Carbon Capture and Storage: A technology overview

29 March 2011

Carbon Capture and Storage Unit
International Energy Agency
CONTENTS

1. CCS in general
2. Capture technologies
3. CO2 transport
4. CO2 storage
5. Current and planned projects
CCS IS A CHAIN

Carbon Capture and Storage is a chain/group of technologies and applications that enable:

1. **Capture of CO₂ from large point sources**
   - Power plants, steel, cement, refineries, gas processing etc.

2. **Its transport**
   - Trucks, ships, pipelines

3. **Storage of CO₂ in geological formations**
   - Depleted oil and gas fields, saline aquifers, EOR, ECBMR etc.
CCS TECHNOLOGY

Capture

Transport

Storage

CO2 source (e.g. power plant)

CO2 transport

CO2 injection

CO2 storage
APPLICABLE CO$_2$ SOURCES

- Power plants
- Cement factories
- Steel plants
- Gas processing plants
- Ammonia production
- Refineries
- H2/synfuel production

Source: Bellona
APPLICABLE STORAGE RESERVOIRS

Storage prospectivity
- Highly prospective sedimentary basins
- Prospective sedimentary basins
- Non-prospective sedimentary basins, metamorphic and igneous rock
- Data quality and availability vary among regions

- Depleted gas/oil fields
- Saline formations
- Enhanced Oil Recovery (EOR)
- Enhanced Coal-bed Methane Recovery (ECBM)
CONTENTS

1. CCS in general
2. Capture technologies
3. CO2 transport
4. CO2 storage
5. Current and planned projects
Overview of CO$_2$ capture processes

Source: IPCC, 2005
Post-combustion CO$_2$ capture

**Process Layout**

**Key challenges & development trends**

- Scale-up of capture equipment; prove commercial size application at power plants
- Low-cost absorber designs
- Develop solvents with reduced energy penalty & minimized slip to ambient

**Demo plants**

Example: 20 MWe Mountaineer demo project, US

Source: Costain

Source: AEP
Pre-combustion CO$_2$ capture

Process Layout

Key challenges & development trends
- Prove integration of IGCC power plant with capture technology at commercial scale
- Optimize system design and process availability
- Further improve high hydrogen gas turbines

Demo plants

Example: Planned pilot site at Buggenum, NL

Source: Costain

Source: Nuon
Oxy-combustion CO₂ capture

Process Layout

Demo plants

Key challenges & development trends

- Reduce air separation energy requirement
- Long-term stability of boiler materials to recycled impurities from combustion process
- Optimize oxygen-firing combustion system
Latest IEA Study

- Reference document for latest information on CO₂ capture cost and performance
- Focus on CO₂ capture from power generation
- In-depth analysis based on major engineering studies

Key average results

<table>
<thead>
<tr>
<th>Fuel (capture route)</th>
<th>Coal (pre-, post-, oxy-combustion)</th>
<th>Natural gas (post-comb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency penalty (%-pts.)</td>
<td>10 (pre-combustion vs. IGCC: 8)</td>
<td>8</td>
</tr>
<tr>
<td>Capital cost increase over baseline without CCS</td>
<td>74% (vs. PC reference)</td>
<td>82%</td>
</tr>
</tbody>
</table>

Notes: Figures are for OECD countries and include only CO₂ capture and compression, but not CO₂ transport and storage; capital costs are overnight costs.

- Substantial variation in costs across regions and depending on fuel and power plant types
Capture Summary

- A variety of capture routes is under development:
  - Post-combustion
  - Pre-combustion
  - Oxy-combustion

- For coal-fired power generation, no capture route outperforms alternative routes

- An increase in capital costs of about 70-80% on top of the costs of the baseline power plant without CCS is estimated (this reflects the size of additional equipment required)

- Substantial variation exists in costs across regions and depending on fuel and power plant types
CONTENTS

1. CCS in general
2. Capture technologies
3. CO2 transport
4. CO2 storage
5. Current and planned projects
CO₂ TRANSPORT (1): PIPELINES

- CO₂ can be transported liquid or in gaseous form, but compressed gas the main option, 10-80 Mpa pressures
- Approximately 5600km of CO₂ pipelines exist (mostly in US)
- Currently handling some 50Mt of CO₂ per year
- Existing conventional technology
- Main issues: pipeline economics, permitting, planning
- Risks: potential high concentrations in low-lying areas in case of rupture; however excellent safety record to date
CO2 TRANSPORT (2): SHIPS

- CO₂ in liquid or in gaseous form, liquid the main option
- Current experience: handful of food-grade CO₂ carriers, no large CO₂ carrier fleet
- Liquid CO₂ only under 1) low-temperature and 2) pressure well-above atmospheric → pressure-type or semi-refrigerated tankers (-54°C, 6-7 bar)
- Technology similar to LNG carriers
- Risks: as in shipping overall; asphyxiation if rupture
CONTENTS

1. CCS in general
2. Capture technologies
3. CO2 transport
4. CO2 storage
5. Current and planned projects
CO2 STORAGE (1)

CO$_2$ storage solutions (Source: IPCC)

- A variety of storage solutions
- Operating: Deep saline formations, oil/gas fields, EOR
## CO2 STORAGE (2)

### Capacity Estimates (Gt CO2)(Source: GHG)

<table>
<thead>
<tr>
<th>Storage Type</th>
<th>Global (IPCC 2005)</th>
<th>Global (IEAGHG)</th>
<th>USA</th>
<th>Europe</th>
<th>Russia (IEA2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSF</td>
<td>1,000 – 10,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depleted Gas</td>
<td>680 – 900</td>
<td>160</td>
<td>140</td>
<td>20 – 32</td>
<td>150-200</td>
</tr>
<tr>
<td>CO2-EOR</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Significant uncertainty and different estimation methods
- Standardization for CO2 storage capacity estimation
CO2 STORAGE (3)

Monitoring : Seismic Survey (Source: STATOIL)

- Various methods for monitoring
- Best practice guidelines for storage monitoring
CO2 STORAGE (4)

Potential Escape Mechanism (Source: IPCC)

- Various potential leakage mechanisms
- Develop safety regulations and criteria
CONTENTS

1. CCS in general
2. Capture technologies
3. CO2 transport
4. CO2 storage
5. Current and planned projects
CURRENT AND PLANNED PROJECTS (1)

Five large-scale projects are currently storing >5Mt CO$_2$ per year
CURRENT AND PLANNED PROJECTS (2)

72 other integrated large-scale projects in various stages of development