Role of CCS Globally: IEA 2013 CCS Roadmap

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Carbon capture and storage defined

Capture
Separation of CO\textsubscript{2} produced during production of power or other products, followed by clean-up and compression of the CO\textsubscript{2}

Transport
Movement of CO\textsubscript{2} by pipeline, truck, rail, ship, or barge to a storage facility

Storage
Injection of CO\textsubscript{2} into a suitable storage unit, selected to safely contain the injected CO\textsubscript{2} for long timescales

Outline

1. CO₂ challenge and role of CCS
2. Status of CCS today
3. Charting the way forward
Record-high CO₂ emissions in 2012

Global energy-related CO₂ emissions

400ppm CO₂ concentration recorded in May 2013

CO₂ emissions trends point to a long-term temperature increase of up to 5.3 °C
Portfolio of decarbonising measures

Emissions Reductions (Gt CO₂)

- Nuclear 8% (8%)
- End-use fuel switching 12% (12%)
- CCS 14% (17%)
- Renewables 21% (23%)
- Power generation efficiency and fuel switching 3% (1%)
- End-use fuel and electricity efficiency 42% (39%)

Near-term solutions important, but not enough!
The case for CCS: fossil fuels

Trend in fuel mix 2010-2050: fossil fuels continue to dominate.

CCS can help to deal with emissions already “locked-in”.

Figure 8.14: Energy-related CO₂ emissions from locked-in infrastructure in 2011 and in the 450 Scenario in non-OECD countries
The case for CCS: process industries

Emissions from key industrial sectors expected to increase.

CCS is the only large-scale mitigation option for many industrial sectors.

Source: IEA ETP 2012 4DS, incorporating recent policy pledges
The case for CCS: economic advantage

Additional USD 36 trillion in investments through 2050 to reach 2DS scenario goals → CCS is 10% of this...

... and if CCS not available for power, investment required in the power sector will increase by 40%
The case for CCS is clear!

A. “ENERGY REALITY”
FOSSIL FUELS ARE PART OF TODAY’S AND TOMORROW’S ENERGY MIX

B. “CANNOT REACH TARGETS WITHOUT IT”
ALTERNATIVE TECHNOLOGY NOT AVAILABLE AT REASONABLE COST

C. “ECONOMIC ADVANTAGE”
IT SAVES US MONEY (POWER SECTOR)

Lock-in → CCS needed for “unlocking”

40% more investment in power if CCS not available

CCS required in industry
Outline

1. CO₂ challenge and role of CCS
2. Status of CCS today
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Carbon capture and storage (CCS)

- Post-process capture
- Syngas/hydrogen capture
- Oxy-fuel combustion
- Inherent separation

Capture technologies are well understood but expensive.

- 6000km existing pipelines
- Existing technical standards
- Transport by ship (albeit in small quantities)

Transport is the most technically mature step in CCS.

- Decades of research
- Natural CO₂ accumulations
- Pilot projects
- Existing large-scale projects

CO₂ storage has been demonstrated but further experience is needed at scale.

Geologic storage with monitoring in saline aquifers, depleted hydrocarbon reservoirs or via EOR
Capture technologies understood but expensive

<table>
<thead>
<tr>
<th>Power Generation</th>
<th>Syngas-hydrogen capture</th>
<th>Post-process capture</th>
<th>Oxy-fuel combustion</th>
<th>Inherent separation</th>
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</thead>
<tbody>
<tr>
<td>Coal</td>
<td>Gas reforming and combined cycle</td>
<td>Natural gas combined cycle</td>
<td>Oxy-fuel combustion</td>
<td>Chemical looping combustion</td>
</tr>
<tr>
<td>Biomass</td>
<td>IGCC</td>
<td>Biomass-fired boiler</td>
<td>Oxy-fuel combustion</td>
<td>Chemical looping combustion</td>
</tr>
</tbody>
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<tr>
<th>Second-phase industrial applications</th>
<th>Syngas-hydrogen capture</th>
<th>Post-process capture</th>
<th>Oxy-fuel combustion</th>
<th>Inherent separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron and steel</td>
<td>Hydrogen reduction</td>
<td>Blast furnace capture</td>
<td>Oxy-fuel blast furnace</td>
<td>-</td>
</tr>
<tr>
<td>Refining</td>
<td>Hydrogen fuel steam generation</td>
<td>Process heater and combined heat and power (CHP) capture</td>
<td>Process heater and CHP oxy-fuel</td>
<td>-</td>
</tr>
<tr>
<td>Chemicals</td>
<td>-</td>
<td>Process heater, CHP, steam cracker capture</td>
<td>Process heater and CHP oxy-fuel</td>
<td>-</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Biomass-to-liquids</td>
<td>-</td>
<td>-</td>
<td>Advanced biofuels</td>
</tr>
<tr>
<td>Cement</td>
<td>-</td>
<td>Rotary kiln</td>
<td>Oxy-fuel kiln</td>
<td>Calcium looping</td>
</tr>
<tr>
<td>Pulp and paper</td>
<td>Black liquor gasification</td>
<td>Process heater and CHP capture</td>
<td>Process heater and CHP oxy-fuel</td>
<td>-</td>
</tr>
</tbody>
</table>

Legend: technical maturity of operational CO₂ capture plants to date.

