

CICERO Report 2007:06

Large-scale carbon capture and storage for coal-fired power: Effect on global carbon dioxide emissions

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11th December 2007

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Titel: Large-scale carbon capture and storage for coal-fired power: Effect on global carbon dioxide emission

Forfatter(e): Asbjørn Torvanger
CICERO Report 2007:06
4 sider

Finansieringskilde: Sargas AS

Prosjekt: Globale CO₂ utslepp – effekt av karbonhandtering i kolfyrte kraftverk

Prosjektleder: Asbjørn Torvanger

Kvalitetsansvarlig: Asbjørn Aaheim

Nøkkelord: Karbonhandtering, globale CO₂-utslepp, kolfyrte kraftverk

Sammendrag: Scenaria i denne rapporten viser at storskala innføring av karbonhandtering i nye kolfyrte kraftverk frå 2015 kan redusere globale CO₂-utslepp med 8-18% i 2030 og 22-25% i 2100. Disse estimata er sensitive med omsyn på valet av business-as-usual scenario, både når det gjeld totale CO₂-utslepp og når det gjeld kraftproduksjon basert på kol.

Språk: Engelsk

Rapporten kan bestilles fra:
CICERO Senter for klimaforskning
P.B. 1129 Blindern
0318 Oslo

Eller lastes ned fra:
<http://www.cicero.uio.no>

Title: Large-scale carbon capture and storage for coal-fired power: Effect on global carbon dioxide emission

Author(s): Asbjørn Torvanger
CICERO Report 2007:06
4 pages

Financed by: Sargas AS

Project: Global CO₂ emission – effect of CCS in coal-based power production

Project manager: Asbjørn Torvanger

Quality manager: Asbjørn Aaheim

Keywords: Carbon capture and storage, global CO₂ emissions, coal-fired power plants

Abstract: The scenarios in this report show that large-scale deployment of carbon capture and storage technologies for new coal-fired power plants from year 2015 may reduce global CO₂ emissions by 8-18% by 2030 and 22-25% by 2100. These estimates are sensitive to the Business-as-Usual scenarios chosen, both for total CO₂ emissions and for power production based on coal.

Language of report: English

The report may be ordered from:
CICERO (Center for International Climate and Environmental Research – Oslo)
PO Box 1129 Blindern
0318 Oslo, NORWAY

Or be downloaded from:
<http://www.cicero.uio.no>

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Preface

This report is financed by Sargas AS. It has been prepared in the period October–December 2007. The background is the CO₂ capture technology developed by Sargas AS and the pilot facility for CO₂ capture at the Värtan coal-fired power station in Stockholm operated by Fortum Värme and Sargas AS that started its operation in November.

1 Introduction

Carbon dioxide capture and storage (CCS) is the process of collecting CO₂ emissions from power plants or large industry sources, transporting the captured gas to a suitable location, and injecting it underground in deep geological formations. This technology is being promoted by both scientists and policy-makers as one of the most promising alternatives for large-scale reductions of greenhouse gases to fight global warming.

Because major emitters, including China, India, and the United States, all have significant coal reserves, coal is likely to play a major role as an energy source for many decades to come – even with aggressive policies in place to address climate change. As a result, CCS is anticipated to be an important part of any portfolio of alternatives for near-term, substantial reductions in global carbon dioxide emissions. However, despite growing interest in CCS technology, there are still several major barriers to creating and maintaining large-scale, widespread CO₂ storage sites. Among these barriers are high and uncertain costs, inadequate regulatory systems, and limited public awareness.

In this report I examine the potential of large-scale CCS in the coal-fired power sector to reduce global CO₂ emissions. The calculations are based on a CCS scenario where, from 2015, all new coal-fired power facilities on a global scale install technology to capture CO₂. One can discuss the likelihood of all coal-fired power production being CCS-based from 2015 at the global level. Therefore this scenario should rather be interpreted as showing the maximum potential of reduced CO₂ emissions at global level if there are no obstacles to the introduction of CCS in coal-based power production from 2015 onwards. On the other hand, there is also a substantial CCS potential for industrial processes, gas-fired power plants, and for gas and oil if and when a centralized hydrogen-based fuel system for vehicles is developed.

All CO₂ is assumed to be safely stored in geological formations. The reduction in CO₂ emissions is compared to total global CO₂ emissions, thus including emissions from energy use and from changes in land use and forestry. The time horizon is up to the end of this century.

2 Method, scenarios and data

Two Business-as-Usual (BaU) scenarios from IIASA are employed.¹ These scenarios are part of a larger family of emission scenarios from the SRES (Special Report on Emission Scenarios) work by IPCC, and which have been used as a basis for projections of climate change contained in the IPCC reports. These scenarios include separate scenarios for coal use by power producers.

The first scenario is B2, which is a medium to low emission scenario, where population growth and income growth are moderate, and where fossil based energy technology development, and non-fossil based energy technologies show moderate progress. In this scenario the average annual growth rate of global CO₂ emissions in the period 2000-2100 is 0.5%, whereas the growth rate of coal-based power production is 0.9%.

