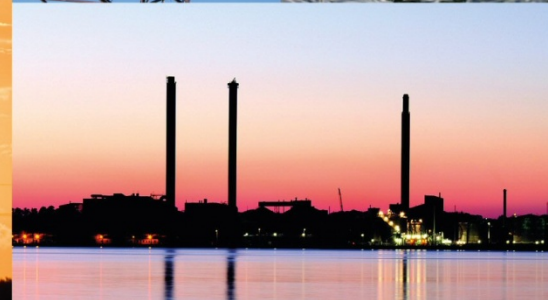
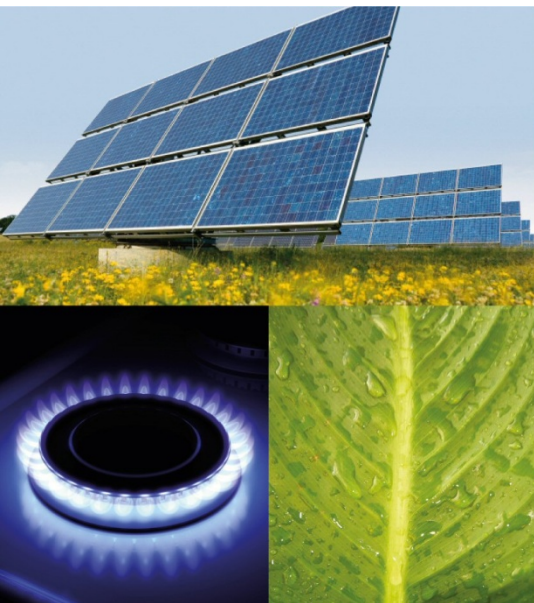


