OPERATING EXPERIENCE AND CURRENT STATUS
OF PUERTOLLANO IGCC POWER PLANT

ELCOGAS S.A

Francisco García Peña
www.elcogas.es
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2. IGCC technology in Spain. ELCOGAS experience.
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Introduction:

IGCC technology. General description
**INTRODUCTION: IGCC TECHNOLOGY. GENERAL DESCRIPTION**

**IGCC Technology. Advantages (1)**

- **High efficiency.** Higher than others technologies of power generation from coal, and great potential to increase: net 42% → 50%
  - Coal (diversity of qualities)
  - Alternative fuels (pet-coke, municipal wastes, biomass, etc.)
  - Availability of secondary fuel to the combined cycle
  - Reliability on energy supply

- **Feedstock flexibility →**
  - Electricity, H₂, CO₂, methanol, NH₃, gasolines, etc.
  - Minor risk: Production according to markets

- **Product flexibility →**
  - Coal stocks for more than 200 years and better distribution
  - Almost any fuel with enough carbon content is admitted

- **Sustainability:**
  - Coal stocks for more than 200 years and better distribution
  - Almost any fuel with enough carbon content is admitted
IGCC Technology. Advantages (2)

**Environment:**
- Lower $CO_2$ emissions than other coal based plants. Best possibilities for zero emissions
- Low emissions of acid gases ($SO_2$, $NO_x$) and particles. Similar or better than NGCC
- Less wastes. Slag, ash, sulphur and salts are sub-products
- Less water consumption than other coal based plant. Similar to NGCC
- No dioxins/furans are produced when organic fuels are used
- Best method to eliminate Hg emissions

**Economics:**
- Low cost fuel. Very competitive with natural gas. Fuels cost of KWh produced with coal is currently one third of produced with natural gas
- Lowest cost of $CO_2$ capture (pre-combustion)
- Wastes are commercial products. No cost disposal
IGCC Technology. Disadvantages

- Technology is in demonstration level
  - Four existing large coal based plants (USA & EU) report current IGCC availability between 60 and 75% (> 90 % considering secondary fuel)
  - Main unavailability causes have been related to lack of maturity:
    ✓ Design of auxiliary systems: Solids handling, down time corrosion, candle filters, proper materials and procedures
    ✓ Performance of gas turbine high class with synthetic gas and other
    ✓ Excessive integration between units, high dependence and delays start up
    ✓ Processes are more complex than other coal based power plants. Learning is required. Existing IGCCs operated by petrochemical companies with refinery residues report IGCC availability over 92 % (Complexity of process similar to chemical industry, several trains in parallel, solids handling easier)

- High investment cost
  - Existing plants cost have been between 1,500 and 2,000 €/KW
IGCC technology in Spain.

ELCOGAS experience.
The ELCOGAS S.A. Company

ELCOGAS shareholders and percentage of capital

Spanish company shared by European companies, which was established in April 1992 to undertake the planning, construction, exploitation and commercialization of a 335 MW ISO IGCC plant located in Puertollano (Spain)
ELCOGAS IGCC process. Block flow diagram
**ELCOGAS operating data**

**Fuel composition**
Mixture of low quality coal (high ash content) and petcoke (high sulphur content)

<table>
<thead>
<tr>
<th></th>
<th>RAW GAS</th>
<th>CLEAN GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO (%)</td>
<td>59,26</td>
<td>59,30</td>
</tr>
<tr>
<td>H₂ (%)</td>
<td>21,44</td>
<td>21,95</td>
</tr>
<tr>
<td>CO₂ (%)</td>
<td>2,84</td>
<td>2,41</td>
</tr>
<tr>
<td>N₂ (%)</td>
<td>14,32</td>
<td>14,76</td>
</tr>
<tr>
<td>Ar (%)</td>
<td>0,90</td>
<td>1,18</td>
</tr>
<tr>
<td>SH₂</td>
<td>0,83 %</td>
<td>3 ppmv</td>
</tr>
<tr>
<td>COS</td>
<td>0,31 %</td>
<td>9 ppmv</td>
</tr>
<tr>
<td>HCN (ppmv)</td>
<td>23</td>
<td>--</td>
</tr>
<tr>
<td>LHV (MJ/Kg)</td>
<td>10,36</td>
<td>9,76</td>
</tr>
<tr>
<td>HHV (MJ/Kg)</td>
<td>10,83</td>
<td>10,19</td>
</tr>
<tr>
<td>Kg/s</td>
<td>56,26</td>
<td>52,37</td>
</tr>
</tbody>
</table>

