# Carbon Capture and Storage: A genuine solution or an impossible placebo?

*Fossil Resources – Final essay*

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## Introduction

As carbon dioxide concentrations in the Earth's atmosphere continue to rise, causing what many predict will be run-away climate change, questions are increasingly being asked as to what solutions can be found to prevent such an occurrence. The reduction of Carbon Dioxide emissions into the atmosphere is widely accepted as vital in mitigating global warming, although the manner of achieving this is still widely debated.

The importance of coal-fired electricity production to the world economy cannot be understated. Coal provides base load power generation for much of the world. In the EU-27, as of 2000, coal-fired power plants provided almost 30% of total electricity produced. This figure, however, is predicted to decrease to around 15% by the year 2030 (E3M Lab, 2009). Coal has long been known as a dirty fuel and efforts (such as use of low-sulphur coal) to produce 'clean coal' are not new. However, while other fossil fuels may be running out, coal is still a plentiful resource. The World Coal Association estimates 119 years of reserves at current extraction rates.

In this context, the coal industry's answer to climate change is Carbon Capture and Storage (CCS). The process is a complicated one, which involves separating $CO_2$ from other exhaust gases (which are allowed to pass into the atmosphere as usual). It is best to produce a gas as pure as possible to mitigate effects of other compounds on cooling/heating, so other gases ($NO_x$, ash, water vapour etc) are still emitted as before. The $CO_2$ gas is then liquefied by cooling it to below -78°C, this liquid is transported by pipeline, ship and/or truck to the pumping station (including a possible intermediate storage stage), then the gas is pumped into exhausted gas/oil fields or into exiting gas/oil fields to increase yield of recovery in a process known as Enhanced oil and gas recovery (EOR). ($CO_2$Net, Nacler et al) A schematic of this process is shown in Figure 1.

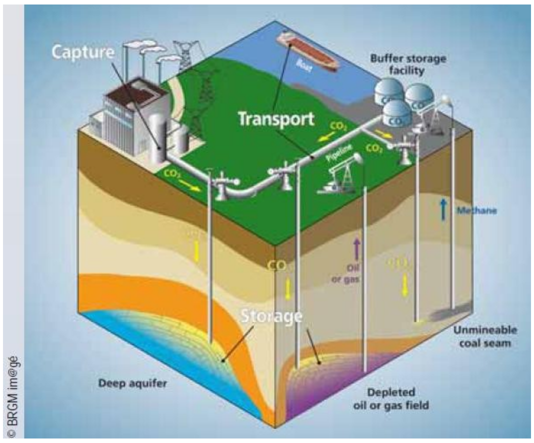


Figure 1: Schematic illustration of Carbon Capture and Storage (CO2 GeoNet)

## Technology of CCS

Carbon Capture and Storage can be broken down into three stages, Capture, transport and storage. The following is a brief summary of the current state of affairs with regard to these three areas.

**Capture**

Capture technology has been proven and applied for many years in the chemical and refining industries, although specific integration of this technology with electricity production has yet to be proved. (Naucler et al).

**Transport**

Over long distances across land, pipelines would be used to transport the $CO_2$ in gaseous form. This technology has been used by the oil and gas industry for some 30 years – including for geological injection of $CO_2$ for EOR. To transport across seas would require vessels of the type used for liquid petroleum gas. (Naucler et al). A third option is transport by vehicle, which would be more expensive and time consuming, although the technology exists for that too.

**$CO_2$ Storage**

As well as the existing use in EOR, $CO_2$ storage has been proven to be possible in Norway, Canada, Algeria and Germany. (Naucler et al). In the Netherlands, controversy over a $CO_2$ storage plant in Groningen has led to delays in construction, although the technology exists and is quite capable of storing $CO_2$ in a safe manner.

## Assessment of Costs of CCS

While individual technologies exist, putting them all together into a coherent CCS system has yet to be achieved on commercial scale. One of the main obstacles to commercial viability is uncertainty over costs and methods for funding. That said, a lot of work has gone into assessing the economics of CCS. This section will detail those existing findings, and subsequent sections will then look at implementation possibilities based on these figures.

A widely referenced report was produced by McKinsey & Co in September 2008. The summary predicts *eventual* costs of between €30-€45 per tonne $CO_2$ abated. This is, however, a figure dependant upon large-scale technology improvements. The report says that initial costs would be around €60-€90/$tonne_{CO2}$, with the proviso that these are predictions, and that full-scale pilot projects would be required to prove such a level. (Naucler et al)

Based on the above study, the IPCC reports that costs of CCS would presumably be passed on to the consumer, and would equate to between 0.9US$ct/kWh and 3.4US$ct/kWh, depending upon place and type of fossil-fuel plant used to produce electricity. (Herzog et al). An alternative survey produced by SFA Pacific, Inc, puts this figure at between 2.5-4US$ct/kWh, and a further study puts this price at between 9.7 US$ct/kWh and 11.7 US$ct/kWh. (Plasynski). This compares to current US electricity prices of around 11.5US$ct/kWh at present, so would have a large effect on consumer costs. (US EIA).

