Technical work on maritime traffic emissions (SO_2, NOx, PM and BC)

TFTEI technical secretariat
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LRTAP TFTEI

Agenda

- Our mandate
- Emissions of pollutants from maritime transport
- Marpol Convention Annex VI for SO_2 and NOx
- Reduction techniques for NOx emissions and their costs
- Reduction techniques for SO_2 emissions
- Next steps

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Mandate of TFTEI
CLRTAP Decision 2018/7

2 - The functions of TFTEI are to:

….

C – initiate work to assess information on emission abatement technologies for the reduction of air pollutant from shipping emissions

Under TFTEI, a guidance document developed in 2016 (by Emisia and IIASA): Guidance Document on Emission Control Techniques for Mobile Sources Covering:

- Road vehicles,
- Non road machineries,
- Aircrafts,
- Electric trams

and

- **Diesel vessels (inland waterways) and seagoing ships**

http://www.unece.org/environmental-policy/conventions/envlrtapwelcome/guidance-documents/gothenburg-protocol.html

Work currently initiated

Scope of the work:

- Diesel vessels (inland waterways)
- Seagoing ships

Deliverable:

An assessment of reduction technologies for SO_2, NOx, PM and BC emission reduction for two types of vessels:

- inland water ways

and

- seagoing ships

In both cases, with cost information

Work started in 2019, focusing on seagoing ships in a first step

Provisional content of the technical document for seagoing ships

- Summary
- Introduction,
- General information on the maritime transport
- Emissions of pollutants from maritime transport
- Marpol Convention annex VI
- Best available techniques for NOx
- Best available techniques for SO_2
- Best available techniques for dust and BC
- Control techniques at berth (Electricity)
- Costs of reduction techniques
- Bibliography

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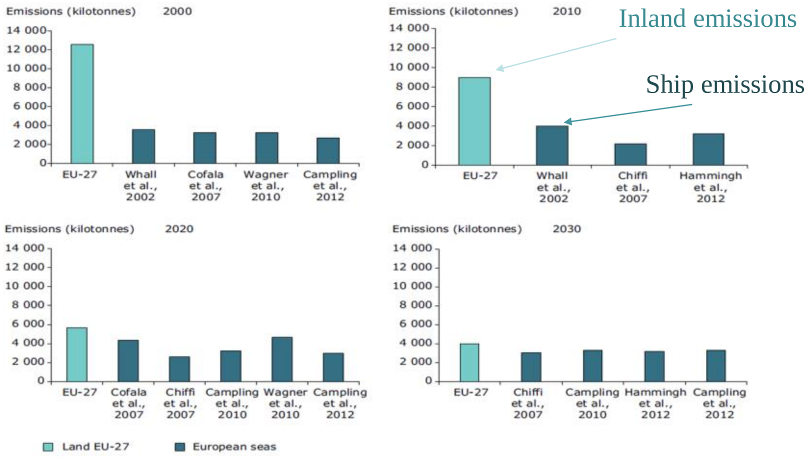
Maritime trafic in Europe – Emissions of NOx

Anthropogenic sources of AP are numerous : industry, residential heating, agriculture, road and off-road transportation … and shipping
In the EU, 2030 shipping emissions might be as large as inland EU emissions



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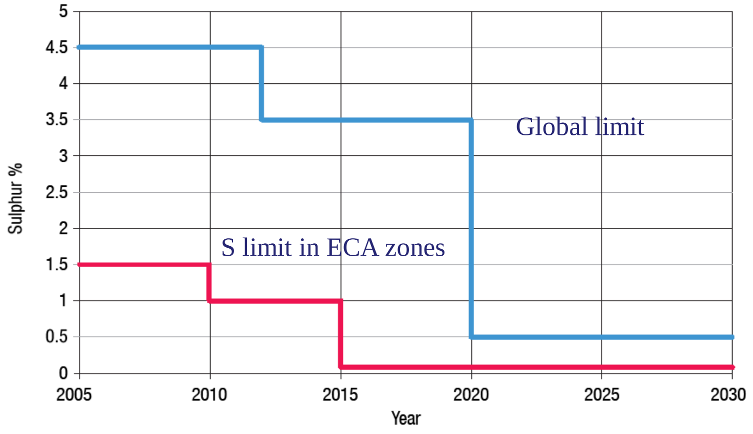
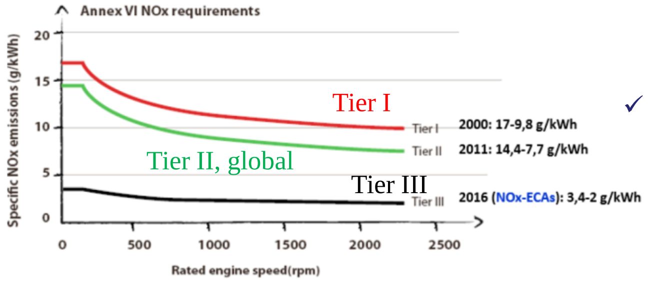
Fuel S limit (%w/w) according to Marpol Convention Annex VI

