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CO_2 capture technologies: An Overview

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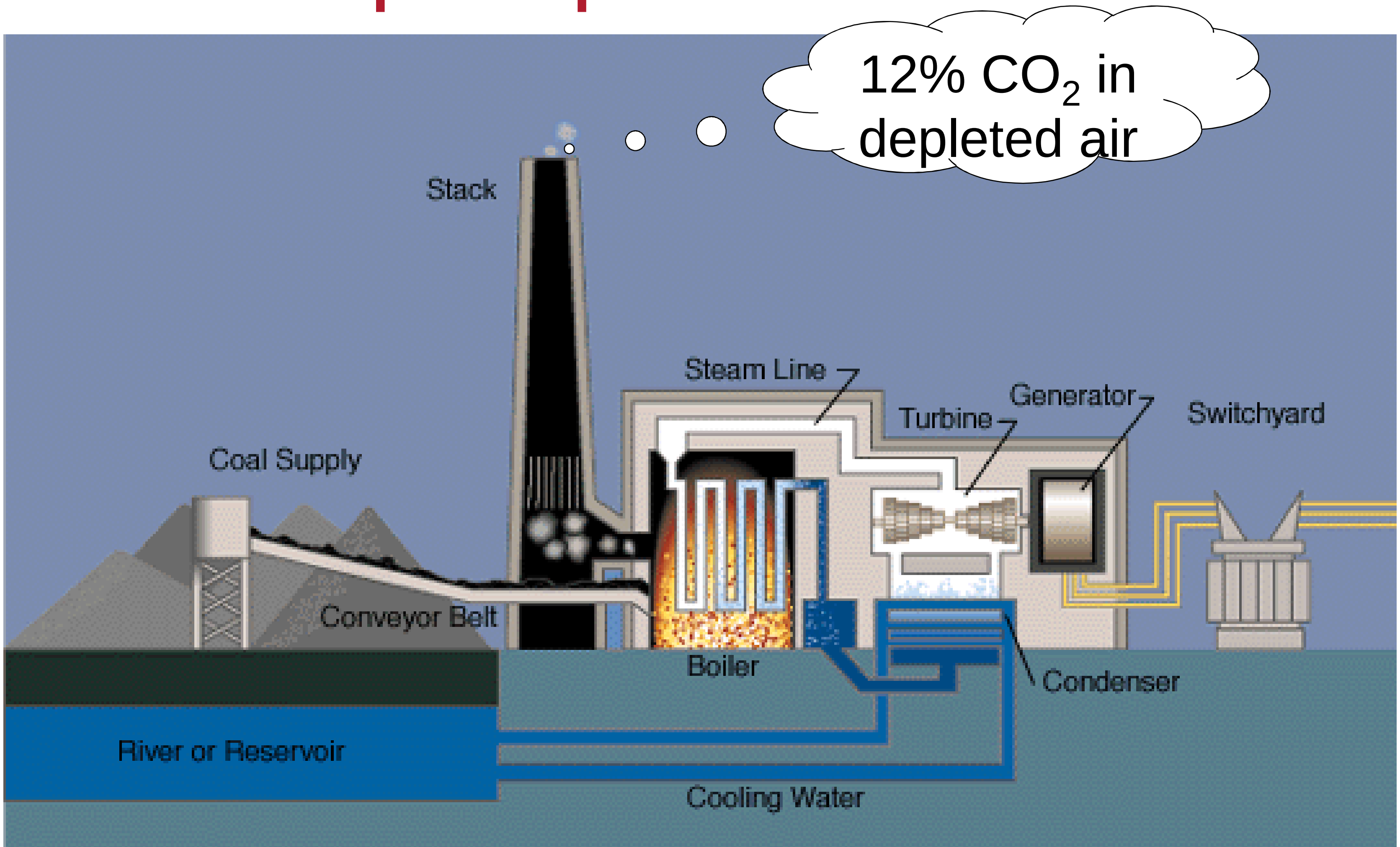
Outline

- Power plants and industry: CO_2 sources and concentrations
- State-of-the-art CO_2 capture: extra fuel required
- Improved CO_2 capture technologies
- Demonstration projects in Europe

