Beyond 90% capture – feasible, but at what cost?

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Timeline: Ubiquitous assumption of 90% cap

The concept of CCS was first proposed in 1977 and early studies assessed capturing up to 90% of CO₂ contained in flue gas. This number has since been become ubiquitous without thorough techno-economic optimisation.

- 1.5°C target makes capture rates >90% cap necessary but at what cost?
- Access to cheap capital is crucial to move towards zero-carbon power plants.

Impact of capital recovery factor

The Capital Recovery Factor CRF significantly impacts the capture cost (shown for a gas- and coal-fired case). It is vital to provide access to cheap capital by policy frameworks to move towards zero-carbon power plants.

Effect of scale and CO₂ concentration

The impact of CO₂ source plant size expressed as flue gas flowrate and CO₂ concentration on the capture costs using 30wt% aq. MEA are shown below. Typical power plant and industrial flue gas compositions are highlighted. Capturing CO₂ from dilute streams e.g., gas power, is significantly more expensive than from higher concentrated streams e.g., iron or steel plants. Economy of scale reduces the specific costs for small plants < 100 kg/s.

- Capturing CO₂ from dilute streams is significantly more expensive
- Economy of scale significantly drives costs down only for small plants

Modelling framework

Schematic flow of information and calculation of key characteristics from input (Excel), equation based process model (gPROMS) [1] and output (Excel). The framework has been designed to provide the user with a live feedback as the model is running.

Impact of capture rate on cost

Non-linear trend between CO₂ composition, capture rate, and Total Annualised Costs TAC is driven by economy of scale versus diluting the residual CO₂ to be captured. Marginal cost indicates nearly constant cost <95% cap, and significant increase >98% cap. Table shows capture rate at minimum and range of low TAC.

<table>
<thead>
<tr>
<th>Flue Gas</th>
<th>min TAC ($/tCO₂)</th>
<th>% cap at min TAC</th>
<th>% cap range of low TAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas-fired, $X_{CO₂}$ = 4%</td>
<td>62.5</td>
<td>75</td>
<td>74-85</td>
</tr>
<tr>
<td>Gas-fired with EGR, $X_{CO₂}$ = 8%</td>
<td>42.5</td>
<td>68</td>
<td>&lt; 94</td>
</tr>
<tr>
<td>Coal-fired, $X_{CO₂}$ = 12%</td>
<td>38.5</td>
<td>76</td>
<td>&lt; 96</td>
</tr>
</tbody>
</table>

- Cost minimum is not at capture rate of 90% cap
- Capturing of up to 96% cap (coal) at low marginal cost possible
- Marginal cost of capture at rates beyond 98% cap is very high

Conclusions

1. Capture rates >90% are feasible, with a reasonable cost increase up to a capture rate of e.g., 94%. This unlocks significant capture capabilities, e.g., sequestering an additional yearly 0.13 Mt CO₂ from one coal-fired power plant.
2. Capturing CO₂ from dilute streams e.g., gas fired power plants, is significantly more expensive than from higher concentrated streams e.g., iron or steel plants. Solvent development needs to particularly address low CO₂ sources e.g., gas power.
3. Near-zero emissions from fossil-fuelled power plants possible at low marginal cost up to 98% cap.

References and acknowledgements


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