UNECE guidance document

Maritime shipping

TFTEI technical secretariat
Grégoire Bongrand (Citepa)

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Guidance document on shipping

- Objective: provide to CLRTAP Parties effective means to minimize impacts of maritime shipping activities on human health and environment
- Scope: all marine ships under the MARPOL convention, during navigation but also while maneuvering in ports and at berth
- Substances targeted: SO_2, NO_x, PM, BC, VOC and CO
- Subject: emission reduction techniques, technical and financial aspects
- Format: 10,000 words (with no images, figures or tables)
- Finalization and submission to the UN in December 2022

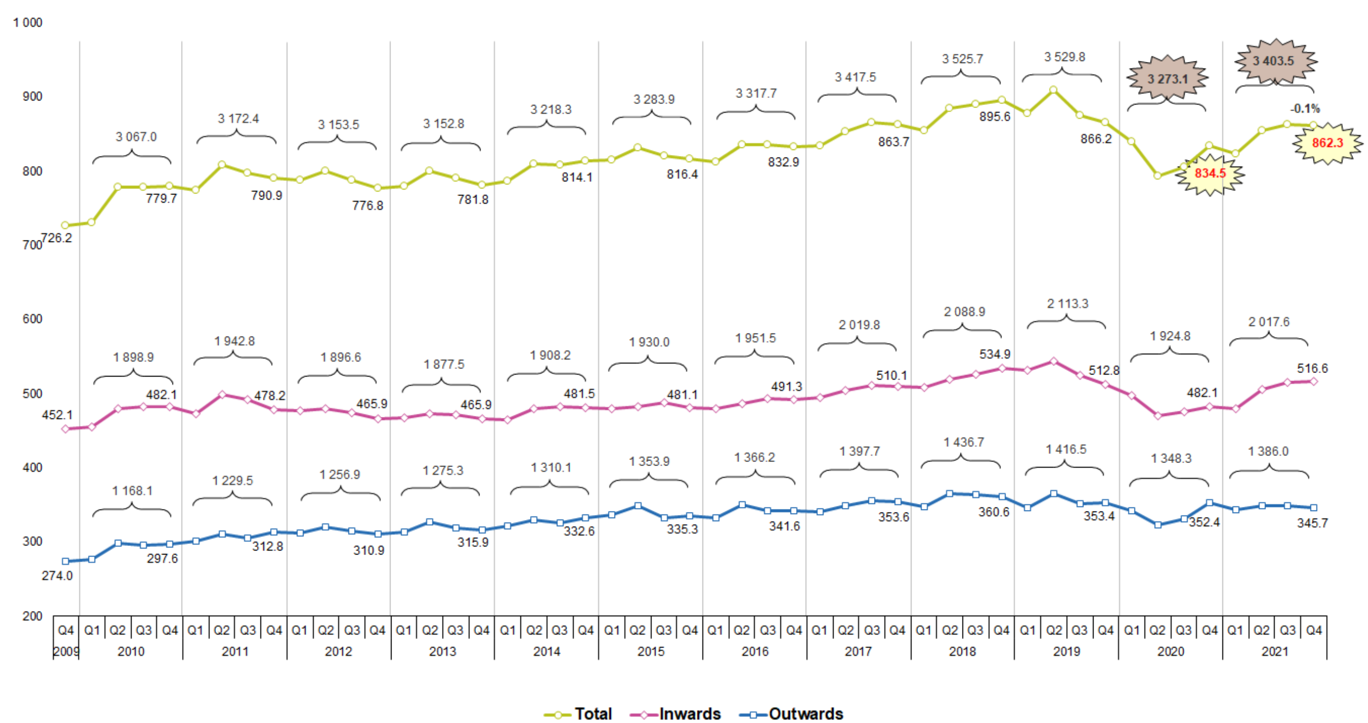
Overview of presentation/guidance doc

- Background information
- Legislative framework
- Primary reduction techniques : fuel switches, slow steaming, etc.
- Secondary reduction techniques : scrubbers, EGR, SCR and filters
- Reduction techniques for ships at berth
- Conclusions and next steps

Background information – generic :

- International shipping transport: ~ 80% of world trade volumes
- Intensifying activities:
  - . Highest amount of goods handled in EU ports in 2019 (2021 ↔ 2017)
  - . Growing oil product consumptions

Gross weight of seaborne goods handled in main ports by direction, EU, 2009Q4-2021Q4
(million tonnes)



