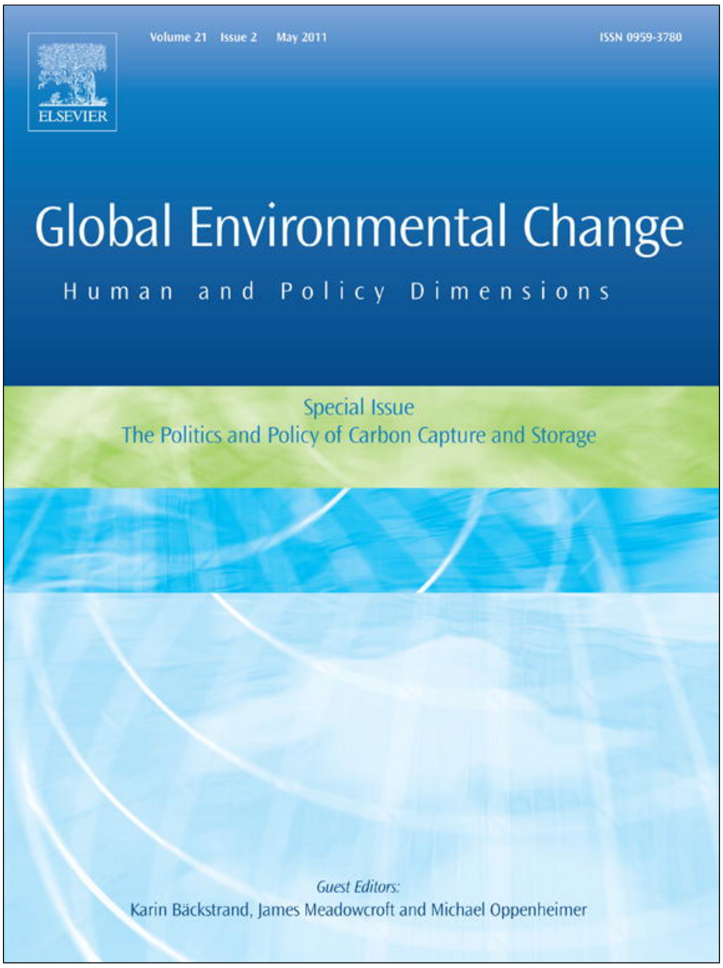
Volume 21 Issue 2 May 2011
ISSN 0959-3780
ELSEVIER
Global Environmental Change
Human and Policy Dimensions
Special Issue
The Politics and Policy of Carbon Capture and Storage
Guest Editors:
Karin Bäckstrand, James Meadowcroft and Michael Oppenheimer

Global Environmental Change 21 (2011) 293–302

Contents lists available at ScienceDirect

Global Environmental Change

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

The social and political complexities of learning in carbon capture and storage demonstration projects

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A R T I C L E   I N F O

Article history:
Received 30 April 2010
Received in revised form 22 December 2010
Accepted 18 January 2011
Available online 26 February 2011

Keywords:
Carbon capture and storage
Technology demonstration
Social learning
Innovation

A B S T R A C T

Demonstration of a fully integrated power plant with carbon capture and storage (CCS) at scale has not yet been achieved, despite growing international political interest in the potential of the technology to contribute to climate change mitigation and calls from multiple constituents for more demonstration projects. Acknowledging the scale of learning that still must occur for the technology to advance towards deployment, multiple CCS demonstration projects of various scales are emerging globally. Current plans for learning and knowledge sharing associated with demonstration projects, however, seem to be limited and narrowly conceived, raising questions about whether the projects will deliver on the expectations raised. Through a comparison of the structure, framing and socio-political context of three very different CCS demonstration projects in different places and contexts, this paper explores the complexity of social learning associated with demonstration projects. Variety in expectations of the demonstration projects' objectives, learning processes, information sharing mechanisms, public engagement initiatives, financing and collaborative partnerships are highlighted. The comparison shows that multiple factors including the process of building support for the project, the governance context and the framing of the project matter for the learning in demonstration projects. This analysis supports a broader conceptualization of learning than that currently found in CCS demonstration plans – a result with implications for both future research and practice.

1. Introduction and objective

As the global community raises its ambitions to tackle climate change, carbon capture and storage technology (CCS) has gained increased interest as a mitigation option (Pacala and Socolow, 2004; IPCC, 2005; Global CCS Institute, 2009). Accordingly, the last decade has seen rapid growth of the knowledge needed to explore and develop CCS technology (Stephens, 2006; van Alphen et al., 2010). However, multiple challenges for technology development remain, including reducing the cost of capture, validating the storage potential of saline aquifers and integrating the components and required infrastructure with power plants or other large-scale CO_2-emitting facilities (IEA, 2004; IPCC, 2005; MIT, 2007; McKinsey, 2008; Stephens and Jiusto, 2010). It is increasingly acknowledged that further advancement of the technology requires large-scale demonstration, in different contexts and configurations, of integrated systems with power plant, capture, transport and storage (de Coninck et al., 2009; van Alphen et al., 2010).

