CSIRO PCC Science & Techonology Seminar
26 March, CSIRO Energy Centre, Newcastle

"Ca-looping for post-combustion CO_2 capture"

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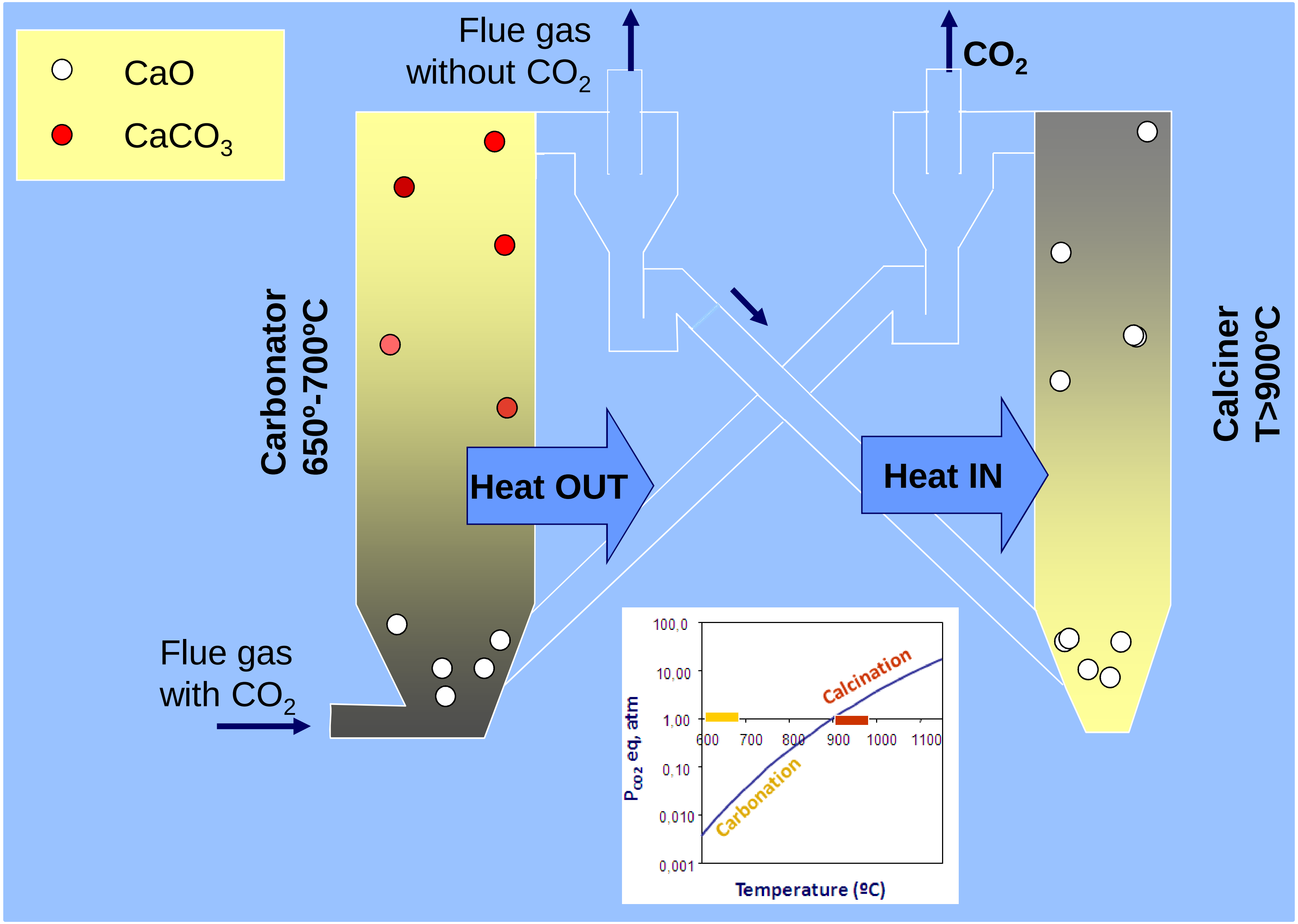
Spanish Research Council (INCAR-CSIC)

