Studies of marine diesel engine exhaust gas treatment

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Sources

Power Plants

Land transport

Marine Transport

Diesel Engines

Health and environmental effects

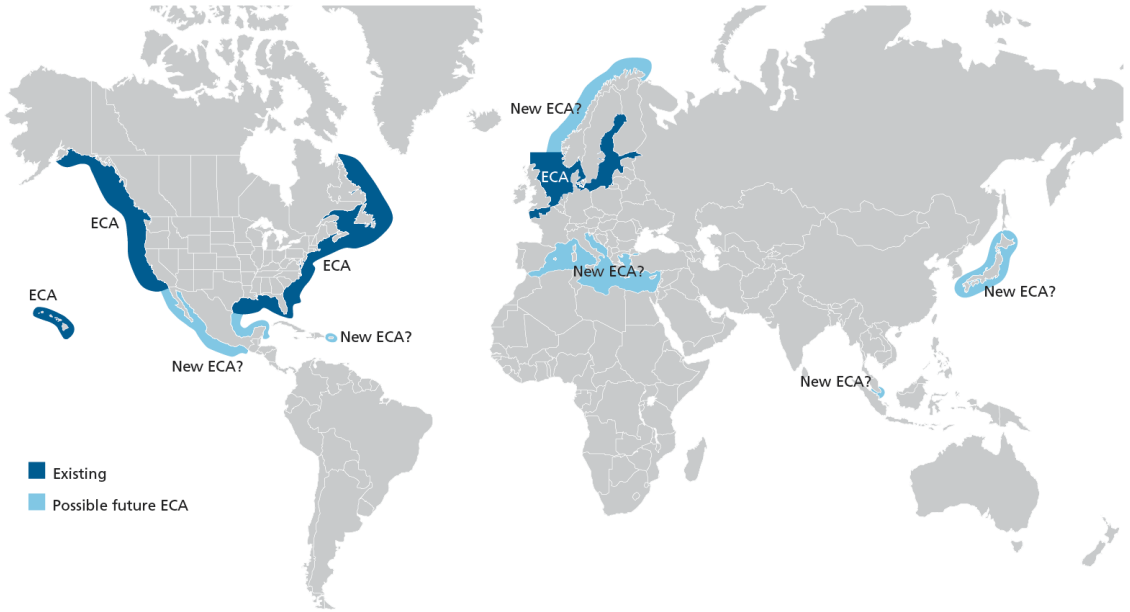
Respiratory diseases

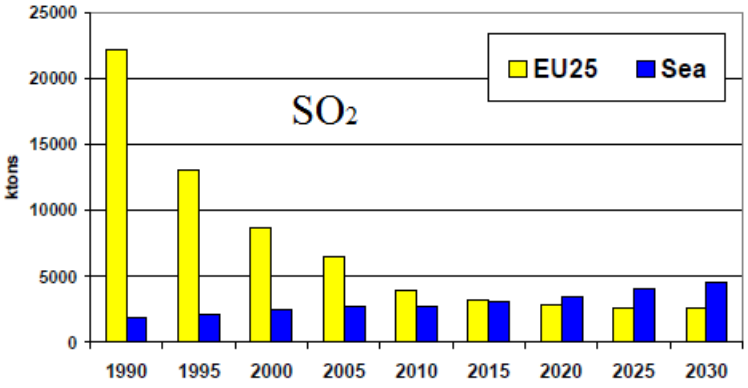
Acid rain

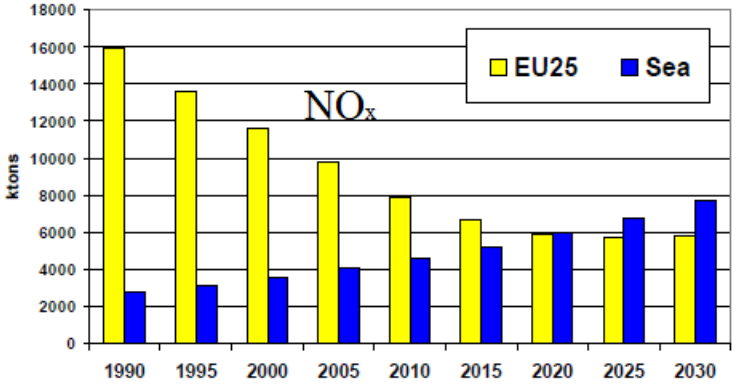
Smog

