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Design of integrated NO_x and SO_x removal in pressurized flue gas systems for carbon capture applications

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AIM

Purpose:

Design efficient and low-cost process units for the control of NOx and SOx in CO2 from oxy-fuel and chemical looping combustion.

Progress of work:

Perform lab-scale evaluations of the N-S chemistry under conditions relevant to CCS

Build and operate scrubbers for technical to semi-commercial scale

Develop modelling capacity to design and evaluate the CO2 upgrading

Present Presentation:

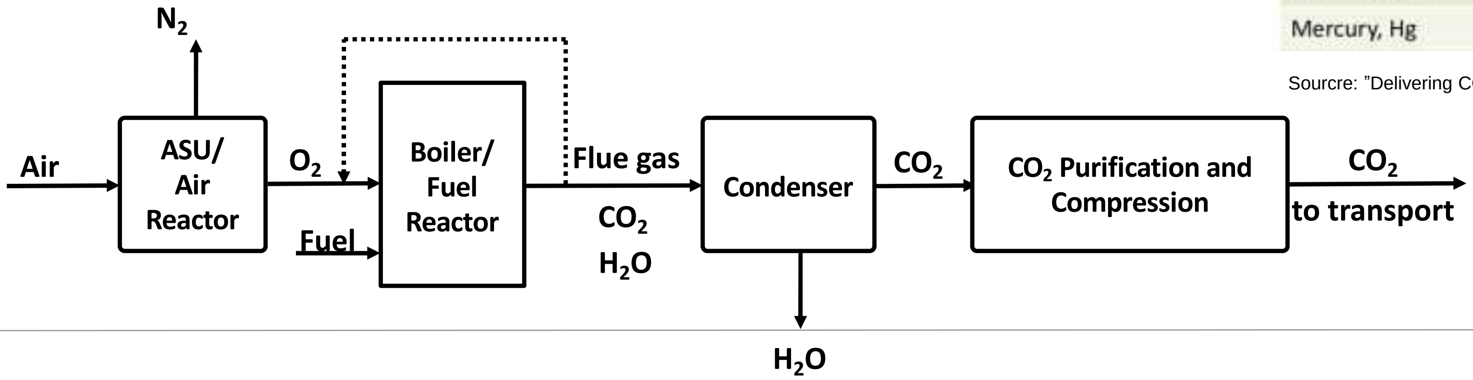
Discussion on the present understanding of systems for integrated NOx and SOx control for oxy-fuel and CLC

Oxy-Fuel and Chemical-Looping-Combustion Systems

- Flue gas mainly CO_2 and H_2O
- Impurities such as O_2, N_2, Ar, NO_x and SO_x
- Strict regulations for impurities for transport and storage