A thermal power plant



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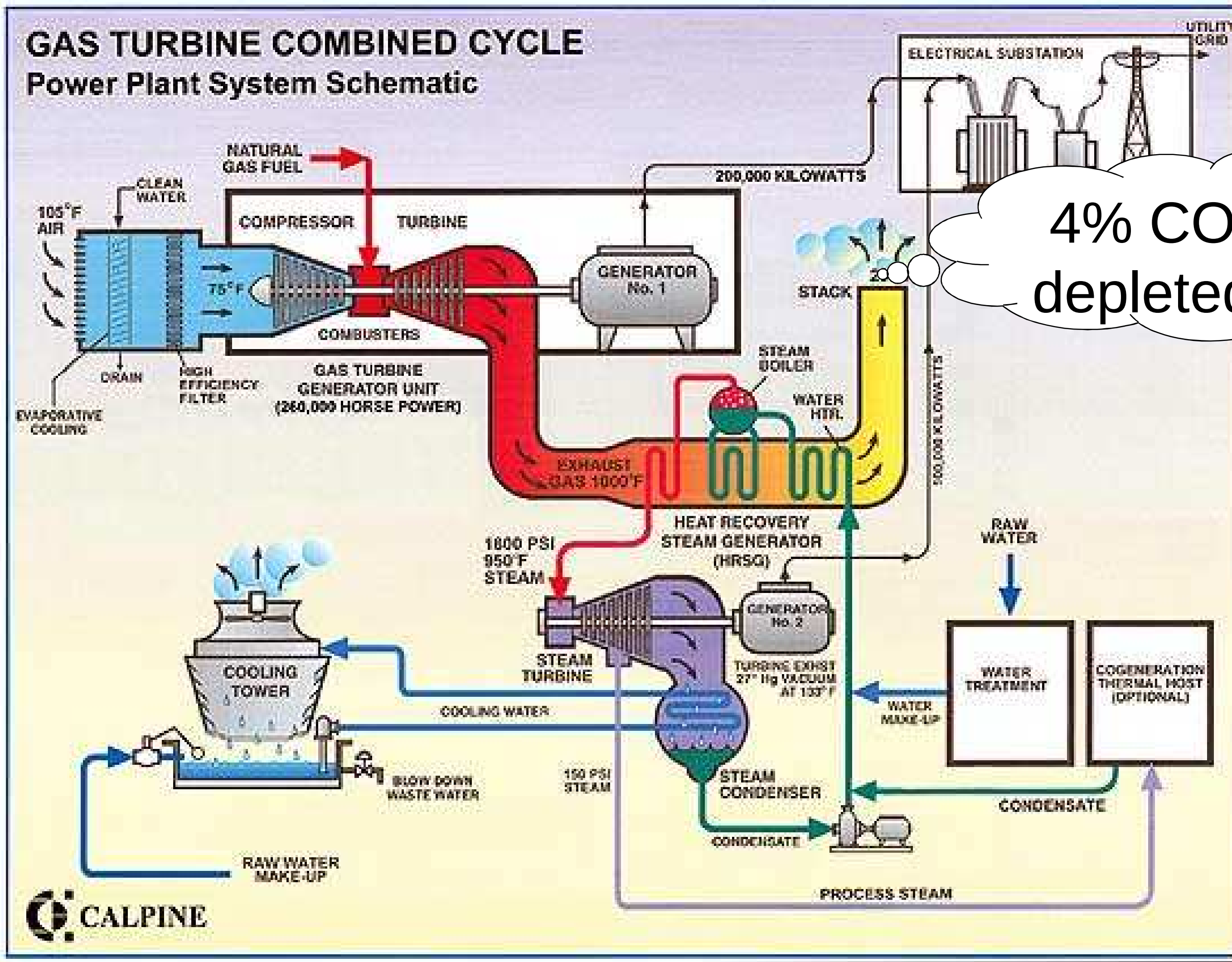
A gas turbine combined cycle power plant



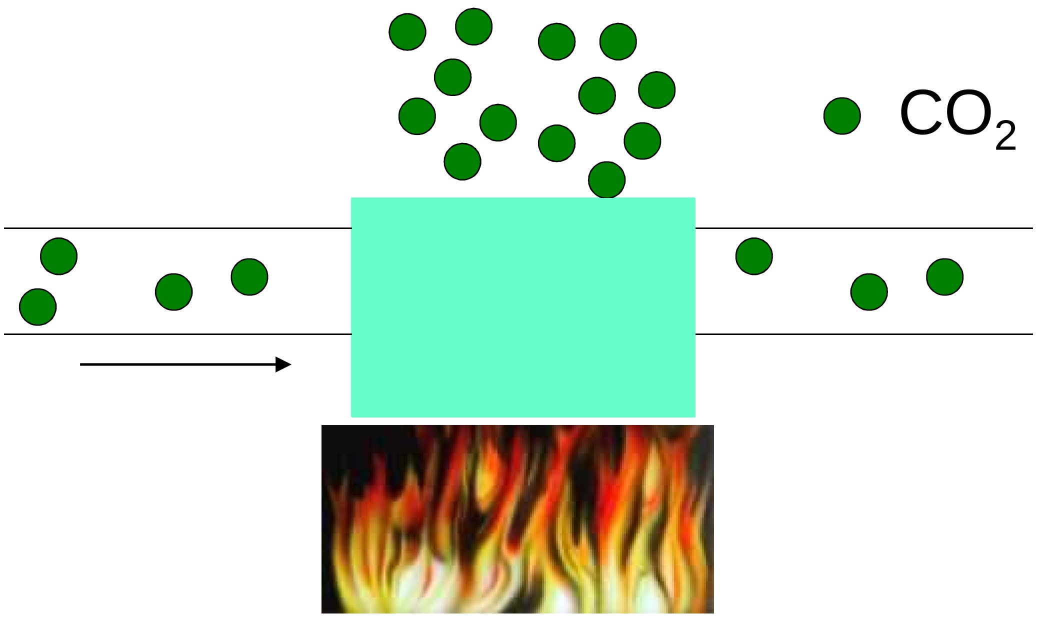
4% CO_2 in depleted air

Industrial CO_2 sources

- Industrial Boilers: diluted CO_2
- Refineries, fertilizer production: concentrated CO_2
- Synthetic fuels production (e.g., biodiesel): concentrated CO_2
- Steel industry
- Cement production: 20% CO_2

