Clean and Efficient Power Generation from Coal
24-25, Gliwice (Poland)

ELCOGAS: R&D activities towards zero emissions IGCC plants

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ELCOGAS, S.A. www.elcogas.es
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1. ELCOGAS COMPANY

European company established in April 1992 to undertake the planning, construction, management and operation of a 335 MW\textsubscript{ISO} IGCC plant located in Puertollano (Spain)
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2. PUERTOLLANO IGCC POWER PLANT DESCRIPTION

Process description

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

- **Gasifier**
  - Raw Gas
  - Coal - N₂

- **HP Boiler**
  - HP Steam

- **MP Boiler**
  - MP Steam

- **Filtration**
  - Quench Gas
  - Fly ash

- **Water wash**
  - Water to treatment

- **Sulfur Recovery**
  - Sulfur (99.8%)
  - Tail Gas
  - Claus gas
  - Air

- **Sulfur Removal**
  - Clean syngas

- **Heat Recovery Steam Generator**
  - Flue gas to stack
  - Steam

- **Air Separation Unit**
  - Compressed air
  - N₂
  - O₂

- **Cooling tower**
  - Condenser
  - Flue gas to stack

- **GAS TURBINE**
  - 200 MWₐₛₒ

- **STEAM TURBINE**
  - 135 MWₐₛₒ
2. PUERTOLLANO IGCC POWER PLANT
DESCRIPTION

Main data

Design Fuel is a mixture 50:50 of coal & petcoke (currently operating at 45:55).

Successful tests with:
- MBM 2% (50 tpd)
- Olive oil wastes 8% (10% planned)
- Washed coal, Venezuela petcoke ...

<table>
<thead>
<tr>
<th></th>
<th>COAL</th>
<th>PET COKE</th>
<th>FUEL MIX (50:50)</th>
</tr>
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<tbody>
<tr>
<td>Moisture (%w)</td>
<td>11.8</td>
<td>7.00</td>
<td>9.40</td>
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<tr>
<td>Ash (%w)</td>
<td>41.10</td>
<td>0.26</td>
<td>20.68</td>
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<tr>
<td>C (%w)</td>
<td>36.27</td>
<td>82.21</td>
<td>59.21</td>
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<tr>
<td>H (%w)</td>
<td>2.48</td>
<td>3.11</td>
<td>2.80</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>
<thead>
<tr>
<th>POWER OUTPUT</th>
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<tbody>
<tr>
<td>GAS TURBINE (MW)</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>182.3</td>
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</table>

<table>
<thead>
<tr>
<th>EFFICIENCY (LHV)</th>
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<tr>
<td>GROSS</td>
</tr>
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<td>47.12%</td>
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<table>
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<tr>
<th>EMISSIONS</th>
<th>g/kWh</th>
<th>mg/Nm³ (6% Oxygen)</th>
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<tbody>
<tr>
<td>SO₂</td>
<td>0.07</td>
<td>25</td>
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<tr>
<td>NOₓ</td>
<td>0.40</td>
<td>150</td>
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<tr>
<td>Particulate</td>
<td>0.02</td>
<td>7.5</td>
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Power output and emissions
Raw and clean gas data

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

## Project milestones

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<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>
</tbody>
</table>

**IGCC:** 11,476 GWh

*Up to 2008, 4450 modifications have been installed in plant*
2. PUERTOLLANO IGCC POWER PLANT: Operating data

IGCC, NGCC and Total yearly 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
Emissions in NGCC and IGCC modes

2. PUERTOLLANO IGCC POWER PLANT: Operating data

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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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

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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4. ELCOGAS R&D INVESTMENT PLAN

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:

- CO₂ emission reduction in utilization of fossil fuels
- H₂ 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. CO₂, H₂, 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

Optimisation of IGCC processes: Oriented to improve availability & costs

Test materials
Gasifier materials/Syngas corrosion processes
Elimination of membrane water leakages at reaction chamber
Gas Turbine burners tests
Ceramic filters
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 $\mathrm{H}_2$ production by gasification of fossil fuels:

- $\mathrm{H}_2$ production in IGCC. Project HYDROSEP (RFCS, to study IGCC adaptation to $\mathrm{H}_2$ production)
- Study and tests of **new** processes of $\mathrm{H}_2$ purification. Project SPHERA (ESP-CENIT)
- Available to collaborate with new $\mathrm{H}_2$ & 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**
To demonstrate the feasibility of capture of CO$_2$ and production of H$_2$ 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.

