10th Trondheim CCS Conference, 18th-19th June 2019, Trondheim, Norway

Integration of a flexible Calcium Looping CO_2 capture system in a back-up power plant

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Development of flexible coal power plants with CO_2 capture by Calcium Looping (FlexiCaL)
(RCFS-709629, 2016-2019) www.flexical.eu

Outline

- Introduction: the need for flexible CO_2 capture
- Thermal integration of FlexiCaL in a Back-Up power plant
- Conclusions

The need for flexible CO_2 capture systems

Fossil fuel power plants undergo flexible operation with load changes, partial load operation or turn off periods due to the increasing amount of renewable energy

PROBLEM:

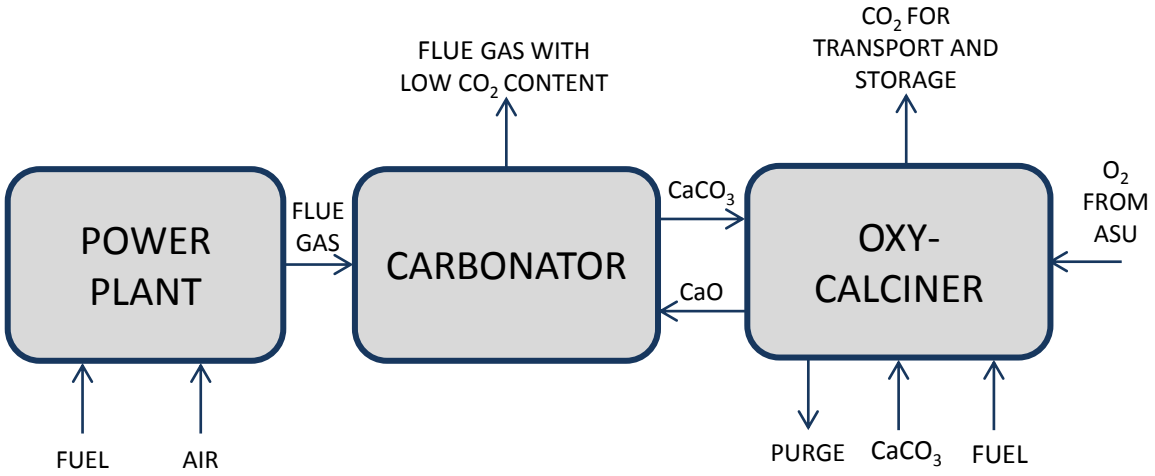
CO_2 CAPTURE TECHNOLOGIES ARE INTEGRATED SYSTEMS WITH LOW FLEXIBILITY AND HIGH CAPITAL INVESTMENT.

OPERATION WITH LOW CAPACITY FACTORS WOULD LEAD TO HIGH CO_2 COST BECAUSE OF WASTE OF CAPITAL

Approaches to address flexibility in existing CO_2 capture technologies:

- Post-combustion using liquid solvent → **Storage tanks of solvent**
- Oxy-combustion → **Cryogenic storage of O_2**
- Pre-combustion → **Storage of hydrogen/polygeneration**

Calcium looping for post-combustion CO_2 capture



ADVANTAGES OF CO_2 CAPTURE BY CaL

- Based on CFB technology
- Low energy penalty → Additional power produced
- Use of CaO as sorbent → Rich CaO purge
- Energy penalties: 6-9 net points
- Developed up to TRL 6-7

FlexiCaL

www.flexical.eu

TO IMPROVE THE FLEXIBILITY OF CO_2 CAPTURE BY DEVELOPING NOVEL CALCIUM LOOPING PROCESS INTEGRATED WITH ENERGY STORAGE SYSTEM

