ZeroGen Project Update
Commercial Scale IGCC+CCS Demonstration

Managing Risks and Uncertainties

Dr Chris Greig, ZeroGen Project Director

Presentation to Gasification Technologies Conference
What is ZeroGen

- ZeroGen is fully owned by the Queensland State Government.

- ZeroGen Pty Ltd was established to...

  *facilitate the development and accelerated commercial deployment of low emissions coal technology to preserve Queensland’s competitive position in power generation and to ensure the continued mining, use and export of Australian black coal.*

- In the second half of 2008, ZeroGen’s board and stakeholders clarified the ZeroGen mission to...

  *develop a commercial scale, integrated IGCC with CCS project in Queensland to operate by 2015-2017.*

- To date the ZeroGen Project has been funded by the Queensland State Government and the Australian Coal Association Low Emissions Technologies Ltd (ACALET).
Project Location & Context

- **Location** – Central Queensland, Australia.
- **Location is driven carbon storage prospect** – Northern Denison Trough.

**North eastern Australia Context:**
- Hot arid climate – water is a precious commodity
- Limited opportunities for EOR or storage in depleted hydrocarbon fields
- Great Barrier Reef prohibits off-shore storage opportunities
- No existing CO₂ pipelines
- Deregulated electricity market
- No established carbon market
Project Elements – Overview

IGCC with Carbon Capture (IGCC+C)

- 530MW (gross) IGCC power plant (Single Gasifier & GT)
- CO₂ capture level 65 (initial) - 90% (during demonstration phase)
- ~ 400 MW Net (at 65% capture)
- CO₂ captured > 2,000,000 tonnes per year (at 65% capture)
- Power Plant site options include 3 mine mouth candidates and independent site (within ~100 km from CO₂ Storage resource)
- Estimated cost of A$3.2 Billion

Carbon Transport & Storage

- 2-3 million tpa supercritical CO₂ transported by pipeline
- Storage – Advanced base case is Northern Denison Trough
- Estimated cost of A$0.8 Billion
- Alternatives under investigation but progress limited due to lack of tenements
Project Development Process

Storage Appraisal & Project Development in Parallel

<table>
<thead>
<tr>
<th>Q3–Q4 2008</th>
<th>Q2 to Q3 2009</th>
<th>Q4 to Q4 2010</th>
<th>Q4 to Q4 2011</th>
<th>Q1 to Q4 2012</th>
<th>Q4 to Q4 2015</th>
<th>2016 →</th>
</tr>
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</table>

**Scoping Study**

**Prefeasibility Study**

**Feasibility Study and Funding Approval**

**Project Execution and Start-up**

**Operations**

**WHAT COULD IT BE?**

**WHAT SHOULD IT BE?**

**WHAT WILL IT BE?**

**SELECT THE BEST CASE**

**Investment decision**

**Deliver the Project**

**Extract the Value**
Project Risks & Uncertainties

- Commercial scale IGCC+CCS early mover deployment brings key risks & uncertainties associated with:
  - Power Generation & Carbon Capture plant performance & integration
  - Carbon Storage development & performance sustainability
  - Regulatory risk – Project licensing / ETS / Carbon storage
  - Stakeholder management including community acceptance
  - Project development & construction funding

- Few if any fully integrated IGCC + CCS demonstrations have been completed and so there are no benchmarks for performance, cost and time.

- Early coal fired CCS demonstrations can not afford to fail-

- Achieving a successful demonstration will demand rigorous and transparent identification, assessment and mitigation of these risks.
Risks for Power Plant with Capture

- **First-of-Kind projects** often experience surprises during delivery including delays, capital cost overruns and under-performance or extended ramp-up times.
- Integration risks are material for **First-of Kind projects**, even if individual unit operations have been proven.
- IGCC + CCS brings a further unique dynamic challenge between **desired stable process operation** and preferred **dynamic electricity market responsiveness**.