A pilot project currently under construction is the Mongstad CCS project in Norway. The project is a joint venture between the Norwegian government (75%) Statoil (20%) Sasol and Shell (2.44% each). It was reported in September 2010 that costs for the project have risen 9-fold since the initial plans, and construction alone will now cost $1.02billion (Fouche). When it is considered that annual emissions of $CO_2$ from the Mongstad plant equate to 2.2million tones (Svendsen Skriung), assuming 100% capture and a lifetime of 30 years for the plant and CO2 capture technology, that equates to a cost of $15/tonne $CO_2$ abated for the construction alone. However, there is a large stock of coal-fired power plants in use world-wide, with no significant CCS-ready building plan, so costs should be calculated for retro fit, which could be as high as US$59/$tonne_{CO2}$ (Tsouris et al).

Additional costs can be found throughout the chain. The most expensive of which is separation. At present, it appears that the best way of separating $CO_2$ from other flue gases is through amine-based solvent carbon dioxide capture and cryogenic coolers. With current technologies, this process alone costs some $150/tonne $CO_2$, although that is predicted to decline with increased market penetration. There is also a 10% reduction in efficiency of the power plant (Naucler et al), which could only be mitigated with increased productivity, requiring more coal. Transport costs are somewhat more unpredictable, depending on method used, although Figure 2 shows the variations that can be expected under certain circumstances, with costs running from zero to €30/Tonne$_{CO2}$.

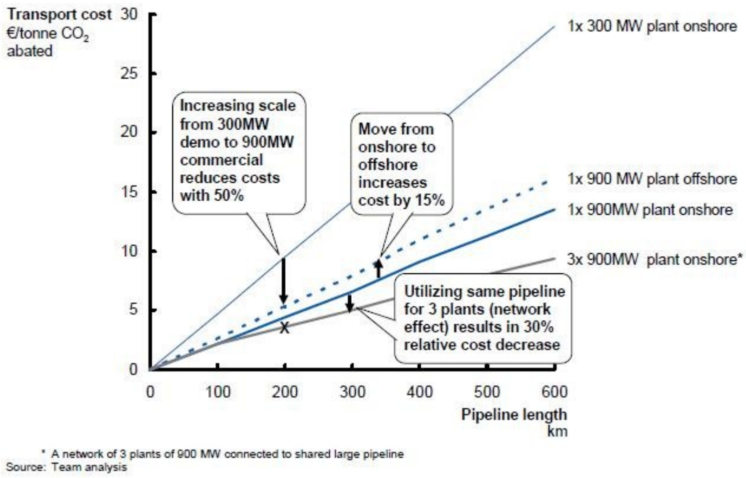


Figure 2: Scale and Distance Effects for CCS pipeline transport (Naucler et al.)

## Possibilities for implementation

> "There are a litany of factors often cited as barriers to the widespread deployment of CCS, but the real barriers are political and financial. Costs for initial commercial-scale CCS demonstration projects will be too high to be supported by expected $CO_2$ prices in the period to 2020. The private sector cannot therefore proceed with this deployment programme on its own."
>
> - World Coal Institute

> "… models indicate that CCS systems are unlikely to be deployed on a large scale in the absence of an explicit policy that substantially limits greenhouse gas emissions to the atmosphere. The literature and current industrial experience indicate that, in the absence of measures to limit CO2 emissions, there are only small, niche opportunities for the deployment of CCS technologies."
>
> - IPCC, 2005 (Herzog et al)

While the debate science of CCS is well-known, there is very little doubt that it will be an expensive operation. This section investigates what financing possibilities exist for CCS and the likelihood of these mechanisms being implemented.

**Private Sector – Carbon Trading**

As the above quote attributed to the World Coal Institute points out, it is unlikely that CCS will be financed purely by the private sector. While renewable energy technologies may be able to provide a return on investment (even if the payback period could be a decade), CCS will provide no return unless a market value is given to $CO_2$. The only way for this to happen is through Carbon Trading schemes.

In order to be truly functional, Carbon trading schemes would have to be a global initiative. It was made an integral part of the Kyoto protocol on climate change in order to facilitate such a move, and included the establishment of a new commodity – Carbon Dioxide. (UNFCCC). Without global acceptance of such schemes, the first economies to implement them would be at a competitive disadvantage over their competitors, as they would have to pay an additional 'tax' for polluting. Another issue lies in the ineffectiveness of a scheme where individual governments are free to set their own limits on $CO_2$ emissions, meaning only lip-service is paid to the Kyoto protocol and industry can effectively carry on as usual. By setting the limits too high in the EU, there has been little effect so far of an emissions trading scheme which started in 2008 and is considered the largest in the world (UNFCCC), although the argument goes that these ceilings will be reduced in later phases of implementation.

