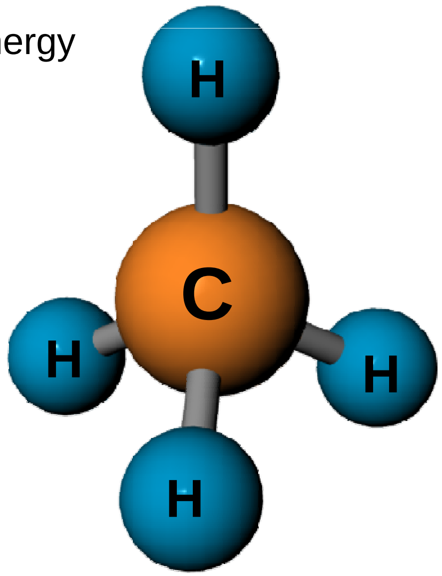
– Natural gas is mostly methane (CH_4)

– Methane contains the highest amount of energy per unit of carbon of any fossil fuel

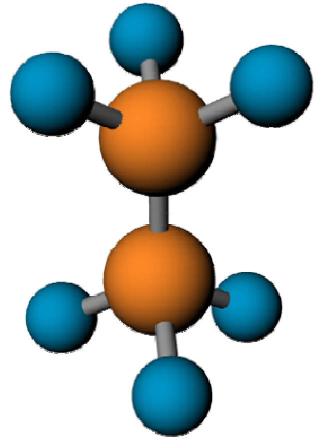
- Carbon to hydrogen ratio 1 / 4 (gasoline: 1 / 2,25)
- Lower CO_2 emissions for same amount of thermal energy

– Natural gas is:

- A very safe fuel
- Non-toxic
- Lighter than air



Methane (CH_4)



Ethane (C_2H_6)

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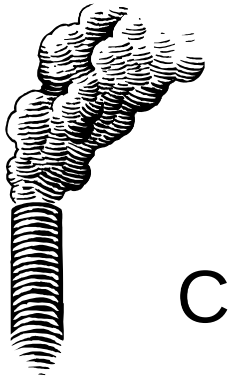
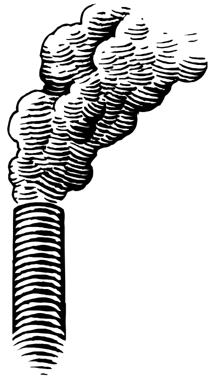
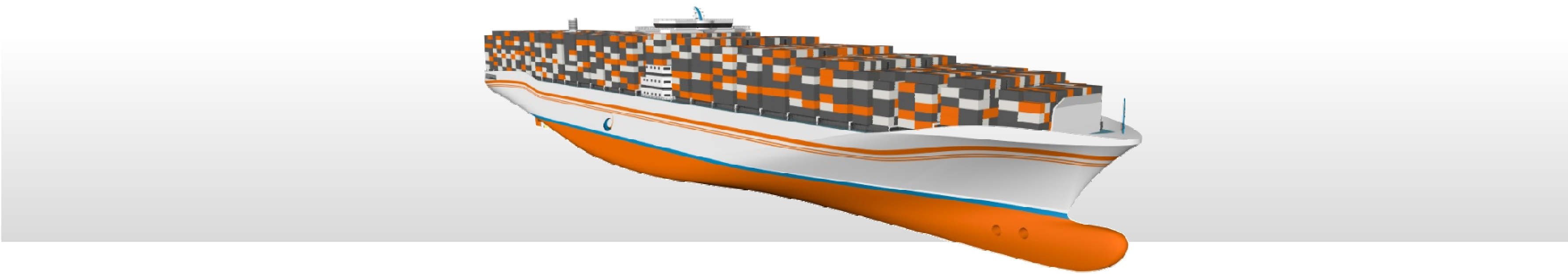
IMO Energy Efficiency Design Index (EEDI)





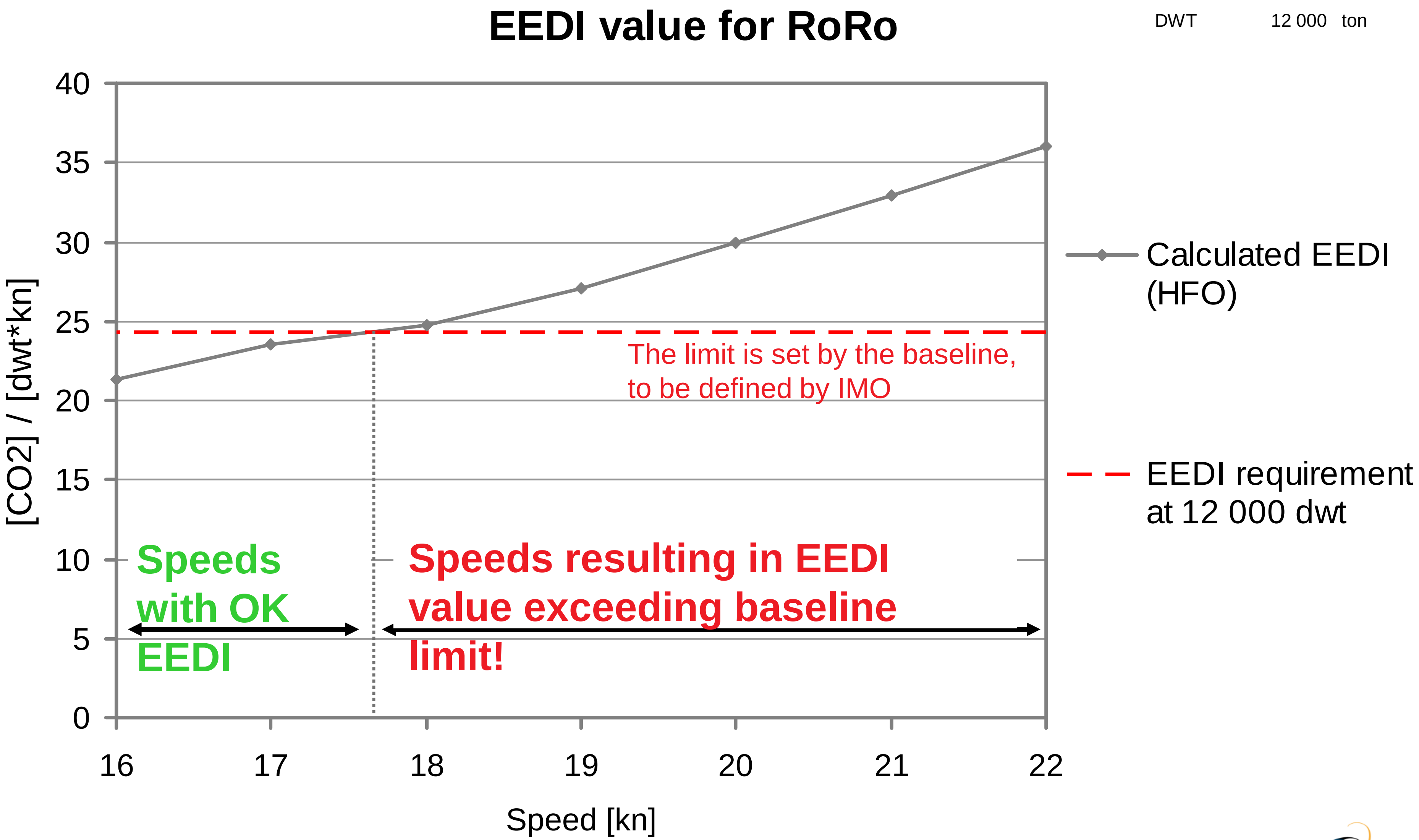
$$\text{EEDI} = \frac{CO_2 \text{ emissions}}{\text{Transport work}}$$



Example: EEDI estimation

Assumptions:

Length, wl	220	m
Beam	33	m
Draft	7.1	m
Displ.	25 000	m^3
DWT	12 000	ton



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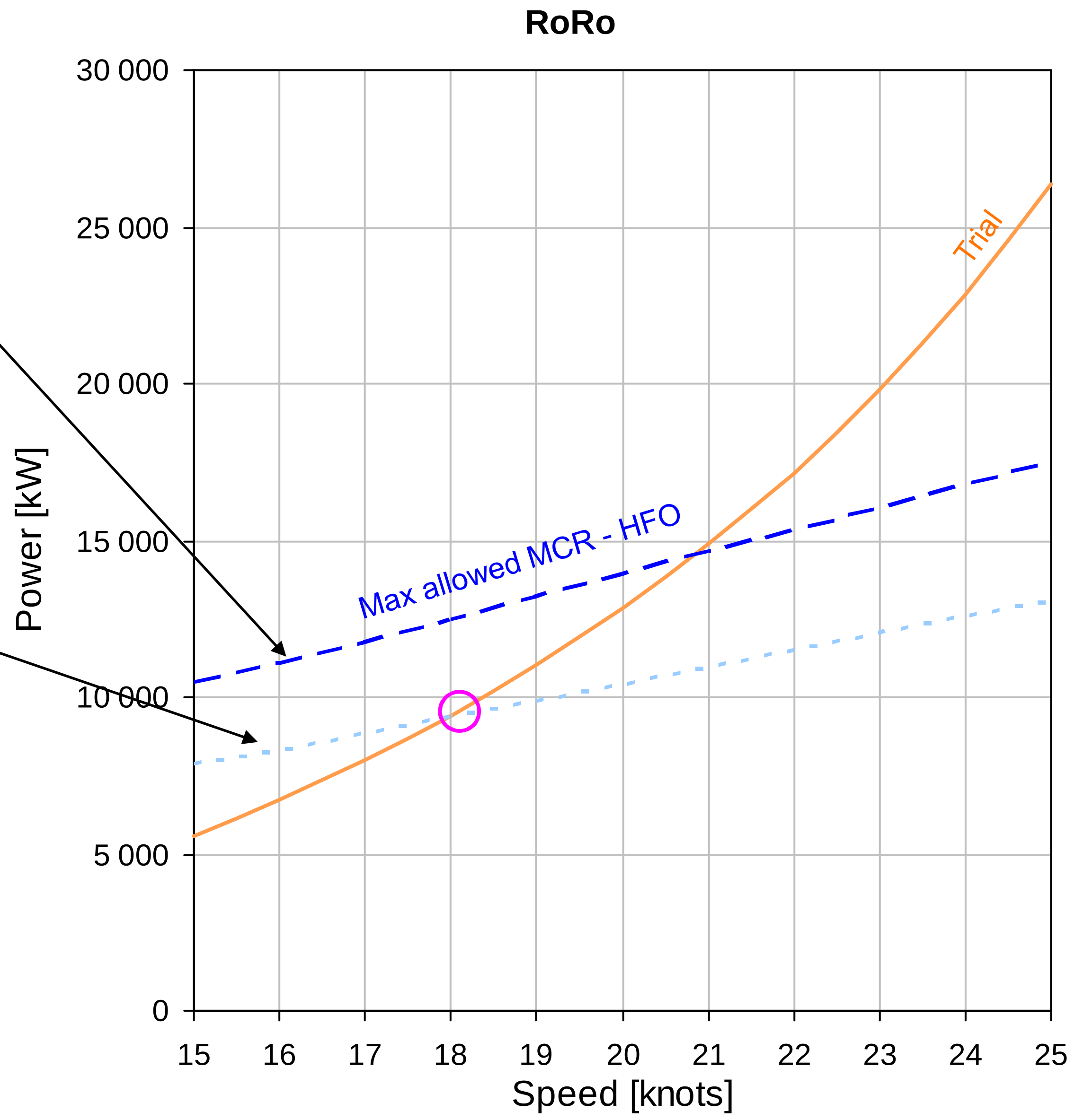
Example: Max allowed power to reach EEDI requirement

HFO: Max allowed MCR_0 to achieve the EEDI limit for each speed (assuming 12 000 dwt capacity)

HFO: 75% of the max allowed MCR_0

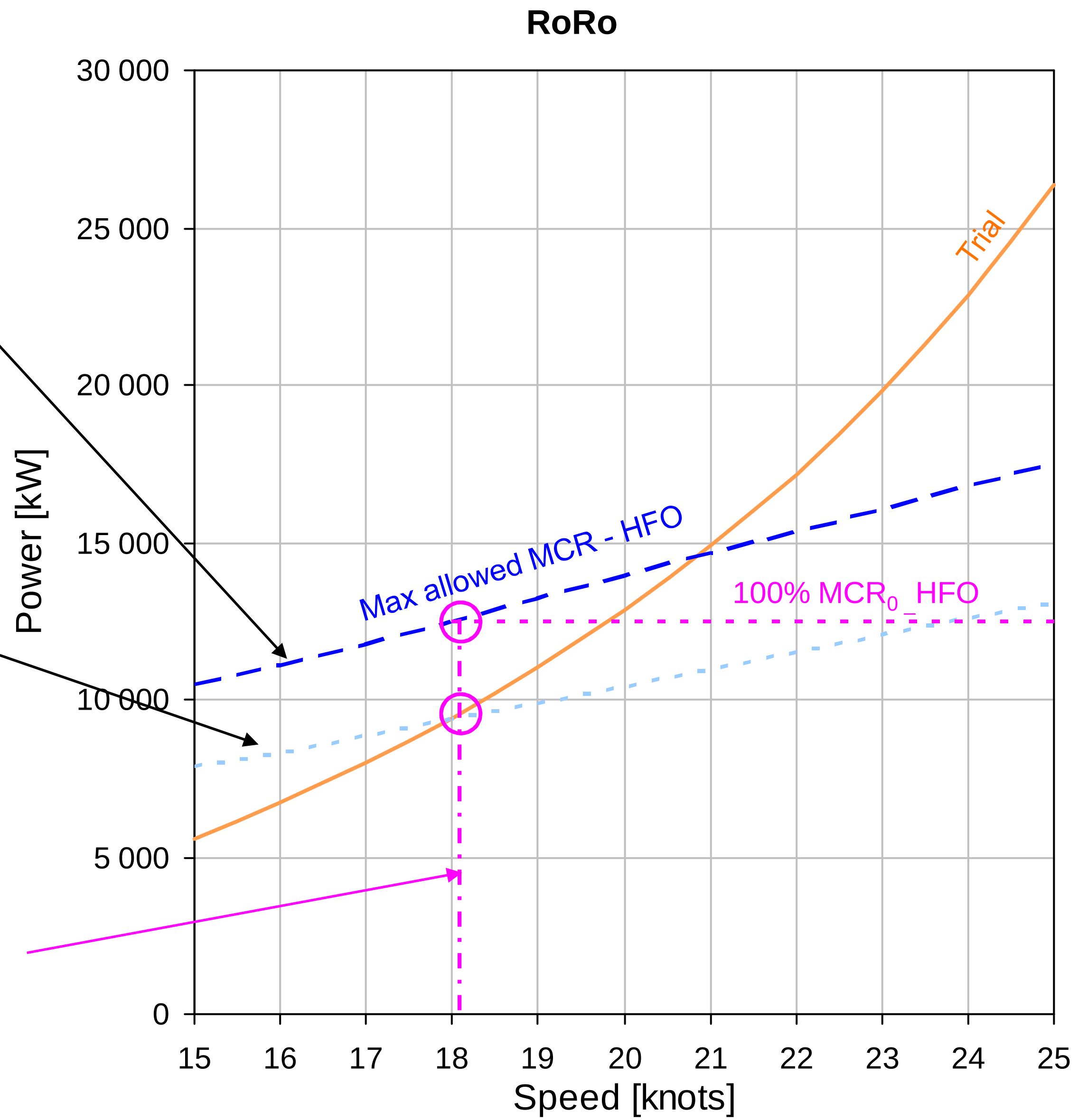


Example: Max allowed power to reach EEDI requirement

HFO: Max allowed MCR_0 to achieve the EEDI limit for each speed (assuming 12 000 dwt capacity)

HFO: 75% of the max allowed MCR_0

Max possible speed acc. to EEDI calculation. Speed at max load condition at shaft power of 75% of max allowed MCR_{ME0}.



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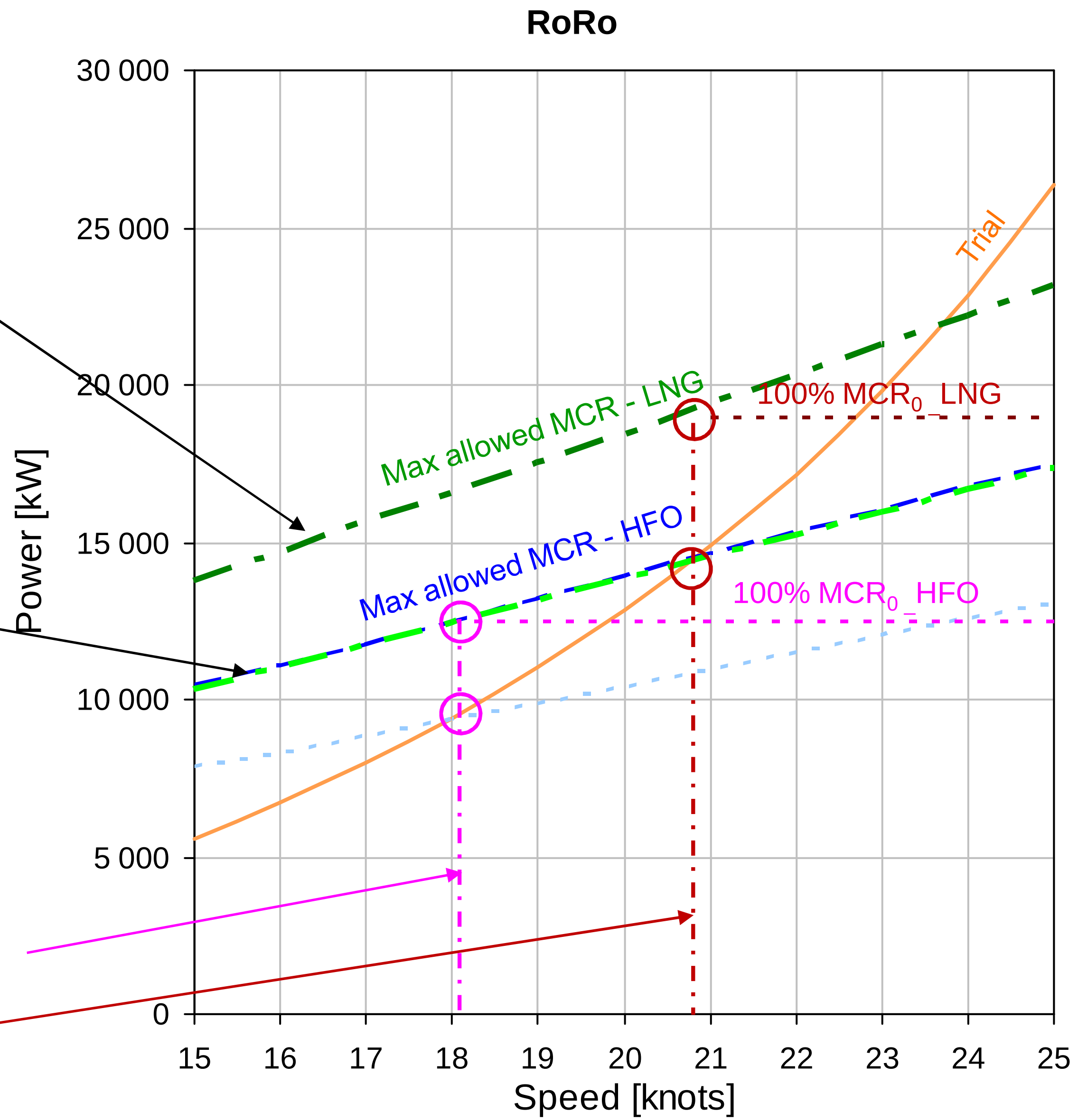
Example: Max allowed power to reach EEDI requirement