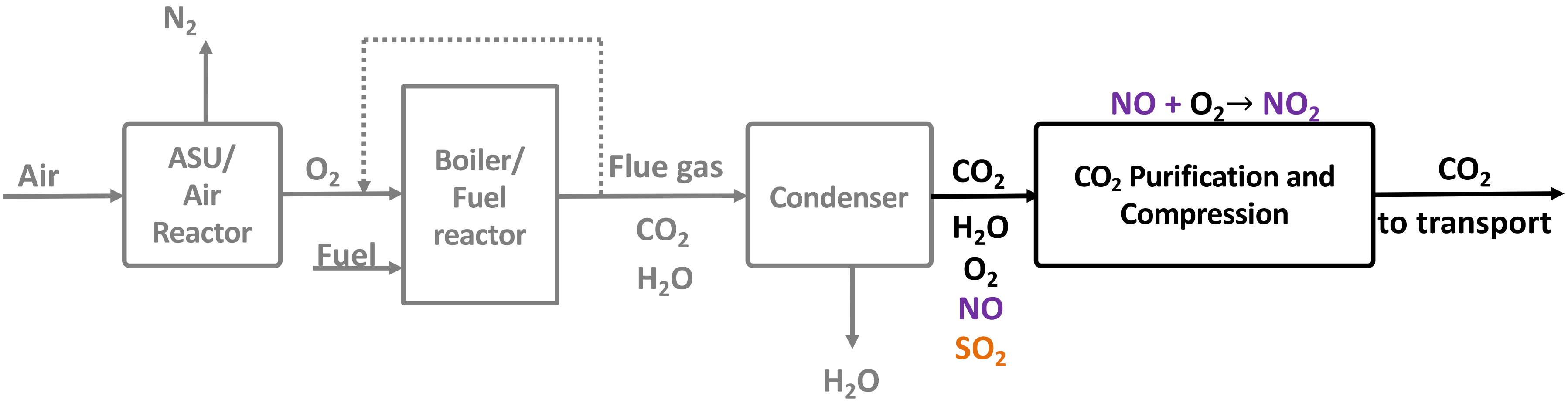
Component	ppm (mol)	Risk
Water, H_2O	≤ 30	Corrosion/hydrate
Oxygen, O_2	≤ 10	Corrosion
Sulphur oxides, SOx	≤ 10	Corrosion
Nitrix oxides/nitrogen dioxide, NOx	≤ 10	Corrosion
Hydrogen sulfide, H_2S	≤ 9	Toxic
Carbon monoxide, CO	≤ 100	Toxic
Amine	≤ 10	Material degrad.
Ammonia, HN_3	≤ 10	Effects unknown
Hydrogen, H_2	≤ 50	Material degrad.
Formaldehyde	≤ 20	Corrosion
Acetaldehyde	≤ 20	Corrosion
Mercury, Hg	≤ 0.03	Toxic

Sourcre: ”Delivering CO2 to the Norwegian CCS chain” Røsjorde 2019



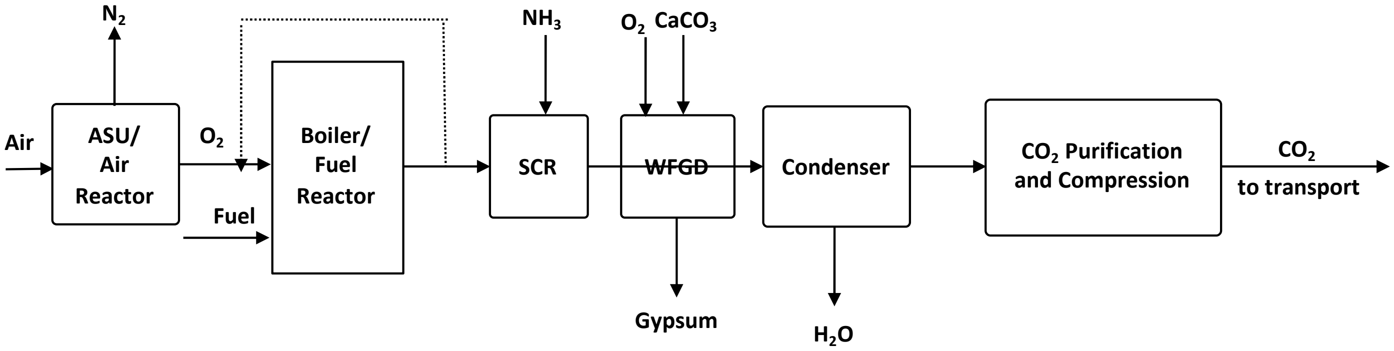
Oxy-Fuel and CLC Systems

- Increased pressure and decreased temperature during CO_2 conditioning changes NO_x and SO_x chemistry from conventional systems
- Significant oxidation of NO to NO_2 in the gas phase