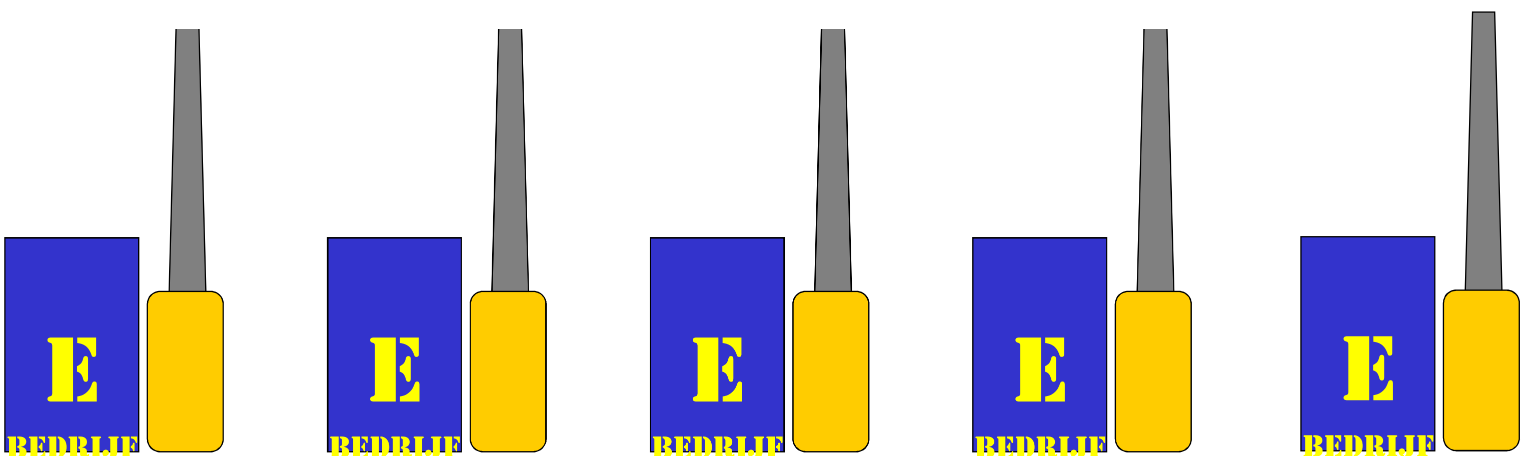
Conventional CO_2 removal used in industry

- CO_2 is captured by a amine solution
- Regeneration costs a lot of energy



Capturing CO_2 costs extra fuel

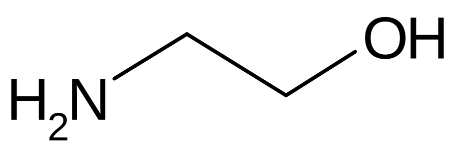
- The efficiency of a power plant is: $\frac{\text{Energy in the fuel}}{\text{Energy in the electricity}}$
- Modern coal plant: 45%; with CO_2 capture: 35%.



