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EXHAUST GAS CLEANING

PIONEERING SOX SCRUBBER SYSTEMS

LOWEST COST FOR MEETING MARPOL ANNEX VI REQUIREMENTS

Emissions and Environment

NO_x

Acid rains

Tier II (2011)
Tier III (2016)

SO_x

Acid rains

3.5% (2012)
ECA 0.1% (2015)

CO_2

Greenhouse gas

Under evaluation by IMO

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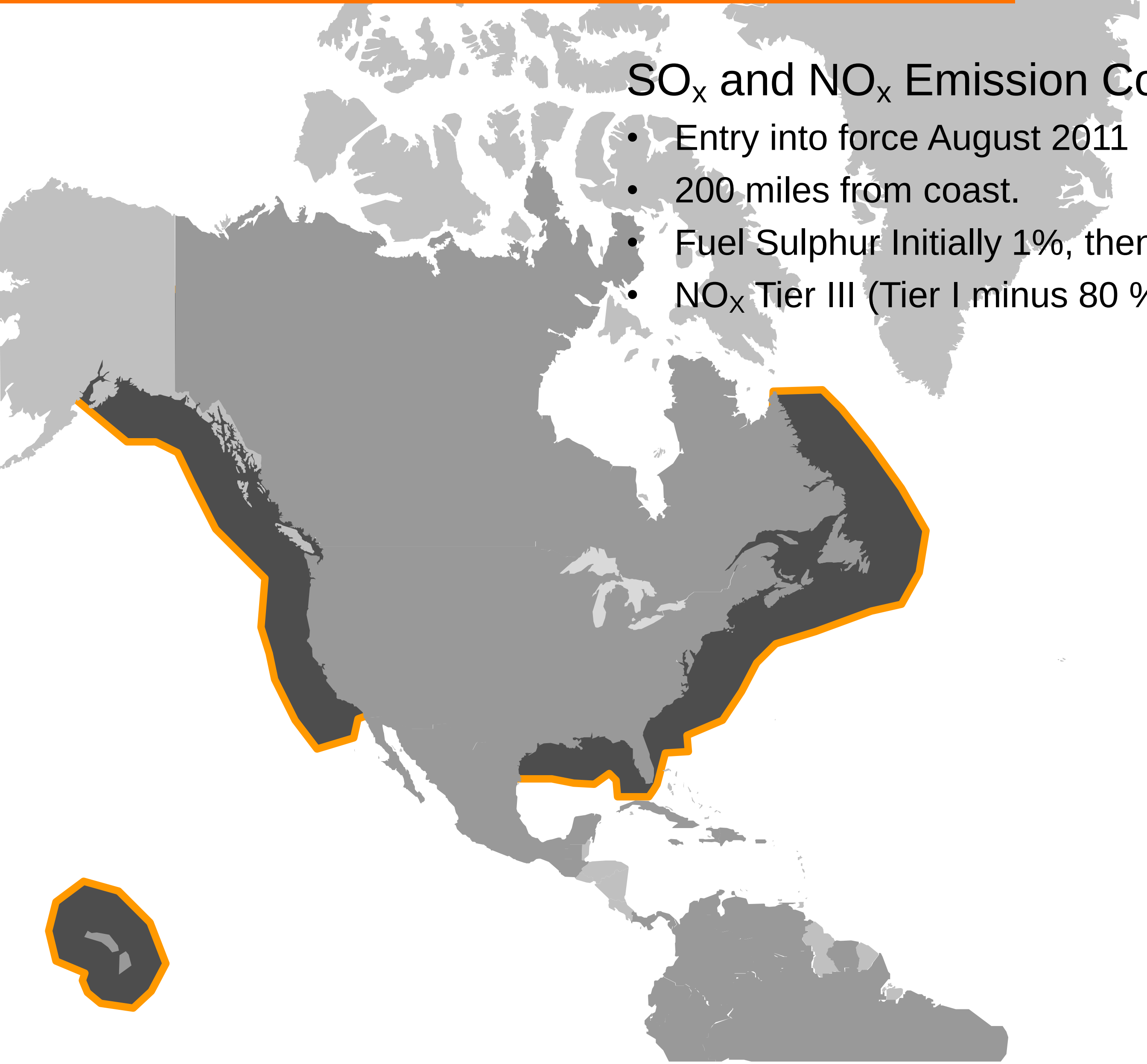
North American SO_X and NO_X ECA



SO_x and NO_x Emission Control Area.

- Entry into force August 2011
- 200 miles from coast.
- Fuel Sulphur Initially 1%, then 0.1 % from 2015, all ships.
- NO_X Tier III (Tier I minus 80 %) 2016, new buildings.

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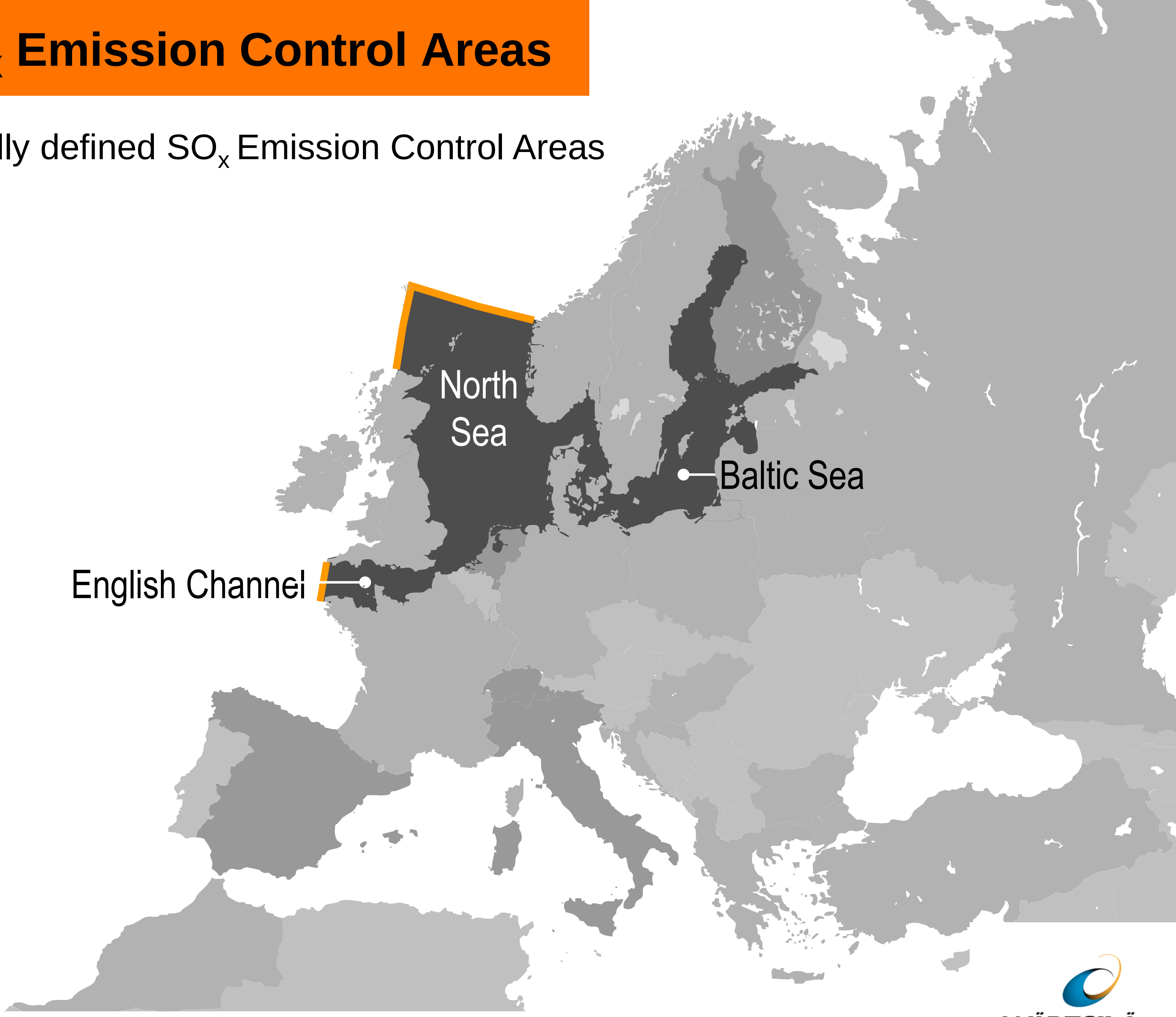
IMO SO_X Emission Control Areas