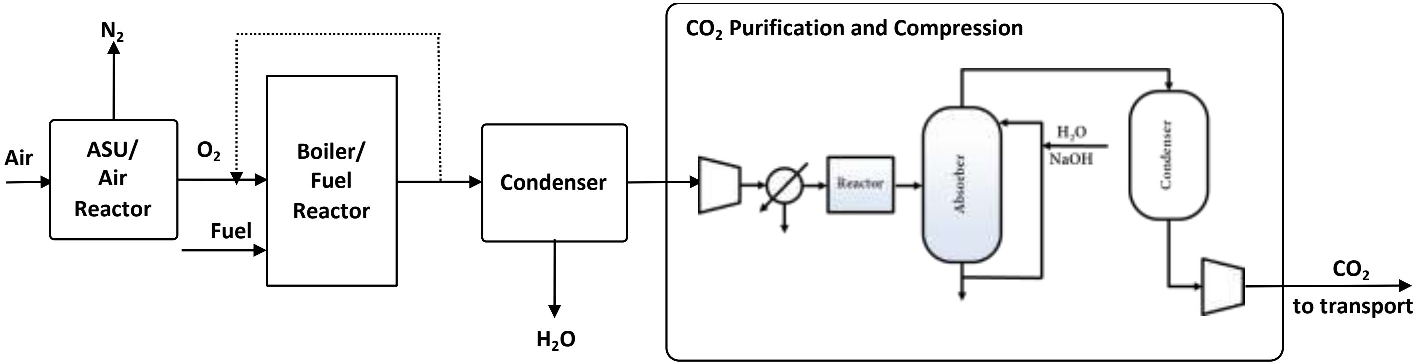


NO_x and SO_x Control

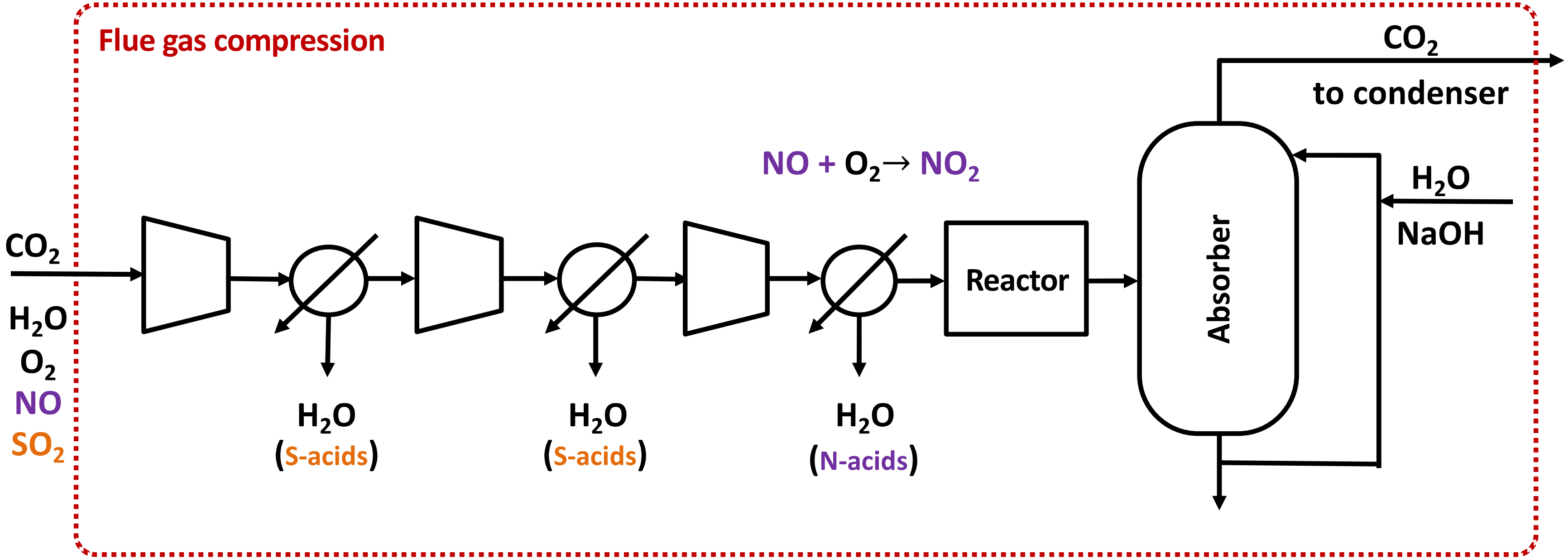
Conventional Techniques



Integrated Removal of NO_x and SO_x



Proposed Integrated Removal of NO_x and SO_x in Oxy-fuel and CLC Plants



Method

Today

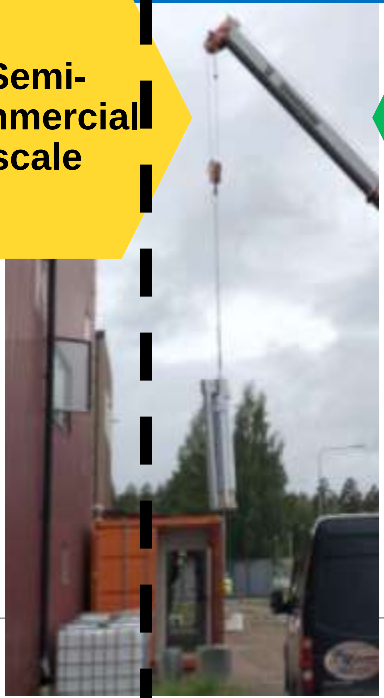
Modelling Capacity