The Zero Emissions Platform (ZEP) proposal on CCS demonstration policy in Europe provides a useful example of the articulated expectations of CCS demonstration. A portfolio of 10–12 demonstration projects across Europe with different combinations of fuels, capture technologies and storage options is proposed. These projects aim to contribute learning about a wide range of aspects of CCS, including technological performance, infrastructure requirements, environmental impact, health and safety, legal and regulatory factors, funding and public understanding (ZEP, 2008). To achieve the expected learning outcomes, the proposal includes recommendations to enhance learning through knowledge sharing. The proposed plans, however, appear limited compared to the ambitious aims. Only four categories of knowledge to be shared are identified: technological, commercial/regulatory, environmental and stakeholder engagement. The report lists relevant stakeholders for knowledge sharing: the public, government and those involved in other CCS projects. However, nongovernmental organizations (NGOs) and other potential stakeholder groups are not mentioned explicitly. This tendency to articulate lofty learning goals without detailing comprehensive mechanisms or plans for achieving the goals is also evident in other reports on CCS demonstration (DNV, 2009; Global CCS Institute, 2009). Such

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doi:10.1016/j.gloenvcha.2011.01.010

circumstances highlight the need for a deeper understanding of learning processes surrounding CCS demonstration. The learning required for demonstration projects does not simply involve technical experts learning about the technological configuration of the project. Rather, the situation calls for a broader process of social learning that includes different types of knowledge and expertise and that involves engagement with a wide range of stakeholders (Rosental, 2004; Desbarats et al., 2010).

Given the multiple uncertainties surrounding CCS technology, its widespread appeal, the high costs of investing in the technology and its perceived value as a critical climate mitigation option, much is at stake with regard to the social, political and technical ramifications of emerging CCS demonstration projects. In the past few years, growing public concern about the safety of CCS has emerged, particularly in Europe (van Alphen et al., 2007; Greenpeace International, 2008) but also in the USA (Van Noorden, 2010), and public opposition to specific proposed projects and to the technology in general has been influential (Bielicki and Stephens, 2008). CCS demonstration projects and their outcomes are, therefore, likely to be contested, although the extent and type of contestation is likely to vary considerably based on project-specific factors including the project design, the host community, the perceived public benefits of the project and the established relationships among industry, government and civil society associated with each project. The learning associated with CCS demonstration projects is also social in the sense of being an outcome of the associated political processes (Collins, 1988).

The specific goals of this paper are to empirically explore the context-specific social and political complexities of learning in CCS demonstration projects and to broaden consideration of and encourage integration of social learning processes in CCS demonstration projects. These goals are achieved through a comparison of the structure, framing and social context of three cases of CCS demonstration projects: the FutureGen project in the USA, the Longannet project in the UK and the Yubari project in Japan. The specific research questions to be addressed by this study are:

1. What are the major differences in the framing of project goals, structure and expectations and how do those differences impact the potential of the demonstration projects to produce social learning?
2. How are the processes of social learning in current and proposed CCS demonstration projects influenced by socio-political factors, including engagement with different actors, project financing and political contexts?

At a general level, this research aims to demonstrate the need recognized by others for further social science research into energy technology innovation (Webler and Tuler, 2010) and energy policy (Allcott and Mullainathan, 2010).

This paper first provides theoretical background on technology demonstration, social learning and framing relevant to CCS demonstration projects and describes the methodology of the comparative approach. Detailed descriptions of the three cases are followed by a discussion of the results, implications and suggested future research directions stemming from this research.

2. Theoretical background

2.1. The social nature of technology demonstration

The word 'demonstration' when used in conjunction with technology has multiple meanings, including a specific stage in the development of a technology (Sagar and Gallagher, 2004) or a project or event having the aim of showing an artifact to an audience (Karlström and Sandén, 2004; Shapin, 1984; Rosental, 2005). These definitions are related, but they highlight different aspects of the concept. The stage of development definition emphasizes that demonstration is an integral part of an innovation process. Demonstration provides a link between R&D and deployment/marketing (Sagar and Gallagher, 2004) and it contributes to the overall progress (or failure) of the technology's development. The project/event definition of demonstration highlights the role(s) of different actors and thus acknowledges the potential social complexities of demonstration.

Demonstration does not generally mean the communication of existing information, but rather implies an activity that is part of a social process of knowledge production and technology development. For example, demonstration activities may backfire and thereby highlight the need for more development work (Collins, 1988). Frequently, tensions emerge in demonstration projects between the need to exhibit success and the need to test prototypes to their limits (Spinardi, 2008). This situation may result in a disconnect between hype and reality (de Coninck et al., 2009). Demonstration is an opportunity to build new social networks around the technology (Karlström and Sandén, 2004) and to expand the set of actors engaged with the technology. Promoting, and even selling, a technology is generally a central aim of demonstration projects (Rosental, 2004). Securing government support for the demonstration may also help legitimize the technology (Karlström and Sandén, 2004). Demonstration is an interactive process focused on establishing consensus about the technology's properties and on building support (Shapin, 1984).

2.2. Demonstration as social learning

Demonstration is often seen as part of a process of technical learning, understood as the establishment of objective facts by the application of scientific and engineering methods and the subsequent communication of these facts by acknowledged experts to a lay audience. Social science has shown that developing and learning about technology is a more complicated social process through which interactions between actors having different types of knowledge and differing claims to expertise will influence both the dissemination and the production of knowledge.

