• The concept of Calcium Looping
• Description of “la Pereda” 1.7 MW_{th} pilot
• Steady state results from the pilot
• Conclusions
Calcium looping: postcombustion process concept?

1. **Standard Power Plant**
   - Input: Coal, Air
   - Output: Flue Gas
   - Reaction: CO₂

2. **Carbonator**
   - Input: Flue Gas
   - Output: CaCO₃, CaO
   - Reaction: "without" CO₂

3. **Oxy-CFB Calciner**
   - Input: CaCO₃, CaO, Purge, Coal
   - Output: CaCO₃, CaO, Power OUT
   - Reaction: O₂

4. **ASU**
   - Input: Air
   - Output: O₂, N₂

5. **Concentrated CO₂**
   - Output: CO₂

Flow diagram shows the process steps from standard power plant to concentrated CO₂.
Process concept: post-combustion Ca-L technologies ... in OCC3?
Process concept 1: post-combustion Ca-L technologies

1. **STANDARD POWER PLANT**
   - Coal
   - Air
   - CO₂
   - Flue Gas

2. **CARBONATOR**
   - CaCO₃
   - CaO
   - Flue gas “without” CO₂

3. **OXY-CFB CALCINER**
   - CaCO₃
   - CaO
   - Purge
   - CO₂
   - O₂
   - N₂

4. **ASU**
   - Air

- **Power OUT**
- **Concentrated CO₂**
Some advantages of postcombustion Ca-looping:

- Low energy penalty (6-7 net points)/low cost per ton CO₂ captured (~30% reduction)
- Purge of CaO: synergies with cement industry if necessary
- Pre-treatment of flue gas no needed (SO₂ co-capture)
- Large scope for further cost reductions (indirect heating calcination, sorbent uses etc)
Developing process leading to “la Pereda 1.7 MWth” pilot

Reactions kinetics, deactivation studies, reactivation methods

Multicycle testing TG at CSIC

From 2000

Twin CFB reactor concept validation in lab scale. Basic reactor and process modeling

From 2008

Industrial partners

0.03 MWth pilot at INCAR-CSIC

From 2012
La Pereda CO\textsubscript{2} pilot plant: Current status
LA PEREDA CO₂ CAPTURE PILOT PLANT: DESCRIPTION

Calciner operating under air or oxy-combustion conditions

Double loop seal to control solid circulation between reactors

Removable cooling bayonet tubes to change heat extraction in reactors

O₂ and CO₂ tanks and gas mixer, to change oxy-combustion ratio

Calciner gas heater and independent steam injection

Continuous coal and limestone feeding system

Reactor Characteristics:
• Height: 15 m
• Made of refractory and Carbon Steel
• High efficiency cyclones
• Fully instrumentallized

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### RESULTS

Range of conditions during the CO₂ capture test:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonator temperature (ºC)</td>
<td>600-715</td>
</tr>
<tr>
<td>Carbonator superficial gas velocity (m/s)</td>
<td>2.0-5.0</td>
</tr>
<tr>
<td>Inlet CO₂ volume fraction to the carbonator</td>
<td>0.12-0.14</td>
</tr>
<tr>
<td>Inlet SO₂ concentration to the carbonator (mg/m³)</td>
<td>100-250</td>
</tr>
<tr>
<td>Inventory of solids in the carbonator (kg m⁻²)</td>
<td>100-1000</td>
</tr>
<tr>
<td>Maximum CO₂ carrying capacity of the solids</td>
<td>0.10-0.70</td>
</tr>
<tr>
<td>Calciner temperature (ºC)</td>
<td>820-950 ºC</td>
</tr>
<tr>
<td>Inlet O₂ volume fraction to the calciner</td>
<td>0.21-0.35</td>
</tr>
<tr>
<td>Inlet CO₂ volume fraction to the calciner</td>
<td>0-0.75</td>
</tr>
<tr>
<td>CO₂ capture efficiency</td>
<td>0.4-0.95</td>
</tr>
<tr>
<td>SO₂ capture efficiency</td>
<td>0.95-1.00</td>
</tr>
</tbody>
</table>

These conditions include the operating window expected in large scale systems
Results from the 1.7 MWth CaL pilot plant of la Pereda

Typical start up and steady state experiment

Example of a typical experimental run in la Pereda pilot plant

~ 380 h in steady state CO2 capture mode (170 h with the calciner working under oxy-fuel conditions). 2000 hours in other combustion modes
Results from the 1.7 MWth CaL pilot plant of la Pereda

SO$_2$ capture in the Ca-looping facility

![Graph showing SO$_2$ capture results](image-url)
Results from the 1.7 MWth CaL pilot plant of la Pereda

Evolution of sorbent utilization with “lifetime” of particles in the system

- Evolution of sorbent utilization with “lifetime” of particles in the system.
- Results from the 1.7 MWth CaL pilot plant of la Pereda.
Results from the 1.7 MWth CaL pilot plant of la Pereda

Effect of average sorbent activity on CO₂ capture efficiency (Oxyfuel combustion-calcination mode)

- $u_{\text{carb}} = 4.0 - 4.3 \text{ m/s}$
- $T_{\text{carb}} = 660 - 690^\circ\text{C}$
- $X_{\text{ave}} = 0.21$
- $X_{\text{ave}} = 0.11$
Results: Characterization of the carbonator reactor

\[
\text{CO}_2 \text{ removed from flue gas } = \text{CaCO}_3 \text{ in circulating solids}
\]

\[
\text{CO}_2 \text{ removed from flue gas } = \text{CO}_2 \text{ reacting with CaO}
\]

\[
\tau_{\text{active}} = \frac{N_{\text{CaO}}}{F_{\text{CO}_2}} f_a X_{\text{ave}}
\]

\[
E_{\text{carb}} = \tau_{\text{active}} \varphi k_s \left( \frac{f_{\text{CO}_2}}{f_e} \right)
\]

A flexible pilot experimental facility is in operation in La Pereda Power Plant to validate Calcium Looping in the 1MW’s size.

CO₂ 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 in the calciner reactor operating in oxyfuel coal combustion mode.

SO₂ capture in the CFB reactors is between 95-99.5 %

Ca-looping is rapidly developing: scale up is “easy” by/if exploiting synergy with CFBCs; cost prospects are already very good for the “standard CaL concept” and further cost reductions are credible with recent innovations and advanced process schemes.