Laboratory scale

100 kW gas boiler

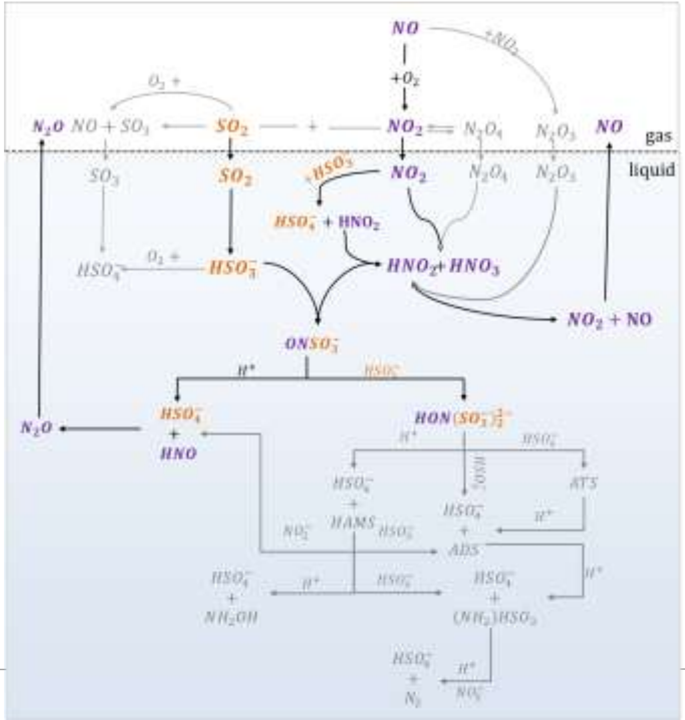
Semi-commercial scale

Pressurized systems

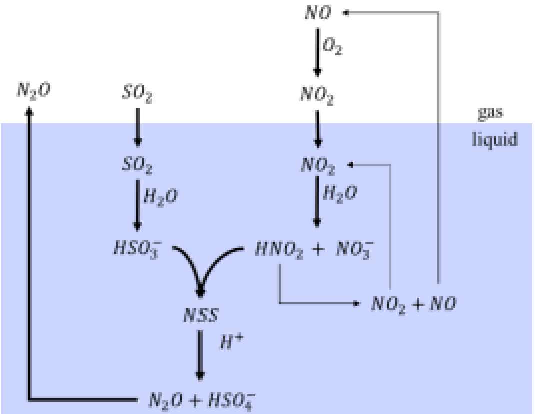


The Chemistry of NO_x and SO_x in Pressurized Flue Gas Systems

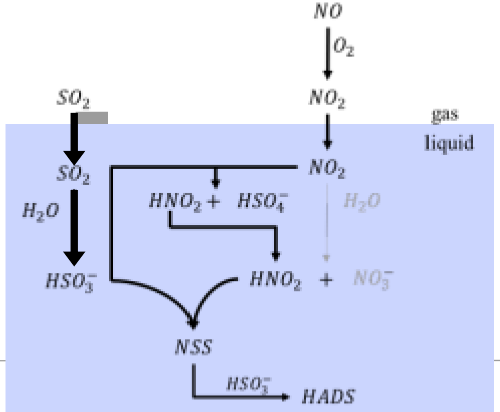
- N-S interactions in the liquid phase and importance of pH