Adopting the notion of 'social learning' (e.g., Wenger, 2000), this paper examines the design and evolution of several CCS demonstration projects. Social learning provides a broad theoretical framework for considering and analyzing societal change and has been explored in multiple contexts, e.g., the advancement of green building (Rohracher and Ornetzeder, 2002) and the diffusion of agricultural technology in India during the Green Revolution (Munshi, 2004). Here, social learning about new technologies implies a distributed process involving a wide range of actors. This process includes interaction and negotiation about what is being learned (Sørensen, 1996). The process not only involves learning about technical facts, but also involves learning about other aspects of the technology and about the wider meaning of the technology (Williams et al., 2005).

This social learning perspective meshes well with the literature on technology demonstration, where demonstration events are seen as interactions between demonstrators and audiences. These interactions involve a focus on demonstrators' efforts to convince audiences about the properties of the technology. An equally important focus is the active role of audiences in establishing agreement or disagreement about these properties (Collins, 1988; Shapin, 1984; Rosental, 2004). The multiple audiences for CCS demonstration projects include local residents, governments, the media, NGOs and the professional CCS community. Asymmetric power relations between demonstrators and lay audiences have been emphasized (Collins, 1988). The social and political context within which each demonstration project is conceptualized, designed and implemented influences both the learning process and the content of the learning that takes place.

2.3. Framing of demonstration

Throughout the development of a demonstration project, from initial conceptualization through development and design to implementation, the framing of the initiative's purpose, structure and potential learning integrates assumptions that reflect the social and political context within which the technology is developing. In the case of CCS, examples of such assumptions include, for example, the need to mitigate climate change, the need to sustain centralized and large-scale electricity supply, the inevitability of continued use of coal, the need for governments to provide financial support for technology innovation and the trustworthiness of CCS experts (Hansson and Bryngelsson, 2009).

The concept of framing has been used to analyze the ways in which these assumptions about matters beyond the immediate artifact (technical system) demonstrated are implicated in technology demonstrations (Rosental, 2005). Multiple definitions of framing have been proposed. These definitions reflect various contexts and purposes. We adopt the one proposed by Gitlin (1980, p. 6), one of the most common citations in the field of framing analysis:

> "Frames are principles of selection, emphasis and presentation composed of little tacit theories about what exists, what happens, and what matters."

Framing is here understood to be strategic (explicit and intentional) action, on behalf of demonstrators or other stakeholders, in the pursuit of their interests (see also Pan and Kosicki, 2003). Moreover, the framing may or may not be successful, in terms of being adopted by other actors, and need not be persistent (cf. Reese, 2001).

Framing is particularly important in considering learning because framing guides learning and delimits the learning domain. The framing of a CCS demonstration project may change over time, but the initial framing will have a major impact on the design (of both the process and the product) of the project. Framing will also determine how learning occurs and what types of learning result from the project. It is also important to note that, in turn, learning may also result in reframing. However, in this paper, the focus is on the effects of framing on the actual learning process.

3. Methodology

This research involves a comparative analysis of the structure, framing and social contexts of three cases of CCS demonstration projects in different contexts, with different scales and different structures. The criteria used to select the CCS demonstration projects included (1) strong industry involvement, (2) some degree of public engagement and (3) national-level government involvement and support. Based on these criteria and a desire for geographic distribution, the three projects selected were the FutureGen project in the US, the Longannet project in the UK and the Yubari project in Japan.

Data collection sought to include perspectives of different project stakeholders, including those involved in the project as well as actors external to the projects. Information on each demonstration project was integrated from available documents (both published and unpublished) as well as from semi-structured interviews with individuals involved in the respective demonstration projects. For the purpose of this exploratory study, only a small number of interviews per case study were undertaken. In the US case study, this information was complemented by informal discussions with additional informants. The interviewees primarily held managerial positions and those interviewed included technical staff in all the cases. In both the US and UK cases, communication staff were interviewed, and in the UK case study, a representative from an environmental NGO (ENGO) was also interviewed.

The interview protocol was structured around several themes including *basic information* about the scope and structure of the projects, the sequence of events so far, as well as organization and financing arrangements. The topic of *social learning* was addressed in depth, through questions on who was involved and what they contributed to and learned from the project. Attention was paid to both core project participants and the roles of other actors, including governments, local publics and ENGOs. Specific questions addressed arrangements for learning from other projects, information sharing and public engagement. To understand the *framing* of the project, a key interview topic was also the project's rationale and justification. This topic was further probed using questions about risks and uncertainties and about the expected roles of external stakeholders.

The comparative analysis of the three cases focused on variation in structure and objectives of each project. The social learning processes were analyzed in terms of who was involved in learning and what aspects of the projects they were learning about. Differences in social learning among the cases were further explored in terms of the impact of the ways in which support was built for the projects, the ways in which the projects were framed and the different governance contexts.

4. Three demonstration projects

4.1. FutureGen, USA

4.1.1. Project scope and design

FutureGen was initially conceptualized by various US energy experts to be the first near-zero emissions, commercial scale power plant (275 MW) that would simultaneously demonstrate CCS, hydrogen production and the advanced coal power plant technology known as Integrated Gasification Combined Cycle (IGCC) (DoE, 2004). The project was announced publicly in February 2003 and was presented as the flagship program for the Bush Administration's strategy on clean-coal technology development and climate change mitigation. Despite almost a decade of planning and political strategizing, FutureGen has not yet been built and the project's design and structure have undergone two major 'restructuring' initiatives.