Source: Eurostat (online data code: mar_qg_qm_ewhd)

eurostat

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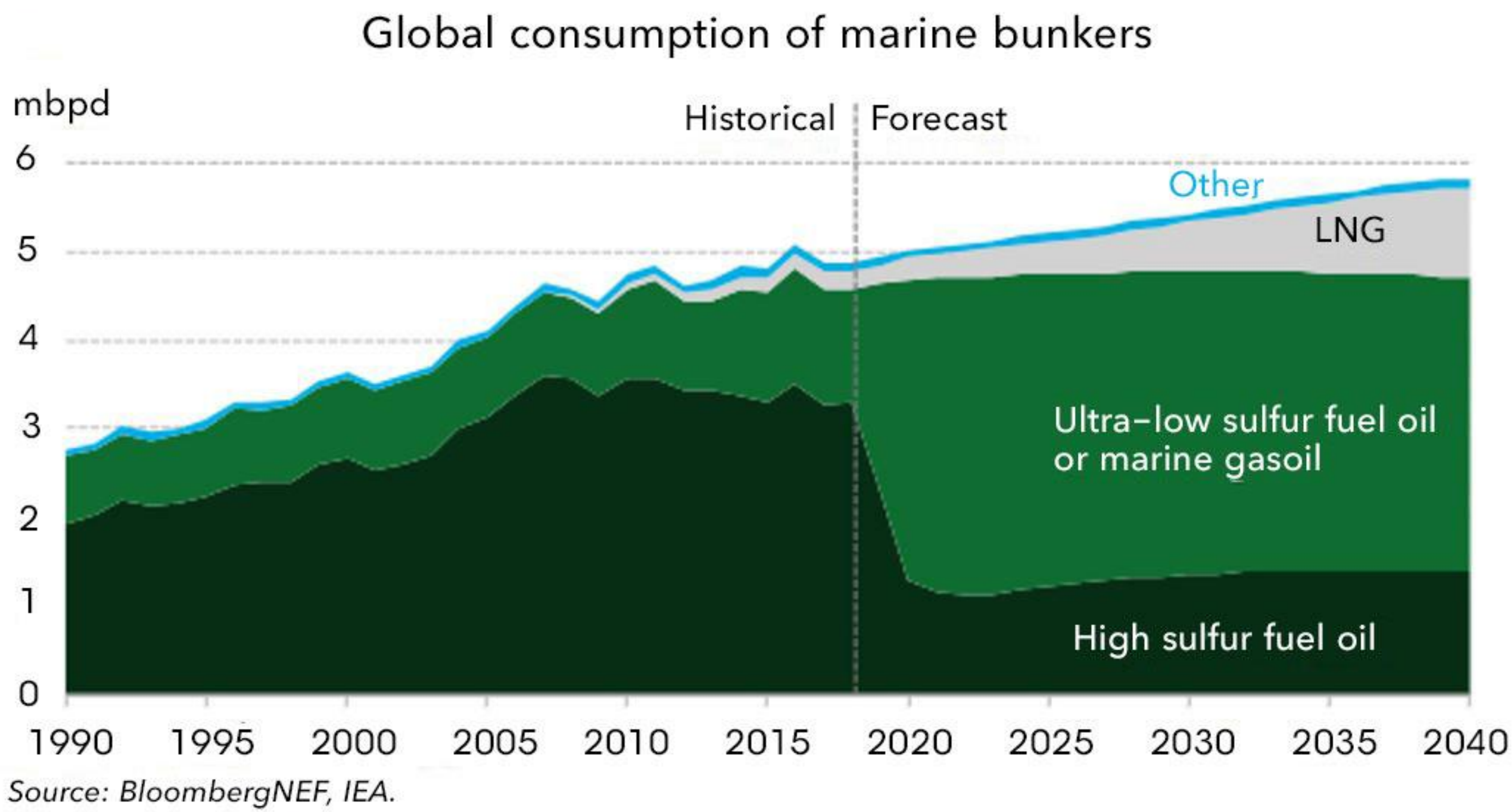
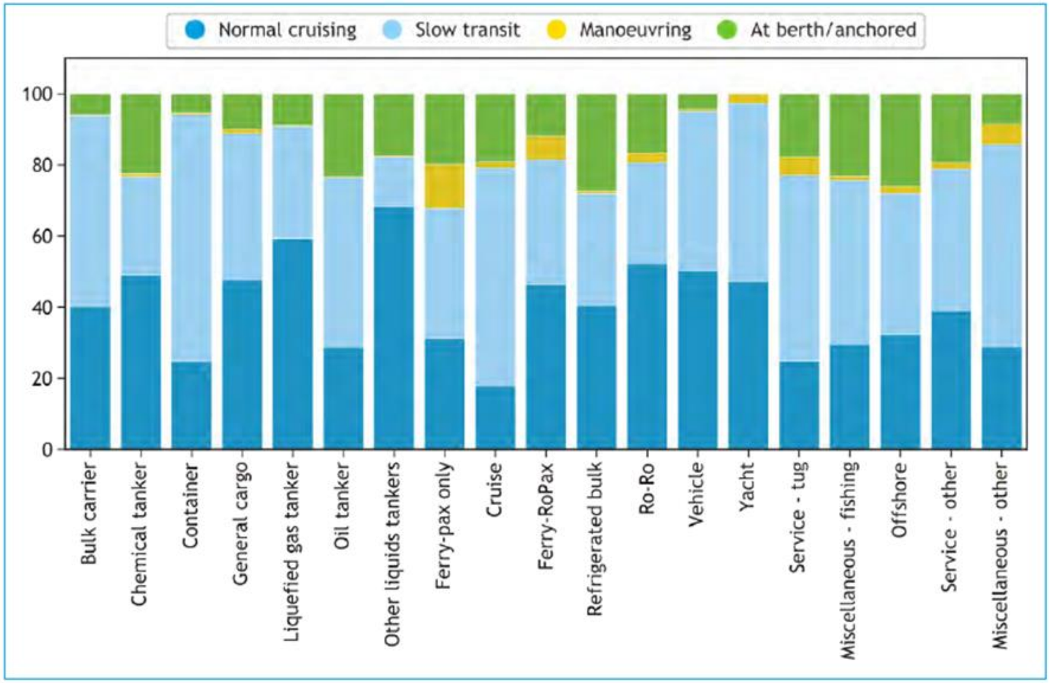


