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An Axens Group company

Nitrogen Oxides Reduction:

DeNOx State of perfromance across industries and future prospectives

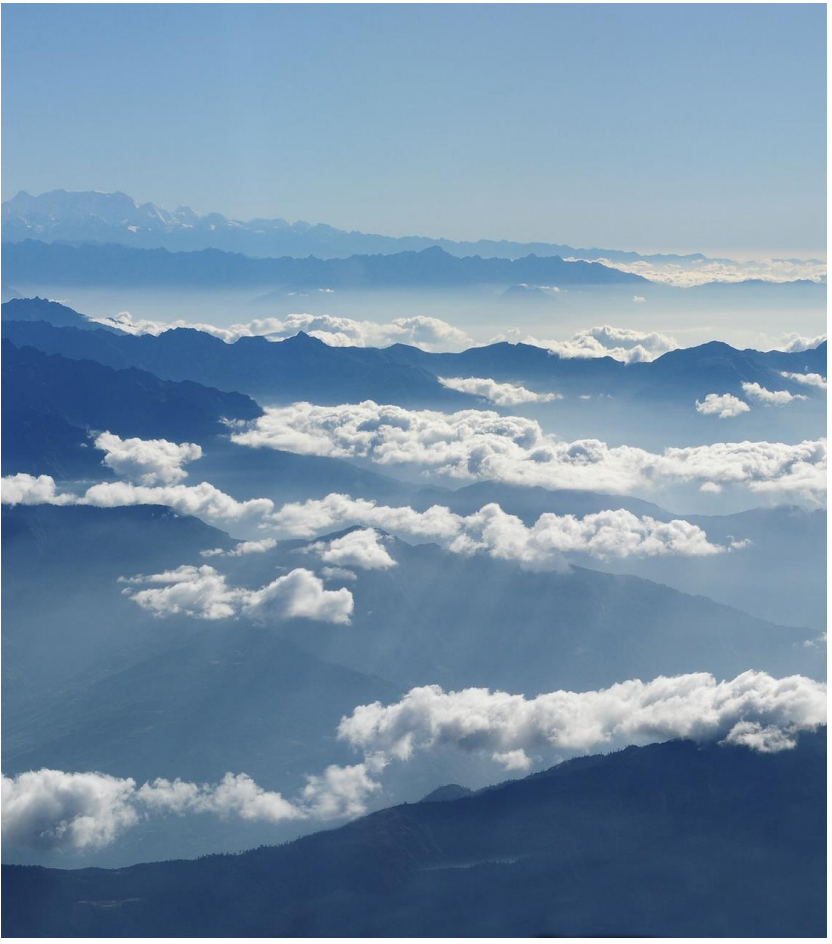
QUALITY SYSTEM CERTIFICATION

DNV·GL

ISO 9001

DNV GL BUSINESS ASSURANCE DENMARK A/S

CONTENTS



- NOx Pollution status across EU
- DeNOx Technology and application
- Case Study: make your investment worthy
- Conclusions

NOx Pollution Across EU: Potential Hazard

Effect on human health

Damage to human respiratory tract with increased risk of heart and lung desease

Acidification

Both Sulphur and Nitrogen oxides react with water in the atmosphere, causing acid rain and acidification of soil and water

