TFTEI

Under the Convention on Long Range Transboundary Air Pollution

Technical work on shipping emissions (SO_2, NO_x, PM and BC)

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Ship Maneuvering out of Port
StLouis du Rhone, near Marseilles

TFTEI 2020 annual meeting
October 22nd, 2020

Summary of the presentation

- Objectives of the technical document
- Evolution of shipping transport
- International legislation for abating SO_2 and NO_x
- Primary reduction measures : fuel switches, slow steaming, etc.
- Secondary reduction measures :
  SO_2 scrubbers, NO_x EGR and SCR and PM filters
- Conclusions and next steps

Objectives of the document

- Provide Parties to the UNECE Convention on the Long Range Transboundary Air Pollution (CLRTAP) with guidance in identifying the best abatement options for shipping emission sources and assist them in meeting their obligations for SO_2, NO_x, PM and black carbon

- Emphasis given both on primary techniques (actions on fuel characteristics or combustion process) and secondary ones (exhaust gas treatment)

- Cost estimation review for each presented techniques

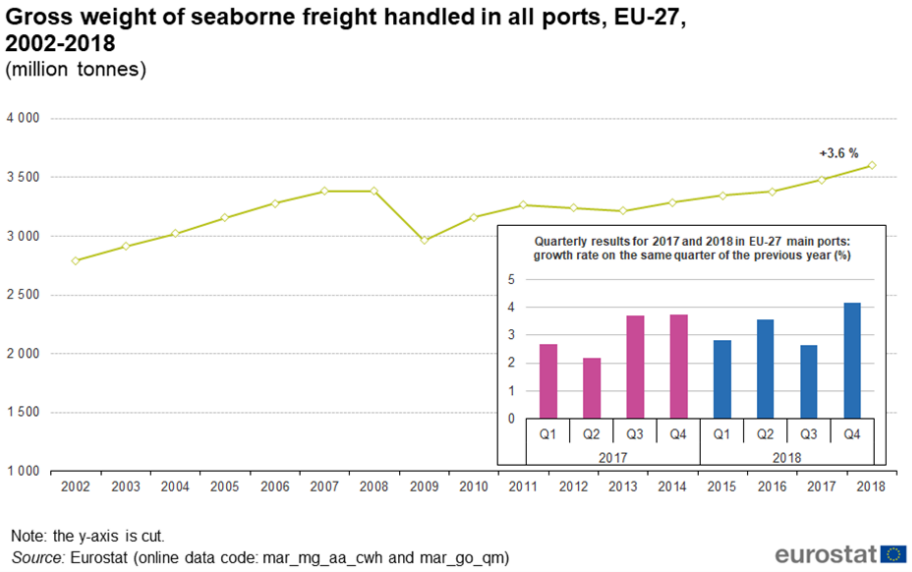
Summary of the presentation

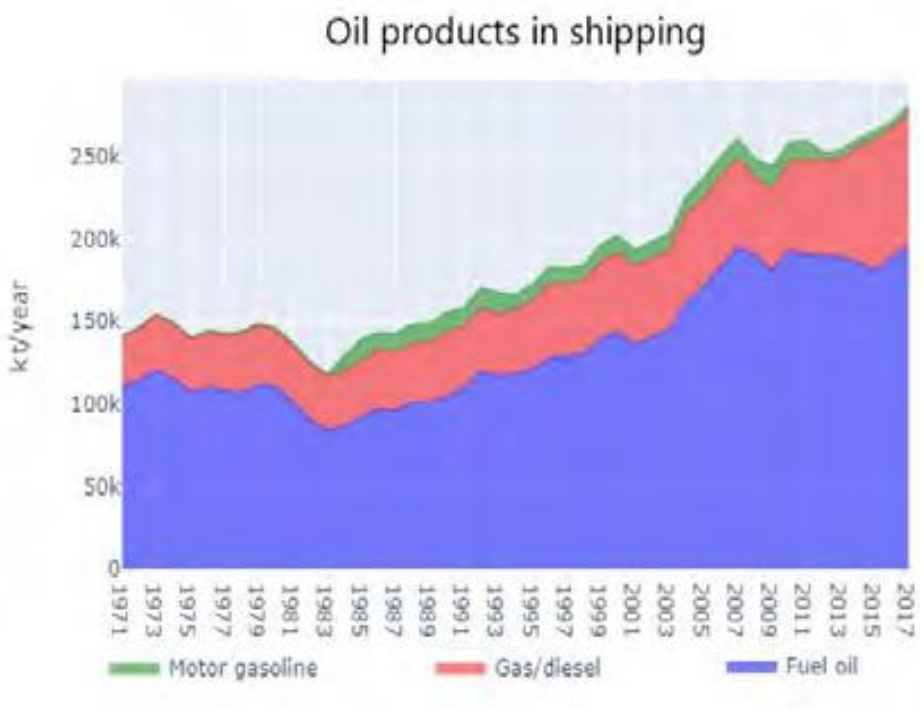
- Objectives of the technical document
- Evolution of shipping transport

Evolution of shipping transport

- International shipping transport: ~ 80% of world trade volumes

- Intensifying activities:
  . +3.6% in 2018, higher than pre-crisis levels of 2009
  . Growing oil product consumptions





