ELCOGAS Pre-combustion Carbon Capture Pilot.
Real Experience of Commercial Technology

Pedro Casero - R&D Department, Elcogas (pcasero@elcogas.es, www.elcogas.es)
Spanish company established in April 1992 to undertake the planning, construction, management and operation of a 335 MWe\textsubscript{ISO} IGCC plant located in Puertollano (Spain)
**Carbon Capture & H₂ Production Pilot Plant**

- Installation unique in the world: 14 MW<sub>t</sub> pre-combustion technology integrated in an existing IGCC.
- In service since October 2010. Operation is intermittent, linked to official Research projects, collaborations and internal research campaigns.
- 800 hours of operation accumulated.
- June 2012. IEA Hydrogen Implementation Agreement awarded the pilot with the **2012 Project Prize**, recognizing excellence in R,D&D and harmony in international cooperation that contributes to the advancement of basic and applied H₂ science.
Integrated CCS Projects in the world (2012)

Carbon Capture Pilot Plant. Block Diagram Process

**COAL + COKE**

- GASIFICATION
  - Raw gas

**FILTRATION SYSTEM**

**PURIFICATION & DESULPHURATION**

**COMBINED CYCLE**

- Syngas
- Tail gas 1.3 bar
- Recycle compressor

**H₂ rich gas**
- 37.5% CO₂
- 50.0% H₂
- 3.0% CO

**CO₂ + H₂S (1.44%)**

**Raw H₂ (80% of purity)**

**CO₂ & H₂ separation**
- Chemical, aMDEA

**HYDROGEN PURIFICATION (PSA)**
- Pure H₂ (2 t/d)
- 99.99% H₂ @ 15 bar

**Background Performance**

<table>
<thead>
<tr>
<th></th>
<th>SWEET</th>
<th>SOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>F (Nm³/h)</td>
<td>3610</td>
<td>4006</td>
</tr>
<tr>
<td>P (bar)</td>
<td>19.8</td>
<td>23.6</td>
</tr>
<tr>
<td>T (°C)</td>
<td>126</td>
<td>138</td>
</tr>
<tr>
<td>% CO</td>
<td>60.45</td>
<td>53.72</td>
</tr>
<tr>
<td>% H₂</td>
<td>21.95</td>
<td>19.57</td>
</tr>
<tr>
<td>% H₂O</td>
<td>0.29</td>
<td>10.4</td>
</tr>
<tr>
<td>% H₂S</td>
<td>0</td>
<td>0.70</td>
</tr>
<tr>
<td>COS</td>
<td>0</td>
<td>0.11</td>
</tr>
</tbody>
</table>

**Performance optimization**

**Cost assessment**

**Scenarios**

**Conclusions**
Background

Performance optimization

Cost assessment. Scenarios

Conclusions
Carbon Capture Pilot Plant. Shift converter unit

Outcome of official tests (2011)

- **Operation** with sour catalyst found to be more stable than with sweet catalyst.
- **Steam/CO ratio and inlet temperature to the first reactor** are the key parameters regarding CO conversion and efficiency.
- Specific tests were carried out to assess the performance of the process produced by variations of these parameters.

A **model of WGS unit** was developed based on thermodynamic of the reaction and taking into account behavior during real tests. Performance matches with expected by supplier heat balances.

The **applications** of this tool will be primarily to:

i. define new tests campaigns in addition to those already made
ii. identify optimal working conditions as input information for a CO₂ capture cost model.
• Lower inlet temperatures lead to higher CO conversions for same ratios.
• Lower inlet temperatures allow operating with lower steam/CO ratios

The lower inlet temperatures the higher the efficiency of the unit for the same CO conversion (~0.5).
CO conversion unit. Operational window

- **Areas of interest for future tests**
- **Real tests**
- **Out of operational limits**
- **Minimum reaction temperature**
- **Coking risk**

