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CO2 capture and storage: The economic costs

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Capturing carbon dioxide from coal (and gas) fired electricity plants. 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. It seems like an excellent solution for continued fossil fuel use in the coming decades.

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 lead to significant cost reductions, making the technology affordable by 2020. There are however two large drawbacks, it will keep costing large sums of money and the process is quite energy intensive. In this post the economic viability of the process is scrutinized. In a previous post the impact of the extra energy cost of the process on coal depletion was quantified.

Not so long ago, I visited a discussion evening about possibilities for the Dutch economy in capturing and storing carbon dioxide. After two interesting talks, one outlining the technical possibilities for storage in the Netherlands and the other the commercial possibilities, one of the other participants made a remark that was spot on. No matter how wonderful the idea of capturing and storing carbon dioxide may sound, it will always be costly to do so.

The additional costs are estimated by the IPCC in their special report on carbon dioxide capture and storage at 1 to 5 dollar cents per kilowatt-hour. The difference depending on the type of power plant, the technology employed for capturing, the reservoir in which the CO2 is stored, the transporting distance and so on. The largest share of the costs originate from the extra energy needed to capture a pure stream of carbon dioxide for storage. The IPCC estimates the costs from a broad range of publications for different power plants as follows:

> "Application of CCS to electricity production, under 2002 conditions, is estimated to increase electricity generation costs by about 0.01–0.05 US dollars per kilowatt hour (US$/kWh), depending on the fuel, the specific technology, the location and the national circumstances. Inclusion of the benefits of EOR would reduce additional electricity production costs due to CCS by around 0.01–0.02 US$/kWh"

More specifically:

> "The application of capture technology would add about 1.8 to 3.4 dollar cents per kWh to the cost of electricity from a pulverized coal power plant, 0.9 to 2.2 dollar cents per kWh to the cost for electricity from an integrated gasification combined cycle coal power plant, and 1.2 to 2.4 dollar cents per kWh from a natural gas combined-cycle power

plant. Transport and storage costs would add between –1 and 1 dollar cents per kWh to this range for coal plants, and about half as much for gas plants. The negative costs are associated with assumed offsetting revenues from CO2 storage in enhanced oil recovery (EOR) or enhanced coal bed methane (ECBM) projects. Typical costs for transportation and geological storage from coal plants would range from 0.05–0.06 dollar cents per kWh."

Power plant system	Natural Gas Combined Cycle (US$/kWh)	Pulverized Coal (US$/kWh)	Integrated Gasification Combined Cycle (US$/kWh)
Without capture (reference plant)	0.03 - 0.05	0.04 - 0.05	0.04 - 0.06
With capture and geological storage	0.04 - 0.08	0.06 - 0.10	0.05 - 0.09
With capture and EOR[17]	0.04 - 0.07	0.05 - 0.08	0.04 - 0.07

Figure 1 - Costs of Carbon Capture and Storage in dollars per kWh from the IPCC report

Type of power plant with CCS	Natural Gas Combined Cycle reference plant US$/tCO$_2$ avoided	Pulverized Coal reference plant US$/tCO$_2$ avoided
Power plant with capture and geological storage		
Natural Gas Combined Cycle	40 - 90	20 - 60
Pulverized Coal	70 - 270	30 - 70
Integrated Gasification Combined Cycle	40 - 220	20 - 70
Power plant with capture and EOR[17]		
Natural Gas Combined Cycle	20 - 70	0 - 30
Pulverized Coal	50 - 240	10 - 40
Integrated Gasification Combined Cycle	20 - 190	0 - 40

Figure 2 - Costs of Carbon Capture and Storage in dollars per ton of CO2 avoided from the IPCC report

Presently the Industrial base price of electricity in the Netherlands resides around 7 eurocents per kWh or 9.6 dollar cents per kWh. This is in the high range relative to other European Countries. For the most likely application, a pulverized coal power plant, the additional costs of capture & storage would amount to 20% to 30% on top of the industrial base price. This is confirmed by a recent study yet to published in Energy Policy, volume 35, Issue 9, September 2007, pages 4444-4454: "Cost and performance of fossil fuel power plants with CO2 capture and storage". The authors, E. Rubin et al, come up with a cost increase figure of 15% to 30%. They base this on a wide range of previous publications.

To cover these costs, companies are looking at two distinct options. Firstly they hope that carbon capture and storage will become a part of the European emissions trading scheme. Secondly, they are investigating the possibility of enhanced oil recovery by carbon dioxide injection in oil fields.
The European emission trading scheme is an initiative under the Kyoto protocol. It provides Europe with a market to trade greenhouse gas emission allowances or emission reduction units. Each individual company is given an assigned amount of Kyoto Protocol Units or Carbon Credits which can be increased or decreased through several mechanisms. Every carbon credit is equivalent to a reduction of one ton of greenhouse gas emissions. Within the trading scheme, a party is allowed to transfer their carbon credits to or from another party. An unlimited number of units may be acquired by emissions trading while only a limited number may be transferred to another party. At the moment, carbon capture and storage is not incorporated as a possibility for mitigation under the emissions trading scheme.

Thus far the European carbon credit market is in it's test stages and will become effective in 2008. During the test stage it has not functioned very well because too many credits were handed out, thereby putting a downward pressure on the price of a ton of carbon. We can see this in

figure 3 below. In april 2006, when news came out that countries had a surplus of credits, their value dropping significantly.

