R&D Plan results and experience in the Puertollano IGCC

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Engineering – R&D Manager
ELCOGAS, S.A.
INDEX

☞ INTRODUCTION

☞ R&D INVESTMENT PLAN. Lines

◆ CO$_2$ capture and H$_2$ co-production pilot plant
INTRODUCTION. The Elcogas company

Spanish company established in April 1992 to undertake the planning, construction, management and operation of a 335 MWe_{ISO} IGCC plant located in Puertollano (Spain)
Puertollano IGCC power plant description

Process description

- **Air Separation Unit**
  - Compressed air
  - Waste N₂
  - Coolant
tower
  - Hot combustion gas

- **Coal preparation**
  - Coal
  - Limestone
  - PetCoke

- **HP Boiler**
  - HP Steam

- **MP Boiler**
  - MP Steam

- **Gasifier**
  - Raw Gas
  - Coal - N₂
  - Quench Gas
  - Slag

- **Filtration**
  - Water wash
  - Fly ash

- **Water wash**
  - Water to treatment

- **Sulfur Removal**
  - Clean Syngas
  - Claus Gas

- **Sulfur Recovery**
  - Sulfur (99.8%)

- **Air Separation Unit**
  - Compressed air
  - Waste N₂

- **Steam Generator**
  - Steam

- **Steam Turbine**
  - 135 MW<sub>ISO</sub>

- **Gas Turbine**
  - 200 MW<sub>ISO</sub>

- **Tail Gas**
  - Water to treatment

- **Fly ash**

- **Coal PetCoke**

- **Limestone**

- **Fly ash**

- **Sulfur Recovery**
  - Sulfur (99.8%)

- **Sulfur Recovery**
  - Sulfur (99.8%)

- **Quench Gas**
  - O₂

- **Coal - N₂**

- **HP Boiler**
  - HP Steam

- **MP Boiler**
  - MP Steam
The design fuel is a mixture 50/50 of coal/pet coke currently operating at 45:55

### Main Design Data

<table>
<thead>
<tr>
<th>Fuel</th>
<th>COAL</th>
<th>PET COKE</th>
<th>FUEL MIX (50:50)</th>
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</thead>
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<tr>
<td>Moisture (%w)</td>
<td>11.8</td>
<td>7.00</td>
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<td>Ash (%w)</td>
<td>41.10</td>
<td>0.26</td>
<td>20.68</td>
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<td>C (%w)</td>
<td>36.27</td>
<td>82.21</td>
<td>59.21</td>
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<td>H (%w)</td>
<td>2.48</td>
<td>3.11</td>
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<tr>
<td>N (%w)</td>
<td>0.81</td>
<td>1.90</td>
<td>1.36</td>
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<tr>
<td>O (%w)</td>
<td>6.62</td>
<td>0.02</td>
<td>3.32</td>
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<tr>
<td>S (%w)</td>
<td>0.93</td>
<td>5.50</td>
<td>3.21</td>
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<tr>
<td>LHV (MJ/kg)</td>
<td>13.10</td>
<td>31.99</td>
<td>22.55</td>
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</table>

<table>
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<th>POWER OUTPUT</th>
<th>GAS TURBINE (MW)</th>
<th>STEAM TURBINE (MW)</th>
<th>GROSS TOTAL (MW)</th>
<th>NET TOTAL (MW)</th>
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<tr>
<td></td>
<td>182.3</td>
<td>135.4</td>
<td>317.7</td>
<td>282.7</td>
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</table>

**Efficiency (LHV)**

- Gross: 47.12%
- Net: 42.2%

**Emissions**

- SO₂: 0.07 g/kWh, 25 mg/Nm³ (6% Oxygen)
- NOₓ: 0.40 g/kWh, 150 mg/Nm³
- Particulate: 0.02 g/kWh, 7.5 mg/Nm³
# Puertollano IGCC power plant description