LNG: Max allowed MCR_0 to achieve the EEDI limit for each speed (assuming 12 000 dwt capacity)

LNG: 75% of the max allowed MCR_0

Max possible speed acc. to EEDI calculation. Speed at max load condition at shaft power of 75% of max allowed MCR_{ME0}.

Speed with LNG



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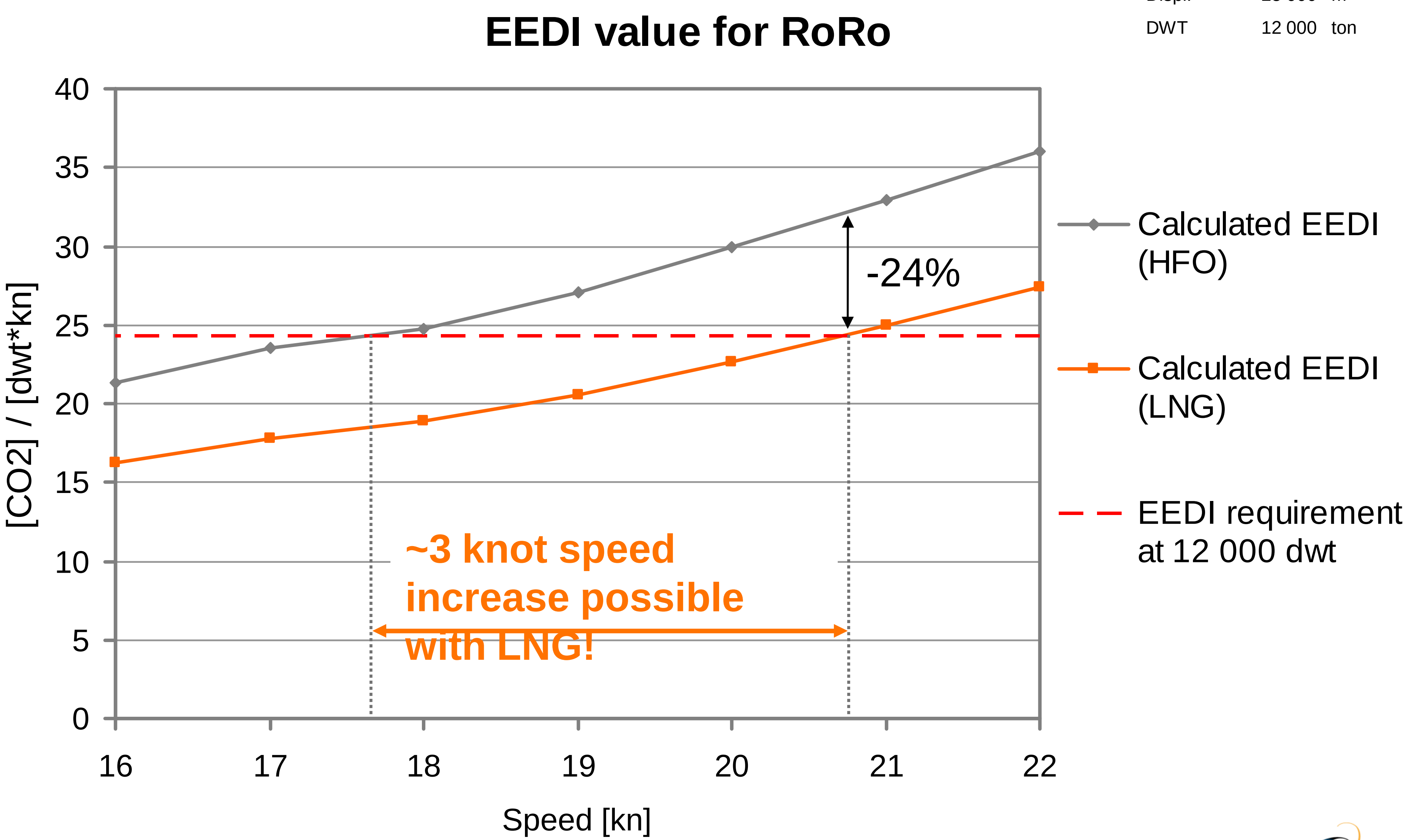
Example: EEDI with LNG vs HFO

Assumptions:

Length, wl	220	m
Beam	33	m
Draft	7.1	m
Displ.	25 000	m^3
DWT	12 000	ton



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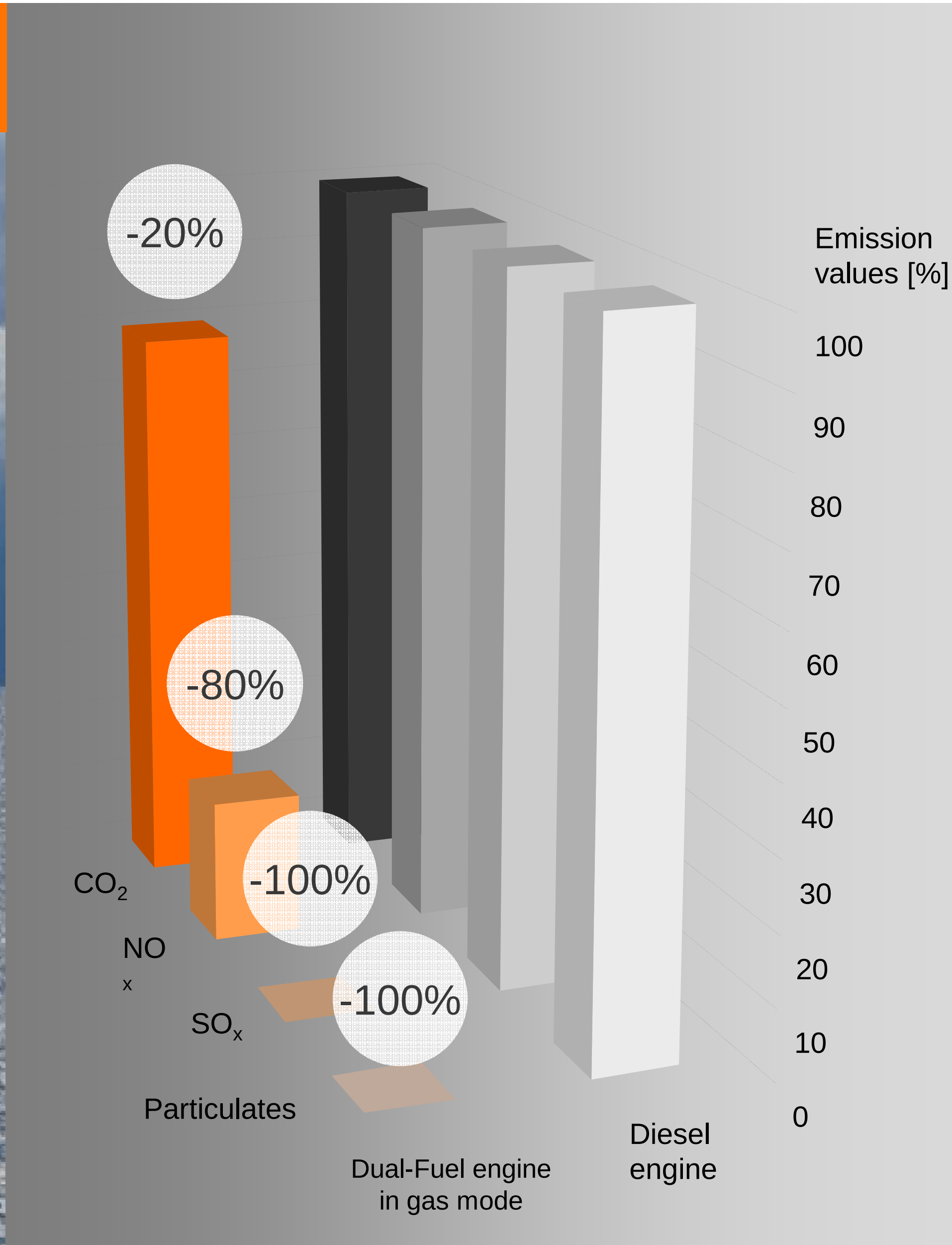
Natural Gas As Marine fuel