Background information – ports :

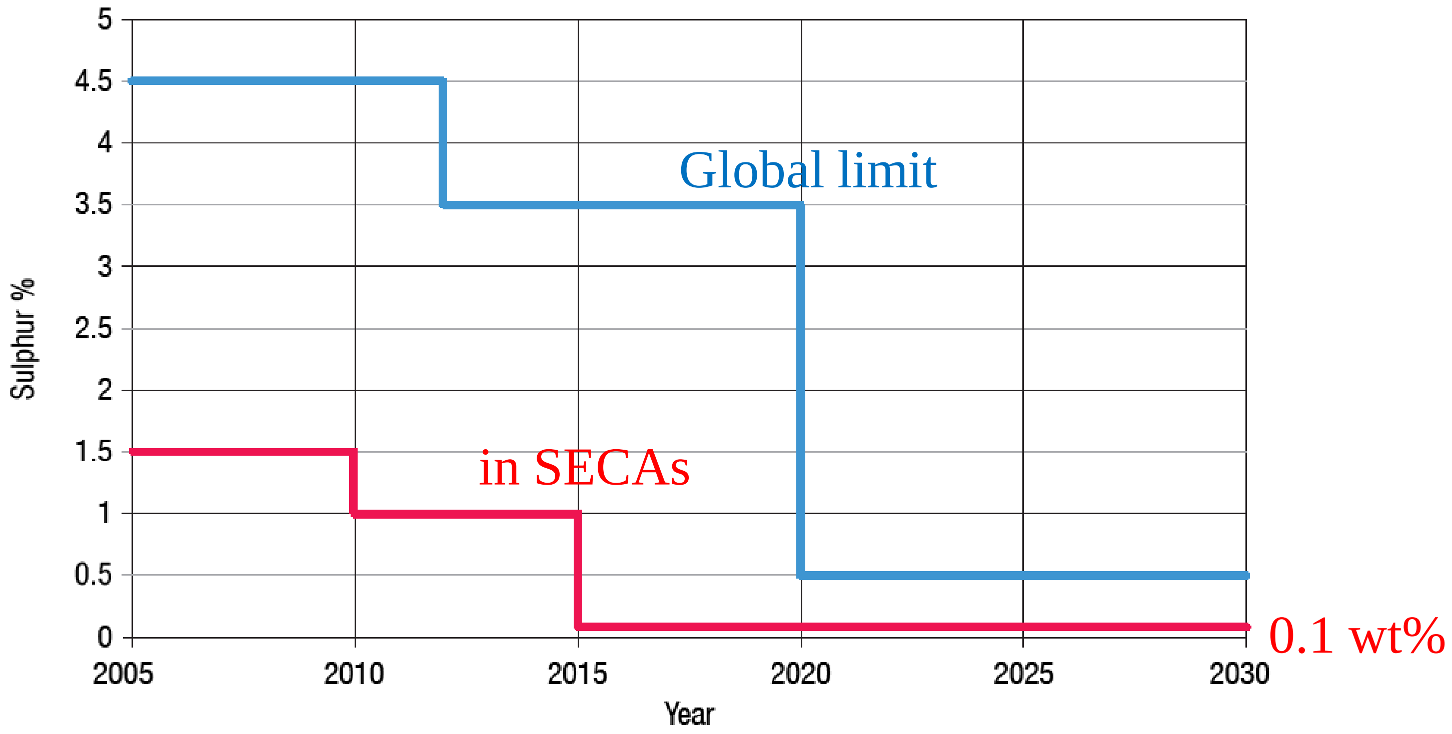
- Increased interest due to the proximity with population
- Manoeuvring and hotelling contribute largely to the ship total fuel consumption (~ 20% for chemical and oil tankers)
  → important pollutant emissions, especially due to operating conditions
- Fugitive VOC emissions due to O&G distribution (2017: 2.5 Mt vs. 0.8 Mt comb.)



