The post-2020 Cost-Competitiveness of CCS
The Costs of CCS –
Post-Demonstration CCS in the EU

1. The process of the study
2. Overall conclusions for integrated CCS projects
3. Capture
4. Transport
5. Storage
6. Next steps
Why is it unique?

» Publicly available cost data on CCS are scarce
» Reliable base for ZEP estimations used new, in-house data provided exclusively by 15 ZEP member organisations (power cos. & power plant CO2 capture equipment suppliers)
» Over 100 contributors and 2 years of work…
» Complete CCS value chains; individual reports analyse costs for:
  • CO₂ Capture
  • CO₂ Transport
  • CO₂ Storage
» Focus on new-build coal- and gas-fired power plants, located at a generic site in Northern Europe from the early 2020s
» The study features a BASE and an OPTIMISED case
» Establishes reference point for costs of CCS, based on a “snapshot” in time (investment costs referenced to Q2 2009)
Key Conclusions

CCS will be cost-competitive with other low-carbon power technologies

- EU CCS demonstration programme will validate and prove the costs of CCS technologies and form the basis for future cost reductions (introduction of 2nd- and 3rd-gen. technologies)
- Results of the reports indicate post-demonstration CCS will be cost-competitive with other low-carbon energy technologies (on-/offshore wind, solar power & nuclear), as a reliable low-carbon power source
Key Conclusions

**CCS is applicable to both coal- and gas-fired power plants**

- CCS can technically be applied to both coal- and gas-fired power plants
- Relative economics depend on power plant cost levels, fuel prices and market positioning, whereas applicability is mainly determined by load regime
- ZEP reports have assumed that in the early 2020s all CCS equipped power plants will operate in base-load
Cost of LCOE for Integrated CCS projects (coal and gas)

Figure 1: The Levelised Cost of Electricity (LCOE) of integrated CCS projects (blue bars) compared to the reference plants without CCS (green bars)

Includes three levels of EUA costs and is based on the following assumptions: costs for an OPTI plant with CO₂ capture; Middle fuel costs; 180 km onshore CO₂ transport; Medium storage costs for an onshore deep saline aquifer.
Total CO₂ Avoidance Costs for Integrated CCS Projects

Figure 10: Total CO₂ avoidance costs for integrated CCS projects – the price of EUAs required to justify building CCS projects vs. a plant without CCS from a purely economic point of view.
Gas price determines relative attractiveness of coal/gas CCS
# Sensitivity analysis

Table 3: Sensitivity parameters and ingoing factors for a supercritical OPTI hard coal-fired power plant, with post-combustion capture; short (180 km) point-to-point transport; and storage in an onshore SA

<table>
<thead>
<tr>
<th>Sensitivity parameters</th>
<th>Ingoing factors</th>
<th>Low LCOE</th>
<th>Medium LCOE*</th>
<th>High LCOE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant load factor</td>
<td>Hours/year</td>
<td>8,000</td>
<td>7,500</td>
</tr>
<tr>
<td></td>
<td>Economic life</td>
<td>Years</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Fuel cost</td>
<td>€/GJ LHV</td>
<td>2</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>WACC</td>
<td>%</td>
<td>6%</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>CAPEX</td>
<td>-25%</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reboiler duty: efficiency drop vs. Reference USC w/o capture</td>
<td>% points</td>
<td>5.5%</td>
<td>7.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CO₂ storage costs</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>- CO₂ stored (capacity one field)</td>
<td>Mt</td>
<td>200</td>
<td>66</td>
</tr>
<tr>
<td>- CO₂ store rate (one field)</td>
<td>Mtpa</td>
<td>5.00</td>
<td>1.65</td>
</tr>
<tr>
<td>- CAPEX storage (one field)</td>
<td>M€</td>
<td>69.5</td>
<td>69.5</td>
</tr>
<tr>
<td>- CAPEX storage (one field)</td>
<td>M€ per (Mtpa)</td>
<td>13.9</td>
<td>42.1</td>
</tr>
<tr>
<td>- OPEX storage (one field)</td>
<td>M€ pa</td>
<td>2</td>
<td>3.1</td>
</tr>
<tr>
<td>- OPEX storage (one field)</td>
<td>€/tonne</td>
<td>0.40</td>
<td>1.88</td>
</tr>
</tbody>
</table>

* Base case
What matters?

Figure 21: Sensitivities of the calculated cost results for a hard coal-fired, supercritical OPTI power plant with post-combustion capture; short (180 km) point-to-point transport; and Medium storage costs for an onshore SA. The nominal cost for this case is €73.6/MWh.
Capture: Key Conclusions

All three CO₂ capture technologies could be competitive once successfully demonstrated

- Currently no clear difference between capture technologies & all could be competitive once successfully demonstrated (using agreed assumptions & LCOE as main quantitative value)
- Fuel/investment costs are main factors influencing total costs
- Reports include the three main capture technologies (post-combustion, pre-combustion and oxy-fuel)...
- …but exclude second-generation technologies (e.g. chemical looping, advanced gas turbine cycles)
- The LCOE and CO₂ avoidance costs calculated are higher than those of previous European capture cost studies, but tend to be slightly lower than majority of recent international studies
LCOE for Hard Coal Plants w/CO₂ Capture (capture-costs only)