CO₂ capture technologies: An Overview

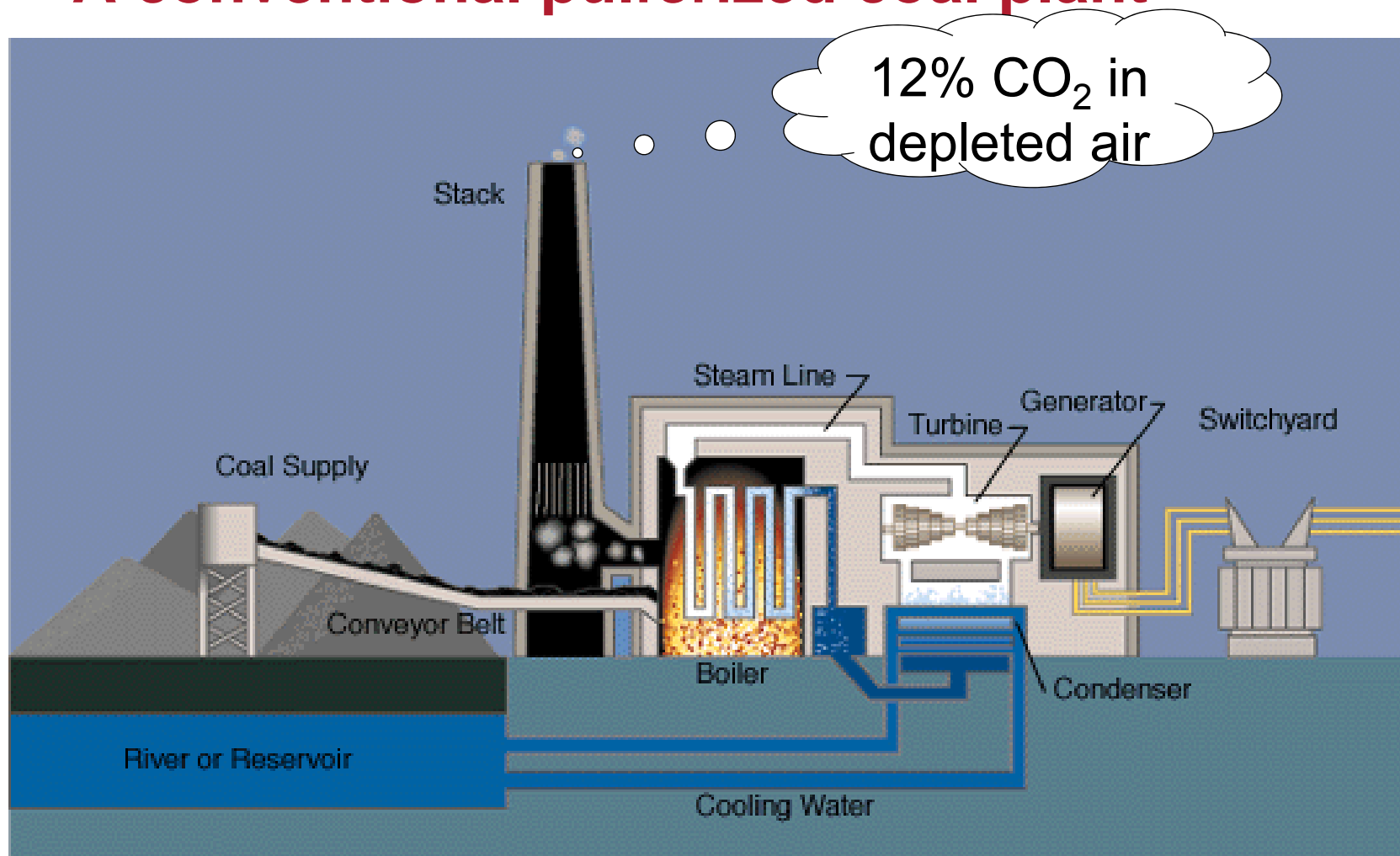
Ruud van den Brink



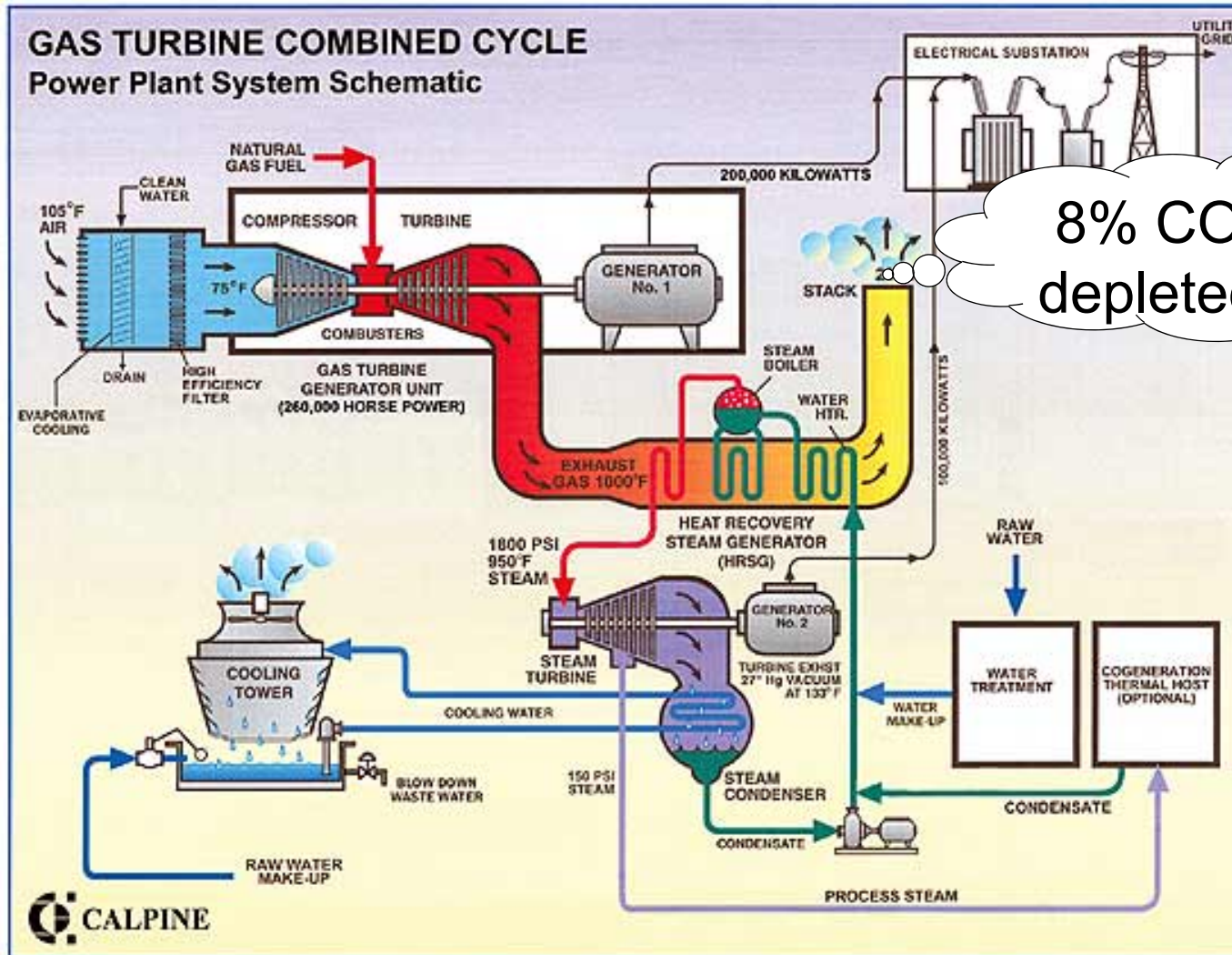
Outline

- CO₂ emissions in power plants and industry
- State-of-the-art CO₂ capture: extra fuel required
- Improved CO₂ capture technologies
- Demonstration projects in Europe

A conventional pulverized coal plant



A natural gas or coal gas fired power plant



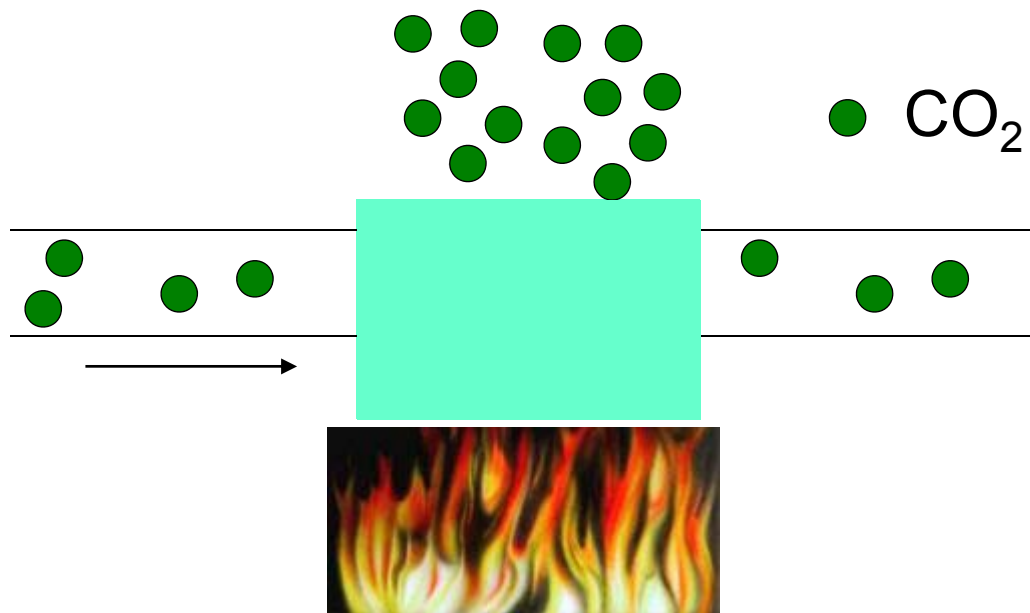
8% CO₂ in depleted air

Industrial CO₂ sources

- Industrial Boilers: diluted CO₂
- Refineries, fertilizer production: concentrated CO₂
- Synthetic fuels production (e.g., biodiesel): concentrated CO₂
- Steel industry
- Cement production: 20% CO₂
- Underground Coal Gasification: gas contains high CO₂ concentration