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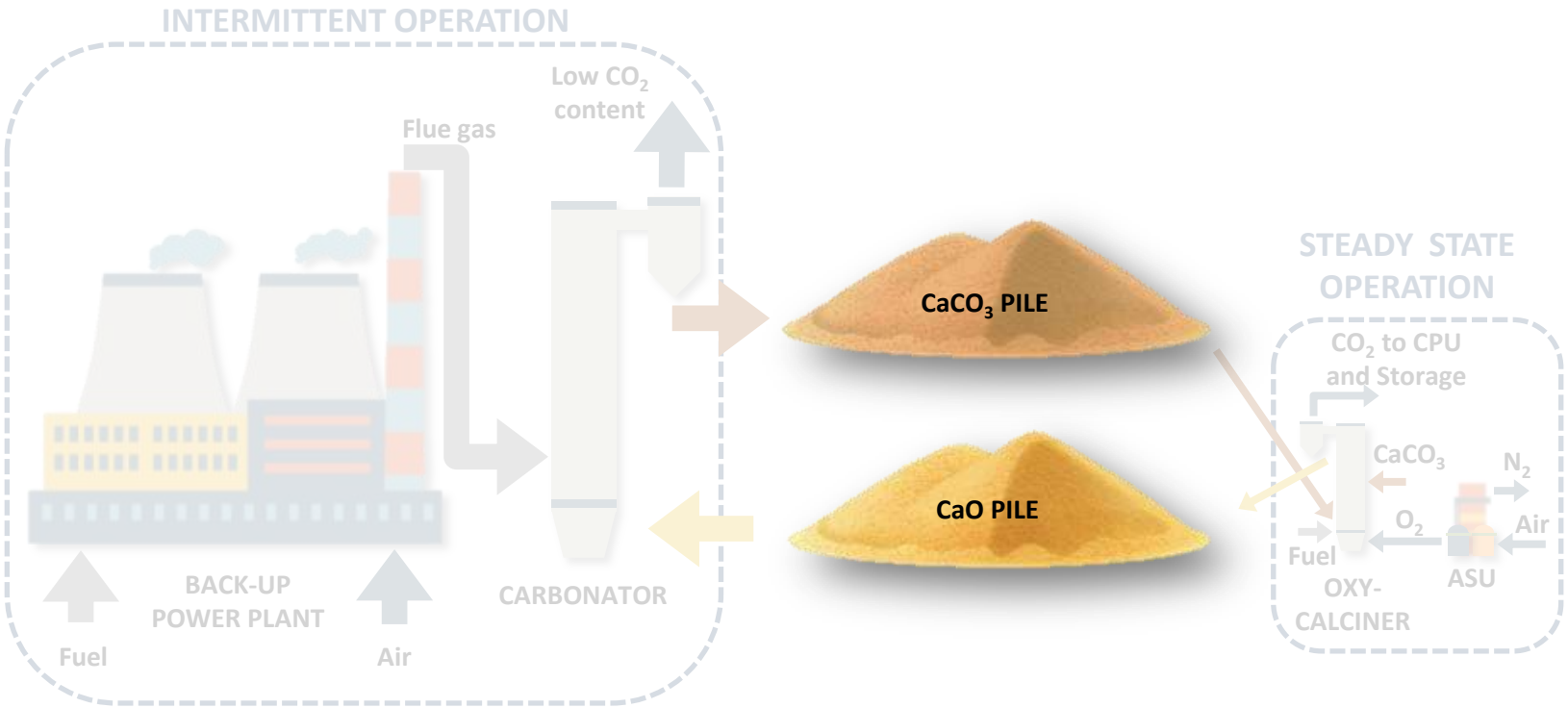
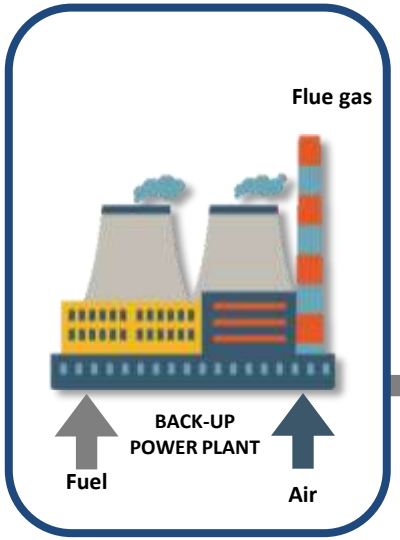
Flexible CaL for back-up power plants



Calcium looping CO_2 capture system for back-up power plants. Y. A. Criado, B. Arias and J. C. Abanades; ***Energy Environ. Sci.,*** **2017**, 10, 1994

CaL for back-up power: integration of the carbonator



Heat recovery?