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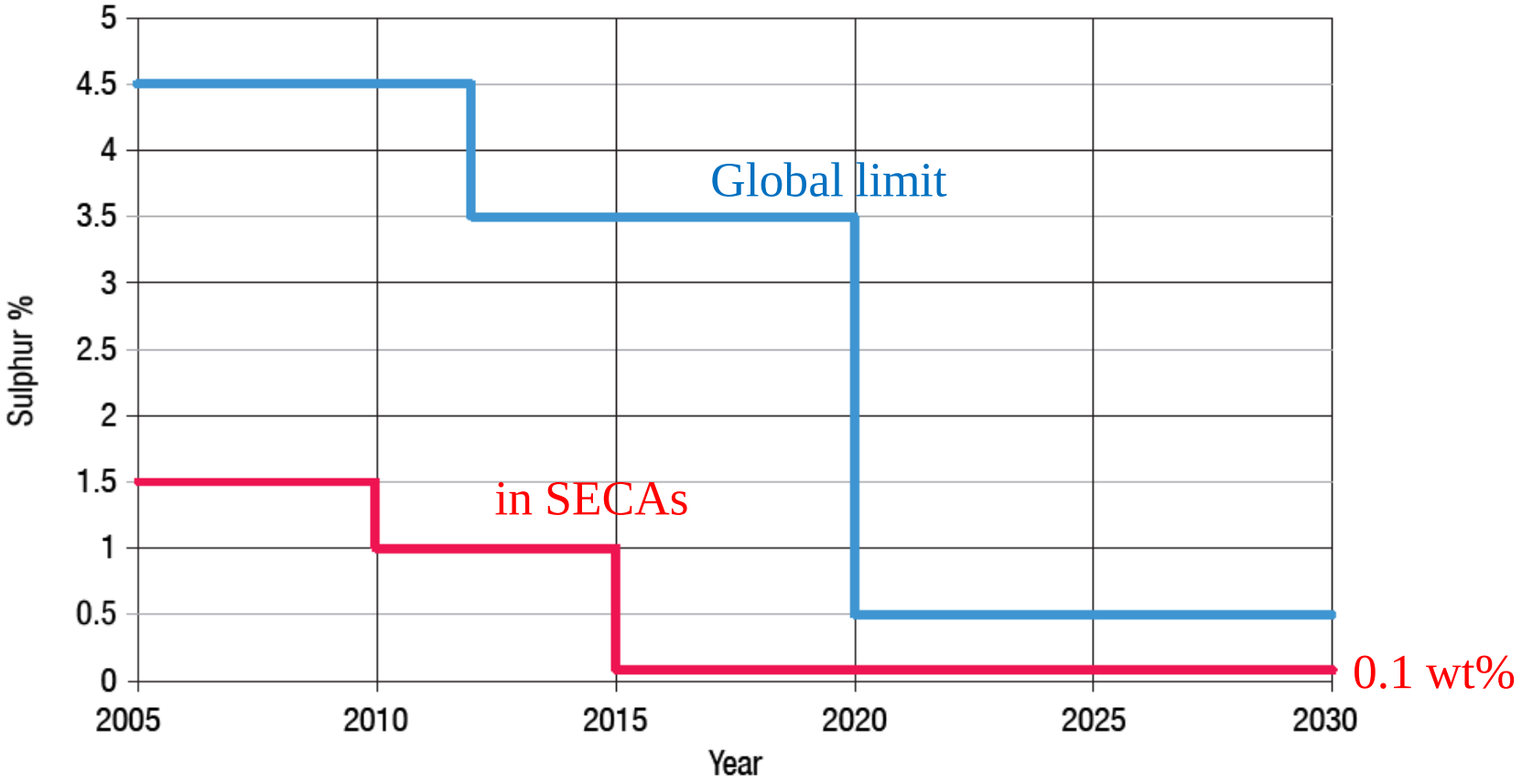
