

The history of conventional pollution and CO₂ regulations in Europe

Keith Whiriskey –
The Bellona Foundation
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Atmospheric Pollution from Power Plants

**Fossil fuel power stations have historically
been responsible for atmospheric pollution**

Including:

NO_x : Acid Rain & Smog

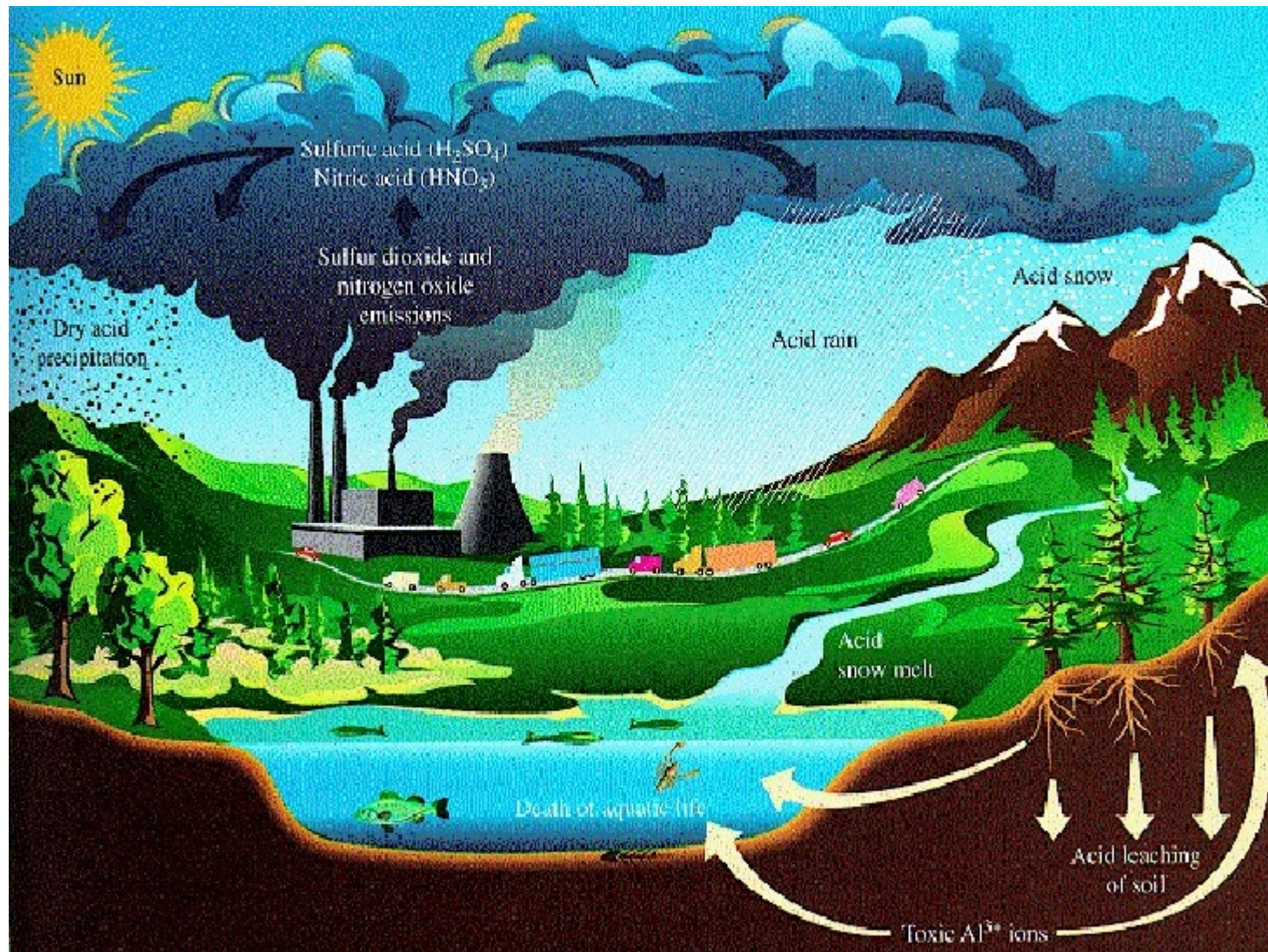
SO_2 : Acid Rain & Smog

Dust/ PM_{10}

NMVOCs



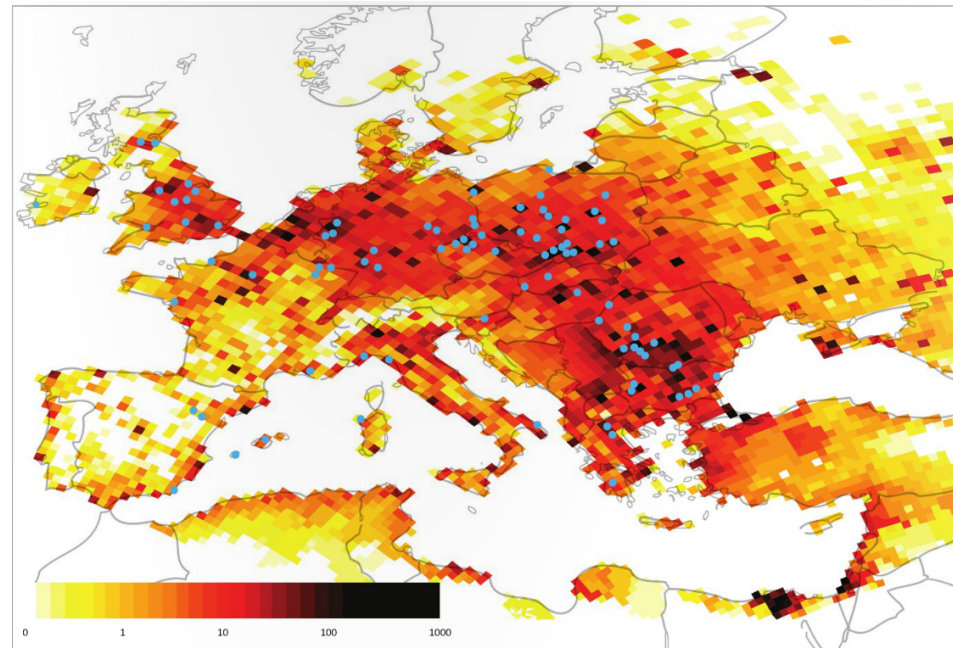
