GE CCUS Technologies

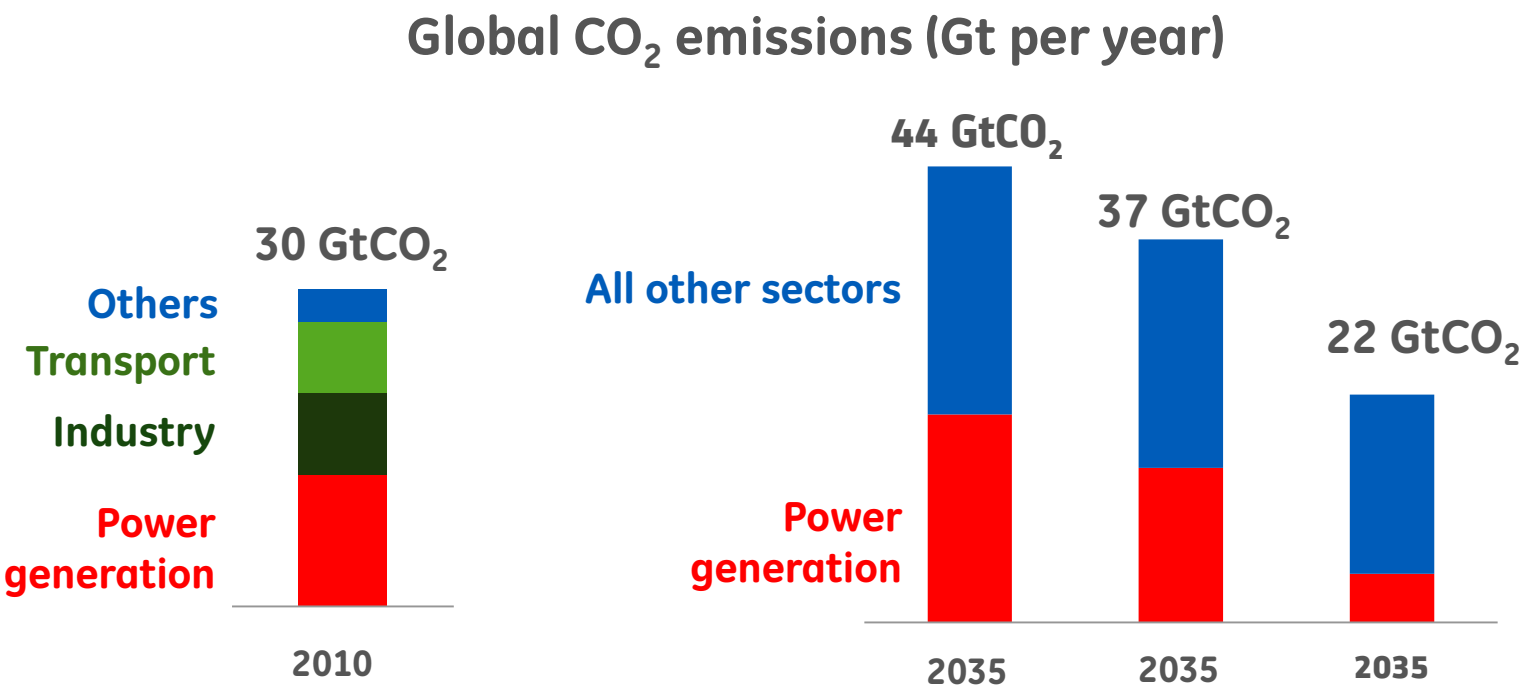
CMC CO_2lloquium, Calgary

November 27th, 2015

Imagination at work

Development Driver

Who is currently emitting CO_2?