Geographically defined SO_x Emission Control Areas



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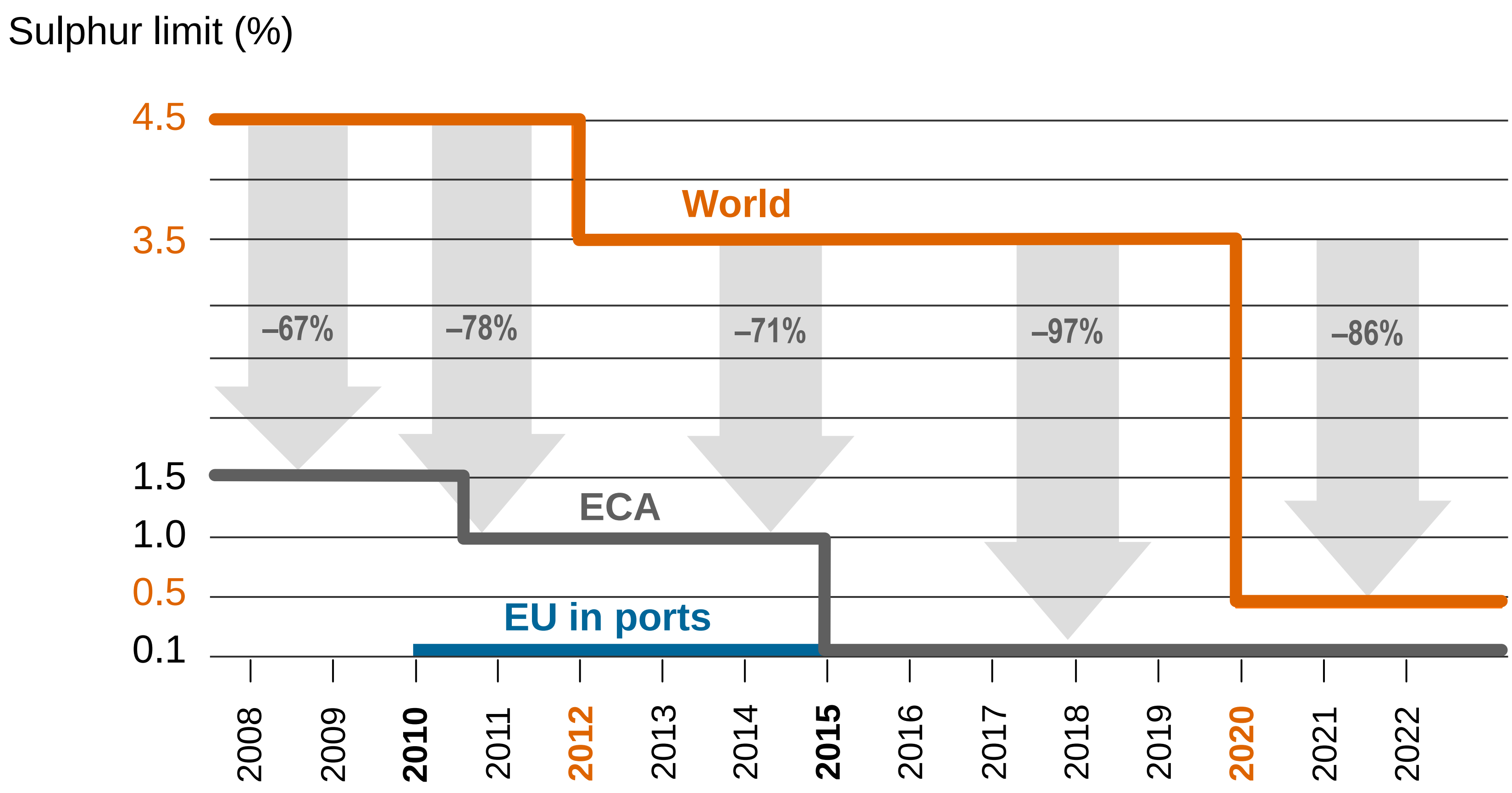
IMO & EU Sulphur Limits



Fuel type	Not regulated = both HFO and distillate are permitted.
Exhaust gas cleaning	Permitted alternative under Regulation 4 to achieve any regulated limit.
Particulate Matter (PM)	No limit values.

Alternatives to reducing SOx

Alternative	+	−
FUEL SWITCH Switch to low sulphur fuel in SECA.	Flexible Small investment	High operating cost in SECA Fuel change over procedures Lube oil TBN management Fuel availability?
CHANGE TO MGO Run full time on Marine Gas Oil (MGO).	Convenient No change over	High operating cost Future availability?
CONVERT TO LNG Convert engines to run on gas (LNG).	A solution which also reduces NO_x and particulates	Investment cost LNG availability
USE SCRUBBERS Install an exhaust gas cleaning system (scrubber).	Works with high S HFO Lowest total lifecycle cost Use everywhere Easy operation	ROI depends on fuel oil price difference between low S fuel oil and high S HFO

