Integrated assessment of the potentials for CCS in India, China, South Africa ("CCSglobal")

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Carbon Capture and Storage as a Low Carbon Technology

Subject of Intensive Debate

- Research and demos focused mainly on USA, EU, Australia, Canada.
- Recent studies for Germany
  - CCS is not necessarily needed for power generation
  - Due to large potentials of energy efficiency and renewable energies.
- However, currently strong increase of coal use by emerging countries

→ possible role for CCS in large coal-based emerging countries until 2050 (India, China, South Africa)

**Figure 8.8**
Trend of installed capacity in coal-fired power generation

- Rest of the world
- Indonesia
- South Africa
- Australia
- United States
- India
- China
- Share of SC & USC

Source: Analysis based on data from Platts, 2011.

**Key point**
The number of plants planned or under construction indicates that growth of coal-fired power generation in Asia will continue.

Source: IEA & OECD 2012 (ETP)
Main results of the German CCS studies

Electricity generation costs of new power plants (with/without CCS, renewable energies)

Fuel price trajectory / CO₂ penalty trajectory - trajectory: \( \Lambda = \) considerable, \( C = \) very low
(interest rate 6%/a, depreciation period 25 a, variable full load hours)

- Natural gas (CC), AC
- Natural gas (CC)-CCS, CA
- Hard coal (steam), AC
- Hard coal (steam)-CCS, CA
- Lignite (steam), AC
- Lignite (steam)-CCS, CA
- Renewable energy mix
- Renewable mix without photovoltaics
- Offshore wind
Integrated assessment covering five different dimensions

1. Analysis of (effective) CO₂ storage capacity and source-sink matching with the amount of available CO₂ (according to coal development pathways)

2. Analysis of levelised cost of electricity generation without/with CCS (using learning-curve approach)

3. Ecological assessment of electricity generation without/with CCS (via life-cycle assessment)

4. Reserves, availability and price of coal

5. Analysis of stakeholder positions towards CCS (literature analysis, expert meetings and interviews, surveys)
CCSglobal – CO₂ storage assessment and source-sink matching

CO₂ emissions that could be stored in China

<table>
<thead>
<tr>
<th>Effective storage capacity scenarios</th>
<th>Energy and industry emission pathways</th>
<th>Matched capacity (Gt CO₂)</th>
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<tbody>
<tr>
<td></td>
<td>E1+I: high (250 Gt CO₂)</td>
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<tr>
<td>S1: high (1,541 Gt CO₂)</td>
<td>216</td>
<td>52</td>
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<tr>
<td>S2: intermediate (494 Gt CO₂)</td>
<td>205</td>
<td>52</td>
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<td>S3: low (65 Gt CO₂)</td>
<td>45</td>
<td>36</td>
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<td>E2+I: middle (178 Gt CO₂)</td>
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<td>S1: high (1,541 Gt CO₂)</td>
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- Effective storage capacity and therefore matched capacity will further be reduced when technical, legal, economic and acceptance factors are introduced.
- More rigorous assessments of the countries’ effective and matched storage potentials required
CCSglobal – ecological assessment

Low net greenhouse gas emissions reduction (pulverised-coal fired power plant, China)

- Similar effect as in Germany, enhanced by the large coal-bed methane emissions during mining in China.
CCSglobal – ecological assessment
Increase of most other environmental impact categories (per kWh, selected categories, example of China)

**Acidification**

-19% decrease for PC + CCS compared to PC.

58% increase for IGCC + CCS compared to PC.

**Human Toxicity**

47% increase for PC + CCS compared to PC.

57% increase for IGCC + CCS compared to PC.
CCSglobal – resource assessment
Reserves, availability and price of coal (example of China)

- 1st in coal resources, 2nd in coal reserves but reliable data are difficult to obtain
- High ash (23%), low sulphur (1%) content
- Proved recoverable reserves about 115 Gt
  - 1,018/5,570 Gt identified reserves/resources
  - Cumulative production between 1991 and 2010 = 30% of reserve → R/P ratio of 25 ys
- Market mechanisms lead to typical supply pattern
  - Increasing depletion of best qualities in early years, followed by
  - declining production at rising prices and lower quality in the second half of production history
- In recent few years, coal demand of power plants rose much faster than the expansion of domestic production

Source: BP 2010, WEC
CCSglobal – economic assessment
Development of levelised cost of electricity generation of CCS based power plants (from 2020) (example of China)

Basic result
- China: Only with high CO₂-price CCS will be competitive. (Note: Additional GHG-emissions not taken into account)
- For other analysed countries (SA, India) this result does not hold
Concluding hypotheses – main result

Overall integrated assessment of the role of CCS in India, China and South Africa

- Ranking from -2 (strong barrier to CCS) to +2 (strong incentive for CCS)
- Bars: Indicate possible impact variations of storage capacity and cost development.