## Synthesis gas composition

<table>
<thead>
<tr>
<th></th>
<th>RAW GAS</th>
<th>CLEAN GAS</th>
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<tbody>
<tr>
<td></td>
<td>Actual Average</td>
<td>Design</td>
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<tr>
<td>CO (%)</td>
<td>59.26</td>
<td>61.25</td>
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<tr>
<td>H₂ (%)</td>
<td>21.44</td>
<td>22.33</td>
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<tr>
<td>CO₂ (%)</td>
<td>2.84</td>
<td>3.70</td>
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<tr>
<td>N₂ (%)</td>
<td>13.32</td>
<td>10.50</td>
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<tr>
<td>Ar (%)</td>
<td>0.90</td>
<td>1.02</td>
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<tr>
<td>H₂S (%)</td>
<td>0.81</td>
<td>1.01</td>
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<tr>
<td>COS (%)</td>
<td>0.19</td>
<td>0.17</td>
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<tr>
<td>HCN (ppm)</td>
<td>23</td>
<td>38</td>
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</table>
Operational data. Production

1st 5 years: Learning curve
2003: Major overhaul Gas Turbine findings
2004 & 2005: Gas turbine main generation transformer isolation fault
2006: Gas turbine major overhaul & candle fly ash filters crisis
2007 & 2008: ASU WN₂ compressor coupling fault and repair MAN TURBO
2010: No operation due to non-profitable electricity price (30-40 days).
ELCOGAS power plant emissions in NGCC & IGCC modes (2010)

Natural gas (NGCC)

- SO2: 29.2, 4.2, 0.8
- Particles: 12.5, 4.2, 0.8
- NOx: 250.0, 169.3

Coal gas (IGCC)

- SO2: 400, 39.3, 50
- NOx: 650, 116.3, 50
- Particles: 200, 5, 5
## Variable Costs

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<tr>
<th>Fuel mode</th>
<th>Fuel</th>
<th>Consume (GJ PCS)</th>
<th>Production (GWh)</th>
<th>Heat rate (GJ PCS/GWh)</th>
<th>Fuel cost (€/GJ PCS)</th>
<th>Partial cost (€/MWh)</th>
<th>Total cost (€/MWh)</th>
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<tbody>
<tr>
<td>GT</td>
<td>Natural gas</td>
<td>68.777</td>
<td>3.79</td>
<td>18.150</td>
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<td>NGCC</td>
<td>Natural gas</td>
<td>84.005</td>
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<td>10.021</td>
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<td>NGCC + ASU</td>
<td>Natural gas</td>
<td>1.725.092</td>
<td>153.19</td>
<td>11.261</td>
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<td>91.48</td>
<td>91.48</td>
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<td>NGCC+ASU+Gasifier (by flare)</td>
<td>Natural gas</td>
<td>616.828</td>
<td>58.93</td>
<td>10.467</td>
<td>8.12</td>
<td>85.03</td>
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<td></td>
<td>Coal</td>
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<td>2.474</td>
<td>3.39</td>
<td>8.37</td>
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<td></td>
<td>Pet coke</td>
<td>455.056</td>
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<td>7.722</td>
<td>2.34</td>
<td>18.06</td>
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<td>IGCC</td>
<td>NG auxiliary consumption</td>
<td>265.814</td>
<td>1.219,61</td>
<td>218</td>
<td>8.12</td>
<td>1,77</td>
<td>27,32</td>
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<tr>
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<td>Coal</td>
<td>2.914.823</td>
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<td>2.390</td>
<td>3.39</td>
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<td>Pet coke</td>
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<td>7.465</td>
<td>2.34</td>
<td>17.46</td>
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</table>

**Note:** Net energy variable costs (average 2010)
1. Gas Turbine

- Optimization of syngas burners to prevent overheating / humming and to accomplish more stability and remaining life of the hot components.

- Up to last design of syngas burner was installed in 2003 preventive inspections of hot gas path every 500 – 1000 syngas operating hours. High rate of ceramic tiles change.
2. Gasifier

- Water leakage of membrane tubes due to flow blockages or local erosion. Design of distributors. Chemical control. Particle filtration. Loose parts.
2. Gasifier (II)

- Gas leakage due to piping corrosion:
  - Proper selection of materials. To avoid “cold ends” and down time corrosion.