Ozone layer depletion

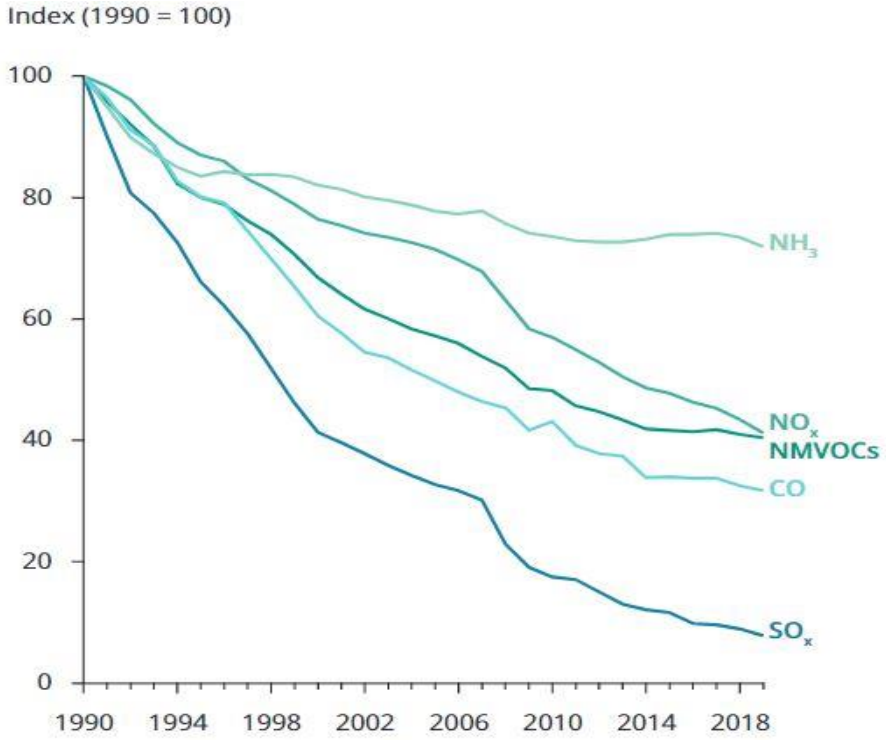
Nitrogen oxides react with the Ozone layer, producing oxygen and NO2 and depleting its abundance

Effect on the ecosystem

The diversity of ecosystems is greatly impacted by the unchecked emission of pollutants into our atmosphere

NOx Pollution Across EU: Where are we now

Nitrogen Oxides emission (NOx) in the EU-28 from 1990 to 2018*



*European Union Emission Inventory Report 1990-2019

NOx Emission results

- 3rd most targeted pollutant in new emission regulation
- 59% Reduction of emission in the past 20 years
- Between 2018 and 2019 NOx emission dropped by 5.2%

NOx Pollution Across EU: How did we get there?

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We changed the way of thinking about emissions, especially in Energy production

- Switch from coal to gas for boiler
- Usage of primary measure and optimized combustion technology
- Implementation of secondary measure: DeNOx Systems now frequently used in Industry

NOx Pollution Across EU: Where We Want to Be

	2020					2030				
Country	NH_3	NMVOC	NO_x	$PM_{2.5}$	SO_2	NH_3	NMVOC	NO_x	$PM_{2.5}$	SO_2
Austria	🟡	✔	✔	✔	✔	🟠	✔	🔴	🟠	✔
Belgium	✔	✔	✔	✔	✔	✔	✔	🟠	✔	✔
Bulgaria	✔	🟡	✔	🟠	✔	✔	🟠	🟡	🔴	✔
Croatia	✔	✔	✔	✔	✔	🟡	🟠	🟠	🔴	✔
Cyprus	✔	✔	🟡	✔	🟤	✔	🟡	🟠	🔴	🟤
Czechia	✔	✔	✔	✔	✔	🟡	🔴	🔴	🟤	🟠
Denmark	🟡	✔	✔	✔	✔	🟡	✔	🟠	🟠	✔
Estonia	🟡	✔	✔	✔	✔	🟡	✔	✔	✔	✔
Finland	🟡	✔	✔	✔	✔	🟡	🟡	🟡	✔	✔
France	✔	✔	✔	✔	✔	🟡	✔	🔴	🟠	✔
Germany	🟡	✔	🟡	✔	✔	🟠	✔	🔴	🟠	🟠
Greece	✔	✔	✔	✔	✔	✔	🟡	🟠	🟡	🟠
Hungary	🟡	✔	✔	🟡	✔	🔴	🔴	🔴	🟤	🔴
Ireland	🟡	🟠	✔	✔	✔	🟡	🟠	🔴	🟡	✔
Italy	✔	✔	✔	✔	✔	🟡	🟠	🟠	🟠	✔
Latvia	🟠	✔	🟡	✔	✔	🟠	🟠	🟡	🟠	✔
Lithuania	🟡	🟠	🔴	✔	✔	🟡	🔴	🔴	✔	🟡
Luxembourg	🟡	✔	✔	✔	✔	🟠	🟠	🔴	✔	✔
Malta	✔	🟠	✔	✔	✔	✔	🟠	🟤	🟡	✔
Netherlands	✔	✔	✔	✔	✔	🟡	✔	🟠	✔	✔
Poland	✔	🟡	🟡	✔	✔	🟠	🟡	🟠	🔴	🟠
Portugal	✔	✔	✔	✔	✔	🟡	🟠	🟠	🔴	🟡
Romania	✔	✔	🟠	🟠	✔	🟡	🟠	🔴	🟤	🟠
Slovakia	🟠	✔	✔	✔	✔	🟠	✔	🟡	✔	🟡
Slovenia	✔	✔	✔	✔	✔	🟡	🟠	🔴	🔴	🟠
Spain	🟡	✔	✔	🟡	✔	🟠	🟠	🟠	🔴	🟡
Sweden	🟡	✔	🟡	✔	✔	🟠	✔	🔴	✔	✔
EU-27	✔	✔	✔	✔	✔	🟠	🟠	🔴	🟠	🟠