Eutrophication of lakes

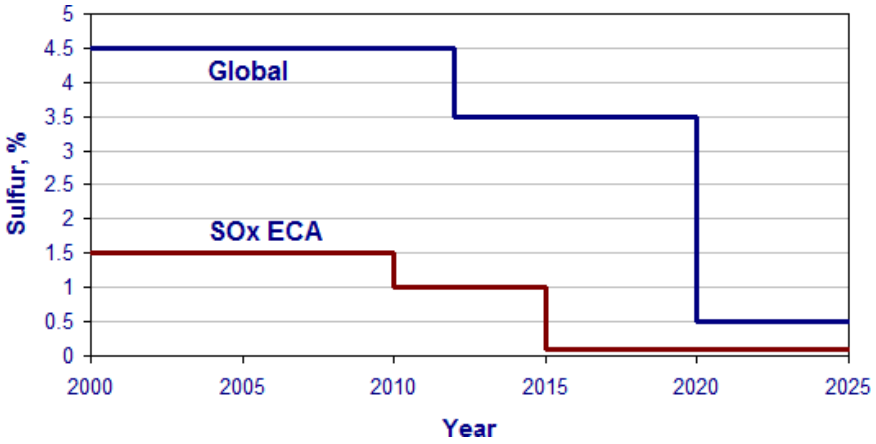
Emission Control Areas



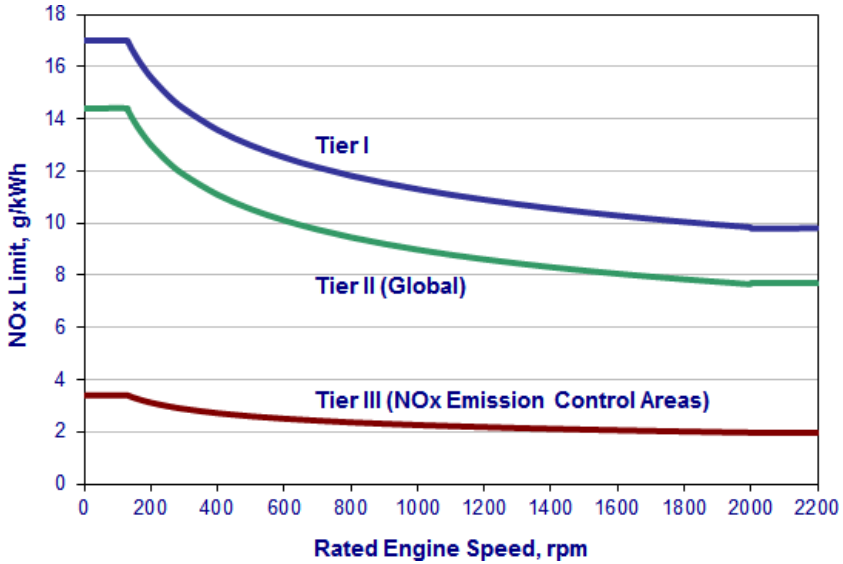




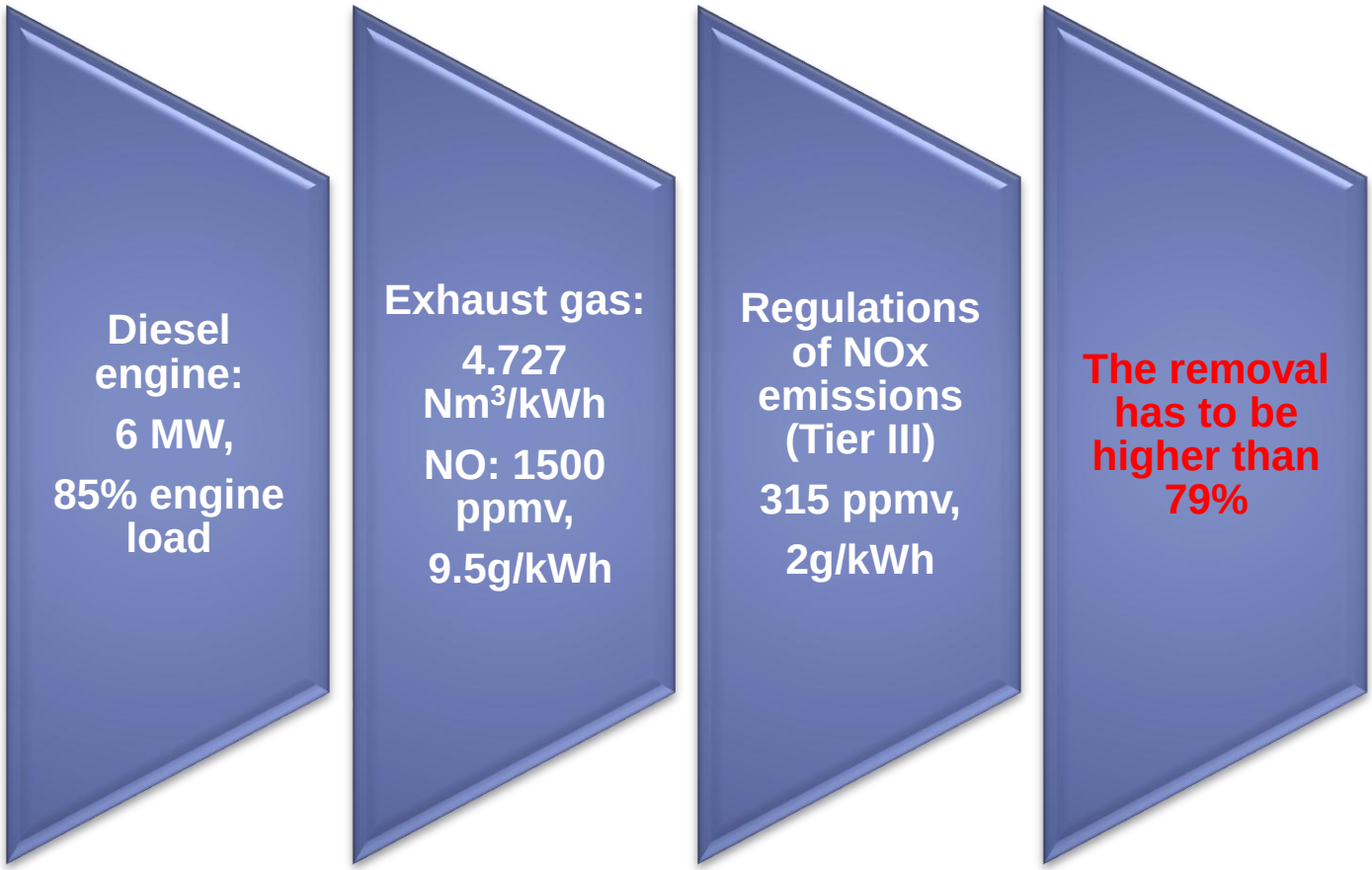
SO_2 and NO_x regulations



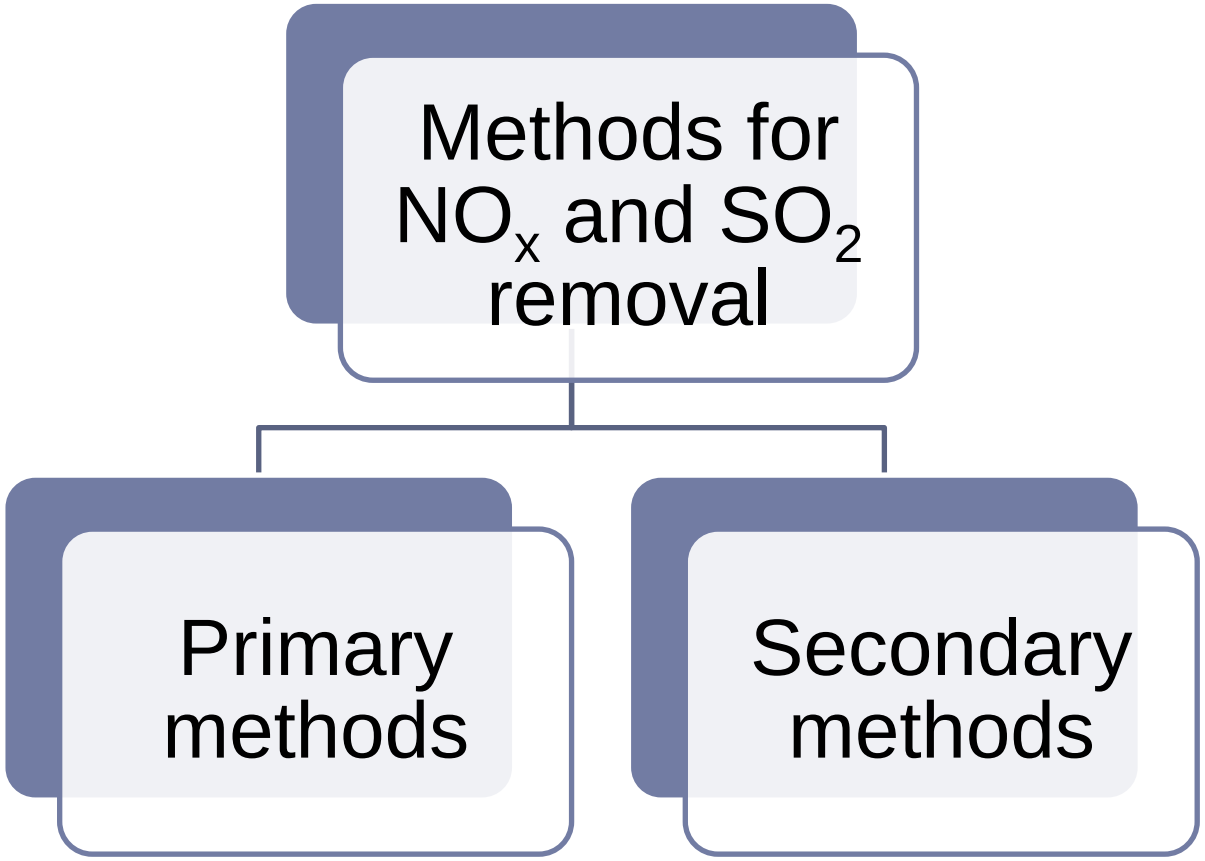
Diesel engine exhaust gas composition	
NOx	50-1500 ppm
SO_2	Proportional to sulphur content in fuel; 500-2000 ppm
HC	50-500 ppm
CO	100-1000 ppm