CSIC
Consejo Superior de Investigaciones Científicas

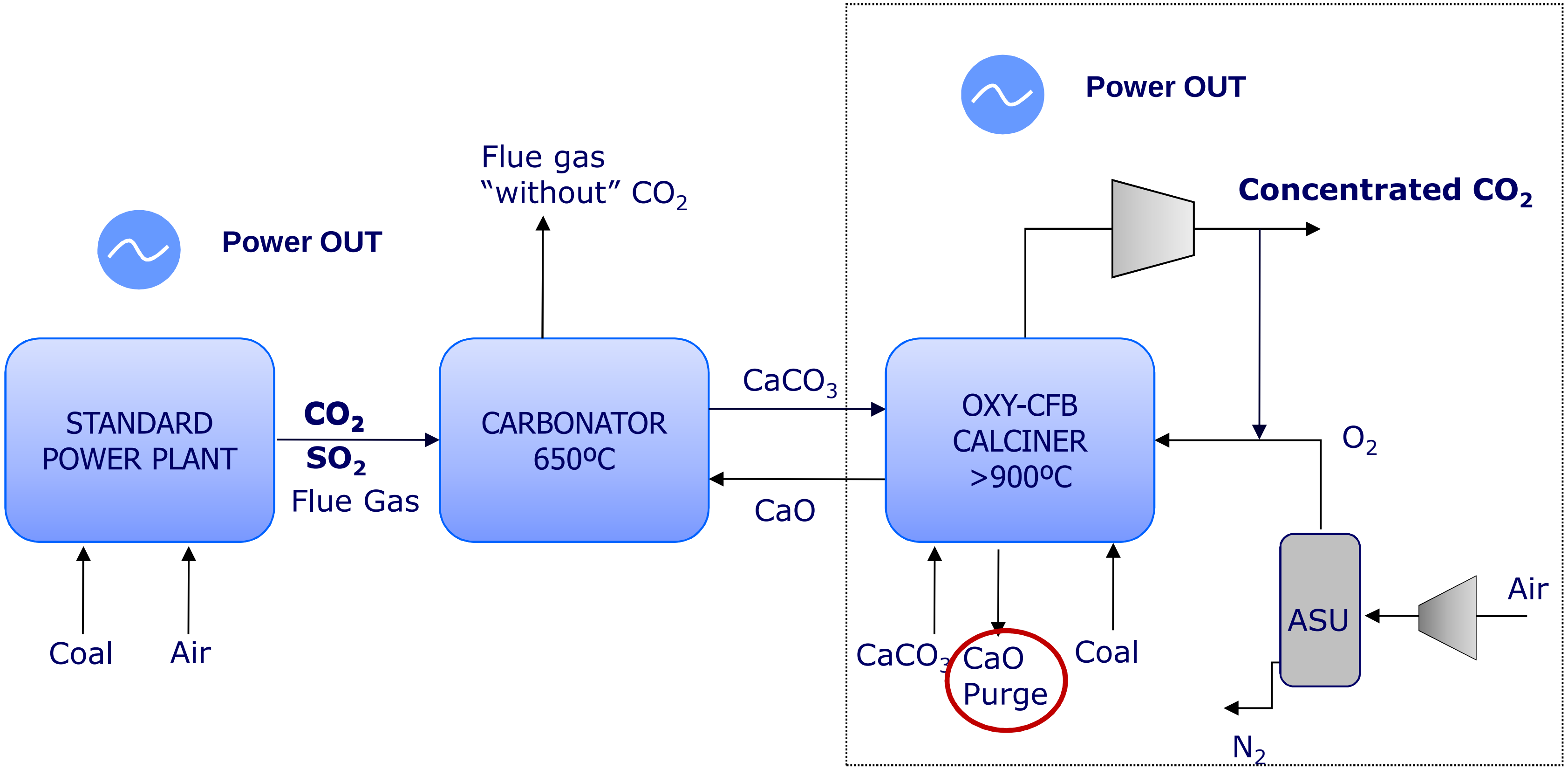
OUTLINE

- Postcombustion Calcium Looping concept
- Pilot plant results from the "CaOling" project
  - Testing lab scale facilities (<30 kW_{th})
  - Testing results from a 1.7 MW_{th} pilot
- Conclusions