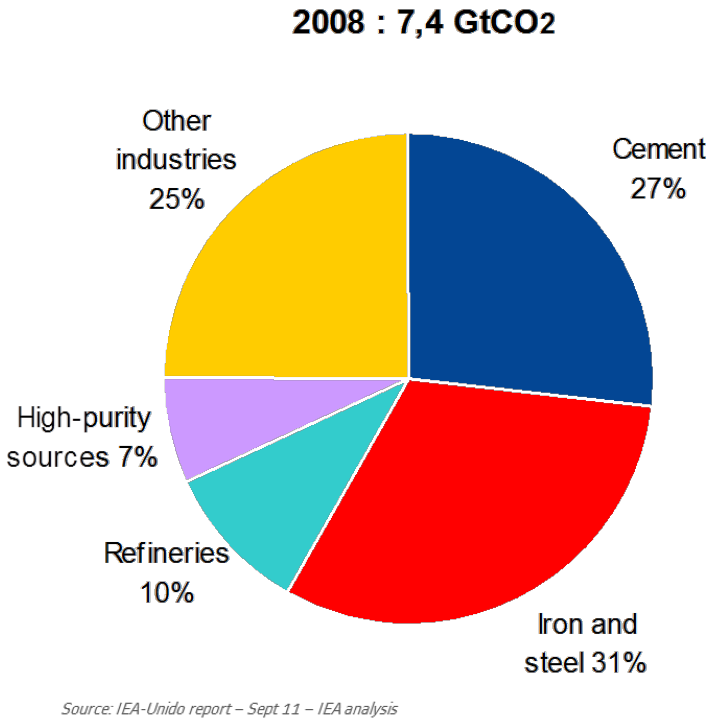
Source: data from © OECD/IEA – CO2 emissions from fossil combustion 2012

Source: © OECD/IEA – World Energy Outlook 2012

Power generation : Largest contributor and easiest to address

Main Industrial Sources of CO_2 Emissions

Direct industrial CO_2 emission projections in the ETP Baseline Scenario

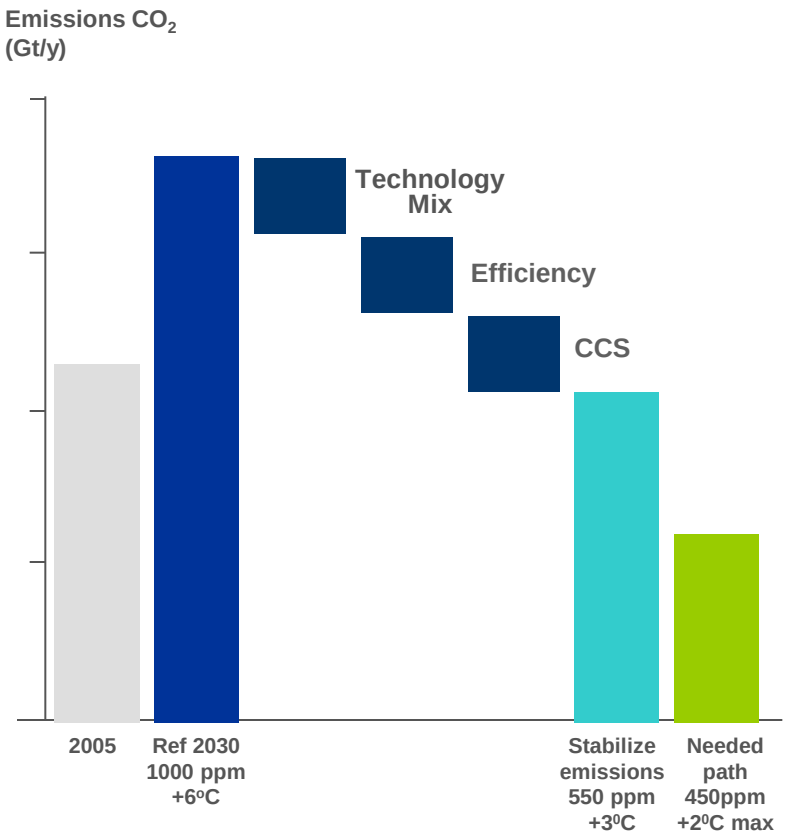


Source: IEA-Unido report – Sept 11 – IEA analysis

Industrial CO_2 emissions contribute relevantly, too.
Yet, they can be only mitigated by Carbon Capture Technology!