Project of pilot plant in existing IGCC of Puertollano is part of a Spanish national initiative, “Advanced technologies of CO$_2$ conversion, capture and storage” and it is coordinated with other related projects:

Project # 2 is to explore CO$_2$ capture with oxyfuel technology in a 20MW pilot plant. To be built in El Bierzo, NW of Spain (coordinator CIUDEN)

Project # 3 is to study and regulate geological storage in Spain (coordinator IGME)

Project #4 is to study public awareness of CCS technologies (coordinator CIEMAT)
4. ELCOGAS R&D INVESTMENT PLAN.
CO₂ line – “Singular and strategic project PSE-CO”

PILOT PLANT

Existing Puertollano IGCC plant

COAL + PETCOKE

GASIFICATION

Raw gas

FILTRATION SYSTEM

Purification & Desulphurisation

COMBINED CYCLE

Recycle gas compressor

Clean gas

183,000 Nm³/h

Clean Gas

2% of total flow (3600 Nm³/h)
22.6 bar
130 °C
60.5 % CO
22.1 % H₂

MP steam

SHIFT REACTOR

(Sour/Sweet)

CO + H₂O → CO₂ + H₂

H₂ rich gas:

37.5 % CO₂
50.0 % H₂
3.0 % CO

CO₂ AND SULPHUR REMOVAL

(Chemical, aMDEA)

100 t/d

Raw H₂ (purity 80% )

100 t/d

CO₂

¿SH₂?

H₂ rich gas:

99.99%

Pilot plant size: 1:50 ~ 14 MWth
4. ELCOGAS R&D INVESTMENT PLAN.
CO$_2$ line – “Singular and strategic project PSE-CO$_2$”

General view of the ELCOGAS power plant

- PRENFLO Gasifier
- Coal Preparation
- ASU
- New CO$_2$ capture Pilot Plant under implementation
- Gas Treatment
- Combined Cycle

3D view (Sept 09)
Done:
- 98% engineering work
- 97% equipments bought
- 30% construction

Mechanical Erection: started on 17th August 2009
End commissioning: March 2010
End of programmed tests (under PSE): March 2011

KEY CONTRACTORS

<table>
<thead>
<tr>
<th>Engineering</th>
<th>Empresarios Agrupados</th>
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<tr>
<td>CO₂ Unit</td>
<td>Linde-Caloric</td>
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<td>PSA Unit</td>
<td>Linde</td>
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<td>Civil work</td>
<td>Construcciones Ocaña-Cañas</td>
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<td>Control</td>
<td>Zeus Control</td>
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<td>Reactors</td>
<td>Tecnical</td>
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<td>Tecnical and Boreal-Vila</td>
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<td>Johnson Matthey</td>
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<td>Piping and fitting</td>
<td>Masa, Sidsa and Cuñado</td>
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<td>GE Power</td>
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<td>On-line analysis system</td>
<td>ABB Process Automation Division</td>
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</table>
Pilot plant for CO\textsubscript{2} capture & H\textsubscript{2} production integrated in an IGCC

Activities to be done after PSE, as R&D platform:

- Water shift reaction **catalyst** optimization. Tests of different catalysts.
- **New processes** to separate CO\textsubscript{2}-H\textsubscript{2}
- CO\textsubscript{2} different **treatment** processes
- Improvement of **integration** efficiency between CO\textsubscript{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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**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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