FutureGen is a public–private partnership between the US Department of Energy (DoE) and the FutureGen Industrial Alliance, Inc., a nonprofit consortium of some of the world's largest coal and energy companies. In addition to cost and risk sharing (initially the DoE was to contribute ~74% of the $1.5 billion project and the Alliance the remainder), the Alliance has had responsibility for the design, construction and operation involved in integrating advanced technologies into the plant. The DoE has been responsible for a major portion of the financing, for independent oversight and for coordinating participation from international governments.

An extensive competitive site selection process occurred throughout 2006 and 2007, during which the 12 potential sites initially identified were narrowed down to 4 semi-finalists: 2 in Texas and 2 in Illinois. Recognizing the potential economic and political benefits to their states of hosting FutureGen, both Texas and Illinois invested in competing for the project by providing technical justification to explain why their state should be selected, and also through public engagement initiatives to raise awareness and acceptance about the project's potential benefits. In January 2008, the Alliance announced that Mattoon, Illinois, was to be the site for the FutureGen plant.

A few weeks later, responding to the increasing projected project costs, the Bush Administration's Secretary of Energy, Samuel Bodman, announced a restructuring of the FutureGen project and the withdrawal of the Federal commitment to contribute funds to project as it was initially conceptualized. This 2008 restructuring of the project from a research demonstration program to a 'near term commercial demonstration' program was justified as a more cost-effective way to advance CCS by redirecting funds to demonstrate components of CCS on multiple existing plants rather than investing in the construction of a new single, large plant. The restructuring also altered the DoE cost-sharing from the original 74% to a maximum of 50% per demonstration project. Then, in the summer of 2009, the Obama Administration's Secretary of Energy, Steven Chu, announced a revival of the initial FutureGen project and pledged government support. In mid-2009, the Alliance purchased a site in Mattoon, Illinois, and ground-breaking for the new power plant was expected in 2010. However, in August 2010 the DoE announced FutureGen 2.0 – another major restructuring of the project. The redefined, limited scope of FutureGen 2.0 includes demonstrating oxyfuel combustion in a nearby existing power plant rather than construction of a new state-of-the-art power plant. Responding to this announced change and to the associated reduced significance and reduced international and national prestige of the project, the community of Mattoon withdrew its involvement in FutureGen. Mattoon expressed disappointment and an unwillingness to participate if the community would only be providing the geological storage location for the captured CO_2. In the fall of 2010, in conjunction with the DoE, the FutureGen Alliance began a new site selection process by which it sought to identify an appropriate CO_2 storage location in the Mount Simon geological formation in Illinois. The announcement of a new site is expected in early 2011 (FutureGen Alliance, 2010).

4.1.2. The learning process

Although FutureGen has not yet been built, the project has become widely known and has received significant media attention, thereby facilitating learning by multiple actors. One particular aspect of the FutureGen case, the competitive nature of the site selection process, has been critical in enhancing social learning about the project, about CCS and about the need for climate change mitigation technologies. Owing to this site selection process, multiple entities (DoE, FutureGen Alliance and the individual states) were simultaneously investing in and promoting public awareness and support for the project and CCS technology. The FutureGen Alliance invested in a stakeholder engagement team that conducted over 200 interviews and group meetings with local communities to listen to concerns, to address questions and to explain the project (Hund and Judd, 2009) and both the states of Illinois and Texas invested resources and instructed relevant agencies to promote and prepare their state for the potential project. This multipronged effort during the competitive site selection process broadened the scope of social learning and awareness about both CCS and the global challenge of climate change. One CCS educational representative from Illinois explained that the FutureGen project is so widely recognized in the state by the general public that it has become a frequent reference within public discourse about CCS.

An explicit mechanism designed to enhance 'learning' in both the initial and current versions of the FutureGen project is a proposed on-site, public-access visitor center that will welcome local as well as national and international visitors (FutureGen Alliance, 2010). This visitor center has been planned to involve a public 'demonstration' of all activities conducted at the site. In the original project design, with the power plant and CO_2 storage in the same location, this proposal would have allowed visitors to witness a range of plant activities, from the coal being unloaded to the pipelines delivering the captured CO_2 to the storage injection site. With FutureGen 2.0, plans for the visitor center are associated primarily with the still-undefined CO_2 storage location rather than with the power plant (FutureGen Alliance, 2010).

From the onset, the FutureGen project was designed to have an international influence. The FutureGen Alliance consists of multinational companies, and the project is designed to facilitate learning throughout the global CCS community. Recognizing that China is another global leader in coal use and has the world's third largest coal reserve base, FutureGen partnered strategically from the outset with the largest coal-fueled utility in China, the China Huaneng Group, particularly in reference to the IGCC design component of the project (FutureGen Alliance, 2009). Although FutureGen was initially designed to be the first full-scale integrated IGCC/CCS demonstration project in the world, China has developed its own very similar project. With the delays and the restructuring of FutureGen, the Chinese GreenGen project is now further along in demonstrating CCS.

The initial FutureGen project was designed to serve as a backbone that would connect other smaller scale CCS R&D efforts and thereby enable the integration and testing of multiple different technological components. The goal was to encourage researchers and research groups worldwide to come to FutureGen to utilize different slipstreams for their R&D efforts, to take advantage of the potential for testing new capture technologies. With the more limited scope of FutureGen 2.0, this ambition has been scaled back. Another critical aspect of the project is that all information and technical advancements developed within FutureGen are to be publicly available, so that intellectual property issues do not produce limitations on learning.

