Flue gas emission considerations when firing biomass in pulverised coal plant

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BiOxySorb

Economic low carbon power Production and Emissions Control for Future and Flexible Biomass Co-fired Power Stations

Research Fund for Coal & Steel

European Commission

Contents

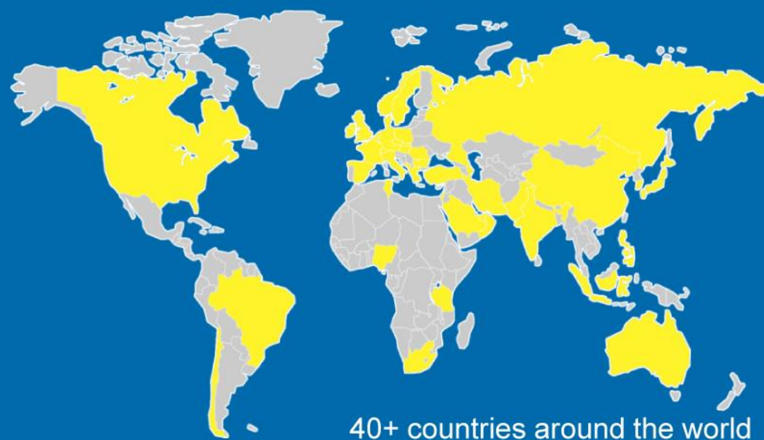
- Uniper
- Biomass possibilities and challenges
- Emissions legislation
- Impacts on emissions and pollution control equipment

We are Uniper

Our operations:

- Power Generation
- Commodity Trading
- Energy Storage
- Energy Sales
- Energy Services

Where we operate:



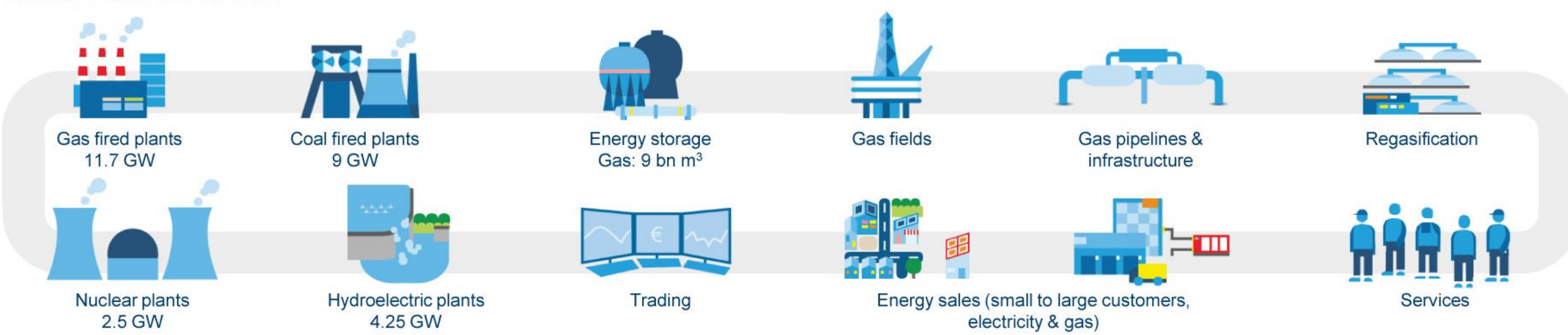
40+ countries around the world
4th largest generator in Europe

Employees: 13,000

- Power generation, Storage, Services - Europe
- Power generation - International
- Commodity Trading, Energy Sales

€1.71bn	100 years	31.6 GW
EBITDA	Experience	Total generation

Main activities:



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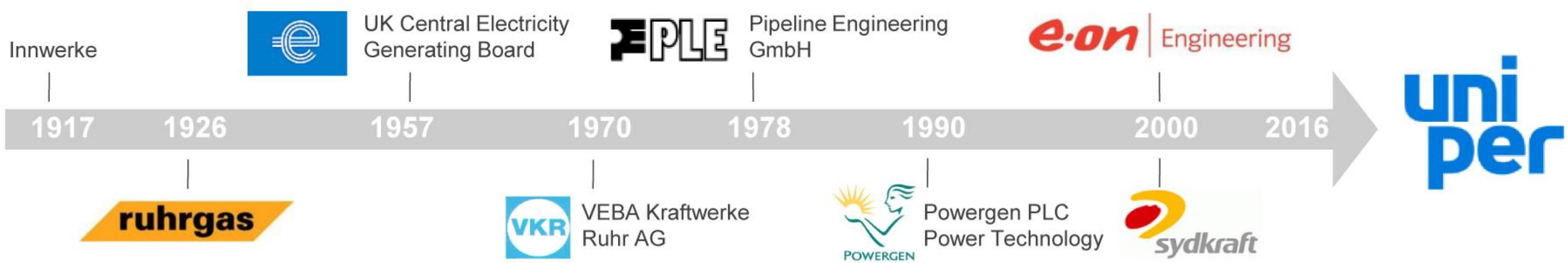
Expertise built on engineering excellence and owner operator asset experience

We are a **one-stop shop** offering a broad range of services that work closely together, reducing complexity and risk for customers

Our **background as an asset owner/operator** gives us deep understanding of the energy industry and our customers' needs

We are **independent** of equipment and component suppliers, giving us freedom to choose the best solution for customers

Expertise based on experience



Energy services to over 600 power sector and industrial customers all over the world


Gas fired generation


Coal fired generation


Industrial generation


Nuclear


Renewables


Energy from waste and biomass

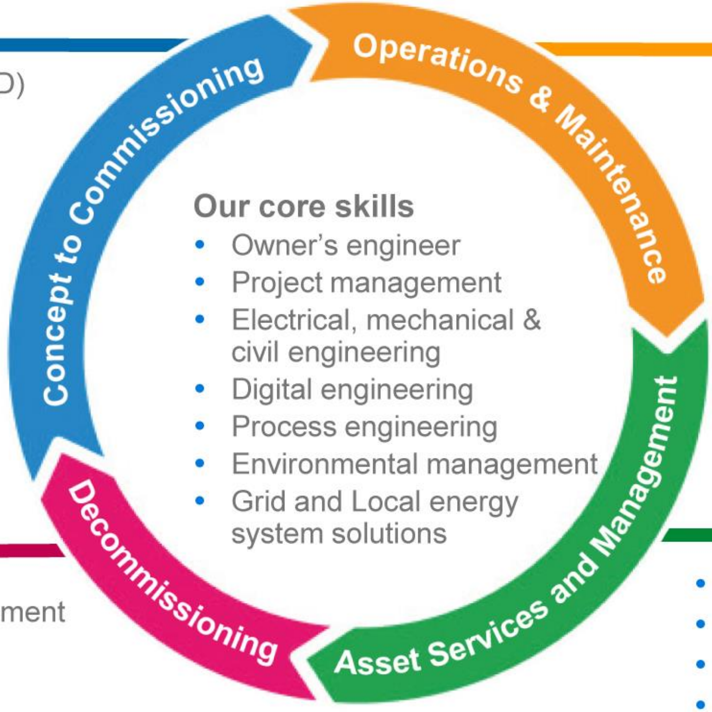

Insurance, banking and finance


Energy distribution


Gas pipelines, storage and LNG

Our energy services

- Front end engineering design (FEED)
- Commercial evaluation
- Engineering, Procurement and Construction tendering and project management
- Construction and site management
- Commissioning



Our core skills

- Owner's engineer
- Project management
- Electrical, mechanical & civil engineering
- Digital engineering
- Process engineering
- Environmental management
- Grid and Local energy system solutions

- Outage support
- Production support
- Maintenance and spares optimisation
- Field services
- Workshop services

- Planning, permit and impact assessment
- Decommissioning and dismantling
- Demolition

- Benchmarking
- Asset lifetime assessment & extension
- Asset risk management
- Compliance and standards
- Technical operational excellence

Biomass Possibilities

- Renewable fuel source
- Subsidies and tax breaks e.g. EUETS, national carbon taxes
- Fuel standards and sustainability cert. increasing
- Dispatchable, flexible, frequency response…..
- Power and heat generation
- Emissions
- Bio CCS – negative CO2 power generation – Stern
- Switch in running mode?

