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From demonstration to deployment: An economic analysis of support policies for carbon capture and storage

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HIGHLIGHTS

- Sensible aim of current climate policy: secure *option* of future CCS deployment.
- But policy makers require flexibility while private investors require predictability.
- Integrating CCS policy into an overall policy architecture can overcome this antinomy.
- We describe the key features of a good policy architecture and give an example.

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ABSTRACT

This paper argues that an integrated policy architecture consisting of multiple policy phases and economic instruments is needed to support the development of carbon capture and storage (CCS) from its present demonstration phase to full-scale deployment. Building on an analysis of the different types of policy instruments to correct market failures specific to CCS in its various stages of development, we suggest a way to combine these into an integrated policy architecture. This policy architecture adapts to the need of a maturing technology, meets the requirement of policymakers to maintain flexibility to respond to changing circumstances while providing investors with the policy certainty that is needed to encourage private sector investment. This combination of flexibility and predictability is achieved through the use of 'policy gateways' which explicitly define rules and criteria for when and how policy settings will change. Our findings extend to bioenergy-based CCS applications (BECCS), which could potentially achieve negative emissions. We argue that within a framework of correcting the carbon externality, the added environmental benefits of BECCS should be reflected in an extra incentive.

1. Introduction

Carbon capture and storage (CCS) is an emerging climate change mitigation technology that prevents CO_2 produced by power stations and by industrial processes from entering the atmosphere. This is achieved by collecting the CO_2 where it is produced and pumping it into deep underground storage formations where it can be trapped by rocks through a variety of physical and geophysical trapping processes (IPCC, 2005). Since the publication of the IPCC's Special Report on CCS in 2005 (IPCC, 2005), the interest in CCS in the climate change policy making community has increased significantly; a relevant role for CCS in a portfolio of measures to achieve large-scale CO_2 emissions reductions is now widely accepted (Edenhofer et al., 2010).

However, it is fair to say that CCS is currently not on the path to deliver on its promises (IEA, 2012a). CCS continues to be an emerging and technically immature abatement technology which is expensive in comparison with other options. Even though there are a few large-scale CCS projects world-wide in operation or under construction, their number falls short of what would be needed for CCS to mature to a cost-effective abatement technology.

Many reasons have been put forward to explain the currently unsatisfying state of CCS (von Hirschhausen et al., 2012). The inadequacy of governmental support policies is probably key among them. High-level political commitments by governments to support CCS are often not translated into policy programmes that effectively and efficiently drive CCS development; in addition, there are no strong expectations that the climate externality will be meaningfully addressed in the near term in a way that would lend support to CCS investment. Examples for this situation can be found in the EU where the reliance on the European Emission

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Trading Scheme to support CCS has so far not delivered a single integrated large-scale project, or in the US where relevant policy action regarding CCS is exhausted by support for demonstration projects. While it is currently unclear whether CCS will indeed develop into a cost competitive component of a future emission reduction portfolio once relevant market failures are addressed, it is clear that CCS will *not* become a viable abatement option without policy support. To secure the *option* of future deployment, a sound policy framework is needed now.

Policy options to promote CCS were analysed in work by Groenenberg and de Coninck (2008), Von Stechow et al. (2011) and Al-Juaied (2010), with the latter papers focussing on the specific application of CCS in the European and US electricity generation sector. Our contribution extends this work by presenting a comprehensive policy framework composed of multiple and mutually supporting policy instruments aimed at promoting the development of CCS from its present immature status towards a potentially cost-competitive technology that could be deployed at large scale in both industrial and power sectors. Rather than focussing on single, uniform policy instruments such as a price on CO_2 emissions, the paper proposes a policy framework for CCS where the policy mix evolves over time. Recognising that CCS may fail to become cost effective, the evolution of policies to support CCS needs to be tied to the performance of CCS relative to other technologies, and should allow for the the possibility of phasing out support for CCS.

After discussing, in the next two sections, the role of CCS for reaching stabilisation targets and examining the current status of CCS technology, we start the construction of the policy framework with a review of the different market failures faced by CCS during its various phases of development. We then proceed to analyse the main economic instruments available to correct relevant market failures, and score their suitability to support CCS at the various stages of development against a set of criteria. Much of our analysis of market failures and the choice of scoring criteria have been inspired by the work of Goulder and Parry (2008) on the selection of instruments for environmental policy. The ranking process produces a set of preferred policies, which we integrate into a policy programme through the incorporation of 'policy gateways'. These gateways spell out the conditions for the transition of policy from one phase to the next. Their objective is to facilitate the smooth transition between different policies, to render policy evolution predictable to private sector investors, and to provide policy makers with the flexibility to learn from experience and to minimise costs.