Forest damage from acid rain





Air pollution from Europe's 300 largest coal plants:

- Causes 22,300 premature deaths a year
- 240,000 years of life lost in 2010
- 480,000 work days a year lost in UK – fifth most coal polluted



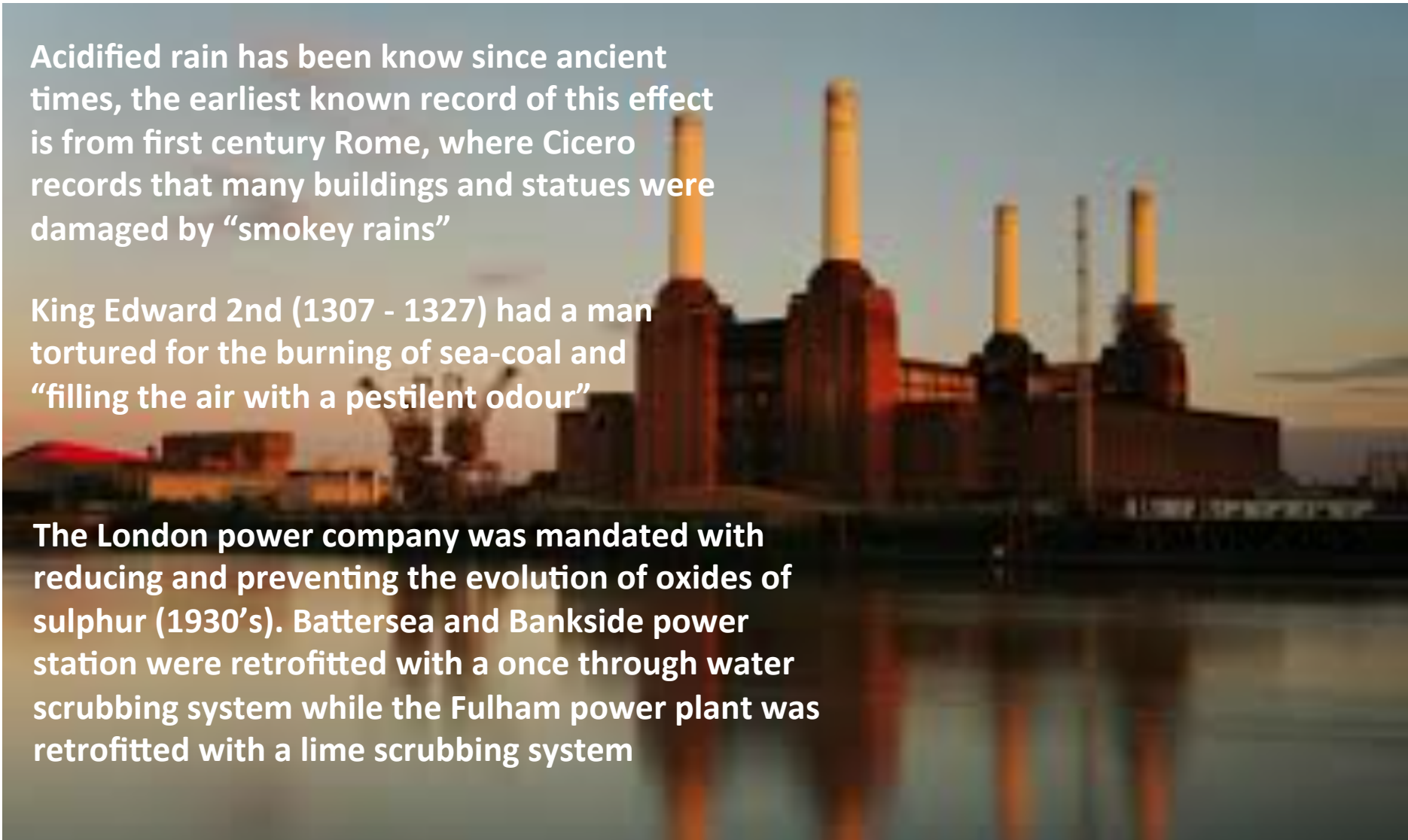
Map source: Greenpeace modelling using the EMEP MSC-W atmospheric chemistry-transport model, input data provided by EMEP and power plant emission data from the E-PRTR database.