CFB Carbonator

Flue gas with low CO_2 content

$CaCO_3$ To storage pile

CaO From storage pile

Power plant → Existing (amortized), providing BACK-UP POWER SERVICES while capturing CO_2

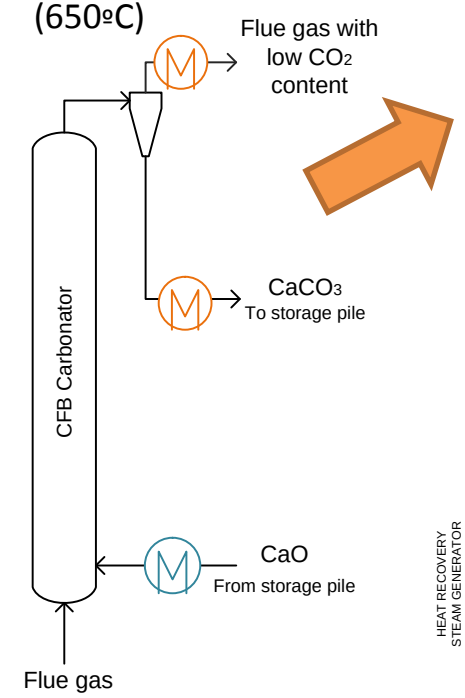
Carbonator (New) is an adiabatic reactor. It is decoupled from the calciner and is fed with stored CaO following the intermittent power plant operation modes

HEAT RECOVERY

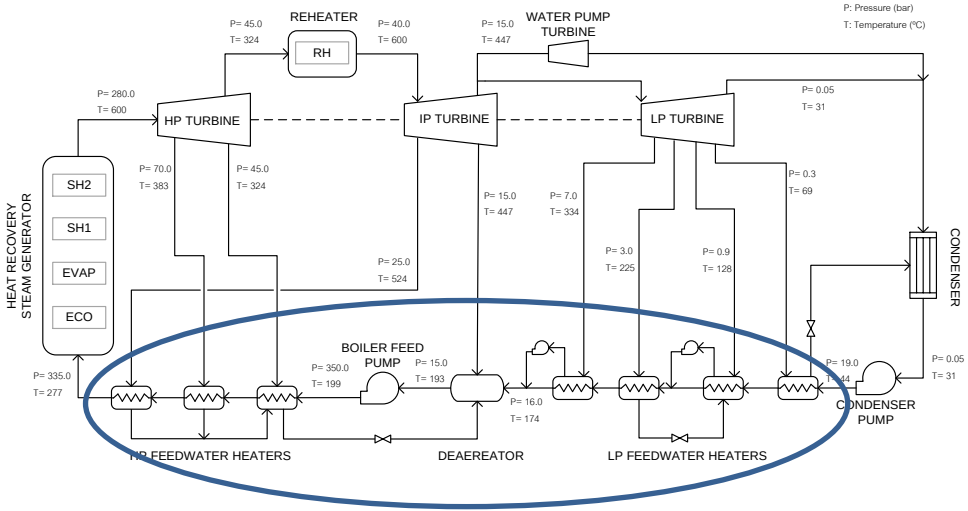
PRE-HEATING

Thermal integration of the carbonator block

ADIABATIC CARBONATOR
(650ºC)



HEAT RECOVERED FROM GAS AND SOLIDS OUTLET STREAMS:



- In an additional steam cycle (SC)

  COE increases for very low CF

- Integrated within the power plant steam cycle

  Allows reducing the coal thermal input for the maximum SC capacity → Reduces CO_2 flow → Lower FlexiCal size required