Approach

Clean Power strategy



N° 1 nuclear* & biomass

* Conventional islands

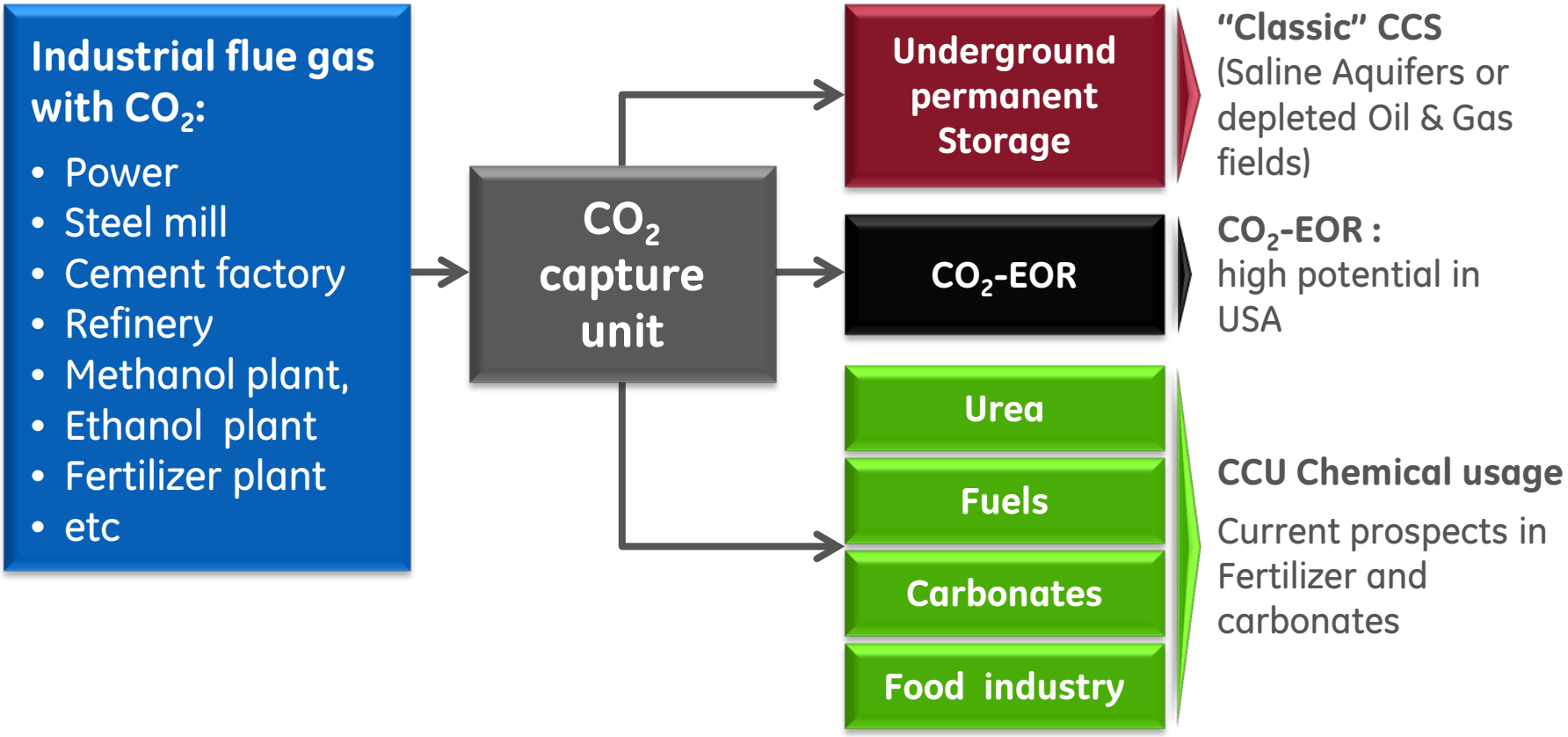
Wind, solar & geothermal

N° 1 hydro

Efficiency: Plant optimisation & retrofit

Carbon Capture & Utilization or Storage

Carbon Capture & Utilization (CCU)
A bridge towards large scale roll-out of CCUS



CCS Technologies developed by GE

Post-combustion

(New + retrofit)