Throughout the almost decade-long FutureGen planning process, different kinds of learning have occurred. Key players in the project have been learning about the unstable and increasing projected project costs, the political instability of government support for the project and the ways in which various publics have responded to the project. In addition, the high-profile nature of the proposed project has resulted in social learning and increased awareness about climate change and the climate-mitigating potential of emerging energy technologies, particularly CCS.

4.1.3. Framing

The notion of the US as the home of the first large-scale, fully integrated coal-fired power plant with CCS emerged from an aspect of US national identity where the country is seen as a technologically advanced world leader (Stephens, 2009). From the onset, FutureGen was framed as a critical project that would demonstrate to the world how a state-of-the-art, near-zero emissions coal-fired power plant could be designed and built. This framing of international technological leadership is also associated with both political and economic benefits. The strength of such international framing as well as the economic benefits associated with FutureGen can be seen in the logo of the FutureGen for Illinois organization: "The world needs FutureGen, FutureGen needs Illinois" (FutureGen for Illinois, 2009).

Given the presentation of FutureGen in public and political discourse, the proposed project has itself become a framing device, i.e., the project signifies US leadership in technological advances on climate change mitigation. The framing also promotes the notion that a zero-emissions coal-fired power plant is possible and thereby supports the concept of 'clean coal'.

4.2. Longannet, UK[1]

4.2.1. Project scope and design

The Longannet CCS demonstration project in Central Scotland involves retrofitting an existing, coal-fired, subcritical power plant by integrating a large-scale CCS system. The project, currently in the planning stage, is one of two proposed projects now competing for UK government funding available to support construction and operation of one CCS facility. The proposed facility is supposed to process the flue gases from the equivalent of 300 MW of power production and be up and running in 2014. Because the size of the Longannet power plant is 2400 MW, the government funding will enable only a fraction of the flue gas to be captured.

The planned project includes capturing the CO_2 using amine post-combustion capture and then piping it offshore to be injected into a depleted gas field in the North Sea. The planned pipeline would include around 100 km of pipe onshore and a few hundred km of pipe offshore. The power plant is owned and operated by the UK utility Scottish Power (SP). SP, formerly a relatively small UK-focused company, was purchased by one of the world's largest utilities, Iberdrola, in 2007.

The UK government set up the competition in 2007 in response to another planned CCS demonstration project at Peterhead (a project later cancelled owing to industry frustration with the delays in government funding). The government's intention was evidently to avoid the perception that it was going to 'pick a winner' (Scrase and Watson, 2009). The competition includes only offshore storage and postcombustion capture for a coal plant, has gone through several stages and now involves only two of the original nine contestants.

The government competition is influencing how the Longannet project is designed. The competition guidelines have specific requirements that address the technology, the type of power plant that is eligible, the timing, the size and the organization of the demonstration project.

4.2.2. The learning process

Multiple actors have been involved in learning throughout the development of the Longannet project. SP has set up a consortium including companies having expertise in capture, transport and storage. This group includes two other companies involved in other demonstration projects: Aker, which will develop the capture technology, and Shell, which is to provide expertise in the gas field work. National Grid is also part of the consortium and will focus on the pipelines.

SP has defined five key stakeholder groups for knowledge sharing: academia, ENGOs, global CCS projects, the industry supply chain and government at local, national and international levels. SP plans to work with these stakeholder categories to facilitate knowledge sharing and communication. In addition, an SP interviewee mentioned the public and financers as important groups with which to communicate.

SP claims not to have learned much from previous CCS projects in terms of technology, but SP does acknowledge learning with regard to communication and engagement with stakeholders. A central lesson so far has come from the In Salah project where the formation of an alliance with academics had proven very useful. The company has set up formal collaborations with a couple of UK universities and now enjoys quite extensive academic contacts. Academic collaborators have contributed research-based knowledge as well as training, mainly in science and engineering.

SP also mentioned being impressed with the outreach activities of the Hydrogen Energy project in California. SP also seeks to learn from the public protests in other European countries, as well as from debates in Australia over clean coal. The need for early involvement with publics is the key lesson SP has learned from this process.

Contacts with ENGOs are based on personalized, preexisting relationships. More contact is expected in the future, when permits and construction will be discussed. WWF says that owing to the commercial and competitive nature of the project, the organization has limited access to project details.

The competition both stimulates and hinders exchange with other CCS projects. On the one hand, SP views itself as advanced and therefore as a resource from which other projects can learn. The government subsidy would also mean that results will be shared (to some extent). On the other hand, until a winner emerges, the ongoing competition with the other proposal will limit what can be communicated. Interaction with companies outside of the consortium has been limited so far.

Government interaction can be characterized as being at 'arm's length' because of the competition. Apart from interaction related directly to the competition, SP has briefed government agencies and regulators on its proposal. For SP, a key benefit of involvement with the government competition has been increased access to UK policymakers.

In the original competition memorandum, IP protection was emphasized, rather than knowledge sharing (BERR, 2007). However, knowledge-sharing requirements have been increasingly emphasized and clarified during the competition process.

Although this project has not yet been built, multiple types of social learning have occurred. A process of social and distributed learning by many actors involved is underway as the government and SP proceed to negotiate multiple issues, e.g., the balance between IP and sharing of results. The actors have also learned how to argue for and promote the project, i.e., they have learned about framing. SP is also 'learning about learning' from other projects by adopting good practices from other projects regarding ways of managing communication with stakeholders, including academics and publics.

