International Activities on CCS

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IEA Greenhouse Gas R&D Programme
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International Activities

• Legal and Regulatory position covered
• Will focus on demonstration project activities
CCS technology components
## Maturity of CCS technology

<table>
<thead>
<tr>
<th>Method</th>
<th>Research phase</th>
<th>Demonstration phase</th>
<th>Economically feasible under specific conditions</th>
<th>Mature market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxyfuel combustion</td>
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<tr>
<td>Post-combustion</td>
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<tr>
<td>Pre-combustion</td>
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<tr>
<td>Industrial separation</td>
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<tr>
<td>Transport</td>
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<tr>
<td>Enhanced Coal Bed Methane</td>
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<tr>
<td>Gas and oil fields</td>
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<tr>
<td>Industrial utilization</td>
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<tr>
<td>Saline formations</td>
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<tr>
<td>Enhanced Oil Recovery</td>
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<tr>
<td>Mineral carbonation</td>
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<tr>
<td>Ocean storage</td>
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</tbody>
</table>

**Source:** IPCC CCS 2005

[www.ieagreen.org.uk](http://www.ieagreen.org.uk)
CCS in coal-fired power generation

- Advanced USCPC Plants: 760°C
- IGCC Plants: 620°C+ to 600°C
- USCPC Plants: 620°C+ to 600°C
- SCPC Plants: <600°C to 565°C

Expected availability can increase with time/learning.

Not all technologies at the same level of maturity.

After EPRI and others.

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Current CO₂ Injection and Storage Projects

- **50 Acid Gas injection sites in North America**
- **4 New CO₂-EOR Pilots in Canada**
- **70 CO₂-EOR projects in U.S.A.**
- **10 New 1Mt injection projects in U.S.A.**

Key:
- **Depleted Oil Field**
- **ECBM projects**
- **EOR projects**
- **Gas production Field**
- **Saline aquifer**

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Sleipner, Norway – injecting 1mt since 1997
In Salah

- Algeria
- BP with Sonatrach & Statiol
- Started in 2004
- Natural gas clean-up
- Storing 1 million tons of CO2 annually
- Injecting into reservoir aquifer
Weyburn

- Capture from coal gasification in the USA by Dakota Gas
- Injection for enhanced oil recovery in Canada by Encana
Size matters!

Cumulative globally sequestered CO$_2$  Weyburn (2000)

Cumulative global need to sequester CO$_2$  Sleipner (1996)
Demonstration Project Initiatives

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>Plans to support up to 12 demonstration projects under its 2007 Directive on Sustainable development of energy from fossil fuels</td>
</tr>
<tr>
<td>UK</td>
<td>Demonstration programme announced with direct financial support for CCS component</td>
</tr>
<tr>
<td>Norway</td>
<td>Incoming Government defined new policy to introduce new NGCC plant with CCS</td>
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<tr>
<td>Australia</td>
<td>Coal 21 Programme established to fund demonstration projects</td>
</tr>
<tr>
<td>USA</td>
<td>Multi billion $ research programmes on Carbon Sequestration and FutureGen established</td>
</tr>
<tr>
<td>Canada</td>
<td>Government/Private sector Task Force established to implement CCS</td>
</tr>
<tr>
<td>BP/Rio Tinto</td>
<td>Joint venture company Hydrogen Energy established to develop CO₂ free power plants</td>
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</tbody>
</table>
Proposed Integrated CCS Projects

Key
- LNG
- Pre-Combustion Capture
- IGCC
- Oxy-Fuel
- Post-Combustion

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Potential CCS demonstration projects
North Sea Basin Task Force

Objectives: In brief, the objectives of the Task Force are to develop broad, common principles that could:

- Form the basis for regulating the transport, injection and storage of CO₂ in the North Sea, and
- Provide a consistent basis for managing the transport, injection and storage of CO₂ in the North Sea.
- Promote the deployment of CO₂ in geological formations beneath the North Sea.

