The European CCS Demonstration Project Network – A forum for first movers

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Abstract

The European CCS Demonstration Project Network was initiated by the European Commission in 2009. The main objective of the network is to accelerate development of CCS technologies by creating a forum for exchange and dissemination of new knowledge generated by the first large scale CCS plants in Europe. This paper provides an overview and understanding of the activities of the network and the political and theoretical context of their development. The paper focuses on how the Network has been structured to add value to demonstration projects and create vital new channels of information for enabling CCS demonstration and deployment to be advanced worldwide.

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1 Introduction

If widely deployed, CO\textsubscript{2} capture and storage (CCS) has the potential to make severe and necessary cuts in the CO\textsubscript{2} emissions resulting from the combustion of fossil fuels. However, to achieve the high levels of CO\textsubscript{2} capture, transport and storage that are foreseen to offer a low-cost route to a future low carbon energy system requires unprecedented technological development and implementation. According to the International Energy Agency (IEA), this will only be possible via expanded international collaboration and exchange of knowledge through industrial collaboration and expansion of developing country CCS capacities [1].

The European CCS Demonstration Project Network (CCS Project Network) has been initiated by the European Commission (EC) to facilitate the exchange and dissemination of new knowledge generated by the first large scale CCS plants in Europe. This paper provides an overview and understanding of the activities of the network and the political and theoretical context of their development.

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2. Background

The EU is committed to a 20% reduction of greenhouse gas (GHG) emissions by 2020 [2]. In line with an agreed target of stabilising global warming below 2°C above the pre-industrial temperature, the EU seeks to secure global emission reductions of at least 50%, and aggregate developed country emission reductions of at least 80-95%, by 2050 compared to 1990 levels [3]. A portfolio of measures – including energy efficiency, increased energy production from renewables and CCS – has been identified as necessary to meet this target [4]. If CCS is to play a role in meeting this target it is necessary that the technologies are accessible for widespread commercial deployment by 2020. To meet this target the EU aims to stimulate the construction and operation of up to 12 carbon capture and storage demonstration projects by 2015. The first projects are underway, partly thanks to early initiatives in several European countries and the EU’s European Energy Programme for Recover (EEPR)².

In support of the early demonstration of sustainable power generation from fossil fuels, in 2008 the EC concluded that it would animate a network of CCS demonstration projects to ‘provide first movers a means of coordination, exchange of information and experience and identification of best practices’ [5]. The CCS Project Network, which is now operational with 6 member projects so far³, aims to add value to European projects by⁴:

- Facilitating the identification of good practices, lessons learned and recommendations with respect to large-scale CCS demonstration and enabling knowledge sharing amongst projects
- Providing a common EU identity to Network members
- Leveraging experience gained from projects and the evidence generated by them, in order to build public confidence about the feasibility and safety of CCS
- Promoting CCS, EU leadership and cooperation potential to third parties/countries [6].

The goal is to create a prominent community of large-scale projects with the shared goal of large-scale CCS demonstration. The process of knowledge sharing will help the European and global CCS communities to ‘learn by doing’ and prepare the ground for the widespread commercial deployment of CCS, which will demand the confidence of investors and the public, and the tackling of any arising research challenges [7].

3. Learning by doing: the role for knowledge sharing for CCS

Kramer and Haigh [8] have outlined a pathway to an atmospheric CO₂ concentration of 550ppm – approximately 160 ppm above current levels – that would involve a very rapid deployment of CCS (Figure 1).

![Energy technology development curves](image1)

**Figure 1. Energy technology development curves, from Kramer and Haigh [8]**

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² http://ec.europa.eu/energy/eepr/ccs/index_en.htm
³ Belchatow, Poland; Compostilla, Spain; Hatfield, UK; Jaenschwalde, Germany; Porto Tolle, Italy; ROAD Rotterdam, The Netherlands.
⁴ Det Norske Veritas (DNV) is providing expert services to the Commission in the areas of knowledge management and CCS technology.
The IPCC consider it likely that a long-term atmospheric concentration of 550 ppm would lead to a temperature increase of 2.9°C above pre-industrial levels [9]. To preserve a 50% or greater chance of restricting warming to 2°C or less by 2100, a scenario in which global CO₂ emissions peak early and are stabilised at or below 450ppm is advocated by climate scientists [10].

To reach 450 ppm, the IEA anticipates that the lowest cost combination of energy demand reduction and technological change that would meet the world's energy needs would require an even steeper roll-out of CCS [15]. Both analyses foresee a sharp increase in CCS capacity, especially in developed countries, between 2015 and 2030 if the 2050 targets are to be met worldwide. These are unprecedented learning rates for energy technologies.