Ca-looping: The main process concept



Main process concept: Post-combustion CO_2 capture

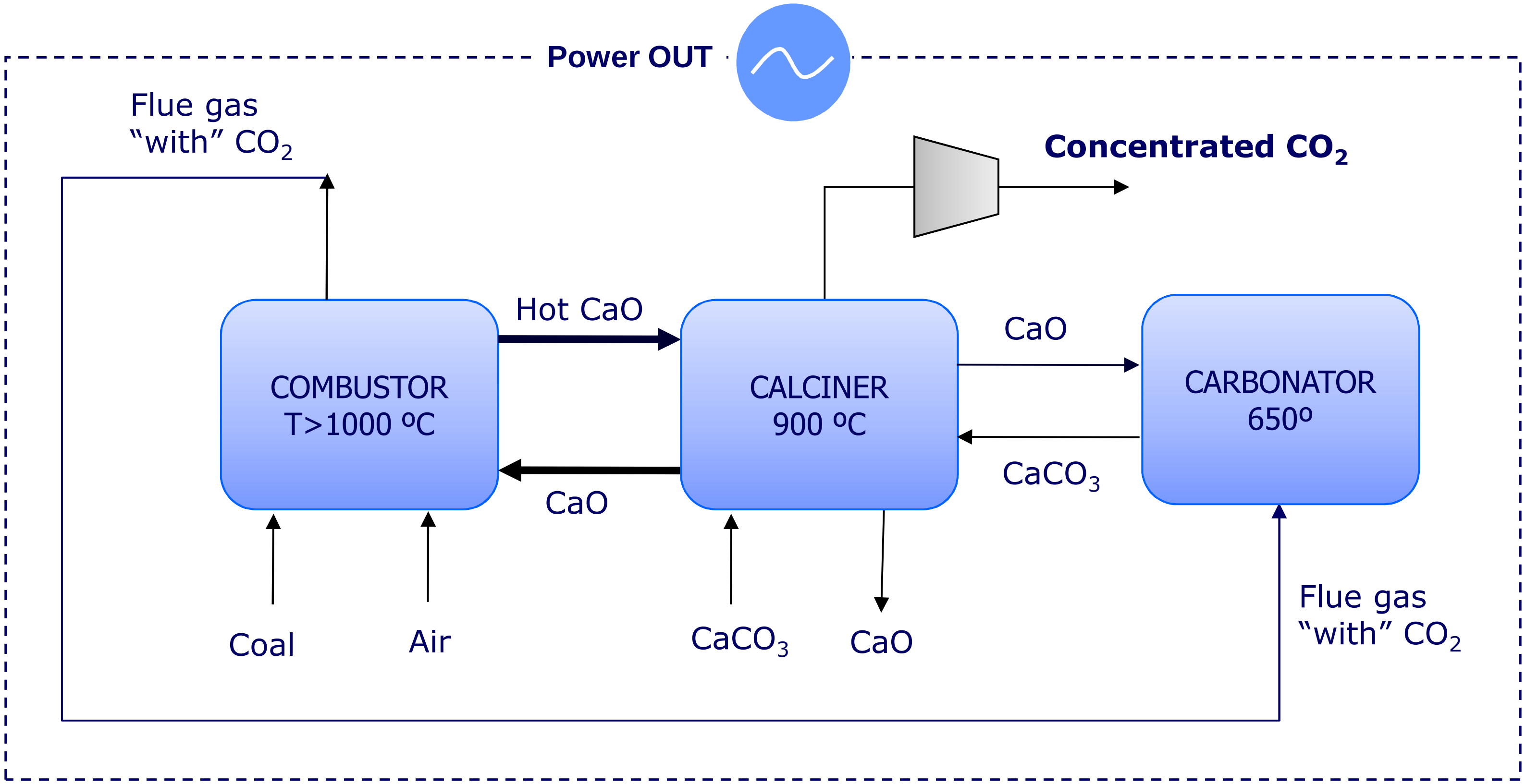


Some features of postcombustion Ca-looping :

- Low energy penalty (6-7 net points)/low cost per ton CO_2 captured
- Purge of CaO: synergies with cement industry and others (i.e. desulfurization of FG)
- Low cost sorbent precursor (low toxicity of materials involved)
- Pre-treatment of flue gas no needed (SO_2 co-capture)
- Benefits and limitations of large scale CFBCs (including oxy-CFB)

Shimizu et al , 1999, *Trans. IChemE 77A, 62–68*

Advanced CaL concept: power plant with inherent CO_2 capture



Some advantages of a Ca-L power plant calcining with "hot CaO":

- No air separation unit required, no energy penalties other than compression and aux.
- Key CFBC equipment already available, but high combustion temperatures asks for coal quality
- High solid circulation required and new scaling up issues for FB calciner.

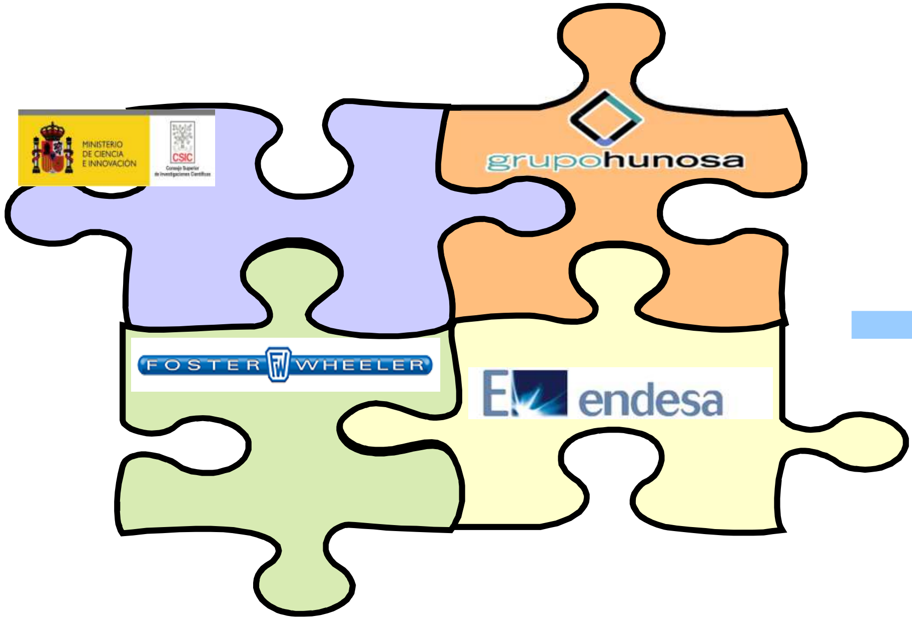
Martínez et al , 20011*Int. J. of Greenhouse Gas Control* 5, (3498-504

OUTLINE

- Postcombustion Calcium Looping concepts
- **Pilot plant results from the “CaOling” project**
  - **Testing lab scale facilities (<30 kW_{th})**
  - **Testing a 1.7 MW_{th} pilot**
- Conclusion