Current emission levels below the emission reduction commitment ✔
Emission reduction needed by less than 10 % from current levels 🟡
Emission reduction needed by 10 % to 30 % from current levels 🟠
Emission reduction needed by 30 % to 50 % from current levels 🔴
Emission reduction needed by more than 50 % from current levels 🟤

New Target coming from Gothenburg agreement

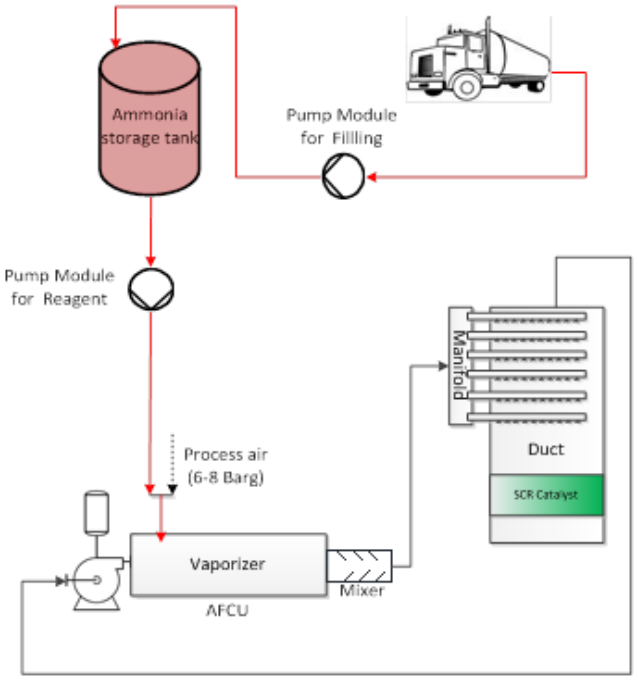
- Most of the EU members complied with NOx emission targets of 2020
- Most of the EU members are more than 20% away from 2030 target
- Avg distance from Gothenburg target in EU27 is 35%