The use of new technologies, or combination of technologies, delivers the necessary knowledge that enables the producers, operators and users of the technology to lower production costs and improve performance [11]. Learning-by-doing and learning-by-using have been acknowledged as two mechanisms that will lead to CCS that is lower cost and more attractive to potential users, respectively [12]. To facilitate a steep roll-out of CO₂ capture from fossil fuel or biomass combustion, combined with safe, permanent geological storage, there is a clear case for ensuring that the learning process can occur in the most efficient manner. Industries, governments and all other organizations involved in CCS share an interest in a non-exclusive exchange of knowledge, particularly in relation to nonrival, excludable goods.

3.1. Rival vs. nonrival goods

Conventional economic goods, such as food, electricity, private power generation and licensed technology, are rivalrous and excludable. Consumption by one consumer prevents simultaneous consumption by other consumers (rival), and producers are able to restrict who has access to the supply (excludable). Public goods, on the other hand, are nonrival and nonexcludable and include such things as a healthy atmosphere and scientific knowledge in the public domain. The interesting case for growth theory, contends Romer, 'is the set of goods that are nonrival yet excludable', the so-called ‘club goods’ [13:p74]. For example, the inventor of a widget has no ability to stop the inventor of a wodget from learning from the design of a widget, but he will often seek to limit access to the underlying knowledge.

A result of public funding for technological research and demonstration, therefore, is an unavoidable conflict between the incentives necessary to encourage the production of these technologies and the incentives that lead to their optimal distribution [14:p354]. Since, as Romer points out, the usual invisible hand result applies only to an artificial economy in which nonrival goods are provided exogenously by nature, political mechanisms may be required in a real economy to enhance the flow of nonrival goods resulting from public funding of technical development by private actors. This is especially true for the case where the ultimate goal is the better provision of a public good, such as a healthier planet. A large initial investment in R&D results in new knowledge that can be applied thereafter at zero marginal cost. Innovation is highly prized precisely because it does not observe the micro-economic principle of diminishing returns.

Addressing the aforementioned conflict will not be fully achieved by the simple appropriation and distribution of knowledge that would ordinarily be private and proprietary. Whilst accurate knowledge of the performance of CCS demonstration projects will be vital for public bodies to objectively shape the regulatory frameworks for the commercialisation of CCS, it is the sharing of nonrival know-how and tacit knowledge of project progress that will assist technology growth, especially in the early stages of project development.

3.2. Interactions between producers and users of CCS technology: tacit knowledge and innovation

The role of learning in the development of sustainable energy technologies has been well-described by researchers considering innovation systems for a transition to a low carbon economy. Foxon states that 'learning as a result of interactions between producers and users is mediated not merely by price mechanisms, but also by closer interactions involving mutual trust and mutually respected codes of behaviour' [15:p11].

5 The IEA analysis suggests that without CCS, overall costs to reduce emissions to half of 2005 levels by 2050 (~13.5 GtCO2/yr), increase by 70%.
Lines of communication between the capabilities of producers and the needs of users and other stakeholder groups are important to effect mutually beneficial learning and, consequently, process or product innovations. Figure 2 provides an overview of the actor groups involved in the innovation process.

Foxon highlights a distinction between that knowledge which is codified and written down and that which is tacit. Tacit knowledge is 'embodied in working practices and individuals’ experience and can only be passed on through sharing experience’ [15:p26]. Nonaka and Takeuchi argue that knowledge creation is a key element in supporting innovation in organisations, taking place at the group level through continuous conversion of tacit knowledge into explicit (or codified) knowledge into tacit knowledge again [18]. Through a spiraling process of socialisation, externalisation, combination and internalisation, groups advance their collective knowledge base.

Thus, the role of socio-technical interactions should be to facilitate a ‘knowledge spiral’ that helps groups of producers and users to articulate and share their experiences with demonstration projects, thus creating a new knowledge pool that underpins advancement of CCS technology.

Geels has described a socio-technical regime as being influenced by 'landscape factors' that exert an exogenous pressure on the technological trajectory – for example, the public perception of climate change – and technological niches [16]. Niches are seen as providing the initial applications for a given technology, usually in areas where its particular characteristics are especially advantageous and sometimes while receiving protection from a regulatory or performance standard. CCS is currently being developed in such a niche. It is not yet a commercial option in the energy system and is thus protected from the rigours of competition by public support. Aside from technical performance, its success will be determined in part from the ability of the actors at the niche level to align and mobilise resources, skills and capacities. Indeed, the seven functions of innovation proposed by Hekkert et al. to be fulfilled for regimes to expand out of niche markets include: knowledge development; knowledge diffusion through networks; guidance of search activities; market formation; mobilisation of resources; and creation of legitimacy/overcoming resistance to change [19].