- Firing in coal assets rather than new build allows;
  - Use of existing facility – staff, equipment, infrastructure, grid….
  - Smaller investment – Ramboll – 4-12 times less capex/kW (conversion)
  - Shorter construction times
  - Benefit from high efficiencies
    - Reduced conversion costs with time?

Biomass Challenges

- Sourcing – less mature market than coal
- Quality
- Logistics – ports, trains….
- Conversions are major engineering projects inc. demolition?
- New equipment and modifications can be numerous
- Less knowledge and experience relative to coal firing – under design/over design, associated costs….
- Condition of existing plant if converting
- Stopping it setting on fire during handling – lots of examples
- Burnout, slagging, fouling, corrosion, emissions (maybe), ash
- Impacts on pollution control equipment
- Control settings, operator regimes, kit replacement
- Economic link to legislation and subsidies

Emissions Legislation – EU Level

- Ever decreasing ELVs and introduction of new species in permits

	ELVs (mg/Nm^3)		
	SO_2	NOx	Dust
LCPD	400	500	50
IED	200	200	20

Monthly averages for large, existing plant

Coal or solid biomass

- Prior 2016
- 2016

- BREF - currently at final draft, compliance expected ~2018-2021 – if passed.

SO_2	NOx	Dust	HCl	HF	Hg	NH_3
10 - 130	65 - 150	2 - 8	1 - 5	<1 - 3	<1 - 4	<3 - 10
<10 - 50	40 - 150	2 - 10	1 - 5	<1	<1 - 5	<3 - 15

- H. Coal
- Bio

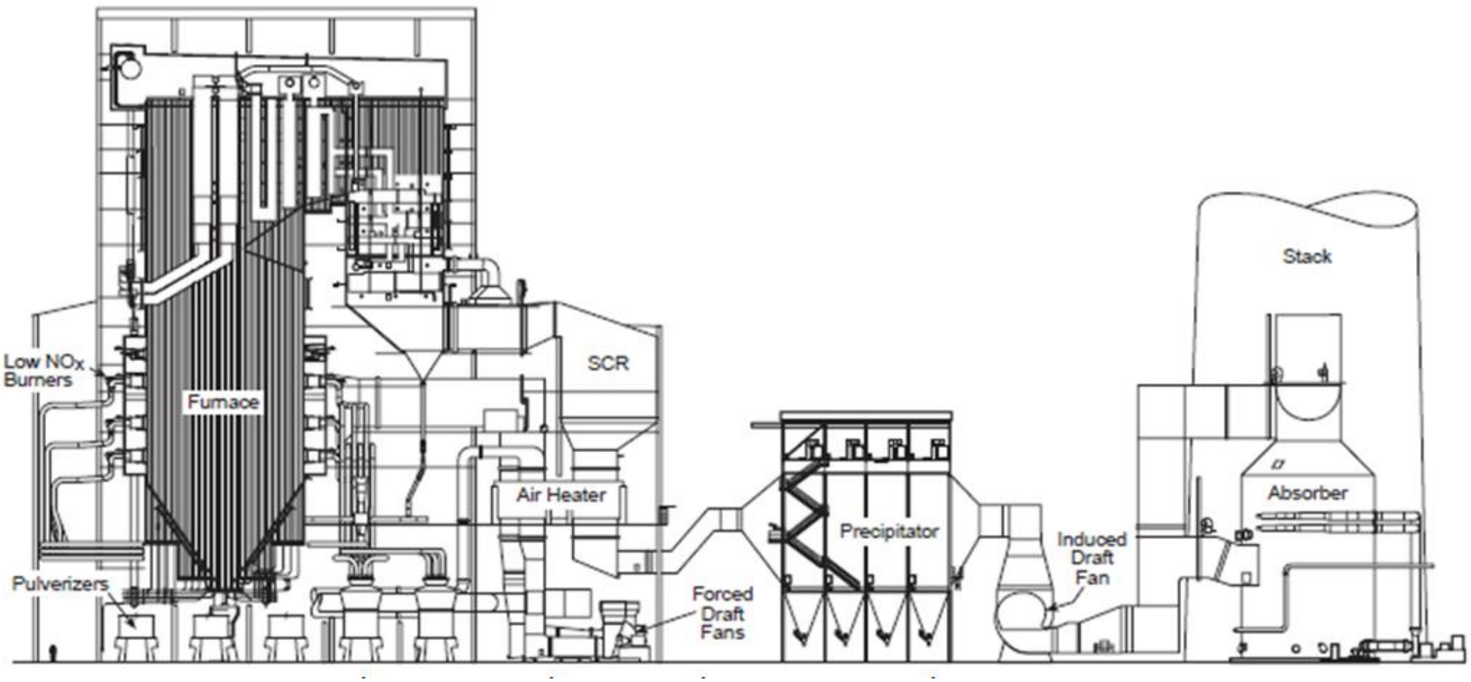
Annual averages in mg/Nm^3 (Hg is µg/Nm^3), for large, existing plant.

