Carbon capture – Potentials and barriers in the Nordic countries

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Outline

- Background
- Carbon capture technologies
- CO$_2$ capture potential in Nordic countries
- CCS barriers in general
- Challenges and barriers to CO$_2$ capture in main Nordic industry sectors
- CCS in Finland
- Meri-Pori
- The way forward
Why do we need to capture CO$_2$?
Postcombustion capture (absorption process)

POTENTIALS

- Closest to commercial scale - several commercial actors
- CO2 source/industry irrelevant
- Retrofit – suitable and easy
- New generation solvents require less energy – more efficient utilization of lower level heat (improved regeneration)
- Several small scale pilots existing – next: Demonstration

CHALLENGES

- Significant CAPEX investment (CO2 conc.)
- Large drop in plant efficiency (power plant 10 – 15 %-units) – increase in electricity production costs
- Require large amount of chemicals (cost + environmental/health effects)
- Treatment of waste streams
- Equipment corrosion
- Lay-out restrictions in existing plants
- Still at development stage for use in other than (petro)chemical industry
  - Dust levels
  - Amine inhibitors (SOx, NOx, HM)
  - Degradation products (nitrous amines)
Precombustion (decarbonisation) capture

POTENTIALS
- Pressurized CO\(_2\) capture mature
- Higher CO\(_2\) content (15 – 60 vol-%)
- Physical solvents (20 – 40 bar)
- Less expensive capture technology (stripping of CO\(_2\) from pressurized processes)
- Lowest drop in plant efficiency compared to other capture technologies
- Worldwide development mainly focused on IGCC and NGCC
- Potential for development

CHALLENGES
- Mainly for IGCC, NGCC, natural gas reforming and production of H\(_2\)
- Combustion of H\(_2\) in gas turbine still in development phase
- CAPEX in line with competing technologies
- Issues related to IGCC technology
  - Technological barriers
  - Complicated IGCC process – not mature – expensive
  - Only few IGCC plants operating
  - IGCC not yet commercially successful

CO-shift: CO + H\(_2\)O → H\(_2\) + CO\(_2\)

Source: Vattenfall
Oxyfuel (O₂/CO₂ recycle) combustion capture

**POTENTIALS**

- High CO₂ concentration
- Moderate energy penalty
- Development potential: Large energy requirements for production of O₂ (e.g. membranes)

**CHALLENGES**

- Primarily applicable only to new power plants
- Technical challenges
  - Operational conditions
  - Overall availability even without CCS
  - Impurity levels
- Requires ASU and handling of O₂
  - Safety
  - CAPEX
  - High energy demand

Source: Vattenfall
Nordic industrial sectors

- Offshore oil and gas
- Oil and gas refining
- Iron and steel
- Non-ferrous metal
- Pulp and paper
- Chemicals, cement and lime
- Power production incl. biofuels
Nordic CO$_2$ emissions > 0.1 Mt/a (2007)

**Facility**
- Cement and lime production
- Iron and steel production
- Non-ferrous metal production
- Offshore oil and gas activities
- Oil and gas refineries
- Other
- Power and heat production
- Production of chemicals
- Pulp and paper production
- Waste treatment or incineration

**Fossil and inorganic CO$_2$ emissions**

**Biogenic CO$_2$ emissions**

- CO$_2$ (Mt/a)
  - 0.1 – 0.5
  - 0.5 – 1.0
  - 1.0 – 1.5
  - 1.5 – 2.0
  - 2.0 – 3.0
  - 3.0 – 4.0
  - 4.0 – 5.0
Barriers to CCS in general

**ECONOMIC**
- Abatement potential vs. cost
- Capture + compression = 75% of total cost
- Costs vary largely (e.g. power production cost up by 20–90%)
- Financial mechanisms – financial conditions not in order
  - Must be covered: tax, subsidies, higher electricity price
- Investment risk (not long-term political decisions)
- The first plants are prototypes!

**POLICIES AND REGULATIONS**
- Global political consensus still missing
  - Ambitious EU targets
- EU CCS Directive implementation
  - CCS in EU ETS – coming 2013
- National and international legislation and regulation – no single solution for all industry
  - Investment in CCS requires long-term political solutions

**PUBLIC PERCEPTION**
- Potential showstopper
  - 4–22% know about CCS
  - Not given that people know about the link between CO₂ and climate change
  - Many respondents who claim that they know about CCS fails to identify what problem it seeks to address
  - Pseudo-opinions (opinions despite little or no knowledge)
  - Information about CCS can increase or decrease support

**SCALE-UP**
- Capture technology in power plant still at development stage
- Vattenfall largest pilot in Germany: Schwarze Pumpe (30 MWth) oxy-fuel

Source: Buhr/IVL
The challenge of scale-up

(CCS: 18% from global electricity production)

[IEA 2008, ACT-scenario]

Stabilizing at 450 ppmv
Cumulative Global Carbon Stored
Between 2010-2050:
~ 100,000 MtCO₂