3.3. Knowledge diffusion through networks

If the public sector identifies that the private provision of suitable knowledge diffusion networks is deficient it may intervene to expedite the development of technologies for sustainability. As Lundvall et al. have stated, 'if firms

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6 For specific examples of actor networks for a CCS project, see Raven et al. [17]
exchange their marginally relevant knowledge via a technology centre, the rate of productivity increase will be larger than if they keep the innovative results for themselves [20:p222]. Bringing together private actors to closely interact for the public good, however, demands attention to certain factors that will shape the quality of the participation and the outputs.

1. **Active engagement.** Without a clear economic incentive for sharing knowledge, lively and willing participation will not be assured. Networks should be designed and promoted for the added value they will provide to their members. This added value can be generated in a sharing platform that brings together industry participants to exchange approaches to common challenges and thus address them more efficiently.

2. **Mutual trust and mutually respected codes of behaviour.** If a network is to be formalised as a forum for knowledge diffusion, reaching a high level of trust between members is important [21]. Trust ensures there is mutual agreement to maximize the excludable knowledge available within the niche. Firstly, an agreement of what types and levels of knowledge are to be requested and shared may be established in advance. This agreement should furthermore indicate the governance of the network or scheme, the ownership of information and any confidentiality provisions and modes of redress. Secondly, it is recommended to allow time for relationships between actors to develop and for trust to emerge as organically as possible; face-to-face meetings can be helpful in this regard.

3. **Inclusive and broad actor groups.** Including all relevant actor groups and numerous participants within each group can help to avoid the unintended creation of tight, supportive networks of vested interests 7. Sharing of knowledge about the innovative technology should include as many of the originators of new knowledge as possible, with two caveats: gaining mutual trust will be more effective if limited to groups that are facing similar challenges; large, geographically diverse networks are likely to be more difficult to govern. These points might be addressed by nested sub-groups or ‘networks of networks’. As system builders, entrepreneurs may need to integrate previously disparate regimes in which they have little or no present experience [23:p52]. Where actors do not yet have excludable knowledge, but need to advance swiftly, added value is likely to be created.

4. **Legitimacy.** New business concepts, such as CCS, require both public and political legitimacy to operate. As described by Aldrich and Fiol, innovative entrepreneurs need strategies to promote their mutual expectations, reasonable efforts, and competence to stakeholders in the absence of existing experience [24]. Networks can be influential in the development and alignment of expectations and the provision of objective information through knowledge sharing, that entrepreneurs would find hard to achieve individually. Their ability to build vital public legitimacy will be influenced by their perceived independence. Modes of governance and dissemination should be sensitive to their impact on public understanding and acceptance, especially in the ‘formative phase’ of technology development [25].

**4. From theory to practice – A knowledge diffusion network for large-scale CCS demonstration projects**

The previous sections described some of the rationale for public intervention in the creation of knowledge diffusion networks for sustainable energy technologies such as CCS. The following sections describe how such a knowledge diffusion network is implemented in Europe, and internationally. This paper specifically elaborates on how the four factors identified in the previous section have been addressed in the establishment of the CCS Project Network.

**4.1. Active engagement**

Globally, several governmental organisations are funding or planning to fund large-scale CCS demonstration, such as the EU’s EEPR. Beneficiaries of EEPR funding are required to undertake knowledge sharing and to join the CCS Project Network. This ensures membership but to guarantee active engagement an initial emphasis has been

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7 As identified in Bennett and Pearson [22]. In extreme cases, vested interests can behave as clubs protecting privileged access to the ‘club goods’ (section 3.1) that the network seeks to diffuse.
placed on common challenges such as: navigating unfamiliar permitting processes, integration of a novel supply chain (for instance, utilities often have little knowledge of gas transport or storage) and the risks associated with CO₂ stream composition. In addition, the CCS Project Network is directed by a Steering Committee (SC) composed of representatives of each member project. The European Commission retains a seat on the SC.