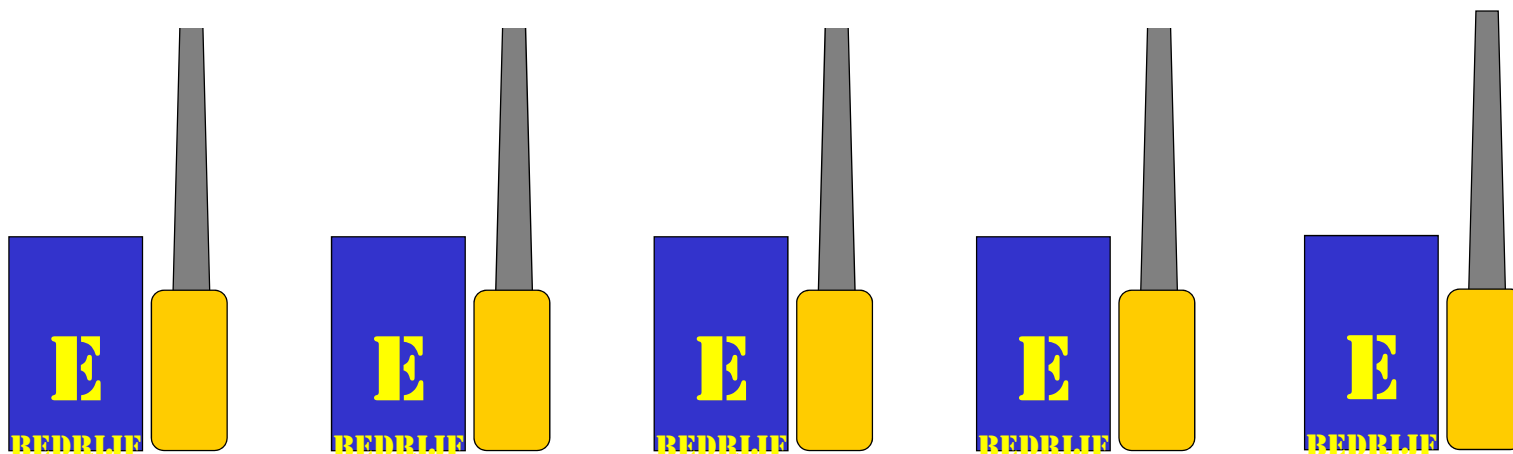
Conventional CO₂ removal used in industry

- CO₂ is captured by a amine solution
- Regeneration costs a lot of energy



Capturing CO₂ costs extra fuel

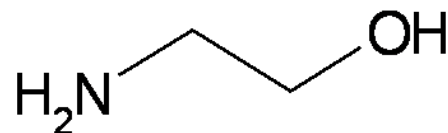
- The efficiency of a power plant is: $\frac{\text{Energy in the fuel}}{\text{Energy in the electricity}}$
- Modern coal plant: 45%; with CO₂ capture: 35%.