- Fouling of Waste Heat boilers:
  - Sticky fly ash (reduced by decreasing gas inlet temperature to cooling surfaces. More quench flow)
  - Fluffy fly ash (reduced by increasing the velocity of the gas)
3. Grinding and mixing systems

Clogging in mills feeding and mixing conveyors. Two trains of 60%. Lack of robustness of equipment.
4. Solids handling (slag and fly ash)

Erosion of components by local high velocities. Substitution of parts for abrasion resistant materials. Revision of design and operating procedures.

5. Ceramic filters

Life time of filtrating elements is half of expected (4000 h). Very expensive cost. To improve by changing supporting design of elements.
6. Fuel dust conveying and feeding systems

Pressure control and fluidization stability. Design of fluidization systems and preventive maintenance of components.

7. COS catalyst

2 – 3 changes by year of alumina based catalyst. Water carryover. Change to Titanium oxide catalyst (3 – 4 years) and pre-heater installation.
IGCC Availability in 2010

Operational data

Availability | Planned Outages | Unplanned Outages
---|---|---
IGCC | 22.8 | 7.5 | 4.5
Gasifier | 9.8 | 7.5 | 3.3
Power Block | 5.5 | 4.5 | 89.9
ASU | 4.5 | 3.3 | 92.2

Operational data
Gasification
- SULPHUR RECOVERY & TAIL GAS RECYLE 1%
- MIXING & GRINDING PLANT 9%
- DUST FUEL CONVEYING & FEEDING 5%
- START-UP BURNER & FLAME MONITORS 3%
- SLAGS 10%
- GAS WET TREATMENT 5%
- WATER STEAM SYSTEMS &
- QUENCH GAS RECIRCULATION 27%
- DRY DEDUSTING & FLY ASH SYSTEMS 40%

Combined cycle
- WATER-STEAM CYCLE; 8%
- GAS SATURATOR; 32%
- GAS TURBINE; 60%

Islands Unavailability
- Gasification 56%
- Combined Cycle 27%

ASU
- GAS OXYGEN PRODUCTION; 63%
- WASTE NITROGEN PRODUCTION; 37%
- PURE NITROGEN PRODUCTION; 0%

Combined cycle
- WATER-STEAM CYCLE; 8%
- GAS SATURATOR; 32%
- GAS TURBINE; 60%

BOP
- ELECTRICAL SYSTEM; 0%
- AUXILIARY SYSTEM; 91%

Operational data. IGCC UNAVAILABILITY 2010
## ELCOGAS IGCC Project General Schedule

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<td>Erection ASU &amp; Gasification</td>
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</table>

- **Scheduled**
- **As was**

### Lessons Learnt
- **Organization (I)**
  - Cabling, 37 km vs 1290 km
  - Auxiliaries, GT
  - Coal preparation, KU
Other lessons learnt. Organization (II)

<table>
<thead>
<tr>
<th>MECHANICAL</th>
<th>ELECTRICAL</th>
<th>I&amp;C</th>
<th>DCS</th>
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<td><strong>Pumps</strong></td>
<td><strong>Transformers</strong></td>
<td><strong>Local instrument</strong></td>
<td><strong>CC &amp; PB</strong></td>
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<td>419</td>
<td>50</td>
<td>7195</td>
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<td><strong>Compressors &amp; fans</strong></td>
<td><strong>High voltage</strong></td>
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<td>237</td>
<td>6</td>
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<tr>
<td><strong>Conveyors &amp; Screw transporters</strong></td>
<td><strong>6/0.4 KV</strong></td>
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<td>46</td>
<td>44</td>
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<td><strong>Heat exchangers</strong></td>
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<td>290</td>
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<td><strong>Tanks</strong></td>
<td><strong>Motors</strong></td>
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<td>300</td>
<td>617</td>
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<td><strong>VALVES</strong></td>
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<td>920</td>
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<td><strong>Auxiliaries</strong></td>
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<th><strong>DCS</strong></th>
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<th><strong>Functionals</strong></th>
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<td><strong>TOTAL</strong></td>
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R&D INVESTMENT PLAN. Lines