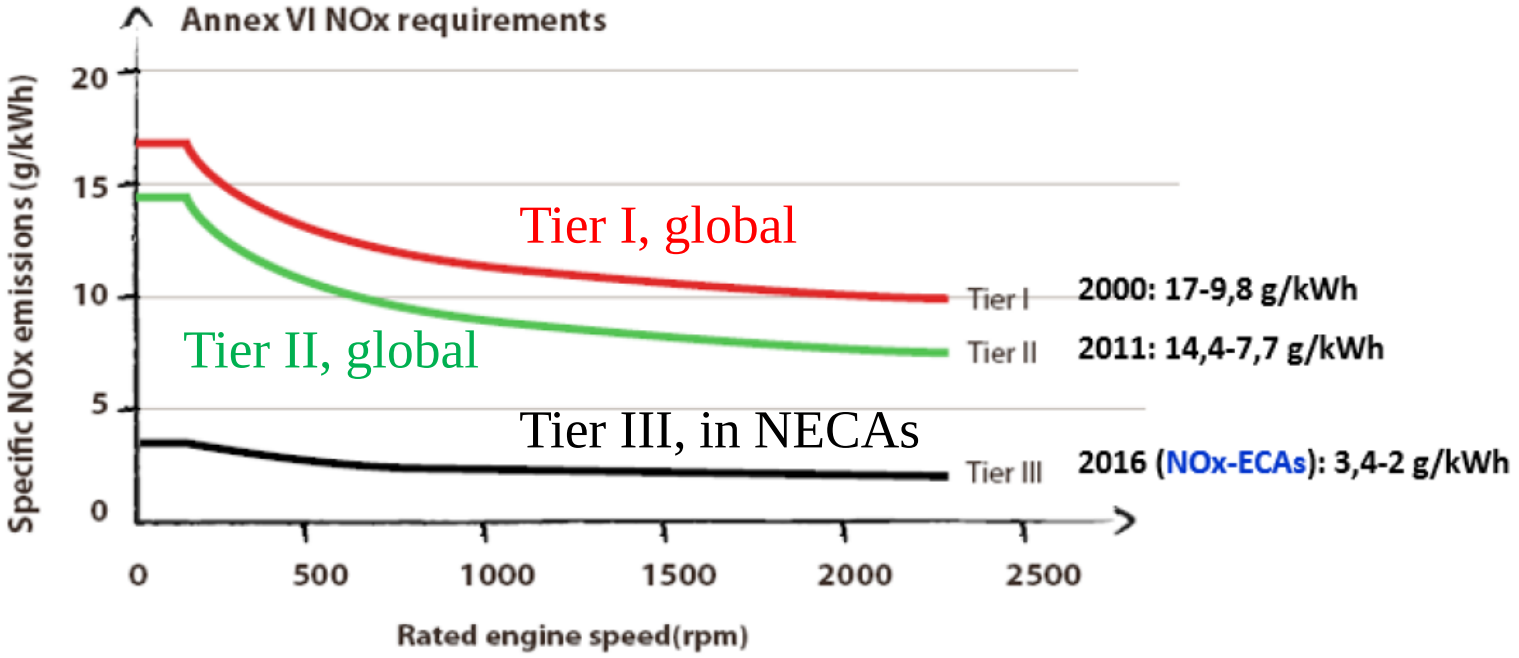
Fuel sulphur content limits (in wt%) according to Marpol Convention Annex VI