Solvent chemistry

- Major solvents: amines

MEA, monoethanolamine

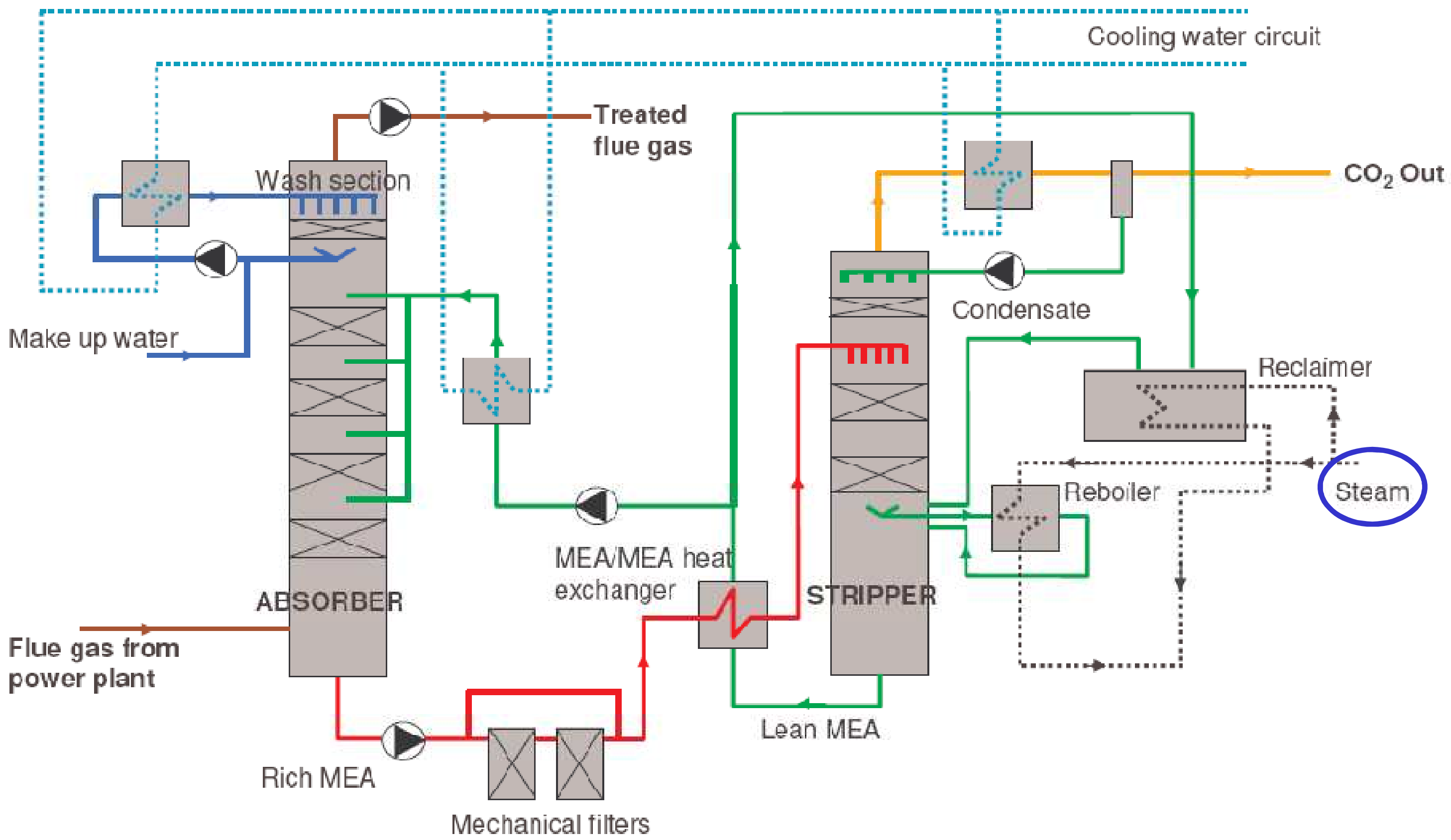


MEA solution (e.g., 30% in water) has the highest capacity and reactivity

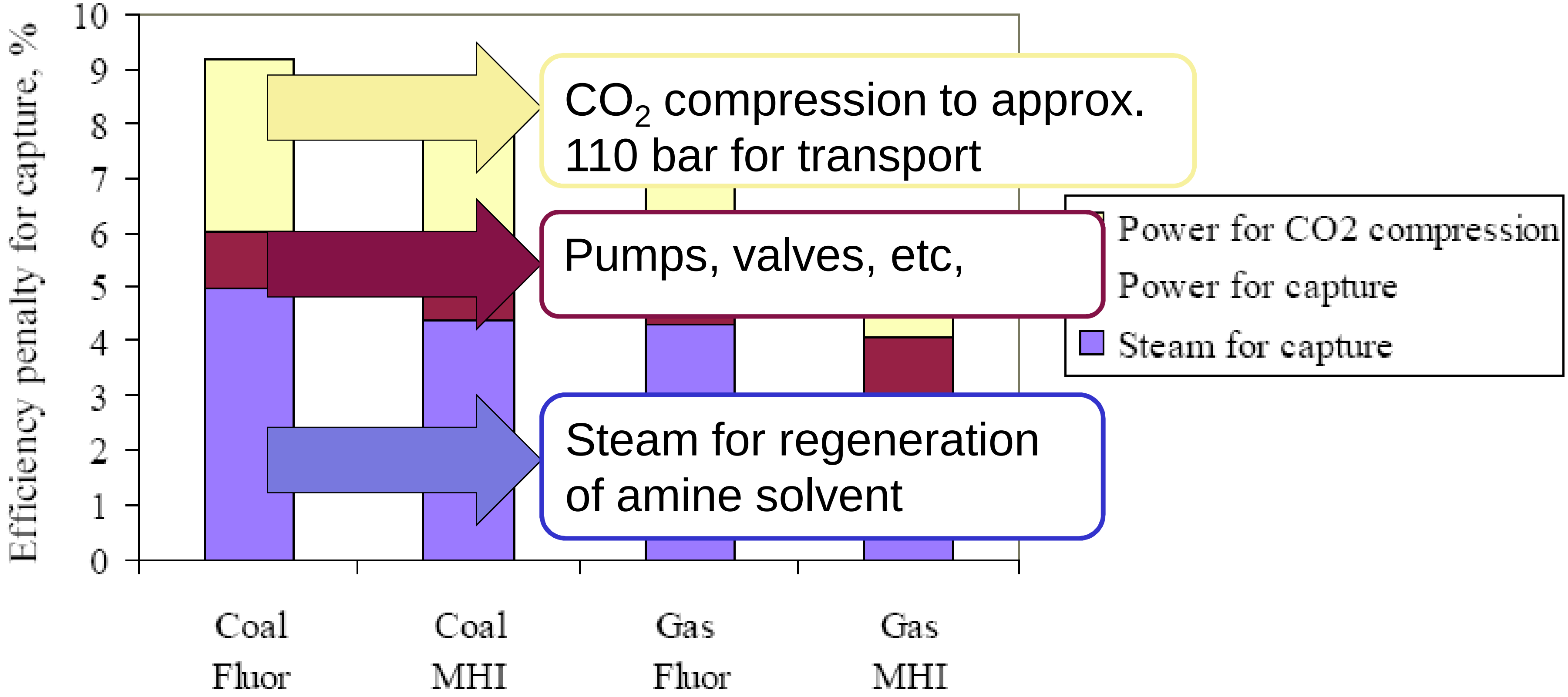
$$CO_2 + 2\ R\text{-}NH_2 \leftrightarrow R\text{-}NHCOO^- + R\text{-}NH_3^+$$

- At low temperature equilibrium at right hand side
- At higher temperatures equilibrium at left hand side