Source: WI 2012
Main results
Prospects of CCS in India, China and RSA

CCS is not *per se* a low carbon option:

- estimates of the **storage potential** currently highly speculative
- **Economic viability** depends on the introduction of a CO$_2$ **pricing scheme** (With quite high price level for CO$_2$)
- Reduction of CO$_2$ (GHG) emissions per kWh of electricity by 74 to 78 (59 to 74) per cent, but **increase of most other environmental impacts**.
- High coal demand development pathway may lead to significant **resource constraints** and rising coal prices in the medium term.
- Public is not yet involved in the debate and **political decision-makers are currently very cautious**.
Main results

What would be needed to make CCS viable?

- In order to overcome barriers
  - a stronger commitment from the industrialised world in terms of technology demonstration and implementation would be required
  - alongside actions from individual countries and analysis.

- Furthermore,
  - a substantial cost reduction and
  - mechanisms for technology cooperation and transfer to developing countries and emerging economies would be needed.
Thank you for your attention!

Final reports (case studies, summary) of CCSglobal available at:
www.wupperinst.org/CCS/

Contact: peter.viebahn@wupperinst.org
Back-up
CCSGlobal – economic assessment

Development of levelised cost of electricity generation of CCS based power plants (from 2020) (example of **INDIA**)

**E2 (middle): levelised costs of electricity (LCOE) with and w/o CCS - w and w/o CO2 penalty**

30% Imported coal; 70% Domestic coal

Carbon price: 42$/t CO₂  >  63 $/t CO₂

- **With CCS**
- **w/o CCS**
- **No carbon pricing**
CCSGlobal – economic assessment
Development of levelised cost of electricity generation of CCS based power plants (from 2020) (example of SOUTH AFRICA)

E2 (middle): Levelised costs of electricity (LCOE) with and w/o CCS - with and w/o CO2 penalty

100% domestic coal

Carbon price: 42$/t CO2

With CCS

No carbon pricing

US-cd (2011)/kWh

2010  2020  2030  2040  2050
Main part: analysis of CO₂ storage capacity

- Storage potential is the basic part of a CCS strategy:
  - Assessments in Europe showed the role of crucial parameters like the efficiency factor.
  - Assumptions for storage calculation often not clear.
- Objective: Estimation of effective storage capacity
  - Desktop study: no geological research, but discussion with national geologists.
  - Screening, discussing and assessing of existing national studies.
  - Classifying the quality of the estimation.

Second step: source-sink matching

- Relating effective storage capacity to amount of cumulated, separated CO₂.
- Geographical matching of sources and sinks concerning transport distance.
Using results of long-term estimation of CCS-CO$_2$

- Power plants
  - Analysis of existing long-term energy scenarios
  - Providing coal development pathways E1–E3 by 2050
  - Illustrating high, middle and low deployment of coal
  - Application of CCS according to certain conditions
  - *Not* illustrating a coherent scenario framework

- Industry
  - Providing rough industrial development pathways
  - In case figures on CCS capacity available

- Commercial availability of CCS from 2030
Concluding hypotheses – storage potential

How much CO₂ could potentially be held in geological storage?

**Hypothesis:** Estimates of the storage potential in the considered countries are currently highly speculative. Consequently any estimates of the large-scale deployment potential of CCS have an unreliable basis.

- The main potential storage sites are saline aquifers, and a small capacity is considered within oil and gas fields. Storage in basalts and coal seams was excluded from all scenarios due to the extent of technical uncertainty.

- Storage scenarios S1–S3 matched with emission pathways E1–E3 yield quite different results for India, China and South Africa, respectively:
  - Using extremely optimistic assumptions, theoretically, a large quantity of CO₂ emissions could be stored (75, 192 and 22 Gt of CO₂).
  - If more realistic calculations of the countries’ effective and “matched” storage potential are taken into account, only a fraction of the separable CO₂ emissions may potentially be stored (less than 5, 30 and 4 Gt of CO₂).

- In practice, this potential will decrease further when technical, legal, economic and acceptance factors are introduced.
Concluding hypotheses – economic assessment
Are CCS-based coal-fired power plants economically viable compared to equivalent power plants without CCS?

**Hypothesis:** Even in the presence of a carbon-pricing regime, only Chinese CCS-based power plants may potentially have an economic advantage compared to equivalent power plants without CCS.