4.2.3. Framing

The proposed Longannet project has been supported by an array of stakeholders and has had minimal public opposition. The Scottish government has supported the proposed project largely because it sees CCS as a critical technology in Scotland's climate mitigation efforts. The local government Council is also supportive. The Council is aware of the jobs provided by the large power plant and it also sees the project as part of an emerging potential for local economic growth related to green energy technology, including renewables and hydrogen energy. ENGOs have supported the project, primarily because it does not require construction of a new coal fired power plant and because integrating CCS into the existing Longannet plant would reduce overall CO_2 emissions.

For SP, a key reason to participate in the Government competition has been to secure the future of the almost 40-year-old Longannet power plant. With the recent flue gas desulphurization technology upgrades, the plant may continue to operate for a few decades if it can comply with future CO_2 emissions regulations.

SP justifies maintaining the Longannet power plant by arguing that the UK faces a risk of power supply shortage during the next decades. It believes that the development of renewables will be too slow to satisfy the increasing demand and that there is no support for new nuclear energy in Scotland. Adding CCS to the plant will also create new jobs and it will contribute to the development of new expertise that can be applied globally. The urgency of the need for CCS and the need for abated fossil fuel capacity is further supported by SP in reference to the critical role of CCS in recent International Energy Agency (IEA) projections.

[1] This case study is based on interviews with representatives of Scottish Power and WWF, as well as the company website and news reported in the media.

Table 1
Project components and the corresponding participants in charge.

Project components	Corresponding participants in charge
Fundamental research work including laboratory testing of coal samples	Hokkaido University (studying the mechanism of CH_4 displacement by CO_2) Kyoto University and RITE (studying the effect of CO_2 injection on coal behaviour (swelling, etc.)) Akita University (developing a model of CH_4/CO_2 behaviour in coal seams
Development of monitoring technology	Non-governmental research organization (Kyoto Shizenshi-Kenkyujo)
Investigation of cost reduction potential of CO_2 capture from flue gas	Waseda University
CO_2 injection micro pilot test in a selected coal seam	JCOAL
Cost reduction of CO_2 capture from flue gas	Kansai Electric Power Co. (KEPCO) and Mitsubishi Heavy Industry limited (MHI)
Investigation of an integrated system of ECBM and its commercialization	The General Environmental Technos Co. Ltd. (GET)

Source: Coal Utilization Technology Evaluation Committee (2005).

The company acknowledges risks associated with the technology. Representatives highlight the risk of capture being too costly and they recognize uncertainties relating to geological storage. But, as expressed by an SP interviewee: "CO_2 going into the atmosphere is most risky" and we need to "demonstrate, demonstrate, demonstrate!".

The project has produced little controversy so far. No major ENGO has argued against it and local publics have been supportive. WWF, an environmental organization, emphasizes that Scotland is a small country in terms of emissions from coal but that the country can make a difference to international mitigation efforts by contributing to CCS development. At the same time, WWF says that "for the demonstration of post-combustion CCS, we favour the demonstration of this on existing plant, rather than new largely unabated plant which would act to increase emissions from the power sector."

4.3. Yubari, Japan[2]

4.3.1. Project scope and design

The Yubari project, which ran from 2002 to 2008, had the ultimate goal of establishing a comprehensive, economically feasible system of Enhanced Coal Bed Methane Recovery (ECBM) via CCS in Japan. It was composed of multiple RD&D tasks. The project is located in the western part of Hokkaido, the northern main island of Japan. It was the first project that actually sought to verify the feasibility of ECBM in Japan and was Japan's second project in the field of CCS RD&D. Japan's CCS RD&D began in the late 1980s (METI, 2006) and Japan has assigned a very important role to RD&D projects. Since then, Japan has been one of the leading countries in developing CCS technology (and especially in technology for CO_2 capture).

Despite the ambition stated above, the project was designed only as a first step towards realizing ECBM-CCS. The main components were a field test of ECBM where a total of about 880 t of CO_2 was injected and an environmental monitoring program conducted during the period of project operation to detect any leakage of the injected CO_2. The project was funded by the government (Ministry of Economy, Trade and Industry, METI) totaling about 17 million US$, of which 80% was allocated for the ECBM field testing.

As listed in Table 1, diverse actors were involved: the Japanese government, private companies, government-related organizations and research institutes, universities and a non-governmental research organization. The main contractor and coordinator was The General Environmental Technos Ltd. (GET). Some public outreach activities took place. The project was subject to an official evaluation process (mid-term and ex-post evaluations) by an external committee set up by METI and consisting of technical experts. Because there had been no protest by the local communities against the project and because no external actors, including Japanese ENGOs, seem to have shown any particular interest in this project, this case study focuses primarily on the participants and on the external evaluation committee.

4.3.2. The learning process

The project was first discussed in 2000 in the context of utilizing CO_2 capture technology developed by KEPCO and MHI, who were also participants of the Yubari project, as a pure technology development proposal. This plan was then proposed to METI and was accepted as one of its CCS RD&D projects without any explicit competition. At its initiation, the project was expanded from a pure technology development project to a more comprehensive set of activities needed for ECBM-CCS (hereafter ECBM). An added component of estimating direct costs for commercial scale deployment of ECBM based on a few commercialization scenarios was of particular importance. These key decisions were made mainly by the private companies. No external actor (including the local communities) was involved in the decision-making.