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: from January 1st, 2016
  - Baltic Sea, North Sea and English Channel from January 1st, 2021



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- Primary reduction measures : fuel switches, slow steaming, etc.

Primary reduction measures: switch to low sulphur fuels or LNG

Low-sulphur content fuel oils:

- SO_2 emissions directly proportional to sulphur content: reductions up to 97%

- Reduction of TSP/PM emissions from 60% to 90% for a switch to distillate fuels
  → BC emissions reduced from 0% to 80% (median at 30%)

LNG:

- In 2015, about 2.4% of the marine shipping consumption was LNG

- Very low sulphur content: SO_2 emissions almost negligible - reductions by 90-100%

- Other important pollutant reductions:
  - 90% for NO_x
  - 98% for PM
  - 75-90% for BC
  - but, CH_4 emission increase

Primary reduction measures: switch to water-in-fuel emulsions (WiFE)

- Mixture of water, emulsifiers and fuel oil (HFO or diesel)

- Lower combustion temperatures → lower NO_x formation (-1% per % added water)
- NO_x emission reductions achievable up to 50-60%

- Other reductions achievable: up to 20-90% for PM, up to 45-85% for BC
- 0-2 % fuel penalty

Primary reduction measures: switch to biofuels or methanol

- **Biofuels:** PM reduced by 12-37% ; BC by 38-75% compared with HFO
- Important CO_2 reductions, but higher consumption : 8-11% lower energy content

- **Methanol or DME:** 95-100% CO_2 reductions if made from biomass, none if made from natural gas
- no sulphur (no more SO_2) ; other reductions: 35-55% NO_x, 99% in PM (solid fraction, ~ 55% in total) compared with diesel, but 9% drop in fuel efficiency

- Limitations of cost and availability for biofuels and methanol made from biomass

Primary reduction measures: slow steaming

- Reducing the sailing speed to achieve fuel savings (up to 50%)

- Environmental benefits, reductions by:
  - 13-50% SO_2,
  - 21-64% NO_x,
  - 18-69% PM and 0-30% BC
  - CO_2 reductions, proportional to fuel savings
  - but, potential negative impacts on CO at lower load factors

- Limits about delivery efficiency (eventual increased ship fleet required, e.g. about 33% more ships for a 25% speed reduction)

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]