<table>
<thead>
<tr>
<th>Potential barriers or enablers</th>
<th>International (I), Regional (R), National (N)</th>
<th>Expected time until solved</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNFCC-PCC National Inventories</td>
<td>N, I</td>
<td>&lt; 2 years</td>
</tr>
<tr>
<td>Kyoto Protocol (CDM and JJ)</td>
<td>I</td>
<td>&lt; 2 years</td>
</tr>
<tr>
<td>UNCLOS</td>
<td>I</td>
<td>&lt; 2 years</td>
</tr>
<tr>
<td>London Convention and Protocol</td>
<td>I</td>
<td>&lt; 2 years</td>
</tr>
<tr>
<td>OSPAR</td>
<td>R</td>
<td>&lt; 2 years</td>
</tr>
<tr>
<td>Trans-boundary movement and/or damage</td>
<td>I</td>
<td>&lt; 2 years</td>
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<tr>
<td>Aarhus Convention</td>
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<tr>
<td>EU ETS</td>
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<tr>
<td>EU enabling legal framework</td>
<td></td>
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<tr>
<td>UK Regulations and CCL</td>
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<tr>
<td>Norway regulations and CCL</td>
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<tr>
<td>Long-term liability</td>
<td></td>
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<tr>
<td>Risk assessment methods</td>
<td></td>
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<td>Risk acceptance, including site approval criteria</td>
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<td>Monitoring and verification</td>
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<td>Public support</td>
<td></td>
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<tr>
<td>Accounting and certification of credits</td>
<td></td>
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<tr>
<td>Costs and economics</td>
<td></td>
<td></td>
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<tr>
<td>Incentives</td>
<td></td>
<td></td>
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<tr>
<td>Technology maturity</td>
<td></td>
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</tr>
</tbody>
</table>

**Adapted from:** IEA Greenhouse Gas R&D Programme

**Image:** Storing CO₂ under the North Sea Basin

**Technical Report:** Norwegian Ministry of Petroleum and Energy

**Report:** Report No. 2006-1/28

**Date:** December 2006

**Author:** Norwegian Vegetable

**Website:** [www.ieagreen.org.uk](http://www.ieagreen.org.uk)
Time line for CCS deployment in Europe

- EC CCS Directive: Agreed 2009
- National Regulations: In Place
- First Demos Operational
- Full Scale Commercial Deployment

- 2008
- CCS can be ‘opted in’ ETS Phase II
- CCS Fully Included in ETS

- 2012

- 2016
- 12 Demonstration Projects Implemented

- 2020

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European Utility Position on CCS

• European utilities co-operating in EU research activities and national R&D programmes
• Technology preferences do differ - all options still on the table
• One position can be considered as:
  • Post combustion capture for near term application and retrofit
  • Second generation PCC technology needed
• Other technologies favoured by some and not others for future applications
  • Oxyfuel – Vattenfall
  • RWe, E.On and NUON - IGCC
COMMERCIAL

Pre-combustion
Post-combustion
Oxyfuel
Cryogenic

500 MW
- Mongstad, No
- Nuon - Magnum, NL

100 MW
- Karsto, No
- RWE, Nordrhein, D
- Vattenfall, Janswalde, D
- ENCOGEN, NL
- UK Competition
- Nordjyllandsværket,
  Vattenfall, De

0 MW
- SEQ Project, NL
- TOTAL, Lacq, F
- Vattenfall Schwarze Pumpe, D
- CUIDAD, Es
- CATO/CASTOR/BRINDISI

NATURAL GAS
LIGNITE
COAL

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Challenges Facing Demonstration Projects

• All pilot projects will proceed with industrial, governmental and EC financial support.
• Will on part of power companies for demonstration projects to proceed
• Influencing factors include:
  • Regulatory development
  • Investment cost uncertainty
  • Project financing
  • Public acceptance

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## Which Will Succeed?

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Project</th>
<th>Political Will</th>
<th>Financing</th>
<th>Regulations</th>
<th>Go Ahead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>Karsto</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2011</td>
</tr>
<tr>
<td></td>
<td>Mongstad</td>
<td></td>
<td></td>
<td></td>
<td>2014</td>
</tr>
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<td></td>
<td>DF-1</td>
<td>Yes?</td>
<td>No</td>
<td>Yes?</td>
<td>NO</td>
</tr>
<tr>
<td>Coal (IGCC)</td>
<td>FutureGen</td>
<td>Yes?</td>
<td>Yes?</td>
<td>Yes</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Nuon</td>
<td>Yes</td>
<td>Yes?</td>
<td>Yes</td>
<td>2015+?</td>
</tr>
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<td></td>
<td>RWE</td>
<td>Yes</td>
<td>Yes?</td>
<td>?</td>
<td>2015+?</td>
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<tr>
<td></td>
<td>DF-3</td>
<td>Yes</td>
<td>Yes?</td>
<td>Yes?</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>ZeroGen</td>
<td>Yes</td>
<td>Yes?</td>
<td>Yes</td>
<td>2015+?</td>
</tr>
<tr>
<td>Coal (PC)</td>
<td>UK Demo</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>Vaestad</td>
<td>Yes</td>
<td>?</td>
<td>?</td>
<td>2015?</td>
</tr>
</tbody>
</table>
International Activities

- Large number of projects being proposed
- Several falling by the wayside already
- Will demonstrate a portfolio of technology if all succeed
- Will we get 20 demos by 2020
  - Who knows?