BASIS of the PUERTOLLANO IGCC R&D PLAN

- Based on the opportunity that an IGCC plant represents
- Contribution can be relevant in:
  - *climate change mitigation*
  - *energy supply reliability*

MAIN LINES of the R&D PLAN

- **CO₂** emission reduction using fossil fuels
- **H₂** production by gasification of fossil fuels
- **DIVERSIFICATION** of raw fuels and products
- Other **ENVIRONMENTAL** improvements
- IGCC processes **OPTIMISATION**
- **DISSEMINATION** of results
R&D INVESTMENT PLAN. Lines

Other environmental improvements: Effluent treatment

- HOMOGENIZATION TANK
- EVAPORATOR Effect n. 1
- EVAPORATOR/CRISTALISER Effect n. 2
- STRIPPER
- FILTER under pressure
- pH adjustment
- Final distillate

Flowchart:
- stripper water
- Slag water
- Live steam
- Clean condensate
- STEAM
- CONCENTRATE
R&D INVESTMENT PLAN. Lines

**IGCC process optimization.** Availability and costs improvement.

- Material life extension.
- Dedusting system improvement.
- **Gas turbine** (availability improvement & lifetime extension).

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New candle filter installation

Gas turbine
Battery of co-gasification tests undertaken with olive oil waste (orujillo)

<table>
<thead>
<tr>
<th>Test Month/Year</th>
<th>orujillo dosage ratio in weight%</th>
<th>orujillo tonnes (t)</th>
<th>Test duration (h)</th>
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<tbody>
<tr>
<td>2007-2009</td>
<td>1 - 2 %</td>
<td>1.572,84</td>
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<td>2008</td>
<td>4 %</td>
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<td>March 2009</td>
<td>6 %</td>
<td>395,86</td>
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<td>June 2009</td>
<td>8 %</td>
<td>383,90</td>
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<tr>
<td>Sept. 2009</td>
<td>10 %</td>
<td>656,68</td>
<td>62</td>
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<td>TOTAL</td>
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<td>3.661,42</td>
<td>1.126,7</td>
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Critical parameter for the biomass selection was the behavior on the ELCOGAS grinding system.

Load during %8 olive oil waste co-gasification test
**Step 1:** Syngas production from **Gasification**

Carbon compound + O₂ + H₂O \(\rightarrow\) CO + H₂ + Impurities

**Step 2:** **Conditioning** → fly ash removal, particles and sulphur comp.

**Step 3:** “Shifting” or **water-gas reaction**

CO + H₂O \(\rightarrow\) CO₂ + H₂

**Step 4:** H₂ and CO₂ **separation**

**CO₂ capture using pre-combustion technology involves H₂ generation**
**TARGETS**

To demonstrate the feasibility of capture of CO₂ and production of H₂ in an IGCC that uses solid fossil fuels and wastes as main feedstock.

To obtain economic data enough to scale it to the full Puertollano IGCC capacity in synthetic gas production.

**PARTICIPANTS & BUDGET**

ELCOGAS – UCLM – Ciemat – INCAR CSIC 14.5 M€ (initially 18.5 M€)

**COORDINATION**

Project of pilot plant in an existing IGCC of Puertollano (pre-combustion technology) is part of a Spanish national initiative, “Advanced technologies of CO₂ conversion, capture and storage” and it is coordinated with other related projects:

**Project # 2** is to explore oxyfuel combustion to be applied in the construction of a pilot plant (20-30 MW) to be built in El Bierzo, NW of Spain. CIUDEN

**Project # 3** is to study and regulate geological storage in Spain. IGME

**Project # 4** is to study public awareness of CCS technologies. CIEMAT
Puertollano IGCC power plant and pilot plant location

Pilot plant general view

IGCC power plant general view
PSE-CO$_2$ project: CO$_2$ Capture Pilot Plant

Pilot plant diagram process

**GASIFICATION**
- COAL + COKE
- Raw gas
- Clean gas
  - 2% of total flow (3,600 Nm$^3$/h)
  - 22.6 bar
  - 130°C
  - 60.5% CO
  - 22.1% H$_2$