Acidified rain has been known since ancient times, the earliest known record of this effect is from first century Rome, where Cicero records that many buildings and statues were damaged by “smokey rains”

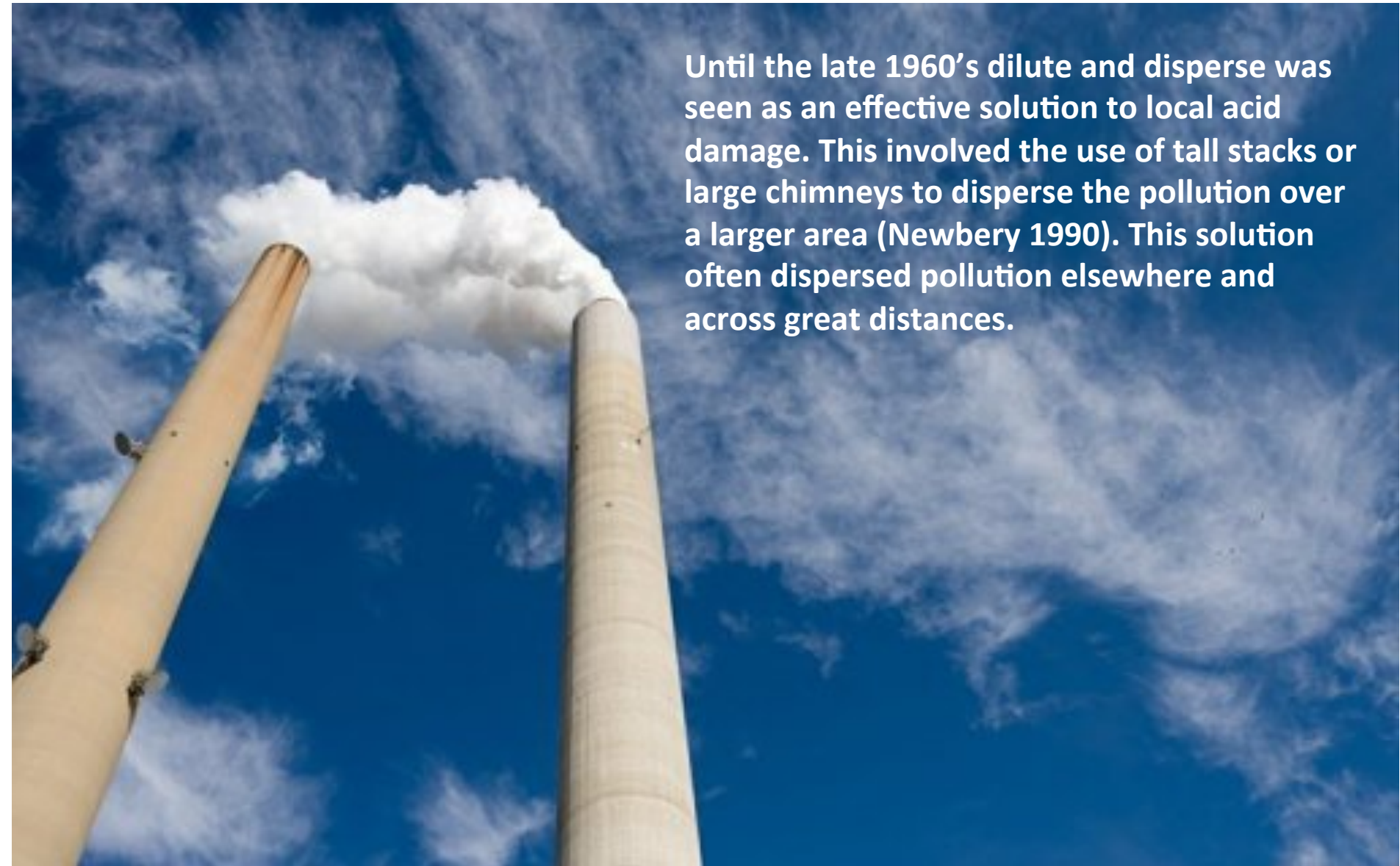
King Edward 2nd (1307 - 1327) had a man tortured for the burning of sea-coal and “filling the air with a pestilent odour”

The London power company was mandated with reducing and preventing the evolution of oxides of sulphur (1930's). Battersea and Bankside power station were retrofitted with a once through water scrubbing system while the Fulham power plant was retrofitted with a lime scrubbing system





Until the late 1960's dilute and disperse was seen as an effective solution to local acid damage. This involved the use of tall stacks or large chimneys to disperse the pollution over a larger area (Newbery 1990). This solution often dispersed pollution elsewhere and across great distances.





How acid rain affects stonework.
The picture on the left was taken in 1908
The picture on the right was taken in 1968





SO₂ derived acid rain does not only affect the country of origin but is often transnational, causing damage and cost on a regional scale.

Canada, New England, Scandinavia and central Europe are often seen as bearing the brunt for of this imported damage.

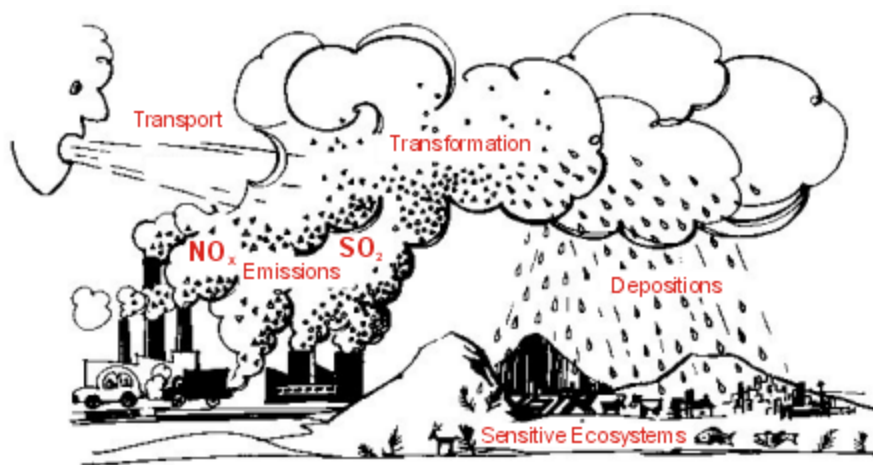
The scale of damage caused by transboundary acid deposition became evident at the **1972 United Nations Stockholm conference** by Swedish reports of massive fish kills and Lake Acidification (Park 1987).