- Advanced Amines Process
- Chilled Ammonia Process
- Amino Silicone Process

2nd Generation Post combustion:

- Regenerative Calcium Cycle (RCC)

Oxy-combustion

(New + retrofit)

- Oxy-combustion with ASU

2nd Generation OxyCombustion:

- Chemical Looping Combustion (CLC)

GE's activities address Installed Base, New Built and Industrial

Post Combustion

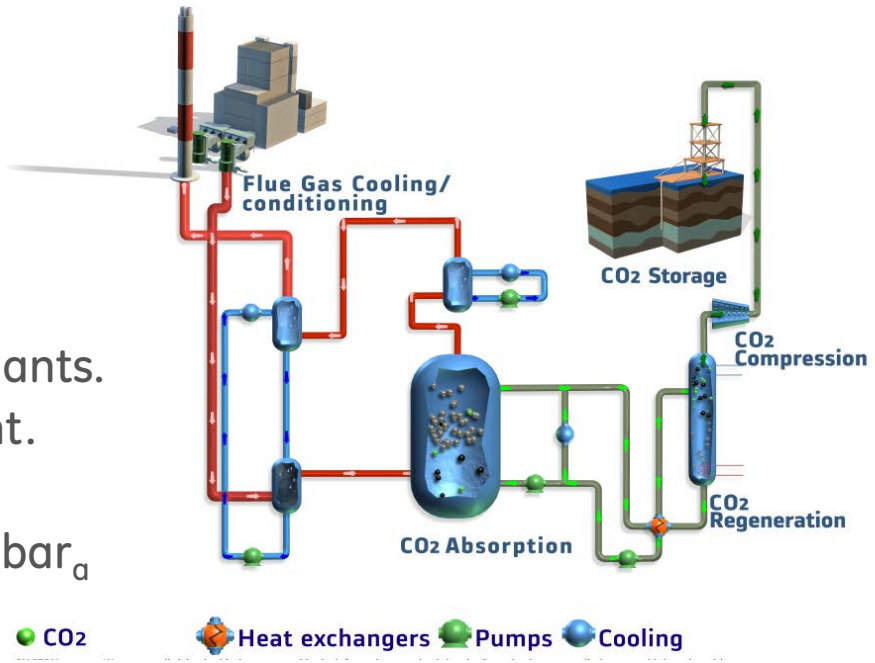
CAP- Chilled Ammonia Process

TECHNOLOGY PRINCIPLE

- At low temperature, flue gas is contacted with an aqueous ammoniated carbonate solution to absorb carbon dioxide
- Raising the temperatures reverses the reaction – releasing pressurized CO_2

ADVANTAGES

- Energy-efficient capture of CO_2 .
- High CO_2 purity, high CO_2 pressure.
- Tolerant to oxygen and other flue gas impurities like SO_x.
- Stable reagent (no degradation).
- No emission of harmful trace contaminants.
- Low-cost and globally available reagent.
- Value by-product (fertilizer).
- Variable Regenerator pressure: 7 to 21 bar_a
- Low CO_2 compression power demand