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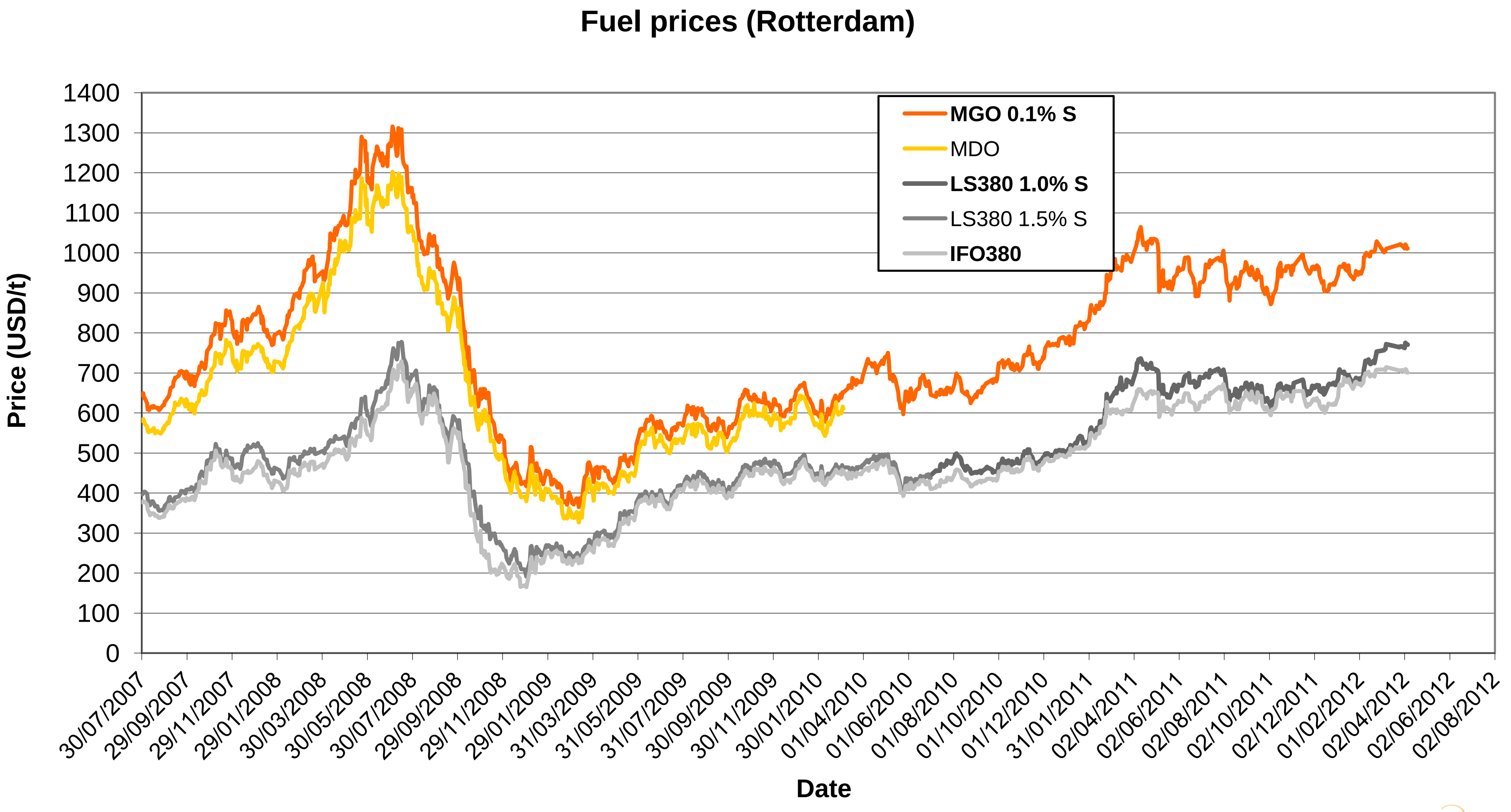
Fuel prices (Rotterdam)

Δ= 140–700$ / ton MGO–HFO



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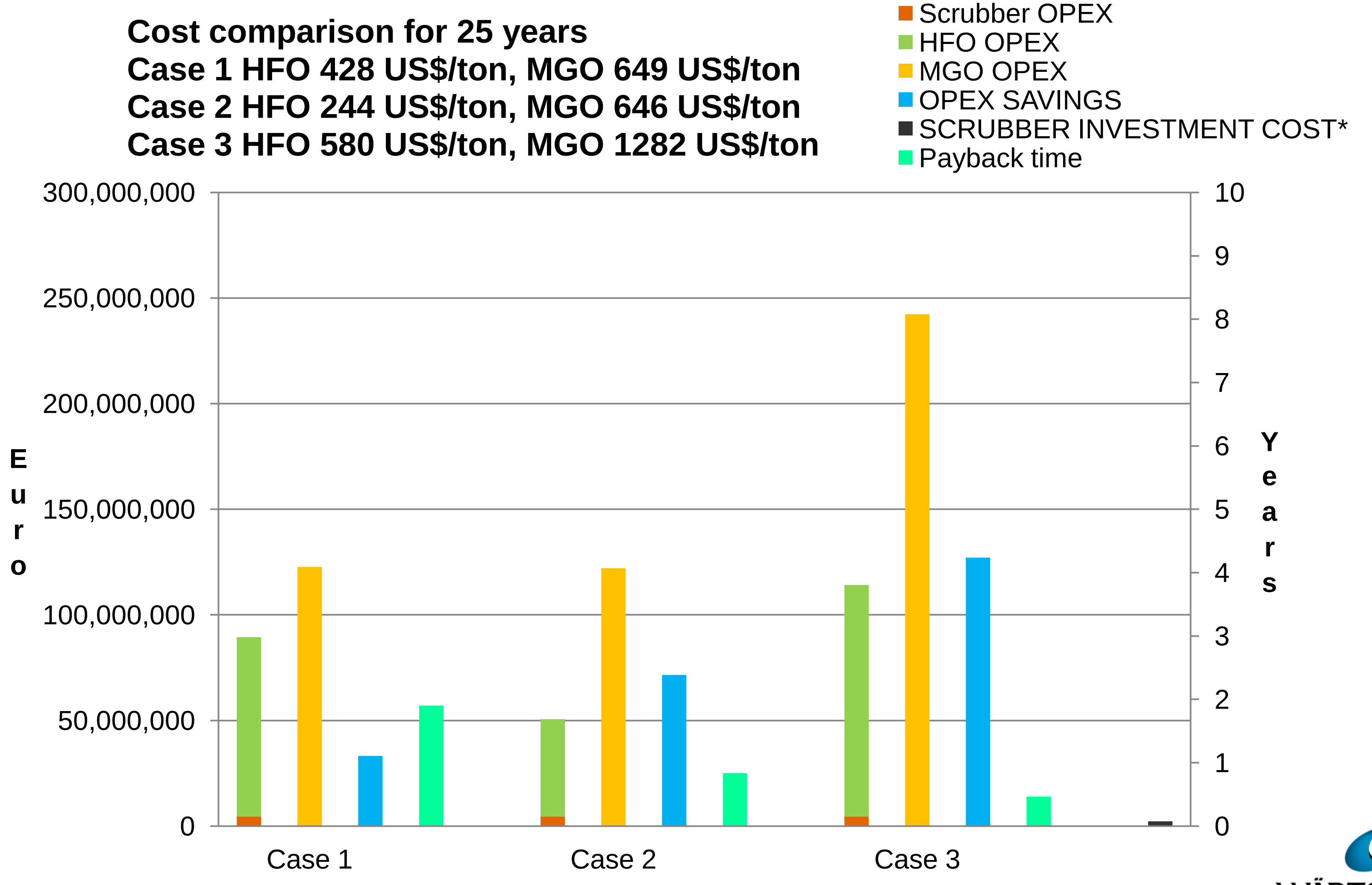
The Big Picture

*System delivery cost (not including installation)
Fuel prices are prices in Rotterdam
Case 1: 31.08.2010
Case 2: August 2008
Case 3: May 2008

Cost comparison for 25 years
Total engine power: 10 MW
Annual fuel consumption: 9800 ton/a
Annual average load: 69%
Interest rate for NPV calculations: 5.0%
Fuel price inflation rate: 4.8% (1980-2010 average)
Currency rate: 1.27 US$/€
NaOH 50%: 200€/ton



Seawater scrubbing system chemistry

Engine Exhaust Chemistry:

$$S + O_2 \rightarrow SO_2 \quad (\sim 95\%)$$
$$SO_2 + {}^{1}/_{2}\, O_2 \rightarrow SO_3 \quad (\sim 5\%)$$