To add to these issues of carbon trading, the US plan for Cap and Trade has effectively been sidelined due to the financial crisis and lack of political will. Cap and Trade no longer features in US budget considerations and is largely discredited. It became too diluted, with concessions made to many of the largest polluters, and was killed off by "…opposition from the oil industry, conservative groups that portrayed it as an economy-killing tax and lawmakers terrified that it would become a bonanza for Wall Street traders and Enron-style manipulators." (Broder)

Discussion of carbon prices often misses the point that the carbon market is looking increasingly unlikely to succeed. Indeed, these discussions continue as usual, and will readily support their arguements with graphs such as Figure 1Figure 3, which not only unaccountably predicts the estimated CCS cost, but also seeks to predict market behaviour up to 2025.

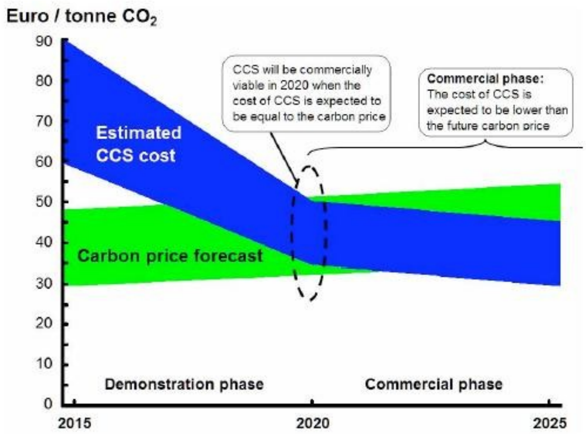


Figure 3: Estimated CCS cost against predicted carbon price (Hoff)

For CCS to be considered, therefore, other financing options must be investigated.

**Direct public subsidies**

A European Directive exists for the storage of carbon dioxide, but does not specify payment arrangements. It does mention, however, that "in the early phase, CCS demonstration projects will require additional finance on top of the incentive provided by the carbon market because the current cost of the technology is substantially higher than the carbon price. To catalyse this additional finance, decisive financial commitment from industry will be crucial and Member State support measures are also likely to play a major role." (Europa). Indeed, the example of the Mongstad CCS plant in Norway can be seen as a case in point – the Norwegian government has already funded much of the shortfall in the budget. (Fouche).

As the World Coal Institute points out, this decision is ultimately political. For CCS to be considered for governmental subsidies, it should be proven that investments in CCS technology would be beneficial against investment in alternative technologies. A paper by Tsouris, Aaron and Williams, published in September 2010, shows that investment in CCS would be more expensive per tonee$_{CO2}$ emitted than investment in either wind or nuclear. The two alternatives also have the added advantage that they will produce electricity, and therefore revenue, totaling $9.05 trillion over the lifetime of a windmill, at a cost of $5.1

trillion. Solar PV was not included in the report as it is still expensive, although with annual market growth rates of 30% (van der Have) this manufacturing cost can reasonably be expected to fall. Therefore, from a cost perspective, it would be wiser for governments to invest in alternative technologies to CCS. This leaves one further option for financing.

**Increased consumer costs**

As the IPCC report (amongst others) referred to above states, electricity costs would be expected to rise by between 0.9US$ct/kWh (IPCC) and 11.7US$ct/kWh (Plasynski). With already increasing energy prices, this would be highly unpopular amongst the general public, and could lead to a large governmental rethink, as was witnessed in the recent renewable energy debate in the USA.

## Conclusions

That something must be done to deal with carbon dioxide emissions is obvious. That this should be done as soon as possible is equally startling. Pilate CCS projects have been constructed and there are a number of sites where this is being preformed. The technology evidently exists. The safety of depositing carbon dioxide is widely debated, especially in the Netherlands, although the arguments against the safety of carbon storage are unconvincing. Finally, the ethical question of burying waste for future generations to deal with has already been answered somewhat (although not satisfactorily enough for many) by nuclear power.

The most fundamental aspect of any such project, however, should be financial. If something can be done at a profit, there is no need for outside intervention in the market. This looks unlikely for CCS, as it would require a carbon price which realistically reflected the value of $CO_2$, and would have to be a properly functioning global commodity. Without that, public financing would be better spent on other forms of energy production, and increased consumer prices, especially for something like CCS, would not be tolerated. Therefore it makes sense to invest the money earmarked for CCS into renewable energy projects which would not only cut carbon dioxide emissions but also increase energy self-sufficiency while making a huge difference in the sustainability of the planet.

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