pH ≤ 1, condensate conditions



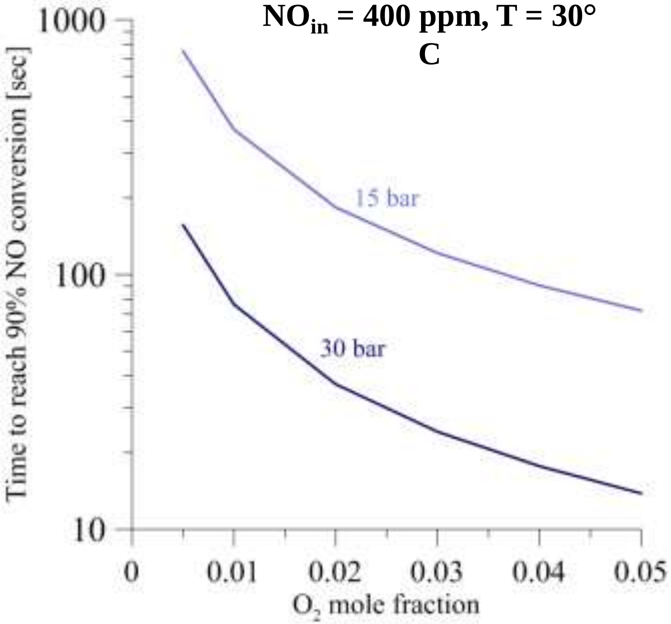
pH ≥ 5, absorber conditions

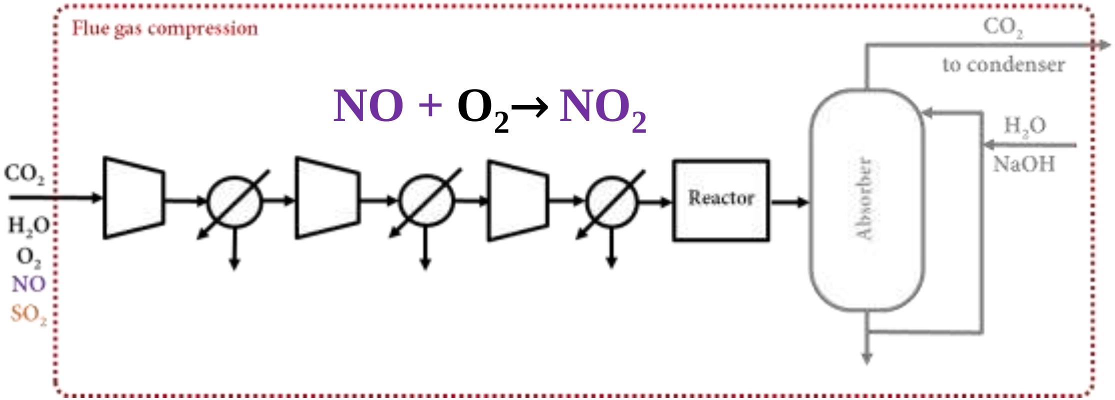


Flue Gas Compression: Extent of NO Oxidation

- **Effect of O_2 concentration and pressure on NO conversion**

NO_{in} = 400 ppm, T = 30° C

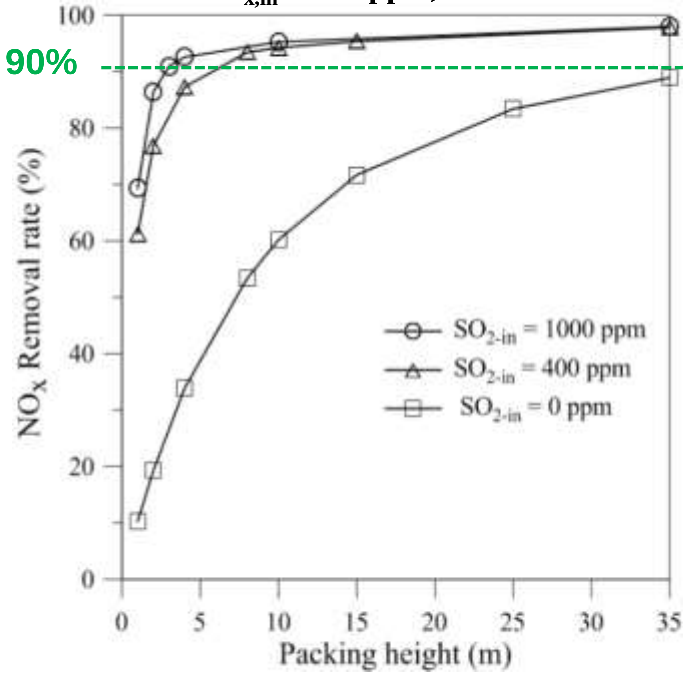


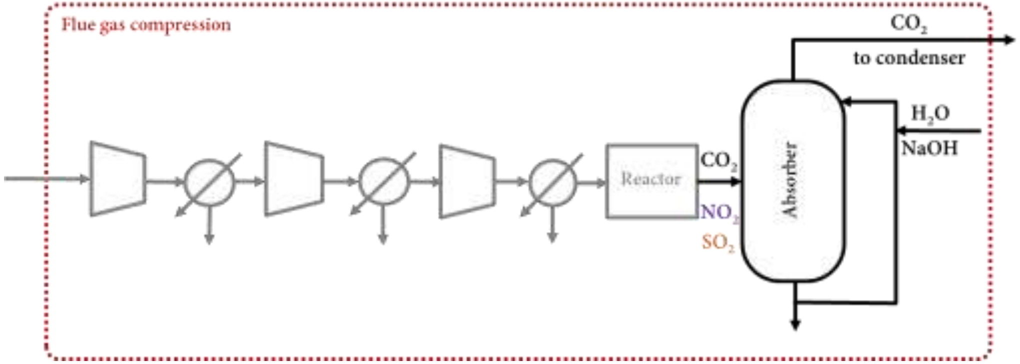


