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Resolving or managing uncertainties for carbon capture and storage: Lessons from historical analogues

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ABSTRACT

Carbon capture and storage (CCS) technologies are often highlighted as a crucial component of future low carbon energy systems in the UK and internationally. Whilst these technologies are now in the demonstration phase world-wide, they are still characterised by a range of technical, economic, policy, social and legal uncertainties. This paper applies a framework for the analysis of these uncertainties that was previously developed by the authors to a historical evidence base. This evidence base comprises nine case studies, each of which focuses on a technology that is partly analogous to CCS. The paper's analysis of these case studies examines the conditions under which the uncertainties concerned have been at least partly resolved, and what lessons can be drawn for CCS. The paper then uses the case study evidence to discuss linkages between the uncertainties in the analysis framework, and how these linkages differ from those that were originally expected. Finally, the paper draws conclusions for the methodological approach that has been used and for strategies to develop and deploy CCS technologies.

1. Introduction

Carbon capture and storage (CCS) technologies are often highlighted as a crucial component of future low carbon energy systems in the UK and internationally. For their supporters, these technologies can square the continued use of fossil fuels with climate change mitigation. According to the International Energy Agency (IEA) World Energy Outlook in 2011, fossil fuels will continue to supply the majority of the world's energy to 2035, even if climate change mitigation is taken very seriously [1]. The IEA '450 scenario' considers a global energy system trajectory that has a significant chance of limiting average temperature increases to 2 °C. Under this scenario, CCS would be fitted to 32% of the world's coal fired power plant capacity (410GW out of 1270GW) by 2035, and 10% of global gas fired capacity (210GW out of 2110GW) by the same date. CCS technologies would account for 22% of the reduction in CO_2 emissions by 2035 when compared to the IEA's alternative 'new policies scenario' in which global greenhouse gas emissions would continue to rise.

Whilst the IEA's '450 scenario' only represents one view of the future, many other scenarios that limit global average temperature rises to 2°C include a prominent role for CCS technologies [2]. However, these technologies are still being developed and demonstrated, and are subject to a range of technical, economic, legal, social and policy uncertainties. It is therefore unclear when these technologies will be technically proven at full scale, and whether their costs will be competitive with other low carbon technologies.

Many governments and companies are now funding and developing CCS technologies. Pilot scale capture plants are in operation in several countries, CO_2 is routinely transported across large distances in the United States, and CO_2 is being injected successfully at a number of storage sites. But full-scale CCS plants are thin on the ground. A recent survey by the Global CCS Institute identified eight large scale integrated CCS projects

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that are already in operation around the world [3]. These focus on gas processing, synthetic fuels and fertiliser production — applications that are less technically demanding and more economically attractive than CCS in the power sector. According to the IEA, 'incorporating CCS into a power plant increases the levelised cost of the electricity produced by between 39% and 64%, depending on the technology and fuel source' [1: 378]. This increase is expected for two main reasons: first, the incremental capital costs of adding CCS to a fossil fuel power plant are substantial; and second, adding carbon capture to a power plant has an energy penalty of around 10 percentage points [4].

This paper presents some of the results from a two-year interdisciplinary research project funded by the UK Energy Research Centre (UKERC). The paper systematically examines the uncertainties facing CCS technologies in the UK, and builds on a previous paper from the same project that developed a framework to identify and analyse these uncertainties [5]. This paper applies this framework to a historical evidence base that comprises nine case studies, each of which focuses on a technology that is partly analogous to CCS. The case studies analyse the conditions under which the uncertainties have been at least partly resolved, and what lessons can be drawn for CCS. The main research question for the paper is therefore: what lessons can be drawn from historical analogue case studies about the conditions under which the uncertainties facing CCS technologies could be managed or resolved?

The remainder of the paper is structured as follows. Section 2 sets out the framework that has been developed to analyse seven uncertainties facing CCS technologies, and explains how this framework has been applied to the analogue case studies. Section 3 focuses on each uncertainty in turn. It includes a summary of case study findings for the uncertainty concerned together with the main lessons for CCS policies and strategies. Section 4 examines the linkages between the seven uncertainties, with a particular focus on additional linkages that were identified as a result of the case study analysis. Finally, Section 5 draws conclusions — both for the methodological approach used in the paper and for strategies to develop and deploy CCS technologies (Figs. 1 and 2).

2. Framework for analysing uncertainties

This section introduces the analytical framework used for analysing the uncertainties of CCS, and describes an approach based on historical analogues for collecting the required data.

The analysis draws on a framework already developed for analysing the uncertainties of CCS innovation. See Markusson, Kern et al. [5] for more detail. Table 1 introduces the seven main uncertainties identified, together with the specific indicators that have been used in this paper to analyse the historical case studies. The framework also specifies the linkages that can be expected between the uncertainties. These are presented and analysed further in Section 4 of this paper.

The framework was developed by first drafting a list of proposed uncertainties based on a review of the social science literature on CCS as well as the wider literature on innovation. This list was then refined through consultations with the interdisciplinary research team and a steering group with representatives from industry, policy and academia. To further ground the framework in an understanding of how actors assess new technologies in practice, technology stakeholder representatives were also interviewed and technology assessment documents reviewed.

Facing a new technology and the uncertainties inherent in this situation, we all draw on our experience of other technologies. This happens both in informal discussions and through formalised, explicit comparisons in the development of designs, policies and so on. See, for example, Reiner and Herzog [6] on regulatory analogues for CO_2 storage. Technology assessment practice and theory is no different in this respect, in that lessons learnt are transferred through the use of theory and assessment methods. There is however

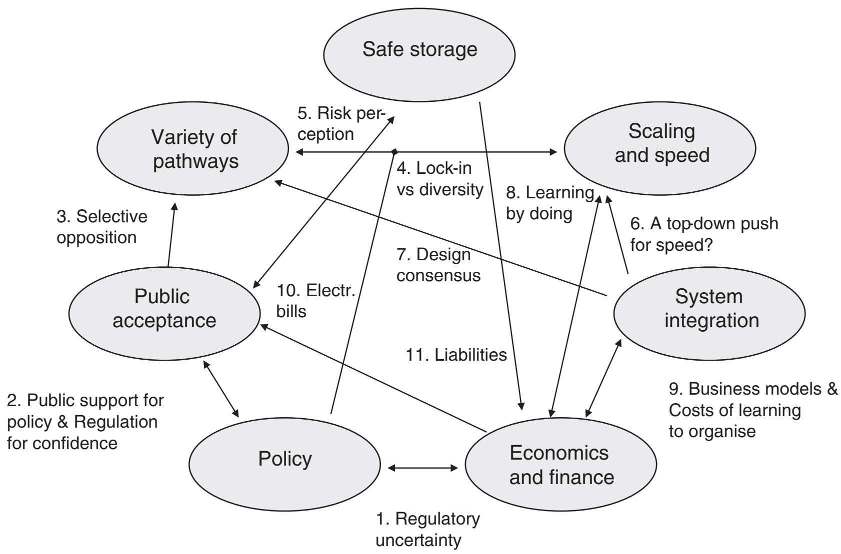

Fig. 1. Linkages between uncertainties as hypothesised in Markusson, Kern et al 2012.