Consortium agreement: CaOling project

23 FEB 2007



23 APR 2009

29 JUL 2008

CaOling

uOttawa

lut.fi

ifk

Imperial College London

DEC 2009

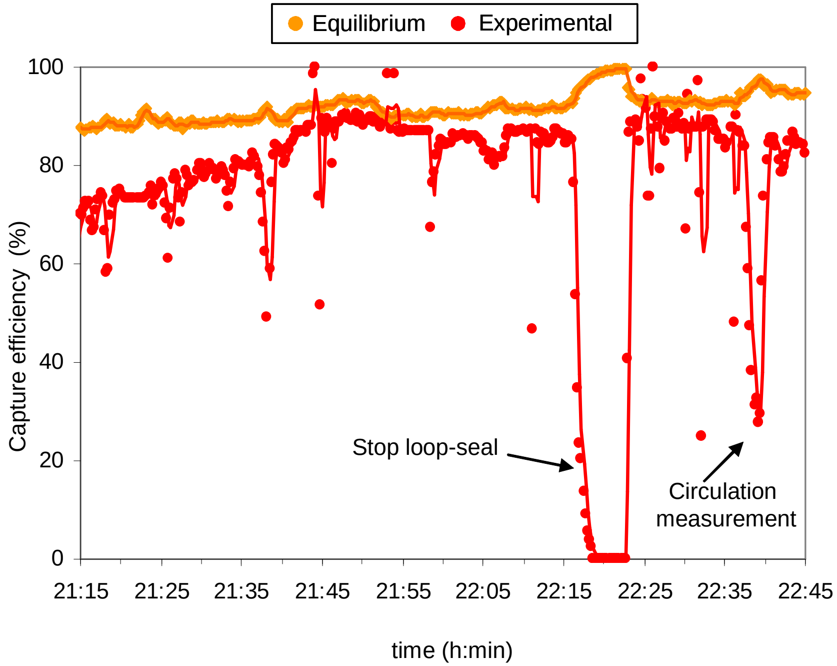
"Development of postcombustion CO_2 capture with CaO in large testing facility"

European Union 7th Framework Programme-FP7

Validation of Ca-looping for post-combustion CO_2 capture at small facilities

Small pilot plant at INCAR-CSIC (30 kWt)

CO_2 capture efficiency in CFB carbonator



Main features:

- Two CFB reactors (Height~6.5 m, diameter=100 mm)
- Electrically heated
- Continuous monitoring temperature, pressure drops, gas composition etc)
- Occasional measurement of solid circulation rates
- More than 450 hours of operation

N. Rodríguez, et al . AIChE Journal, 57, 1356-1366,2010

Results: Characterization of the carbonator reactor

CARBONATOR REACTOR MODELLING

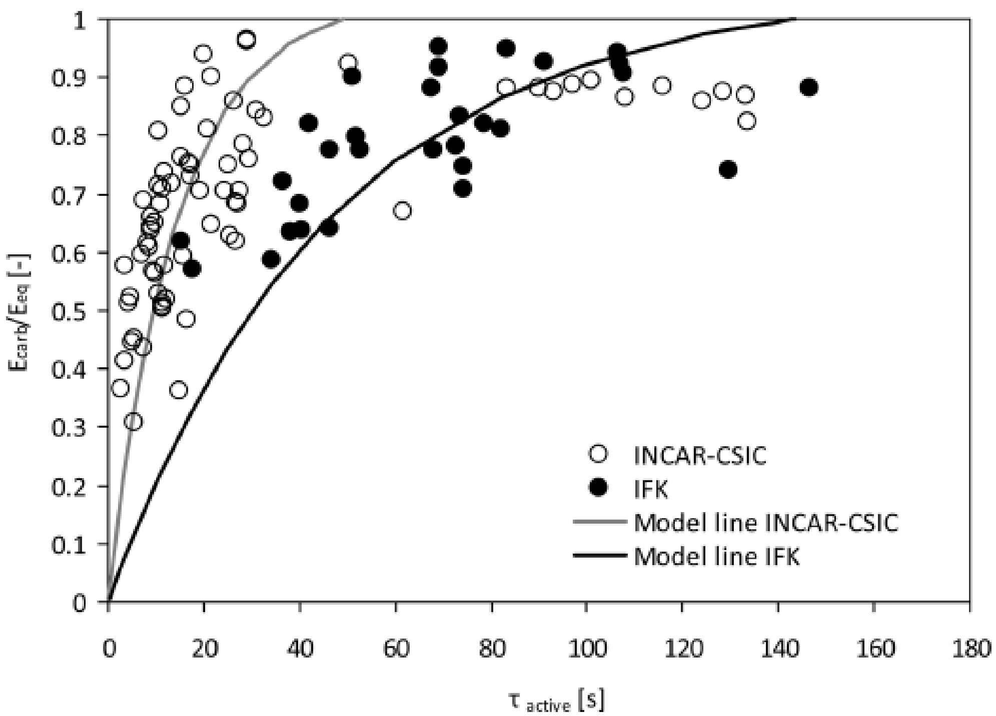
CO_2 reacting with CaO in the bed = **CO_2 removed from the gas phase**

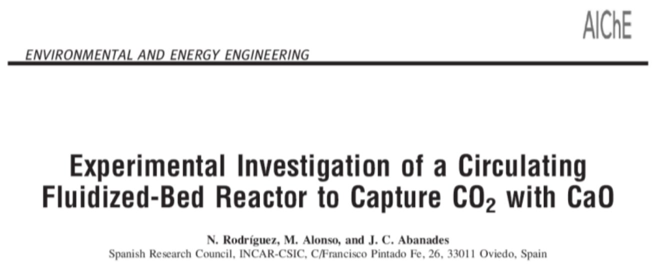
Initial assumptions carbonator reactor:

- Instantaneous and perfect mixing of the solids
- Plug flow for the gas phase

$$E_{carb} = \tau_{active} \varphi k_s \left(\overline{f_{CO2} - f_e} \right) \qquad \tau_{active} = \frac{N_{CaO}}{F_{CO2}} f_a X_{ave}$$

EXPERIMENTAL RESULTS FROM THE SMALL FACILITIES AT INCAR-CSIC AND IFK (10's kW)





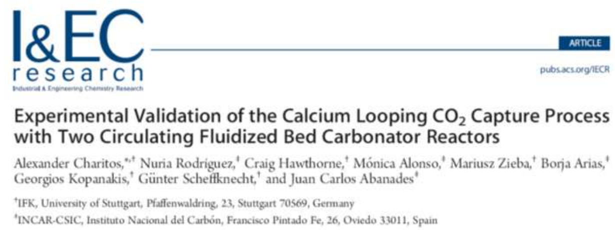
AIChE

ENVIRONMENTAL AND ENERGY ENGINEERING

Experimental Investigation of a Circulating Fluidized-Bed Reactor to Capture CO_2 with CaO

N. Rodríguez, M. Alonso, and J. C. Abanades

Spanish Research Council, INCAR-CSIC, C/Francisco Pintado Fe, 26, 33011 Oviedo, Spain



I&EC research

ARTICLE

pubs.acs.org/IECR

Experimental Validation of the Calcium Looping CO_2 Capture Process with Two Circulating Fluidized Bed Carbonator Reactors

Alexander Charitos,[*,†] Nuria Rodríguez,[‡] Craig Hawthorne,[†] Mónica Alonso,[‡] Mariusz Zieba,[†] Borja Arias,[‡] Georgios Kopanakis,[†] Günter Scheffknecht,[†] and Juan Carlos Abanades[‡]

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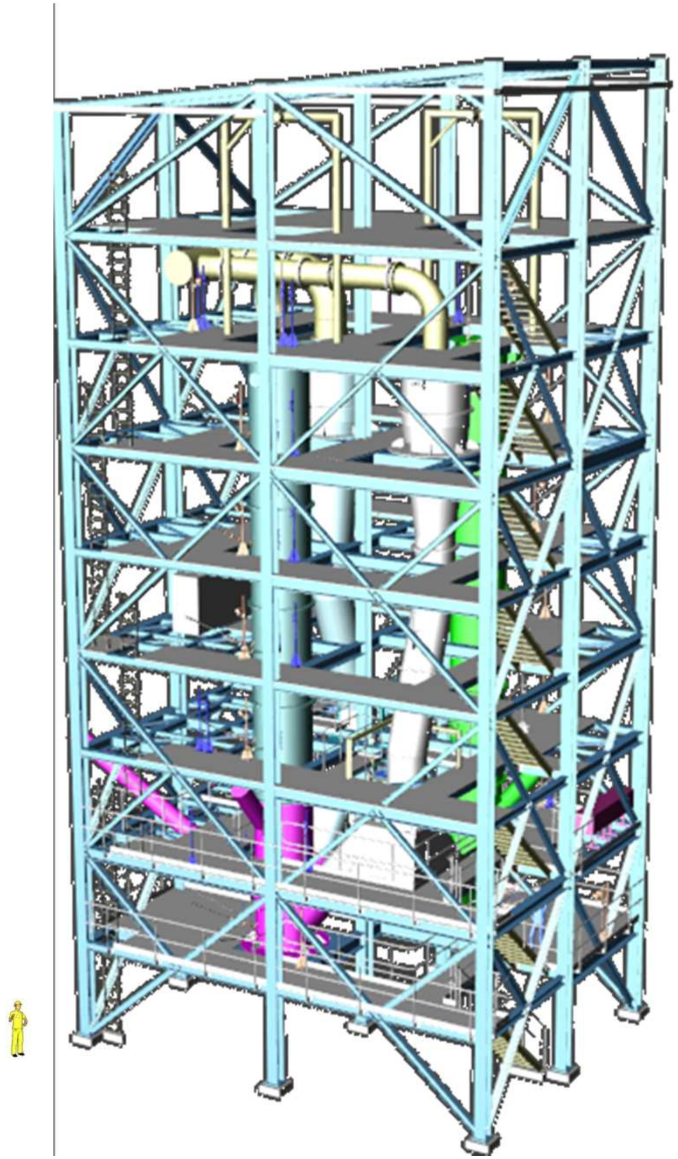
Scaling up: La Pereda CO_2 Ca-L pilot plant