AAP - Advanced Amine Process

TECHNOLOGY PRINCIPLE

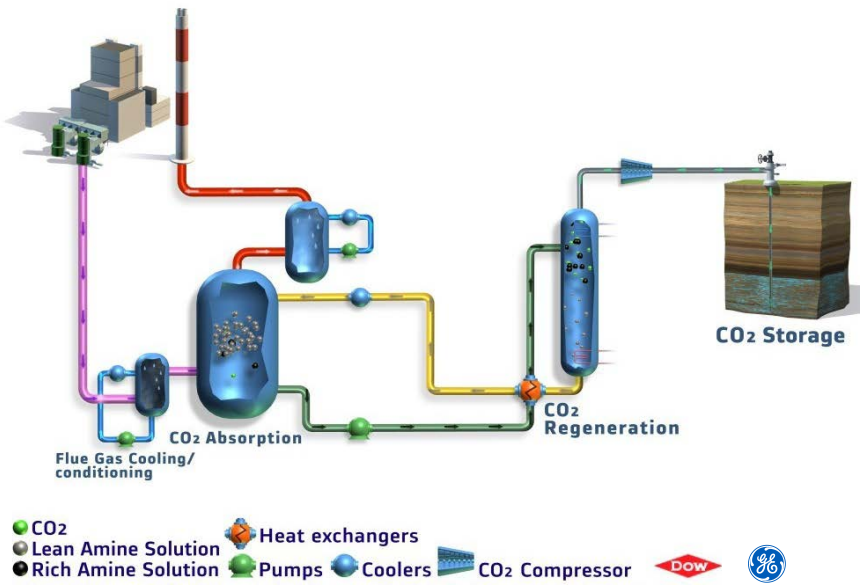
- An amine based solvent reacts with the CO_2 in the flue gas
- Raising the temperature reverses this reaction, the CO_2 is released and the solvent recycled

ADVANTAGES

- Proven in natural gas & syngas purificat
- More efficient capture of CO_2 and less solvent degradation than MEA
- Higher tolerance against oxygen & trace contaminants

MARKET INTRODUCTION

- Ready for small-scale and CCU full commercial offering
- Ready for large-scale demonstration projects