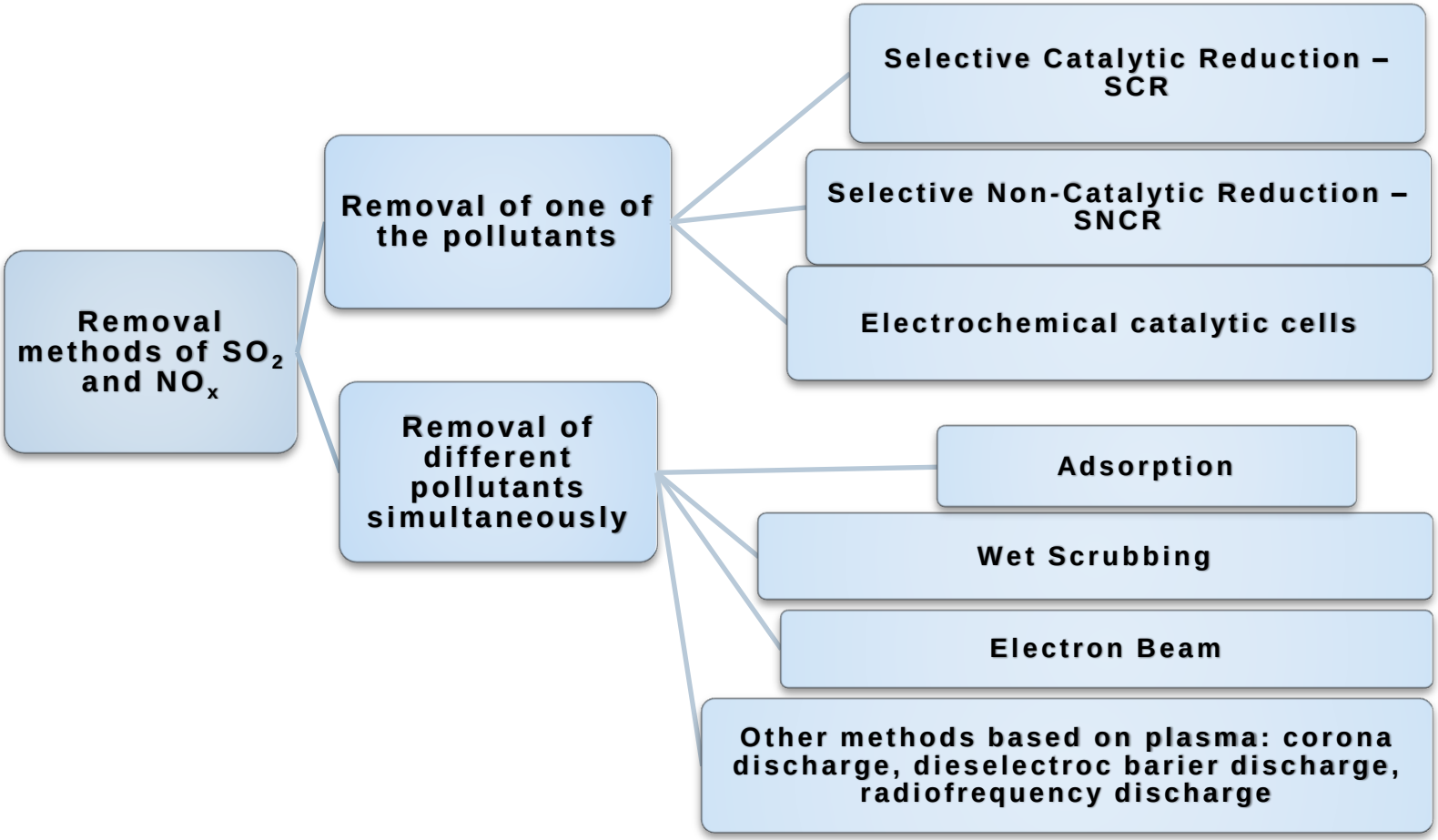
Exhaust gases vs regulations



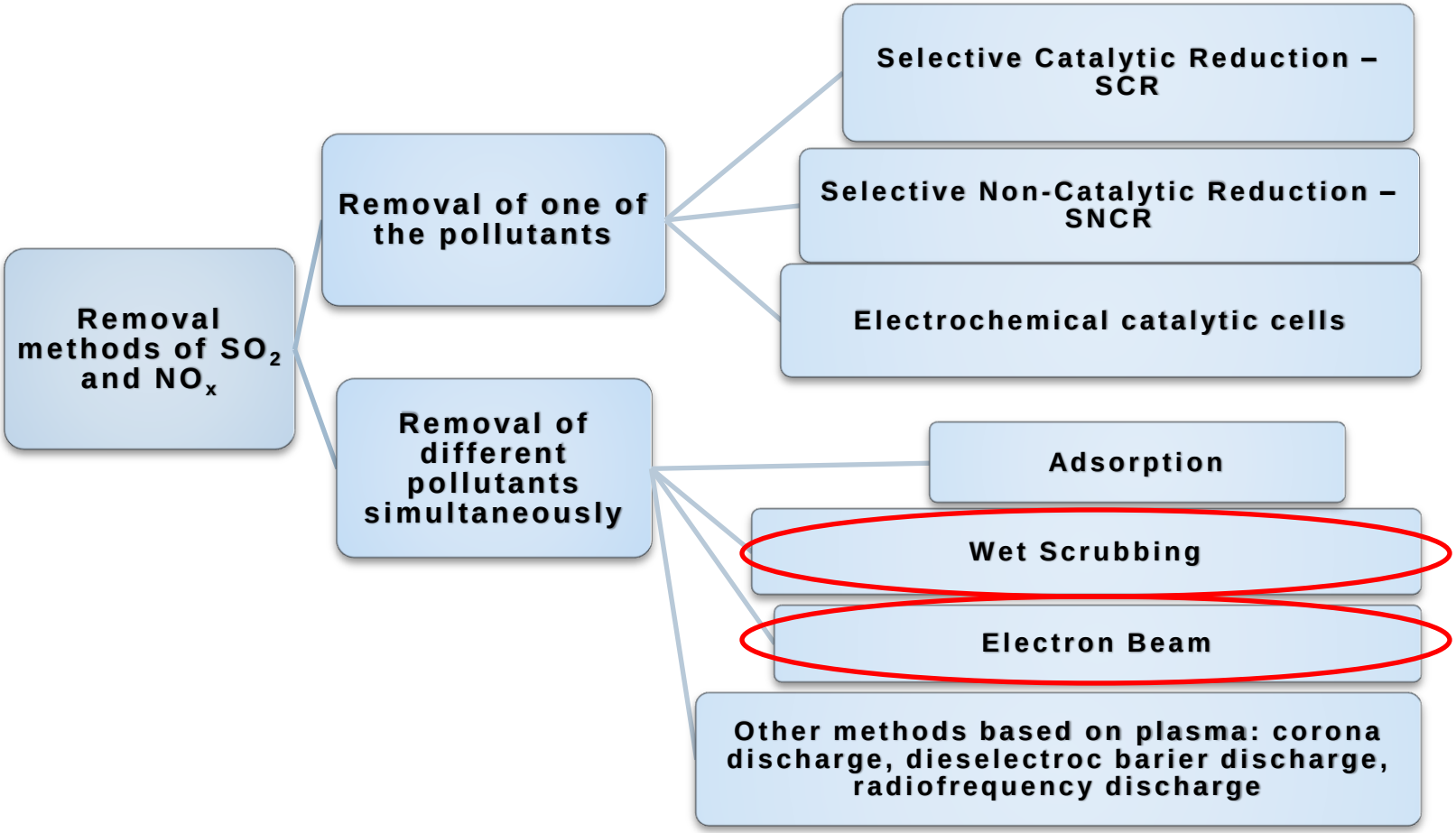
Removal of NO_x and SO_2



NO_x and SO_2 removal methods



NO_x and SO_2 removal methods



NO_x and SO_2 removal with Electron Beam

Main reactions, which occur during NO_x removal:

$NO + O(^3P) + M \rightarrow NO_2 + M$

$O(^3P) + O_2 + M \rightarrow O_3 + M$

$NO + O_3 + M \rightarrow NO_2 + O_2 + M$

$NO + HO_2\cdot + M \rightarrow NO_2 + \cdot OH + M$

$NO_2 + \cdot OH + M \rightarrow HNO_3 + M$

By-product production:

$HNO_3 + NH_3 \rightarrow NH_4NO_3$

Main reactions, which occur during SO_2 removal:

1) Radiation-induced pathway:

$SO_2 + \cdot OH + M \rightarrow HSO_3 + M$

$HSO_3 + O_2 \rightarrow SO_3 + HO_2\cdot$

$SO_3 + H_2O \rightarrow H_2SO_4$

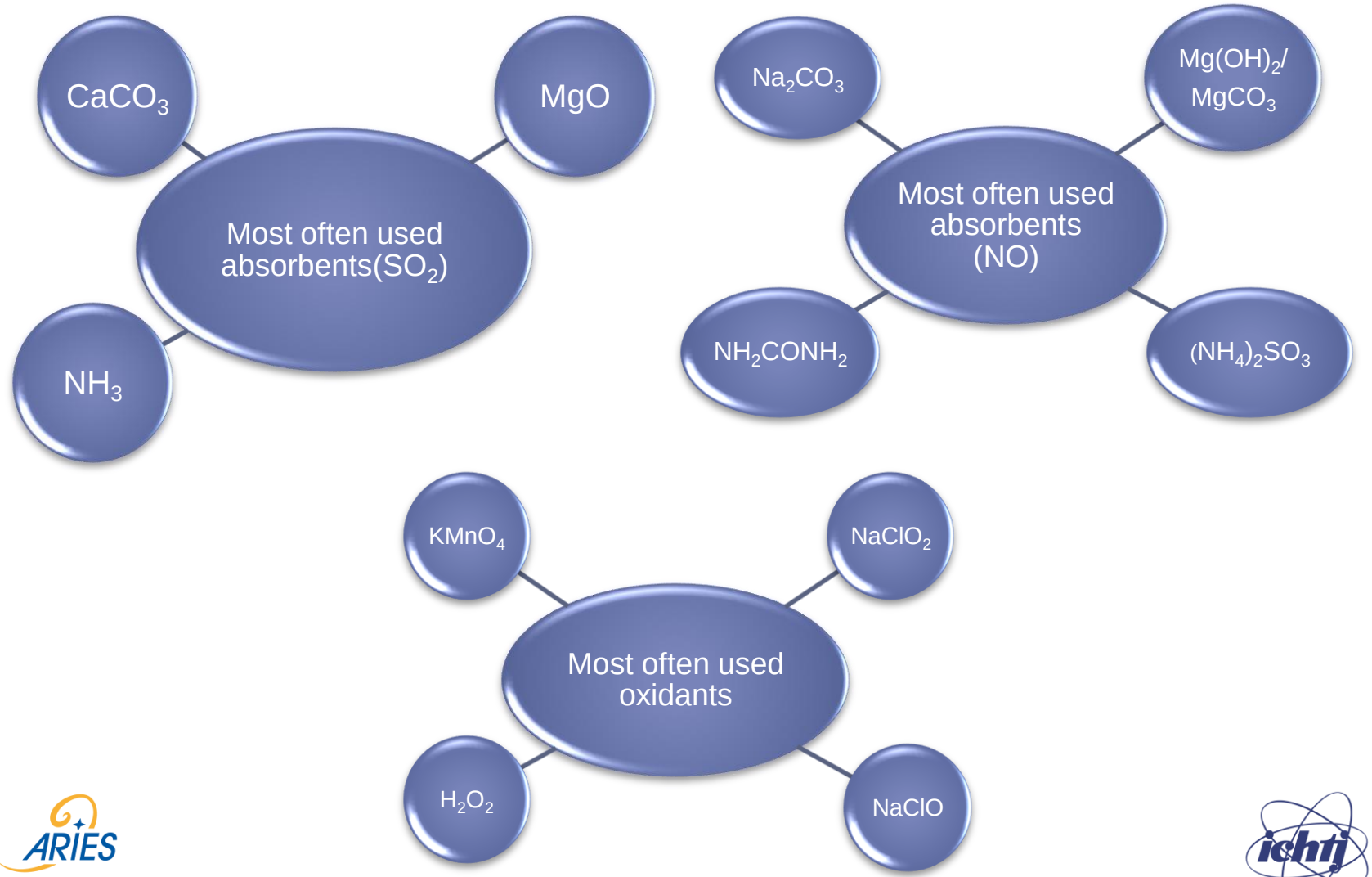
$H_2SO_4 + 2\ NH_3 \rightarrow (NH_4)_2SO_4$

2) Thermal pathway:

$SO_2 + 2\ NH_3 \rightarrow (NH_3)_2SO_2$

$(NH_3)_2SO_2\ (O_2, H_2O) \rightarrow (NH_4)_2SO_4$

Absorption methods for NOx and SO_2 removal



Hybrid technology

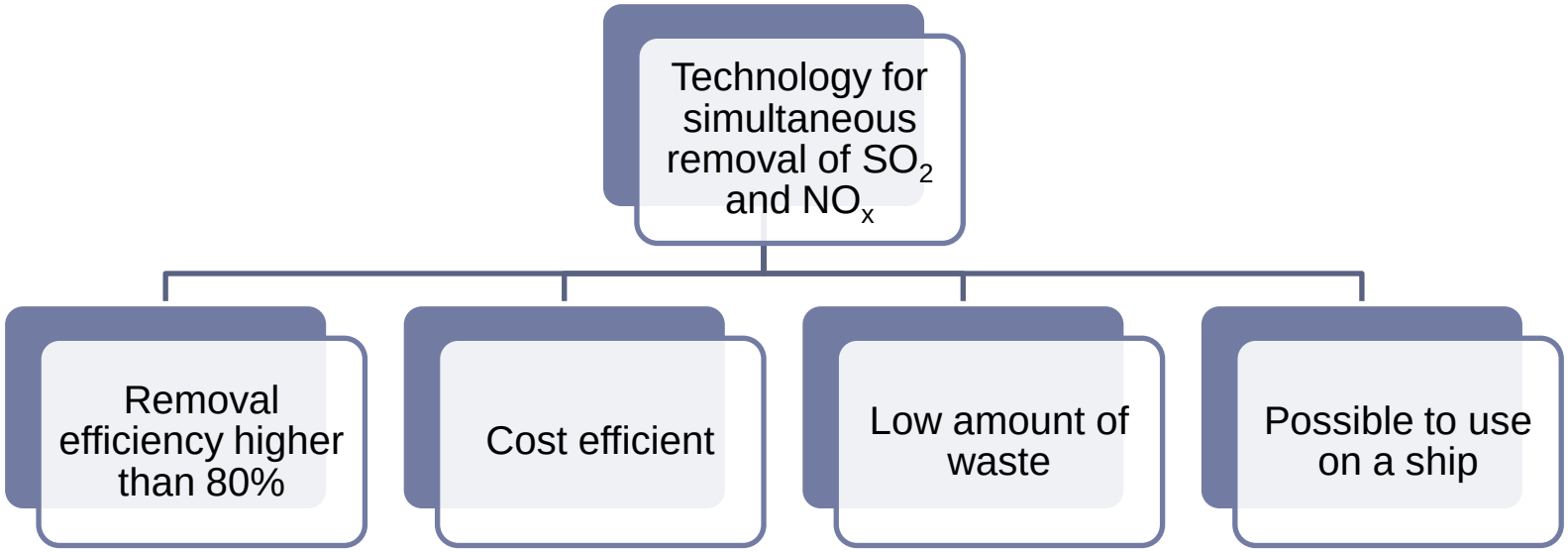
Diesel exhaust gases

Electron Beam

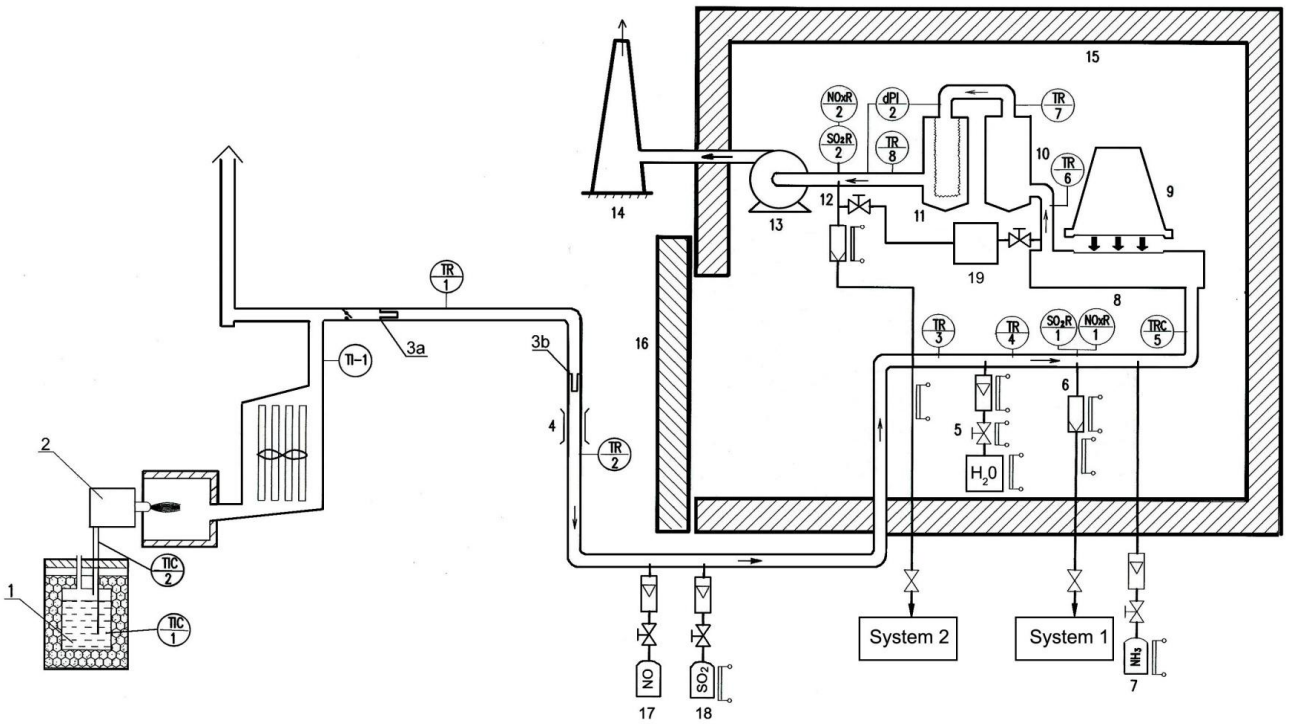
Wet Scrubbing

Clean gases

Aim of the research

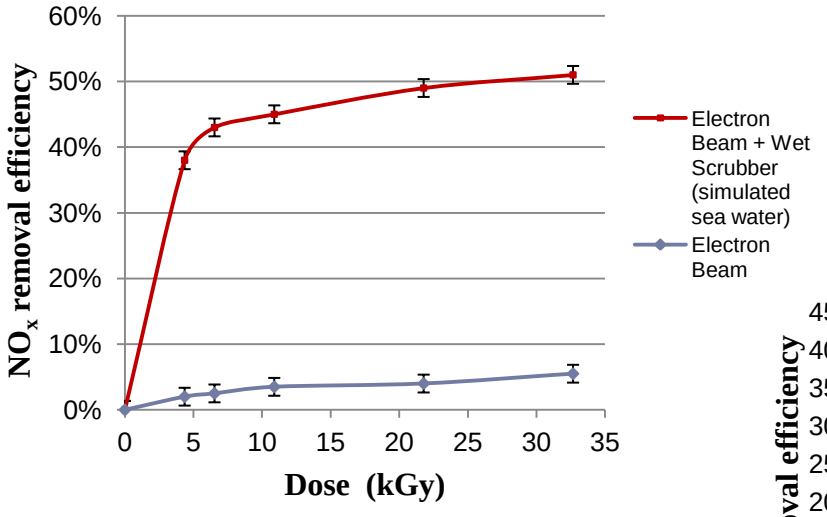


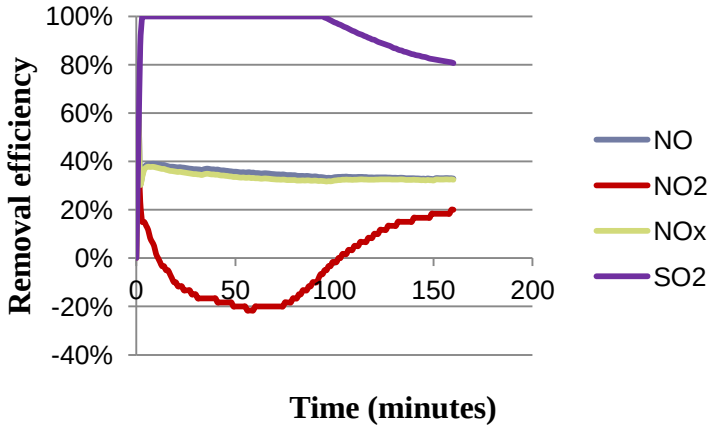
Installation

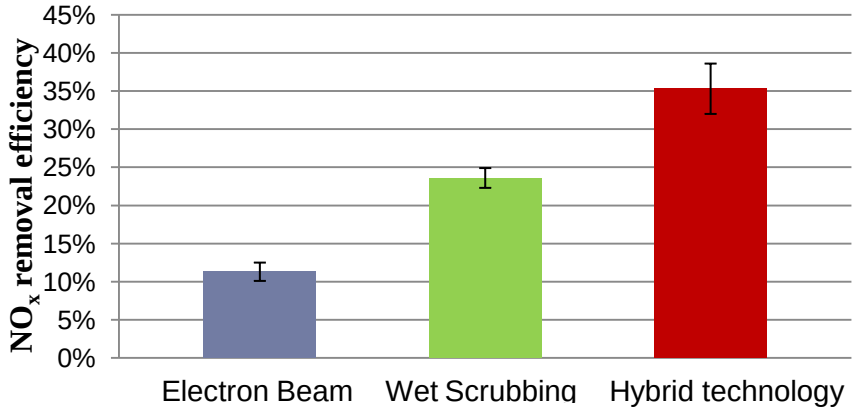


Scheme of the Electron Beam Flue Gas Treatment technology (Basfar et al., 2008).
1-Liquid fuel, 2-Oil Burner, 3-Filters for PM and soot, 4-orifice, 5-dosage of water vapour, 6-gas sampling point-process inlet, 7-ammonia injection, 8-process vessel, 9-electron beam accelerator, 10-retention chamber, 11-bag filter, 12-gas sampling point-process outlet, 13-induced-draugh fan, 14-stack, 15-concrete shielding wall, 16-concrete shielding door, 17-NO cylinder, 18-SO_2 cylinder, 19-scrubber

Hybrid technology – NaCl solution

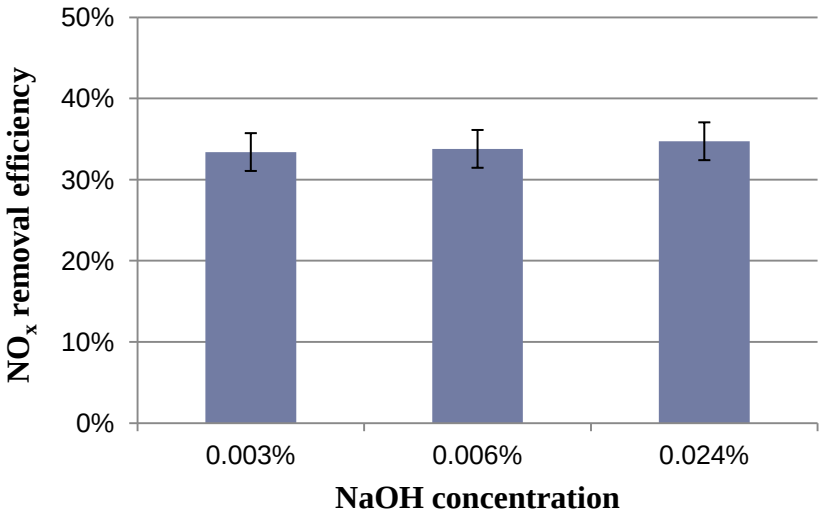


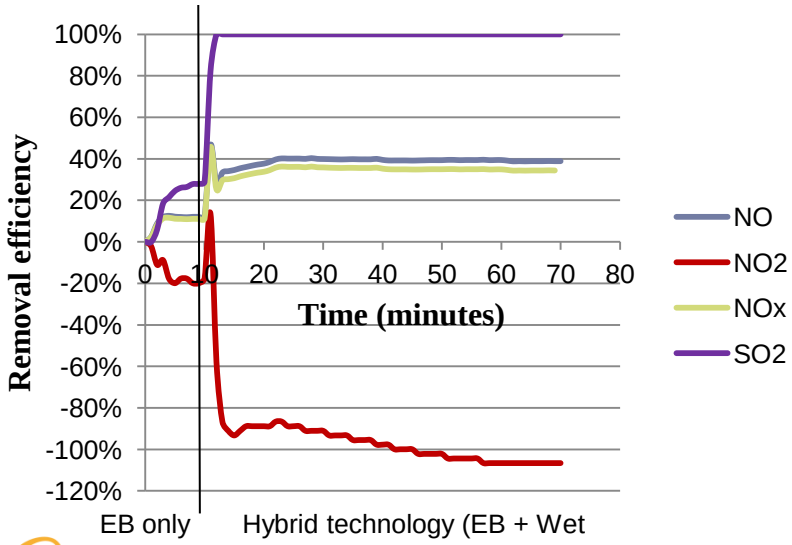


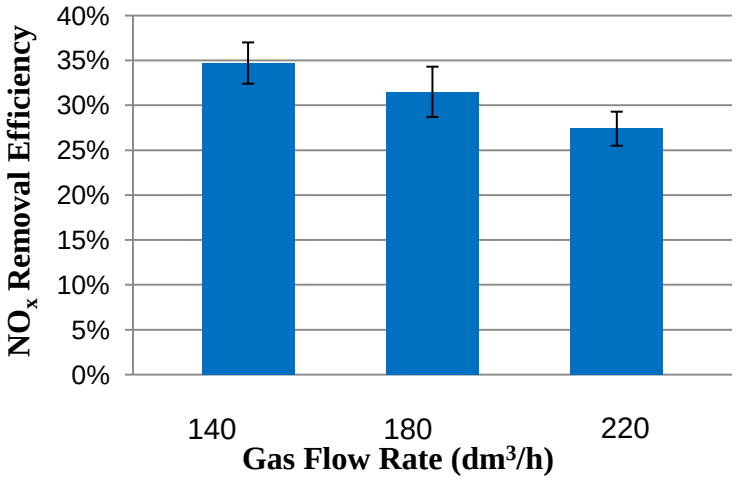


Average NO_x removal efficiency:
- 11,3% ± 1,2% for electron beam,
- 23,6% ± 1,3% for wet scrubbing
- 35,3% ± 3,3% for hybrid technology