In **1979** with the signing of the **UN Convention on Long-range Transboundary Air Pollution (LTARP)** which acknowledged SO₂ as a dangerous pollutant





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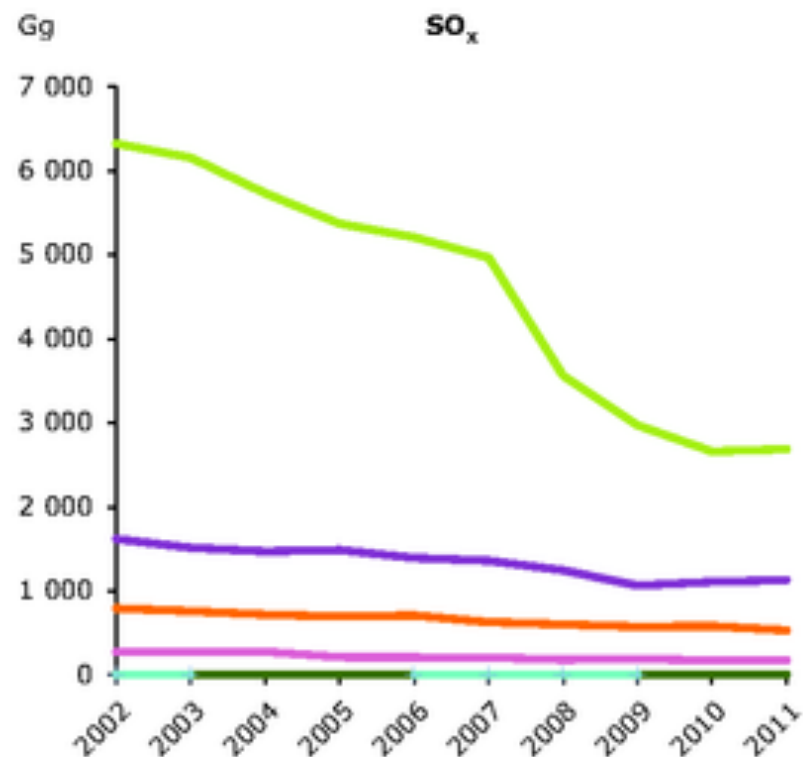
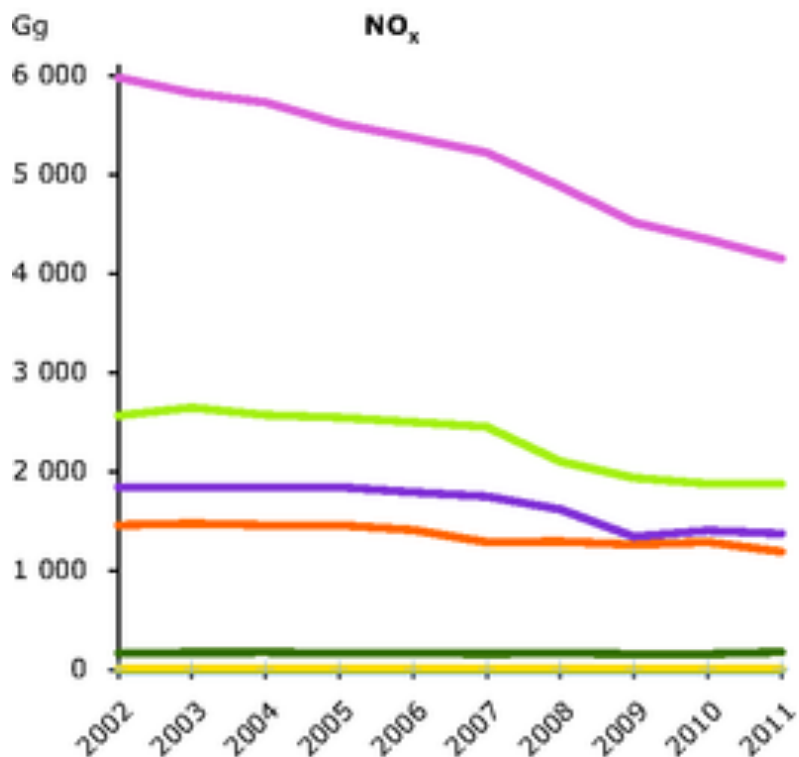
**1979 - UNECE Long-range Transboundary Air
Pollutants
(CLRTAP)**

**1983 - German Ordinance on Large Combustion
Plants (GFAVo)**

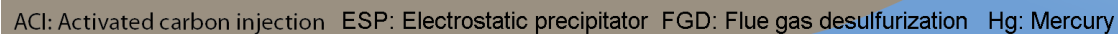
**1985 - UNECE Protocol on the Reduction of Sulphur
Emissions (Helsinki)
“30% Club”**