CSIC lab-plant

2008: 30 kWt

x 60



24 m

2011: 1,7 MWt

La Pereda CO_2 pilot plant: Current status

Status of the pilot plant

-Building finished in September 2011

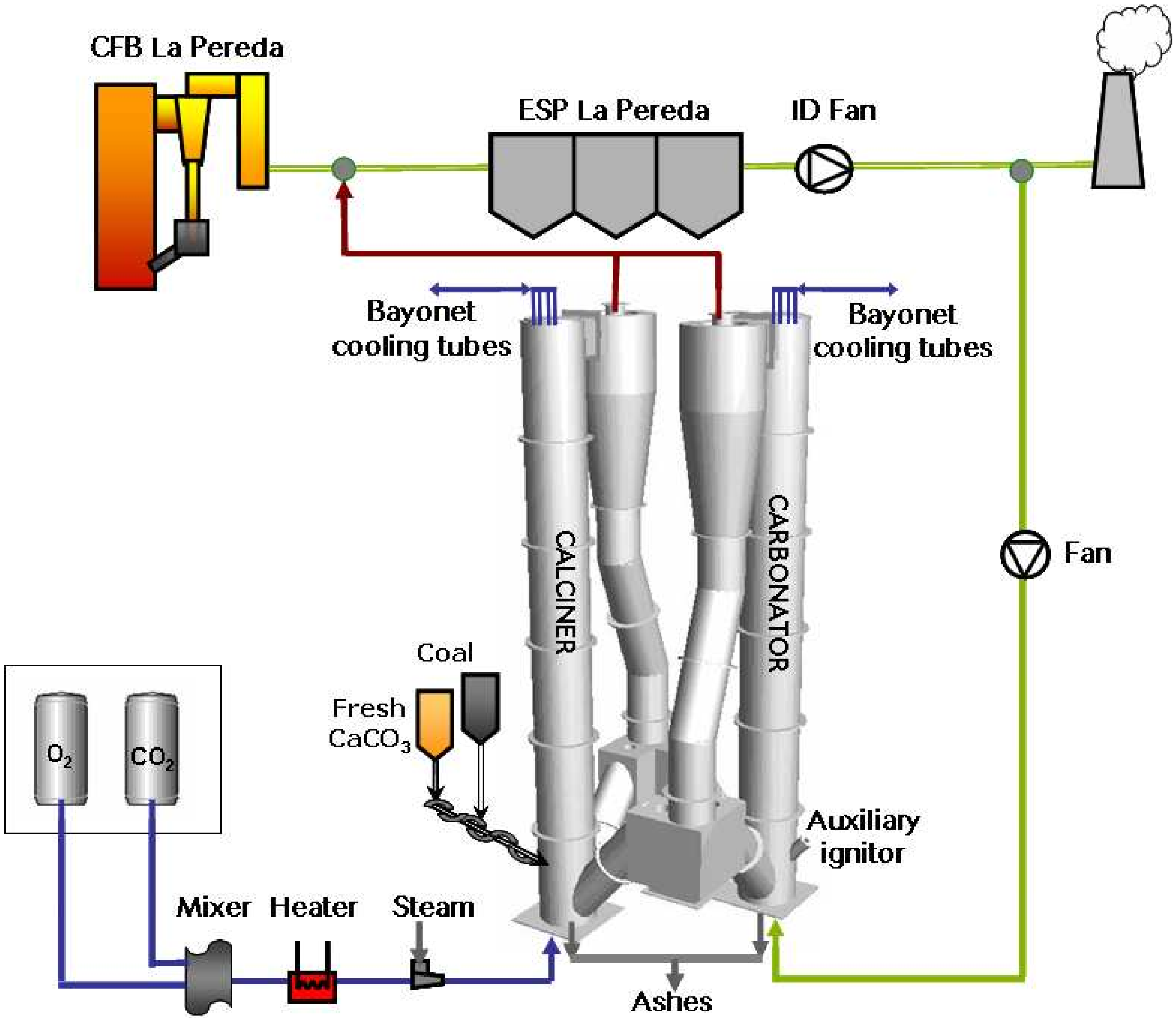
-Start of cold commissioning: October 2011

- Start of hot commissioning: January 2012

- Operational hours with coal combustion (dual fluidized bed mode): ~ 1500 h

- Operational hours in CO_2 capture mode : ~ 310 h (approximately 120 h with the calciner working under oxy-fuel conditions)

La Pereda CO_2 pilot plant: Power plant integration



RESULTS

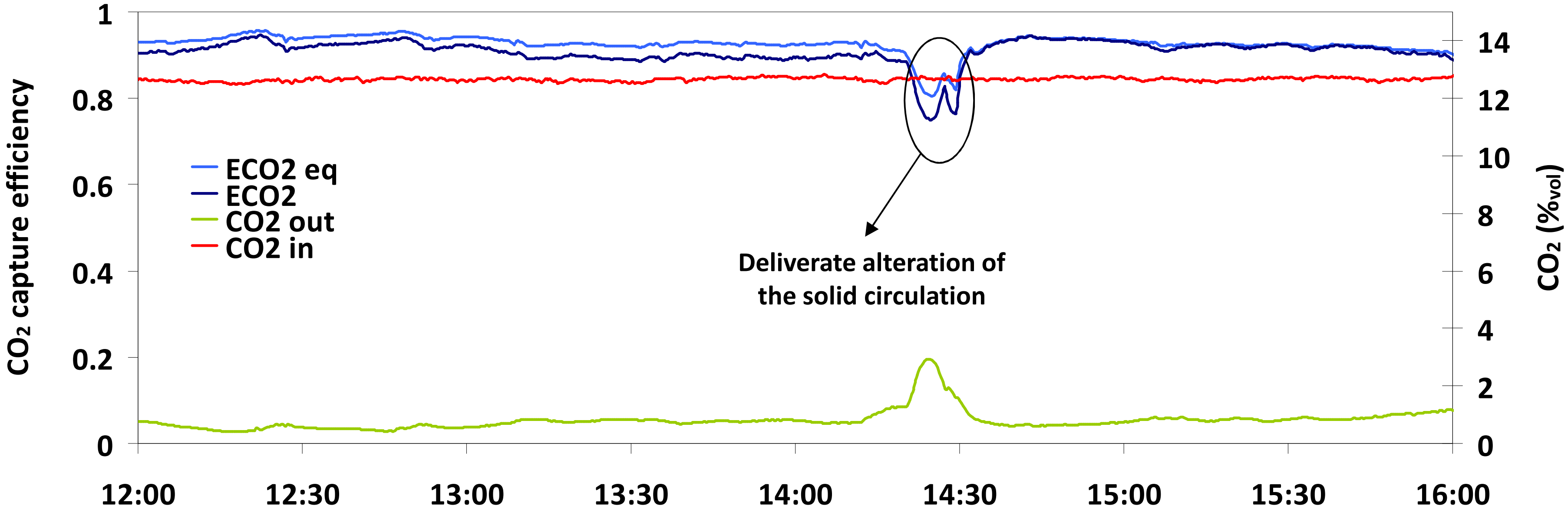
Range of conditions during the CO_2 capture test:

Carbonator temperature (ºC)	600-715
Carbonator superficial gas velocity (m/s)	2.0-5.0
Inlet CO_2 volume fraction to the carbonator	0.12-0.14
Inlet SO_2 concentration to the carbonator (mg/m^3)	100-250
Inventory of solids in the carbonator (kg m^{-2})	100-1000
Maximum CO_2 carrying capacity of the solids	0.10-0.70
Calciner temperature (ºC)	820-950 ºC
Inlet O2 volume fraction to the calciner	0.21-0.35
Inlet CO2 volume fraction to the calciner	0-0.75
CO_2 capture efficiency	0.4-0.95
SO_2 capture efficiency	0.95-1.00

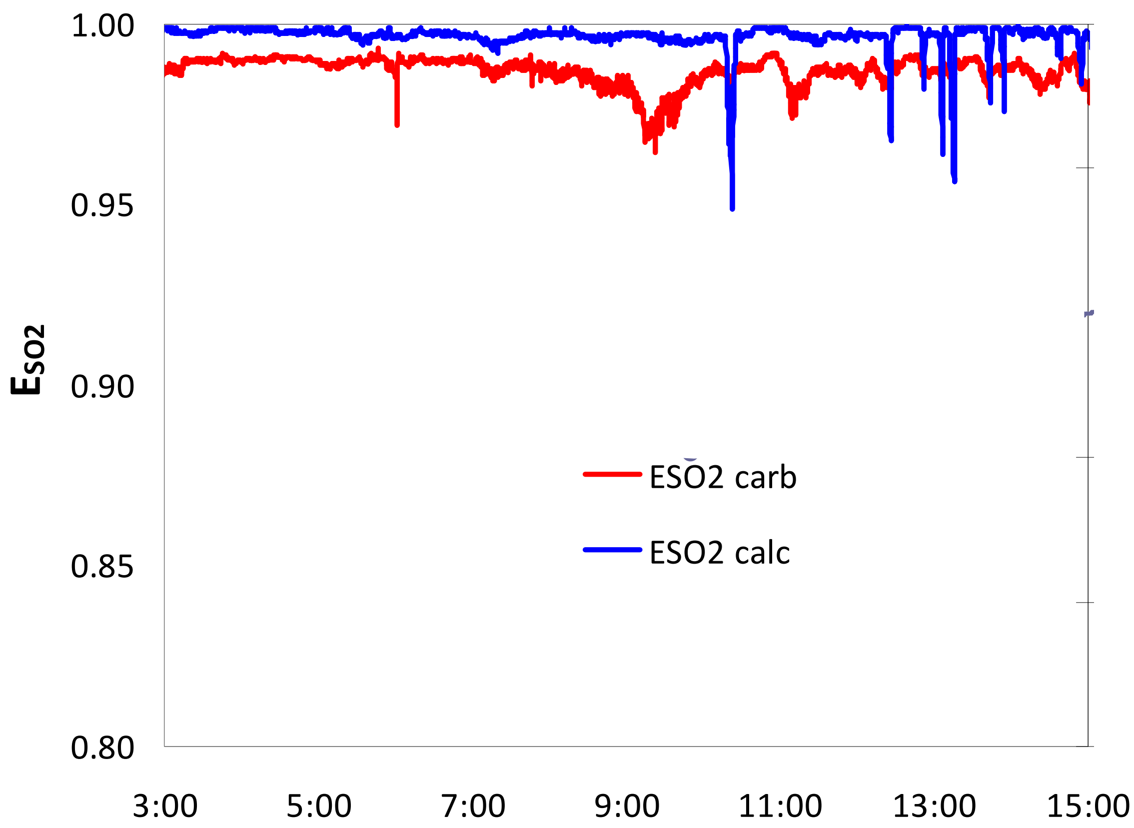
Results from the 1.7 MWth CaL pilot plant of la Pereda

Typical examples of steady state tests

- Inventory of solids in carbonator = 300-400 kg/m2
- Average carbonator temperature= 660 ºC
- Xave = 0.3-0.1

