ELCOGAS: R&D activities towards zero emissions IGCC plants

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ELCOGAS, S.A. www.elcogas.es
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European company established in April 1992 to undertake the planning, construction, management and operation of a 335 MW ISO IGCC plant located in Puertollano (Spain).

ELCOGAS shareholders and percentage of capital:

- ENDESA Generación: 40.9%
- EDF International: 31.4%
- Iberdrola Generación: 12.0%
- Energías de Portugal: 4.3%
- Hidrocantábrico: 4.3%
- Autocartera: 2.5%
- Krupp Koppers: 0.4%
- Babcock Wilcox Española: 0.0%
- National Power: 0.0%
- ENEL: 4.3%
- Siemens: 0.3%
- EDF Internacional: 31.4%
- National Power: 0.0%
- ENDESA Generación: 40.9%
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2. PUERTOLLANO IGCC POWER PLANT DESCRIPTION

**Process description**

- **Coal preparation**
  - Coal
  - Petroleum Coke
  - Limestone
  - Coal - N₂

- **Gasifier**
  - Raw Gas
  - Quench Gas
  - Slag

- **HP Boiler**
  - HP Steam
- **MP Boiler**
  - MP Steam

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

- **Water wash**
  - Water
  - O₂

- **Sulfur Recovery**
  - Clean syngas
  - Claus gas
  - Tail Gas
  - Air
  - O₂

- **Sulfur Removal**
  - Sulfur (99.8%)

- **Air Separation Unit**
  - N₂
  - O₂
  - Waste N₂

- **Condenser**
  - Hot combustion gas

- **Steam Turbine**
  - 135 MWₑₜₒ

- **GAS Turbine**
  - 200 MWₑₜₒ

- **Compressed air**

- **Flue gas to stack**

- **Steam**

- **Cooling tower**

- **Compressed air**
2. PUERTOLLANO IGCC POWER PLANT DESCRIPTION

Main design data

### Fuel

<table>
<thead>
<tr>
<th></th>
<th>COAL</th>
<th>PET COKE</th>
<th>FUEL MIX (50:50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%w)</td>
<td>11.8</td>
<td>7.00</td>
<td>9.40</td>
</tr>
<tr>
<td>Ash (%w)</td>
<td>41.10</td>
<td>0.26</td>
<td>20.68</td>
</tr>
<tr>
<td>C (%w)</td>
<td>36.27</td>
<td>82.21</td>
<td>59.21</td>
</tr>
<tr>
<td>H (%w)</td>
<td>2.48</td>
<td>3.11</td>
<td>2.80</td>
</tr>
<tr>
<td>N (%w)</td>
<td>0.81</td>
<td>1.90</td>
<td>1.36</td>
</tr>
<tr>
<td>O (%w)</td>
<td>6.62</td>
<td>0.02</td>
<td>3.32</td>
</tr>
<tr>
<td>S (%w)</td>
<td>0.93</td>
<td>5.50</td>
<td>3.21</td>
</tr>
<tr>
<td>LHV (MJ/kg)</td>
<td>13.10</td>
<td>31.99</td>
<td>22.55</td>
</tr>
</tbody>
</table>

### Power output and emissions

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

<table>
<thead>
<tr>
<th>EFFICIENCY (LHV)</th>
<th>GROSS</th>
<th>NET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>47.12%</td>
<td>42.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EMISSIONS</th>
<th>g/kWh</th>
<th>mg/Nm³ (6% Oxygen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>0.07</td>
<td>25</td>
</tr>
<tr>
<td>NOₓ</td>
<td>0.40</td>
<td>150</td>
</tr>
<tr>
<td>Particulate</td>
<td>0.02</td>
<td>7.5</td>
</tr>
</tbody>
</table>
## 2. PUERTOLLANO IGCC POWER PLANT DESCRIPTION

### Raw and clean gas data

<table>
<thead>
<tr>
<th></th>
<th>Raw Gas</th>
<th></th>
<th>Clean Gas</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual average</td>
<td>Design</td>
<td>Actual average</td>
<td>Design</td>
</tr>
<tr>
<td><strong>CO (%)</strong></td>
<td>59.26</td>
<td>61.25</td>
<td><strong>CO (%)</strong></td>
<td>59.30</td>
</tr>
<tr>
<td><strong>H₂ (%)</strong></td>
<td>21.44</td>
<td>22.33</td>
<td><strong>H₂ (%)</strong></td>
<td>21.95</td>
</tr>
<tr>
<td><strong>CO₂ (%)</strong></td>
<td>2.84</td>
<td>3.70</td>
<td><strong>CO₂ (%)</strong></td>
<td>2.41</td>
</tr>
<tr>
<td><strong>N₂ (%)</strong></td>
<td>13.32</td>
<td>10.50</td>
<td><strong>N₂ (%)</strong></td>
<td>14.76</td>
</tr>
<tr>
<td><strong>Ar (%)</strong></td>
<td>0.90</td>
<td>1.02</td>
<td><strong>Ar (%)</strong></td>
<td>1.18</td>
</tr>
<tr>
<td><strong>H₂S (%)</strong></td>
<td>0.81</td>
<td>1.01</td>
<td><strong>H₂S (ppmv)</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>COS (%)</strong></td>
<td>0.19</td>
<td>0.17</td>
<td><strong>COS (ppmv)</strong></td>
<td>9</td>
</tr>
<tr>
<td><strong>HCN (ppmv)</strong></td>
<td>23</td>
<td>38</td>
<td><strong>HCN (ppmv)</strong></td>
<td>-</td>
</tr>
</tbody>
</table>
2. PUERTOLLANO IGCC POWER PLANT