Solvent chemistry

- Major solvents: amines

MEA, monoethanolamine

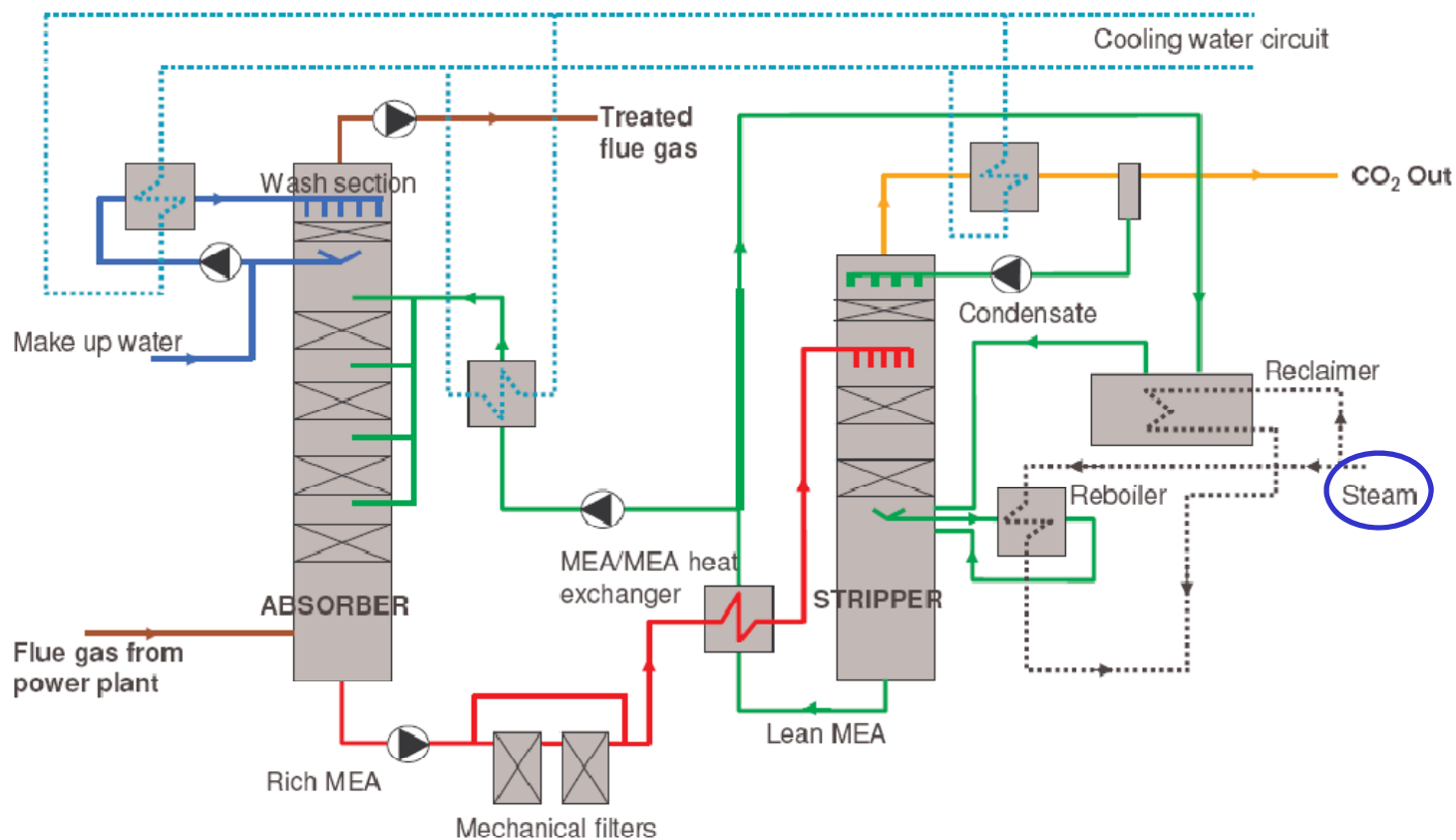


MEA solution (e.g., 30% in water) has the highest capacity and reactivity

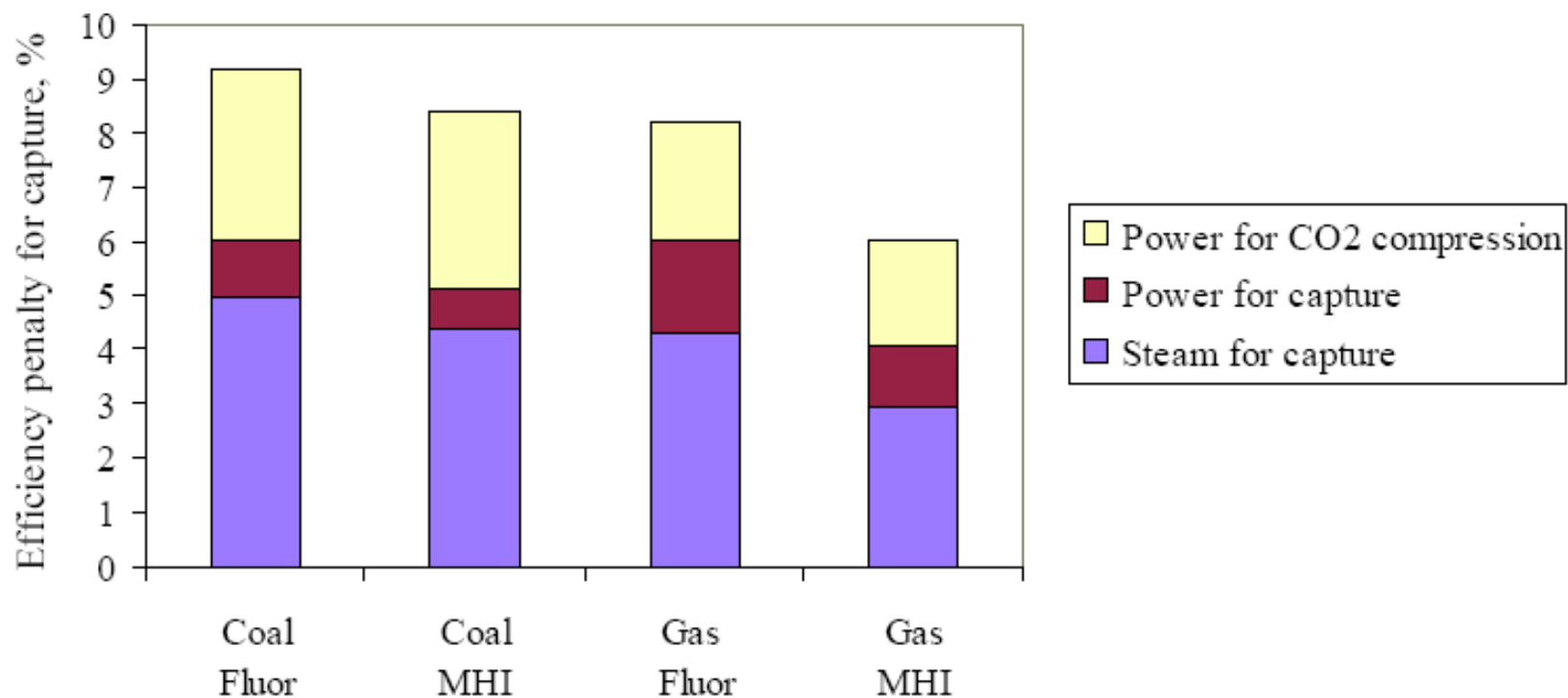


- At low temperature equilibrium at right hand side
- At higher temperatures equilibrium at left hand side