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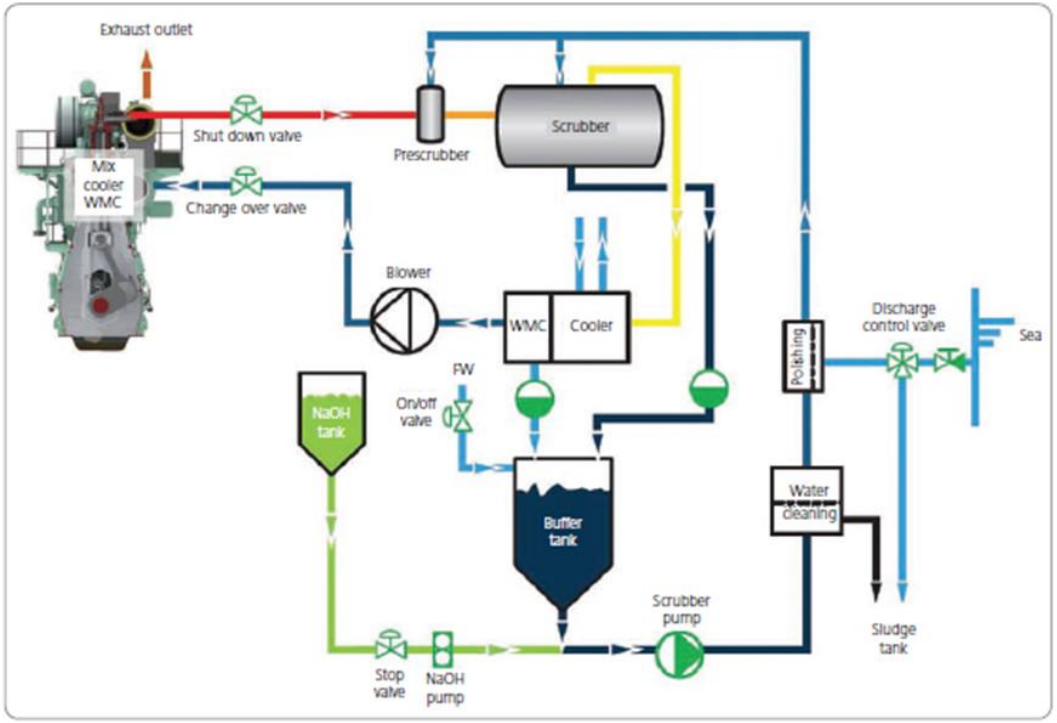
Secondary reduction measures: EGR

- Recirculation of exhaust gases into the combustion chamber: decrease combustion temperature, pressure and oxygen content → lower NOx formation
- Exhaust gases need to be cleaned to prevent corrosion (coupled w/ DPF or scrubber)
- Pollutant reductions : 25-80% NO_x, 0-20% BC and PM due to gas cleaning

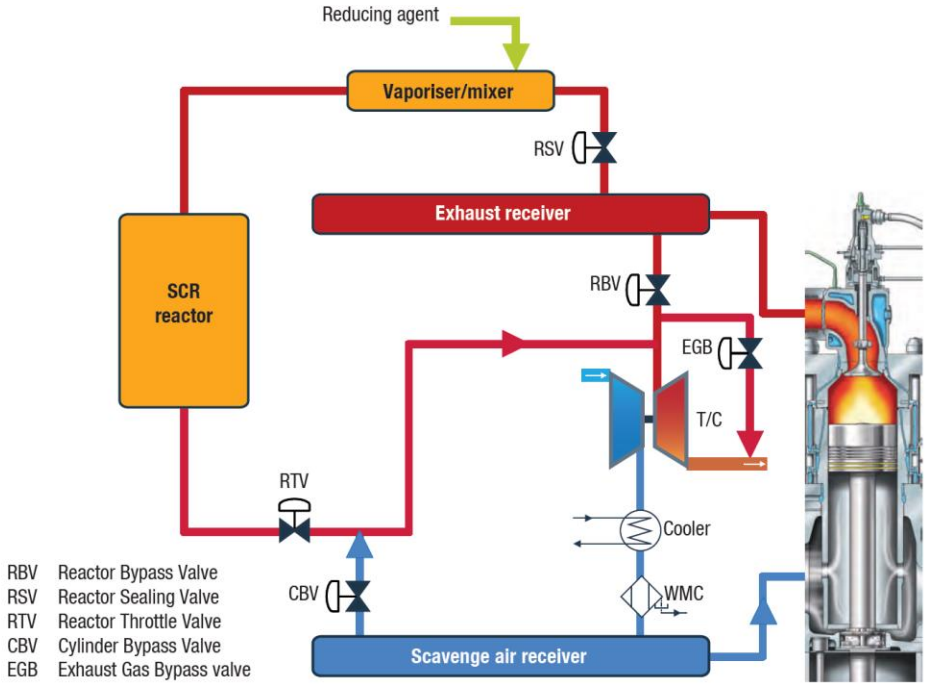


Source: Lloyd's Register (2012). Understanding exhaust gas treatment systems.