Stabilizing at 550 ppmv
Cumulative Global Carbon Stored
Between 2005 and 2050:
33,000 MtCO₂

Cumulative U.S. Carbon Stored
Between 2005 and 2050:
8,000 MtCO₂

World CCS Projects
Projected Lifetime CO₂ Storage
0-10 MtCO₂
10-20 MtCO₂
20-30 MtCO₂
> 250 Million tons CO₂
(approximate amount CO₂ storage needs of one 1000MW IGCC operating for 50 years)

[Joint Global Change Research Institute, Pacific Northwest National Laboratory Battelle, IEA 2008]
## Deployment of carbon capture in different industrial sectors

<table>
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<th>Industry</th>
<th>Technologies</th>
<th>Potentials</th>
<th>Barriers</th>
<th>Deployment</th>
<th>Cost</th>
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<td>Power production</td>
<td>Post-combustion</td>
<td>Large sector and large point sources</td>
<td>Efficiency drop</td>
<td>Mostly developed</td>
<td>Base case</td>
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<td>Pre-combustion</td>
<td>Most focus/development</td>
<td>Low CO₂ concentration</td>
<td>Scale-up to commercial</td>
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<td>Oxy-fuel combustion</td>
<td>Carbon intensity of power production</td>
<td>EU ETS allowance price</td>
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<td>Advanced</td>
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<tr>
<td>Iron and steel</td>
<td>Post-combustion</td>
<td>Current processes are dependent on coal</td>
<td>Carbon leakage</td>
<td>NER 300 – OBF</td>
<td>Potentially lower</td>
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<td></td>
<td>Oxygen Blast Furnace (OBF)</td>
<td>Large point source emission</td>
<td>CO₂ neutral steel plant is not possible within feasible frames</td>
<td>Demonstration: European steel producers, France</td>
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<td>Pilot plant Sweden</td>
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<td>Cement and lime</td>
<td>Post-combustion</td>
<td>Local end-product market</td>
<td>No carbon leakage –</td>
<td>Little research</td>
<td>Potentially lower</td>
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<td></td>
<td>Oxy-fuel combustion</td>
<td>High CO₂ concentration</td>
<td>local markets</td>
<td>No project experience</td>
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<td>Calcium Looping Cycle</td>
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<td>Flue gas contaminants</td>
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<td>No power production</td>
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<td>Pulp and paper</td>
<td>Post-combustion</td>
<td>28% of Nordic CO₂ emissions</td>
<td>Carbon leakage</td>
<td>No industrial initiatives</td>
<td>Higher cost</td>
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<td>Pre-combustion</td>
<td>Potentially high CO₂ concentration</td>
<td>Biogenic CO₂</td>
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<td>Carbon sink</td>
<td>Small point source emissions</td>
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<td>Limited potential in</td>
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<td>Europe</td>
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<tr>
<td>Oil and gas</td>
<td>Post-combustion</td>
<td>Large emissions</td>
<td>(Carbon leakage) –</td>
<td>Existing</td>
<td>Potentially lower</td>
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<td>Pre-combustion</td>
<td>Close to storage</td>
<td>refineries?</td>
<td>(drying and compression only)</td>
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<td></td>
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<td>Technology knowledge</td>
<td>Location/space limitations</td>
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<td>EOR</td>
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<td>Waste heat available</td>
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CCS activities in Finland

- CCS Finland (2008 – 2011)
- 2008 – 2010: FINNCAP Meri-Pori CCS demonstration project
- 2011 – 2015: National Carbon Capture and Storage Program CCSP
- Largest CO$_2$ production plant: Neste Oil Refinery
  - Aga Linde produces 400 000 t/a CO$_2$ for commercial use - PSA capture from steam reformer
- Development of power plant concept with CCS
- Industry-driven development of oxy-fuel combustion for fluidized bed boilers
- Development of mineral carbonization processes
- No underground storage possibilities in Finnish ground
  - Baltic Sea, North Sea or Barents sea
- No plans for large-scale projects in near future
FINNCAP Meri-Pori

- Joint demonstration project Fortum and Teollisuuden Voima (TVO)
- 565 MW coal-fired condensing power plant
- 1,25 Mt/a CO₂ (50% of flue gases with 90% capture) – 1,5% of Finnish CO₂ emissions in 2007
- 500 M€ project - EU NER 300

Financial
- Investment would not be feasible
- NER 300 application not submitted

Strategic
- Change of strategy – CCS no longer core business
- No large-scale focus on CCS in the future
The way forward

- Technology development – energy penalty (more efficient use of lower level heat)
- Risk management
  - Development in site selection methods
  - Development in measuring, monitoring and verification of stored CO₂
- Succeeding in CCS technology demonstrations 2010 – 2020
- Increased competitive power of CCS technology compared to other emission reducing methods
- Long-term political decisions
- International commitment → consumers pay
- Ensuring storage stability and safety
- Public acceptance and awareness

Courtesy of Statoil, 2010
Thank you for your attention

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