- **Commercial**
- **Demonstration**
- **Pilot**
- **Lab or concept**
### Three CO₂ capture routes in power

<table>
<thead>
<tr>
<th>CO₂ Capture Route</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-combustion CO₂ capture</td>
<td>• Fossil fuel or biomass is burnt normally and CO₂ is separated from the exhaust gas</td>
</tr>
<tr>
<td>Pre-combustion CO₂ capture</td>
<td>• Fossil fuel or biomass is converted to a mixture of hydrogen and CO₂, from which the CO₂ is separated and hydrogen used for fuel</td>
</tr>
<tr>
<td>Oxy-combustion CO₂ capture</td>
<td>• Oxygen is separated from air, and fossil fuels or biomass are then burnt in an atmosphere of oxygen producing only CO₂ and water</td>
</tr>
</tbody>
</table>

*At the present time, none of the options is superior; each has particular characteristics making it suitable in different power generation applications.*
Selected CCS demonstration projects in process industries

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Sector (Process)</th>
<th>Size (MtCO₂/y)</th>
<th>Operation Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Plains Synfuel</td>
<td>North Dakota, USA</td>
<td>Refining (SNG)</td>
<td>3</td>
<td>2000</td>
</tr>
<tr>
<td>ADM Decatur</td>
<td>Illinois, USA</td>
<td>Biofuels (Fermentation)</td>
<td>1</td>
<td>2013</td>
</tr>
<tr>
<td>Shell Quest</td>
<td>Alberta, Canada</td>
<td>Refining (H₂)</td>
<td>1</td>
<td>2015</td>
</tr>
<tr>
<td>NWR Sturgeon</td>
<td>Alberta, Canada</td>
<td>Refining (H₂)</td>
<td>1</td>
<td>2016</td>
</tr>
<tr>
<td>ESI-Masdar</td>
<td>Abu Dhabi, UAE</td>
<td>Iron &amp; Steel (DRI)</td>
<td>&lt;1</td>
<td>2015</td>
</tr>
<tr>
<td>Gorgon</td>
<td>Barrow Island, Australia</td>
<td>Gas Processing</td>
<td>3</td>
<td>2015</td>
</tr>
</tbody>
</table>
Progress with large-scale capture projects

Power (pre-combustion)
- Enid, United States, 1982
- Val Verde, United States, 1972

Power (post-combustion)
- Kemper, United States
- Weyburn, United States
- Great Plains, United States

Iron and steel
- Shute Creek, United States, 1986

Biofuels
- Sleipner, Norway, 1996
- Gorgon, Australia, 1996

Chemicals
- Shute Creek, United States, 1986

Refining
- Medicine Bow, United States

Gas processing
- Sleipner, Norway, 1996
- Val Verde, United States, 1972
- Shute Creek, United States, 1986

CO₂ used for EOR
- HECA, United States
- TCEP, United States
- ACTL Redwater, Canada

CO₂ used for storage without EOR
- ESI, United Arab Emirates
- Spectra, Canada

Size = 1MtCO₂/yr captured

Source: IEA
The need for project experience in industry-CCS

Source: Industry-CCS annex to TCEP report 2013
Low-carbon & CCS investment to date

- Investment in CCS 2004-2012: USD $20\text{bn}$
- Investment in all clean energy in 2004-2012: USD $1670\text{bn}$

Source: BNEF
## Assembling the parts – still a challenge

### Economics
- High cost of capture
- Limited business opportunity (EOR, small scale use)
- Unvalued benefit of CCS technology learning

### Policy
- Uncertainty about long term climate mitigation goals
- Lack of political recognition of the role of CCS
- Low or inexistent carbon price
- Lack of or limited incentives for CCS

### Technology
- No large-scale experience in power and many industrial applications
- Technical complexity of adding capture
- Risks related to storage
- Complex commercial arrangements

### Stakeholder views
- Unfavorable views on CCS as perpetuating a fossil fuel world
- Concerns over risks of CO$_2$ escape
- Opposition to projects
- Lack of understanding
Outline

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IEA vision: 120 Gt of CO$_2$ stored by 2050

**Goal 1: 2020.** Over 30 large projects are in operation in power and across a range of industrial processes, storing 50Mt CO$_2$ per year.

**Goal 2: 2030.** Over 2Gt of CO$_2$ is stored per year. CCS is routinely used in power and certain industrial applications.

**Goal 3: 2050.** Over 7Gt of CO$_2$ is stored per year. CCS is routinely used in all applicable power and industry.
Seven key actions for next seven years

- Introduce **financial support mechanisms** for demonstration and early deployment.

- Develop laws and regulations that effectively require new-build power capacity to be **CCS-ready**.

- Significantly increase efforts to **improve understanding** among the public and stakeholders of CCS technology.

- Implement policies that **encourage storage** exploration, characterisation and development for CCS projects.

- Reduce the **cost of electricity** from power plants equipped with capture through continued technology development.

- Prove capture systems at pilot scale in **industrial applications**.

- Encourage efficient development of CO₂ **transport infrastructure**.
CCS in industrial applications needs a boost

SIX RECOMMENDATIONS:

1. Commit public funds to 10 pilot and demo scale projects
2. Support projects for contribution to knowledge (not short-term emission reductions)
3. Include CCS into industrial strategies
4. Start to address competitiveness concerns
5. Exploit synergies between sectors
6. Involve all sectors and stakeholders
THANK YOU!

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DOWNLOAD THE ROADMAP AT:
http://www.iea.org/topics/ccs/ccsroadmap2013