Underlined - upper ends can be extended NOx -160, SO2 -100, HCl -7, 20, 25

- Lots of caveats, different limits for; different size plant, running hrs, new plant, lignite, daily & hrly limits, 8yrs. National requirements. MCPD

Pollution Control Train

- Example layout for a pulverised coal plant



- Other options e.g. – OFA, SNCR, cyclones, FF, SDA, sorbent injection….

Wood Sulphur

- Biomasses can have much lower S compared to coal

- Bioxysorb examples torrified poplar, torrified pine, wood pellet, saw dust <0.05% to ~ 0.1% dry

- EN ISO 17725 grade wood pellets ≤0.04% or ≤0.05% dry

- Bituminous coals generally fired by coal power plant in the EU 0.5-2.5% - order of 10-50 times higher

→ Expect reduced SO_2 formation

Wood SO2

Stuttgart 500KWth tests

- 25% thermal share of biomass, furnace exit

Fuel/Blend	Measured SO2 (ppmvd) @ 3% O2	Drop in SO2 Relative to Coal (%)	Measured SO2 (ppmvd) @ Actual O2	Theoretical SO2 (ppmvd) @ Actual O2	Difference (%)
Coal (2.4% S)	1709		1734	1963	12
Coal & T. Pine	1090	36.2	1053	1457	28
Coal & T. Pop.	1186	30.6	1207	1511	20
Coal & Wood	1276	25.4	1267	1492	15

- Higher alkali content in biomasses – inherent desulphurisation

Fuel	Fuel Ash Ca+Mg+K (%)
Coal	7
Torrified Wood	50
Wood	36

Raw fuel only not mix

Wood SO2

CIUDEN 20MWth tests

- ~8% thermal share saw dust
- Average results from 2 campaigns on each fuel or fuel mix

Fuel	Fuel S (% db)	ID Fan SO2 (ppmvd at 3% O2)	S in Fly Ash (% db)
Coal	0.850	617	1.8
Coal & Biomass	*0.845*	522	2.9

~16% drop in SO2

Others

- 50% thermal share of wood at 20kWth - ~50% drop in SO2
- Some commercial scale plants firing neat biomass – ≥80% desulphurisation

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Impacts on PP/DeSOx from Biomass – SO2

- Co-firing may allow coal basket to be increased e.g. cheaper HS USA
- Reduced stack emissions - aids compliance with SO2 ELVs
- Lower deSOx costs e.g. limestone, lime, water, power….but less gypsum
- Switch to cheaper deSOx option
- V high biomass shares may allow the FGD to be turned off – other emissions?
- Suppression of SA dew point – reduced AH corrosion/plugging

- AH plugging leads to forced outages, lost generation and cleaning cost

Impacts on PP/DeSOx from Biomass – SO2

- Possible shift of SA condensation to downstream components?
- Lower SO3 – impact on ESP performance?
- Move from alkali sulphates to alkali chlorides formation? – linked to furnace deposition and SH corrosion – possibly low risk with EN wood pellets
- S in fly ash – use
- Suppression of MIT for SCR operation
  - Calculations reveal tens of °C reduction in ABS dew point from coal to biomass
  - Quicker SCR start up – reduced plant min. load, reduced NOx taxes….