**1988 - Large Combustion Directive
(88/609/EEC)**

**2001 - Revised Large Combustion Plants Directive
(2001/80/EC)**

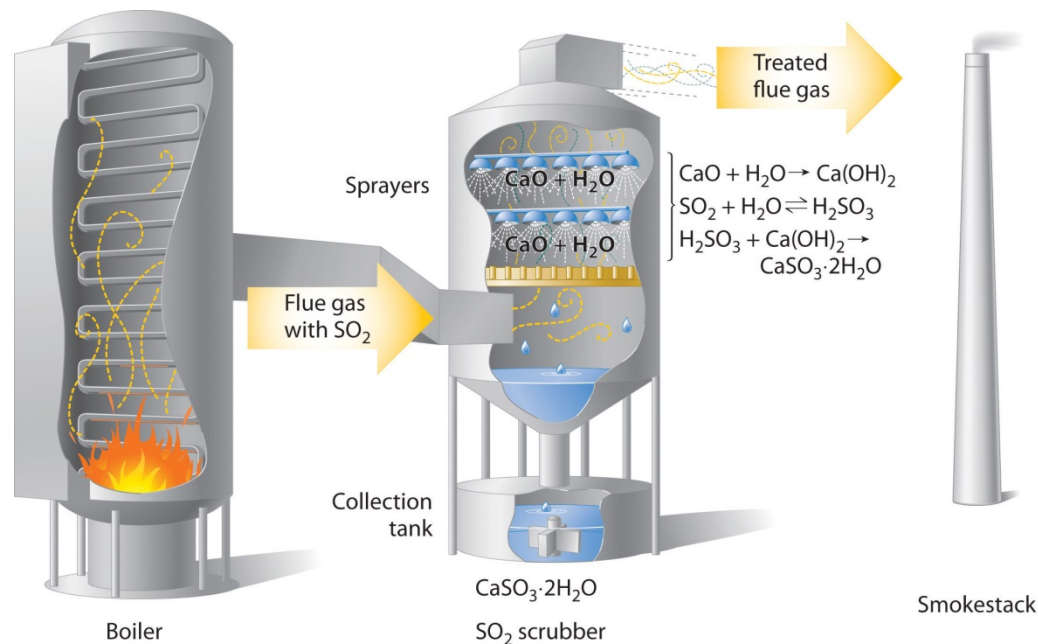


- Transport
- Industry
- Commercial, institutional and household fuel combustion
- Solvent and product use
- Agriculture
- Energy ex. industry
- Waste
- Other





In coal-burning power plants, SO_2 can be removed (“scrubbed”) from exhaust gases by its reaction with a lime (CaO) and water spray to produce calcium sulfite dihydrate ($\text{CaSO}_3 \cdot 2\text{H}_2\text{O}$). Removing SO_2 from the gases prevents its conversion to SO_3 and subsequent reaction with rainwater (acid rain). Scrubbing systems are now commonly used to minimize the environmental effects of large-scale fossil fuel combustion.





Wet FGD systems capital cost reduction since the early 1970's \$/kWe

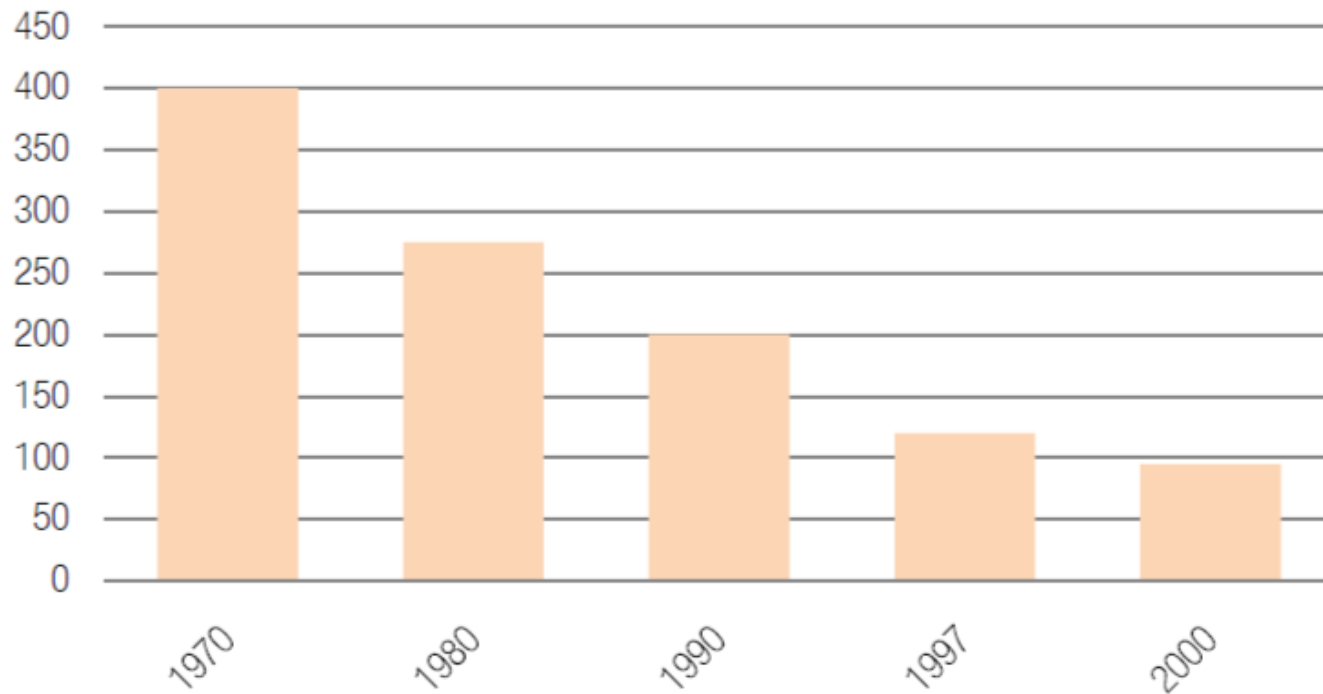


Figure 5.4 Capital costs of wet FGD systems 1970-2000 (Soud 2000)