Share of GHG emissions (in CO_{2e}) of international shipping in 2018 (source: IMO 2020)

Legislative framework – SO_2

Fuel sulphur content limits (in wt%) according to Marpol Convention Annex VI



→ Recent update : implementation of a SECA in the Mediterranean sea in 2025

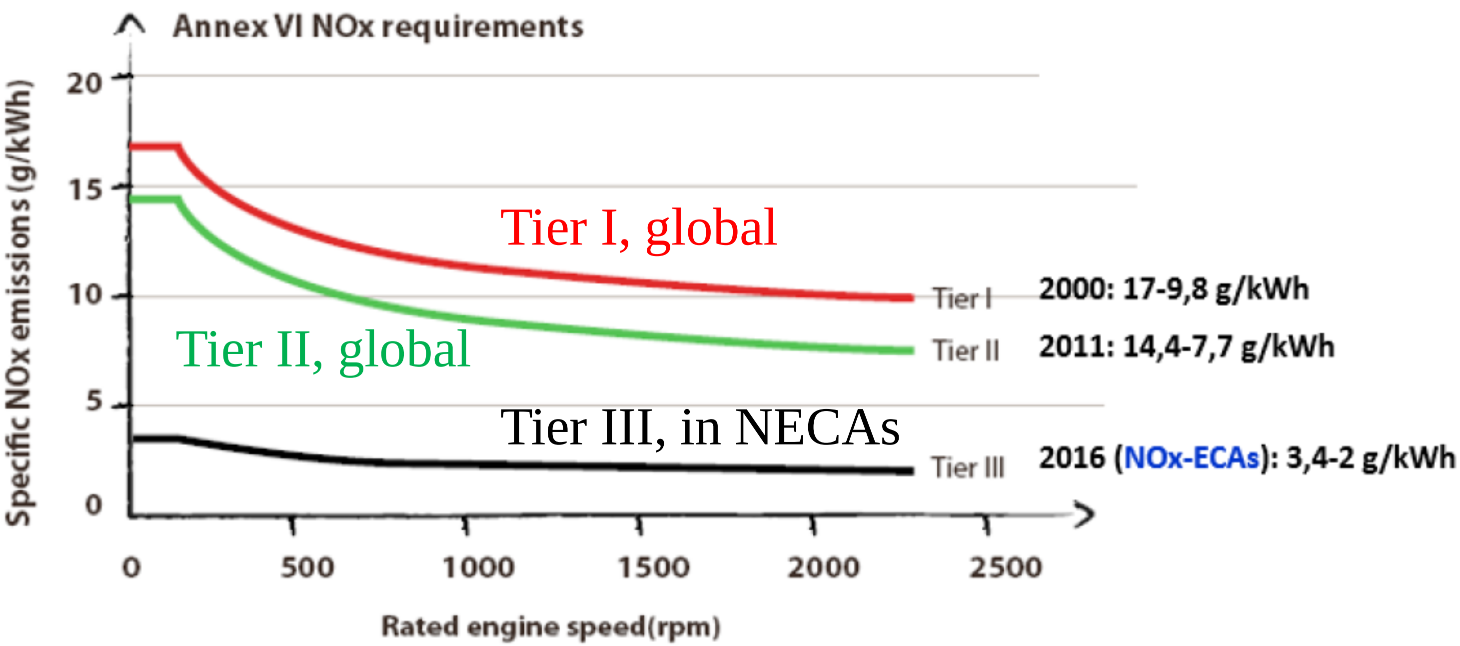
In ports : regional regulations imposing 0.1 wt% (Dir. 2012/33/EU for EU or in California within 24 nm zone)

