CCS in industry and niche markets

Tom Mikunda, 7th March 2012, Mexico City
Agenda

• Emissions from industry
• IEA BLUE Map Scenario
• Capture options for major industrial processes: -
  - Cement
  - Iron and steel
  - Refineries
• CCS in niche sectors
• CCS with biomass
• Costs of deployment
• Case studies
• Key messages
• 40% of global CO₂ emissions from industry
• Emissions from industry expected to more than double by 2050
Why consider CCS for industry?

• There are few alternatives for making deep emission cuts in industries such as cement and steel production.

• Energy efficiency has a role, but many unit processes already optimised.

• Alternative materials and production processes (i.e. steel production through electrolysis) at early stages of development

• Heterogeneity of industry presents challenges and opportunities

• Early low cost opportunities for CCS deployment exist within industrial and upstream sectors ‘niche markets’
Carbon Capture and Storage in Industrial Applications:

Technology Synthesis Report
Working Paper - November 2010

Technology Roadmap
Carbon Capture and Storage in Industrial Applications
IEA ‘BLUE Map’ scenario

• By 2050, 50% reduction in annual CO₂ emissions from 2005 levels
• Bottom-up MARKAL model that uses cost optimisation to identify least cost mixes of energy technologies and fuels to meet energy demand
CO₂ reduction in the cement industry

• 30% of direct CO₂ emissions from industry globally

• CO₂ is produced through calcination ‘process CO₂’ (60%) and the heat requirement ‘fuel CO₂’.

• CO₂ emissions from calcination are largely unavoidable

• Abatement options include:
  - Thermal and electrical efficiency
  - Alternative fuel use
  - Clinker substitution
  - Carbon capture and storage

• Both post-combustion technologies and oxyfuel can be considered
Cement – post combustion

- Retrofit possible
- Cement production unaffected
- Steam needed for solvent regeneration - €50/ton captured
CO₂ reduction in the iron and steel industry

- 19% of direct emissions from industry
- 70% of global steel production from integrated steel mills
- Between 65% and 75% of CO₂ emission from the burning of coke in the blast furnace – flue gas rich in CO and CO₂
- The use of CO₂ capture is being investigated for a number of steel production process:
  - Top gas recycling in blast furnaces
  - Direct reduced iron
  - HIsarna smelting reduction process
Top gas recycling blast furnace

- Iron ore smelted, use of coke as fuel and reductant – 65-75% emissions from BF
- Useful components – CO+H₂ can be recycled back into the furnace and reused as reducing agents, reduce use of coke.
- Process can be retrofitted
- Successfully tested at LKAB Sweden in 2007 – 2015 commercial?
### Where to capture CO$_2$ from refineries?

<table>
<thead>
<tr>
<th>CO$_2$ emitter</th>
<th>Description</th>
<th>% of total refinery emissions</th>
<th>Concentration of CO$_2$ stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heaters and boilers</td>
<td>Heat required for the separation of liquid feed and to provide heat of reaction to refinery processes such as reforming and cracking Post/Pre/Oxyfuel?</td>
<td>30-60 %</td>
<td>8-10%</td>
</tr>
<tr>
<td>Utilities</td>
<td>CO$_2$ from the production of electricity and steam at a refinery. Post/Pre/Oxyfuel?</td>
<td>20-50%</td>
<td>4% (CHP Gas turbine)</td>
</tr>
<tr>
<td>Fluid catalytic cracker</td>
<td>Process used to upgrade a low hydrogen feed to more valuable products Post combustion of flue gases</td>
<td>20-35%</td>
<td>10-20%</td>
</tr>
<tr>
<td>Hydrogen manufacturing</td>
<td>For numerous processes, refineries require hydrogen. Most refineries produce this hydrogen on site. The requirements for Hydrogen increase with demands of stricter fuel quality regulation. Compression / Low cost</td>
<td>5-20%</td>
<td>90-99%</td>
</tr>
</tbody>
</table>
CCS in niche markets

- Carbon capture from dilute gas streams (4-14% CO₂) is the most expensive part of the CCS chain.
- The CO₂ must be concentrated to >95% in order to make transport and storage feasible.
- Impurities can also be present which require gas conditioning.
- There are a number of industrial process that include high-purity CO₂ offgases:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Source</th>
<th>CO₂ Conc (%)</th>
<th>Pressure (Mpa)</th>
<th>Partial pressure (CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas processing</td>
<td>Process (amine/memb)</td>
<td>100</td>
<td>0.9</td>
<td>0.05 - 4.4</td>
</tr>
<tr>
<td>Ammonia/Fert</td>
<td>Process (gasifier/reform)</td>
<td>100</td>
<td>2.8</td>
<td>0.5</td>
</tr>
<tr>
<td>H₂ production</td>
<td>Process (gasifier/reform)</td>
<td>15 - 100</td>
<td>2.2 - 2.7</td>
<td>0.3 - 0.5</td>
</tr>
<tr>
<td>CtL</td>
<td>Process (gasifier)</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ethylene oxide</td>
<td>Process (desorption)</td>
<td>100</td>
<td>2.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Industry total = 7.6 GtCO₂
High purity total = 0.37 GtCO₂
Biomass

- Fermentation of biomass to ethanol – concentrated CO₂ stream
- Biomass with CCS – negative CO₂ emissions!
- Existing biomass industry based on 1ˢᵗ gen unsustainable biomass – 2ⁿᵈ gen in development
- Demand for biomass products needs stimulating (biofuel/BioSG)
- How to credit for negative emissions?
Costs of CCS in industry

- High-purity
- Biomass conversion
- Cement
- Iron and steel
- Refineries

Cost of abatement (USD/tCO₂ avoided)
Current and potential industrial projects

- GREEN HYDROGEN – Air Liquide, Rotterdam, North Sea. Capture CO$_2$ from hydrogen production, shipping to mature Danish oil fields and injected for EOR. Applied for NER300 – 2016?

- IN SALAH CCS PROJECT – BP, Sonatrach, Statoil, Algeria. Capture from natural gas processing plant, storage in depleted gas reservoir. 1.2 Mt CO$_2$ injection per year since 2004

- ARCELORMITTAL & ULCOS – Florange, France. Post-combustion capture from blast furnace, storage in onshore saline aquifer. Applied for NER300 funding – 2015?

- EMIRATES STEEL INDUSTRIES – Abu Dhabi, UAE. Capture from steel production plant, 0.8 MTCO$_2$ per year for use in EOR. Expected operation date 2015
Key messages

• There is significant potential for CCS to reduce emissions from industry

• In some cases, CCS may be the only option to decarbonize certain industrial processes

• The majority of research has focused on applying CCS to power generation, however fundamental processes are similar

• Current demonstration initiatives are industry led, knowledge (cost) sharing issues.

• High-purity ‘niche sectors’ combined with CO₂ utilization could provide the first true business cases for CCS
Thankyou

mikunda@ecn.nl