Global Developments in Industrial CCS & Overview of IEAGHG Industry CCS Activities.

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General Manager
IEA Greenhouse Gas R&D Programme
CCS in Industry Workshop
Vienna, Austria
28th April 2014
2013 CCS Roadmap: Key findings

- CCS is a **critical component** in a portfolio of low-carbon energy technologies, contributing 14% of the cumulative emissions reductions between 2015 and 2050 compared with business as usual.

- The individual component technologies are generally well understood. **The largest challenge is the integration** of component technologies into large-scale demonstration projects.

- Incentive frameworks are urgently needed to deliver upwards of **30 operating CCS projects by 2020**.

- CCS is not only about electricity generation: 45% of captured CO₂ comes from **industrial applications** between 2015 and 2050.

- The largest deployment of CCS will need to occur in **non-OECD countries, 70% by 2050**. China alone accounts for 1/3 of the global total of captured CO₂ between 2015 and 2050.

- The urgency of CCS deployment is only increasing. **This decade is critical** in developing favourable conditions for long-term CCS deployment.
Rationale for CCS: Only large-scale option for many industries

CCS is the only large-scale mitigation option for many industrial sectors.
Commercial Application of CCS (to date)

- **Sleipner**: 1 Mt/y CO₂ (1996)
- **Weyburn**: 2.5 Mt/y CO₂ (1998)
- **In-Salah**: 1.2 Mt/y CO₂ (2000)
- **Snohvit**: 0.7 Mt/y CO₂ (2002)
- **Gorgon**: 4 Mt/y CO₂ (2004)

**Locations and Pipelines**

- **Sleipner**: 350km overland pipeline
- **In-Salah**: 160km sub sea pipeline

**Timeline**

- 1996
- 2000
- 2004
- 2008
- 2012
- 2014
- 2016
- 2018
Industry Sector drivers

- CO₂ removed to meet pipeline standards
  - High purity CO₂ stream
- Additional costs of injection low relative to power plant
  - Norway = offshore emission tax $35/t
- CO₂ capture plants in close proximity to storage resources
- Industry has gas injection/storage reservoir expertise
Major CCS Demonstration Projects

Project Locations & Cost Share

**FutureGen 2.0**
Large-scale Testing of Oxy-Combustion w/ CO₂ Capture and Sequestration in Saline Formation
Project: ~$1.65B – Total; ~$1.0B – DOE
SALINE – 1M MTPY 2017 start

**Summit TX Clean Energy**
Commercial Demo of Advanced IGCC w/ Full Carbon Capture
~$1.7B – Total, $450M – DOE
EOR – ~2.2M MTPY 2017 start

**HECA**
Commercial Demo of Advanced IGCC w/ Full Carbon Capture
~$4B – Total, $408M – DOE
EOR – ~2.6M MTPY 2019 start

**Air Products and Chemicals, Inc.**
CO₂ Capture from Steam Methane Reformers
EOR in Eastern TX Oilfields
$431M – Total, $284M – DOE
EOR – ~0.93M MTPY 2012 start

**Leucadia Energy**
CO₂ Capture from Methanol Plant
EOR in Eastern TX Oilfields
$436M – Total, $261M – DOE
EOR – ~4.5M MTPY 2017 start

**Southern Company**
Kemper County IGCC Project
Transport Gasifier w/ Carbon Capture
~$4.12B – Total, ~$270M – DOE
EOR – ~3.0M MTPY 2014 start

**NRG**
W.A. Parish Generating Station
Post Combustion CO₂ Capture
$775 M – Total
$167M – DOE
EOR – ~1.4M MTPY 2016 start

**Archer Daniels Midland**
CO₂ Capture from Ethanol Plant
CO₂ Stored in Saline Reservoir
$208M – Total, $141M – DOE
SALINE – ~0.9M MTPY 2015 start
## Portfolio of Capture and Storage Approaches