Legislative framework – NO_x

NO_x: Marpol Convention annex VI requirements

- ✓ **Tier I limits to be met globally** by all ships from January 1st, 2000
- ✓ **Tier II limits to be met globally** by all ships constructed after January 1st, 2011
- ✓ **Tier III limits to be met in NO_x Emission Control Areas** (NECA)

North America NECA (2016) and Baltic Sea, North Sea and English Channel (2021)



In ports : regional only ; e.g. 6 Californian ports impose shore power or else alternative techniques to achieve similar reductions (> 85-90 % ; for PM as well)

Primary reduction measures: fuel switch

Low-sulphur content fuel oils:

- Large SO_2 reductions since IMO 2020 but further possible
- Distillate fuels: reductions of PM of 50-90% and BC of 0-80%

LNG:

- SO_2 emissions almost negligible (90-100% reductions)
- Other reductions: 64-90% NO_x, 60-98% PM, 75-90% BC but CH_4 increase
- Gain in fuel consumption (5-10%) → hence CO_2

Biofuels:

- Lower carbon footprint: 70-100% on LCA basis, but fuel penalty of 8-11%
- PM reductions 12-70% and 38-75% for BC compared with fuel oil

Primary reduction measures: fuel switch

Methanol:
- Drastic CO_2 reductions if made from biomass
- SO_2 almost negligible; reductions of PM > 90% and NO_x from 30-60%
- Fuel penalty of ~ 9%

Hydrogen (H_2):
- Large CO_2 reductions if made from water electrolysis (no CO_2 if nuclear or RE)
- If use in fuel cells → zero emission
- Problems of space, availability and safety + fuel cell matureness for ships

Ammonia (NH_3):
- Ammonia is carbon-free, but energy-intensive production → green ammonia
- Main problem is toxicity; but better than H_2 for space, storage and infrastructures

Primary reduction measures: other

Water-in-fuel emulsions (WiFE):

- Lower combustion temperature → less thermal NO_x formation (up to 60% reduct°)
- Other reductions: 20-90% for PM, 0-85% for BC
- Fuel penalty of 0-2%

Slow steaming (reducing sailing speed):

- Fuel savings up to 50% → CO_2 and SO_2 emission reductions
- Other reductions: 21-64% for NO_x, 18-69% for PM, up to 30% for BC, but CO ↗

Battery-powered ships (electric or hybrid):

- CO_2 emission reductions of 10-40% for hybrid; no CO_2 for electric if production made from nuclear or renewable → though interest in LCA
- Transfer of pollutant emissions to TPP which are better equipped

Wind-propulsion assistance:

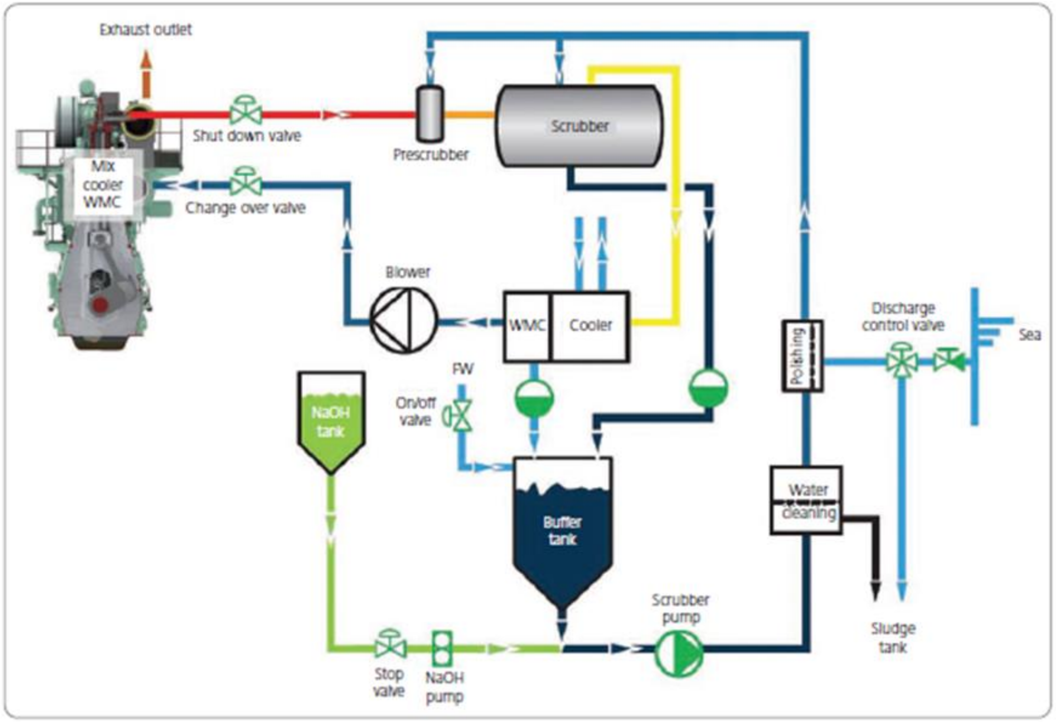
- Fuel savings up to 50% possible but average annual savings observed at 8-10%

