24 Carbon capture and storage: Promise or delusion?

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Fossil fuels currently dominate the global energy mix, and there is no indication of a significant reversal of this trend in the near future. The recent decline in oil prices, the revolution in extraction of gas and oil, and the abundance of global coal resources suggest that whatever strategy will be devised to deal with climate change, it will have to confront a large supply of competitive fossils. To this end, the possibility to sequester and store CO_2 geologically offers an important way to decouple fossil fuel use from greenhouse gas emissions. It could also provide incentives to engage fossil fuel producers in international climate action. CCS, if coupled with biological sources, also offers the potential to remove CO_2 from the atmosphere and is a technology that will be needed in the future if ambitious climate targets will need to be attained. Yet, the commercialisation of large-scale CCS plants has proven much more difficult and slower than originally envisioned. This chapter explores the importance of CCS for short- and long-term climate policies, drawing quantitative insights from the scenarios recently collected for the IPCC Fifth Assessment Report. It confronts the predictions of the models with the engineering assessment of the cost and performance of the technology, both in its current form and for different assumptions about technological progress in the foreseeable future. We conclude with a set of policy recommendations aimed at promoting the development of a large-scale and well functioning CCS programme.

1 Why CCS?

Carbon capture and storage (CCS) is a technology which allows capturing waste CO_2, transporting it to a storage site, and depositing it in such a way that it will not go into the atmosphere, for example in a geological or oceanic storage site. The key distinguishing feature of CCS is that it makes extraction and combustion of fossil fuel energy sources compatible with climate mitigation objectives. This is an important characteristic, because fossil fuels provide abundant sources of energy now and for the foreseeable future. As testified by the shale natural gas boom that occurred in the US in the past decade as well as in the recent drop in oil prices, fossil fuels remain extremely competitive. Although the estimates of fossil reserves and resources are highly uncertain, it is safe to say that the total fossil fuel reserves contain sufficient carbon, if released, to warm the planet well above any safety threshold (Rogner et al. 2012). This is particularly true for coal, which scores the highest among fossil fuels both in terms of reserves and carbon intensity.[1] Thus, CCS could effectively allow for the procrastinated use of fossil fuels while limiting – if not eliminating – their impact in terms of greenhouse gas emissions. Moreover, CCS can in principle be coupled with non-fossil energy sources, such as biomass, thereby possibly allowing CO_2 to be absorbed – rather than emitted – in the atmosphere. This would create a 'negative emission' technology, which could help remove some of the CO_2 that has already been or will be put into the atmosphere. Finally, by making emissions reduction strategies compatible – at least to a certain extent – with fossil fuels, CCS can have important repercussions on the climate negotiation process. In the remainder of this brief chapter, we explore the role of CCS for climate stabilisation, and discuss the current status of the technology and its role for climate and energy policy.

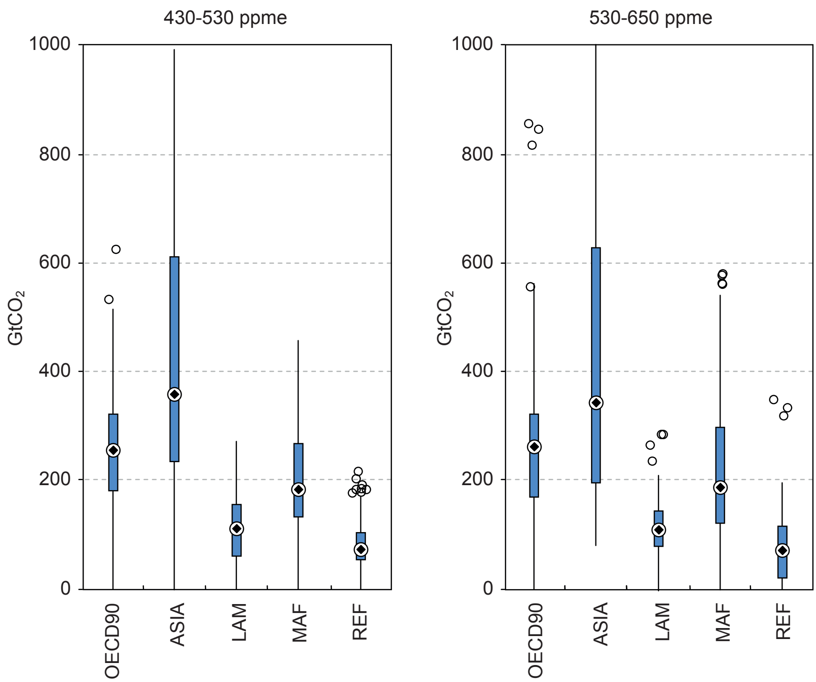
2 CCS and climate stabilisation

In order to provide information about the importance of CCS as a climate stabilisation strategy, let us look into the results of the scenarios recently produced for the Working Group III of the IPCC Fifth Assessment Report (see IPCC 2014, Chapter 6). These scenarios are generated by integrated energy economic models and describe possible realisations of the energy systems throughout the entire century, under different assumptions about climate policy. Figure 1 reports the total amount of CO2 that would need to be captured via CCS for different climate policy objectives, and five