CO_2 capture Installation



Power losses caused by CO_2 capture



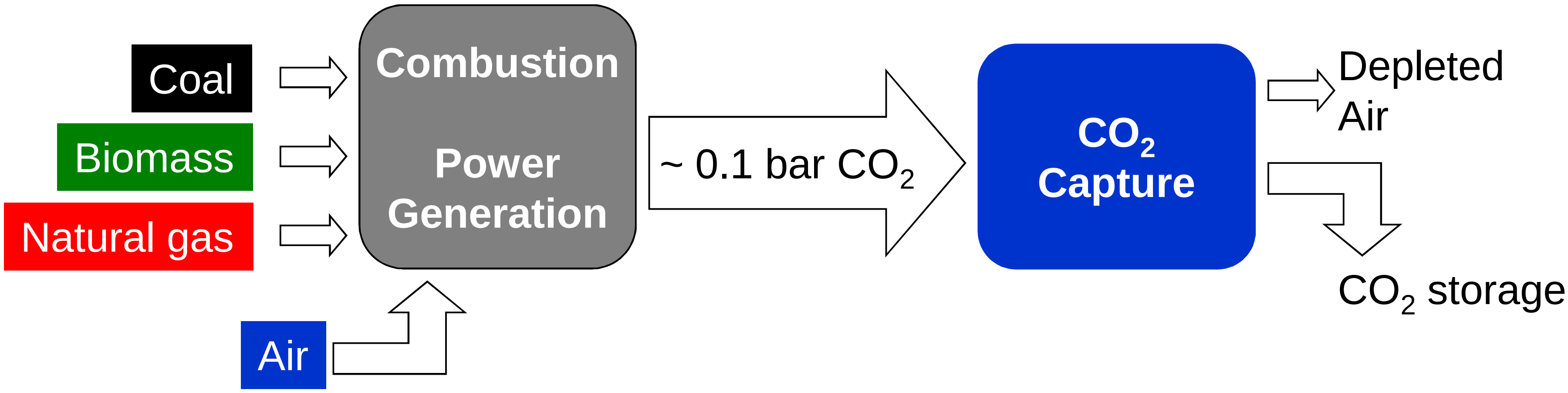
How to improve CO_2 capture ?

- Reduce the efficiency penalty and the CO_2 capture costs by:
  - Save steam for regeneration of the amine solvent:
    - capture CO_2 from more concentrated streams
    - Better integration in the power plant
  - Save compression costs: make CO_2 available at higher pressure

CO_2 capture technology

- There are three possible ways of CO_2 capture:
  - Post-combustion capture
  - Pre-Combustion capture
  - Oxyfuel

Post-combustion CO_2 capture

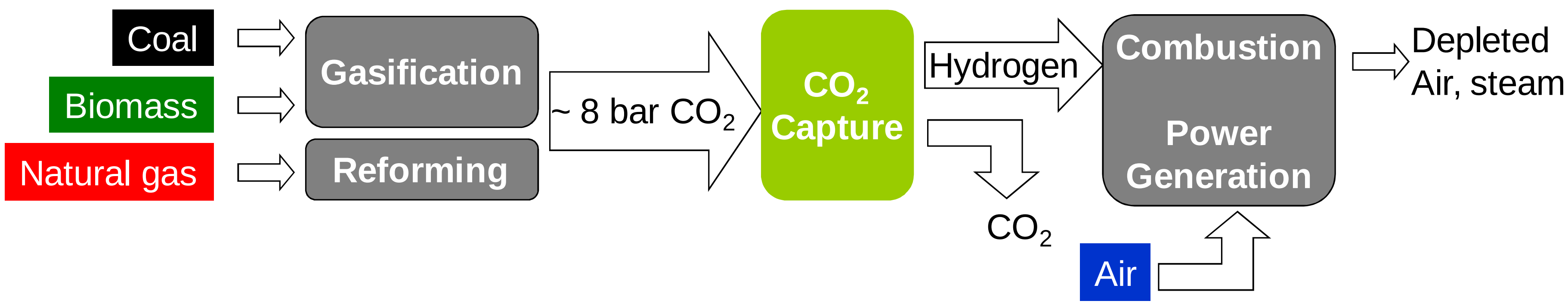


+ 'Standard' power plant
+ Retrofit to existing power plants is possible
- High efficiency penalty
- Not yet proven on large scale in power plant
- Solvent losses, environmental pollution