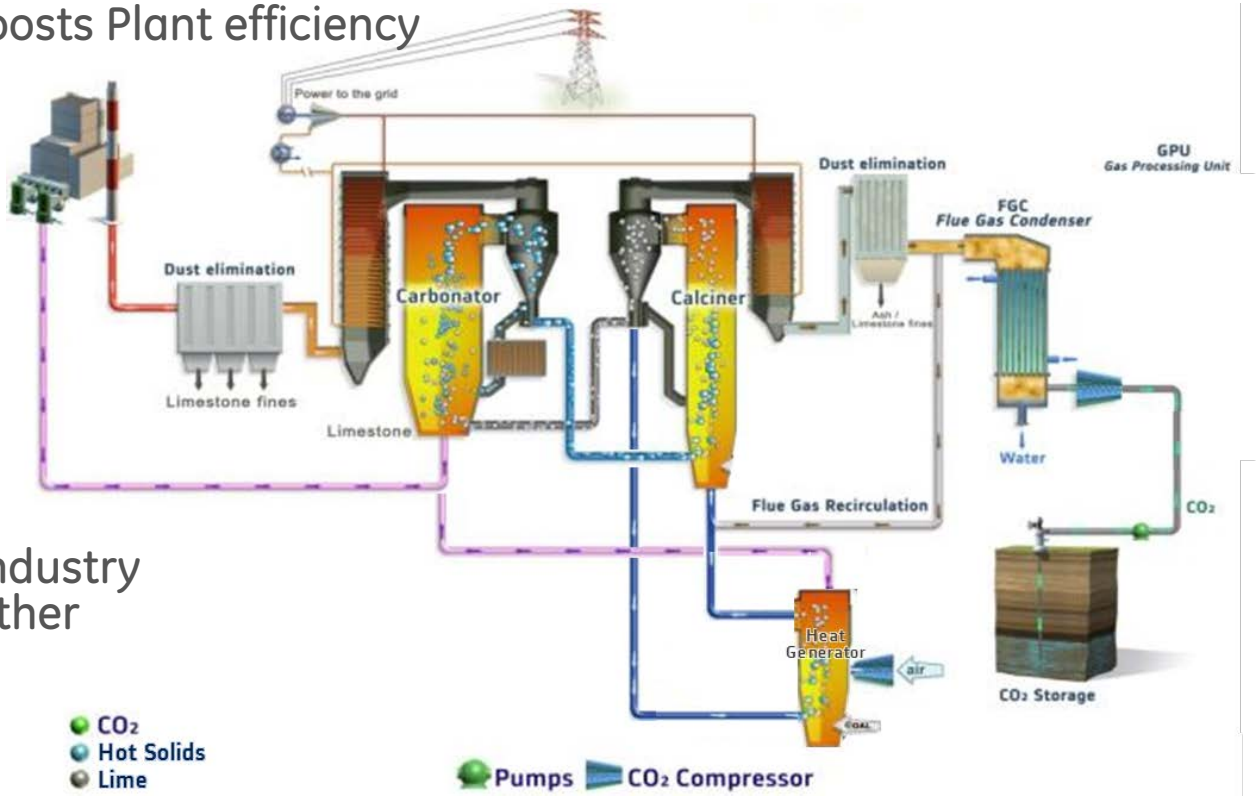
RCC- Regenerative Calcium Cycle

TECHNOLOGY PRINCIPLE

- Lime reacts with the CO_2 in the flue gas to form Limestone while producing heat
- Raising temperature reverses reaction, CO_2 is released and sorbent recycled
- Indirect heat transfer boosts Plant efficiency and CO_2 quality

ADVANTAGES

- RCC increases the total power production, adding capacity
- High potential for lower net cycle efficiency penalty
- Ideal fit to the cement industry (and good potential in other industries)
- Spent limestone can be reused



Oxy Combustion

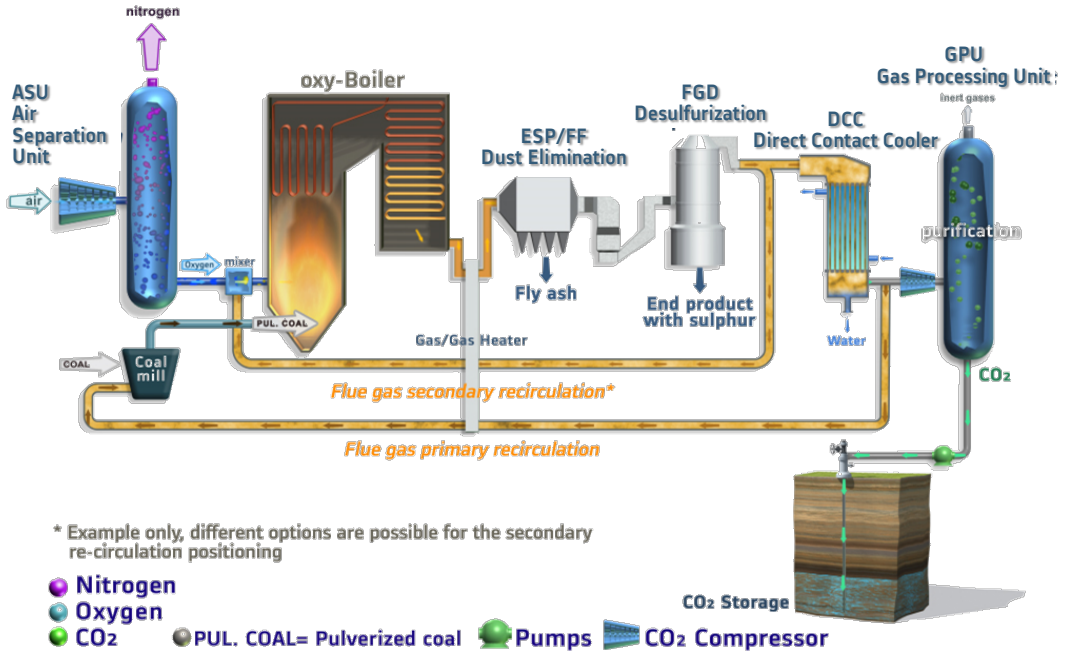
Oxy-Combustion Process

TECHNOLOGY PRINCIPLE

- Fuel is burned in a mixture of Oxygen and re-circulated flue-gas.
- Due to absence of Nitrogen, flue gas is enriched in CO_2 and H_2O
- After H_2O condensing and purification, CO_2 is compressed and send to storage

