Feasibility Study of the CCS Deployment to Australia by Use of Oxyfuel Technologies

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Feasibility Study of the CCS Deployment to Australia by Use of Oxyfuel Technologies

- Background & Initial Approach of FS
- Power Plant
  - Specifications
  - System Flow Diagram
  - Plant Layout
  - Performances
- CO₂ Pipeline Routing
- Cost Evaluation
  - Levelized Cost of Electricity
  - Utilization of Gases
  - Utilization of Water
  - Economy
- Conclusions - Passage to 500MW Oxyfuel-
Features of Oxyfuel Technology

- Many reports indicate Oxyfuel is the cheapest among three capture options,
- The higher is the thermal efficiency, the lower is the energy penalty,
- Main energy source to capture CO\textsubscript{2} is electricity and the impact to conventional power plant system is small,
- Huge amount of nitrogen and water can be obtained as byproduct,
- Sulfuric acid or gypsum can be obtained as byproduct if FGD is not necessary to be installed to normal power stations in the subject area,
- SCR and ammonia are not needed because NO is automatically decomposed in the boiler furnace, and
- There will be no other toxic emissions to the atmosphere than air firing.
Features of Australia

- 94% of primary energy is fossil fuel, 70% of electricity is produced by coal, and per-capita CO₂ emission is relatively high like US or Canada,
- Very positive about CO₂ reduction; carbon pricing, regulations, GCCSI, etc.,
- Very supportive to RD&D of CCS; CCS Flagship, Coal21 Fund, ANLECR&D, CO2CRC, etc. Callide Oxyfuel Project is supported by Federal and QLD State government and Australian coal industry,
- There are extensive geological data and steady property management as a country of resources,
- Population is small in a vast area of land, that means a little number of landowners to negotiate about routing pipeline,
- Arid area and lack of water, and
- Coal firing power plants do not have SCR and FGD.
Background of FS (3)

- **Oxyfuel in Australia**

  ✓ The amount of makeup water can be reduced in arid area by utilizing water captured in the process of gas purification. It will be increased when PCC is applied,
  ✓ SCR and FGD should not be installed in the main stream to control NOx and SO2 emissions in air firing, and
  ✓ The Callide Oxyfuel Project is a collaborative project between Australia and Japan and is the biggest one in Australia not only in capacity but also in budget applying CCS technologies to coal-fired power plants.

Because Australia is very suitable country to apply oxyfuel technology and the deployment of the outcome from demonstration projects is vital, we conducted a feasibility study of the CCS deployment to Australia by use of oxyfuel technologies.
The feasibility study was conducted for the following CCS project in Australia:

Subject area: The Southeast of Queensland
Power plant: USC+CCS
   Fuel: Pulverised coal (black coal)
   Output (gross): 1,000MW
      (250MW (oxyfuel)+750MW (capture-ready))
Steam condition: Ultra supercritical with reheat
Cooling system: Dry cooling
CO₂ transportation: Pipeline
CO₂ storage: Wandoan site (Surat basin)
   1 Mtpa from 250MW unit with additional 3 Mtpa in the future

1000MW unit is too large considering;
✓ Near term storage capacity,
✓ Site size (ASU and CPU need a large space), and
✓ Power grid capacity.
Combination of 250MW and 750MW is difficult to operate.

Reduce the output to 500MW
Specifications of Power Unit

- **Ambient conditions**
  - Dry-bulb temperature: 30°C
  - Barometric pressure: 97.5kPa
  - Relative humidity: 42%

- **Cooling System**
  - Dry Cooling

- **Output (Gross)**
  - 500 MW

- **Power Plant Steam Conditions**
  - Main steam pressure (HPT inlet): 25.0MPa
  - Steam temperature (HPT/IPT inlet): 600/600℃

- **Coal Properties**

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific value(HHV)</td>
<td>MJ/kg, as fired</td>
<td>20.1</td>
</tr>
<tr>
<td>Carbon</td>
<td>wt%, as fired</td>
<td>46.7</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>wt%, as fired</td>
<td>4.0</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>wt%, as fired</td>
<td>0.6</td>
</tr>
<tr>
<td>Oxygen</td>
<td>wt%, as fired</td>
<td>9.7</td>
</tr>
<tr>
<td>Sulfur</td>
<td>wt%, as fired</td>
<td>0.3</td>
</tr>
<tr>
<td>Total moisture</td>
<td>wt%, as fired</td>
<td>12.4</td>
</tr>
<tr>
<td>Ash</td>
<td>wt%, as fired</td>
<td>25.4</td>
</tr>
<tr>
<td>Fuel ratio</td>
<td>-</td>
<td>0.86</td>
</tr>
</tbody>
</table>
Specifications of ASU & CPU

- **Specifications of ASU**
  - Type: Cryogenic
  - Maximum $O_2$ production: 200t/h x 2 trains
  - $O_2$ purity: 96.5 vol%

- **Specifications of CPU**
  - Maximum flow rate: 270t/h x 2 trains
  - Gas composition at the inlet:
    - $H_2O$: 8.1 vol% wet
    - $CO_2$: 72.84 vol% wet
  - Product:
    - $CO_2$: Liquid (45°C x 16 MPa(abs))
    - Purity: 99.9%
    - Recovery rate: >98%
Plant Layout (2D)