Scrubber Chemistry:

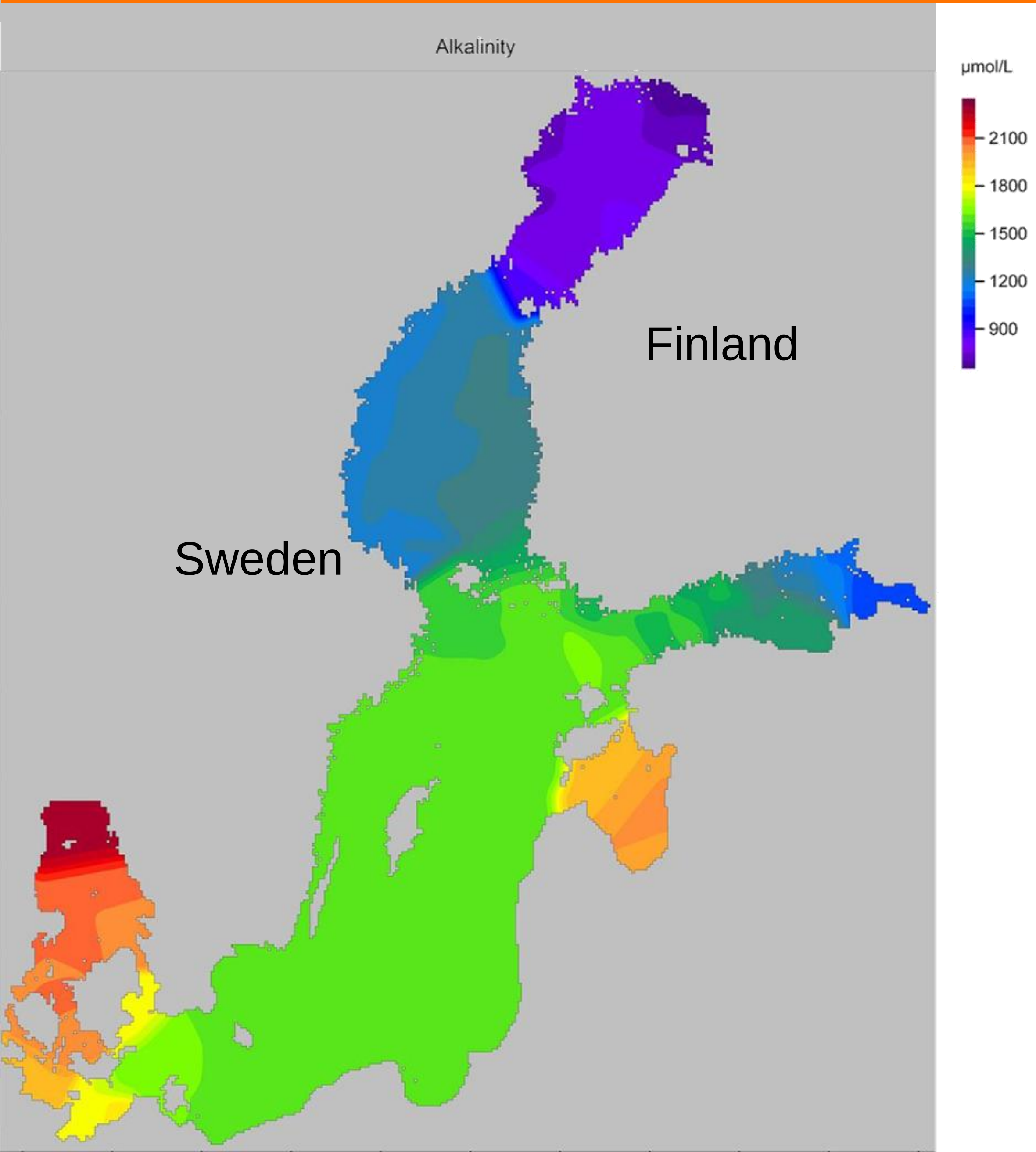
$$SO_2 + H_2O \rightarrow H_2SO_3 \text{ (Sulphurous Acid)}$$
$$SO_3 + H_2O \rightarrow H_2SO_4 \text{ (Sulphuric Acid)}$$

Scrubber Reactions:

$$CaCO_3 + H_2SO_3 \rightarrow CaSO_3 + H_2O + CO_2$$
$$2CaSO_3 + O_2 \rightarrow 2CaSO_4 \text{ (Calsiumsulphate)}$$

Alkalinity (Bicarbonates (HCO_3^-) and carbonates (CO_3^{2-}))
– **neutralize** and help to buffer the pH rapidly

Example alkalinity in the Baltic Sea



- Open sea alkalinity
- Surface data (0… 15 m)
- Data from 2001-2005

- Typical open sea alcalinity outside Baltic Sea is ca. 2200 – 2400 µmol/L

SOx Scrubbers and Survey Schemes

Freshwater closed loop	Seawater open loop	Hybrid (seawater closed loop)
Not dependent on seawater alkalinity	Dependent on seawater alkalinity (issue for limited areas such as lakes, few ports close to estuaries, Northern and Eastern part of Baltic Sea; limitation: 1000 umol / L)	Possibility to operate independently from seawater alkalinity for a limited period (limitation: 1000 umol / L)
Zero effluent discharge for some time	No possibility for zero discharge	Zero effluent discharge for limited period
Needs caustic soda as a reagent	No need of NaOH (and logistics)	Needs caustic soda for intended closed loop operations
Low power demand (0,5-1,0 % additional engine power demand)	Slightly higher power demand (2,0 % additional engine power demand)	Slightly higher power demand (2,0 % additional engine power demand)
Slightly more complex system	Simple system	Slightly more complex system
Needs FW (possibility to use AWP treated water)	No need for additional FW	No need for additional FW
No issues related to sea chests	Sea chest capacity (retrofits)	Sea chest capacity (retrofits)
More tank requirements (alkali, buffer tank, holding tank, sludge tank)	Lower tank space demand (residence tank, sludge tank)	More tank requirements (alkali, 2x residence tanks, holding tank, sludge tank)

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SOx Scrubbers and Survey Schemes

	Type of scrubber		
	Fresh water	**Sea water**	**Hybrid**
Alkaline reactant	NaOH	Sea water	NaOH / SW
Operating modes	Closed loop	Open loop	Closed / open loop
Zero discharge mode	Periodical	No	Periodical
Scrubbing water flow, m3/MWh	24	45	24/45
Fresh water consumption, m3/MWh	0.1…0.2	Zero	0.1…0.2 / zero
Water piping, m3 (large cruise ship)	18	41	> SWS
Pumping power, % of engine power*	0.5	1.4	0.5/1.4
Suitable certification scheme**	Scheme A or B	Scheme B	Scheme B

* In case of Integrated Scrubber additionally fan power, load dependent, 0.1 – 0.5 %

** Refers to IMO Resolution MEPC.184(59)

Scrubber approval alternatives according to IMO

SCHEME A – Exhaust gas cleaning (EGC) **system approval**, survey and certification using **parameter and emission checks**

- Compliance demonstrated by emission tests
- Possible to obtain for serially manufactured units and for a certain production range

SCHEME B – Exhaust gas cleaning (EGC), survey and certification using **continuous monitoring of SO_x emissions**