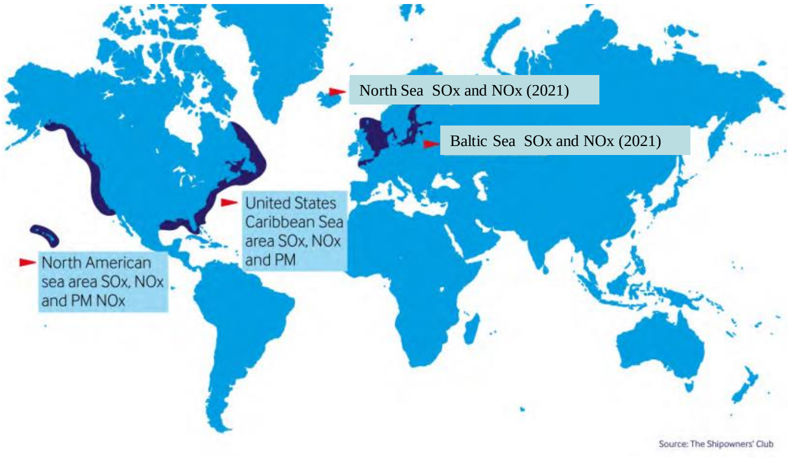


NOx: Marpol Convention annex VI requirements



- ✓ **Tier II limits to be met globally** by all ships constructed from 1st 2011
- ✓ **Tier III limits to be met in NOx Emission Control Areas** (NECA)
  - North America NECA: from 1st January 2016
  - Baltic Sea, North Sea and English Channel from 1st January 2021

Emission control zones in place



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Reduction techniques for NOx emissions to reach Tier III levels

1 – Primary measures:

EGR (Exhaust Gas Recirculation)

2 – Treatment of waste gases

SCR (Selective Catalytic Reduction)

3 – Use of other fuels, new techniques

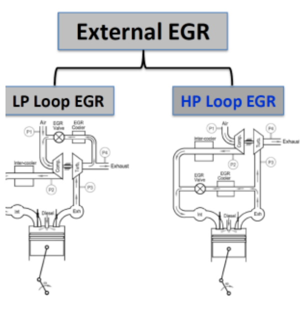
LNG, other alternative fuels (hydrogen…)

For SCR and EGR, possibility to switch from TIER II mode to NECA (TIER III) mode by specific arrangements

Source of picture: Man diesel – Emission project guide - 2018

Principles of EGR

Reduction technique based on recirculation of a part of exhaust gases.
Exhaust gases are cooled and cleaned
Reduction of temperature and oxygen content reduces NOx formation



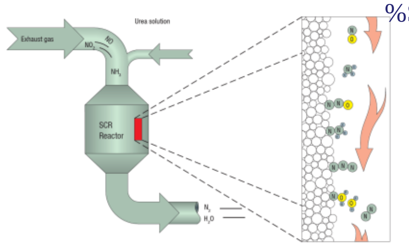
Exhaust gases must be cleaned to remove dust emissions and water must be neutralized (use of NaOH)
Configurations more or less complex according to the cases : high pressure or low pressure EGR

With a fuel at 0.1% S: fuel penalty of around 0 to 5 g/kWh according to the load /engine optimized for tier II, according to the configurations

Ref: Man 2018 – NOx reduction – Tier III solutions
Yandis 2016 – NOx reduction technologies for marine diesel engines