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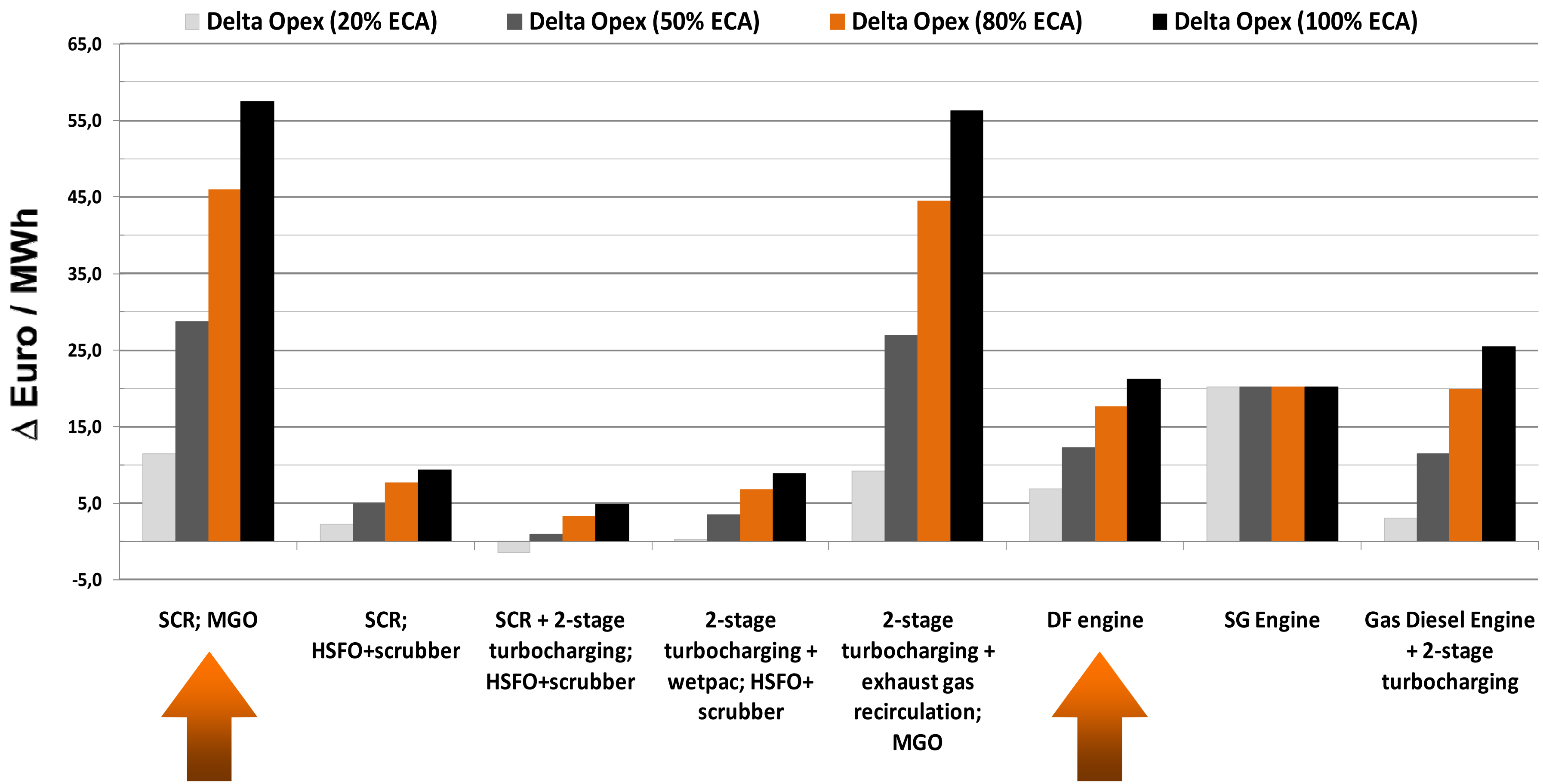
Additional operating costs for IMO TIER III compliance

Reference = W46F Tier II compliant



= solution available; other solutions are under investigation

  January 20, 2011

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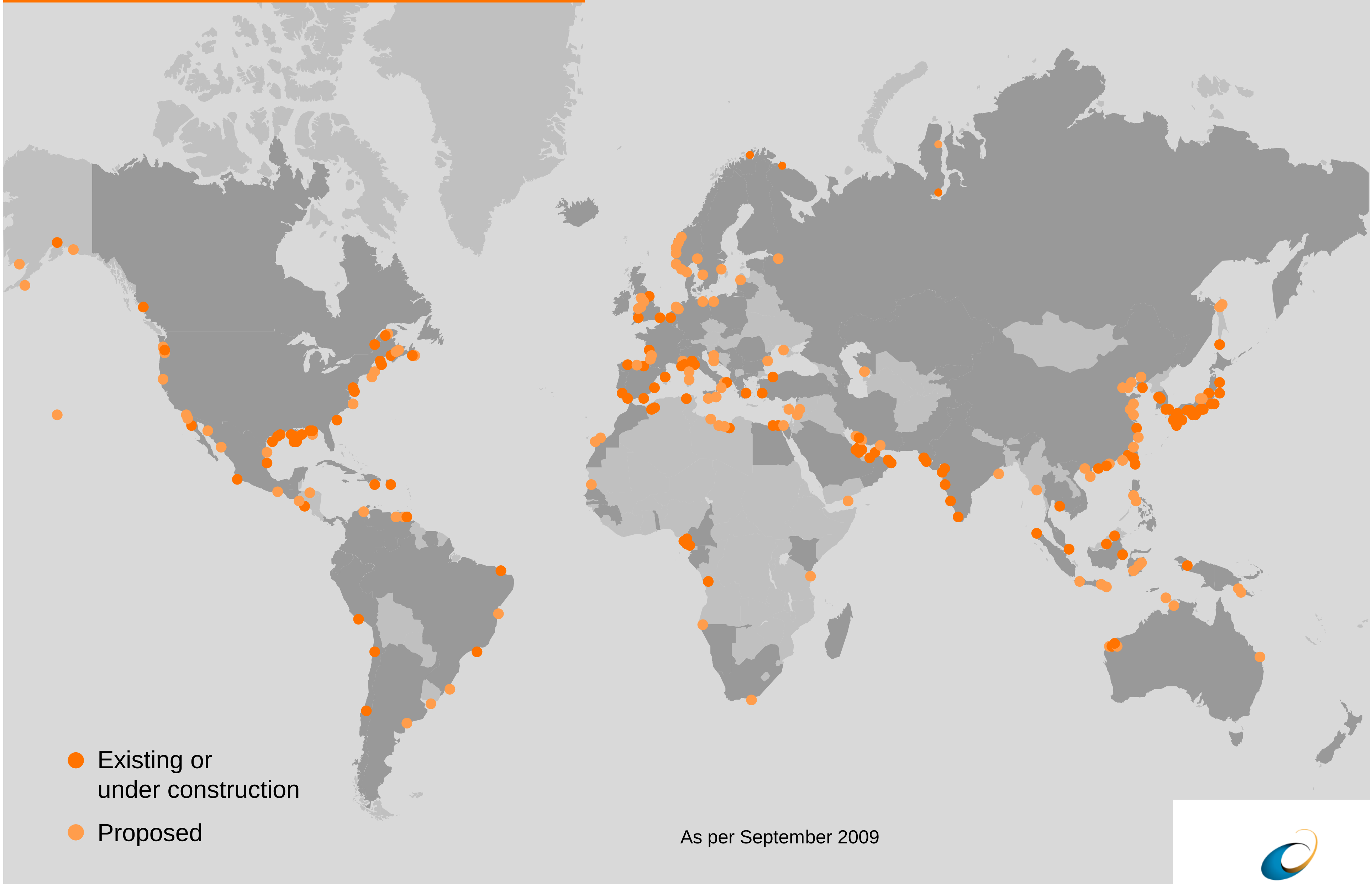
Natural Gas As Marine fuel

