



Carbon Capture and Storage: Energy Costs Revisited

Posted by [Rembrandt](#) on April 23, 2010 - 10:30am in [The Oil Drum: Europe](#)

Topic: [Environment/Sustainability](#)

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This is a slightly edited repeat of a [post](#) by Rembrandt from 2007, since the situation really hasn't changed much.- Gail

Capturing carbon dioxide from coal (and gas) fired electricity plants, and subsequently transporting the carbon dioxide from the plant and storing it underground in (abandoned) oil/gas fields, in other geological formations or on the ocean floor, *seem* like an excellent solution for continued fossil fuel use in the coming decades. In fact the European Union wants to have 12 large CO₂ capture and storage demonstration projects in place by 2015, requiring an investment of 5 billion euro. The expectation is that this development will cause significant cost reductions, making the technology affordable by 2020. There are two large **drawbacks**, however:

- The process is quite energy intensive, and thus will use up coal supplies faster.
- The process is quite expensive, and can be expected to continue to be quite expensive, even as experience is gained in the process.

In this post, I will discuss the extra energy cost of the process and quantify its expected impact on future coal depletion. I will discuss the economics in another post in the near future.

A short overview of carbon capture and storage

There are three approaches to creating a nearly pure stream of carbon dioxide at the power plant for storage:

Post combustion, in which the mixture of CO₂ and flue gases after combustion is separated by using a liquid solvent.

Pre combustion, where the fuel is processed prior to combustion resulting in a mixture of mainly CO₂ and hydrogen. Both gas streams are subsequently separated, so that the hydrogen can be combusted for electricity production and the CO₂ for storage.

Oxyfuel combustion, using pure oxygen instead of air when combusting resulting in flue gas that contains mainly water vapour and CO₂. Both streams can easily be separated and treated further if necessary.

All three processes have already been applied in several industries, on smaller scales, but not for storage purposes. No attempt has been made to date to capture CO₂ at large power plants. The choice for the system to be used is highly dependent on the type of power plant. For instance, in a gasification coal power plant, pre combustion already occurs to a significant extent, so this option is much cheaper for such a plant. Most coal power plants built so far do not rely on gasification. For these plants, post combustion is the best option.

Transport of the CO₂ can be done either by pipeline or by ship to a preferred storage site. Quite a

number of depleted oil and gas fields, saline formations (porous reservoir rocks saturated with brackish water or brine) and possibly coal seams are well suited for storage. In addition, carbon dioxide injection into mature oil fields can provide enhanced oil recovery by a process called *miscible gas flood*.

There are approximately one hundred carbon storage demonstration projects in various scales running at the moment. Of these, only three are of the scale to be somewhat representative for future large scale storage systems of a large power plant. These are

(1) Weyburn in Canada, is an enhanced oil recovery project. There, 3000 to 5000 tons of carbon dioxide have been injected since 2000 in the Weyburn oilfield on a daily basis to produce more oil.

(2) Sleipner in Norway, a saline formation 800 meters below sealevel. 3000 tons of carbon dioxide per day have been injected from the nearby Sleipner West natural gas field since 1996, because of the strict Norwegian carbon dioxide emission taxes of 45 euros per ton of emitted CO₂, making it cheaper to inject than to emit.

(3) Salah in Algeria, where 3000 to 4000 tons of carbon dioxide have been re-injected per day the In Salah gas field since 2004.

For comparison, a coal power plant of 800 megawatts emits around 13700 tons of carbon dioxide per day.

The energy costs of carbon capture

Creating a nearly pure carbon dioxide stream at a power plant is unfortunately quite energy intensive. The energy costs are the result of several different processes: Firstly, the added heat needed to create temperatures of 100 to 140 degrees celsius to regenerate the solvent that captures the CO₂ out of the flue gas/CO₂ stream. Secondly the energy to create steam that acts as a stripping gas to remove the CO₂ from the solvent. Thirdly the electricity to operate the flue gas fan and pump the CO₂ to its destination where it can be compressed. Fourthly the energy costs of compression of the CO₂ to make it transportable towards its final destination where it can be stored.

Overall such processes raise the energy costs to produce the same amount of electricity in a cleaner way by 24-40% for new (supercritical) conventional coal plants using the post combustion approach and by 14% to 25% for coal based Integrated Gasification Combined Cycle (IGCC) systems using pre combustion. Nearly all coal plants today are conventional. IGCC plants are expected to be more efficient, but are more costly to build.