- Under current conditions, which are characterised by a low CO$_2$ price development, there is a significant barrier to the economic viability of CCS in each of the analysed countries.
- The introduction of a CO$_2$ pricing scheme would therefore be a crucial prerequisite for the commercialisation of CCS in India, China and South Africa.
- A higher CO$_2$ price development (in this study, a CO$_2$ price starting at USD 42/t CO$_2$ by 2020 and rising to USD 63/t CO$_2$ by 2050 was assumed) would provide a strong incentive for installing CCS equipment in China’s coal-fired power stations.
- However, power plants in India and South Africa would require a more ambitious CO$_2$ price development.
Concluding hypotheses – ecological assessment

What are the ecological advantages and disadvantages of CCS-based power plants in India, China and South Africa?

**Hypothesis:** CCS-based coal-fired power plants have the potential to achieve a substantial reduction in specific greenhouse gas emissions. However, most other environmental impacts would increase. For this calculation, the durability of CO₂ storage sites was presumed.

- The prospective life cycle analysis (LCA) of future CCS-based pulverised power plants and integrated gasification combined cycle (IGCC) plants yields conflicting results regarding the environmental impacts of CCS.

- On the one hand, CCS-based power plants could provide lower-carbon electricity by 2030 since the CO₂ emissions per kilowatt hour of electricity would be reduced by 74 to 78 per cent and total greenhouse gas emissions by 59 to 74 per cent.

- However, the reduction rates are lower than the CO₂ capture rate due to the additional energy consumption and the emissions released in the whole process chain.

- On the other hand, most other environmental and social impacts (such as stratospheric ozone depletion and health risks) would increase.
Concluding hypotheses – reserves/resources analysis

What are the possible constraints of CCS in India, China and South Africa with regard to coal resources supply?

Hypothesis: In each of the considered countries, a high coal demand development pathway may lead to significant resource constraints and rising coal prices in the medium term. This trend would be strengthened by the increased coal consumption of CCS-based coal-fired power plants, thereby questioning the underlying assumptions on the economic feasibility of CCS.

- All of the investigated countries have a typical coal production supply curve. Assuming the current proven coal reserves, even the present growth rates will not facilitate continued coal production in the long run.
- Since both India and China are importing increasing amounts of coal, coal trading prices are expected to increase on the global market.
- These trends would be reinforced by an increased coal consumption per unit of electricity, caused by the application of CCS.
- Increasing prices of national coal production has not yet factored in regarding the economic calculation which may cause worse economic feasibility of CCS.
Concluding hypotheses – stakeholder analysis

How do decision-makers and the public perceive the possible role of CCS in India, China and South Africa?

Hypothesis: The political decision-makers in the three analysed countries are very cautious with regard to CCS. The public is not yet involved in the debate.

- Due to the high costs involved, a significant energy penalty and a lack of large-scale demonstration projects in the industrialised world, political decision-makers in the considered countries have adopted a cautious approach towards the commercialisation of CCS.
  - The Indian government has a cautious attitude towards the commercialisation of CCS.
  - The Chinese government is not an enthusiastic advocate of CCS. However, political and industrial decision-makers regard CCS as a back-up or emergency technology for complying with possible long-term CO₂ mitigation obligations.
  - In South Africa, key players have taken important action in terms of the research and development and the politics of CCS. The South African government recognises that CCS could become an important CO₂ mitigation technology.

- In most cases, the public is not yet involved in the discussion process.
Main results of the German CCS studies

Net greenhouse gas emissions reduction (over the whole life cycle)

**Greenhouse gas emissions of electricity generation based on CCS and on renewable energies 2020/2025 and 2050**

- **Minimum**
- **Margin (depending on process and assumptions)**
- **Mean of margin**

**Basic assumptions**
- Capture rate of around 90 per cent
- Future efficiencies and energy penalties of 4-18 percentage points assumed

**Basic results**
- Energy penalty and additional processes like production of solvents, transport and storage decrease the net reduction rate of GHG
Main results of the German CCS studies

General conclusions for Germany

- The existing energy policy targets of considerable improvements in efficiency and the required significant expansion of renewable energies leave only minimal scope for the substantial use of CCS technology, even in the case of ambitious climate protection targets.
- Use of CCS would be prudent in a future energy supply that only achieves moderate successes in increasing efficiency and renewables.
- The significant expansion of renewables and the intended higher share of CHP will have an increasing impact on the utilisation period of fossil fired power plants (base load operation will gradually decrease, average utilisation period decreases from 5,600 h/a to 3,600 h/a).
- A power plant mix from the perspective of optimum CCS operation would have a much smaller share of renewable energies. They would have to be base loadable renewables such as biomass, geothermal energy or solar thermal power plants.
- Large-scale availability will be later than previously assumed (rather 2025-2030 than 2015). CCS therefore looses the role as bridging technology towards renewable energies.