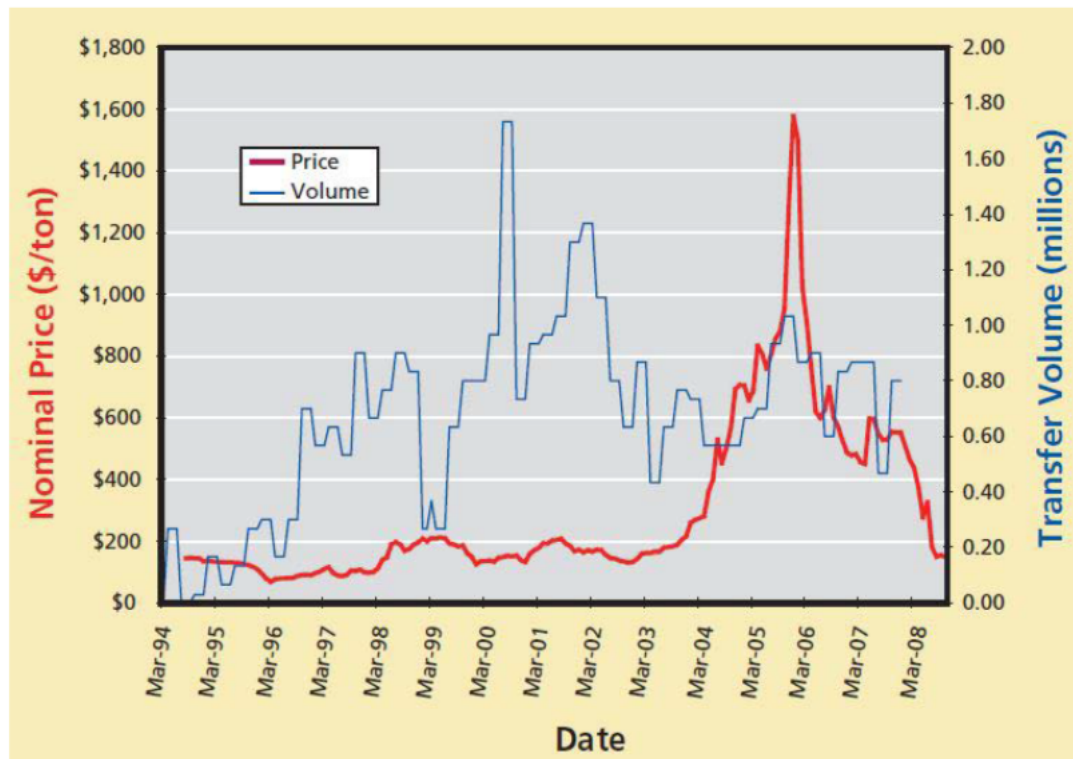
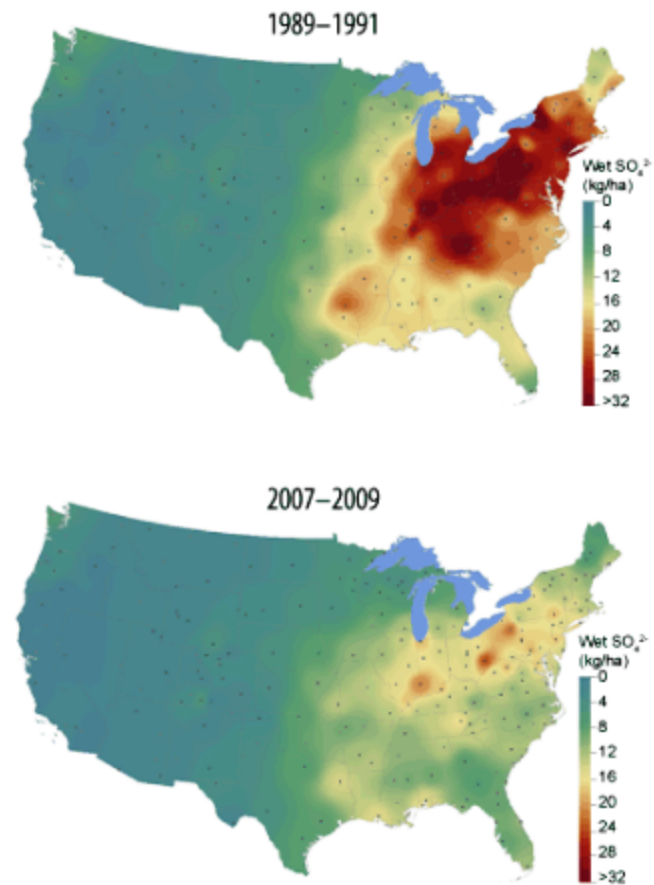