Wärtsilä Dual Fuel Engines

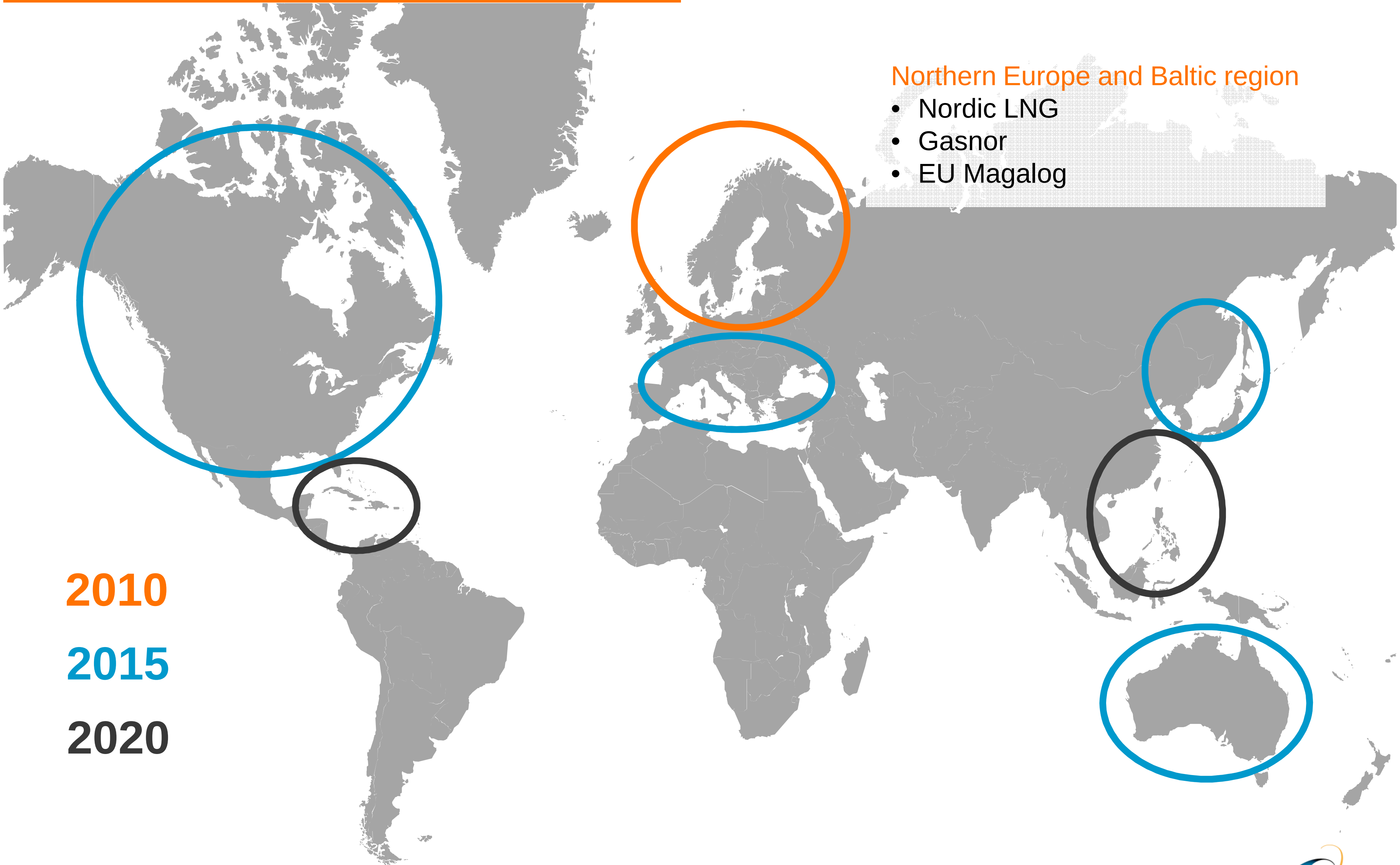
Fuel flexibility optimizes
Operational Expenses:

- In ECA zones, no exhaust after treatment technology is required.
- Outside ECA zones, the most advantageous fuel can be selected

LNG marine terminals



Expected LNG availability



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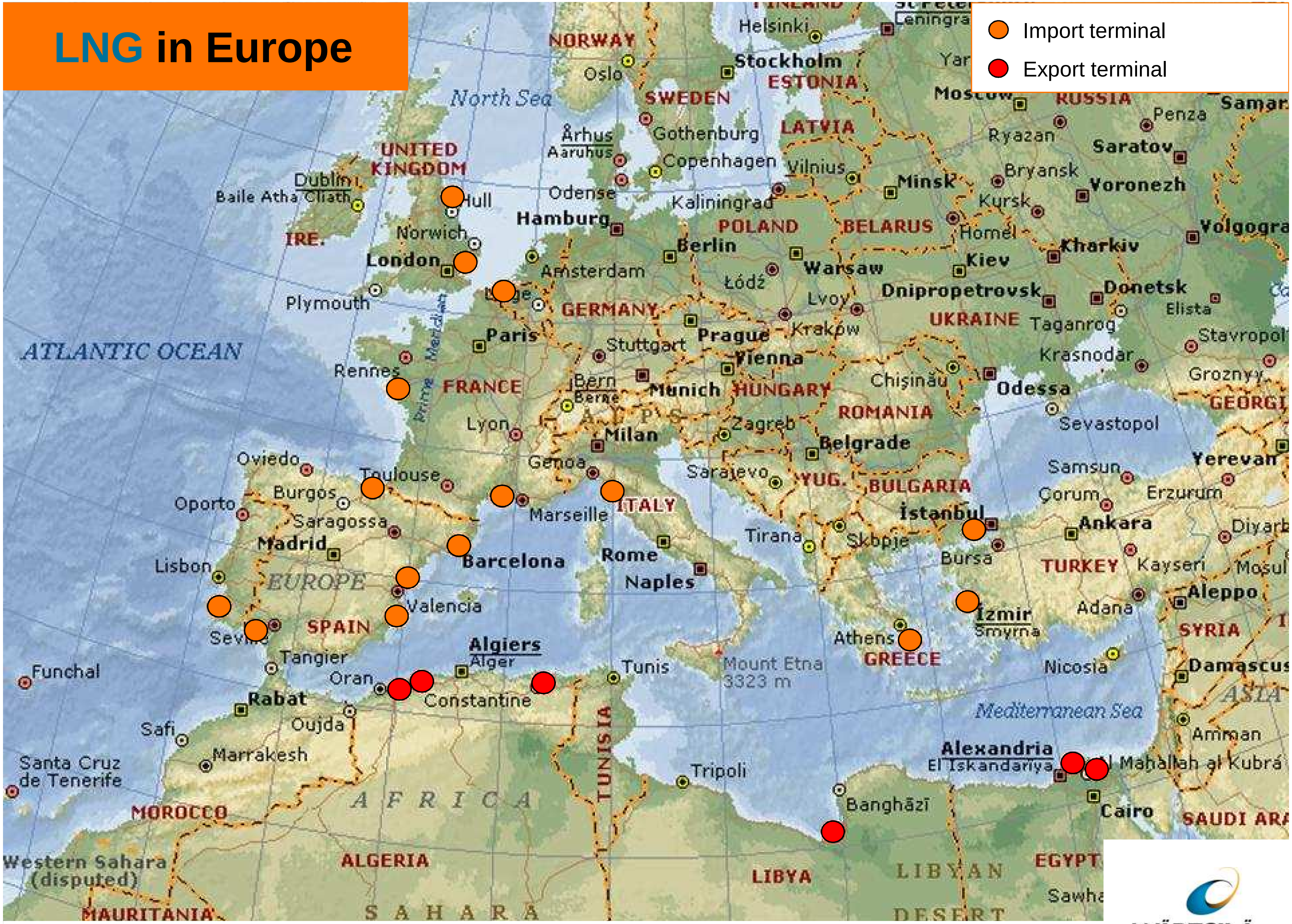
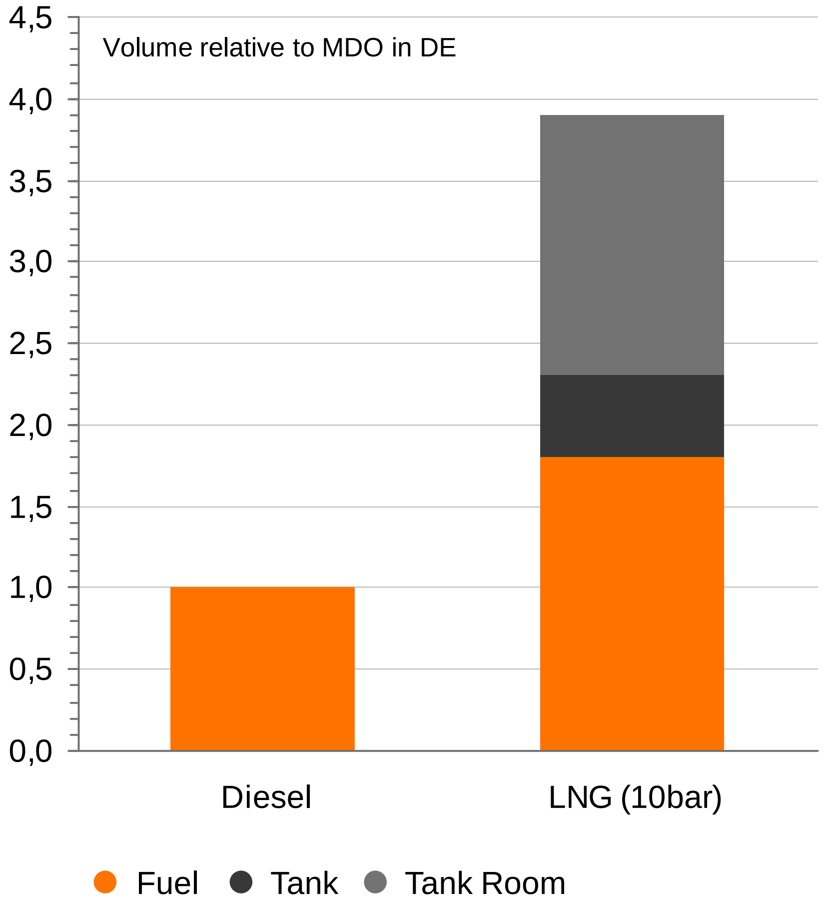
LNG in Europe