- Compliance demonstrated in service by continuous exhaust gas monitoring

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Wärtsilä Scrubber Portfolio

- **Sea water scrubber (SWS) – open loop system**
  - Uses seawater i.e. no freshwater needs
  - Slightly higher power demand than FWS
  - Does not need caustic soda
- **Applications:** main alternative for ocean-going ships

- **Fresh water scrubber (FWS) – closed loop system**
  - Not dependent on seawater alkalinity
  - Zero effluent discharge an option
  - Low power demand
  - Needs caustic soda as a reagent
- **Applications**: seas with extremely low alkalinity and for operators looking for zero discharge

- **Hybrid scrubbers – both open loop and closed loop operations**
  - Flexible system
  - More complex system
- **Applications:** ships requiring full flexibility of operations (e.g. sailing both in low alkalinity areas as well in open oceans)

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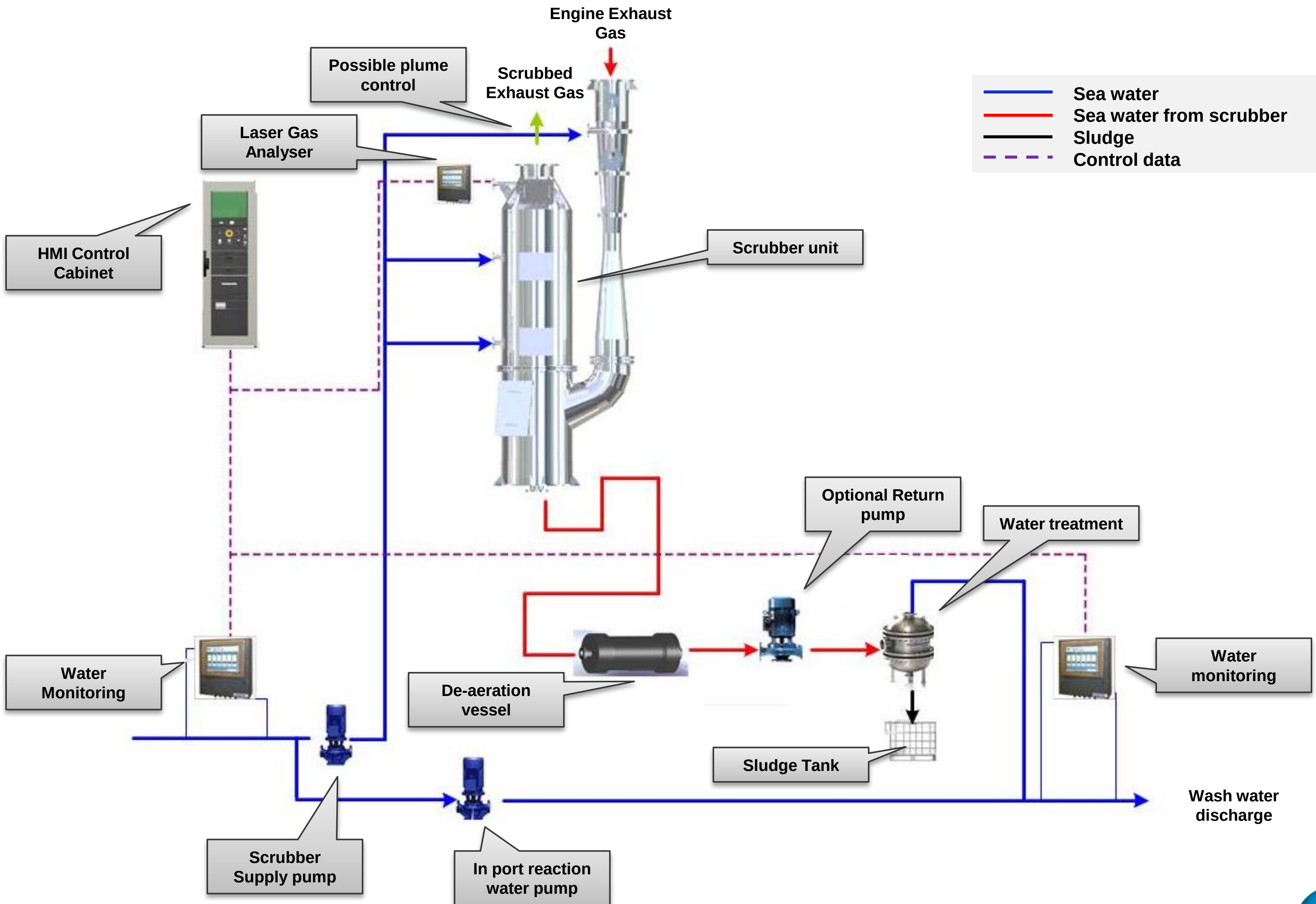
Wärtsilä Open loop scrubber