ZeroGen is responding to these First-of-Kind challenges as follows:

- **Rigorous, assessment of technology options** to identify preferred technology.
- **Early involvement by the technology vendors** in Prefeasibility Study especially in settling Design Basis, Functional Specification and trade-off studies to optimise project configuration – includes 3rd party technology providers.
- Negotiate **sharing** significant engineering, procurement and construction **performance risk**, as well as critical integration risk with the technology provider.
- Seek **must-run, base load** generation status.
Mitsubishi Heavy Industries agreed to provide an “EPC Wrap” (air-blown IGCC).

- Make-Good performance / availability guarantees – incl. 3rd Party technologies
- Significant price surety - MHI lump-sum portions + Open Book transparency

The Mitsubishi “EPC Wrap”
Power Plant Site Selection

- Power plant location chosen to minimize the long-run cost of power.
  
  Trade-off studies (technical & commercial) which optimize:
  
  - Fuel Specification & Cost
  - Revenue – Gas Turbine output power, Marginal Loss Factor
  - CO$_2$ Transport Cost (distance & corridor geography from Plant to Storage)
  - Network Connection Cost
  - Water Supply Cost
  - General Site Development
  - Sustainability & Development Risk

- Currently shortlisted to 3 mine-mouth options and 1 independent site.

- Selection to be finalised in Q1 2010, with single preferred case to carry forward to the Feasibility Study.
The ZeroGen project is focussed on supercritical storage in deep sandstone formations of the northern Denison Trough.

Supercritical CO₂ will be transferred via a dedicated project pipeline.

In order to meet the stakeholders target deployment schedule – operational by 2015 – the Carbon Transport & Storage challenge is:

To delineate a sustainable, probability adjusted storage capacity of 60 million tonnes with a total sequestration cost (transport & storage) ≤ A$50 per tonne CO₂ (including Cost of Capital and O&M).

- Pre-Feasibility Study will seek to demonstrate this objective to a P₅₀ level of confidence, by early 2010.
- Feasibility Study will seek to demonstrate this objective to a P₇₅ level of confidence, by mid 2011.
Carbon Storage Opportunity

Most prospective storage targets

- Tenements are essential to any exploration programme.
  - Can be converted to GHG Storage Leases.
  - So far these are the only GHG tenements granted under Queensland Legislation.
  - Total area of tenements = 1,225.5 Km².
  - No further tenements expected before Q2 2010.

Emerald
- Power Plant Site D
- Power Plant Site A
- Power Plant Site C

Springsure
- Power Plant Site B
- Rolleston
The Storage Evaluation Process must be able to quantify the outcomes of the Exploration Program.

3 key issues to resolve storage uncertainty:

1. **Storage Capacity & Containment**
   - **Low risk** - adequate pore space will exist under ZeroGen’s acreage.
   - geological seal of high integrity means secure storage
   - low permeability means CO₂ plume does not migrate far from well

2. **Cost of Transport & Storage**; and
   - **Low Risk** - Pipeline Cost & Unit Cost of wells are well understood
   - **Critical Issue** is **Storage Cost** – driven by Total Well Count
     - depends on reservoir injectivity & connectivity

3. **Confidence Level / Probability** measure.
   - **Methodology** to determine P₅₀ or P₇₅ etc?
   - Probability distribution.
Methodology to determine Well Count Distribution

- A probability distribution for the expected well count is established.

- First need sufficient data / knowledge of the critical variables, and

- A Statistical Assessment of those variable/parameter -
  - **Injectivity**
    - Reservoir kH
    - Well Skin Factor
    - Relative Permeability (\(k_{\text{AIR}}/k_{\text{WATER}}\))
    - Capillary Pressure
    - Relative (directional) Permeability (\(k_{\text{h}}/k_{\text{v}}\))
  - **Reservoir Continuity / Connectivity**

A Monte Carlo type simulation is then run in conjunction with the single well reservoir modelling which will provide a distribution of possible well counts.
Carbon Storage Exploration is a long expensive process

- The program to prove an economic storage resource requires extensive testing data acquisition including:
  - Desktop investigations
  - Seismic surveys
  - Drilling multiple stratigraphic wells
  - Analysis & testing of drill core
  - CO₂ Injection testing
  - Water Injection testing

- ZeroGen has drilled 10 cored wells, and one CO₂ injection well - >50% of exploration wells world wide for the specific purpose of defining storage resources (not associated with hydrocarbon exploration & production).