NOx Pollution Across EU:
Making the most from Secondary Measures

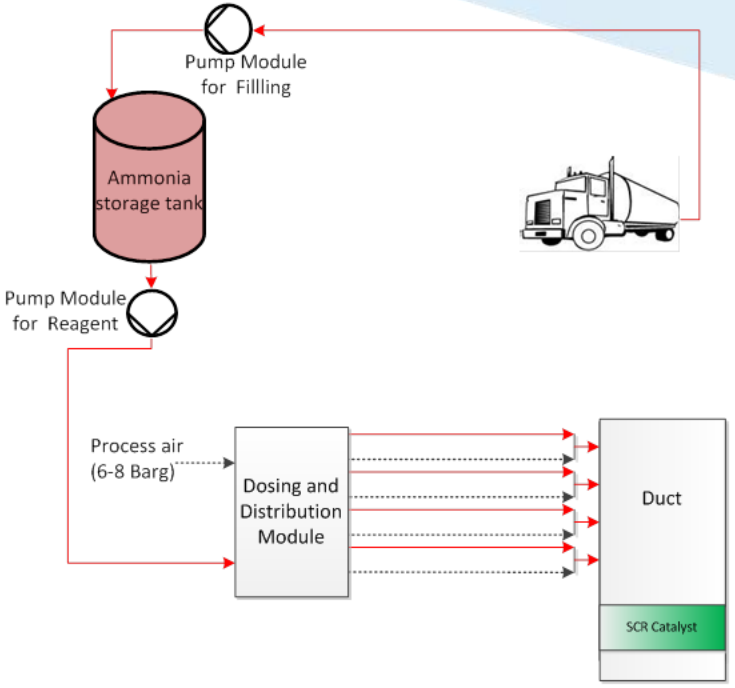
What are Secondary Measures?

- Adsorption and Absorption of NOx using solvents
- DeNOx SNCR Technology
- DeNOx SCR Technology