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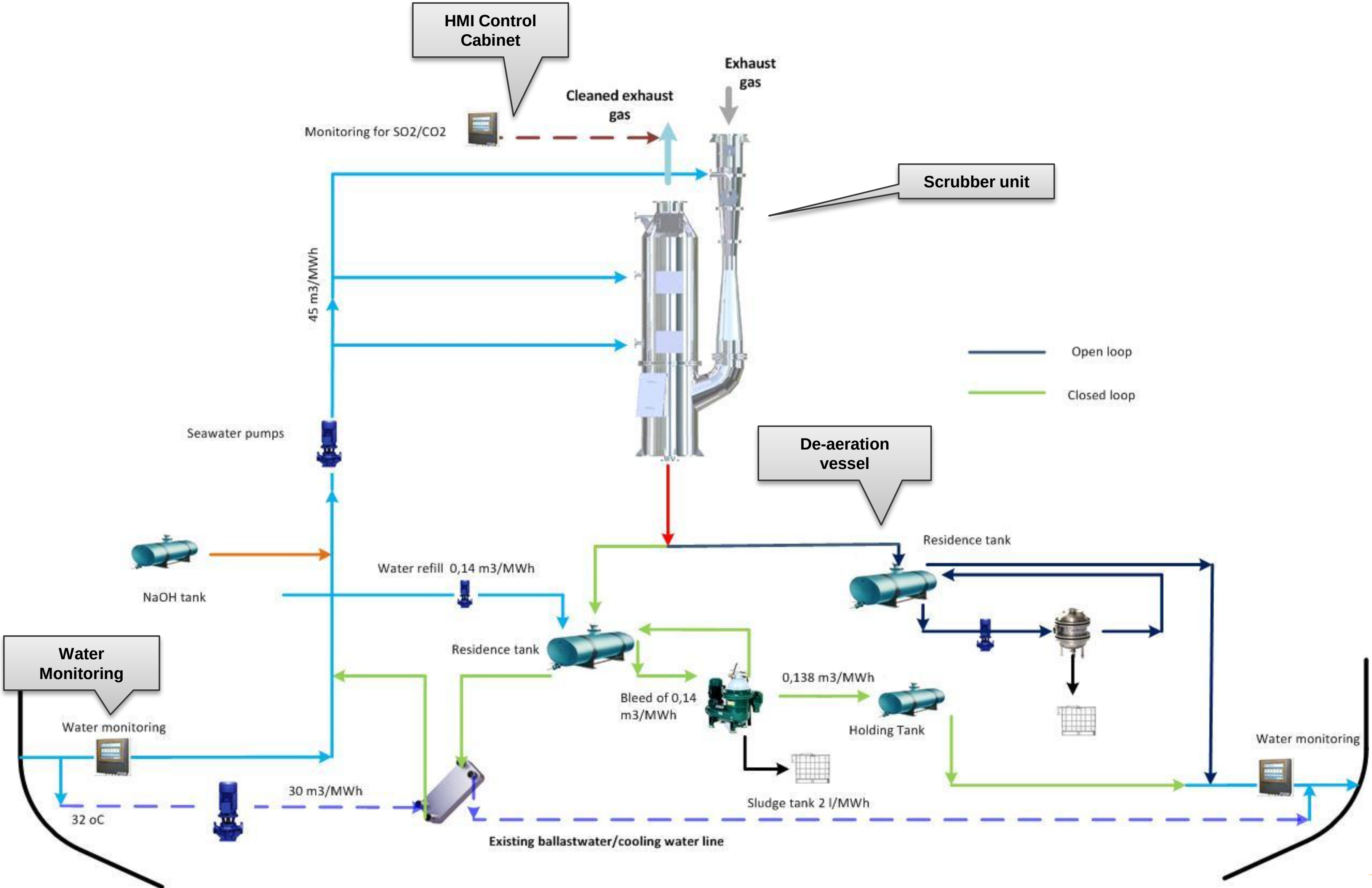
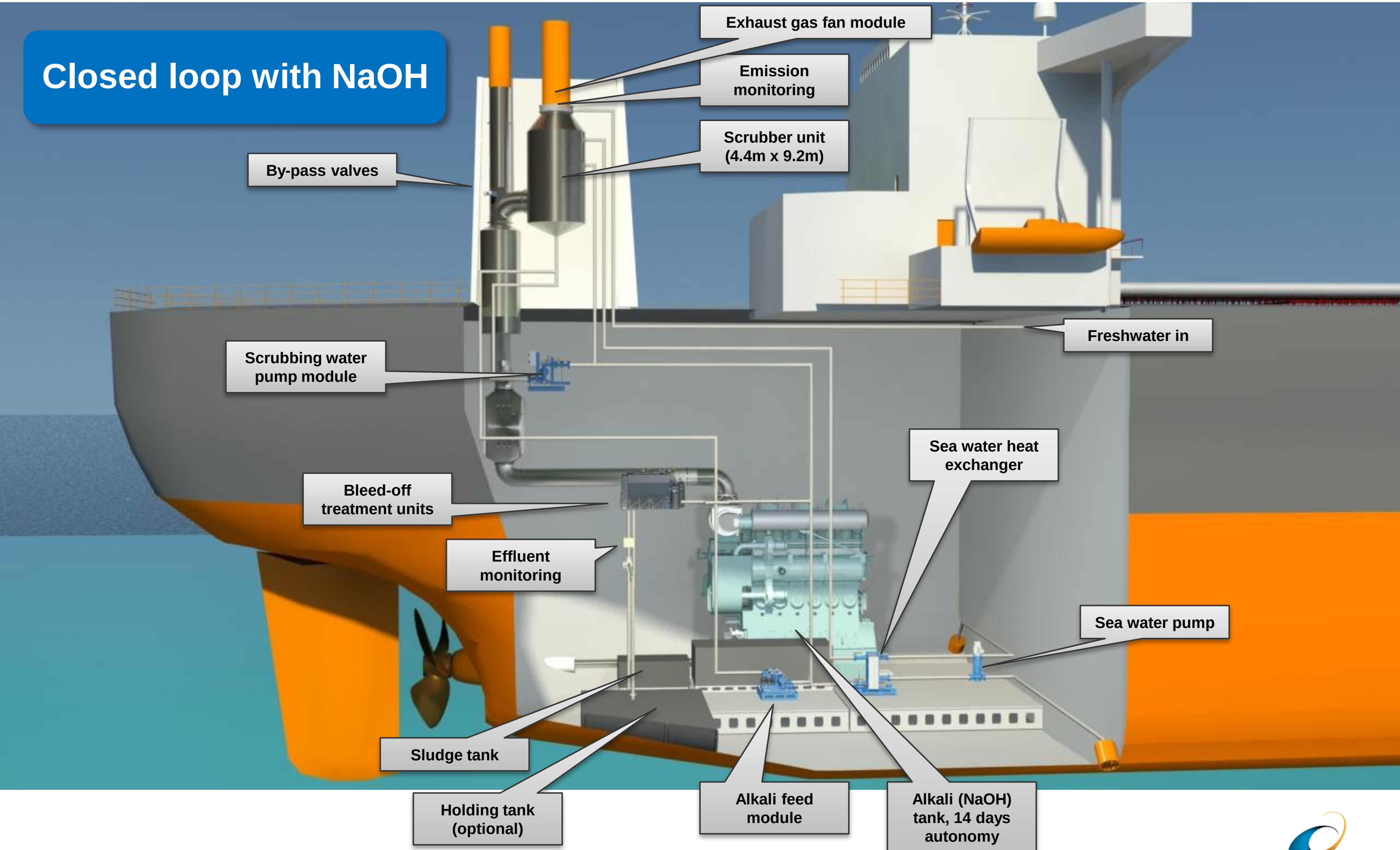
Wärtsilä Hybrid scrubber



Wärtsilä Closed loop scrubber



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Wärtsilä Integrated Scrubber

Main features

- For diesel engines and oil-fired boilers
- One common scrubber unit with suction fan for all combustion units onboard
- Suction branches with by-pass valves from all exhaust gas and flue gas pipes
- Constant under-pressure at scrubber inlet prevents undue flow of gases