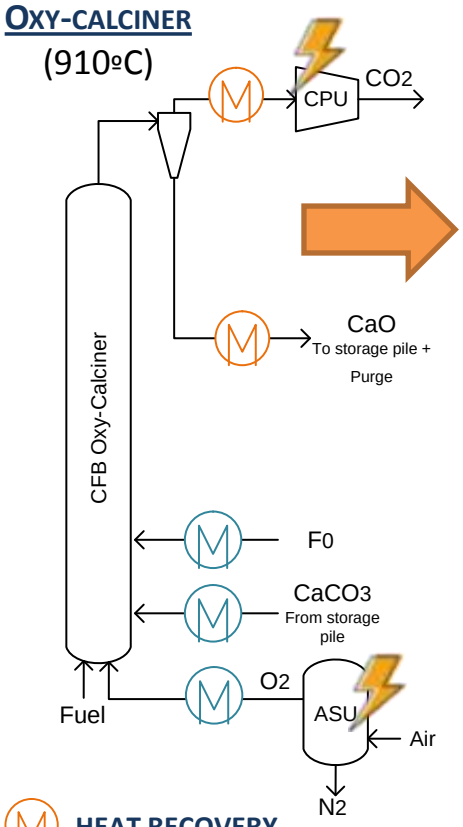
Replace bleedings to HP and LP feedwater heaters:

Reduced modifications in the existing power plant → Low Capex

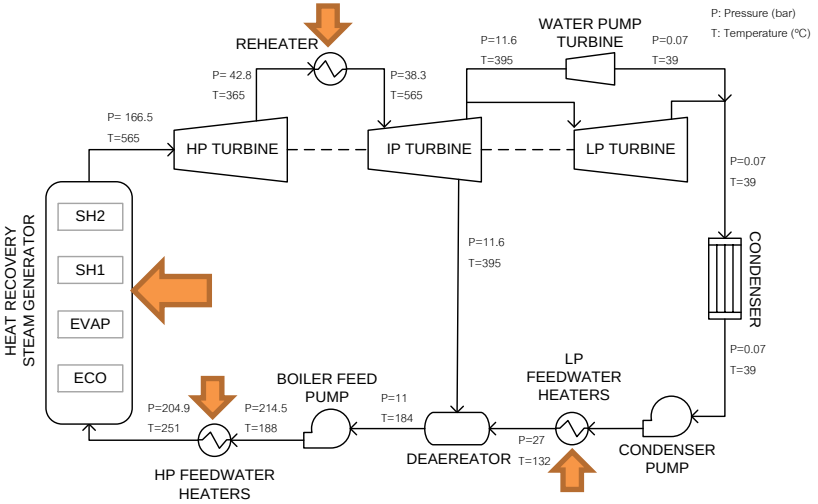
HEAT RECOVERY

PRE-HEATING

Integration of the oxy-calciner block



HEAT RECOVERED FROM GAS AND SOLIDS OUTLET STREAMS TO RUN A SMALL SUBCRITICAL STEAM CYCLE



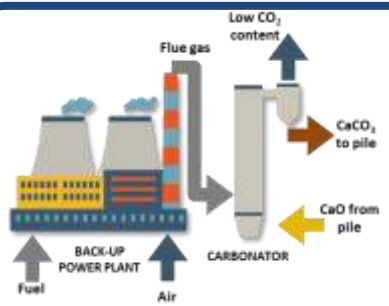
Enough power available as to cover the electricity demand in CPU, ASU and auxiliaries of the oxy-calciner block

Results for a case example

MAIN ASSUMPTIONS:

Existing power plant: 350 MW_e power plant (reference 777 MW_{th} for η=45%) operated under **CF=0.1**

Calcium looping: T_{Carb}=650ºC, T_{Calc}=910ºC, X_{ave}=0.35, E_{Carb}=0.9 and E_{Calc}=1