Absorber Performance: Effect of Sulfur on NO_x Removal Rate

- Absorption rate of SO_2 faster than NO_2 in the column

$NO_{x,in}$ = 400 ppm, P = 30 bar

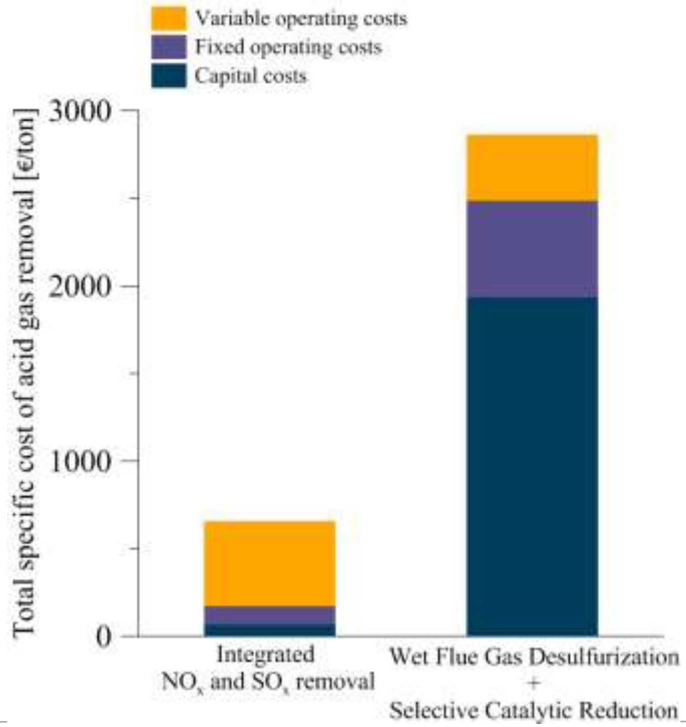




Cost Estimation: Integrated Removal vs. Conventional Techniques

- Integrated removal offers significantly lower cost of emission control compared to conventional tecniques
- Difference corresponding to 5 €/tonne CO_2 captured