¹ Confer: <http://www.iiasa.ac.at/web-apps/ggi/GgiDb/dsd?Action=htmlpage&page=series>

In comparison, the second scenario, A2r, has relatively high population growth, low income growth, and low technology development for non-fossil energy technologies. The present trend in global emissions is much closer to this scenario than the B2 scenario. In this scenario the average annual growth rate of global CO₂ emissions in the period 2000-2100 is 1.2%, whereas the growth rate of coal-based power production is 1.6%.

Two CCS scenarios are developed. In both scenarios CCS is introduced for all new coal-fired power plants from 2015 onwards. They differ only with respect to the capture rate, which is 90% in first and 95% in the second scenario.

Based on these scenarios, the following steps are undertaken to calculate the effect of the CCS scenario on global CO₂ emissions until 2100:

1. Convert annual coal-based power production from EJ to Mt of CO₂, based on a conversion factor from EJ to TWh, and from TWh to Mt CO₂ based on the energy efficiency from coal use in electricity production (using data from IEA and the average efficiency from year 2000).²
2. Assume that global coal-based power production remains the same in the CCS scenarios as in the BaU scenarios.
3. Insert linear phase-out of non-CCS coal power starting in 2015 and ending up with zero emissions from such plants by 2050.
4. Fill the gap between coal-based power production in the BaU scenarios and residual non-CCS coal-based power capacity by new CCS-based power plants that are able to capture 90% or 95% of CO₂ emissions. This means that from 2050 onwards, 90% or 95% of all coal-based power related emissions are captured.
5. Calculate reduced annual CO₂ emission from coal-based power and subtract this from global BaU emissions.
6. Draw global CO₂ emission curves for each of the BaU scenarios and for the CCS scenarios in the period 2000–2100.

3 Results and discussion

The resulting CO₂ emission curves are shown in figures 1 and 2, and the reduction in absolute figures and percentages compared to BaU for 2030 and 2100 are shown in Table 1.

² The conversion factor from EJ coal-based electricity production to Mt CO₂ is 243.

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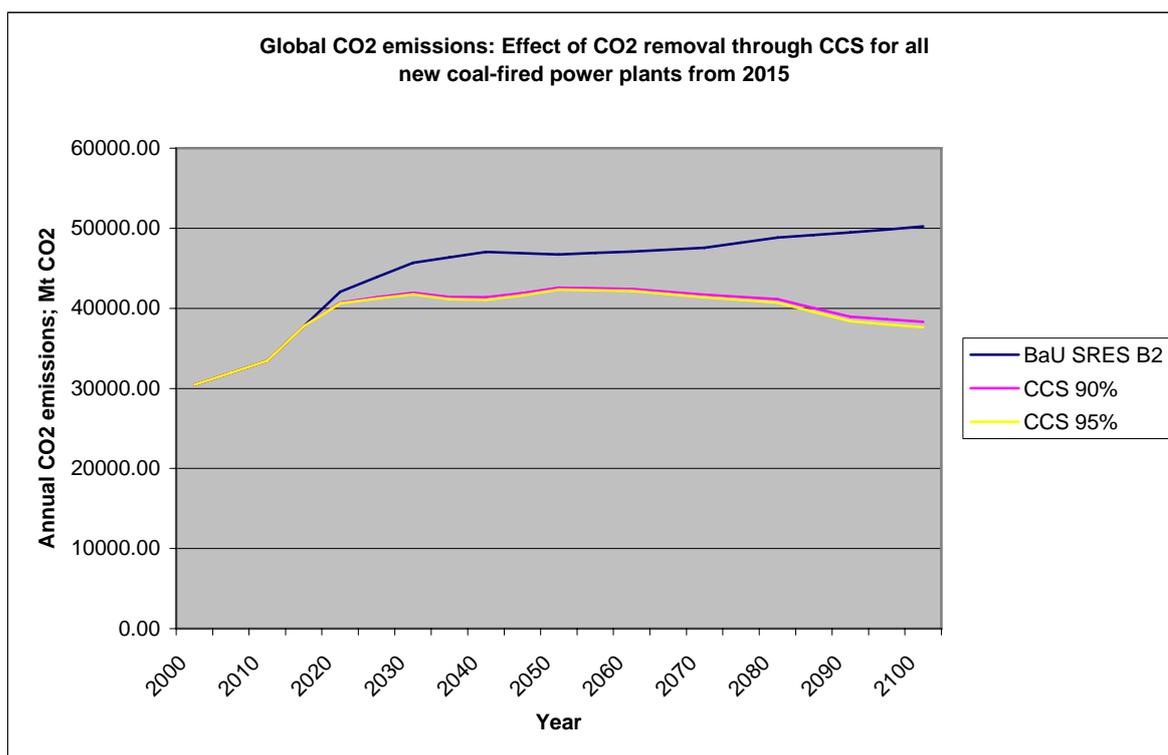


Figure 1. Comparison of global CO₂ emission for the B2 BaU scenario and the CCS scenarios.