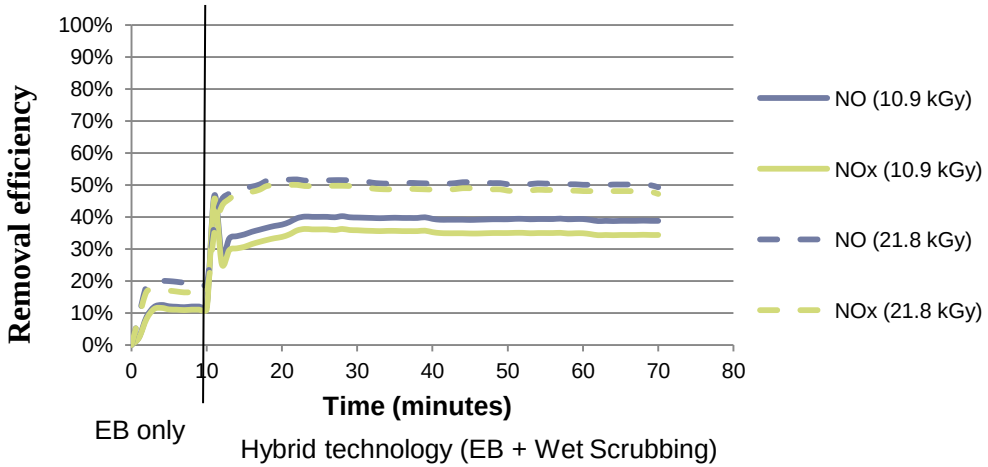
Hybrid technology – NaOH solution

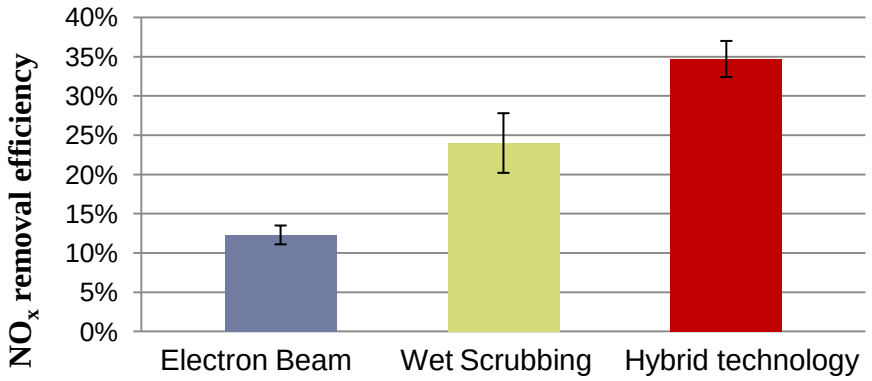






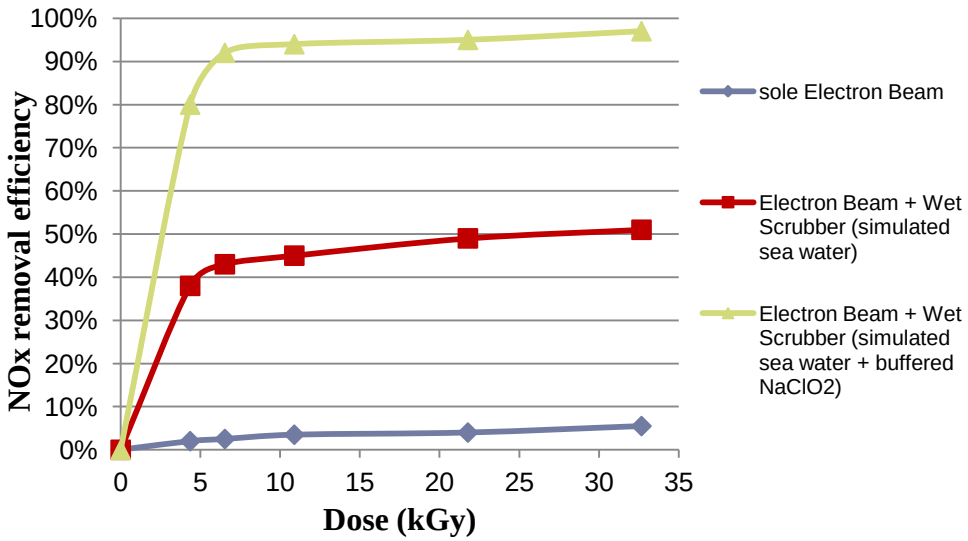
Hybrid technology – NaOH solution

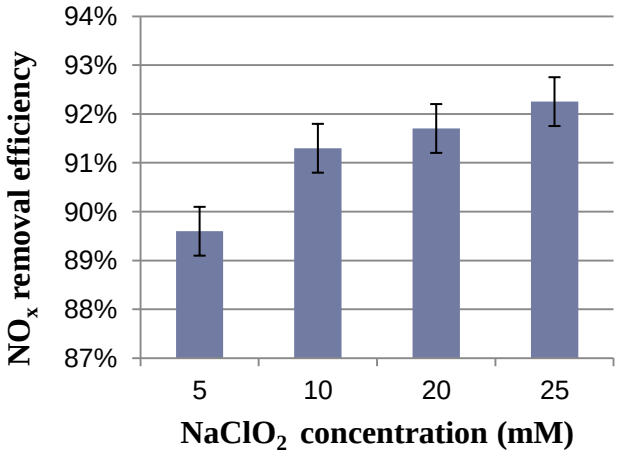


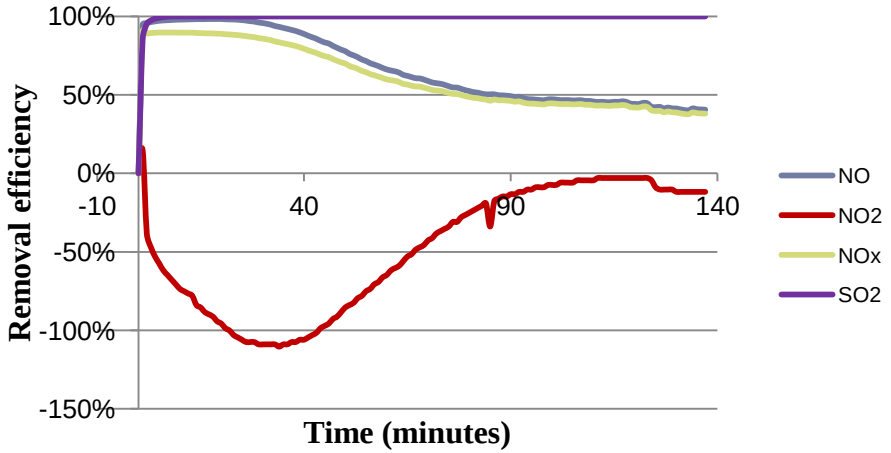


Average NO_x removal efficiency:
- 11,3% ± 1,2% for electron beam,
- 24,0% ± 3,8% for wet scrubbing
- 34,7% ± 2,3% for hybrid technology