Summary for primary measures

Reduction techniques :	SO_2	NO_x	PM	BC	fuel penalty	Investments costs (€/kW)	Operation & maintenance costs
Primary measures:							
- Switch to low sulphur fuels	up to 97%[1]	-	60-90%	30-80%	-	-	88-223 €/t fuel
- Switch to LNG	90-100%	90%	98%	75-90%	- 5-10%	219-1603	- 43 €/t fuel (+ fuel savings)
- Switch to water-in-fuel emulsions	-	1-60%	20-90%	up to 85%	+ 0-2%	11-44	33-271 k€/year[5]
- Switch to biodiesel and biofuels	-	-	12-37%	38-75%	+ 8-11%	-	-
- Switch to methanol	100%[3]	55%	99%	97%[2]	+ 9%	-	10-15 €/MWh
- Slow steaming	13-50[4]%	21-64%	18-69%	0-30%	- 15-50%	71	- 42-77% (fuel savings)[6]

Secondary reduction measures: EGR

- Recirculation of exhaust gases into the combustion chamber: decrease combustion temperature, pressure and oxygen content → lower NO_x formation
- Pollutant reductions : 25-80% NO_x, 0-20% BC and PM due to gas cleaning
- Fuel penalty of 0-4% (hence CO_2 increase)

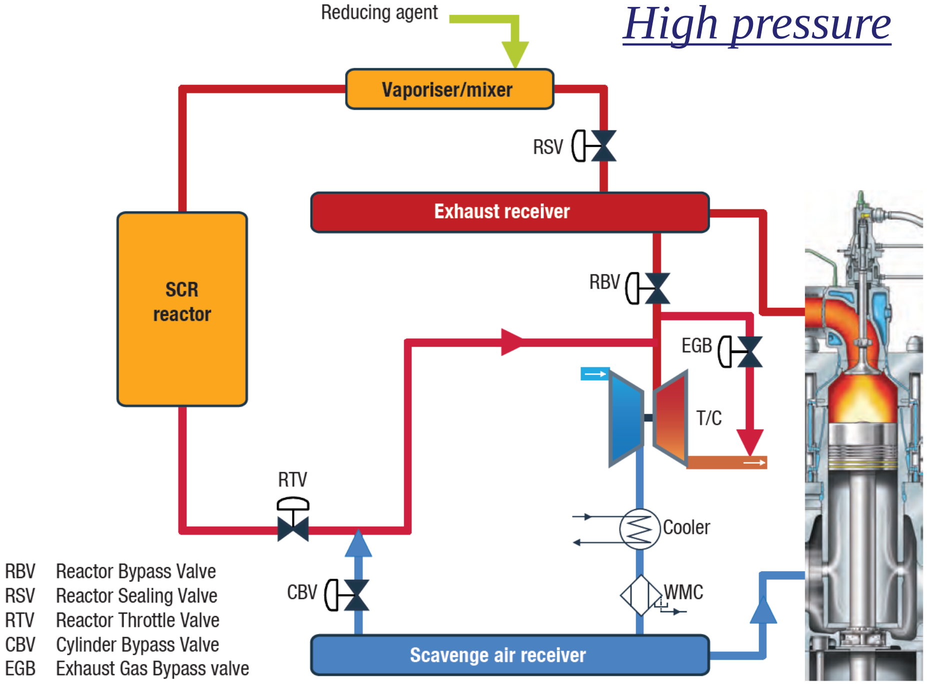


Source: Lloyd's Register (2012). Understanding exhaust gas treatment systems.