CO₂ capture Installation



Post-combustion Power losses



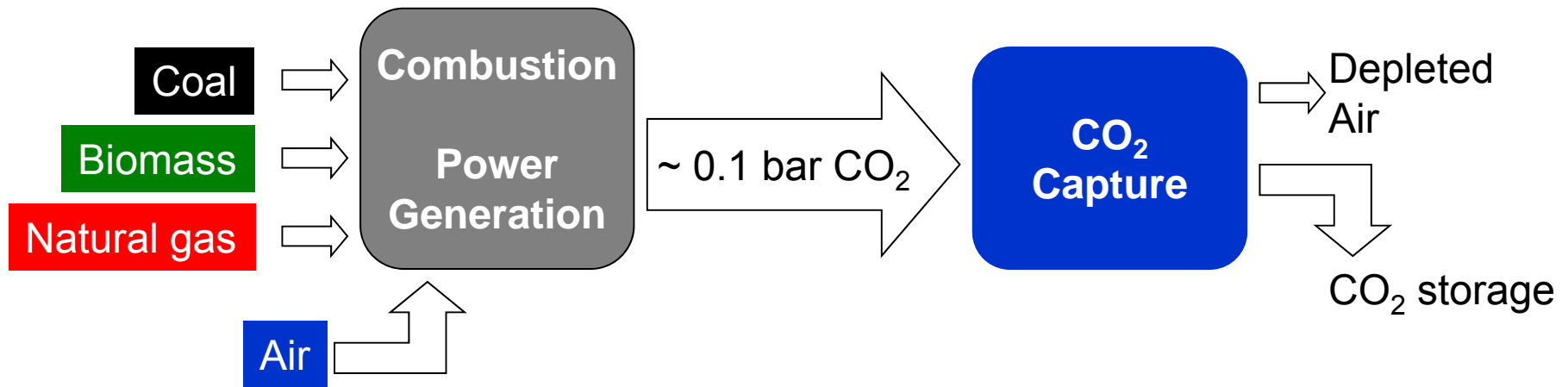
How to improve CO₂ capture ?

- Reduce the efficiency penalty and the CO₂ capture costs by:
 - Save steam for pressure:
 - capture CO₂ from more concentrated streams
 - Better integration in the power plant
 - Save compression costs: make CO₂ available at higher pressure

CO₂ capture technology

- There are three possible ways of CO₂ capture:
 - Post-combustion capture
 - Pre-Combustion capture
 - Oxyfuel

Post-combustion CO₂ capture



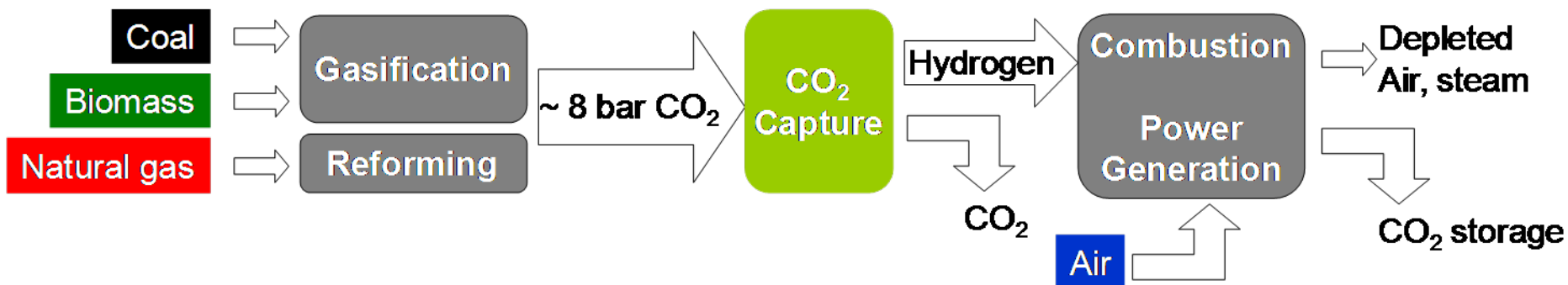
- + 'Standard' power plant
- + Retrofit to existing power plants is possible
- High efficiency penalty
- Not yet proven on large scale in power plant
- Solvent losses, environmental pollution