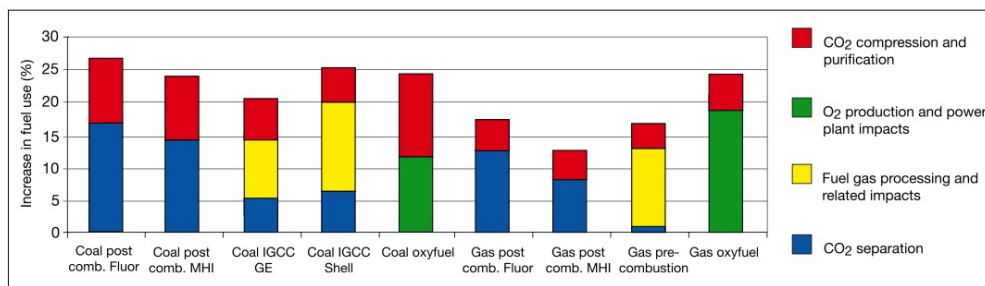


Figure 3.7 Percentage increase in fuel use per kWh of electricity due to CO₂ capture, compared to the same plant without capture (Source data: Davison, 2005; IEA GHG, 2004; IEA GHG, 2003; IEA GHG, 2000b; Dillon *et al.*, 2005).

Chart 1 - Additional energy costs of carbon capture for different electricity plants, source: [IPCC Special Report on Carbon Dioxide Capture and Storage](#).

To look at the expected impact of wide scale application of CO₂ capture and storage, the additional energy costs of one “carbon wedge” is taken. The carbon wedge is a concept from the

University of Princeton, telling us that if we want to stop the current growth path of CO₂ emissions, we need to introduce technologies that can counter growth of annual emissions from 7 Gigatons now to 14 Gigatons by 2055. If CO₂ capture and storage would count for 1 Giga ton of avoided annual emissions by 2055 or one “wedge,” this technology needs to be implemented at approximately 855 coal power plants of 1000 megawatts in the coming decades.

This figure of 855 coal plants was derived by the following calculation: A 1000 megawatt coal power plant emits 5.5 Megatons of carbon dioxide per year. Converting this to carbon emissions (from CO₂ to C) results in 1.37 Megatons of carbon per year. CO₂ capture and storage efficiency is approximately 85%, so per power plant around 1.17 Megatons of carbon emissions per year would be reduced. Dividing 1 Gigatons of emissions by 1.17 Megatons gives 855 coal power plants.

An average 1000 megawatt coal power plant consumes 2,000,000 tons of oil equivalent fuel per year. Assuming that 25% more fuel would be needed, the additional fuel would come down to 425 million tons of fuel in oil equivalents per year to implement CO₂ storage and capture at 855 coal power plants of 1000 megawatts. In 2006 coal consumption was 3090 million tons of oil equivalent per year according to the BP Statistical Review.

The effects of increased energy costs on coal depletion

If we reflect the impact of the additional 425 million tons on coal production forecasts, the effects on available energy from coal become clearer. For this I have taken the coal production scenario from the German Energy Watch Group ([pdf](#)), released a few months ago. In this scenario peak coal production is expected around 2020-2030 with at slow declining slope. When carbon dioxide capture and storage (CCS) is added the peak in energy provided shifts forward five years to 2015-2025. Furthermore the decline is much faster after the peak. The effect on more optimistic coal production scenarios would be different, because CCS would be introduced earlier before the peak that is expected later. That implies that the net energy peak would occur relatively earlier but the net energy slope after the peak will be less sharp.

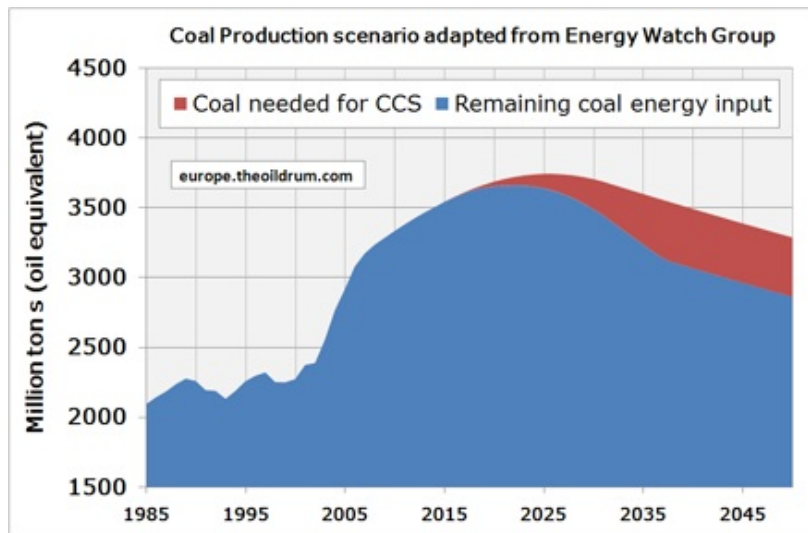


Chart 2 - Coal Production Scenario with energy input costs for Carbon Dioxide Capture and Storage (CCS). Source of Production scenario: [Energy Watch Group \(PDF\)](#).



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