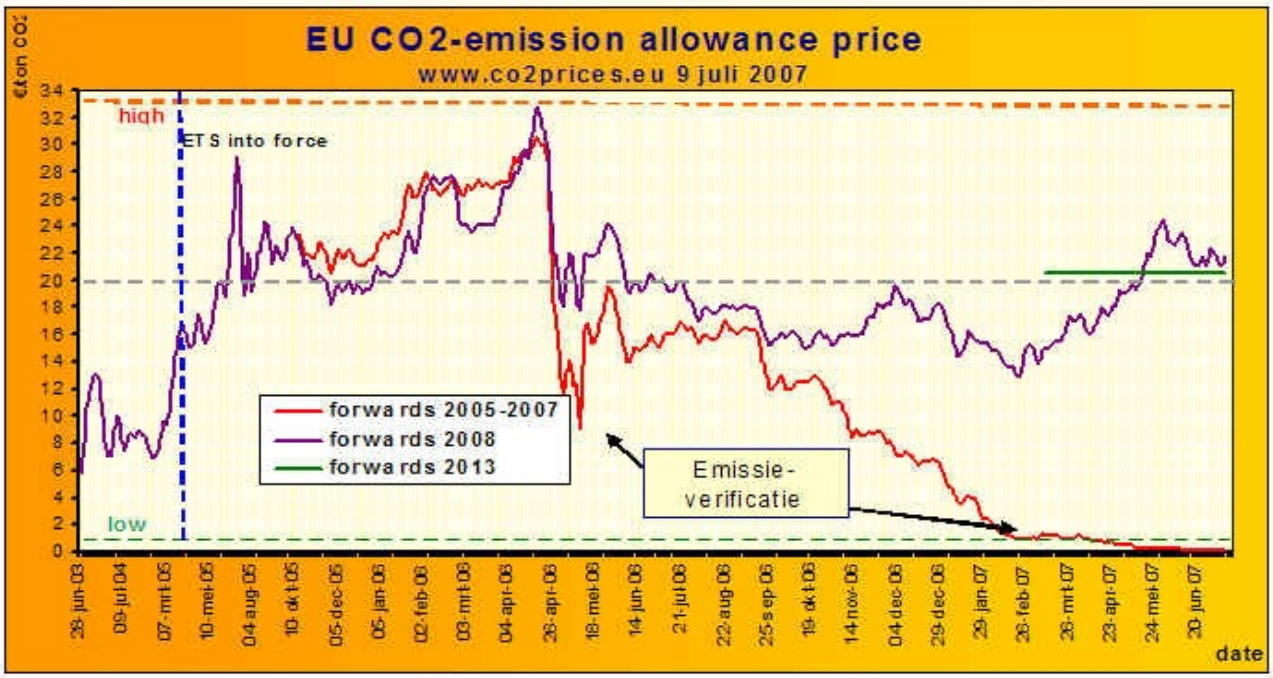

Figure 3 - Price development per ton of Carbon dioxde under the European emission trading scheme, source: www.emissierechten.nl.

Currently the price for a carbon credit resides between 20 to 26 dollars euro's per ton CO2. In relation to the costs of carbon capture and storage this is too low. In table 2 the cost estimates from the IPCC can be read for a pulverized coal power plant. Giving between 30 to 70 dollars per ton CO2 or 20 to 50 euro's. The present price would make the technology only economically viable at the cheapest locations. It is difficult to predict whether the price of carbon will increase because of the development of the market is heavily dependent on political negotiations. For instance, are more countries outside the European Union going to join in the trading in the future? Will the air transport sector be incorporated in the emissions trading scheme? And most important for carbon capture and storage, will it be added as a full possibility for mitigation under the trading scheme?

Next to emissions trading there are high hopes for enhanced oil recovery. To my opinion overblown hopes, given that the technique can only be applied commercially at very few oil fields. This was recently highlighted by Statoil and Shell. The companies dropped plans to store CO2 at the Draugen oilfield in Norway because economic analysis showed that it was uneconomical to do so. Nonetheless, enhanced oil recovery is often considered as a possible option as explained in the case study below.

Pioneering Carbon capture and Storage: Rotterdam Harbour

One of the 12 large CO2 capture and storage demonstration projects that the European Commission wants to develop by 2015 could very well arise in the Dutch harbour of Rotterdam. Recently the environmental agency of the Rijnmond Region, in which Rotterdam Harbour lies, has calculated that it would be possible to capture and storage up to 20 million tons of carbon emissions from the region Rotterdam annually for only 24 euro per ton of CO2 (PDF in Dutch, 3.6 MB, 56 pages). A price that is much lower than normal thanks to efficient usage of energy. A significant amount of heat created by the local industry is wasted which can be applied for usage in the capture process. The environmental agency has assumed that this waste heat can be utilised for free as input in the capture process, hence the huge reduction in costs for capture and

storage. However, it still remains to be seen whether the local companies will comply with giving away their waste heat for free, no one has asked the companies formally thus far.

If the price of 24 euro's per ton of CO2 proves to be real, then it would be viable under the current price in the European emission trading scheme. Additional funding could be gained by the application of enhanced oil recovery according to the environmental agency of Rijnmond. Their basic assumptions being two additional barrels of crude oil production for every ton of injected CO2. In their cost/benefit an oil price of 30 dollars per barrel is assumed. However, this income flow is very variable. When applicable at an oil field, the injection of carbon dioxide will only be maintained for a few years. Beyond that period it does not deliver additional production benefits slowing down and halting the income flow. Also time is running out, because many fields that appear to be suitable for carbon dioxide injection will be closed down in the period of 2008 to 2012. By 2018, very few oil fields will be available for injection purposes.

Summarizing

While the idea of carbon dioxide capture and storage seems excellent, the costs are a large hurdle that might cancel this option altogether. Only with continued political support will this technological mitigation option for climate change become viable. The best option is full support of carbon dioxide capture and storage in the European emissions trading scheme, to make pioneering projects such as the one proposed at Rotterdam harbour viable. For larger application beyond a few projects, the price of a ton of carbon needs to increase, or the costs of capture and storage will need to come down significantly.