Principles of SCR

Chemical reactions involved



Urea solution (at 40%) preferred / ammonia solution at 24.5%

$(NH_2)_2CO_{(aq)} \rightarrow (NH_2)_2CO_{(s)} + x\,H_2O_{(g)}$

$(NH_2)_2CO_{(s)} \rightarrow NH_{3(g)} + HNCO_{(g)}$

$HNCO_{(g)} + H_2O_{(g)} \rightarrow NH_{3(g)} + CO_{2(g)}$

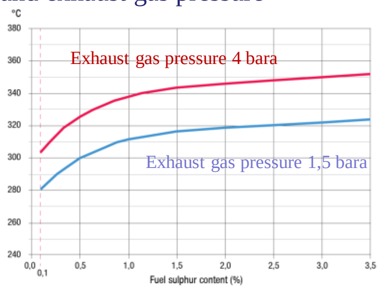
Reactions with NO and NO2

$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6\,H_2O$

$2NO + 2NO_2 + 4NH_3 \rightarrow 4N_2 + 6H_2O$

$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$

Required temperature for SCR according to %S and exhaust gas pressure



Risk of formation ammonium bisulfate at low t°C which can condensate and reduce catalyst efficiency

Minimum temperature in the catalyst bed required to avoid possible condensation

Risks lower with low sulphur fuels

With 0.1% S fuels, 310 °C is sufficient

Ref: Man 2018 – NOx reduction – Tier III solutions

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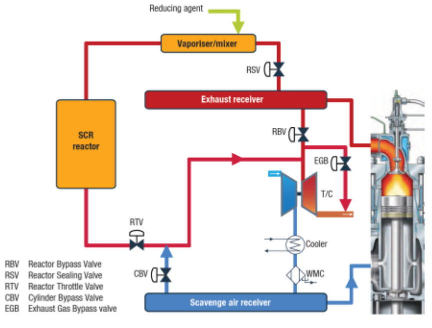
Principles of SCR

High pressure



Adapted to fuels with high S content

To have adequate temperatures, SCR located before the turbo charger (+50 to175°C/LP)

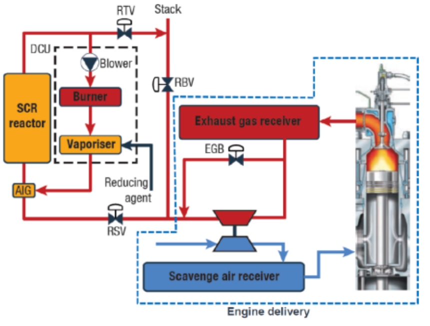
Outside NECA , SCR can be stopped

SCR is stopped if load < 15%

Fuel penalty: 0.5 à 2 g/kWh according to load/ optimized motor in tier II

Ref: Man 2018 – NOx reduction – Tier III solutions

Low pressure



Only possible with fuels with low sulphur content of around 0.1%

The SCR is placed after the turbo charger

Outside NECA, SCR can be stopped

Reheating system necessary to avoid condensation

Fuel penalty: 1 à 2 g/kWh according to load/ optimized motor in tier II

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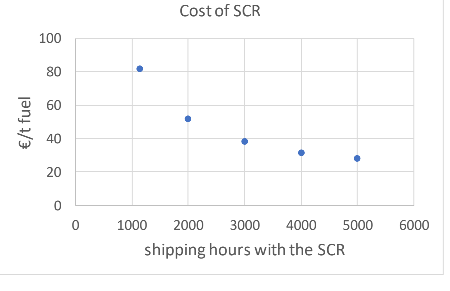
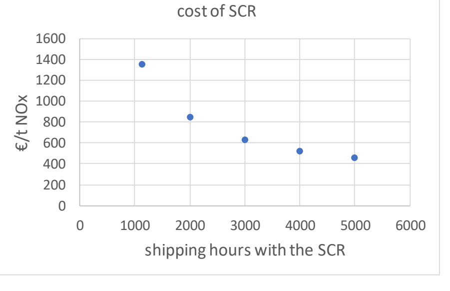
Costs of SCR

Cost component	Average value	Range of values
Investment €/kW New	**59**	19 à 100
Investment €/kW Retrofit	80	24 à 97
Urea Price €/kg	**0.21**	0.17 à 0.29
Urea consumption kg/kWh	**10.9**	6.5 à 16.5
Catalyst replacement €/kWh	**0,55**	0.25 à 0.75
Maintenance	**1.2% of investment**	
Fuels	**- 1 % of the consumption**	Some references give savings

Source: Rasmus Parsmo and alls. NOx abatement in the Baltic sea. An evaluation of different policies. IVL. May 2017 and other sources

Impact of shipping time in NECA zone on cost of SCR per t of NOx removed and t of fuel consumed





Costs for a ship 12 MW

- Interest rate 4%
- Lifetime 20 years

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Reduction techniques for SO_2 emissions

- Use of low sulphur fuels and alternative fuels
- Use of scrubbers

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Use of low sulphur fuels

Use of low Sulphur fuels or alternative fuels (Liquid Natural Gas)