**Inlet temperature to reactor 1 (°C)**

**Molar steam/CO ratio**

**Background Performance**

- Optimization

**Cost assessment. Scenarios**

**Conclusions**
**Scenario 1 (update):** Retrofitting of a carbon capture unit based on pilot plant in the Puertollano IGCC Plant (sweet)

**Capital Expenditure** (not PSA, scale factor, 25 years, IR: 3 %).  
349,800,000 €

**Fixed O&M Costs:** Spare, consumables, maintenance,… (based on in-house information)  
416,232 €/y

**Variable costs:** Production loss (OH: 6,500; load factor: 0.92; \( \eta_{\text{net penalty}} \): 9%; electricity price: 40 €/MWh)  
13,906,880 €/y

**Cost of non-emitted CO\(_2\) (capture rate of 90%, without compression):**  
26.3 €/tonne

**When adding compression cost (in the range of 7-9 €/tonne):**  
~35 €/tonne
**Scenario 2:** Retrofitting of a carbon capture unit based on pilot plant in the Puertollano IGCC Plant (sour)

In a **new IGCC with sour carbon capture**, the cost would be significantly reduced because the capital cost would be much lower (carbon capture and sulfur removal in a single unit)

<table>
<thead>
<tr>
<th>Cost for retrofitting of existing plant</th>
<th>Sweet (scenario 1)</th>
<th>Sour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment Costs</td>
<td>349,800 k€</td>
<td>349,800 k€</td>
</tr>
<tr>
<td>Fixed O&amp;M Costs</td>
<td>416 k€/y</td>
<td>354 k€/y</td>
</tr>
<tr>
<td>Variable O&amp;M Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net efficiency with CO₂ capture</td>
<td>33 %</td>
<td>35 %</td>
</tr>
<tr>
<td>Cost</td>
<td>13,900 k€/y</td>
<td>12,980 k€/y</td>
</tr>
<tr>
<td>Total of CO₂ captured</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Cost of non-emitted CO₂ (without compression)</td>
<td>26.3 €/t CO₂</td>
<td>25.6 €/t CO₂</td>
</tr>
</tbody>
</table>
**Scenario 3:** Effect of WGS efficiency optimization on CO₂ capture cost (retrofitting sweet)

- **The penalty of efficiency** when adding capture drops as the capture rate lowers due to: reduction of steam used in WGS, and reduction of energy consumption in the separation unit (less CO₂ to be captured by amine).
- There is a clear efficiency optimization when operating with lower inlet temperatures to 1st reactor.
- The **variable capture cost** (basically function of efficiency penalty) follows exactly the same tendency.
**Scenario 4 (update):** Assessment of $\text{H}_2$ and electricity co-production

- Hydrogen is produced in the pilot at 15 bar and 43°C, so it requires **conditioning** prior being commercialized.
- Taking into account the O&M costs of the $\text{H}_2$ production, for the depicted conditions (40 €/MWh, 1,1 €/kg), a minimum of 1850 operating hours per year is required.
- **Modification of the existing Environmental Permit** would also be required.
- Very few references for the sell price of $\text{H}_2$ in fuel hydrogen stations for vehicles. The prices varies between 8 and 15 €/kg.
Background

Performance optimization

Cost assessment. Scenarios

Conclusions
Elcogas continues accumulating experience with the Carbon Capture Pilot through different R&D European projects, and other collaborations.

There are evident ways to improve the efficiency of the CO₂ capture within the pilot through steam/CO ratio and inlet temperature to the 1st reactor.

A useful tool (WGS operating window) has been elaborated to define new real tests campaigns in addition to those already made, aiming at identify optimal working conditions.

This Pilot gives an excellent opportunity for giving real knowledge of the different issues related to economics of CO₂ capture and H₂ production: availability of the economic data of commercial technology at a relevant size, and integration in an existing plant in operation.

New economic scenarios are being assessed (a new IGCC incorporating carbon capture based on Puertollano experience) and real tests are scheduled for the following months.
Session 5C - Demonstration Projects: Capture and Transport

Thank you for your attention