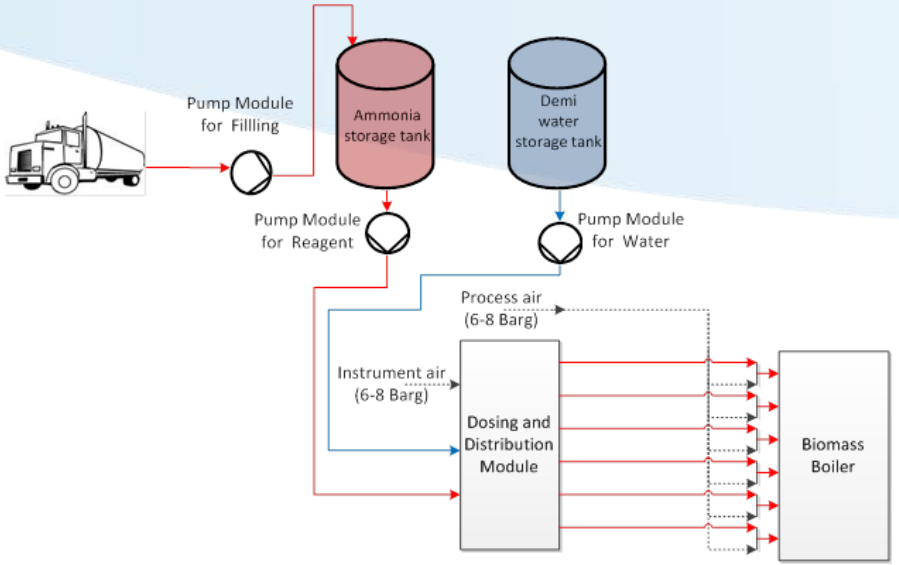
DeNOx system



Typical SCR with ext. evaporation



Typical SCR with direct injection



Typical SNCR

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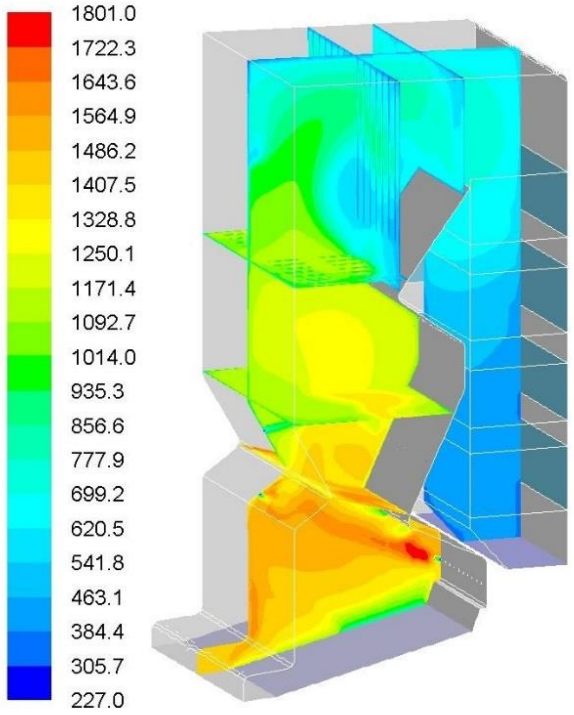
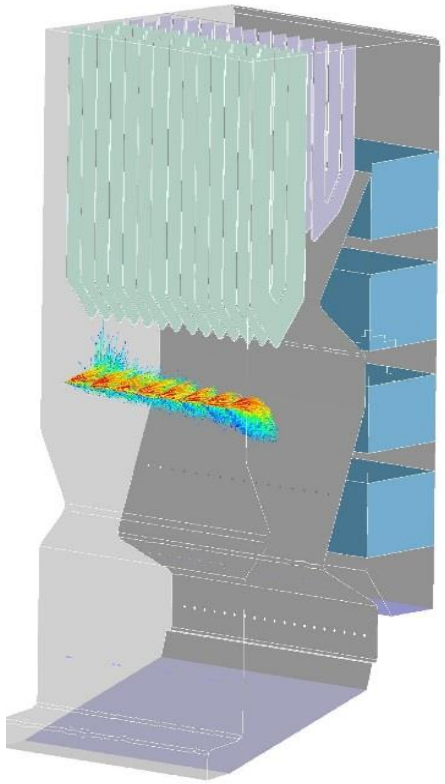
DeNOx SNCR System

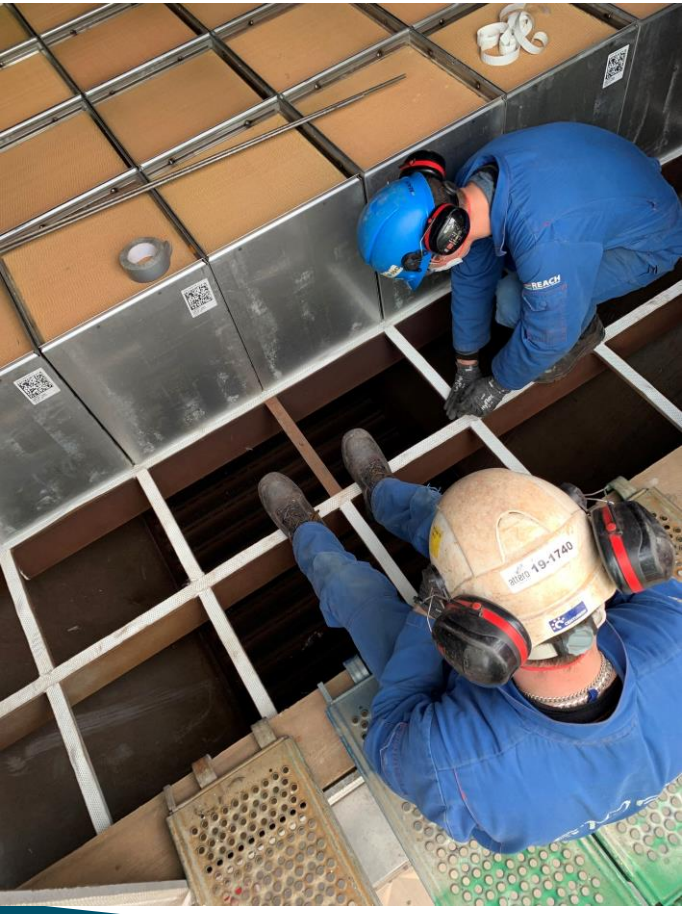




Selective NON Catalytic Reduction

- NOx conversion efficiency — Up to 80%
- High operating temperature range — 850 - 950 °C
- Ammonia or Urea reagent
- Dilution water might be needed
- Multiple injection point designed for maximum area coverage
- Multiple injection layer for boiler operation changes