Figure 14: The LCOE for hard coal-fired power plants with CO₂ capture (using Middle fuel costs)
LCOE for Natural Gas Plants w/CO$_2$ Capture (capture costs only)

Figure 16: LCOE and CO$_2$ avoidance costs for natural gas-fired power plants with CO$_2$ capture are heavily dependent on the fuel cost. The vertical blue lines for €4.5, €8 and €11/GJ represent the Low, Middle and High cases used for gas fuel cost.
Dependence on Plant Load Factor (hard coal) – pre-combustion

Figure 17: Dependence on Plant Load Factor for all three coal technologies, based on OPTI plants. Reference power plant load is kept at 7,500 hours per year for the calculation of CO₂ avoidance costs. Achieving high plant availability is key to keeping costs competitive.
Dependence on Plant Load Factor (hard coal) – post-combustion

Hard coal-fired power plants with post-combustion capture
Dependence on Plant Load Factor (hard coal) – oxy-fuel
Transport: Key Conclusions

Early strategic planning of large-scale \( \text{CO}_2 \) transport infrastructure is vital to reduce costs

- Clustering plants to a transport network can achieve significant economies of scale – in both \( \text{CO}_2 \) transport/storage in larger reservoirs (on- and offshore)
- Large-scale CCS requires the development of a transport infrastructure equivalent to the current hydrocarbon infrastructure
- Greatly reduced long-term costs can be ensured with early strategic planning – including the development of clusters and over-sized pipelines – and the removal of cross-border restrictions
## CO₂ Transport Cost Estimates for Demo Projects

Table 1: Cost estimates (in €/t CO₂) for commercial natural gas-fired power plants with CCS or coal-based CCS demonstration projects with a transported volume of 2.5 Mtpa

<table>
<thead>
<tr>
<th>Distance km</th>
<th>180</th>
<th>500</th>
<th>750</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Onshore pipeline</strong></td>
<td>5.4</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td><strong>Offshore pipeline</strong></td>
<td>9.3</td>
<td>20.4</td>
<td>28.7</td>
<td>51.7</td>
</tr>
<tr>
<td><strong>Ship</strong></td>
<td>8.2</td>
<td>9.5</td>
<td>10.6</td>
<td>14.5</td>
</tr>
<tr>
<td><strong>Liquefaction (for ship transport)</strong></td>
<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
</tr>
</tbody>
</table>
## CO₂ Transport Cost Estimates for Large-Scale Networks

Table 2: Cost estimates for large-scale networks of 20 Mtpa (€/tonne CO₂). In addition to the spine distance, networks also include 10 km-long feeders (2*10 Mtpa) and distribution pipelines (2*10 Mtpa)

<table>
<thead>
<tr>
<th>Spine Distance km</th>
<th>180</th>
<th>500</th>
<th>750</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore pipeline</td>
<td>1.5</td>
<td>3.7</td>
<td>5.3</td>
<td>n. a.</td>
</tr>
<tr>
<td>Offshore pipeline</td>
<td>3.4</td>
<td>6.0</td>
<td>8.2</td>
<td>16.3</td>
</tr>
<tr>
<td>Ship (including liquefaction)</td>
<td>11.1</td>
<td>12.2</td>
<td>13.2</td>
<td>16.1</td>
</tr>
</tbody>
</table>
CO₂ Storage Cost Ranges

Figure 19: Storage cost per case, with uncertainty ranges; purple dots correspond to base assumptions

€/tonne CO₂ stored

Case | Range
--- | ---
1. Onshore DOGF with legacy wells | 1 - 3 - 7
2. Onshore DOGF with no legacy wells | 1 - 4 - 10
3. Onshore SA with no legacy wells | 2 - 5 - 12
4. Offshore DOGF with legacy wells | 2 - 6 - 9 - 14
5. Offshore DOGF with no legacy wells | 3 - 6 - 10 - 14 - 20
6. Offshore SA with no legacy wells | 6 - 10 - 14 - 20

Ranges are driven by setting field capacity, well injection rate and liability transfer costs to Low, Medium and High cost scenarios

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20 www.ieagreen.org.uk
21 www.geology.cz/geocapacity
22 In the commercial phase
Key Conclusions: Storage

A risk-reward mechanism is needed to realise the significant (offshore) aquifer potential for CO$_2$ storage
Key Conclusions

CCS requires a secure environment for long-term investment

- Price of Emission Unit Allowances (EUAs) will not, initially, be a sufficient driver for investment after the first generation of CCS demonstration projects is built (2015 - 2020)
- Enabling policies required in the intermediate period – after the technology is commercially proven, but before the EUA price has increased sufficiently to allow full commercial operation
- The goal: to make new build power generation with CCS more attractive to investors than without it
What’s Next?

- ZEP acknowledges costs of CCS will be inherently uncertain until further projects come on stream

- Cost reports don’t provide a forecast of cost development but…

- …will be updated every two years in line with technological developments and the progress of the EU CCS demo programme

- Future updates will also refer to co-firing with biomass, combined heat and power plants, and the role of industrial applications