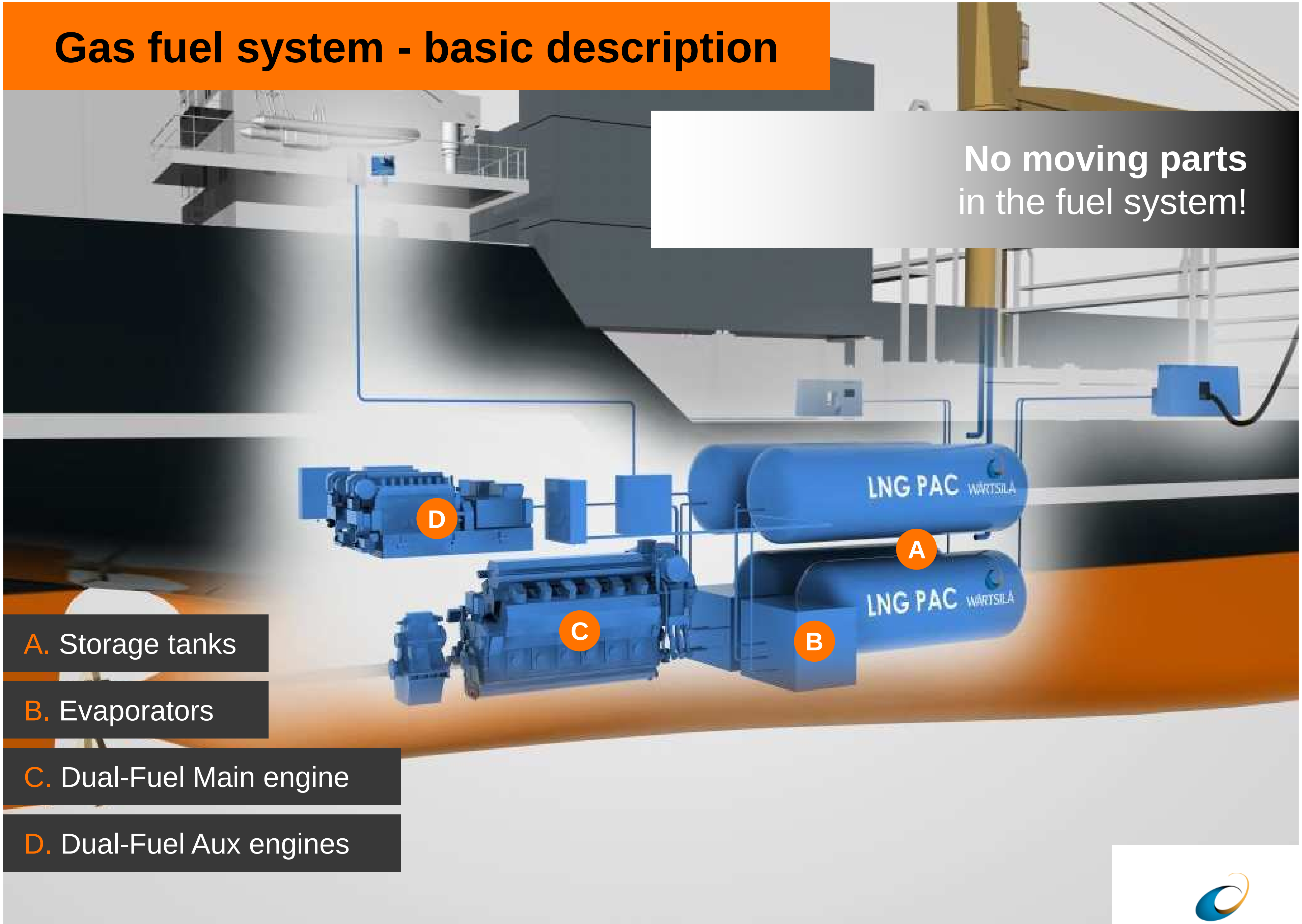


LNG storage

Storage volume (Relative)



Gas fuel system - basic description



No moving parts
in the fuel system!

A. Storage tanks

B. Evaporators

C. Dual-Fuel Main engine

D. Dual-Fuel Aux engines

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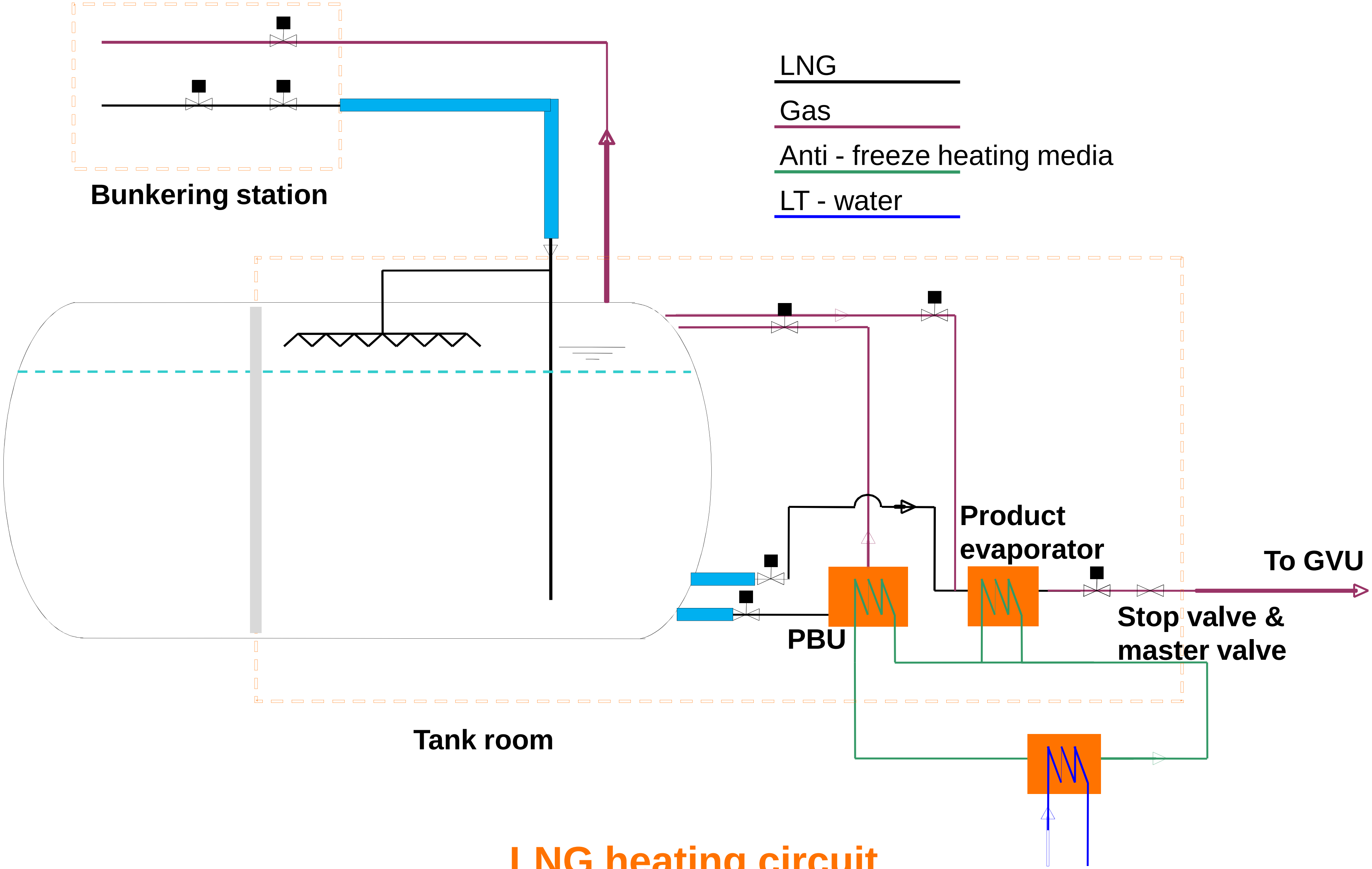
LNGPac Simplified P&ID



LNG heating circuit connected to AC cooling circuit

Modularized solutions

- LNGPac is a modularized solution that fits multiple vessel profiles
  - Ship's autonomy
  - Gas consumption (DF engine(s) power)
- Process skid modularization ↔ high degree of pre-engineering

SHIP'S AUTONOMY (DAYS) → / GAS CONSUMPTION ↓

	Tank 1 (m^3)	Tank 2 (m^3)	Tank 3 (m^3)	Tank 4 (m^3)	...
Gas cons. (Kg/s) range 1	●	●	●	●	
Gas cons. (Kg/s) range 2		●	●	●	
Gas cons. (Kg/s) range 3			●	●	
…					