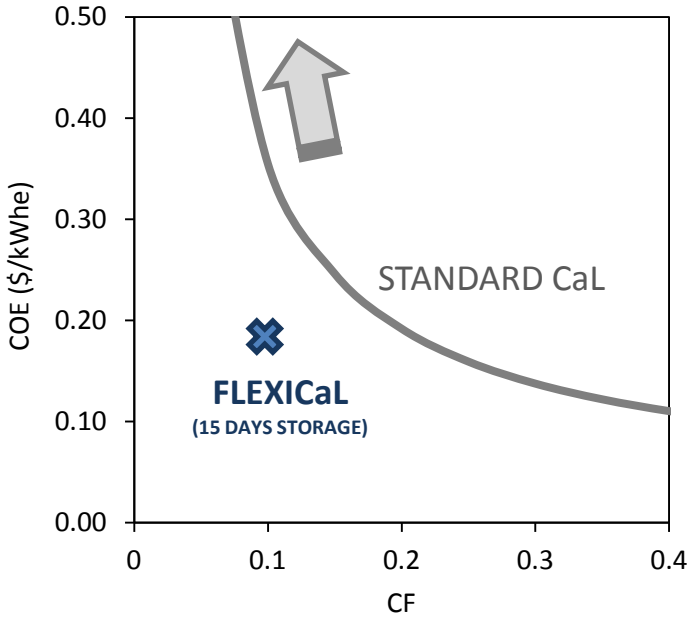


- 206 MW_{th} from the carbonator are recovered in the power plant steam cycle
- Thermal power plant input in the back up plant can be **reduced by a 12%**
- Due to the absence of bleeds there is a certain penalty (~3 net points) on the steam cycle efficiency.

- CaO can be stored at **156ºC** and $CaCO_3$ at **207ºC**
- Between **20000** and **25000 m^3** of solids per operation day of the power plant are required
- A purge of 0.1 Mton is annually produced

- Only represents an **8% of the total thermal capacity** (66 MW_{th})
- 12.5 MW_e are produced in the associated steam cycle, being required about 11 MW_e in the ASU, CPU and auxiliaries
- Net OVERALL energy efficiency 28%.
- **Net energy efficiency DURING PICK POWER with CO_2 capture: 42%**

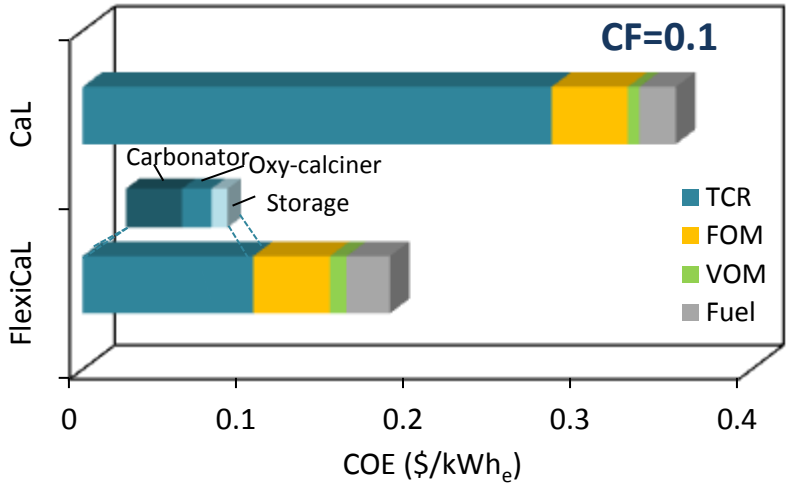
Cost analysis for the case example



AVOIDANCE COSTS ARE HIGH (190 $/t$_{CO2}$) BUT LESS THAN HALF OF THE COST OF AN EQUIVALENT REFERENCE CAPTURE SYSTEM WITH CF=0.1

- Standard CaL (as other "conventional" CO_2 capture technologies) heavily penalized for extremely low capacity factors mainly due to the CAPEX
- Thanks to the reduced oxy-calciner size and the low-cost storage silos costs **below 0.2 $/kWhe** are estimated for retrofitting amortized coal power plants with a **CF of just 0.1**

TECHNOLOGY	TCR ($/kWe)
Standard CaL	2450
FlexiCaL (15 days storage)	900



Outline

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- Flexible Calcium Looping for back-up
- Integration in a back-up power plant
- **Conclusions**

Conclusions

- Calcium looping is a CO_2 capture technology with a large flexibility potential by its integration with a $CaO/CaCO_3$ solid storage system, which allows very low CF.
- Heat from the carbonator block can be recovered in the existing power plant steam cycle, reducing up to 12% fuel consumption
- Oxy-calciner block can operate in steady state mode. ASU and CPU can be self-sustained power generation from calciner waste heat
- Energy penalty is high (overall net energy efficiency ~ 0.28) but energy is consumed during periods of low power demand, while 0.42 efficiency is retained during Back-up periods with CO_2 capture

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