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

**Asbjørn Torvanger**

11<sup>th</sup> December 2007

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**Sammendrag:** Scenaria i denne rapporten viser at storskala innføring av karbonhandtering i nye kolfyrte kraftverk frå 2015 kan redusere globale CO<sub>2</sub>-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 CO<sub>2</sub>-utslepp og når det gjeld kraftproduksjon basert på kol.

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**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 CO<sub>2</sub> 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 CO<sub>2</sub> emissions and for power production based on coal.

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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 CO<sub>2</sub> capture technology developed by Sargas AS and the pilot facility for CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub>. 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 CO<sub>2</sub> 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 CO<sub>2</sub> is assumed to be safely stored in geological formations. The reduction in CO<sub>2</sub> emissions is compared to total global CO<sub>2</sub> 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.<sup>1</sup> 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 CO<sub>2</sub> emissions in the period 2000-2100 is 0.5%, whereas the growth rate of coal-based power production is 0.9%.

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<sup>1</sup> 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 CO<sub>2</sub> 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 CO<sub>2</sub> emissions until 2100:

1. Convert annual coal-based power production from EJ to Mt of CO<sub>2</sub>, based on a conversion factor from EJ to TWh, and from TWh to Mt CO<sub>2</sub> based on the energy efficiency from coal use in electricity production (using data from IEA and the average efficiency from year 2000).<sup>2</sup>
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 CO<sub>2</sub> emissions. This means that from 2050 onwards, 90% or 95% of all coal-based power related emissions are captured.
5. Calculate reduced annual CO<sub>2</sub> emission from coal-based power and subtract this from global BaU emissions.
6. Draw global CO<sub>2</sub> emission curves for each of the BaU scenarios and for the CCS scenarios in the period 2000–2100.

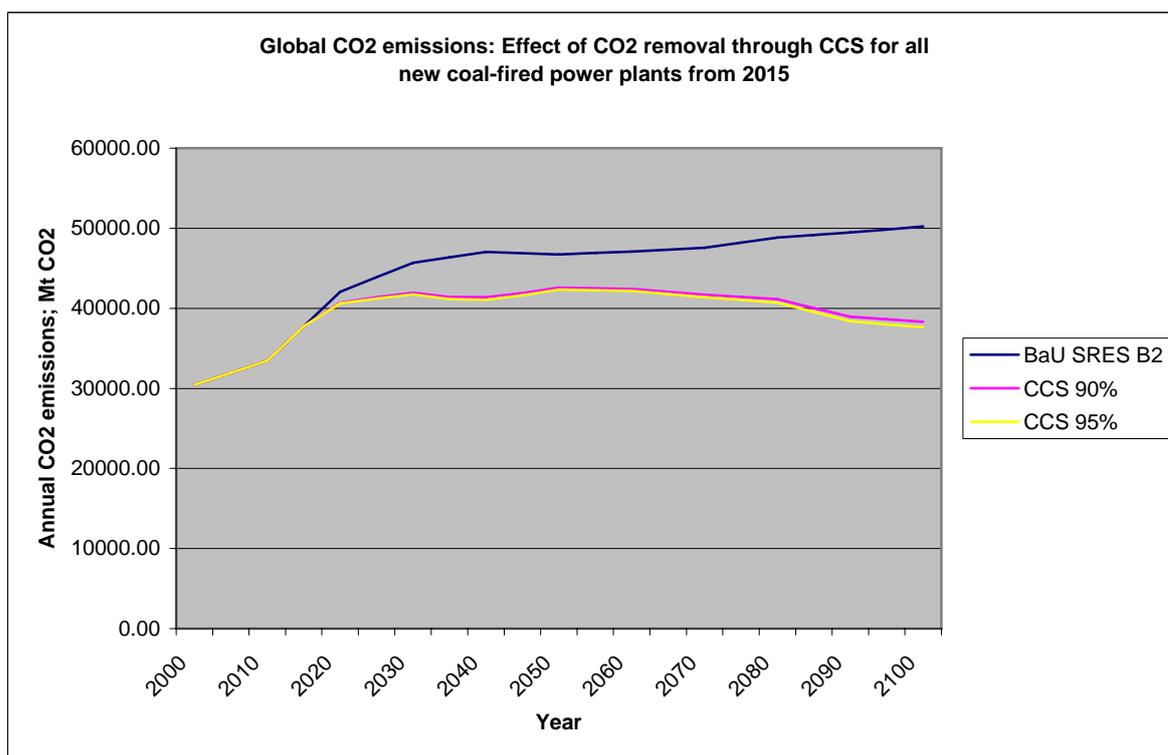
### **3 Results and discussion**

The resulting CO<sub>2</sub> 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.