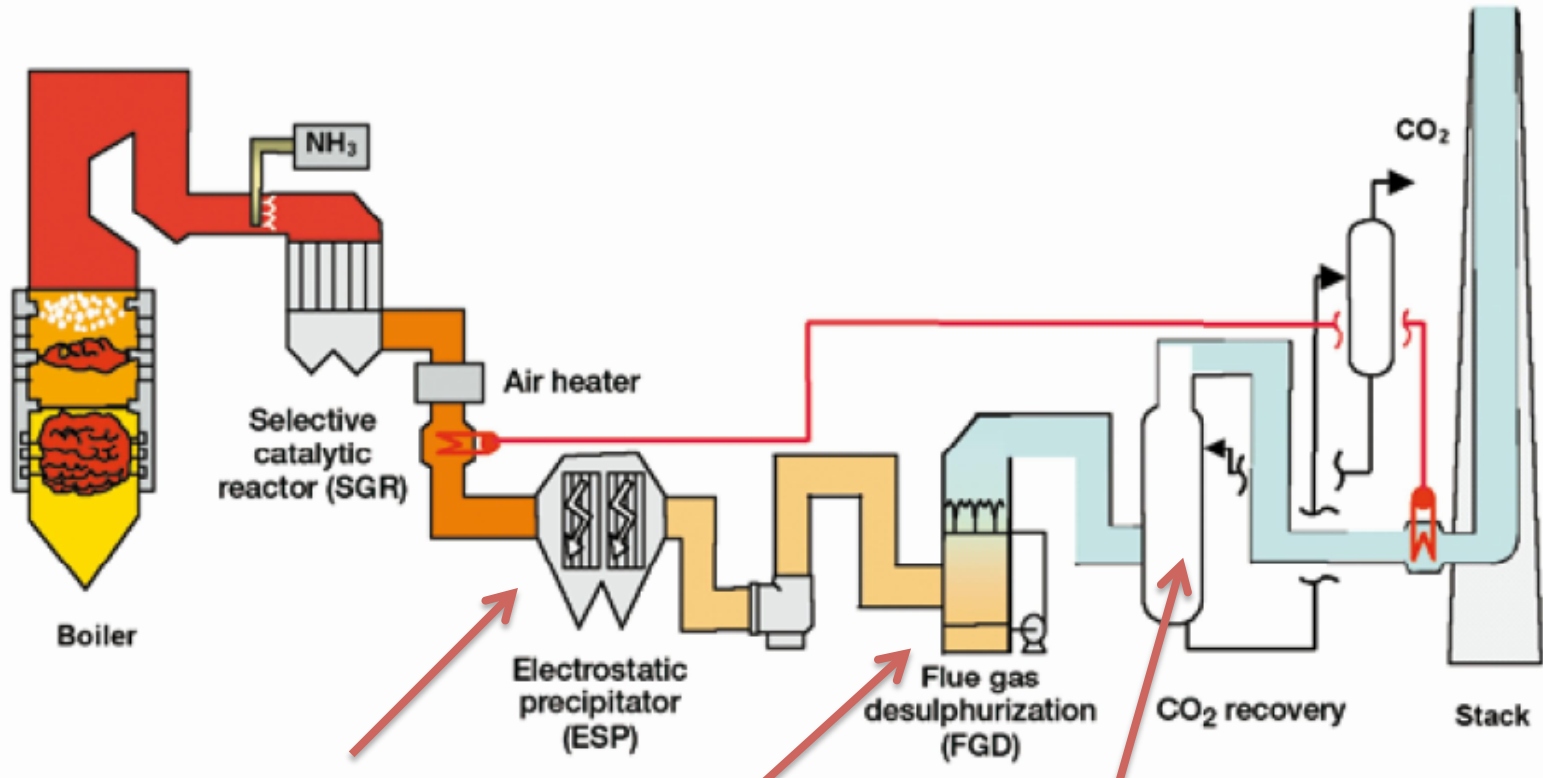
Figure 8.2 U.S. SO₂ trading scheme prices & trading volumes 1994-2008 (U.S. EPA 2007)