● = modularized process skid

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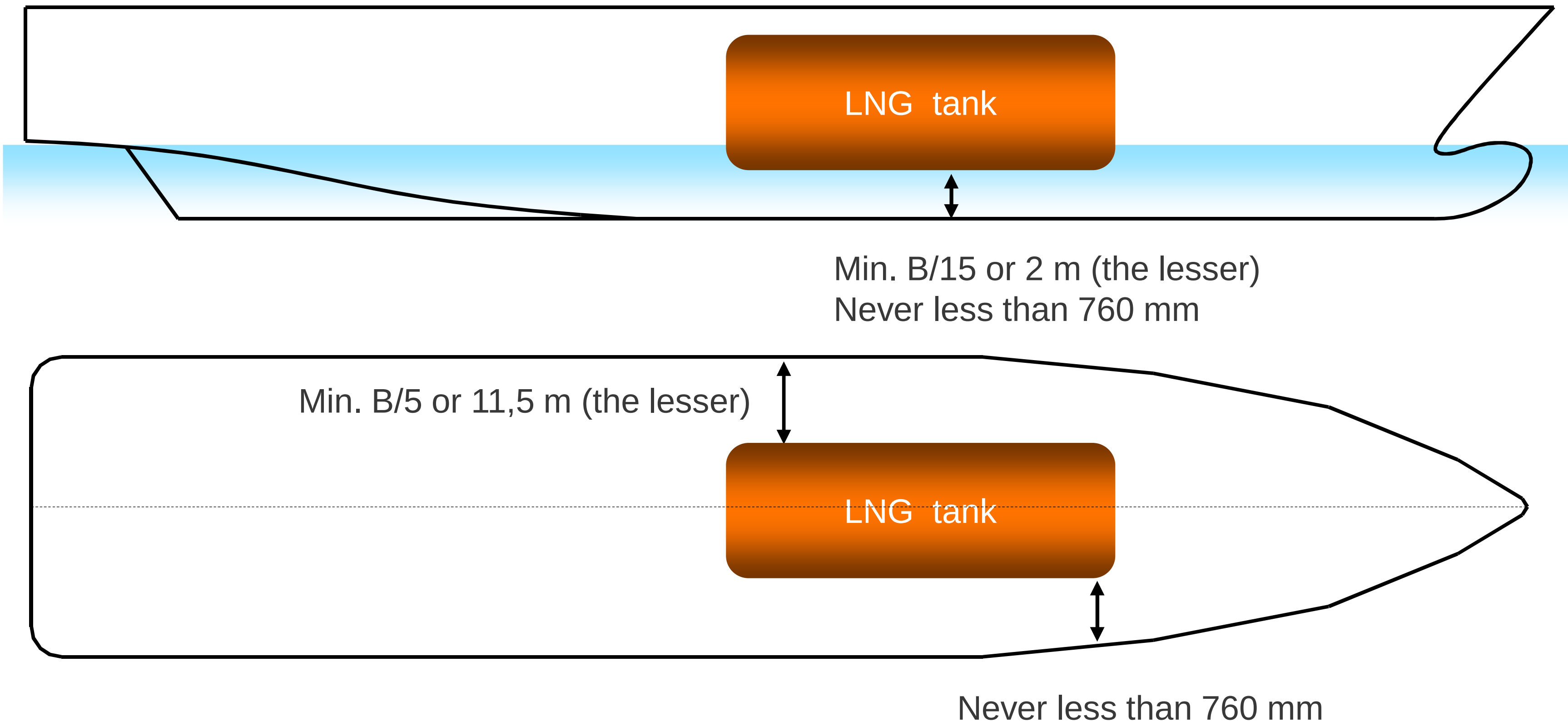
LNG storage location

Gas storage below deck



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LNG – regulatory bodies

Maritime regulations for gas fuelled ships

- Classification societies
  - DNV
  - LR
- IMO
  - IMO MSC adopted the Interim Guidelines on safety for natural gas-fuelled engine installations in ships (resolution MSC-86-285)
- Flag states
  - Today only the Norwegian Maritime Directorate has got rules available
- International Gas Carrier (IGC) code

Running on gas in port

Lower emissions in port
No need for shore connection!

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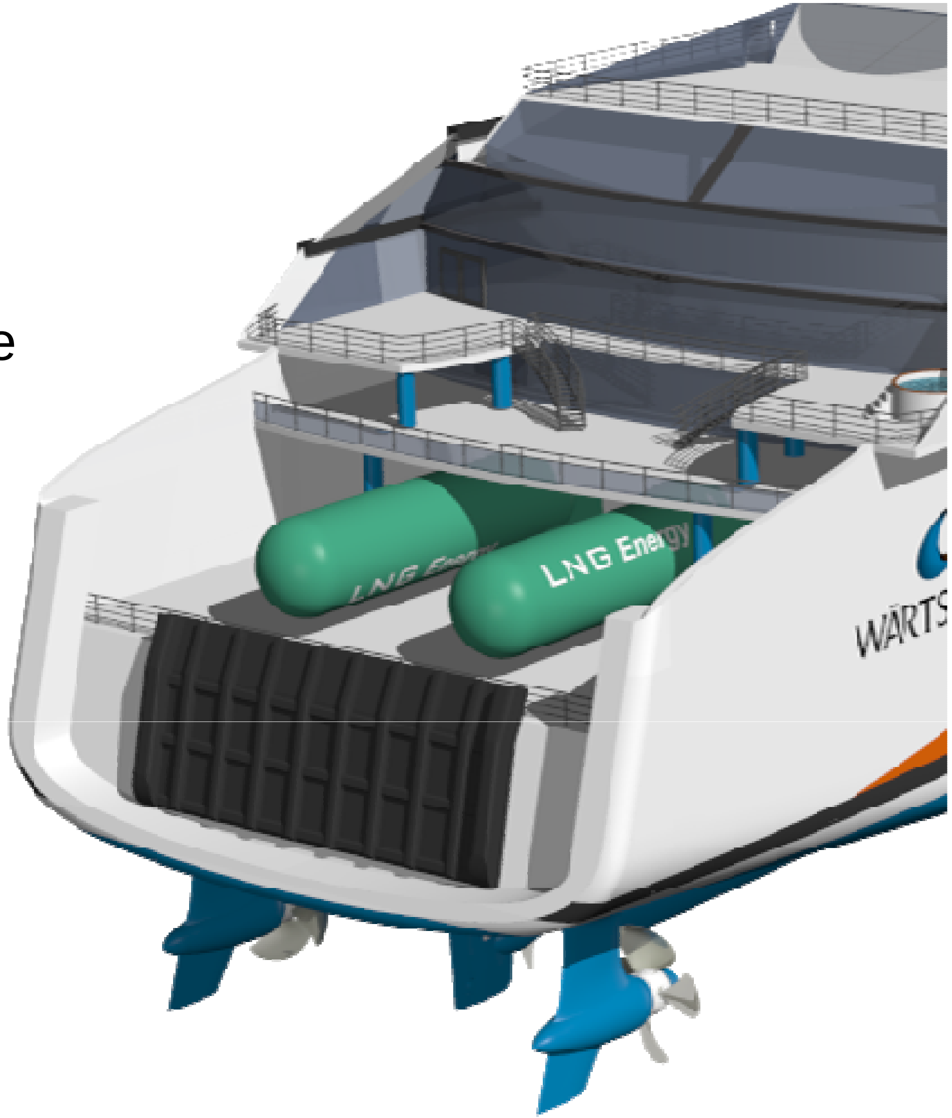
LNG tanks located outside

The LNG tanks can be located outside

- Does not take up space inside ship
- Good ventilation
- No ventilation casing needed trough accommodation
- Visible location for good PR



Bunkering

- Tanker truck
- Land based storage tank
- Tanker ship / barge
- ISO container
- Trailer on board

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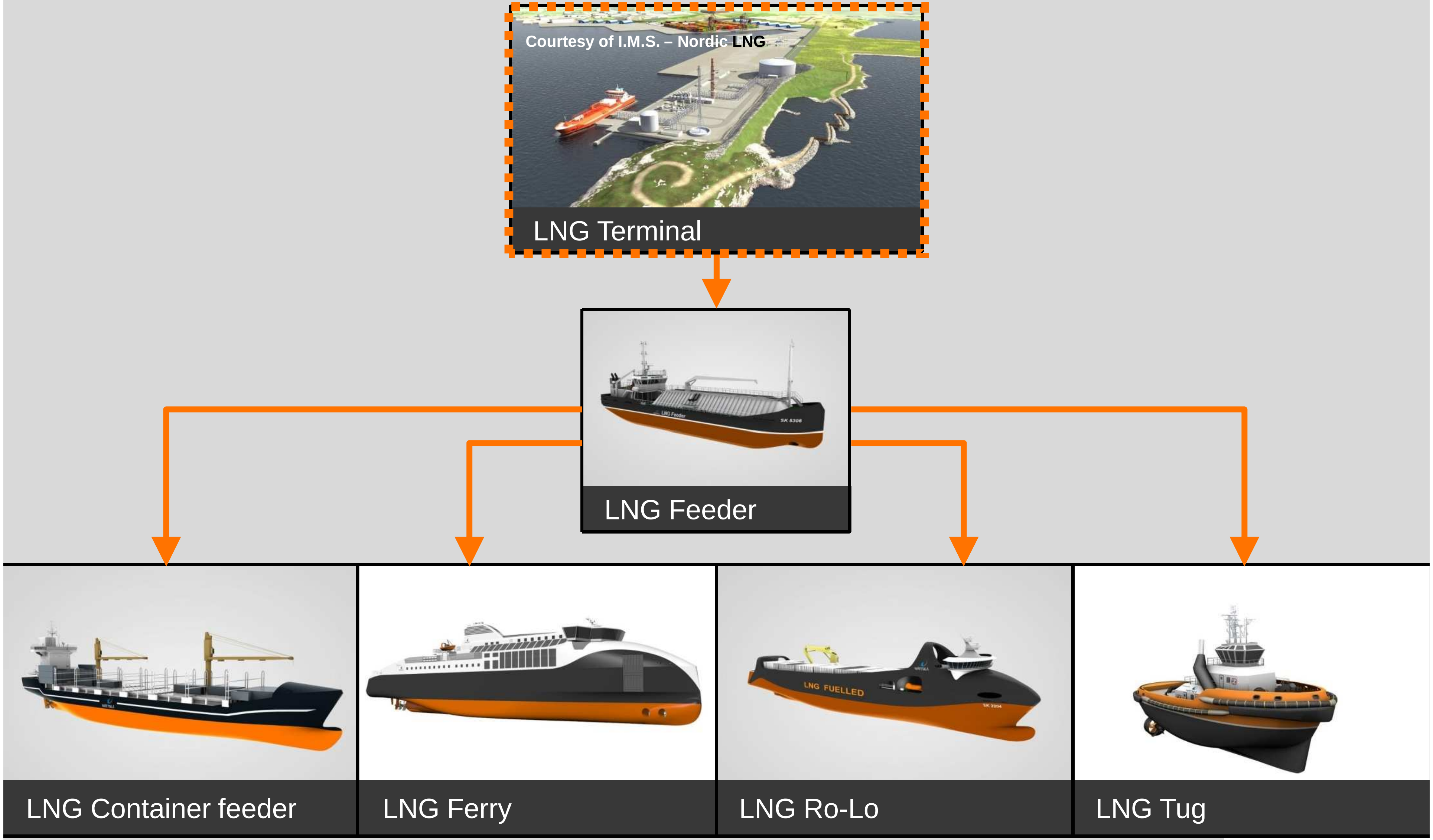
Natural Gas As Marine fuel – distribution chain