NOx

- Generally wood biomass have lower fuel nitrogen and higher VM contents compared to coal – helps suppress NOx emissions

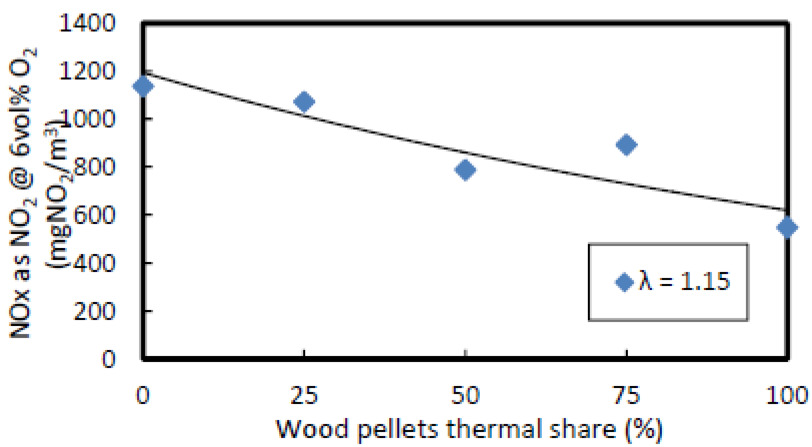
Fuel	US2.5 coal	SA coal	Wood pellets	Torr. wood	Torr. straw
Proximate analysis					
W [%, raw]	1.6	2.84	7.95	6.12	7.89
A [%, wf]	9.43	16.06	1.38	0.14	4.36
VM [%, waf]	38.72	20.77	79.53	79.15	76.17
C_{fix} [%, waf]	61.28	79.23	20.47	20.85	23.83
Ultimate analysis					
C [%, waf]	81.91	82.67	51.11	59.09	53.13
H [%, waf]	5.20	4.45	4.78	4.86	4.89
N [%, waf]	1.59	1.73	0.63	-	0.52

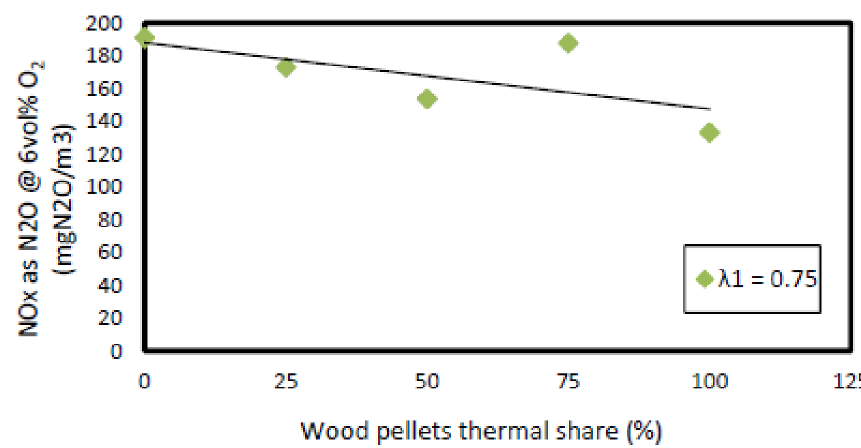
- However combustion factors play a strong role in NOx formation e.g. burner geometry, flame structure, fuel/air mixing…

NOx

Stuttgart 20kWth tests

- Firing with bituminous coal





- 100% biomass showing ~30-50% NOx reduction

NOx

CIUDEN 20MWth tests

- ~8% thermal share saw dust
- Average results from 2 campaigns on each fuel or fuel mix

Fuel	SCR Inlet NOx (ppmvd at 3% O2)
Coal	477
Coal & Biomass	549

~15% increase in NOx

Others

- Growing evidence of reduced NOx levels with increased biomass firing, especially with combustion modifications
- Some commercial scale plants firing neat biomass have shown ~25-50% NOx reduction