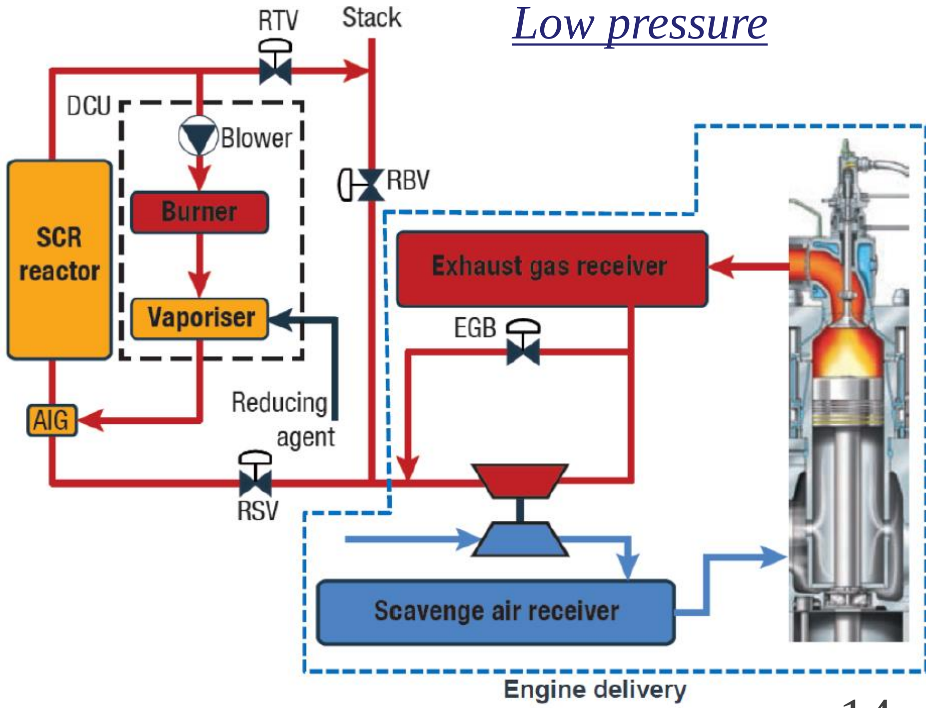
Secondary reduction measures: SCR

- Chemical reaction with ammonia solution to neutralize NO_x and form N_2 and H_2O
- Emission reductions: 70-95% for NO_x, but NH_3 potential leaks
  + 10-40% for PM and 50-90% for CO and VOC if oxidation catalyst is used
- Fuel penalty of 0-2%

High pressure



Low pressure



Source: Man 2018 – NOx reduction – Tier III solutions

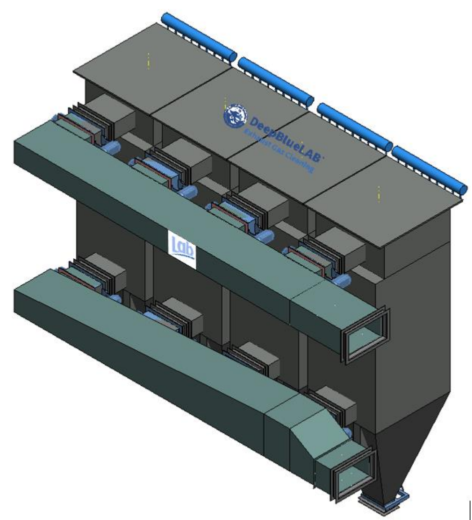
Secondary reduction measures: PM filters

Diesel particulate filters (DPF):

- Porous ceramic substrate to trap particles + burning (i.e. maintain efficiency)
- Emission reductions: 45-92% for PM, 70-90% for BC
  + if oxidation catalyst (only with low sulphur fuels) 60-90% for VOC/CO
- Fuel penalty of 1-4%