The injection site, Yubari town, had experienced a difficult economic recession. The town was chosen because both the expected amount of CH_4 production and the prospects for acceptance by the neighboring communities were larger than for other candidate towns. Before the actual injection of CO_2, explanatory meetings with the neighboring communities were held without any trouble. The project was basically welcomed as a positive effort to mitigate climate change. It was seen as offering some hope for economic benefits and new employment opportunities in return.

When the injection started, it was soon found that the CO_2 injection rate and the CH_4 production rate were low. Nevertheless, measurements showed that the latter rate was enhanced fivefold due to CO_2 injection compared with CH_4 production in the absence of CO_2 injection. Because of this development, the mid-term evaluation of the external committee resulted (predictably) in a relatively low score. The report of the committee recommended setting numerical targets for the CO_2 injection and CH_4 production rates. Targets of a CO_2 injection rate of 5 t/day and a CH_4 production rate of 600 m^3/day were set based on computer simulations. The committee also recommended strengthening the capacity of management to coordinate the project components and the internal structure of the project was changed accordingly.

To achieve the new injection rate target, the engineers tried to inject N_2 in FY 2006. This measure was expected to shrink the coal, thereby making more room for CO_2 absorption. The experiments showed that, although N_2 injection actually enhanced the CO_2 injection and CH_4 production rates, the former effect did not last long enough to achieve the injection target value. Overall, the

[2] This case study is based on interviews with project participants, official documents (Coal Utilization Technology Evaluation Committee, 2005; METI and The General Environmental Technos, 2008; Industrial Structure Council, 2009, etc.) and unpublished documents (The General Environmental Technos, 2003).

Table 2
Comparison of basic case study data.

	FutureGen*	Longannet	Yubari
New build/retrofit	New build/retrofit	Retrofit	(No connection to actual power plant)
Capture technology	Pre-combustion/oxyfuel	Post-combustion (chemical absorption)	Post-combustion (chemical absorption)
Storage option	Saline aquifer	Depleted gas field	ECBM
Integration	Yes	Yes	No
Scale	Large	Large	Small
Stage	Site to be identified	Funding not clear FEED starting	Project completed
R&D <-> demonstration	Plans for capture R&D	Capture R&D ongoing in parallel	RD&D, but no large-scale demonstration

*FutureGen plans have changed considerably from initial to current plans.

actual injection rate of CO_2 was 3 t/day. This value fell short of the injection target, but the CH_4 production rate target was achieved.

Furthermore, it was confirmed that some inter-project learning had resulted from dissemination of technical knowledge produced by the Alberta (Canada) Research Council's project.

Summing up, the project was able to enhance both the CO_2 injection and CH_4 production rates, based on technical learning. Regarding learning on other aspects, the project administration changed the institutional structure and set indicative numerical targets for CO_2 injection and CH_4 recovery, following advice from the external evaluation committee.

4.3.3. Framing

The framing of the Yubari project is predominantly 'technocratic'. That is, the justification of the project, the overall goals and results and the project's relationship with society have been presented almost exclusively on technical and economic grounds.

The project justification includes two major arguments. The first argument cites the need for government to be involved in advancing technology. The basis for this claim is the assertion that the GHG reduction target of 6% below 1990 level of the Kyoto Protocol puts a heavy burden on the Japanese government and that, therefore, technological innovation, including CCS, is needed. The Industrial Structure Council acknowledges ECBM as an innovative technology that can be utilized after 2010 (METI and The General Environmental Technos, 2008), but that to realize the potential of this technology, the government must invest directly in ECBM R&D projects because the risk and associated costs are too high to be managed solely by private companies. The project itself is justified primarily by emphasizing the potential amount of CH_4 production by ECBM in Japan, namely 254 million m^3 and the benefits that can be expected from the project: economically efficient GHG reduction and enhanced energy security through CH_4 production. The economic benefits of ECBM through selling CH_4 are also emphasized in terms of the advantage of this approach relative to CCS in saline aquifers.

The second argument justifying the project is associated with the assumed public acceptance of ECBM. In this argument, the relative ease of public acceptance of ECBM compares favorably with the risks to marine ecosystems associated with ocean storage.

In this project, the general public is considered completely external. It is assumed that the major societal concerns of the project are associated with environmental impacts and safety issues. The project addresses such concerns exclusively through monitoring of the injected CO_2: "Monitoring is regarded as essential to demonstrate that the sequestration is safe, does not create local environmental impacts".[3] Informational meetings with local communities were held twice during the project lifetime but were mainly based on a one-way communication model. No feedback mechanisms that would have allowed learning from these interactions were built into the project. Some minimal efforts to investigate existing public knowledge and acceptance of CCS were made, but these efforts received very little emphasis.

5. Analysis

The empirical examination of the three cases illustrates the diverse nature of CCS demonstration activities, spanning multiple and varied dimensions, including technology, scale, public engagement and status of the project. FutureGen is an example of a public–private partnership in which industry has been willing to invest because of a large government funding commitment. Longannet is an industry-led investment project initiated in response to a government competition for funding. Whereas both cases include elements of R&D alongside large-scale integrated projects, the smaller-scale Yubari case is closer to a pure R&D project, with no immediate plans for larger scale investment. A summary of key characteristics of the three demonstration projects is presented in Table 2.