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Sequestration</th>
<th>Feedstock</th>
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<td>Power</td>
<td>Industrial</td>
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<td>Pre-combustion</td>
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<td>Southern-Kemper Co. (IGCC)</td>
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<td>Leucadia, Lake Charles (Methanol &amp; Hydrogen)</td>
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<td>ADM (Ethanol Production)</td>
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<td>FutureGen 2.0</td>
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*Rate in million metric tons per year

- CCPI
- ICCS
- FutureGen 2.0

U.S. DEPARTMENT OF ENERGY
Fossil Energy
Archer Daniels Midland Company (ICCS)

CO₂ Capture from Biofuel Plant

- Decatur, IL
- CO₂ is a by-product (>99% purity) from production of fuel grade ethanol via anaerobic fermentation
- Up to 90% CO₂ capture; dehydration (via triethylene glycol) and compression – ~900,000 tonnes CO₂/year
- Sequestration in Mt. Simon Sandstone saline reservoir
- Total Project: $208 Million
  DOE Share: $141 Million (68%)

Key Dates
- Phase 2 Awarded: Jun 15, 2010
- FEED Complete: Apr 2011
- NEPA FONSI: Apr 2011
- Construction start: May 2011
- UIC Class VI Injection Well Permit: Q2 2014
- UIC Class VI Operating Permit: Jan 2015
- Sequestration start: Feb 2015

Status
- Construction ~60% complete
- UIC Class VI permit submitted: Jul 2011
- Two monitoring wells drilled: Nov 2012
- Commissioning compression and dehydration: began in July 2013
Leucadia Energy (ICCS)

Pet coke Gasification to Methanol

- Lake Charles, LA
- GE Energy Gasification
  (4 gasifiers: 3 hot/1 spare)
- 700 million gallons/year methanol; 110 mm scfd hydrogen
- Fuel; Pet coke
- 89% CO₂ capture (Rectisol® process);
  4,500,000 tonnes CO₂/year
- CO₂ to Denbury pipeline for EOR in Texas at
  West Hastings oil field
- Total Project: $436 Million

Key Dates
- Phase 2 awarded: Jun 17, 2010
- Complete CCUS FEED: Jul 2011
- Financial close: March 2014 (est.)
- Construction: March 2014 (est.)
- Operation: Mar 2017 (est.)

Status
- Product off-take contracts finalized (BP, APCI)
- NEPA ROD released on Dec 28, 2013
- FEED in progress for gasification plant
Air Products & Chemicals (ICCS)

Steam Methane Reforming with CO₂ Capture

• Port Arthur, TX (Hydrogen plant at Valero Refinery)
• 90%+ CO₂ capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding ~925,000 tonnes CO₂/year
• ~30 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and compression equipment
• CO₂ to Denbury for EOR - West Hastings oilfield
• Total Project: $431 Million
  DOE Share: $284 Million (66%)

Key Dates
- Phase 2 Awarded: Jun 15, 2010
- FEED complete: Nov 2010
- Permit By Rule (PBR) and Standard Air Permits issued: May 2011
- NEPA FONSI: Jul 2011
- Construction start: Aug 2011
- Operation start: Dec 2012

Status
- PA-1 initiated operation: Mar 3, 2013
- PA-2 initiated operation: Dec 16, 2012
  - Operating continuously since Dec 31, 2012
  - Total CO₂ delivered: 680K tons (Dec 2013)
  - Full capacity achieved: April 2013
- Final MVA report submitted: Feb 2013
CO₂ as an EOR agent has been endorsed:
• Success of the ESI CCS Project and Rumaitha / Bab Injection are key to future development.

Changing landscape in Abu Dhabi with potential CO₂ targets for field testing and development:
• CO₂ capture linked to ADNOC field demand and performance;

Whilst preliminary, the EAA CCS Value Proposition study forecast a growing CO₂ demand in the next 25-30 years, based on ADNOC estimations.
EU 2011 Roadmap for a competitive low carbon economy in 2050,

Emission reductions will be required to take place in all sectors,

\( \text{CO}_2 \) emissions from the industrial sectors reduced by 34% to 40% by 2030, and by between 83% to 87% by 2050.