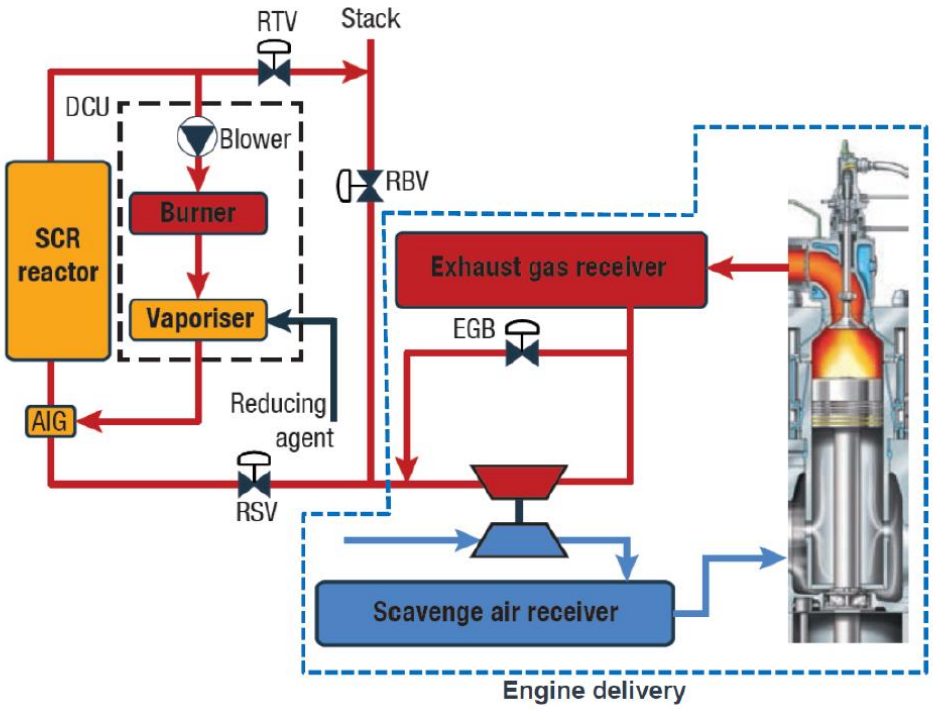
Secondary reduction measures: SCR

- Chemical reaction with ammonia solution or urea (NH_3) to neutralize NO_x and form N_2 and H_2O

High pressure



Low pressure



Source: Man 2018 – NOx reduction – Tier III solutions

Secondary reduction measures: SCR

- Risk of ammonia solution leakage
  + risk of ammonium bisulfate formation at low T° (> 300°C w/ HFO)

- Pollutant reductions :
  - 70-95% NO_x,
  - BC emissions to some extent,
  - but, risk of NH_3 emission increase

  if an oxidation catalyst is present, potential reductions of :
  - 20-40% for PM,
  - 50-90% for CO and VOC,

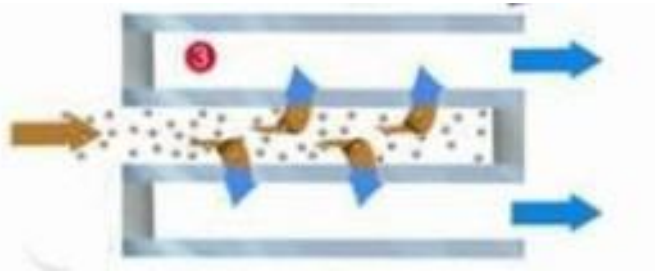
  suitable with fuels with low sulphur content only.