Project milestones

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>Main contracts award</td>
</tr>
<tr>
<td>Jun 1996</td>
<td>First synchronization of gas turbine</td>
</tr>
<tr>
<td>Oct 1996</td>
<td>Commercial operation with natural gas</td>
</tr>
<tr>
<td>Jun 1997</td>
<td>Performance test of the Air Separation Unit</td>
</tr>
<tr>
<td>Mar 1998</td>
<td>First switch over from natural gas to coal gas</td>
</tr>
<tr>
<td>Nov 2000</td>
<td>First 1,000 GWh produced with coal gas as IGCC</td>
</tr>
<tr>
<td>Dec 2008</td>
<td>Total: 17,551 GWh</td>
</tr>
<tr>
<td></td>
<td>IGCC: 11,476 GWh</td>
</tr>
</tbody>
</table>
2. PUERTOLLANO IGCC POWER PLANT: Operating data

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
2. PUERTOLLANO IGCC POWER PLANT: Operating data

Emissions in NGCC and IGCC modes

**Emissions in NGCC mode**

**Natural gas (mg/Nm³ at 6% O₂ dry)**

- EEC 88/609
- ELCOGAS Environmental Permit
- ELCOGAS 2008 average

**Emissions in IGCC mode**

**Coal gas (mg/Nm³ at 6% O₂ dry)**

- EU Directive 88/609/EEC
- ELCOGAS Environmental Permit
- ELCOGAS 2008 average
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3. FUTURE OF IGCC TECHNOLOGY. H₂ co-production and CCS

Step 1: Syngas production from gasification

Carbon compound + O₂ + H₂O → CO + H₂ + Impurities

Step 2: “Shifting” or water-gas reaction

CO + H₂O → CO₂ + H₂

Step 3: H₂ and CO₂ separation

H₂ & CO₂

H₂ production from fossil fuels involves CO₂ generation ⇒ To talk about “clean” H₂ it is required to consider CCS
3. FUTURE OF IGCC TECHNOLOGY. CCS

CLIMATE CHANGE MITIGATION - IPCC


http://www.ipcc.ch/ipccreports/
3. FUTURE OF IGCC TECHNOLOGY. CCS

CLIMATE CHANGE MITIGATION

CCS Within a Carbon Abatement Portfolio

![Graph showing emissions reduction](image)

- Baseline emissions: 62 Gt
- BLUEmap emissions: 14 Gt

CCS: a Key Part of a Low-cost GHG Strategy

- Without new policies, global emissions increase 130% by 2050, corresponding to a 4-7°C temperature rise
- CCS provides 1/5th of the needed CO₂ reductions in 2050
- Without CCS, cost of stabilisation rises by 70%
- CCS is the only low-carbon solution for coal, cement, and iron & steel sectors
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PUERTOLLANO IGCC ACTIONS

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

Main lines of R&D plan are:

- \( \text{CO}_2 \) emission reduction in utilization of fossil fuels
- \( \text{H}_2 \) production by gasification of fossil fuels
- Diversification of raw fuels and products
- Other environmental improvements
- IGCC processes optimisation
- Dissemination of results
4. ELCOGAS R&D INVESTMENT PLAN

Dissemination of results:

- Forum participations. CO$_2$, H$_2$, and sustainability associations and Technological Platforms. European and Spanish. Coordinating working groups in Technological Spanish Platforms.
- Participation in conferences, seminars, congresses.
- Consulting services. Germany, China, Chile
- Attending and promoting technical visits. Generally international visits.

www.elcogas.es
4. ELCOGAS R&D INVESTMENT PLAN

Optimization of IGCC processes: Oriented to improve availability & costs

- Gasifier materials/Syngas corrosion processes
- Ceramic filters
- Elimination of membrane water leakages at reaction chamber
- Test materials
Other environmental improvements:

- Liquid wastes reduction. Change of waste water treatment plant

- Improvement of syngas cleaning systems. Currently participating in project AGAPUTE (RFCS, 2004-08, to study improvements in syngas cleaning). Hg task.

- Improvements in Sulphur Recovery plant. In progress several modifications to improve availability and to reduce S emissions.

