Energy Policy 55 (2013) 683–689

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Communication

Ten times more difficult: Quantifying the carbon capture and storage challenge

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HIGHLIGHTS

- Four key challenges for CCS are found to be of an order magnitude greater than often recognized.
- The possibility for CCS to be commercially available by 2020 is greatly exaggerated.
- Reducing CO_2 emissions with CCS is a political challenge, not a technological.

ARTICLE INFO

Article history:
Received 15 May 2012
Accepted 5 December 2012
Available online 20 January 2013

Keywords:
Carbon capture and storage
Technology innovation system
Climate change

ABSTRACT

Carbon Capture and Storage (CCS) is receiving much attention and is being promoted as an important low-carbon technology. This paper communicates key insights and conclusions from a larger study that conducted review work, policy analysis, and interviews with actors in the global CCS community (Varnäs et al., 2012). No judgment is made of the desirability of choosing CCS as a low carbon technology option, but if this technology is indeed pursued, four challenges are found to be 10 times greater than often recognized. These are; (i) a tenfold up-scaling in size (MW) from pilot plants to that of commercial demonstration, (ii) a tenfold increase in number of large scale demonstration plants actually being constructed, (iii) a tenfold increase in available annual funding over the coming 40 years and, (iv) a tenfold increase in the price put on carbon dioxide emissions. It is clear that the current development path will not fulfil expectations of CCS being commercially available at the end of this decade, nor will CCS be widely applied in time for significant contributions to needed CO_2 emission reductions. CCS will only be developed if policymakers continue to favour coal based power generation while simultaneously developing stringent climate policy.

1. Introduction

Carbon Capture and Storage (CCS) promises continued use of fossil primary energy without net emissions of CO_2. This technology is particularly interesting for coal based power generation as coal is the single most important source of energy that must be replaced in a world with curbed CO_2 emissions. Research indentifies only limited technological challenges, but before the technology becomes a viable option, there are several other challenges that need to be resolved, including integration of technologies in large scale plants, investment costs, the price on CO_2 emissions, legitimacy, and regulatory uncertainty (Claes and Frisvold, 2009; Gough et al., 2010; van Alphen et al., 2010a). Technological maturity and the promise of significant CO_2 emission reductions, are set against severe barriers for market penetration, making it difficult to set expectations for CCS. Most research on CCS focuses on technology development or the relative functioning of the different parts of the CCS innovation systems in individual countries. There is a need for a realistic assessment of the promise of low carbon coal power, as there have been few attempts to summarize the magnitude of the most important barriers for market penetration at a global level. This paper presents findings from such a research effort.

The chosen case studies are the US and Europe. They constitute the most important regions for CCS due to emerging political agendas and significant research and demonstration activities. The study used Technology Innovation System (TIS) theory, first mapping relevant actors, institutions, and policy landscapes, and then assessing the progress in terms of innovation functions[1] (Bergek et al., 2008a; Hekkert et al., 2007). Results were gathered

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[1] TIS studies use slightly different lists of functions. In this research, data is gathered for Entrepreneurial Activity, Knowledge Development, Knowledge Diffusion, Guidance/Influence on the Direction of Search, Market formation, Resource mobilization, and Legitimization.

0301-4215/$ - see front matter
http://dx.doi.org/10.1016/j.enpol.2012.12.026

through literature reviews and interviews with a range of actors, including global manufacturing and reengineering companies, energy utilities (or organizations representing energy utilities), CCS lobbying and network organizations, research organizations, and policy actors. Interviews were semi-structured and probed the overall progress of CCS R&D, the perceived drivers, uncertainties and barriers, and the influence of policy-making. Findings provided descriptions of each TIS function. The method has recently been applied in several innovation studies of CCS (van Alphen et al., 2010a; van Alphen et al., 2010b; van Alphen et al., 2009). For a complete account of interviewees and further information on method, see Varnäs et al. (2012).

The contribution of this paper is not primarily to further explore the functioning of the CCS TIS, but to draw quantitative conclusions based on such analysis. Both previously published research on the CCS TIS in different countries and our research highlight similar barriers, emphasizing that the functions ‘‘entrepreneurial activity’’, ‘‘market formation’’, and ‘‘resources mobilization’’ are among the least developed (Varnäs et al., 2012, van Alphen et al., 2010a). The four challenges presented in this paper were identified as the most important indicators that quantify the development of these functions, but each of the following sections also provides further details on the state of the TIS in the two cases. The remainder of this paper is organized as follows: first, a short introduction to the development of the CCS agenda and expectations of CCS in EU and the USA is provided, results are then provided for each challenge, and finally conclusions drawn.