**FILTRATION SYSTEM**
- 183,000 Nm$^3$/h

**PURIFICATION & DESULPHURATION**
- H$_2$rich gas
  - 37.5% CO$_2$
  - 50.0% H$_2$
  - 3.0% CO

**CO$_2$ & H$_2$ separation**
- (Chemical, aMDEA)
- CO + H$_2$O $\rightarrow$ CO$_2$ + H$_2$

**HYDROGEN PURIFICATION (PSA)**
- Pure H$_2$ (2 t/d)
- 99.99% H$_2$ @ 15 bar
- 100 t/d CO$_2$?
- 1,3 bar Tail gas
- 80% of purity Raw H$_2$

**PILOT PLANT**
- 40% CO$_2$
- ¿H$_2$S?
- 100 t/d
- 40%
- 1:50 ~ 14 MWt

**Pilot plant size:**
- 1:50 ~ 14 MWt
**Shifting Unit** (several suppliers):
1. Desulphurization reactor
2. Shifting reactors
3. Heat exchangers: kettles and shell&tube

**PSA Unit** (Linde):
1. Adsobers – 6.5 m
2. Tail gas drum – 12.5 m
3. Valve skid

**CO₂ Capture Unit** (Linde Caloric):
1. Syngas absorber – 12 m
2. CO₂ stripper – 16.5 m

**Electrical/control building**:
1. Control room
2. Electrical room
Main suppliers

<table>
<thead>
<tr>
<th>Engineering</th>
<th>Empresarios Agrupados</th>
<th>Linde-Caloric</th>
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<tbody>
<tr>
<td>CO₂ Unit</td>
<td>Linde</td>
<td>Construcciones Ocaña-Cañas</td>
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<tr>
<td>PSA Unit</td>
<td>Zeus Control</td>
<td>Técnicas Reunidas</td>
</tr>
<tr>
<td>Civil work</td>
<td>Técnicas Reunidas y Boreal-Vila</td>
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</tr>
<tr>
<td>Control</td>
<td>Johnson Matthey</td>
<td>Sidsa y Cuñado</td>
</tr>
<tr>
<td>Reactors</td>
<td>SAMSON, Tyco Valves and Controls y SAIDI</td>
<td></td>
</tr>
<tr>
<td>Heat exchangers</td>
<td>GE Power</td>
<td></td>
</tr>
<tr>
<td>Catalysts</td>
<td>ABB Process Automation Division</td>
<td></td>
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<tr>
<td>Piping and fitting</td>
<td>HGL y MASA</td>
<td></td>
</tr>
<tr>
<td>Valves</td>
<td>MEISA</td>
<td></td>
</tr>
</tbody>
</table>
Pilot plant diagram process (I)

Shifting unit (design data for sweet capture)

<table>
<thead>
<tr>
<th></th>
<th>Flow kg/h</th>
<th>P bar</th>
<th>T °C</th>
<th>CO %</th>
<th>H₂ %</th>
<th>CO₂ %</th>
<th>H₂O %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal gas</td>
<td>3,677</td>
<td>19.8</td>
<td>126</td>
<td>60.45</td>
<td>21.95</td>
<td>2.66</td>
<td>0.29</td>
</tr>
<tr>
<td>Shifted gas to separation unit</td>
<td>8,732</td>
<td>17.3</td>
<td>274</td>
<td>1.68</td>
<td>28.37</td>
<td>21.34</td>
<td>43.26</td>
</tr>
<tr>
<td>IP saturated steam to feed</td>
<td>5,055</td>
<td>34.0</td>
<td>243</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100</td>
</tr>
</tbody>
</table>

General view of Shifting Unit
Pilot plant diagram process (II)

Separation unit
(design data for sweet capture)