Fossil fuels with different sulphur content available

- Residual oil with aroound 2,5 % S
- Maritime diesel with 0.5 % S compliant with the global limit from 2020 of 0.5% S
- Maritime gasoil with 0.1 % S compliant with the global limit from 2020 of 0.1% S used in ECA zones

Fuel	Price		Price difference			
			€/GJ		€/t SO2 abated	
	€/t	€/GJ	RO to MD	MD to MGO	RO to MD	MD to MGO
Residual oil (RO) ~ 2.5 % S	275	6.7	-	-	-	-
Marine diesel (MD) ~0.5% S	363	8.5	1.79	-	2,055	-
Marine gasoil (MGO) 0.1% S	401	9.4	2.69	0.90	2,454	4,958

Source: IIASA – the potential for cost –effective air emission reductios from international shipping through designation of further emission control area in EU waters with a focus on the Mediterranean SEA, 2019

The different types of scrubbers

Two types of scrubbers :

- Wet scrubbers
- Dry scrubbers

Wet scrubbers can be classified in 3 categories :

- Open loop scrubbers
- Close loop scrubbers
- Hybrid scrubbers able to work in close loop mode or in open loop mode

SO_2 scrubbers

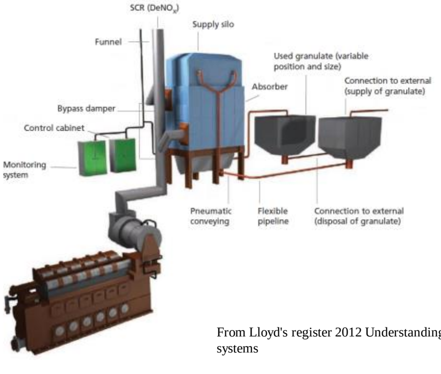
Open-loop scrubber:
Use of seawater (SO_2 removed by alkalinity of sea water).
Average water consumption : 45 m^3/MWh for a fuel at 2,7%S
Efficiency decreasing with higher seawater temperatures, requiring specific dispositions to keep it constant
Discharge of washwaters

Closed-loop:
Fresh water used,
Sodium hydroxide (NaOH) used to neutralize SO_x. Sodium sulphates produced
Washwater recycled after treatment in the scrubber.
Average fresh-water consumption : 20 to 30 m^3/MWh
Wash water discharge 0.1 to 0.8 m^3/MWh if no storage
Average power consumption of 0.5 to 1% of the power of the engine
Scrubbers used in zones where washwater discharge is not allowed

Hybrid system: able to work in both modes. More sophisticated and more complex

SO_2 scrubbers

Dry scrubber:
Solid alkaline reagent used (Ca(OH)2, sodium bicarbonate…)
Operate between 240 to 450 °C
Average power consumption of 0.15 to 0.20% of the power of the engine
Storage of consumables and wastes necessary



From Lloyd's register 2012 Understanding exhaust gas treatment systems

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Next steps

- Finalize a first draft of document (by the end of the year)
- Set up a working group for comments and validation (in November 2019)
- Finalize a document by June 2020

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- ❑ Other information

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Some Useful links

ECAMED: Technical Feasibility Study for the Implementation of an Emission Control Area (ECA) in the Mediterranean Sea – INERIS, CITEPA, CEREMA, PLAN BLEU for the French Ministry for an Ecological Transition - 2018
https://www.ecologique-solidaire.gouv.fr/sites/default/files/R_DRC-19-168862-00408A_ECAMED_final_Report_V5.pdf

The potential for cost-effective air emission reductions from international shipping through designation of further Emission Control Areas in EU waters with focus on the Mediterranean Sea – IIASA for the European Commission – 2018
http://pure.iiasa.ac.at/id/eprint/15729/

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Some recent studies

France took the lead for implementation of an ECA for SO_2 and NOx in the Mediterranean Sea

•**2019:** Informal preparatory work for a decision of the European Union Council-Diplomatic Initiatives to Mediterranean Countries

•**2nd semester 2019:** decision of the European Union Council

•**March 2020:** submission to IMO

•**April 2020:** approval of the ECA by IMO (1st phase of the decision)

•**Autumn 2020 or July 2021:** adoption of the ECA by IMO (2nd phase of the decision) - Entry into force fixed during the negotiations

•**2022:** ECA zone entry into force target

Thank you very much for your attention! Questions?

TFTEI Technical Secretariat