Filip Johnsson
Energy technology, Chalmers
Strong growth in RES investments

- **Global RES Investments (Billion US$)**
- **Share of Total Primary Energy Demand (%)**

Graph showing an upward trend in global RES investments from 2004 to 2015, with a significant increase around 2010. The share of total primary energy demand also shows a steady increase during the same period.
Strong growth in RES investments – zero reduction in fossil fuel share!

TPED = Total Primary Energy Demand
Primary energy from fossil and NHRES

Fossil fuels

NHRES Non-Hydro Renewables

Johnsson et al, The choice between Scylla and Charybdis for energy policymakers 2016 (forthcoming)
Rationale for CCS

• The abundant resources of fossil fuels
  – CCS makes it easier for fossil fuel-dependent economies to comply with stringent greenhouse GHG reduction targets
  – Without CCS – urgent agreement of making fossil reserves stranded assets will be required

• To stabilize climate to well below 2°C warming (in line with COP21) will require negative emissions post Year 2050 – Bio Energy CCS (BECCS) makes this possible

• To facilitate carbon intensive industry (e.g. cement and iron and steel) to meet stringent emission reductions (such as the Swedish target of zero net emissions by Year 2045)
  – CCS does not replace other measures, but is part of an overall mitigation portfolio
Scandinavia – large emission sources (cluster)

Large emission sources including biogenic

- **Biogenic** – Combined heat and power, pulp and paper, new processes (e.g. for transportation fuels), increased share of biomass feedstock in existing processes
- **Fossil** – cement, iron and steel, refineries

![Biogenic and fossil emission sources](image-url)
Large storage volumes available

https://data.geus.dk/nordiccs/
Example of industrial cases

Oil refinery: Hydrogen production
Preem refinery (SE)

Pulp and paper: Recovery Boiler
SCA (SE)

Power plant: Nordjyllandsverket (DK)

Biogenic emissions

Aluminum plant: Hydro (NO)
Capture rate and amount of CO$_2$ captured

Reduced activity level in refineries

Biomass in iron and steel and cement industries

Reduced fraction of clinker in cement

BAT replacing existing process technology

Without CCS Total potential -35% reduction in Year 2050 relative to Year 2010

Key energy intensive industries in the Nordic countries

With CCS Total potential -85% reductions in Year 2050 relative Year 2010

Key energy intensive industries in the Nordic countries

With CCS Total potential -85% reductions in Year 2050 relative Year 2010

Significant costs due to increased energy use
Large volumes of CO₂ to handle

Example of transportation systems (ship/pipeline)
NORDICCS: Potential pipeline system

Cost declines rapidly as volume increases

<table>
<thead>
<tr>
<th>Dispatch site</th>
<th>Storage site</th>
<th>Distance (km)</th>
<th>Pipe breaking point, Mt CO₂</th>
<th>Cost pipe at breaking point, €/ton</th>
<th>Cost ship at pipe breaking point, €/ton</th>
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</thead>
<tbody>
<tr>
<td>Preem, Lysekil</td>
<td>Gassum</td>
<td>163</td>
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<td>Amager, Köbenh</td>
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<td>Hub NW Jutland</td>
<td>Utsira</td>
<td>490</td>
<td>3.5</td>
<td>13.6</td>
<td>13.8</td>
</tr>
</tbody>
</table>

Note: Feeders & Distribution NOT included

Kjärstad, J. et al., (2013) Recommendations on CO₂ transport solutions, NORDICCS report (D20)
Example - Nordic basic material industry (Cement & Steel)
Measures to comply with Year 2050 targets ~100€/ton CO₂
EU-ETS < 10 €/ton CO₂

Cement industry
Price increase cement +70%

Steel industry
Price increase steel +25%

Price increase building Less than +0.5%
Price increase car Less than +0.5%

Rootzén and Johnsson, (2015)
Se http://www.dn.se/debatt/plan-saknas-for-att-minska-basindustrins-klimatpaverkan/
Chalmers – CCS research

- From basic research to systems studies on conditions for CCS
- Experimentally based research on chemical looping combustion and oxyfuel combustion (unique experimental infrastructure)
- Post combustion capture – assessment of solvents and process evaluation
- Process integration – assessment of integration of CCS technologies in power plants and industrial processes
- Energy systems analysis investigates the role of CCS in a complete mitigation portfolio in the energy system and in different industrial sectors. Includes studies on how to ramp-up of transportation and storage infrastructure
- Significant spin-off research (e.g. pressurized flue gas cleaning and industrial combustion processes)

100 kW combustion unit for oxyfuel and air-combustion
• CCS is required if Sweden should take lead in reduction in carbon emissions from energy and industry
  — Large biomass resources - negative emissions possible
  — High knowledge - Chalmers, technology providers, process and materials industry

• BECCS and CCS part of a portfolio of measures
  — Does not replace other measures

• Policy measures: New ways of pricing CO2 emissions is required
  — Analysis of the entire supply chain from basic materials to end products – yield small price increase
  — If the world moves towards 1,5ºC warming – per definition very high demand for non-emitting products and services
  — Incentives for negative emissions required

• Sweden: ”bred nollutsläppsstrategi för basmaterialindustrin bör utvecklas” (Miljömålsberedningen SOU 2016:21, Energikommissionen, SOU 2017:2)
New project!

MISTRA Carbon Exit