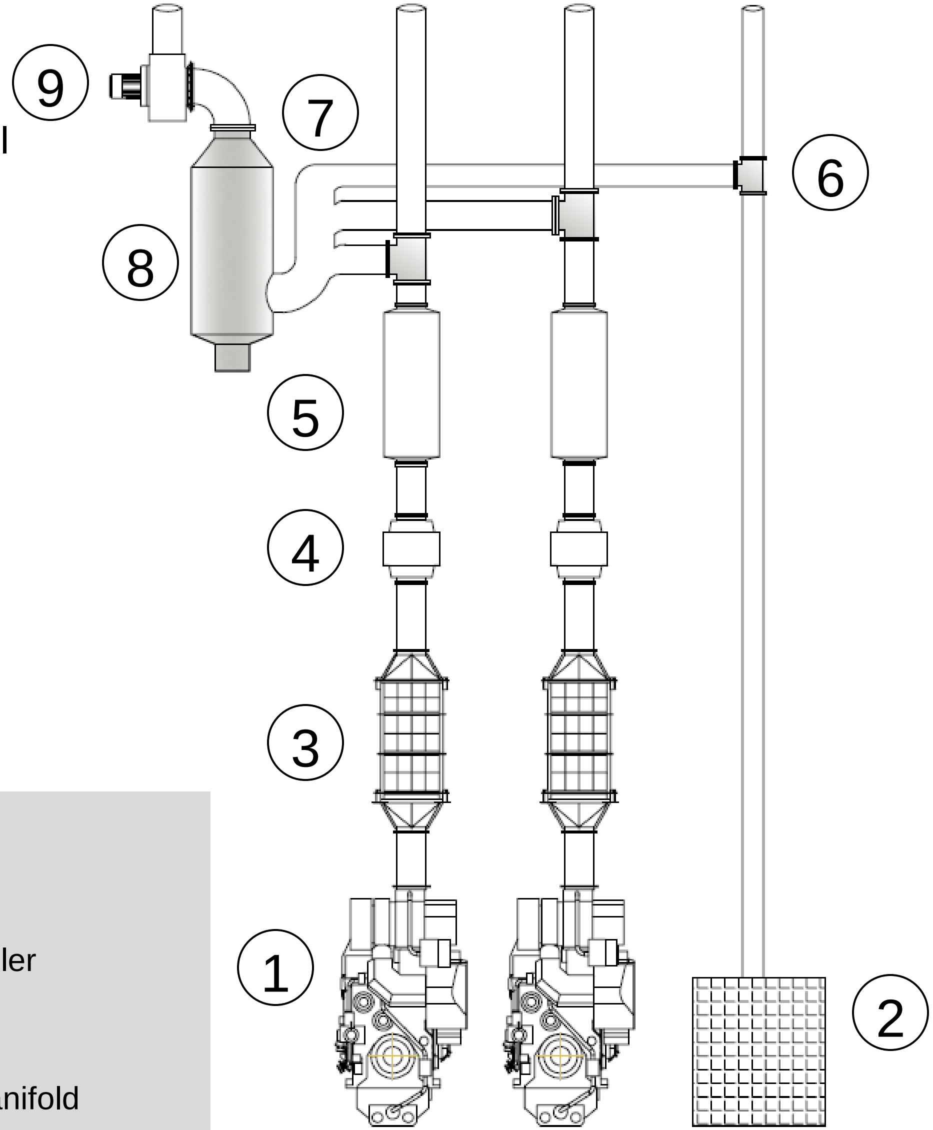
Benefits

- Completely avoids increased exhaust gas back pressure
- Minimizes the amount of equipment

Ideal for

- Single engine cargo ships with HFO gensets
- Multi engine ships
- Tankers with large boilers

1. Diesel engine
2. Oil-fired boiler
3. SCR
4. Exhaust gas boiler
5. Silencer
6. By-pass valve
7. Exhaust gas manifold
8. Scrubber unit
9. Exhaust gas fan



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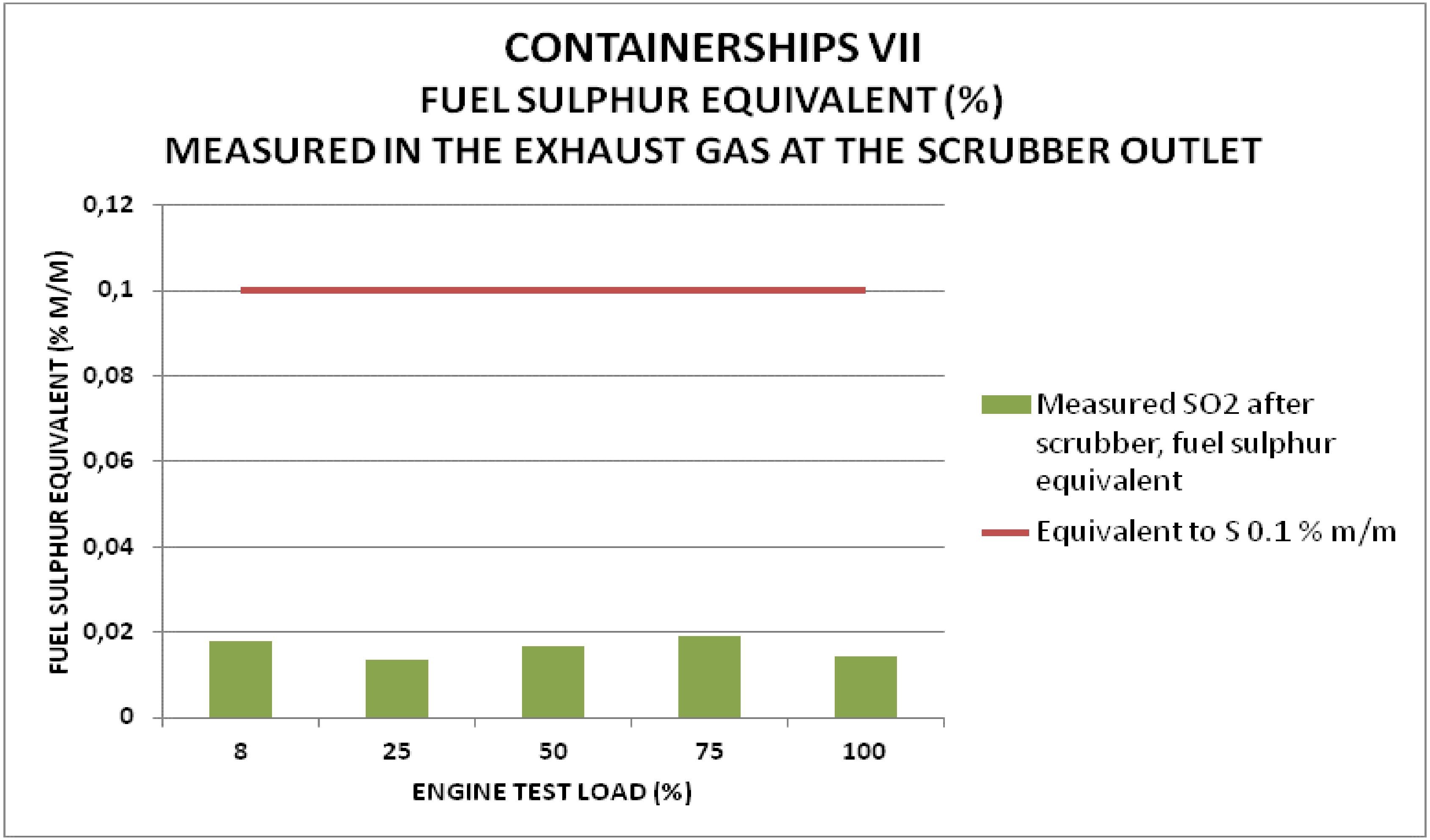
Containerships VII SOx measurements

- *Fuel sulphur content 1.84 %.*
- *Measurement by ackredited third party 2.12.2011.*



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Sludge Seawater Systems

The collected sludge:

Non-hazardous by legislation

To be disposed of ashore

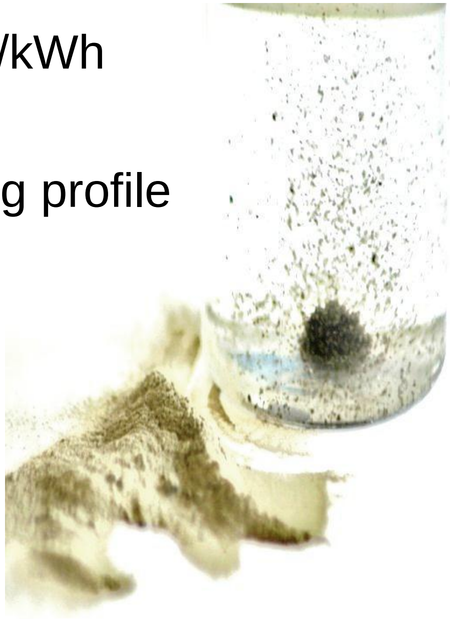
Can be disposed with the vessels waste oils/sludge