2. Why CCS?

CCS involves the collection of CO_2 produced by large stationary sources, transport of the CO_2 to a suitable storage site, and its injection into deep geologic formations for storage where it remains contained for thousands of years. Potential storage options include deep (800 m or deeper) saline aquifers and oil fields, where injected CO_2 can enhance oil production while being stored. However, the majority of the global storage resource is found in saline aquifers, with a smaller portion of the resource being in oil fields.

Deployment of CCS, including where injection of CO_2 is used to enhance oil recovery, is exclusively driven by concerns over climate change. This feature of CCS differentiates it from other low-carbon technologies, such as renewable-based electricity generation technologies, which typically bring multiple benefits, and has implications for the policy framework that is best suited to support CCS.

The contribution that CCS could make to reaching climate change stabilisation goals is significant. The issue has been reviewed in detail by the IPCC in its 2005 Special Report on Carbon Dioxide Capture and Storage (IPCC, 2005), and is corroborated in numerous other more recent studies (e.g. Edenhofer et al., 2010, Edmonds et al., 2007). For example, in the IEA Technology Perspectives (ETP) 2 °C Scenario (2DS), in which emissions are reduced to levels consistent with a 2 °C global average temperature increase, CCS contributes about one-fifth of the total emission reduction needed between 2015 and 2050 (IEA, 2012a). In this scenario the deployment of CCS in the electricity generation sector is driven by its cost-competiveness in relation to other low-carbon power generation options (e.g. nuclear and renewable-based generation). Certain industrial sectors, including iron and steel, cement, and natural gas processing have few, if any, technical options other than CCS for achieving deep emission reductions. Without CCS the industrial sector cannot meet emission reductions consistent with a 2 °C target (IEA, 2012a) (Fig. 1) In line with this, in the 2DS the global share of emissions reductions between 2015 and 2050 is split roughly equally between industrial applications of CCS (e.g. iron and steel, chemicals) and applications in power generation, although this global aggregate masks strong regional differences in this share (Fig. 2).

The combination of biomass energy with CCS (referred to by the acronym BECCS) has the potential to reduce the stock of atmospheric carbon as opposed to merely avoiding emissions to the atmosphere. This will be the case when the amount of CO_2 sequestered from the atmosphere during the growth of biomass and subsequently stored underground is larger than the CO_2 emissions associated with the production of biomass, including those resulting from land-use change, and the emissions released during the transformation of biomass to the final product. The relevance of BECCS for meeting aggressive reduction targets has been analysed in work by Obersteiner et al. (2001) and Azar et al. (2006). In the 2DS of the IEA scenario, BECCS accounts for 17% of the CO_2 captured between 2015 and 2050, with the majority of the CO_2 captured from production of biofuels.

3. Status

The component technologies used to capture, transport and store CO_2 are by and large technically mature. CO_2 capture is already commercially deployed in many industrial processes such as gas processing and ethanol production, and capture technologies for power generation are following close behind (IEA, 2012a). Relevant commercial experience also exists for the other two steps comprising the CCS technology chain, namely transport and injection. In the US over 6600 km of pipelines transport more that 60 million tonnes of CO_2 annually, produced primarily from geological accumulations, for the purpose of enhancing oil recovery (Bliss et al., 2010). Nonetheless, CCS is still a pre-commercial technology. There is limited experience in combining CO_2 capture, transport and storage to create integrated CCS projects, and there is a need to gain further experience with aspects related to the long-term containment of injected CO_2.

Currently there are four large-scale CCS projects in operation worldwide. Three of these projects (two in Norway, one in Algeria) are in the natural gas sector. These store CO_2 that has been captured as part of the production and processing of natural gas. These projects inject about 2.7 million tonnes of CO_2 annually into deep aquifers (Global CCS Institute, 2011). The fourth project, located in North America, involves capturing CO_2 from a synfuels plant in North Dakota and transporting it across the border to Canada, where it is used to enhance recovery from the Weyburn-Midale oil field in the Canadian province of Saskatchewan.