Post combustion
Ways forward

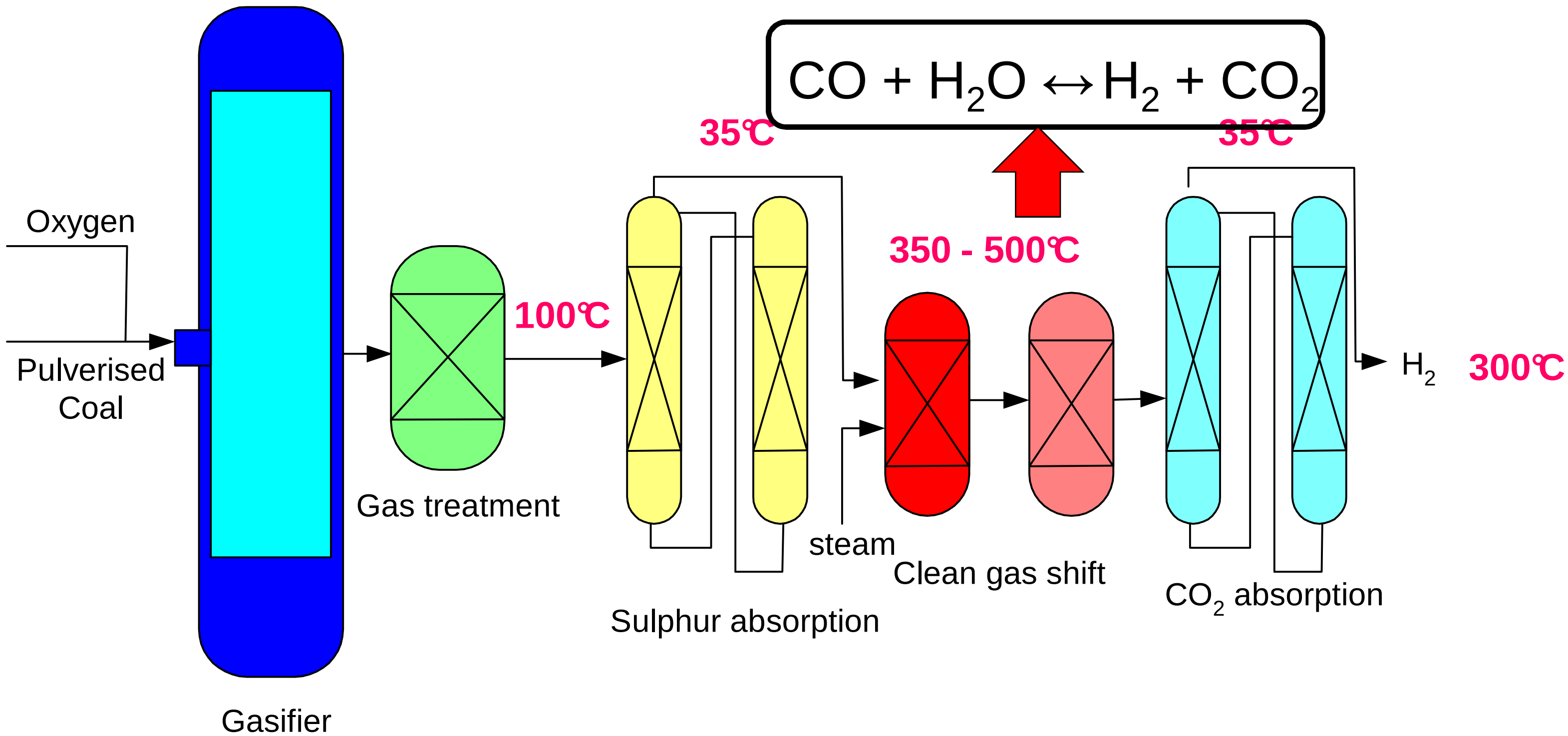
- Novel solvents:
  - Low regeneration energy, high stability
  - E.g., CORAL, and many, many others
- Chilled Ammonia
  - Requires much less steam for regeneration
  - Still to be proven at scale

Pre-combustion CO2 capture



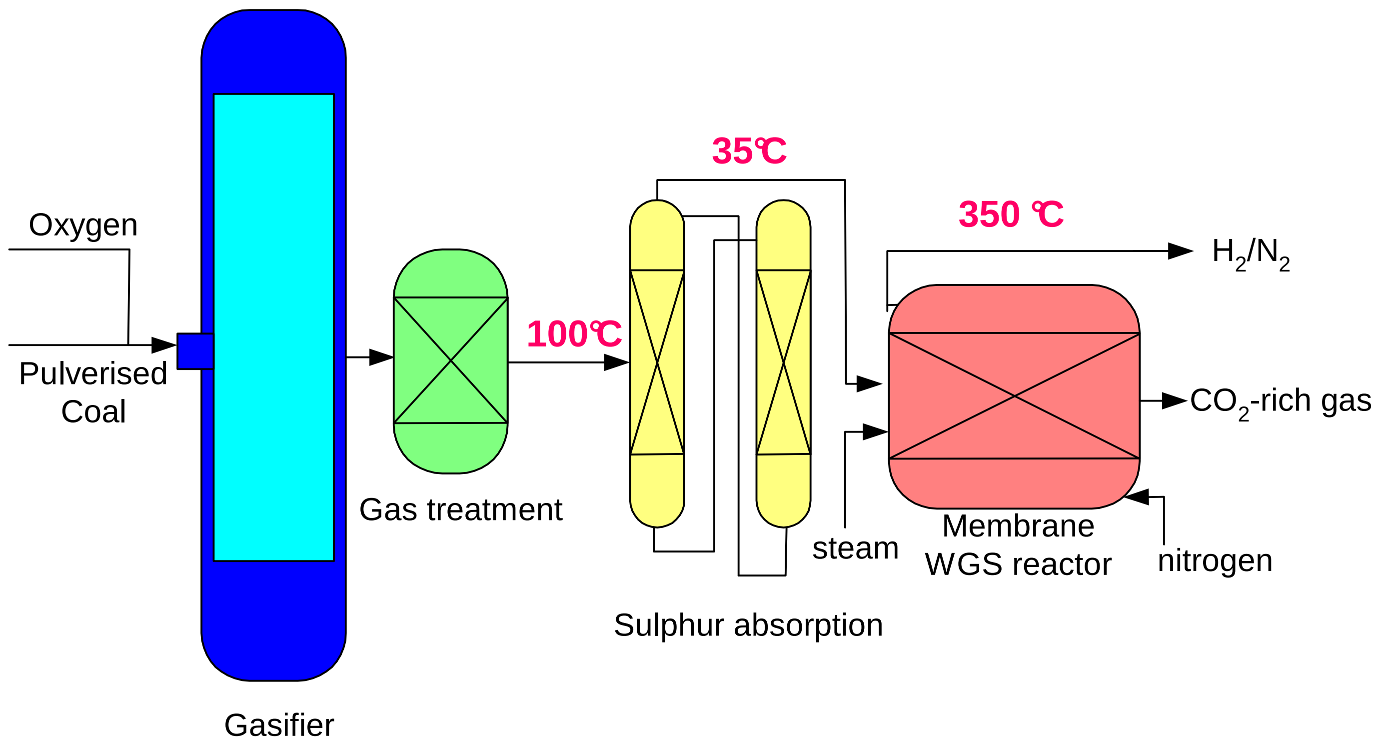
- \+ Lower efficiency penalty
- \+ Proven in large scale hydrogen production
- \+ Different products possible
- \- Coal gasifier is needed
- \- Many process steps