- Overall the process from identifying a storage target to developing an economic storage resource is >$100 million over at least 4 years.
**Monte Carlo Simulation** for key parameters from exploration data - multiple distribution types

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate (Average)</th>
<th>Worst</th>
<th>Best</th>
<th>SIMULATION SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connectivity (Sand Packet Size in km²)</td>
<td>2</td>
<td>0.1</td>
<td>4</td>
<td>LOGNORMAL</td>
</tr>
<tr>
<td>Permeability (mD m)</td>
<td>200</td>
<td>20</td>
<td>2000</td>
<td>PERT FUNCTION</td>
</tr>
<tr>
<td>Skin Factor</td>
<td>1.2 (50%)</td>
<td>2 (30%)</td>
<td>1 (20%)</td>
<td>DISCRETE</td>
</tr>
<tr>
<td>Fracture Pressure gradient ( )</td>
<td>1.1</td>
<td>0.9</td>
<td>1.3</td>
<td>UNIFORM</td>
</tr>
<tr>
<td>Relative Permeability</td>
<td>1</td>
<td>1.2</td>
<td>0.6</td>
<td>UNIFORM</td>
</tr>
</tbody>
</table>
Sample Determination of $P_{50}$ for Total Well Count

Monte-Carlo simulation over the potential well models within field Reservoir Models with simulated parameter distributions to determine the potential distribution of Well Count outcomes -

<table>
<thead>
<tr>
<th>Well Count Simulations (from Reservoir Modelling)</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
<th>Simulated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>220</td>
<td>70</td>
<td>PERT</td>
</tr>
</tbody>
</table>

Well Count Comparison with Pert(25,70,220)

- P_{25} = 25.0%
- P_{50} = 50.0%
- P_{75} = 25.0%

Slide 16
ZeroGen commenced supercritical CO$_2$ injection testing in the Denison Trough this week.
ZG 11 Injection Well & CO$_2$ Injection Facilities
Project Development & Construction Funding

- **Prefeasibility & Exploration Funding** to date from:
  - Queensland Government ✓
  - ACALET ✓
  - Mitsubishi Corporation & MHI ✓

- **Funding for the Feasibility Study & Plant** will be sought from:
  - Above foundation funders ✓
  - Commonwealth Government (Clean Energy Initiative CCS Flagship Program)
  - Japanese Government
  - Strategic industrial investors
    - Power utilities
    - Fuel suppliers
    - Carbon storage operators

- **Operational Subsidy** eg CCS Certificate will also be mandatory for viability.
Australian Clean Energy Initiative

- Complements the Government’s National Low Emissions Coal Initiative and the Global Carbon Capture and Storage Institute (GCCSI)

- Funding of $2.0 billion to build at least two, industrial-scale carbon capture and storage projects in Australia
  - to support the non-commercial costs of demonstrating and deploying large-scale integrated CCS projects
  - target – 1000MW low emission fossil fuel generation.

- An independent assessment panel will assess projects, after a competitive selection process.

- Projects are expected to be chosen next year for construction beginning in 2012 for commissioning by 2015.

- Indicative timeline:
  - short listed projects announced Q4 2009
  - preferred projects recommended Q3 2010
  - selected projects announced Q3/Q4 2010
Summary – Managing Risks & Uncertainties

Commercial scale IGCC+CCS early mover deployment brings key risks & uncertainties:

► **Power Generation & Carbon Capture** plant performance & integration
  + Rigorous selection of technologies
  + Early involvement of technology providers
  + MHI EPC Wrap

► **Regulatory risk**
  + Greenhouse Gas Storage Act now in force in Queensland
  + Still no ETS / No confirmation on Must-Run base load generation

► **Carbon Storage** development & performance sustainability
  + Extensive exploration & testing program
  + Robust appraisal & assessment methodology

► **Project development & construction** funding
  + Strong support from foundation funders (Queensland Government & ACALET) & Mitsubishi / MHI
  + Australian Government’s Clean Energy Initiative – **CCS Flagship Program**
  + Seeking additional support from Japanese Government

Strategic industrial investors