1 For reference, the emission factors for electricity generated by coal is close to 1,000 grCO_2/kWh, with natural gas being around 600 grCO_2/kWh.

representative regions. These numbers represent the economically optimal CCS strategy in the context of the global transformation of the energy sector needed to achieve climate stabilisation roughly consistent with 2°C and 3°C temperature targets (left and right panels, respectively), as foreseen by integrated assessment models under a wide range of assumptions about policy implementation and alternative low carbon mitigation options. The figure illustrates the importance of CCS as an emission reduction strategy. Despite differences across regions, models, and policies, the average quantity of CO_2 captured and stored throughout the entire century is in the order of hundreds of $GtCO_2$. By comparison, current CO_2 emissions are in the order of 35 $GtCO_2$ per year. Summing up the regional contributions, the global sequestered CO_2 would exceed 1,000 GtCO2, an amount similar to the total carbon budget compatible with keeping temperature increase below 2°C.

Figure 1 Projections for cumulative CO_2 capture by region under two policy scenarios, 2010-2100.



Notes: LAM stands for Latin and Central America, MAF for Middle East and Africa, REF for Reforming Economies or Economies in Transition. Black dots are the medians, thick bars show the 25-75 percentiles, and thin bars extend to 99 percentile, outliers are shown as circles.

Source: Author's elaboration using the AR5 IPCC WGIII database.

The convenience of CCS under a climate policy regime is that it can be applied to different fossil sources, such as gas and coal, as well as to biological ones, as previously discussed. This flexibility makes CCS appealing for different levels of climate policy stringency, as shown in Figure 1. The capacity of biomass and CCS (commonly referred to as BECCS) to generate net negative emissions – at least in theory – by capturing the CO_2 stored in the biomass and sequestering it underground provides additional incentives in favour of CCS. Although the costs of BECCS and other negative emission technologies are currently above those of conventional mitigation technologies (e.g. above \$100 per tCO_2), models foresee a large role for CO_2 removal, especially during the second half of the century, when carbon prices will rise to sufficiently high levels. Despite its potential, it remains unclear whether BECCS can deliver the CO_2 absorption rates foreseen by economic optimisation models, when considering the technological and institutional limitations and the need to provide CO_2-neutral biomass. The uncertainties around the potential of negative emissions are therefore huge (Azar et al. 2013, Tavoni and Socolow 2013, Fuss et al. 2014).

These large uncertainties are also reflected in the wide range of the scenario results in Figure 1, which includes cases in which models have assumed that CCS would not be available, as shown by confidence interval bars including no CO_2 captured. Such analysis has further revealed that among all mitigation technologies, CCS is the one with the highest economic value – foregoing or banning CCS would lead to a significant increase (i.e. a doubling or more) in the economic costs of achieving a given climate stabilisation, especially for the most stringent mitigation scenarios (Tavoni et al. 2012, Kriegler et al. 2014: 27). Although a broad portfolio of low-carbon technologies is needed to achieve climate stabilisation, CCS stands out as one of the most important since it is the only one that would allow continued use of fossil energy sources.

3 Status of and prospects for the technology

The climate stabilisation scenarios call for a massive scaling up of CCS over the next several decades, a requirement that stands in stark contrast to the limited deployment of CCS observed in reality. At the time of writing, approximately 14 pilot CCS projects are operating, four of which are for enhanced oil recovery.[2] Several others have been announced, but an equally large number have been cancelled. One of the obvious reasons for this is the high capital costs of these technologies compared to conventional ones. For example, the US government's recent decision to pull the plug on the FutureGen project resides in the fact that, despite the $1 billion of federal money, investors remained wary of the economic viability of the carbon capture project. It is also due to the fact that cheap natural gas and the falling costs of renewable energy sources currently provide more economical solutions for reducing CO_2 emissions. In addition, public support for CCS remains a critical factor for its development – CCS involves infrastructure as well as storage sites, both of which require public acceptance. In Europe, adverse public acceptance has recently led to the cancellation of two CCS projects in the Netherlands and in Germany. Moreover, CCS alone would not eliminate other kinds of pollution coming from coal combustion, such as those responsible for local air quality. Last, but not least, if CO_2 were to leak from the reservoirs where it is stored, the benefits of CCS would be undone. Although current tests do not seem to indicate leakage to be a particularly critical issue, the long-term effects of storing CO_2 are not yet fully understood. Looking ahead, by 2020 the number of CCS projects in operation is expected to double, but this will mostly come from demonstration plants, with the aim of recovering oil (de Coninck and Benson 2014).