DeNOx SCR System



Selective Catalytic Reduction

- High NOx conversion efficiency Up to 99%
- Low operating temperature range 180 - 450 ◦C
- Ammonia or Urea reagent
- Catalyst design, chemistry and geometry according to your plant needs
- We provide several type of catalyst:
  - Plate type (coated metallic substrate),
  - Honeycomb type (full body ceramic extruded)
  - corrugated type

DeNOx Technology: Where can we go

What results can be reached by DeNOx system?

- Higher NOx abatement imply higher NH3 or CH4N2O (Urea) consumption due to stoichiometry of the reaction

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

$$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$$

- DeNOx SNCR Technology requires higher reagent consumption
- DeNOx SCR Technology requires higher CAPEX but can get to the lowest achievable emission and optimize reagent consumption

DeNOx SCR System – external evaporation

Case Study: Bio Methanol plant

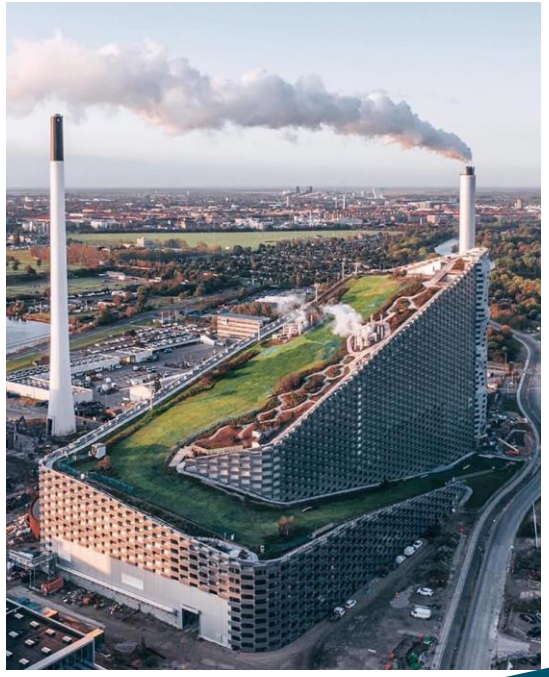
Methanol Unit

- 300,000 Nm3/h data
- NOx emission requirement (BREF 2021*) 150-10 mg/Nm3
- 95% NOx Reduction
- NH3 slip < 2 mg/Nm3 @ 3% O2

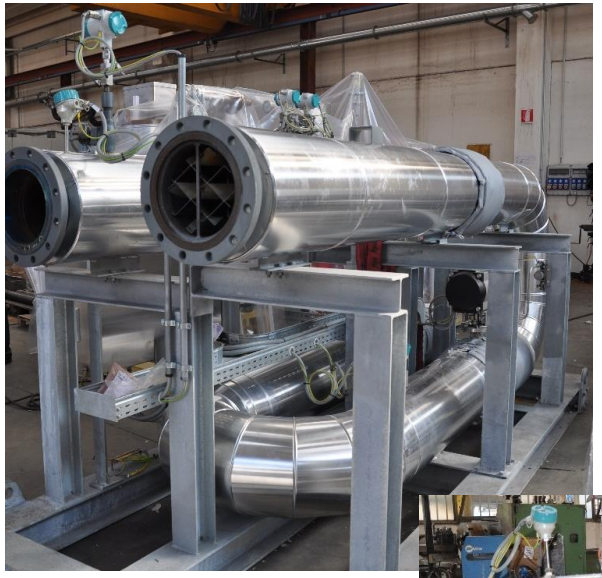
DeNOx SCR System – direct injection

Case Study – Amager Bakke WTE

- 2x 840 tpd WTE
- NOx Emission requirement (BREF 2019) 50-150 mg/Nm3
- 96% NOx Reduction
- NH3 slip < 2 mg/Nm3 @ 11% O2



DeNOx Low –T SCR Technology



The BAT for Saving your Energy

- NOx conversion efficiency Up to 95%
- Lowest operating temperature range 150 - 200 ◦C
- Ammonia reagent
- External Evaporation of reagent
- Significant lower OPEX

How do We get the Most from those Technology?

