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Carbon Capture and Storage: Economic Costs Revisited

Posted by Rembrandt on April 29, 2010 - 10:20am in The Oil Drum: Europe
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This is an updated version of post by Rembrandt from 2007.-Gail

Capturing carbon dioxide from coal (and gas) fired electricity plants, and subsequently transporting 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.

When I looked at the situation in 2007, the European Union hoped to have 12 large CO2 capture and storage demonstration projects at coal plants of at least 250 MW of capacity in place by 2015, requiring an investment of 5 billion euro. Progress has been slow, however. At the end of 2009, after 13 months of discussion, the European Union finally made the decision to invest 1 billion euro in six demonstration projects. In February, 2010 another 300 million euro was made available, which would be sufficient for two more CO2 capture and storage demonstration projects. The expectation behind these investments are that they will lead to significant cost reductions, making the technology affordable by 2020.

Even as these projects get off the ground, there are two large **drawbacks**:

- The process is quite energy intensive, and thus will use up coal supplies faster.
- Because of the additional energy cost the process will remain quite expensive, it is not certain that costs can be reduced sufficiently

In this post, I will talk about the second item, the high economic cost. In my previous post, I quantified the impact the extra energy cost might be expected to have on coal depletion.

In 2007, I participated in an evening group discussion about possibilities for the Dutch economy relating to 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 relative to current electricity production costs.

The additional costs were estimated by the IPCC in a 2007 special report on carbon dioxide capture and storage at 1 to 5 cents per kilowatt-hour (with these cents computed in US$), with 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 other variables. 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 using 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$/kWh), depending on the fuel, the specific technology, the location and the national circumstances. Inclusion of the benefits of EOR [enhanced oil recovery] would reduce additional electricity production costs due to CCS by around 0.01–0.02 US$/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

When I did my analysis in 2007, the industrial base price of electricity in the Netherlands was about 7 eurocents per kWh or 9.6 dollar cents per kWh. This was in the high range relative to other European countries. For the most likely application--a pulverized coal power plant--the additional cost of capture and storage would amount to 20% to 30% over and above the industrial base price. This is confirmed by a recent study 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, estimate a cost increase of 15% to 30%. They base this on a wide range of previous publications.

To cover these costs in the long run in a market environment, companies are looking at two distinct options. First, there is the hope that carbon capture and storage can be paid by the pricing of carbon dioxide through the European emissions trading scheme. Second, the possibility

of enhanced oil recovery by carbon dioxide injection in oil fields could offset some of the costs incurred.

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.

The European carbon credit market passed its test phase and became effective in 2008. During the test stage before 2008, it did not function 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 began dropping significantly. During 2008 when more players entered the market and the market became effective, the cost of a ton of CO2 rose significantly, up towards 40 euro, but from June onwards the price dropped significantly due to investor expectations being adjusted by developing events in the economy. As the economy has only slowly picked up somewhat, and energy consumption is still low relative to early 2008 levels, the price of CO2 is still very low as shown in Figure 4 below.

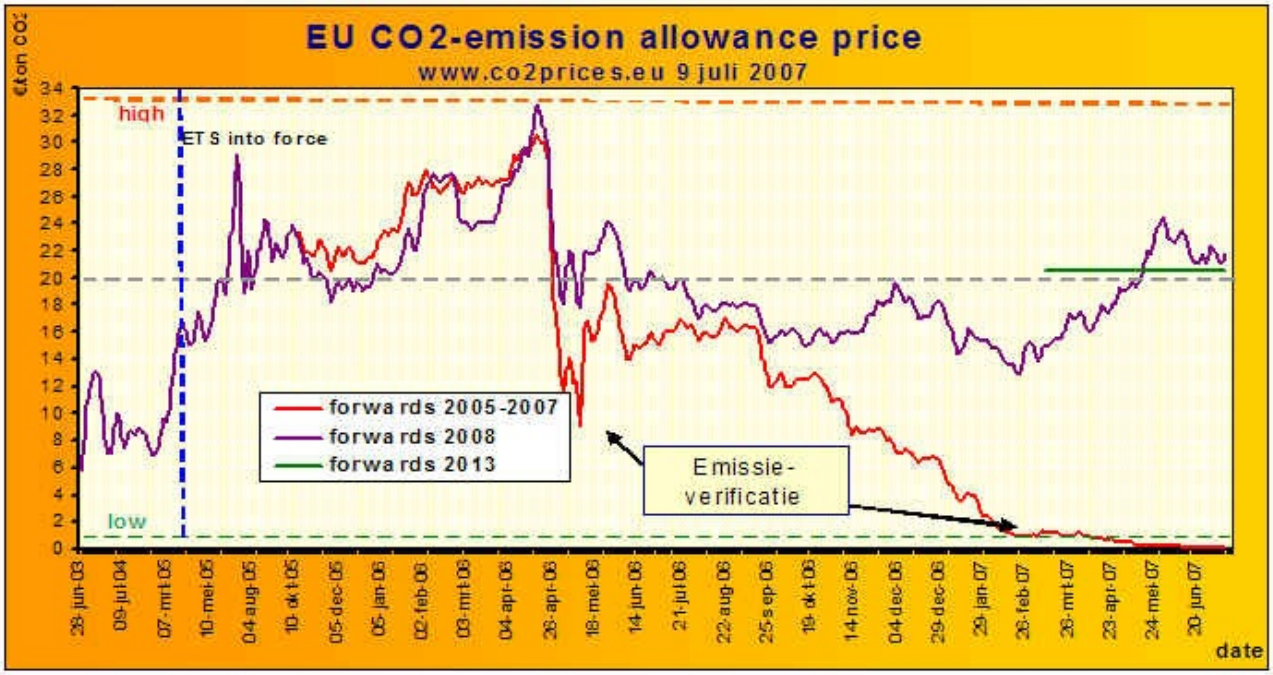

Figure 3 - Price development per ton of Carbon dioxide under the European emission trading scheme, source: [www.emissierechten.nl.](www.emissierechten.nl)