Hybrid technology – NaCl + $NaClO_2$ solution

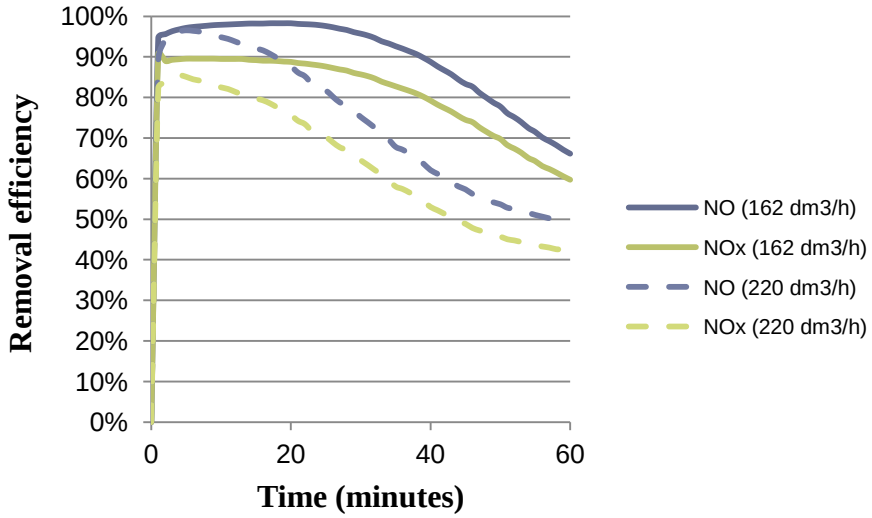


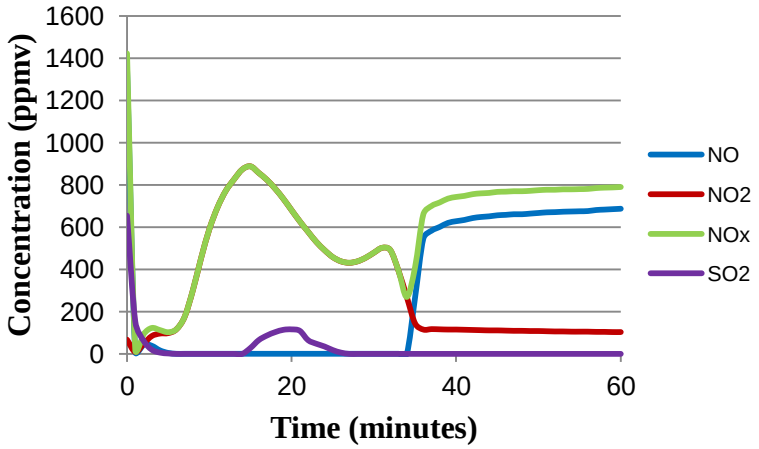


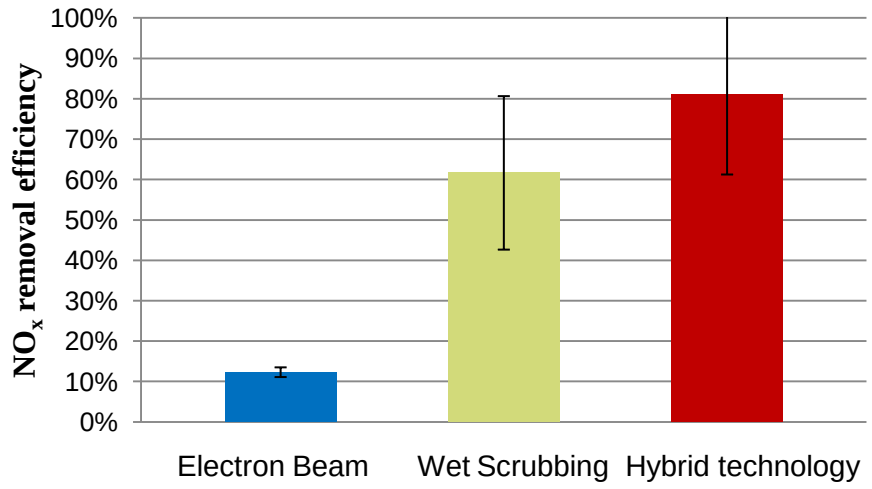


- NO_x removal efficiency depends on oxidant concentration
- During the process the NO_x removal efficiency decreases

Hybrid technology–NaCl + $NaClO_2$ solution



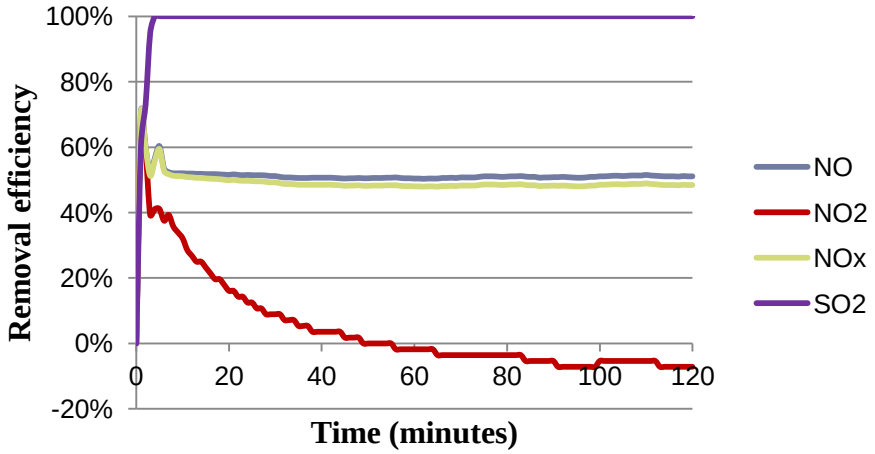




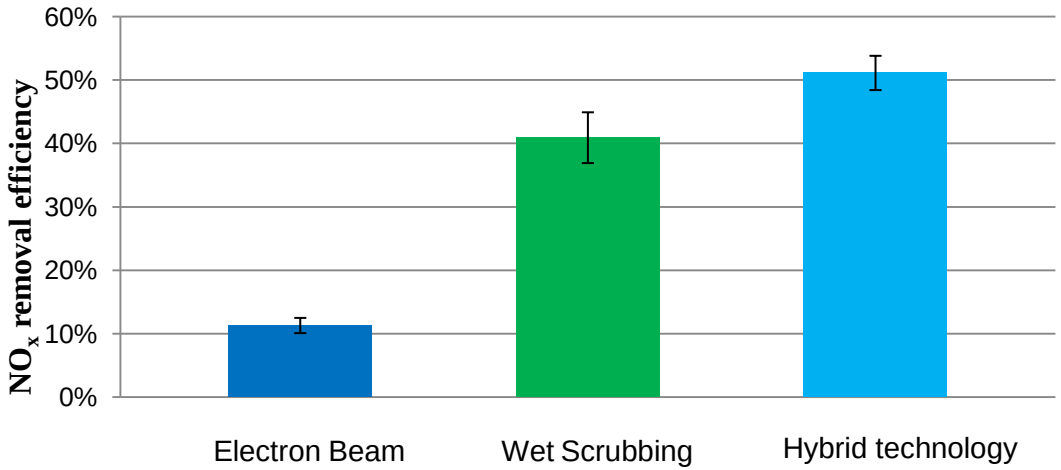
Average NO_x removal efficiency:

- 11,3% ± 1,2% for electron beam,
- 61,7% ± 19,1% for wet scrubbing
- 81,1% ± 19,5% for hybrid technology