Needs to Understand what is the technology limit

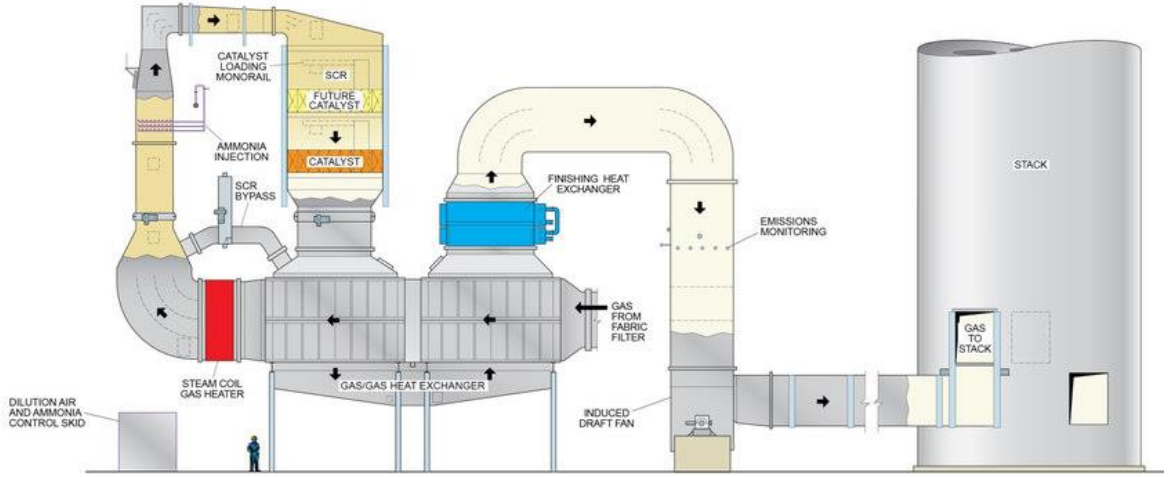
99.9% of the DeNOx Systems installed today must answer to one customer need: Can I run my plant in compliance with the current regulation?

BUT… is it the right question?

What if… Case study for DeNOx SCR

Avg Size WTE DeNOx Installation actual performances

- Flowrate 28600 Nm3/h
- NH3 solution Consumption 22 kg/h
- DeNOx efficiency 80%
- NOx emitted in the atmosphere 80 mg/Nm3



What if… Case study for DeNOx SCR

Avg Size WTE DeNOx SCR Installation Maximum Performances

- Flowrate 28600 Nm3/h
- NH3 solution Consumption 27 kg/h
- DeNOx efficiency 95%
- NOx emitted in the atmosphere 20 mg/Nm3

14.5 ton/year of NOx SAVED

What if… Case study for DeNOx SCR

Avg Size WTE DeNOx SCR Installation-Cost Benefit comparison

	OPEX	CAPEX
Actual CASE	100	100
Maximum performences	120	110

10% CAPEX and 20% OPEX more for 14.5 ton/y NOx saved

Conclusion: what does the emission limit range imply?

- Once a DeNOx Technology is required the impact in going from higher to lower Nox emission within the range is < 20% (i.e. for WTE 50-150 mg/Nm3)
- If SCR Technology is required, the increase in reagent consumption is smaller compared with SNCR system
- The most complicated scenario is switching from SNCR to SCR technology

DeNOx Smart Installation: How do we Achieve our target

Combined effort for 2030:

- Policy Maker: Trust the technology
- End User: ask for what you can achieve not what you should achieve
- System Suppliers: more flexibility and ready-to-improve system

FLOWVISION®

Your Best Partner for Emission Control

Thank you for your attention