4.2. Mutual trust and mutually respected codes of behaviour

The CCS Project Network is founded upon three core documents: the Qualification Criteria, Knowledge Sharing Protocol and Membership Agreement [6, 26]. The Knowledge Sharing Protocol outlines the expectation that members will share as much information as possible through meetings and web-based discussion in addition to data reporting. Sharing of intellectual property is not foreseen unless obliged by a public funding contract. The Knowledge Sharing Protocol divides knowledge into five categories covering the full CO₂ capture, transport and storage value chain:

i) Technical Set-up and Performance  
ii) Cost Levels  
iii) Project Management  
iv) Environmental Impact  
v) Health and Safety

In addition to technical data, good practices, lessons learned, case studies and project management plans will all be of use within the Network. Two sharing levels for knowledge are identified. Level 1 has been established to ensure that members are able to exchange experiences on a reciprocal basis wherever possible, or to ensure added value for sharing parties in the identification of good practices. Knowledge shared at this level is available within the Network. Level 2 has been established to ensure that external stakeholders have access to sufficient information to meet their needs. In the case of the public, all information on health, safety and environment is made accessible. In the case of the wider CCS community, information that enables the identification of research needs and informs global project developers about CCS costs and risks is made accessible. The default position is that members agree to share as much information as possible unless there is a serious, legitimate and substantiated commercial concern.

The knowledge sharing process and the effective diffusion of information through reports or other channels is managed by the secretariat of the CCS Project Network, currently funding by the EC. It is vital to recognise the value of getting new knowledge to potential users. For this purpose the website www.ccsnetwork.eu has been launched as a recognised repository of practical information regarding CCS demonstration.

Regular provision of standardised project information in the five categories is by completion of an electronic knowledge-sharing form. The form covers items such as progress against the schedule/milestones, key operating results, CO₂ captured, permits obtained and changes in estimates (including costs) and update of baselines. Tacit knowledge is shared at regular sharing events on identified key themes. Three such events per year, plus ongoing secure online interaction, are currently planned, and will be publicly reported (with Level 1 knowledge provided in aggregated form).

As each member signs a common Membership Agreement there is mutual understanding of each party's codes of behaviour and knowledge sharing requirements. This agreement sets the 'rules of the game' for a community of members who themselves identify topics with value for structured and coordinated sharing [27, 28]. To establish common codes for international knowledge sharing, a global knowledge sharing working group comprising governmental bodies that are sponsoring large-scale CCS demonstrations has worked to develop global principles and criteria [29:p35].

4.3. Inclusive and broad actor groups

The CCS Project Network is open to any project that fulfils the Qualification Criteria, regardless of whether the project is in receipt of public funding [6]. Any consortium partner can participate in the CCS Project Network in addition to the project's lead developer – each may sign the Membership Agreement and be bound by its codes of
behaviour. The basic eligibility criteria considered necessary to ensure a focused group of similarly mature and committed projects are:

- Sound plans to demonstrate the full CCS value chain by 2015
- For a fossil fuel-fired power plant, a minimum gross production of 250MWe before CO₂ capture and compression, or, for an industrial plant realise a minimum of 500kt per year of stored CO₂.
- Capture rate not be less than 85% of the treated flue gas stream
- Located within the European Economic Area (EEA)
- Committed to knowledge sharing as described in the Knowledge Sharing Protocol.

To ensure that the needs of the wider CCS community are met by the actions of the CCS Project Network, it is guided by an Advisory Forum that gathers views on the knowledge diffusion process from a group of relevant stakeholder groups.

4.4. Legitimacy

Projects entering the CCS Project Network gain visibility and a marketable identity as part of an EU-driven initiative. An objective of the CCS Project Network is to increase the understanding of, and confidence in, CCS by the wider public by leveraging experience gained from projects and the evidence generated by them. It is considered that, in the early stages of project development, where legitimacy is critical to obtaining permits to proceed, development of good practices and agreement of common messages can contribute to the success of each project. In the operational stages, the evidence generated can contribute to the overall legitimacy of CCS worldwide. Public communication strategies of demonstration projects are one of the three topics addressed by the CCS Project Network meetings in 2010. Lessons learned at these events seek to receive and share information that complements other regional and international public communications activities.

5. Conclusion

The establishment of CCS as a low carbon technology rests on the successful demonstration of capture, transport and storage at a large-scale, and the technology becoming available for wide scale implementation from 2020. In the near-term there is international recognition of the importance of large-scale demonstration of CCS technologies, for which the EU has made resource available and provided political commitment for up to 12 such projects. In this paper we have described the theoretical rationale for initiating the CCS Project Network as a tool for the facilitation of sharing and dissemination of knowledge gained by these projects. The protocols and the governance structures that have been put in place to enable the network to become fully operational in 2010 with its first six members and a stakeholder forum have also been described. We believe this is an important milestone for the social and technical development of CCS, and that the CCS Project Network is set to generate valuable understanding about the public supervision of knowledge sharing and the advancement of CCS.

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