Conventional CO_2 scrubbing



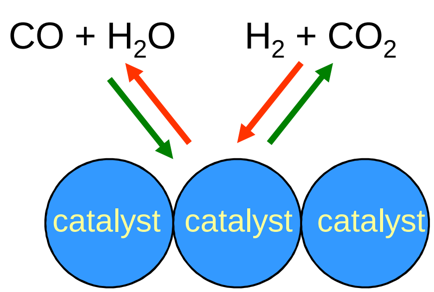
- Multiple process steps
- Hydrogen-rich gas is at low temperature before gas turbine

Membrane water gas shift reactor

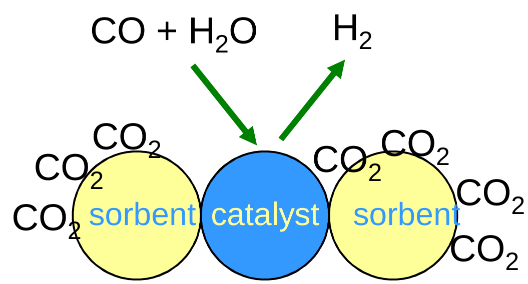


Sorption-enhanced water gas shift (SEWGS)

- Catalyst is combined with CO_2 sorbent
- When sorbent is saturated with CO_2, it is regenerated with steam