Secondary reduction measures: Diesel particulate filters (DPFs)

- Porous ceramic substrate to trap particles + burning (i.e. maintain efficiency)

- Important reductions:
  - 45-92% for PM,
  - 70-90% for BC
  - 60-90% for VOC/CO, if oxidation catalyst but only with low sulphur fuels

- Limits: - fuel with max. 0.5 wt% S required
  - fuel penalty of 1-4%



Secondary reduction measures: scrubbers

- Chemical reaction with alkaline solution (solid or liquid) to neutralize SO_2
- Two types: dry or wet, and three configurations for wet types: open-loop, closed-loop or hybrid
- Similar reduction rates achieved: 90-98% for SO_2, up to 70-90% for PM and up to 25-70% for BC
- Fuel penalties of about 0.5-3%
- Dry scrubbers do not require washwater treatment systems
  → savings in power consumption (0.15-0.2%) compared with wet systems

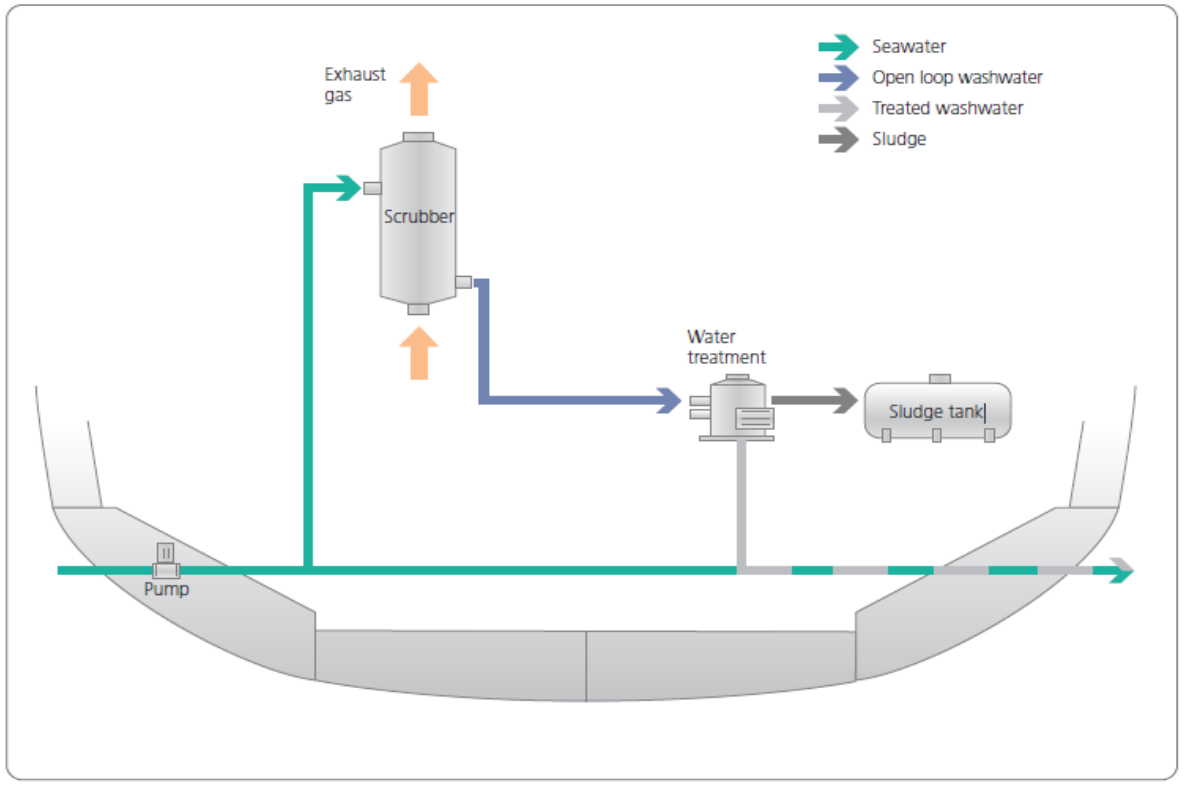
Secondary reduction measures: scrubbers

Open-loop scrubber:

Use of seawater, SO_2 removed by alkalinity of sea water to form sulphuric acid

Specially meant for seagoing ships as freshwater directly available

Limit: discharge of washwater sometimes impossible in some areas



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

Secondary reduction techniques: scrubbers

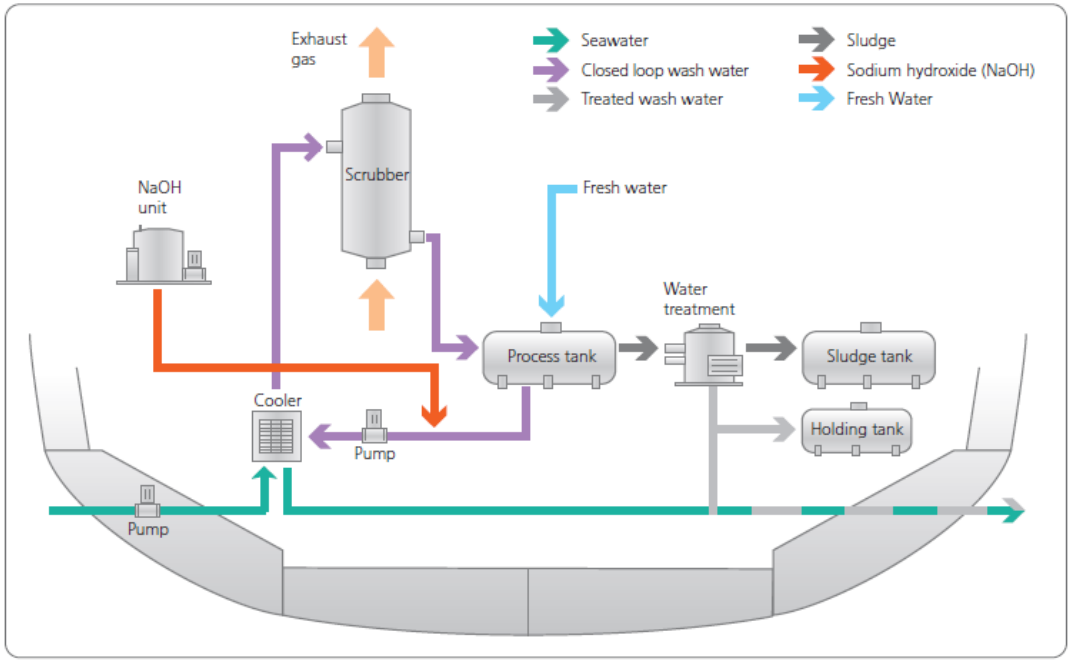
Closed-loop:

Fresh water used with caustic soda (NaOH) to form sodium sulphates

Washwater recycled after treatment in the scrubber

Average power consumption of 0.5-1% of the engine power

Useful in areas with low alkalinity seawater or if washwater discharge is not allowed



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Summary of results

Reduction techniques :	SO_2	NO_x	PM	BC	fuel penalty	Investments costs (€/kW)	Operation & maintenance costs
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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)

Next steps

- Add information about reduction measures and their costs for ships at berth and national navigation
- Follow-up on feedbacks and information provided by the drafting group
- Another meeting scheduled early November with drafting group to finalize the report for early December
- The next year: another document for other water-borne navigation means (e.g. recreational crafts and others)

Thank you very much
for your attention!
Questions?

TFTEI Technical Secretariat

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