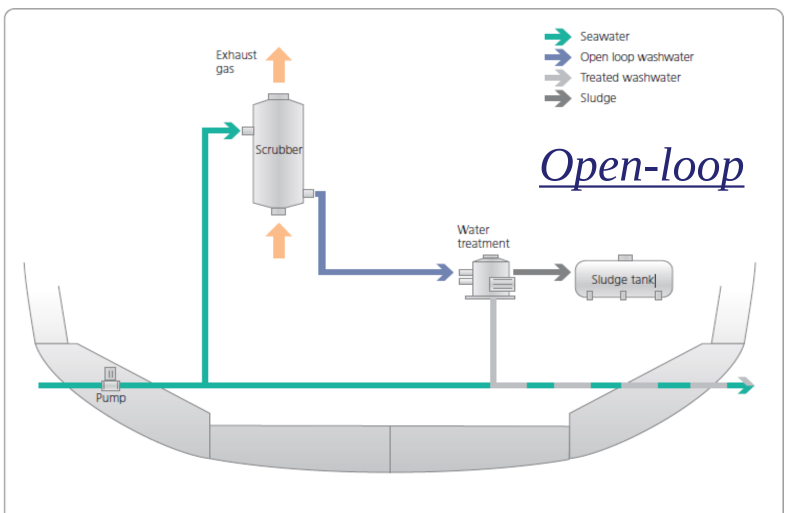
Baghouse filters:

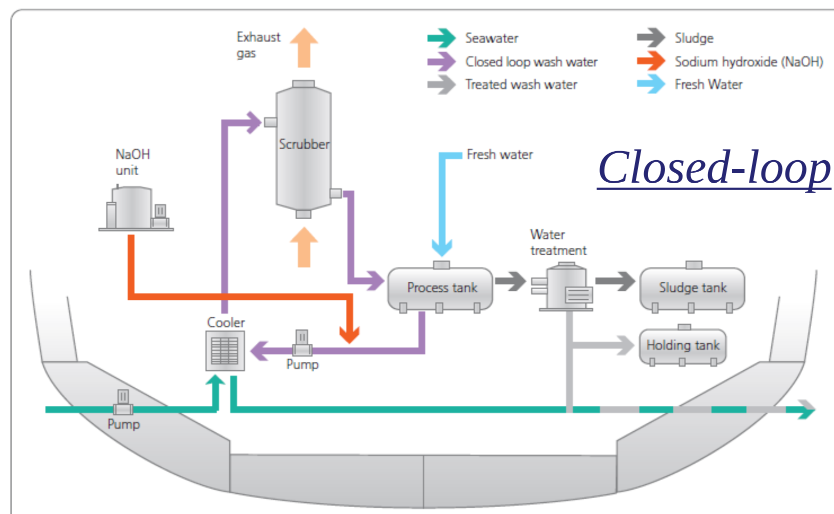
- Sodium bicarbonate injected to tackle SO_2 and ensure good efficiency
- PM and BC reductions > 99%



Secondary reduction measures: scrubbers

- Chemical reaction with alkaline solution (solid or liquid) to neutralize SO_2
- 2 types: dry or wet, and 3 configurations for wet: open-loop, closed-loop or hybrid
- Reductions: 90-98% for SO_2, 70-90% for PM and 25-70% for BC
- Fuel penalties of about 0.5-3%





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Summary of results

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- Slow steaming	13-50[4]%	21-64%	18-69%	0-30%	- 15-50%	71	- 42-77% (fuel savings)[6]
Secondary measures:							
- Exhaust Gas Recirculation (EGR)	-	25-80%	-	0-20%	+ 1-2%	36-60	17-25€/kW
- Selective Catalytic Reduction (SCR)	-	70-95%	20-40%	-	-	19-100	3-10 €/MWh
- PM filters	-	-	45-92%	70-90%	+ 1-2%	16-130	+1-4% fuel penalties
- Scrubbers	90-98%	-	70-90%	25-70%	+ 0.5-3%	100-433	0,7[7]-12 €/MWh (~2% of capital investments)

Reduction techniques for ships at berth

- BAT for propulsion engines applicable in ports, only some secondary measures unavailable at very low engine loads

- For fugitive VOC: vapor recovery systems tackle 99% of VOC emissions

<u>On-shore power supply systems</u>:

- Efficient if and only if electricity production is regulated/clean

→ NO_x, SO_2, PM and VOC emissions can be reduced by up to 95%

- Implementation in Europe could reduce CO_2 emissions by 39% (up to 99% locally)

<u>Shore-based exhaust cleaning systems</u>:

- Plug to ship exhaust stacks to clean their flue gas
- General system: scrubber combined to SCR
- Reductions: > 85% for SO_2 and VOC, 98% for PM and 95% for NO_x

Thank you very much for your attention!

Questions?

TFTEI Technical Secretariat

(contact : gregoire.bongrand@citepa.org)

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Karlsruher Institut für Technologie

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