Annual Mean Wet Sulfate Deposition



Source: NADP, 2010

Post-Combustion Capture



Dust & PM Removal

Stringent SO_2
Removal

CO_2 Capture



CCS Reduces So_x Emissions



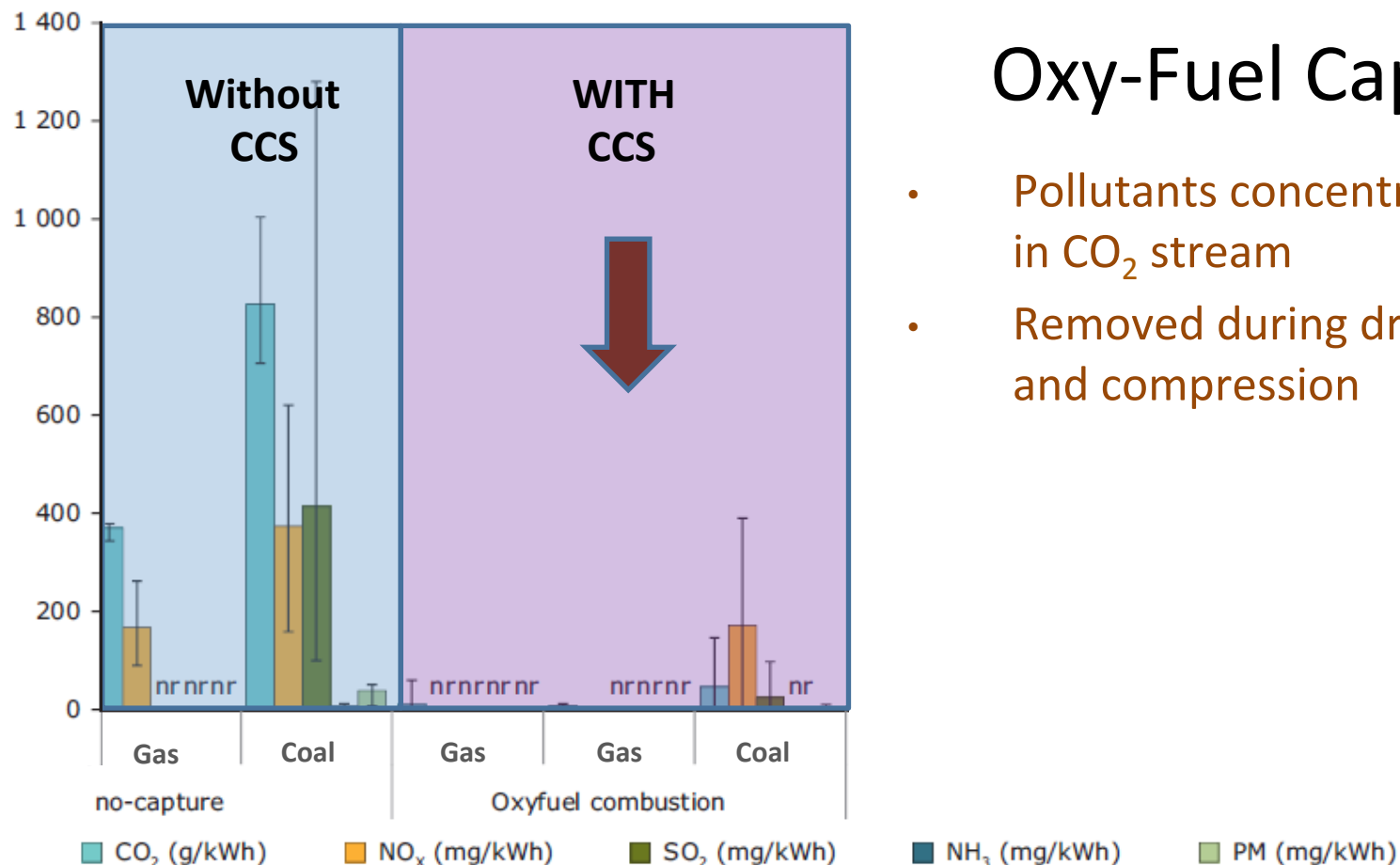
Post-Combustion CO_2 capture at Boundary Dam Coal power plant (Saskatchewan, Canada)

- So_x removal installed = Reduction in acid emissions



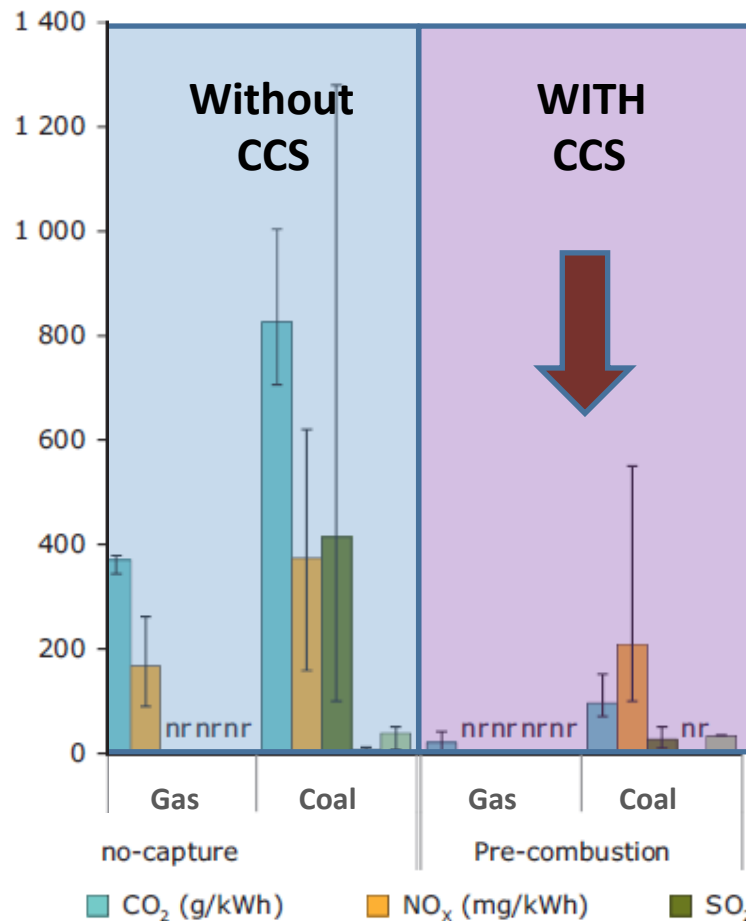
Oxy-Fuel Capture

- Pollutants concentrated in CO₂ stream
- Removed during drying and compression



Notes: The indicated values are based on various fuel specifications and are dependent on the configuration and performance of the power plant and CO₂ capture process.
 'nr' = not reported; IGCC = Integrated Gasification Combined Cycle; NGCC = Natural Gas Combined Cycle; PC = Pulverised Coal; GC = Gas Cycle.

Source: Horssen et al., 2009; Koornneef et al., 2010, 2011.



Pre-Combustion Capture

- Pollutants separated prior to combustion

Notes: The indicated values are based on various fuel specifications and are dependent on the configuration and performance of the power plant and CO₂ capture process.
'nr' = not reported; IGCC = Integrated Gasification Combined Cycle; NGCC = Natural Gas Combined Cycle; PC = Pulverised Coal; GC = Gas Cycle.

Source: Harrison et al., 2009; Keeney et al., 2010, 2011





London *Pea Souper* (*killer fog*)

1952 – 12,000 people died