General view of Separation Unit

<table>
<thead>
<tr>
<th></th>
<th>Flow kg/h</th>
<th>P bar</th>
<th>T °C</th>
<th>CO %</th>
<th>H₂ %</th>
<th>CO₂ %</th>
<th>H₂O %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shifted gas to absorber</td>
<td>5,318</td>
<td>15.9</td>
<td>45</td>
<td>2.9</td>
<td>49.7</td>
<td>37.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Process condensated</td>
<td>3,414</td>
<td>15.9</td>
<td>45</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>CO₂ product</td>
<td>4,185</td>
<td>1.5</td>
<td>40</td>
<td>0</td>
<td>0.18</td>
<td>95.32</td>
<td>4.47</td>
</tr>
<tr>
<td>H₂ to PSA</td>
<td>481.7</td>
<td>15.2</td>
<td>40</td>
<td>4.63</td>
<td>79.37</td>
<td>0.5</td>
<td>0.48</td>
</tr>
<tr>
<td>Rich H₂ gas</td>
<td>1,190.1</td>
<td>15.6</td>
<td>40</td>
<td>4.63</td>
<td>79.37</td>
<td>0.5</td>
<td>0.48</td>
</tr>
<tr>
<td>LP Steam to reboiler</td>
<td>4,763</td>
<td>4.1</td>
<td>144</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100</td>
</tr>
</tbody>
</table>
Pilot plant diagram process (III)

PSA unit (design data for sweet capture)

<table>
<thead>
<tr>
<th></th>
<th>Flow Nm³/h</th>
<th>P bar</th>
<th>T °C</th>
<th>CO %</th>
<th>H₂ %</th>
<th>CO₂ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂ from separation unit</td>
<td>1,431</td>
<td>15.2</td>
<td>40</td>
<td>4.63</td>
<td>79.37</td>
<td>0.5</td>
</tr>
<tr>
<td>H₂ product</td>
<td>795</td>
<td>14.7</td>
<td>43</td>
<td>0.0004</td>
<td>99.99</td>
<td>0.0001</td>
</tr>
<tr>
<td>Tail gas</td>
<td>636</td>
<td>1.3</td>
<td>35.9</td>
<td>10.42</td>
<td>53.58</td>
<td>1.13</td>
</tr>
</tbody>
</table>

General view of PSA unit
The main learning in project phase:

- **The finance delay**: MICINN (Spanish Science & Research Minister) and JCCM (Regional Government).
- **Delay in main equipment supply**: more than 12-14 months.
- **Detailed engineering**: conditioned by suppliers.
- **PP construction step**: delay due to safety permits since it is installed in an operating plant.
- **Delay of commissioning**: low availability of experimented personnel.

The main learning in commissioning & operation phases:

- **Investment costs**: lower than € 13 million
- **Unexpected reactivity**: 95% CO conversion in first step of shifting unit
  Estimated: 85% → consider a shifting process with only one step.
- **CO₂ and H₂ design specifications**: easily achieved
- **CO₂ capture rate**: 91.7%
- **Auxiliary consumption**: lower than estimated in design
- **Integration of O&M in the existing IGCC**: very easy

CO₂ > 99 %
H₂ pure > 99.995 %
Expected vs. obtained compositions of main streams (SWEET)

<table>
<thead>
<tr>
<th></th>
<th>Shifted gas</th>
<th>CO₂</th>
<th>H₂ rich gas</th>
<th>Pure H₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design</td>
<td>Lab Analysis</td>
<td>Design</td>
<td>Lab Analysis</td>
</tr>
<tr>
<td>H₂</td>
<td>50.05</td>
<td>51.88</td>
<td>0.19</td>
<td>0.314 - 1.31</td>
</tr>
<tr>
<td>CO</td>
<td>2.92</td>
<td>1.85</td>
<td>0</td>
<td>0.053 - 0.07</td>
</tr>
<tr>
<td>CO₂</td>
<td>37.56</td>
<td>37.36</td>
<td>99.78</td>
<td>98.2 - 99.622</td>
</tr>
<tr>
<td>N₂</td>
<td>8.76</td>
<td>8.30</td>
<td>0.01</td>
<td>0.05 - 0.28</td>
</tr>
<tr>
<td>Ar</td>
<td>0.71</td>
<td>0.60</td>
<td>0.02</td>
<td>0.01 - 0.09</td>
</tr>
</tbody>
</table>

i) All compositions are in % vol. (dry basis)
ii) Analysis carried out by ELCOGAS Laboratory

**CO₂ capture & H₂ co-production pilot plant. Tests**

- Comparison of **sweet & sour catalysts**: sweet tests up to Feb 2011, sour tests up to June 2011
- Optimization of **steam/gas** ratio at shifting unit
- Optimization of **energy balance**
- **Real costs** of CO₂ capture and H₂ production.
The high conversion obtained in the first step (near 95%) will make considering a shifting process only with one step.
CO₂ Capture Costs Comparison

1) **Scaled up 100%** Puertollano IGCC synthetic gas from the 14MWt pilot plant.