Post combustion

Ways forward

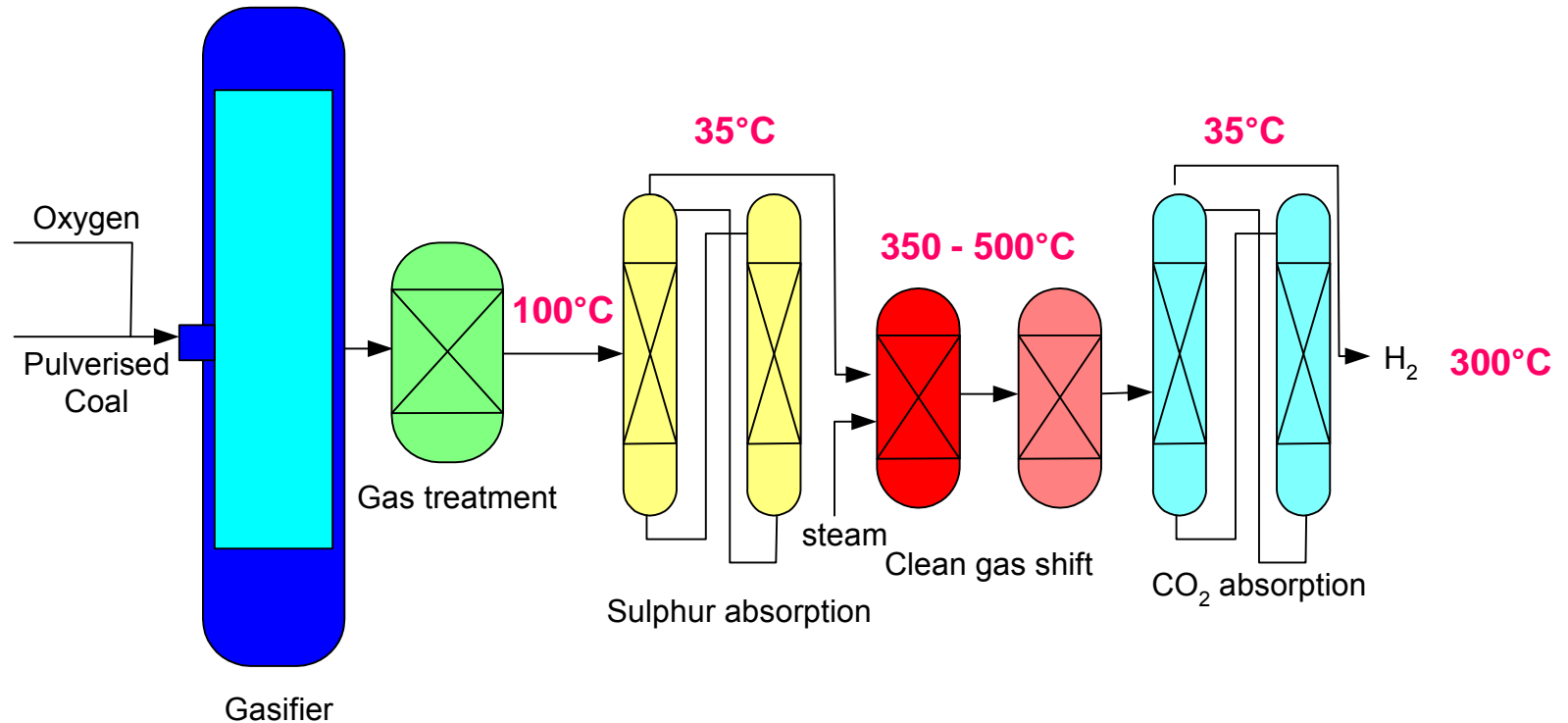
- Novel solvents:
 - Low regeneration energy, high stability
 - E.g., CORAL (TNO), and many, many others
- Chilled Ammonia
 - Breakthrough technology
 - Still to be proven at scale

Pre-combustion CO₂ capture



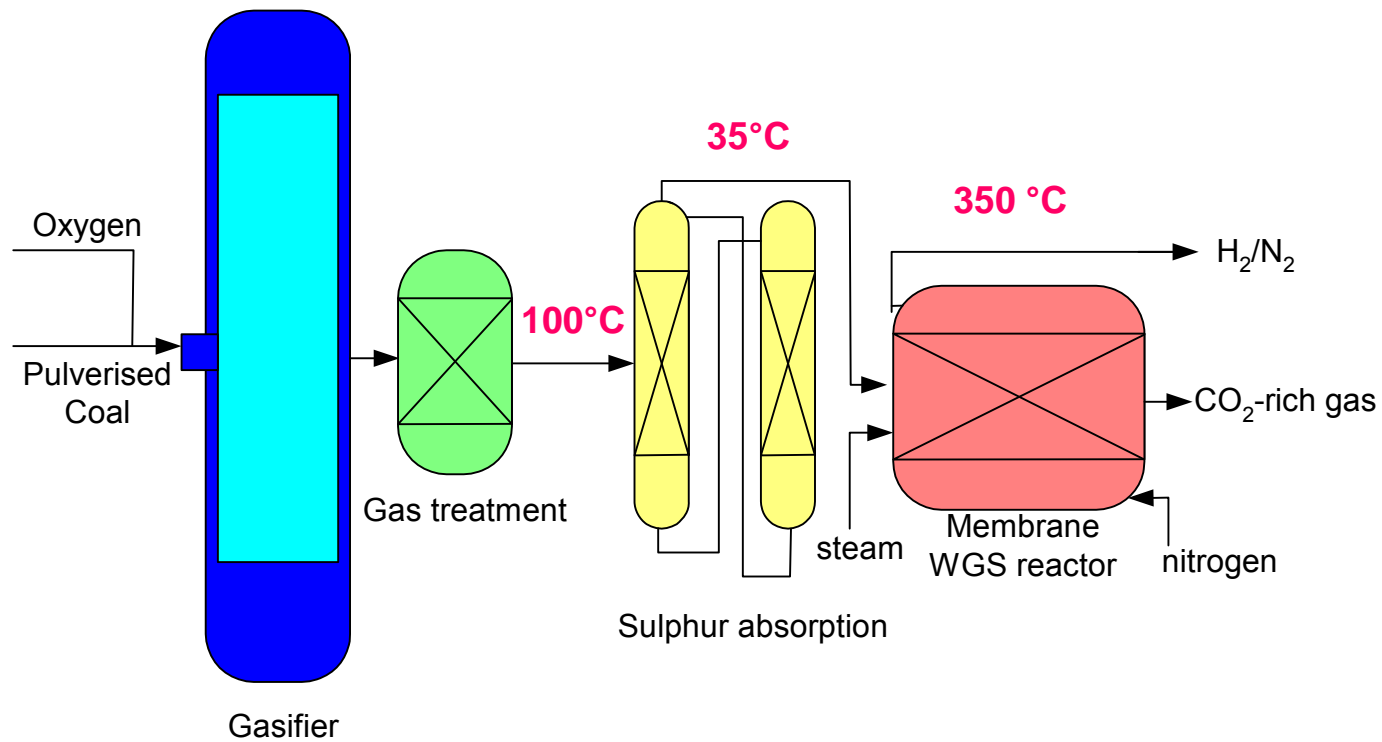
- + Lower efficiency penalty
- + Exists at large scale hydrogen production
- + Different products possible
- Coal gasifier is needed
- Many process steps