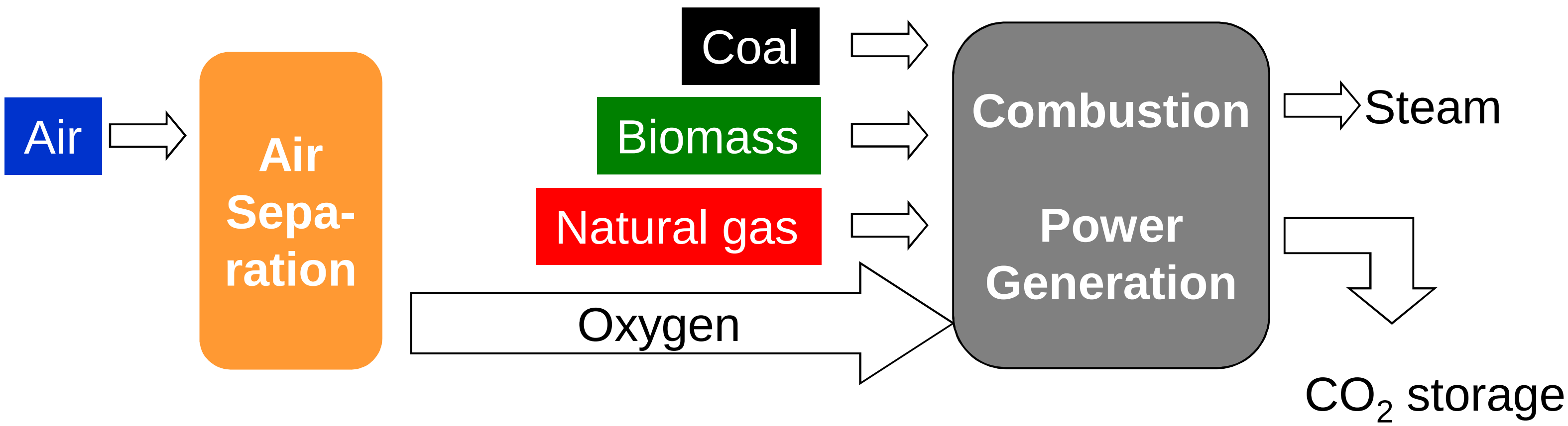


Ordinary water-gas shift



Sorption-enhanced water-gas shift

Oxyfuel CO_2 capture

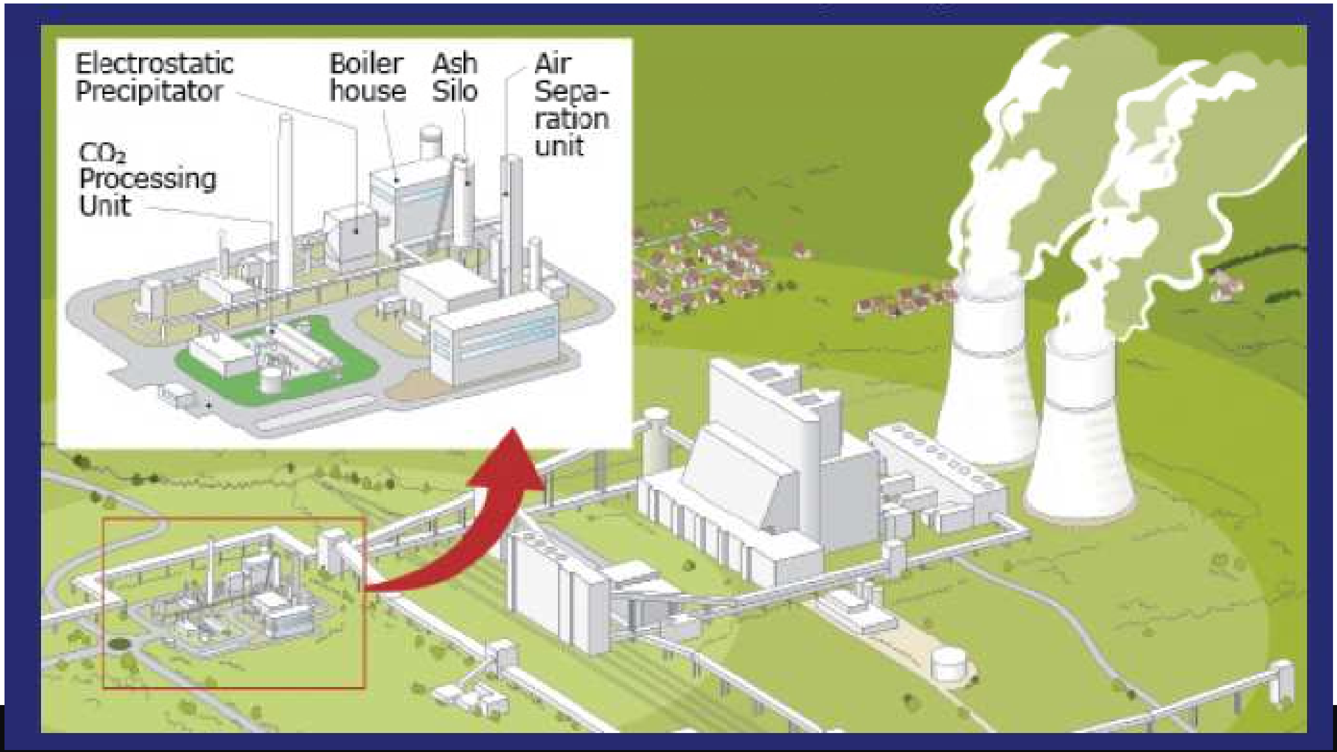


- \+ Air separation is proven technology
- \- Air separation is expensive
- \- Burning coal of gas in pure oxygen requires new technology

Oxyfuel demonstrations

Vattenfal: Schwarze Pumpe (D)

30 MW pilot plant under construction



CCS in the Cement Industry

- The cement industry contributes approximately 5% of global CO2 emissions
- There are possibilities to capture CO_2 from the cement process
- It has been estimated that 77% of the CO_2 emissions could be abated using post combustion capture
- Although the cost of a plant could be twice as much as a non-CCS equivalent
- Oxy-fuel capture is being investigated, and is expected to have lower costs

CCS and natural gas processing (NGP)

- Natural gas reservoirs, in addition to natural gas, often contain a mixture of acid gas: H_2S and CO_2
- Depending on the type of field gas extracted, the CO_2 content can be between 2 and 70%,
- CO_2 must be reduced to below 2% for transport and pipeline specifications
- CO_2 is removed through amine technology, but is normally vented or incinerated
- Instead, the captured CO_2 can be transported and stored at marginal costs between 10 - 30 $/t$CO_2$

Awarded EU Demonstration Projects

Germany, Jaenschwalde Vattenfall: 180 MEuro	Oxyfuel and the post combustion technology on an existing power plant site.
Netherlands, Rotterdam EON and Electrabel: 180 MEuro	Coal power plant with 250MW equivalent using post-combustion technology. Storage of CO2 in a depleted offshore gas field near the plant.
Italy, Porto-Tolle ENEL: 100 MEuro	Post-combustion capture to treat flue gases corresponding to 250 MW electrical output of a new 660 MW coal plant. Storage in an offshore saline aquifer nearby.
Poland, Belchatow PGE: 180 MEuro	Capture from flue gases corresponding to 250MW electrical output in a new supercritical lignite-fired plant. Storage in saline aquifer nearby.
Spain, Compostilla Endesa: 180 MEuro	Oxyfuel and fluidised bed technology on a 30MW pilot plant which will be upscaled to 320 MW. Storage in a saline aquifer nearby.
UK, Hatfield Powerfuel: 180 MEuro	Demonstration of CCS on a new, 900 MW IGCC power plant. Storage in an offshore gas field nearby.

Conclusions

- CO_2 capture can be done from different sources in thermal power plants and in industry.
- Most practised CO_2 capture technology is post-combustion capture using amines
  - Big demonstration projects being built to prove CO_2 capture in power plants
  - Efficiency can be improved, costs reduced
- New, more efficient technologies are in development