Impacts on PP/DeNOx from Biomass - NOx

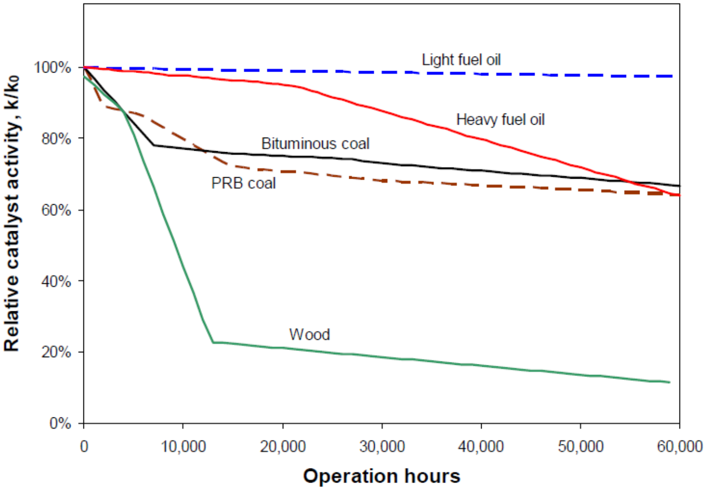
- Care with combustion control – can see increased NOx levels
- Probably reduced NOx - aids compliance with ELVs, reduced NOx taxes
- Turn down post combustion NOx control equipment – lower costs e.g. NH3
- Safety factors e.g. less NH3 deliveries, less site inventories…
- Adoption of much cheaper capex NOx controls e.g. SNCR not SCR (€10s M)
- Fate of ammonia slip – expect less in ash – more pass through to FGD/WW/stack
- SCR catalyst - increased deactivation (K, Na, P, CaS)

Coal

	SA	US
K2O	0.71	2.37
Na2O	0.21	0.66
P2O5	1.9	0.2
Total	2.8	3.2

Biomass

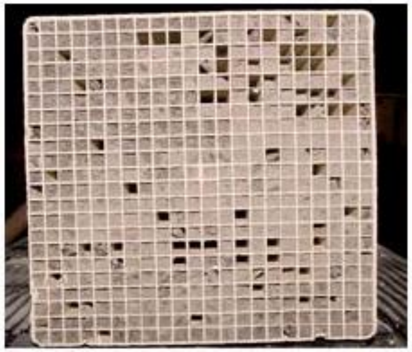
	Wood	Torr. Wood
K2O	11.43	18.8
Na2O	1.53	1.37
P2O5	2.69	7.05
Total	15.7	27.2



Ref: Haldor Topsoe

Impacts on PP/DeNOx from Biomass- NOx

- Increased catalyst replacement costs
- Impact on catalyst guarantees?
- Need for control strategies to manage deactivation – limit co-fire ratios, additive injection, switch to tail-end SCR……
- Catalyst plugging (+/-) – less mass but some larger particles



- Further suppression of MIT for SCR operation – Min load, NOx taxes

Impacts on PP/ESP from Biomass

- Lower masses of fly ash - 10-15% fuel ash to ≤1-2 from bit. coal to wood
- All factors being equal – if ESP performance not impacted
  - Lower - stack emissions, FA sale/disposal, ash in gypsum….
- Factors to suggest better ESP performance – more Fe, Na in ash – lower resistivity
- More factors to suggest decreased performance - more Ca+Mg in ash, reduced SO3 leading, increase in fine ash content….
- Likely reduced performance but exit emissions can still be lower

- Possible increase in fine particles at stack releases, to tail-end SCR
- Fine particulate emissions increasingly discussed by EU regulators
- UBC carryover – AH/ESP fires – greater care needed including ash handling
- Lower silica and quartz – reduced erosion

Trace Emissions

- Lower wood pellet Cl resulted in less HCl production

- But wood pellet Cl can be lower, same or higher than coal

- Hg emissions were also lower with biomass firing

- Hg in wood pellets has always been lower than coal based on Uniper testing

BUT

- EN wood pellet standard has a max threshold of 0.1mg/kg which is higher than some coals

Take Aways

- Biomass presents existing coal power plants with numerous opportunities;
  - Renewable power and heat production
  - Maintains much needed grid services – flexible, dispatchable etc
  - In coal assets - quicker to grid and cheaper vs dedicated plant

- Can promote cleaner power production;
  - Reduction in most emissions possible (NOx, SOx, dust, HCl, Hg)
  - IED and BREF compliance tool – potential to save €10’s millions
  - Reduction in some pollution control costs e.g. limestone, ammonia…
  - Chance to alleviate some common restrictors e.g. SCR MIT, AH fouling

- Technical challenges (with costs) are present;
  - Plant modifications, safety risks, logistics, SCR catalyst, fine particulates….

With CCS - a front runner for CO2 negative power and heat production?

Many thanks to the BiOxySorb project and partners