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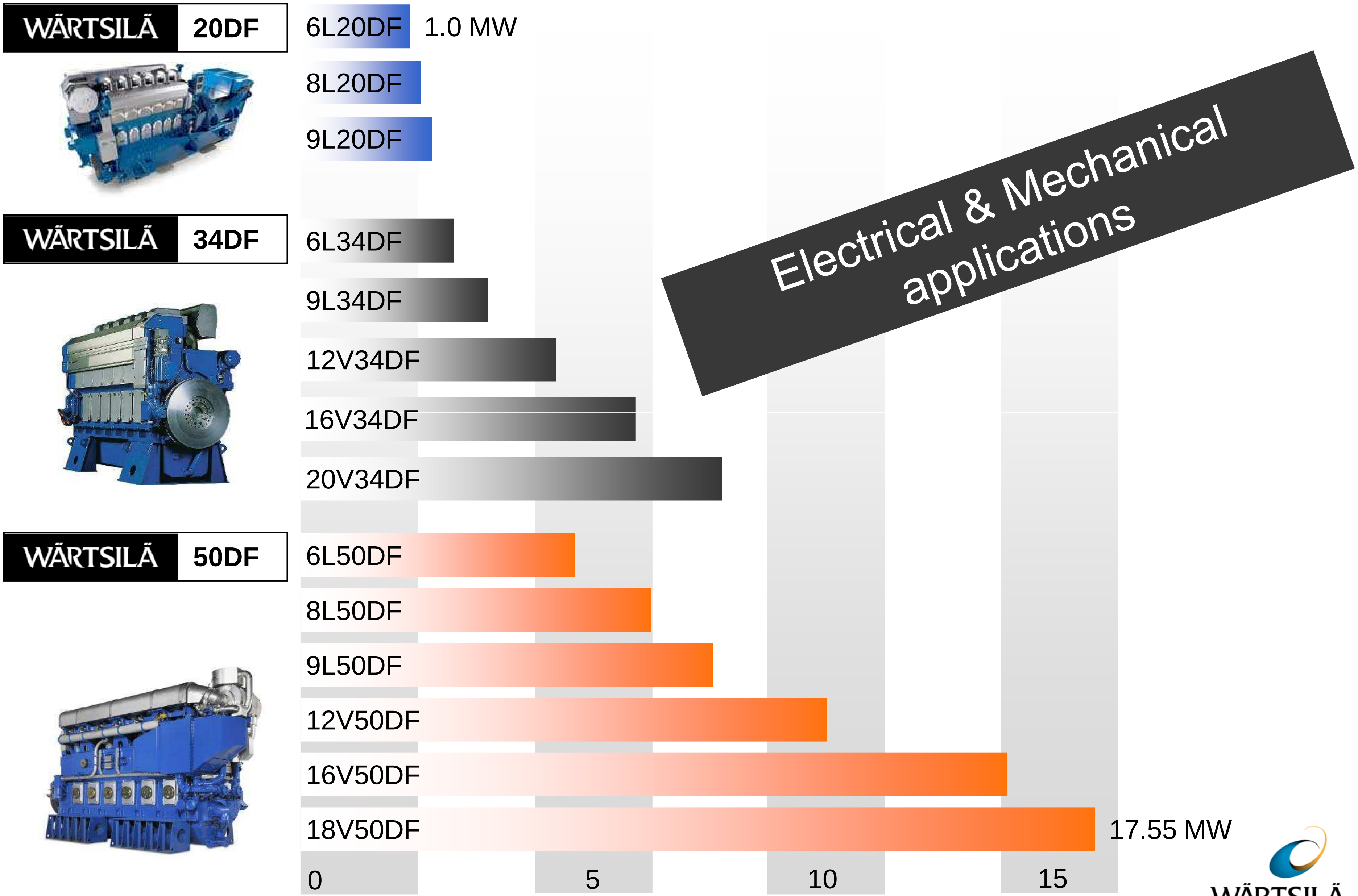
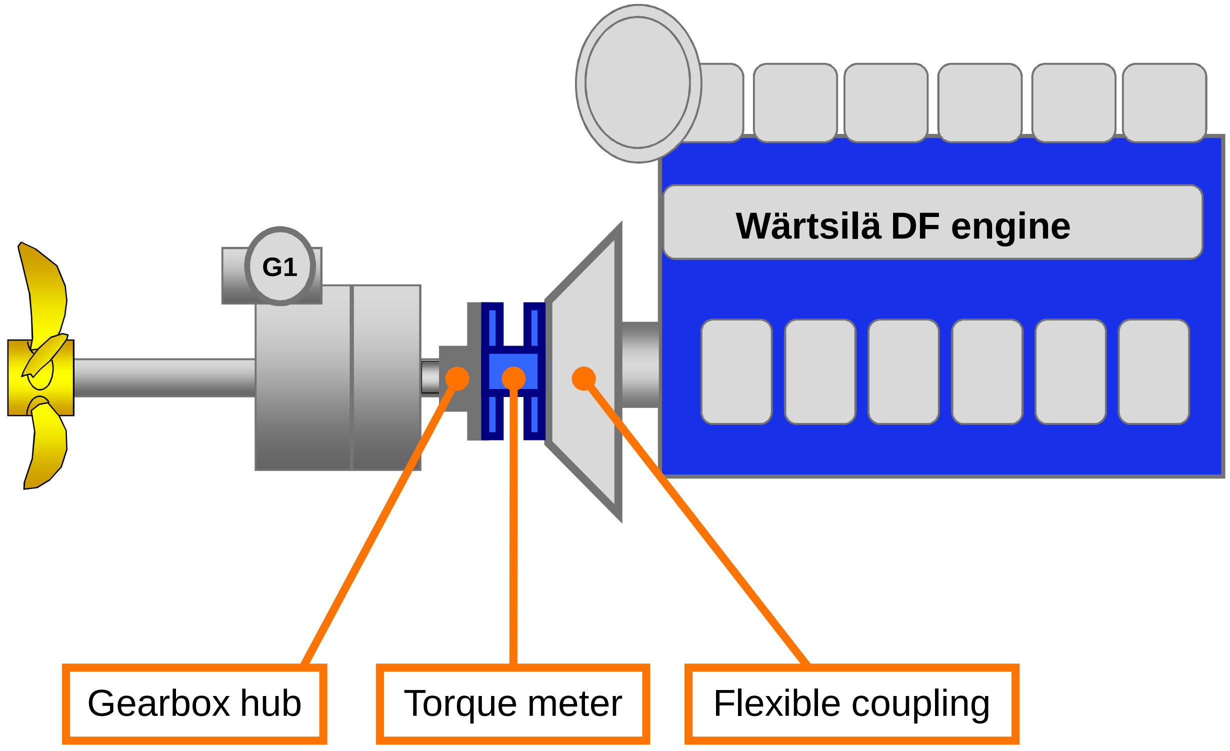
Total Concept Optimization

Wärtsilä engineers solutions for LNG delivery, storage, transportation and utilization onboard.

Dual-Fuel Engine Portfolio



Torque meter position in mechanical drive (DF) installation



Conclusion

- DF became in very short time dominating solution for BOG in LNG carriers
- More stringent emission requirements increase CAPEX and OPEX for when using liquid fuels making LNG an attractive alternative
- Natural gas burned according lean burn otto cycle meets known and upcoming legislation with primary methods
- Dual fuel offers highest flexibility and therefor our choice for shipping

The technology is avialable but the infrastructure is the limiting factor at this moment!

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