**Syngas composition**

<table>
<thead>
<tr>
<th></th>
<th>COAL</th>
<th>PETCOKE</th>
<th>MIXTURE (50:50w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>11,80</td>
<td>7,00</td>
<td>9,40</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>41,10</td>
<td>0,26</td>
<td>20,68</td>
</tr>
<tr>
<td>Carbon (%)</td>
<td>36,27</td>
<td>82,21</td>
<td>59,21</td>
</tr>
<tr>
<td>Hydrogen (%)</td>
<td>2,48</td>
<td>3,11</td>
<td>2,80</td>
</tr>
<tr>
<td>Nitrogen (%)</td>
<td>0,81</td>
<td>1,90</td>
<td>1,36</td>
</tr>
<tr>
<td>Oxygen (%)</td>
<td>6,62</td>
<td>0,02</td>
<td>3,32</td>
</tr>
<tr>
<td>Sulphur (%)</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>
<tr>
<td>HHV (MJ/kg)</td>
<td>13,58</td>
<td>32,65</td>
<td>23,12</td>
</tr>
<tr>
<td>Kg/s</td>
<td></td>
<td>29,68</td>
<td></td>
</tr>
</tbody>
</table>

**Fuels composition**
Mixture of low quality coal (high ash content) and petcoke (high sulphur content)
Operational experience

Environmental results (2004)

The environmental emissions of $SO_2$, $NO_x$ and particulated material are much lower than the maximum allowed by the ELCOGAS Permission.
### Operational experience

**Commercial viability results: Production costs (2004)**

<table>
<thead>
<tr>
<th>Operating mode</th>
<th>Fuel</th>
<th>Heat rate ((kJ_{HHV}/kWh))</th>
<th>Fuel price ((€/GJ_{HHV}))</th>
<th>Fuel partial cost ((€/MWh))</th>
<th>Production cost ((€/MWh))</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNCC</td>
<td>Natural gas</td>
<td>7.649</td>
<td>3.84</td>
<td>29.37</td>
<td>29.37</td>
</tr>
<tr>
<td>IGCC</td>
<td>Coal</td>
<td>2.934</td>
<td>2.06</td>
<td>6.04</td>
<td>14.55</td>
</tr>
<tr>
<td></td>
<td>Petcoke</td>
<td>5.994</td>
<td>1.18</td>
<td>7.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Additional NG consumption</td>
<td>376</td>
<td>3.84</td>
<td>1.44</td>
<td></td>
</tr>
</tbody>
</table>

The resulting production cost demonstrates IGCC competitiveness in the Spanish liberalized electricity market.
Operational experience

Commercial viability results: Learning curve

IGCC, NGCC and Total Yearly Production

YEAR

GWh

1998 1999 2000 2001 2002 2003 2004

IGCC NGCC
Main unavailability causes (1)

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.
   - 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 preheater installation.
### Lessons learned: Summary of improvements (1)

<table>
<thead>
<tr>
<th>System / equipment</th>
<th>Potential improvements</th>
<th>Cost reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal preparation</td>
<td>Natural Gas consumption 3 grinding trains for availability</td>
<td>Elimination of mixing equipment. Elimination of steam preheaters</td>
</tr>
<tr>
<td>Coal dust conveying, sluicing and feeding</td>
<td>N₂ saving Resizing of vessels and nozzles</td>
<td>Elimination of concrete building, coal storage and lock hopper system simplification by pneumatic pumps</td>
</tr>
<tr>
<td>Gasifier</td>
<td>Recycling of fine slag Membranes flow distribution Quench gas ratio</td>
<td>Removing auxiliary burners. Reduction of surfaces by increasing velocity</td>
</tr>
<tr>
<td>Slag handling</td>
<td>Replacement of filtering system by settling system.</td>
<td>Simplification of slag water circuit. Elimination of one slag lock hopper and extractor.</td>
</tr>
</tbody>
</table>
# Lessons learned: Summary of improvements (2)