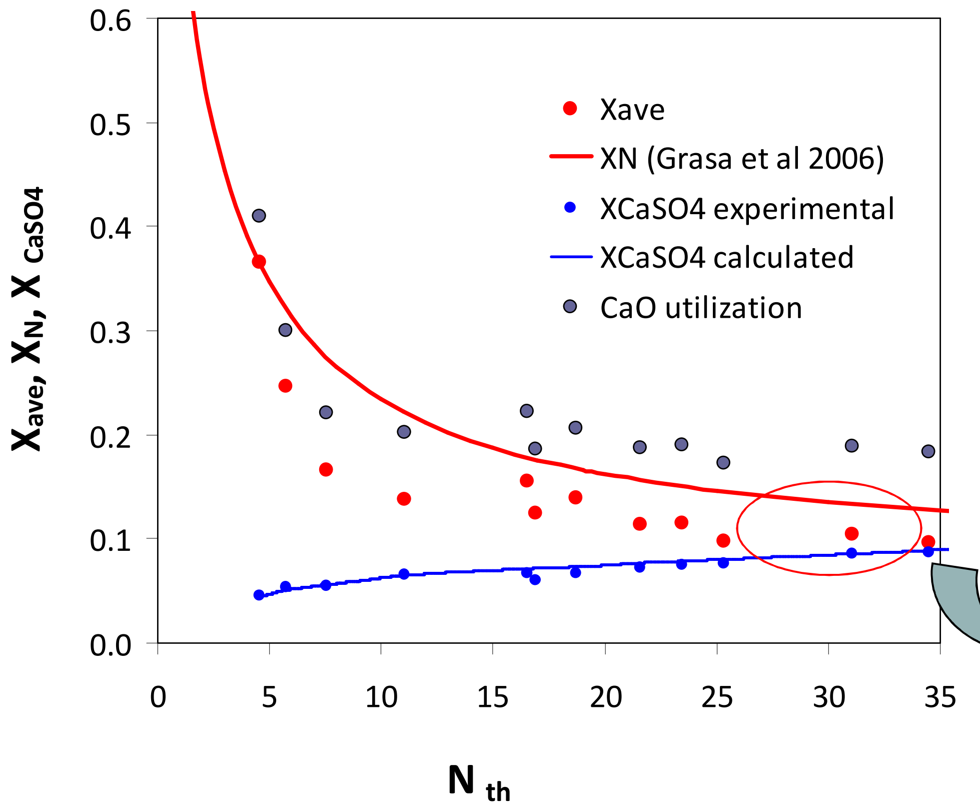


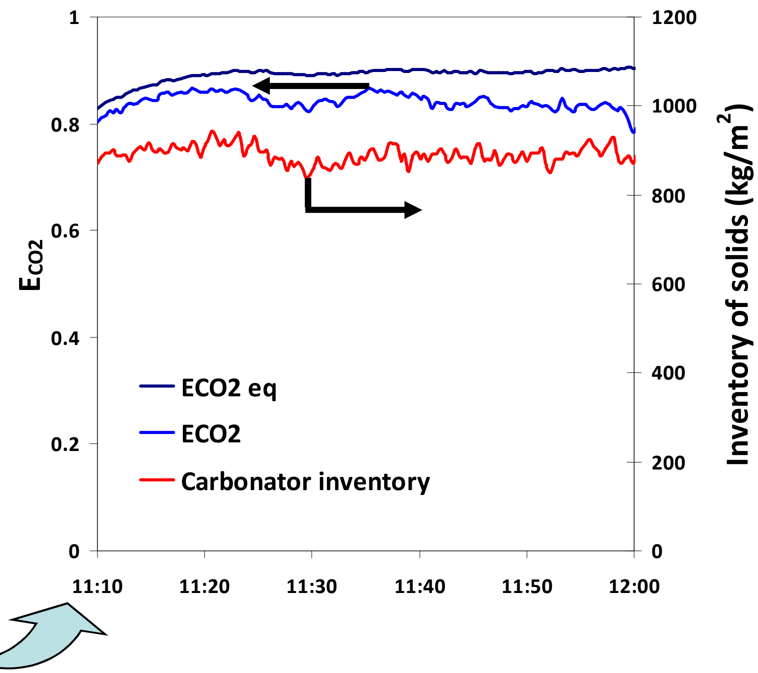
SO_2 capture in the Ca-looping facility



Results from the 1.7 MWth CaL pilot plant of la Pereda

Evolution of sorbent utilization with "lifetime" of particles in the system





Number of times that the inventory of CaO is carbonated up to the maximum CO2 carrying capacity

$$N_{th} = \int_0^t \frac{F_{CO2} E_{carb(t)}}{N_{Ca} X_{ave}} dt$$

MAIN CONCLUSION

- **A flexible experimental facility is in operation in La Pereda Power Plant aiming to validate the technology in the 1MW's size**
- **CO_2 capture efficiencies over 90% achievable in a CFB carbonator reactor operating with "standard" CaO solids, bed inventories, gas velocities, solid circulation rates and reaction conditions in the carbonator and calciner reactors (oxyfuel coal combustion)**
- **SO_2 capture in the CFB carbonator is over 95%**
- **The concept of post-combustion Ca-looping in continuous mode of operation has been successfully proven with two interconnected CFBCs at the MWth scale**

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Thanks for your attention

www.caoling.eu

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