Estimated amount closed loop: 2 l/MWh

Estimated amount from Engine Manufacturers open loop: 0,1 g/kWh

The amount depends on silt content in water and engine running profile

Sludge is collected in standard 1m^3 plastic container



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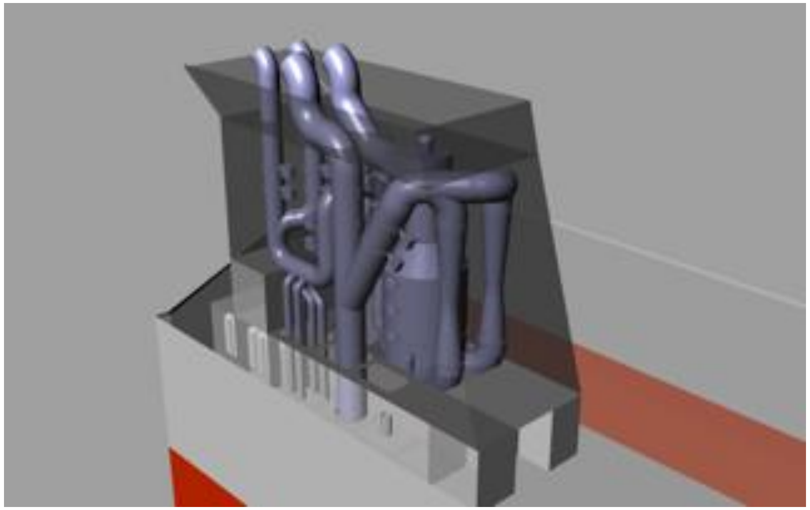
Wärtsilä's unparalleled reference list

Hybrid – Wilhelmsen

- **Vessel :** **MV Tamesis**
- **Size of SWS :** **1 x 25 MW**
  1 x 6 MW
- **Installation type:** **Retrofit**
- **Delivery :** **November 2012**
- **Performance :**
  - **97% SOx Removal**
  - **85 % Particulate Removal**
  - **3,5% fuel sulphur content**



Wärtsilä's unparalleled reference list

An installation in cooperation with Port of Long Beach and APL

- **Vessel :** **APL England**
- **Size of SWS :** **1 x 8 MW with 3 inlets**
  Each inlet for a 2,94 MW engine
- **Installation type** **Retrofit**
- **Delivery :** **January 2011**
- **Performance :**
  - **97% SOx Removal**
  - **85 % Particulate Removal**
  - **3,5% fuel sulphur content**

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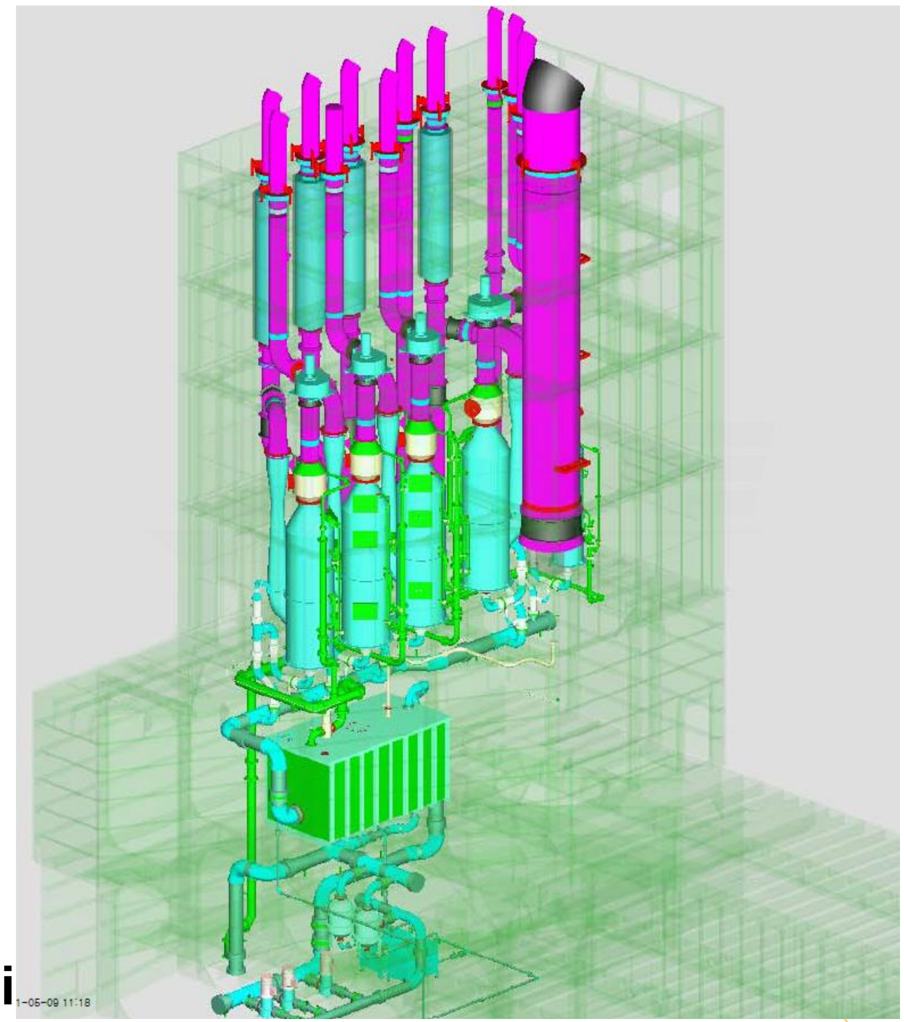
Wärtsilä's unparalleled reference list

Ignazio Messina & C

- **Vessel :** DSME Hull 4465/66/67/68
- **Size of SWS :** 4 x 2 MW auxiliary
  1 x 1 MW boiler
- **Installation type** New building
- **Delivery :**

January 2011	**January 2012**
July 2011	**June 2012**

- **Performance :**
  - **98% SOx Removal**
  - **60-80% Particulate Removal**
  - **Up to 4,5% fuel sulphur content**
  - **Prepared for main engine scrubbi**



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Wärtsilä Moss Test Facility

- **1 MW Exhaust Gas Cleaning installation**
- **Tests run continously**
- **Training for ships crew on Inert Gas Systems**
- **Future training on Exhaust Gas Cleaning Systems**
- **Demonstration for potential customers**

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Scrubber installation, retrofit aspects

For existing ships, the retrofit of a scrubber requires tailor-making.
Some aspects to be considered for retrofits are:

- Space; design of exhaust gas funnel
- Ship stability
- Space available for tanks, pumps and water treatment unit(s)
- Power demand for the scrubber system
- Sea chest , capacity of supplying water to the scrubber system
- Fresh water capacity (closed loop and hybrid scrubber only)

Wärtsilä – added value partnership

- technology choice to suit the ship type and operational profile
- turnkey supply capability
  - trusted partnership
  - survey and equipment selection
  - engineering and project management
  - procurement and equipment delivery
  - installation, commissioning and certification
  - through life technical, spares and service support
- credible supplier to the marine and offshore sector
- proven global support capability

Conclusions

Reflections on fuel prices and attractiveness of solutions

- Global demand for distillates is likely to increase → Price of MGO is expected to increase while price of HFO will stay the same or even decrease
- Scrubbers demonstrated to work in marine environment
- Scrubbers allow for same bunkering and same engine operation as before
- European SECA now ratified, more SECAs can be expected
- Wärtsilä has the largest portfolio of marine scrubber solutions
- Wärtsilä scrubber solutions are fit for new buildings and retrofits, for any engine and boiler brands

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Thank You!

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