Only CCS can provide the required large-scale emission reductions in EU industry
US Industrial CCS Drivers

CO₂-EOR OPERATIONS, CO₂ SOURCES: 2014

Oil production, 2014
- CO₂-EOR projects: 136
- Oil production, 1,000 b/d: 300

CO₂ supplies, 2014
- Number of sources: 17
  - Natural: 5
  - Industrial: 12
- CO₂ supply, M Mcf/d:
  - Natural: 2.8
  - Industrial: 0.7

136 Number of CO₂-EOR projects
- Natural CO₂ source
- Industrial CO₂ source
- CO₂ pipeline
- CO₂ proposed pipeline

Source: Advanced Resources International Inc. based on US EOR Heavy Oil Survey 2014 and other sources.
CO2-EOR Driving Expansion Of Industry CCS.
EU Industry considerations

- Core business is making globally competitive products e.g. steel, cement, chemicals…….
- Is there a business case for CCS in industry?
  - Probably not – price on CO2 currently too low
- Industry has no experience of transport and storage
  - same as power sector initially
- Ideally would like a storage company to handle out of gate storage
  - No market outside North America such as EOR
  - In EU therefore no such companies currently exist
Infrastructure considerations

- Each industrial site will be site specific
  - No generalities possible like CCS Ready Guidelines for Power sector
- Need a gas gathering system?
  - More than one stack
  - Central capture plant or multiple?
  - Or do you target most competitive single source – 45% capture enough
- Development of transport infrastructure
  - Strategic planning
  - Who pays?
Hubs and Clusters

- Port of Rotterdam
- Port of Antwerp (Belgium)
- LeHavre (France)
- Humberside
- Baltic Sea Energy Co-operation (BASREC)
Experience to date

- Experience from demonstration projects in power sector
  - Need to start storage assessments early
  - Highest source of project risk
  - Large up front cost, which you may lose
    - Who pays for those costs and takes the risks?
  - Who undertakes work? – geological surveys or geoengineering contractors
- Biggest issue regarding public acceptance
  - Security of storage issues
Some Examples of CCS Research in Steel Industry

- **ULCOS Project - Europe**
  - Developing oxy blast furnace with top gas recycle and capture

- **Japan - COURSE 50 Project**
  - Demonstrate post combustion capture from blast furnace – 30tpd pilot scale

- **Korea**
  - Demonstrate ammonia scrubbing of blast furnace gas, 2\textsuperscript{nd} stage pilot testing (~10tpd)
CCS Research in Cement Industry

- European Cement Research Association (ECRA)
  - Phased development project for pilot scale demonstration of oxy fuel firing of cement kiln in late 2013.

- NORCHEM/CLIMIT & ECRA
  - Pilot scale project for post combustion capture on cement kiln in 2013/14

- ITRI – Taiwan
  - 10 MW Calcium Looping pilot plant constructed in 2013
Industry CCS activities

- **Steel sector**
  - 1st Steel industry CCS workshop with VDEH in Germany in November 2011
  - Techno- economic assessment of CCS in steel sector – completed 2013
    - Included a case evaluating Oxy-Blast Furnace with TGR & MDEA CO2 Capture
  - Overview of the current state and future development of CO2 capture technologies in the Iron Making Process, TR3, April 2013
  - 2nd Steel industry CCS workshop in Japan November 2013 – collaboration with WSA and IETS

- **Cement Industry**
  - Techno- economic assessment completed in 2008
  - Studies on barriers to implementation completed in 2013 (with GCCSI)

- **Oil Refining Sector**
  - Techno- economic assessment to start mid 2014
  - Industrial sources of Hydrogen to start late 2014

- **Natural Gas Processing**
  - CO2 Capture by novel solid adsorption processes underway

- **Pulp and Paper** - Study in planning for 2015 start
October 5 - 9
TWO THOUSAND FOURTEEN
AUSTIN, TX – USA

www.GHGT.info

Technical Programme
• Two technical sessions
  – 10 papers on CCS in Industry
• 20 industry CCS papers in poster sessions
• One panel discussion session on Industrial CCS

Key dates
• Registration opened 7th March 2014
• Early bird closes 13th June 2014