- Operation and additives parameters optimization. Included in AGAPUTE to study dosing of limestone, oxygen, steam, vs. concentration of contaminants in slags, fly ash and washing water

- Emissions reduction during start up and other transitory situations.
4. ELCOGAS R&D INVESTMENT PLAN

Diversification of raw fuels and products:

Project PIIBE (ESP-CENIT). To impulse biofuels technologies in Spain. ELCOGAS coordinates the subproject about **biodiesel** from gasification by real co-gasification 10% of biomass and syngas characterization (F-T process in laboratory)

Agreement with a private European Company to install a pilot plant in IGCC of Puertollano to develop process to obtain **gasoline from syngas**

Project PEIXE VERDE. (ESP-PSE). Technical-economic study about **uses of syngas** as fuel for fishing ships in different scales of production

Co-gasification of car manufacture **wastes** (shredder fibres) was agreed with supplier.

Available to do tests of gasification of **different fuels** at large scale to help in design of new IGCC plants

Clean H₂ production by gasification of fossil fuels:

- H₂ production in **IGCC**. Project HYDROSEP (RFCS, to study IGCC adaptation to H₂ production)
- Study and tests of **new** processes of H₂ **purification**. Project SPHERA (ESP-CENIT)
- Available to collaborate with new H₂ & Fuel Cells **Experimental National Centre** of Puertollano
4. ELCOGAS R&D INVESTMENT PLAN

**CO₂ EMISSION REDUCTION**

*IGCC Efficiency Optimisation*

Analysis of viability to improve efficiency based on **Critical Assessment** of Puertollano IGCC design (3-6% efficiency improvement and 20-30% fixed costs reduction)

**Auxiliary** consumption optimisation. **New revision**

Development of **tools** to improve efficiency. Supervision on line of main (120) equipment efficiency. **Installed and in tests**

Integration optimisation. Improvement of **controls** to adjust heat & mass balances in real operation

And

**CO₂ capture for CCS with IGCC**
4. ELCOGAS R&D INVESTMENT PLAN.
CO₂ line – “Singular and strategic project PSE-CO₂”

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 13 M€ (initially 18.5 M€)

COORDINATED

Project of pilot plant in existing IGCC of Puertollano 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 CO₂ capture with oxyfuel technology in a 20MW pilot plant. 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
4. ELCOGAS R&D INVESTMENT PLAN. CO\textsubscript{2} line – “Singular and strategic project PSE-CO\textsubscript{2}”

COAL + PETCOKE

GASIFICATION

Raw gas

183,000 Nm\textsuperscript{3}/h

FILTRATION SYSTEM

Clean Gas

2\% of total flow
(3600 Nm\textsuperscript{3}/h)

22.6 bar

130 °C

60.5 \% CO

22.1 \% H\textsubscript{2}

Pilot plant size: 1:50 ~ 14 MW\textsubscript{th}

PILOT PLANT

SHIFT REACTOR

(Sour / Sweet)

CO + H\textsubscript{2}O \rightarrow CO\textsubscript{2} + H\textsubscript{2}

H\textsubscript{2} rich gas:

37.5 \% CO\textsubscript{2}

50.0 \% H\textsubscript{2}

3.0 \% CO

MP steam

CO\textsubscript{2} AND SULPHUR REMOVAL

(Chemical, aMDEA)

100 t/d

CO\textsubscript{2} ¿SH\textsubscript{2}?

Recycle gas compressor

Fuel Gas

1.3 bar

2 t/d

H\textsubscript{2}

99.99\%
4. ELCOGAS R&D INVESTMENT PLAN.
CO$_2$ line – “Singular and strategic project PSE-CO$_2$”

View (March 09)

3D view

General view of the ELCOGAS power plant
4. ELCOGAS R&D INVESTMENT PLAN. CO$_2$ line

**Pilot plant** for CO$_2$ capture & H$_2$ production integrated in an IGCC

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

**Other proposals** from Industry or Research community to use the IGCC plant and its pilot plant to develop of process, equipments, components or even pre-engineering of new plants with CCS and Zero emissions
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5. CONCLUSIONS

**IPCC** → Unless greenhouse gas emissions are cut by 50-80% by 2050 (especially CO\(_2\)), the impact of global warming will be disastrous.

**World energy demand** → Expected to double by 2050.

**So** → We must **act fast using a portfolio of solutions** (mainly, energy efficiency improvement, renewables and CCS) to reduce CO\(_2\) emissions in the required massive scale.

**IGCC technology can contribute to this aim** because:

- Existing IGCC plants are an opportunity to **develop cleaner electricity with fossil fuels**

- **Diversification of fossil fuels use** according to the reserves and total life cycle is absolutely necessary

- **Clean co-production of H\(_2\) and electricity** is possible and can be adapted to market demand

- **Massive H\(_2\) production is currently possible** and technology is available
ELCOGAS: R&D activities towards zero emissions IGCC plants

Thank you for your attention

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