2) Existing plant capture cost = f (investment costs and operational costs).

\[
\text{CO}_2 \text{ capture cost, } \epsilon/\text{t CO}_2 = \frac{\text{CAPEX} + \text{OPEX}}{\text{Captured CO}_2 \text{ tonnes}}
\]

3) **First ELCOGAS estimations** show values of **25-30 €/t CO₂**

4) **Comparing to other studies**

---

**Fuente:** DOE/NETL CCS RD&D ROADMAP December 2010

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30 for **ELCOGAS retrofit**
PSE-CO₂ project: CO₂ Capture Pilot Plant

<table>
<thead>
<tr>
<th>Variables</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected life</td>
<td>25</td>
</tr>
<tr>
<td>Bank interest</td>
<td>3.0 %</td>
</tr>
<tr>
<td>Bank fee</td>
<td>0.5 %</td>
</tr>
<tr>
<td>Scale factor</td>
<td>0.75</td>
</tr>
<tr>
<td>Operating hours (IGCC mode)</td>
<td>6,500 h</td>
</tr>
<tr>
<td>Average load factor</td>
<td>0.92</td>
</tr>
<tr>
<td>Electricity price</td>
<td>40 €/MWh</td>
</tr>
<tr>
<td>Net efficiency of power plant with CO₂ capture</td>
<td>33 %</td>
</tr>
<tr>
<td>Treated gas</td>
<td>100 %</td>
</tr>
</tbody>
</table>

**CO₂ Capture Costs (SWEET)**

**BASE CASE**

**PSE-CO₂ project: CO₂ Capture Pilot Plant**

Variables

- Expected life: 25
- Bank interest: 3.0%
- Bank fee: 0.5%
- Scale factor: 0.75
- Operating hours (IGCC mode): 6,500 h
- Average load factor: 0.92
- Electricity price: 40 €/MWh
- Net efficiency of power plant with CO₂ capture: 33%
- Treated gas: 100%

Graph showing IGCC plant efficiency with CO₂ capture, % against CO₂ cost, €/t CO₂ for various operating hours (27 to 37% efficiency with 3000 h to 7500 h).
PSE-CO₂ project: CO₂ Capture Pilot Plant

Minimum pure H₂ price depending on the electricity price

Better to sell H₂

Minimum H₂ price per fix cost of production (external personal and spares) depending on annual production hours.

Better to sell electricity

- 60,000 Kg/y 720h
- 90,000 Kg/y 1080h
- 120,000 Kg/y 1440h
- 180,000 Kg/y 1440h
- 420,000 Kg/y 2160h

€/Kg

€/MWh
Pilot Plant beyond PSE project

**Pilot plant** for CO$_2$ capture and production of H$_2$ and electricity with IGCC technology

**Other** activities: To be done after PSE as R&D platform:

- Water shift reaction **catalyst** optimization. Tests of different catalyst
- **New processes** to separate CO$_2$-H$_2$
- CO$_2$ different **treatment** processes
- Improvement of **integration** efficiency between CO$_2$ separation processes and IGCC plant

ELCOGAS offers both the Puertollano IGCC and the Pilot Plant for CO$_2$ capture and H$_2$ production as technical platforms to develop of process, equipments, components, or even pre-engineering of new plants with CCS and Zero emissions
Gasification conference
6th – 7th June 2011, London (UK)

R&D Plan results and experience in the Puertollano IGCC

Thank you for your attention

Mr. Francisco García-Peña
Engineering – R&D Director
ELCOGAS, S.A.