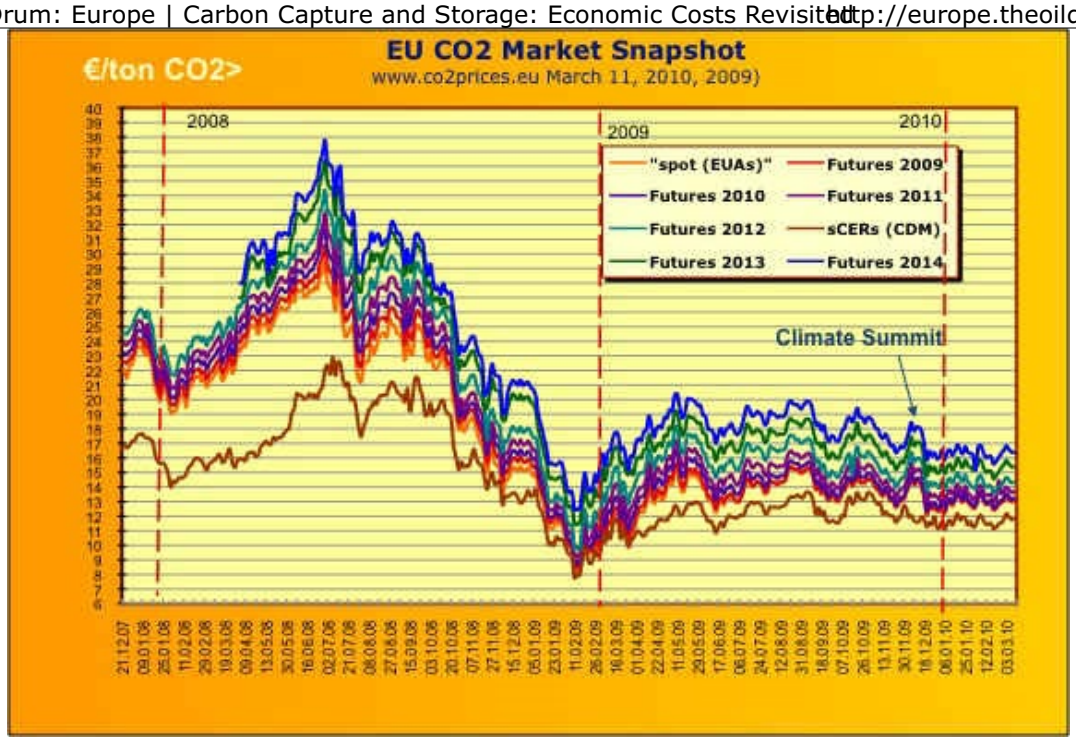

Figure 4 - Price development per ton of Carbon dioxide under the European emission trading scheme from November 2007 to March 2010, source: [www.emissierechten.nl.](www.emissierechten.nl)

Now, in 2010, the price for a carbon credit lies between 12 and 18 euros per ton CO2. In relation to the costs of carbon capture and storage this is much too low. In Table 2, the cost estimates from the IPCC for a pulverized coal power plant are shown to be between 30 to 70 dollars per ton CO2 or 20 to 50 euros. The present price makes the technology an economic disaster at any location. It is difficult to predict whether the price of carbon will increase because the development of the market is heavily dependent on economic developments and political negotiations. For instance, will more countries outside the European Union join in the trading in the future? Will the amount of carbon credits handed out be adjusted to the new economic situation?

Next to emissions trading, there are high hopes for enhanced oil recovery. In my opinion, these hopes are overblown, 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 be located in the Dutch harbour of Rotterdam. In 2007, the environmental agency of the Rijnmond Region, in which Rotterdam Harbour lies, calculated that it would be possible to capture and store up to 20 million tons of carbon emissions from the Rotterdam region 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 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.

In the analysis of the agency, if a price of 24 euros per ton of CO2 can be realized (which is much higher than the current trading range of 12 to 18 euros), then this project would be viable under the European emission trading scheme. Additional funding could be gained by the application of enhanced oil recovery according to the environmental agency of Rijnmond. In the agency's analysis, they assume that two additional barrels of crude oil will be produced for every ton of injected CO2. They also assume an oil price of 30 dollars per barrel. 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 is not expected to not deliver additional production benefits, so the income flow can be expected to slow down and then come to a halt. Furthermore, time is running out, because many fields that appear to be suitable for carbon dioxide injection for enhanced oil recovery 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 in pursuing this technology 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. Whether this will happen in the long term future is doubtful.