The figures show that global CO₂ emissions are gradually reduced from 2015 due to CCS, ending up at 22-25% reduction by 2100. Since the A2r scenario involves about a doubling of coal-based power production compared to B2, the volume of CO₂ emissions reduction is also doubled in this scenario compared B2. The reduction is at 23-24 Gt CO₂ for A2r and 12-13 Gt CO₂ for B2, highest for the 95% CCS capture scenario.

BaU scenario	Year	2030		2100	
	CCS scenario capture rate; %	Reduction in emissions; Gt CO ₂	%	Reduction in emissions; Gt CO ₂	%
B2	90	3.7	8.2	11.9	23.8
	95	3.9	8.6	12.6	25.1
A2r	90	8.7	16.6	22.5	21.9
	95	9.2	17.5	23.8	23.2

Table 1. Emission reductions in CCS scenarios compared to BaU scenarios in 2030 and 2100.

By 2030 the global emissions reduction in the CCS scenarios compared to the A2r scenario is around 17-18% compared to 8-9% for the B2 scenario. In absolute numbers the reduction is 4 Gt CO₂ for B2 and 9 Gt CO₂ for A2r.

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Figure 1 shows that global CO₂ emissions by 2100 in the CCS scenarios are down to the 2015 level in the B2 scenario.

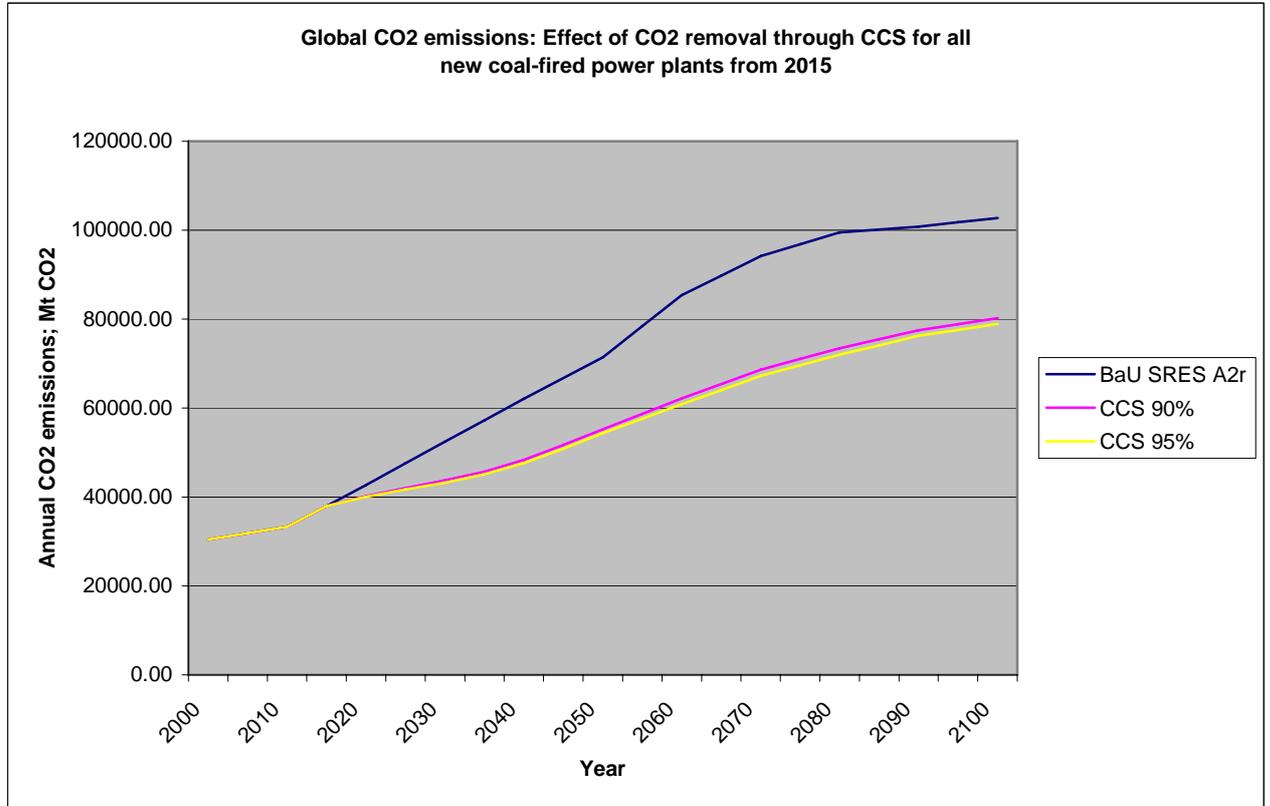


Figure 2. Comparison of global CO₂ emission for the A2r BaU scenario and the CCS scenarios.

4 Summary

The scenarios analyzed in this report show that large-scale deployment of carbon capture and storage technologies for all new coal-fired power plants from year 2015 onwards can reduce global CO₂ emissions by 8-18% by 2030 and 22-25% by 2100 compared to business-as-usual. The global business-as-usual emission scenarios include both energy-related CO₂ emissions and emissions due to land-use change and forestry. These CCS scenarios are illustrations only, and are sensitive to the business-as-usual scenarios chosen, both for total CO₂ emissions and for power production based on coal.