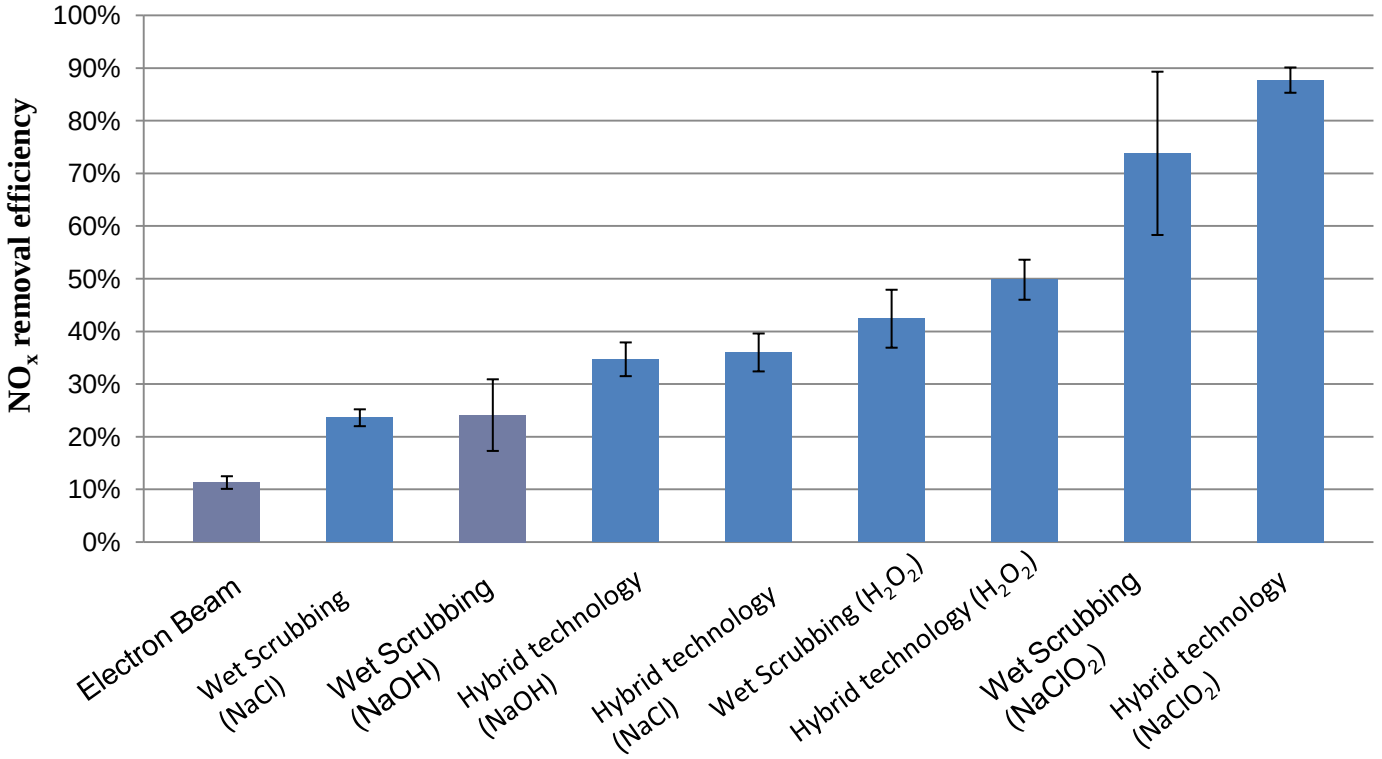
Hybrid technology– NaCl + H_2O_2



Average NO_x removal efficiency:
- 11,3% ± 1,2% for Electron Beam,
- 40,9% ± 4,0% for Wet Scrubbing
- 51,1% ± 2,7% for Hybrid technology

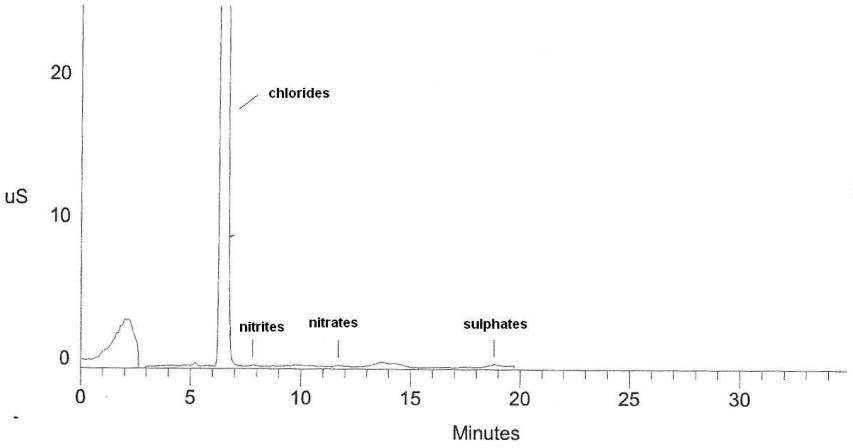


Comparison

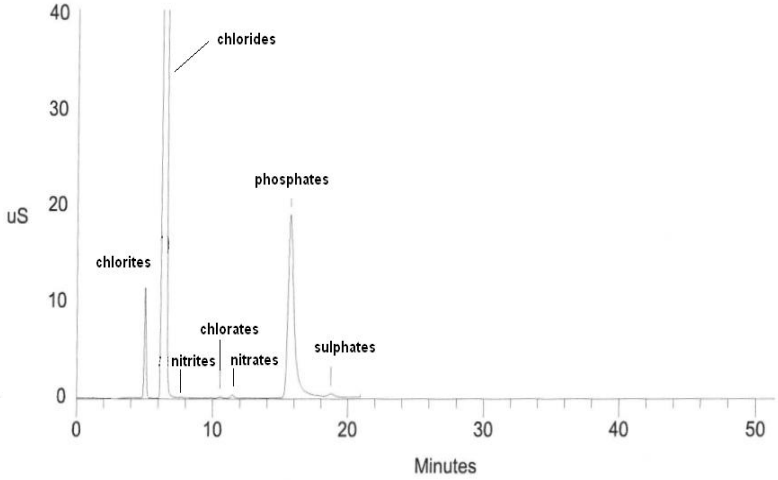

NO_x removal efficiency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Electron Beam
Wet Scrubbing (NaCl)
Wet Scrubbing (NaOH)
Hybrid technology (NaOH)
Hybrid technology (NaCl)
Wet Scrubbing (H_2O_2)
Hybrid technology (H_2O_2)
Wet Scrubbing ($NaClO_2$)
Hybrid technology ($NaClO_2$)

Analysis of the exhaust scrubbing solutions

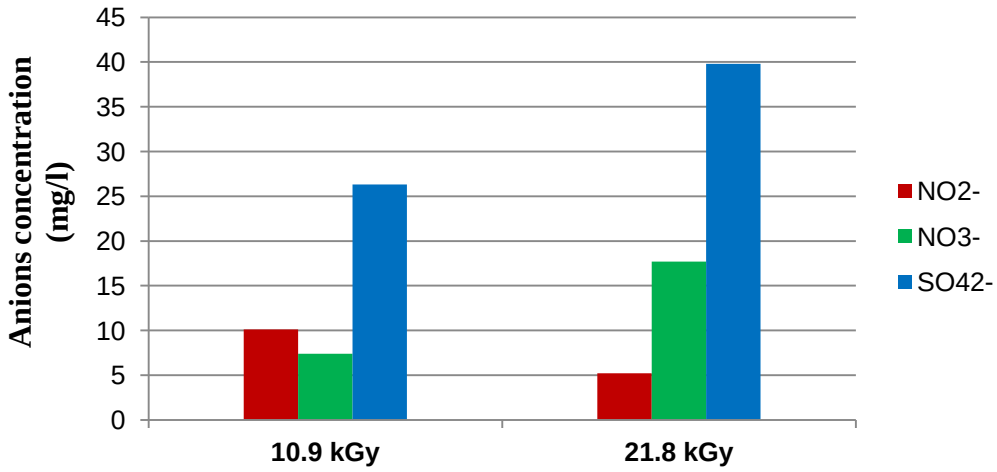
Hybrid technology– NaCl solution



Hybrid technology– NaCl + $NaClO_2$ solution



$$4ClO_2^- + 2H_3O^+ \rightarrow 2ClO_2 + ClO_3^- + 3H_2O + Cl^-$$



Conclusions

- Best results were obtained for the wet scrubbing solution with the addition of buffered $NaClO_2$
- The instalation should work in „hybrid” or „closed loop” system concerning postprocess liquid
- Obtained results comply with the new regulations
- Both pollutants are removed simultaneously
- There is a need for continous development of the method
  - Addition of water droplets?
  - Possible problems with titanium window?
  - Reduction of reagents usage?

Acknowledgement

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- INCT Polish ministerial statutory funding, task 4.3

Thank you for your attention!