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<sup>2</sup> The conversion factor from EJ coal-based electricity production to Mt CO<sub>2</sub> is 243.

## Large-scale carbon capture and storage for coal-fired power



**Figure 1. Comparison of global CO<sub>2</sub> emission for the B2 BaU scenario and the CCS scenarios.**

The figures show that global CO<sub>2</sub> 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 CO<sub>2</sub> emissions reduction is also doubled in this scenario compared B2. The reduction is at 23-24 Gt CO<sub>2</sub> for A2r and 12-13 Gt CO<sub>2</sub> for B2, highest for the 95% CCS capture scenario.

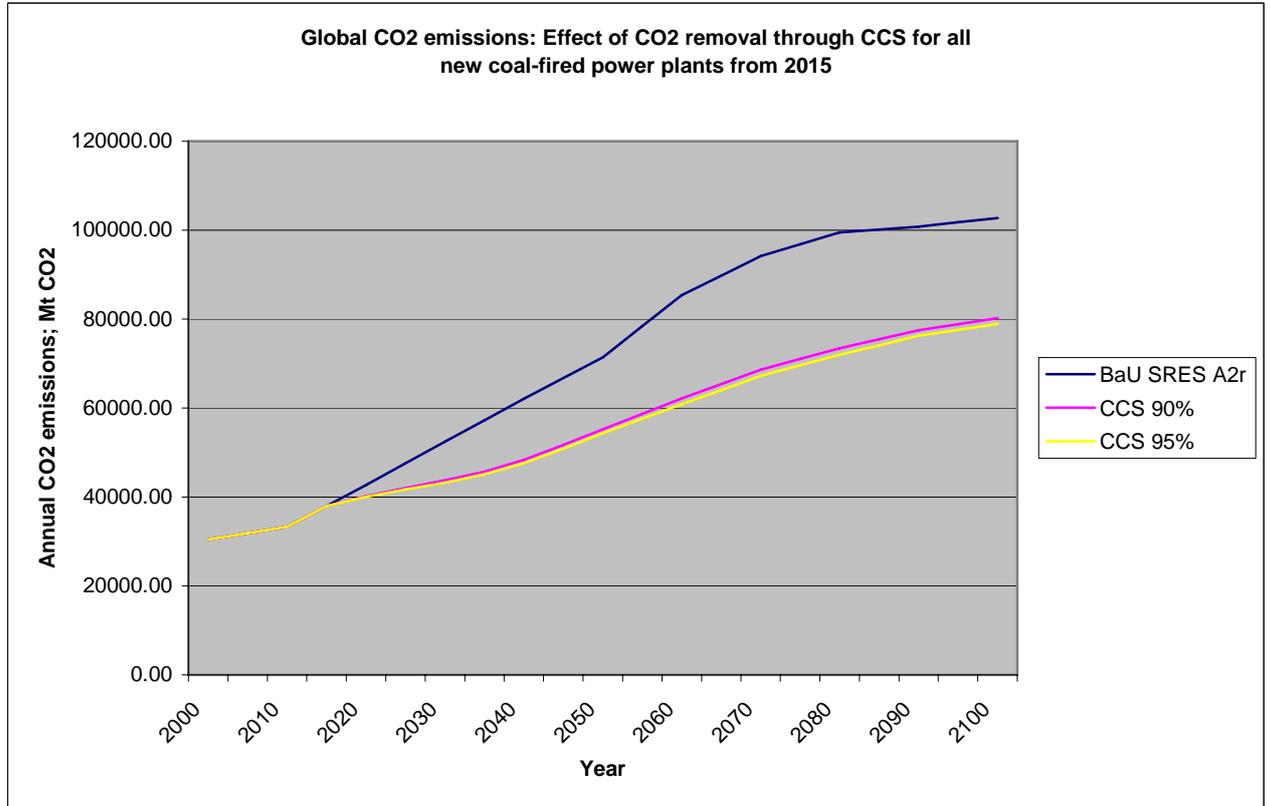
BaU scenario	Year	2030		2100	
	CCS scenario capture rate; %	Reduction in emissions; Gt CO <sub>2</sub>	%	Reduction in emissions; Gt CO <sub>2</sub>	%
B2	90	3.7	8.2	11.9	23.8
	95	3.9	8.6	12.6	25.1
A2r	90	8.7	16.6	22.5	21.9
	95	9.2	17.5	23.8	23.2

**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 CO<sub>2</sub> for B2 and 9 Gt CO<sub>2</sub> for A2r.

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Figure 1 shows that global CO<sub>2</sub> emissions by 2100 in the CCS scenarios are down to the 2015 level in the B2 scenario.



**Figure 2. Comparison of global CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> emissions and for power production based on coal.