Laydown Area for New Power Station

ASU
Dry Cooling
Turbine
Oxyfuel Boiler
FGD
CPU

Existing Power Plant

Existing Plant

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Plant Layout (3D)
Performances of Power Plant

### Performances

<table>
<thead>
<tr>
<th></th>
<th>Oxy-firing</th>
<th>Air-firing</th>
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</thead>
<tbody>
<tr>
<td>Gross output</td>
<td>MW 500</td>
<td>MW 500</td>
</tr>
<tr>
<td>Net output</td>
<td>MW 345</td>
<td>MW 473</td>
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<tr>
<td>Gross Thermal Efficiency (HHV base)</td>
<td>% 45.7</td>
<td>% 42.1</td>
</tr>
<tr>
<td>Net Thermal Efficiency (HHV base)</td>
<td>% 31.5</td>
<td>% 39.9</td>
</tr>
<tr>
<td>Auxiliary power consumption</td>
<td>MW 155</td>
<td>MW 27</td>
</tr>
<tr>
<td>CO₂ emission (Net base)</td>
<td>Mtpa 0.0505</td>
<td>g/kWh 20</td>
</tr>
<tr>
<td>CO₂ captured</td>
<td>Mtpa 2.49</td>
<td></td>
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<tr>
<td>Fuel consumption</td>
<td>t/h 196</td>
<td>t/h 212</td>
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<tr>
<td>Heat rate (Gross)</td>
<td>kJ/kWh 7880</td>
<td>kJ/kWh 8550</td>
</tr>
<tr>
<td>Heat rate (Net)</td>
<td>kJ/kWh 11412</td>
<td>kJ/kWh 9038</td>
</tr>
</tbody>
</table>
Pipeline length 140km
φ200 for 1Mtpa / φ350 for 4Mtpa
Design Pressure 160bar
Breakpoint is 50AUD/t-CO₂ with public support for CCS facility.
Breakpoint is 85AUD/t-CO₂ without public support.

[Assumptions for LCOE Calculation]
- Economic life time: 30 years
- Plant availability: 85%
- Post-tax nominal WACC (Weighted Average Cost of Capital): 8.7%
- Income tax rate: 0%
- Inflation rate: 2.5% (2.5% x 75% for fuel cost, 4.25% for Labor cost until 2018, then 2.5%)
Utilization of Gases

- **Gas Quantity**
  - About 20% of supplied air is sent to the boiler as purified $O_2$.
  - About 20% of supplied air is used to regenerate molecular sieves in ASU.
  - About 60% of supplied air can be utilized as gaseous $N_2$.
    (Usually gaseous $N_2$ is used for ASU cooling)

- **Conditions for $N_2$ Utilization**
  - 20% as middle pressure (0.37MPaG) $N_2$ and 40% as low pressure (0.01MPaG) $N_2$ can be utilized unless $N_2$ is used for ASU cooling.
  - Additional power demand for cooling is equivalent for 3-4% of that for air compressor.

- **$N_2$ Gas Purity**
  - $O_2 < 1$ppm.
Water treatment system is required to utilize condensed water.
Specifications of water treatment system depends on usage of water.
500MW Oxyfuel Power Plant

**Electricity**
- 345MW

**CO₂**
- 0.97t/MWh
- 2.5Mtpa
- (85% Availability / 98% Recovery)

**N₂**
- 2.2t/MWh
- 5.7Mtpa
- (85% Availability / 90% Recovery)

**H₂O**
- 0.21t/MWh
- 0.54Mtpa
- (85% Availability / 90% Recovery)

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Byproducts sales case for mining industry

**Coal**
- 4702t/d

**Flue Gas Treatment**
- 1728t/d

**H₂O**
- 18360t/d

**Fracturing**
- 18360t/d

**Shale Gas Production**

**Byproducts sales case for chemical plants**

**Coal**
- 4702t/d

**Flue Gas Treatment**
- 1728t/d

**H₂O**
- 8040t/d
Conclusions - Passage to 500MW Oxyfuel -

The Callide Oxyfuel Project is a collaborative project between Australia and Japan and is the biggest one in Australia not only in capacity but also in budget applying CCS technologies to coal-fired power plants. Because the deployment of the outcome from demonstration projects is vital, we conducted a feasibility study of the CCS deployment to Australia by use of oxyfuel technologies.

Passage to 500MW Oxyfuel;

- **Better business environment**
  - Public funding system for CCS dedicated facility. (around 500MAUD for 500MW)
  - System to maintain high carbon pricing or Implementation to cover the deficit.
    (e.g., U.K. CfD (Contract for Difference))
  - Reliable, continuous and certain governmental policy and support.

- **Study on technology and manufacturing**
  - Cost reduction targeting on CAPEX.
    (Especially on ASU and CPU)

- **Study on business model**
  - Business scheme to sell electricity and gases by utility company or project body.
  - Innovation of industrial process for fertilizer or chemical products by low price N₂
    (Finding invisible needs)
  - Viewpoint of a N₂ and CO₂ producing plant with a function to supply electricity.
Acknowledgement

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Thank you for your attention.