Conventional CO₂ scrubbing



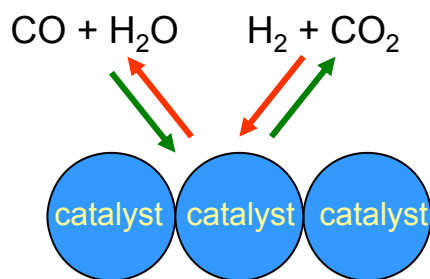
- Multiple process steps
- Hydrogen-rich gas is at low temperature before gas turbine

Membrane water gas shift reactor

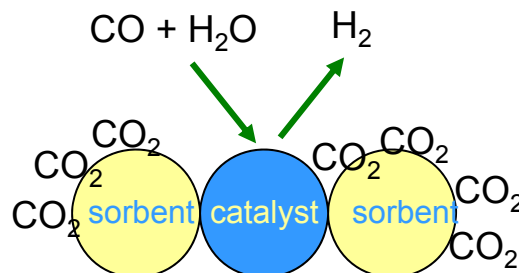


Sorption-enhanced water gas shift (SEWGS)

- Catalyst is combined with CO₂ sorbent
- When sorbent is saturated with CO₂, it is regenerated with steam

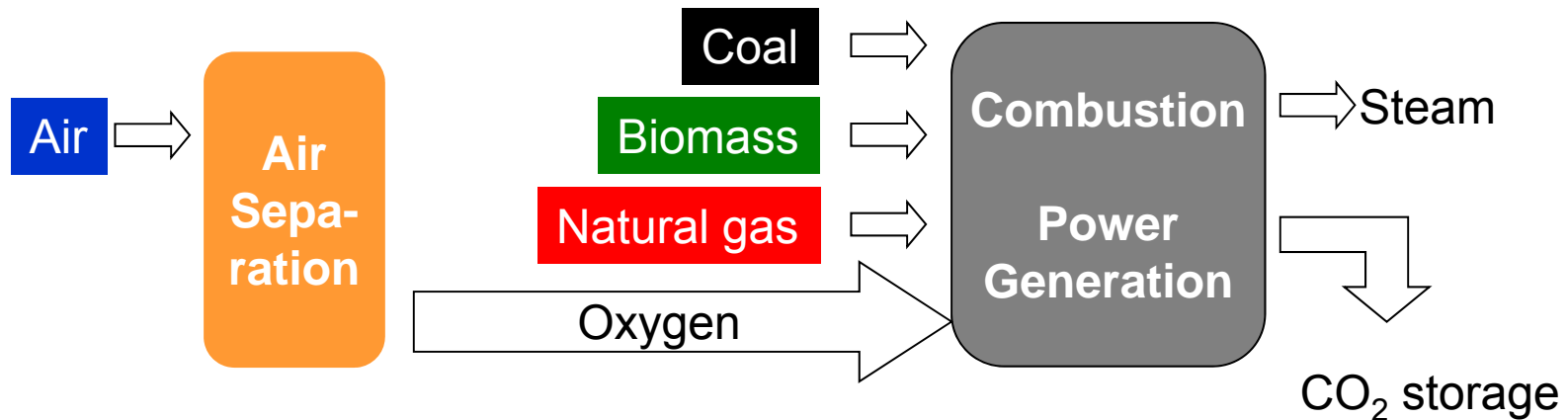


Ordinary water-gas shift



Sorption-enhanced water-gas shift

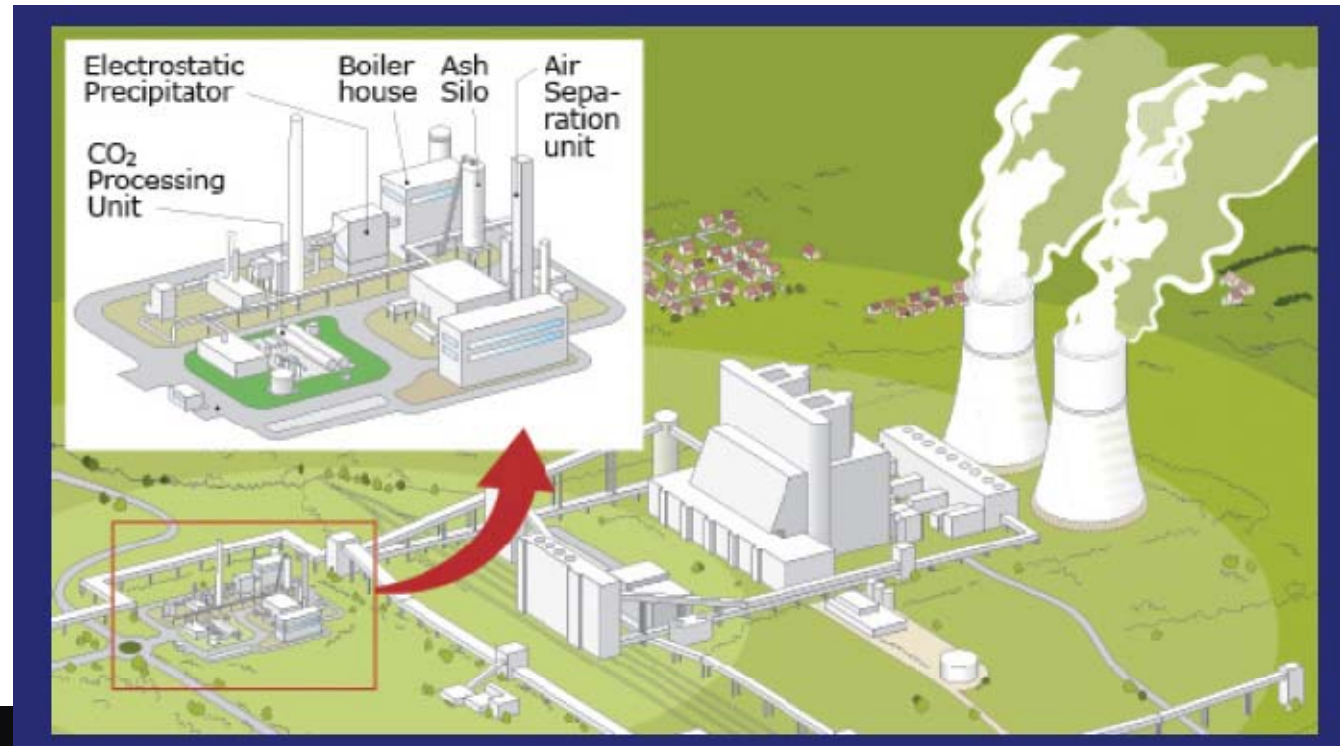
Oxyfuel CO₂ capture



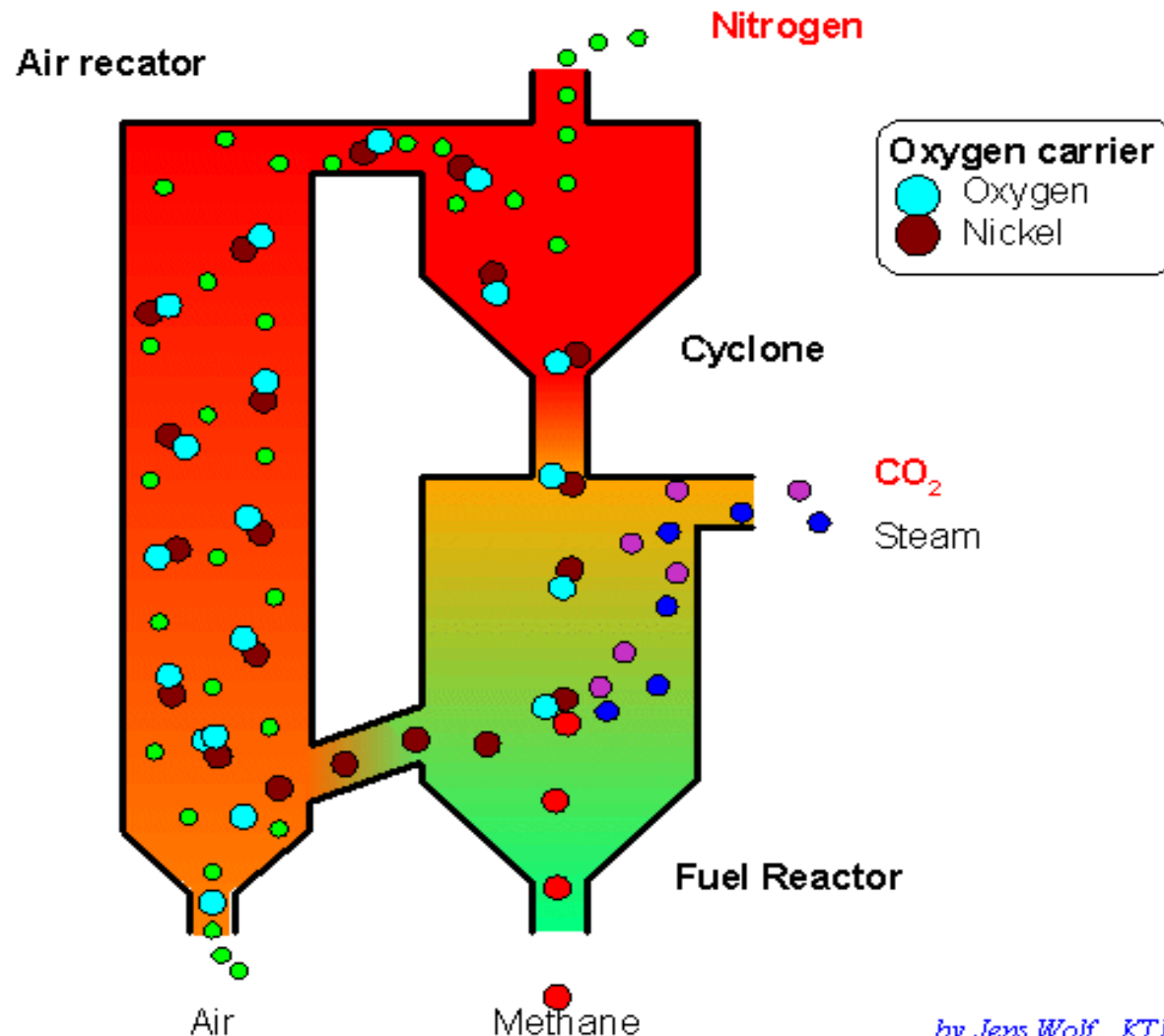
- + Air separation is proven technology
- + Large potential for improvement
- Air separation is expensive
- Burning coal or gas in pure oxygen requires new technology

Oxyfuel Demonstrations

Vattenfal: Schwarze Pumpe (D)
30 MW pilot plant under construction



Oxyfuel Chemical looping combustion



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 CO ₂ 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

- CO₂ capture can be done from different sources in the power sector and in industry.
- Most practised CO₂ capture technology is post-combustion capture using amines
 - High efficiency penalty
- New, more efficient technologies are in development
- In Europe and US demonstration projects are being build to prove CO₂ capture on power plant scale