Large scale power plant (350 MW_e)



CONCLUSION

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Recommendations for future research:

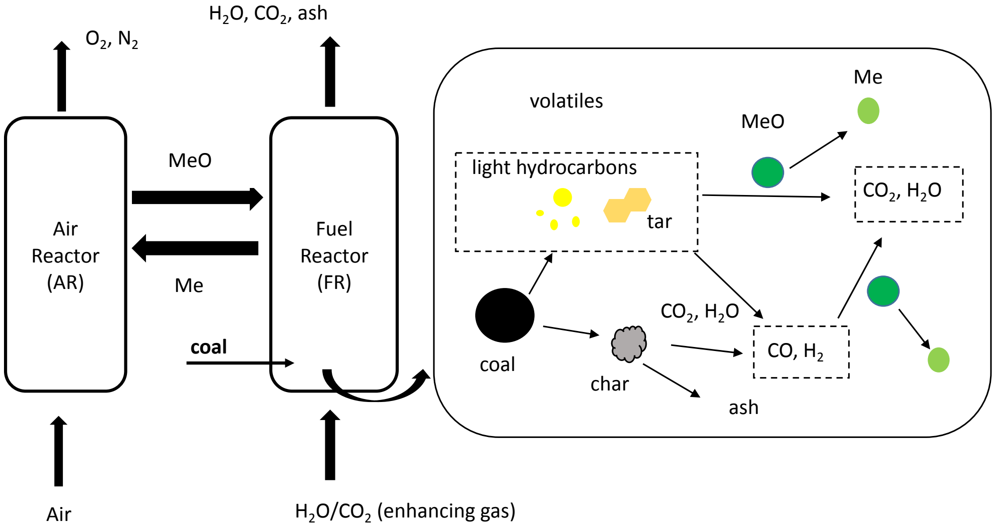
Build and operate test-units for integrated removal under pressurized conditions

Develop the understanding of the N-S interactions – especially the sulphite oxidation

Read more

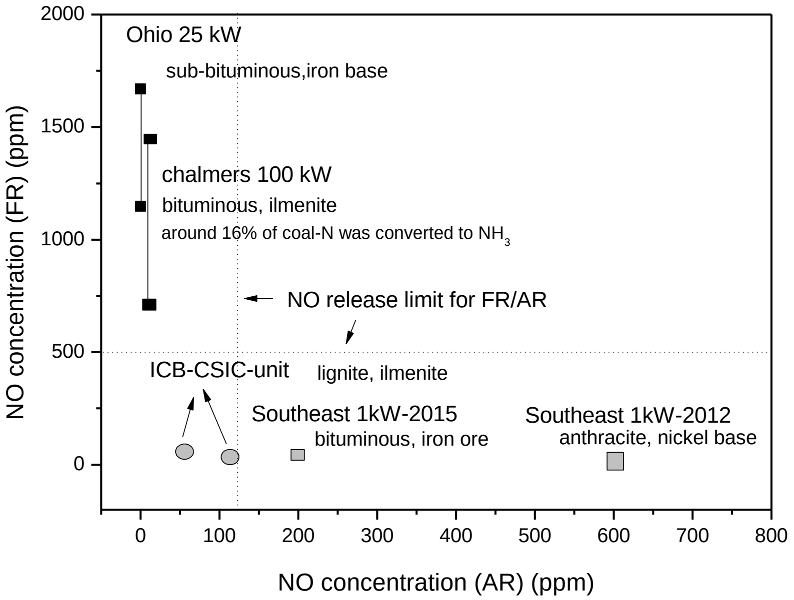
- **PhD-Thesis and papers therein by Sima Ajdari**
- **Recent papers by Jakob Johansson**

Chemical-Looping Combustion



- Volatiles react with MeO
- Char is gasified and the products react with MeO
- Gas-phase interactions

NOx Formation in CLC – FR vs. AR



- NO in AR is due to char transport
- Thermal NO formation from N_2 in AR is negligible
- Considerable NO formation is measured in FR in some cases

[7,8,9,11,13,14]