ADVANTAGES

- Reliability
- Adaptable to all boiler types and fuels
- Rapid scale-up to >1,000 MW_{el} range
- Retrofit in Oxy can be addressed
- Higher efficiency with supercritical/ultra-supercritical cycles



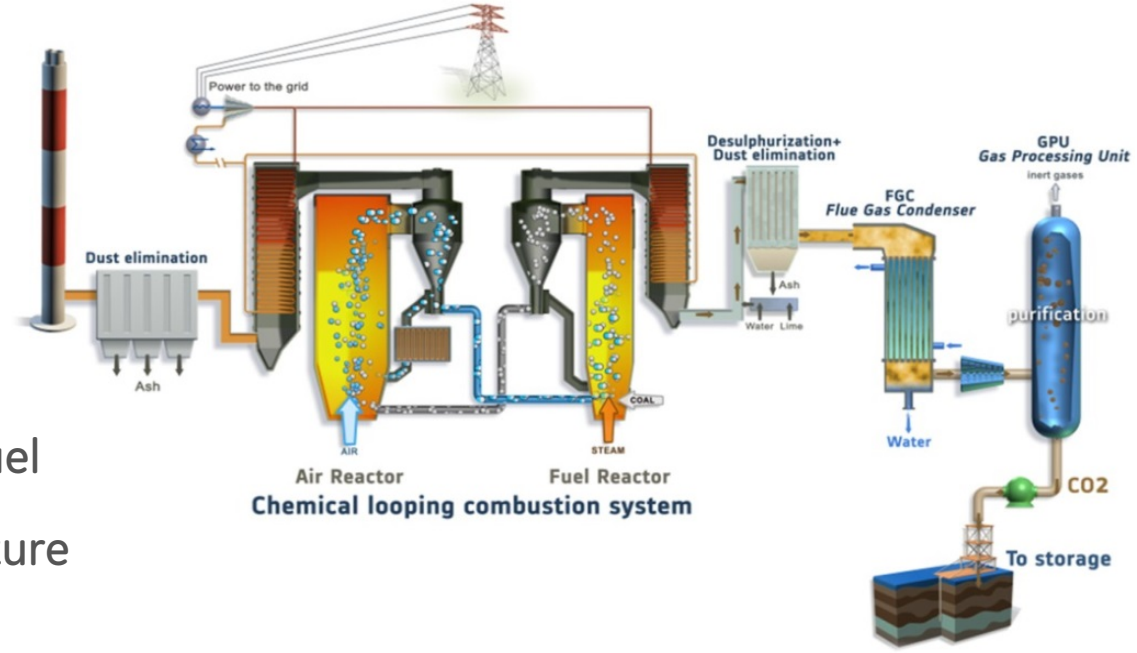
CLC - Chemical Looping Combustion

TECHNOLOGY PRINCIPLE

- Oxygen Carrier picks up oxygen in Air Reactor and brings oxygen to the Fuel Reactor for Combustion
- Oxygen Carrier regenerated in Air Reactor

ADVANTAGES

- Eliminates need for energy intensive ASU
- Heat generated to produce steam for electricity
- Concentrated CO_2 leaves Fuel Reactor for utilization and storage (CCUS) → 90% Capture



Summary

CCUS development conclusion

- CCUS is the sole solution to address CO_2 emissions from industries
- Recognized leader on CCUS technology based on last 10 years development including 13 pilots and validation plants
- Proven and robust technologies capable to serve power and industry
- 2nd gen technologies promise to be breakthrough technologies in terms of energy penalty and CoE
- R&D focused on closing technology gaps, supporting new large demo-plants and develop 2nd generation to maintain a leading role in CCUS Technologies

We are a recognized leader in CCUS Technologies for a promising market after 2020