<table>
<thead>
<tr>
<th>System / equipment</th>
<th>Potential improvements</th>
<th>Cost reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry dusting filter</td>
<td>Improvement of candle filter cleaning system.</td>
<td>Fly ash recycle removal, reduction of vessels</td>
</tr>
<tr>
<td></td>
<td>Improvement of candle filter material and design.</td>
<td>Elimination of fly ash wet discharge system</td>
</tr>
<tr>
<td>Gas scrubbing and stripping</td>
<td>Reduction of water carryover from scrubber (Start up)</td>
<td>Controlling filter removing/Scrubber resizing</td>
</tr>
<tr>
<td>Sulphur removal</td>
<td>COS catalyst</td>
<td>Equipment dimension decrease using enriched air</td>
</tr>
<tr>
<td>Air Separation Unit</td>
<td>Increase of liquid N₂ storage capacity</td>
<td>Oxygen storage removing</td>
</tr>
<tr>
<td></td>
<td>Start up compressor</td>
<td></td>
</tr>
<tr>
<td>Gas turbine</td>
<td>New higher efficiency gas turbine</td>
<td>Scale benefits</td>
</tr>
<tr>
<td></td>
<td>Syngas preparation</td>
<td>Simplification of control &amp; control components</td>
</tr>
</tbody>
</table>
Future R&D overview
Future of IGCC technology

IGCC TECHNOLOGY. FUTURE OVERVIEW

GASIFICATION

GAS CLEANING

PREPARATION

COMBINED CYCLE

STEAM

BFW

N₂

O₂

AIR

SEPARATION UNIT

WASTE N₂

AIR

START UP
compressor

RAW GAS

COAL WASTES

Biomass

WATER STEAM

CO₂

CO₂

SEPARATION

FUEL CELL

CHEMICALS

H₂

PURIFICATION

CO₂

WATER SHIF

CO + H₂O ↔ CO₂ + H₂

Water shift

H₂
### Future of IGCC technology

IEA estimation \( \text{H}_2 \) production cost year 2020 (\( \text{€}/\text{GJ} \))

<table>
<thead>
<tr>
<th>Source of Hydrogen</th>
<th>Cost Range (( \text{€}/\text{GJ} ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{H}_2 ) from natural gas with ( \text{CO}_2 ) capture</td>
<td>5.6 – 8.9</td>
</tr>
<tr>
<td>( \text{H}_2 ) from coal – IGCC, with ( \text{CO}_2 ) capture</td>
<td>6.5 – 8.9</td>
</tr>
<tr>
<td>( \text{H}_2 ) from biomass (gasification)</td>
<td>8.1 – 14.5</td>
</tr>
<tr>
<td>( \text{H}_2 ) from nuclear energy</td>
<td>12.1 – 16.2</td>
</tr>
<tr>
<td>( \text{H}_2 ) from wind energy</td>
<td>13.7 – 18.6</td>
</tr>
<tr>
<td>( \text{H}_2 ) from solar thermic</td>
<td>21.8 – 28.3</td>
</tr>
<tr>
<td>( \text{H}_2 ) from solar photovoltaic</td>
<td>38.0 – 60.6</td>
</tr>
</tbody>
</table>
IGCC technology: Main challenges

1. **To improve reliability.** It has to be achieved by introducing in next generation of plants the lessons learned, giving continuity to the technology.

2. **To decrease investment costs.** Main points are: scale economy (larger plants), better efficiency with last generation of gas turbines and combined cycles, design optimization according to lessons learned.

3. **To introduce CO$_2$ capture concept.** IGCC technology is the best option for zero emission plants based on fossil fuels.

4. **To introduce the technology in the H$_2$ economy.** Diversification of products will improve economic scenarios.

5. **To improve environmental performance even more.** By considering the use of wastes and biomass in co-gasification with coal.
ELCOGAS pilot plant project

✓ Project aims: $CO_2$ capture and hydrogen production from a 2% of the syngas produced at the plant:

- $H_2$ production: 2,500 Nm³/h, to direct sold or to applications (fuel for engines, gas turbines or fuel cells, chemical synthesis)

- $CO_2$ captured: 25,000 t/year (capture efficiency > 85%) to direct use or to geological sequestration tests

✓ Total investment: 15 million €

✓ Project has been presented to the spanish R&D National Programme (2005)