1.1. The emerging CCS agenda in Europe and the USA

In Europe CCS only gained significant political attention as recently as 2005 (EC, 2005). The first dedicated European Commission communication on CCS was published in 2006 (EC, 2006). Claes and Frisvold (2009) describes this appearance as emerging from the two agendas of security of energy supply and climate change. In particular, following from the development of the Climate and Energy package in 2007, CCS was suddenly included and envisioned as a key solution in combating climate change in the EU. Policy and funding have developed rapidly since then, as have the CCS community as whole (Stephens et al., 2011). The European Commission is pushing for CCS, launching the CCS directive (EC, 2009b), several funding mechanisms for large scale demonstration plants, and networks for knowledge sharing including the Zero Emissions Platform (ZEP)[2] and the CCSNetwork.[3]

In the US, the current interest in CCS can be partly explained by the fact that US withdrew from the Kyoto protocol in 2001. Instead of policies putting a price or cap CO_2 emission, domestic technology development for, e.g., cleaner coal energy was pursued as the means for reducing emissions (Stephens, 2009). In 2002, energy experts initiated the FutureGen project as a proposed commercial scale power plant to demonstrate a number of CCS technologies specifically aimed for emissions reductions. The project was made a flagship initiative by the Bush administration in 2003 (Markusson et al., 2011). Seven regional CCS-Partnerships were also launched, creating networks of academic actors, national laboratories, and industry (Wilson et al., 2009). However, in contrast to the EU, the CCS agenda in the USA is also led by actors in the oil and gas industry developing carbon capture technology for Enhanced Oil Recovery (EOR). These two agendas do not necessarily align, and for example, legislation regulating injection of CO_2 tends to regulate EOR rather than permanent storage (Pollak et al., 2011).

In both the EU and the US, it is envisioned that more than 10% of CO_2 emissions reductions would come from CCS by 2030 (EU estimate by e.g. Claes and Frisvold (2009) and US estimates by McKinsey (2007)). IEA scenarios ranks CCS as one of the key solutions for CO_2 mitigation through 2050, covering a fifth of envisioned total reductions needed by 2050 (IEA, 2009). The global long term potential has been estimated by IPCC to be between 15% and 55% of cumulative emissions reductions by 2100 (IPCC, 2005). Furthermore, total costs, including transport and storage, have been estimated as 40% higher without CCS in EU through 2030 (EC, 2008), while global estimates are between 50% and 80% more expensive long term climate change mitigation costs excluding CCS (Azar et al., 2006; IEA, 2009). This strictly economic rational in favour for CCS is argued by many researchers and policy makers. According to our interviews, this is also the underlying reason for manufacturing and utility companies betting on a CCS future. However, the question largely remains whether CCS will indeed play such an important role. As the following section will now show, the first step of making CCS commercially available the coming decade, requires efforts to be scaled up by an order magnitude.

2. Results

2.1. Challenge I: Scaling up pilot plants 10 times

It is clear that the technological challenge for CCS lies in integrating existing technologies (Claes and Frisvold, 2009; Gough et al., 2010; van Alphen et al., 2010a). As Pollak et al. (2011, p. 313) conclude, CCS is not new, but applying it to Climate Change mitigation is. One of the interviewed experts described this as ‘‘to integrate a chemical plant and a power plant’’. On top of that, integration with large scale transport and storage sites is needed.

Both CCS knowledge development and diffusions are well advanced (Stephens and Jiusto, 2010; van Alphen et al., 2010a; van Alphen et al., 2010b). CO_2 capture technology emerged in the food and chemical industry already in the 1930s, and separation of CO_2 from natural gas streams in the 1950–60s (IEA, 2009). The latter technology has been implemented as a low-carbon technology in the Norwegian Sleipner project since 1996 (van Alphen et al., 2009). Knowledge sharing platforms and collaborations through pilot plants in Europe ensure that experience is shared and concerns for intellectual property are resolved (Varnäs et al., 2012). In the US, regional CCS partnerships have created similar networks of academic actors, national laboratories, and industry (Wilson et al., 2009). CO_2 has been produced, transported and sold on a market for much of the 20th century, and global companies that supply CCS technology, such as Alstom and Siemens, even state that they are in principle ready to take orders for large-scale CCS plants, with cost and performance guarantees (Varnäs et al., 2012).

However, there is still no large scale coal power plant CCS project in operation, and all large CCS projects are gas processing facilities (see e.g., the list of operating plants in DOE (2010)). Interviews indicate that all major new projects in the US are conditioned on Enhanced Oil Recovery (EOR), which is also confirmed by the recent Obama Task force report (DOE, 2010, pp. 32–33). CCS for the purpose of climate change mitigation is still not being pursued, and large uncertainties of the actual net benefits emission reductions exist for EOR (Jaramillo et al., 2009). Climate mitigation and EOR largely constitute two different communities with different agendas (Pollak et al., 2011).

[2] http://www.zeroemissionsplatform.eu/.
[3] http://www.ccsnetwork.eu/.