4 Policy issues and gaps

The gap between the currently observed rates of investment in low-carbon technologies and the actual levels needed for the transition towards a low-emission society is particularly significant in the case of CCS. Despite recent changes in the energy markets, coal and gas remain the dominant technologies in power generation (globally 40% and 23%, respectively), especially in the developing world (Steckel et al. 2015). As a result, developing a technology that is able to limit the CO_2 emitted by fossil fuel plants seems particularly valuable. In order for this to happen, several things would need to change at the policy level. First of all, the technology remains unproven at the

2 See http://sequestration.mit.edu/tools/projects/index_pilots.html.

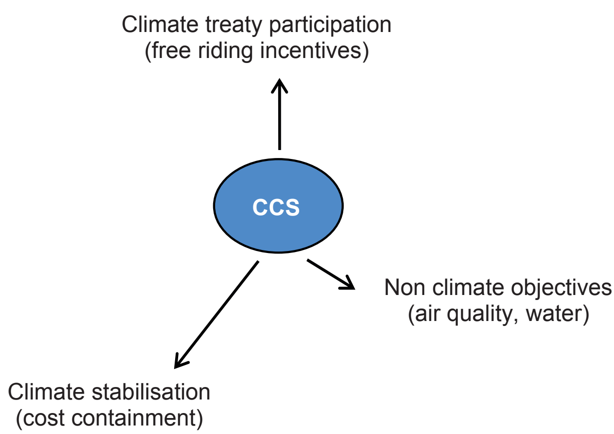
required scale. Several countries have embarked on or announced pilots, but more will be needed in order to test and demonstrate which among the different designs works best. Low natural gas prices now offer an additional and technologically easier way of testing whether CCS works, since this does not require the complicated gasification process needed for coal. Second, research and development is needed to close the cost gap between plants with and without CCS. Currently, the cost of CO_2 capture appears to be around \$100 per tCO_2, well above the carbon prices discussed in policy contexts. Expert elicitation studies indicate that R&D could reduce the additional CCS cost to a few cents per KWh by the year 2030, if incentives (see below) to innovate were in place (Baker et al. 2009). However, despite some considerable R&D investments in the recent past, CCS plants have not materialised as expected, highlighting the many enabling conditions that are needed to demonstrate CCS. These include climate policies that provide the appropriate economic incentives to sequester CO_2 – even if CCS develops further economically and technologically, it will always require a significant economic incentive in order to be viable and to compete with alternatives. Last but not least, several other enabling conditions will also need to be met at the same time in order for CCS to flourish: public and political support, trust of investors, and a transparent procedural justice (de Coninck and Benson 2014).

5 CCS in the context of climate negotiations

The barriers outlined above represent significant obstacles, which will not be easily overcome in the next few years. CCS might indeed never materialise at the scale foreseen by the scenarios depicted in Figure 1. In light of this uncertainty, to what extent should CCS be an important part of the current negotiation process? One thing we know now is that keeping the option open is vital for climate strategies. As shown in Figure 2, CCS represents one of the few levers that can be used to engage fossil fuel-rich countries in climate mitigation efforts, and to reduce the risks of carbon leakage via trade and intensified extraction of fossil fuels in anticipation of stringent climate legislation. The biggest challenge for international climate policy is to ensure participation and overcome free-riding incentives. If a climate coalition that reduces emissions is formed, non-participants have an economic incentive to increase fossil fuel consumption (see also the chapter by Fischer in this book). A possible way to overcome this conundrum, as recently highlighted by Harstad (2012), would be to buy fossil fuel deposits in the non-participating countries. However, this would require significant political capital and would have equity considerations (see the chapter by Collier in this book). CCS has the potential to achieve the same results and with higher chances of being successful. In order to do so, a technology agreement aiming at developing and commercialising CCS in all the major fossil fuel-rich countries (and especially countries rich in coal) could enrich the climate agreements, which as currently discussed are focused on the demand side of emissions quotas. Sufficient R&D investments aimed at reducing the currently high mitigation costs of CCS would be also needed in order to engage fossil-endowed countries and thus reduce the free-riding incentives.

Summing up, CCS would not provide significant benefits outside the climate ones. However, it remains an incredibly important option for climate policymakers, both in terms of providing incentives to participation in a broad climate treaty, as well as for ensuring climate stabilisation is attained at a minimum societal cost.

Figure 2 CCS and environmental policy goals, schematic representation



Note: The lengths of the arrows represent the potential benefit of CCS for three selected policy goals.

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