5.1. Social learning

5.1.1. Who is learning?

In all three cases, as with most CCS demonstration projects worldwide, academia and research institutions are working with private companies and various 'publics' are involved in or aware of the demonstration project processes to varying degrees. Key differences among the cases are found in two areas: (1) the relationship between industry and government and (2) the involvement of civil society.

The Longannet case has been characterized by an arm's-length relationship between the project companies and the government during the competition for funding. In contrast, close collaboration between government and industry is apparent in the other cases, as the projects are organized as public–private partnerships.

The Longannet and FutureGen cases involve quite extensive engagement with civil society: local communities, ENGOs and media. With FutureGen, the competitive selection process mobilized extensive outreach and education campaigns at multiple levels and locations and the two government 'restructurings' of the project have created media attention and frustration within the partnership. In the Yubari case, minimal outreach to the local community was coupled with largely one-way communication. The project was generally closed and had little interaction with the wider society.

The Yubari case involves the least amount of international exchange. In both the FutureGen and Longannet cases, international exchange of information is planned and the projects themselves have been conceptualized based on international strategy. In both cases, some international learning has already occurred through the participation of multinational companies.

5.1.2. What is being learned?

The three cases differ in their relative focus on purely technical learning versus broader social learning beyond the limits of technical performance and cost. The goals of both FutureGen and

[3] IEA RD&D Projects Database, www.ieaghg.org/rdd/project_specific.php?project_id=113 (last accessed 03/2010).

Table 3
Variations in the framing and learning arrangements.

	FutureGen	Longannet	Yubari
Framing			
Time scale	Long term	Short, but increasingly long, term focus	Long term
Geographical scale	National and local	National and local	National
Learning arrangements			
Outreach	Local and regional	Mainly local	Minimal
Collaboration	Some, and intent to integrate into plans	Limited so far	Minimal
Knowledge management	Intent for open access of information	IP protection, but growing focus on knowledge sharing	Published results

Longannet integrate broader social dimensions. These dimensions include, for example, public acceptance and education as well as development of regulation, whereas the Yubari case is more narrowly focused on technical learning. This difference reflects the almost exclusive orientation towards R&D of the Yubari project, but also a more technocratic model of governance in Japan, where civil society input is not generally given much value. As Joseph Wayne Smith puts it, in the Japanese model of technocracy "the political process is completely degraded into a form of scientific management of public opinion" (Smith, 1991, p. 2). More engagement with civil society, as in the FutureGen and Longannet cases, would likely have required a less technical framing and a broader scope for learning.

Each of these cases exhibits learning from other, earlier CCS projects, but given the limited number of completed CCS demonstration projects worldwide (Global CCS Institute, 2009), the scope for such learning has been limited. Both the FutureGen and Longannet projects have plans for sharing the knowledge produced in the demonstration projects. The Longannet project is also learning explicitly about and applying knowledge-sharing techniques from other CCS projects.

5.2. Factors shaping social learning

5.2.1. The building of support

Controversy surrounding each of these three demonstration projects has been minimal. However, public opposition has played a role in the cancellation of several other proposed CCS demonstration projects, including the Vattenfall storage projects in Denmark and Germany (Buhr and Hansson, 2010) and Shell's and Exxon Mobil's storage project in Rotterdam (Chazan, 2009). With the recently restructured FuturGen 2.0 project design, the community of Mattoon has withdrawn its participation, an indication of local opposition and controversy. In each of the three demonstration projects explored here, alignment of the different interests of various stakeholders was apparent throughout most of the planning process and opposition was minimal.

Initial alignment of interests seems to have been constructed in somewhat different ways across the three cases. With FutureGen, a close collaboration of private and public interests was achieved. This alignment was not sustained as the costs of the proposed project rose and the government twice announced major restructuring of the project, with minimal participation by the industry alliance partners in these decisions. With Longannet, alignment of interests was achieved as a consequence of the alliance of rather different interests. Multiple framings were aligned in support of the project. Specifically, the ENGO supported the project for different reasons than did industry or government. With Yubari, achieving alignment of interests was facilitated through the shared technocratic worldview among the participants, a worldview that tends to regard the actors who do not share such a view, e.g., local communities, as non-crucial stakeholders. The way in which interests have aligned in each case relates to early learning about how projects are planned and designed and this initial alignment also shapes the subsequent learning process by determining whose concerns are taken into account.

5.2.2. Framing

The discourse surrounding these projects appears to have been dominated by two frames: the potential value of learning about CCS as an important *climate mitigation* technology and expectations of potential *economic benefits* associated with the projects.

Difference among the cases emerges, however, in terms of their emphasis on particular economic beneficiaries. The framing of the FutureGen project emphasized the benefits to the local economy, to the state of Illinois and also potential economic benefits at the national level associated with the US identity as a technological leader. This framing contributed to and drew from plans to share all knowledge acquired. The emphasis is on technological advances expected to lead indirectly and over time to economic gains. Additionally, the site competition produced an emphasis on local and state-level benefits. These benefits took the form of near-term jobs. Increasing projected costs led to the restructuring of the FutureGen project. The restructuring included a shift from a research demonstration focus to a near-term commercial demonstration focus. The Yubari project is framed in terms of its contribution to national and industrial benefits, with little attention to any local benefits. As with FutureGen, the focus is primarily on technological benefits that will lead to economic gains over time. The focus on costs and revenues increased marginally over the time of the project. Initially, the key themes of the Longannet project were national competitiveness and industry gains, with emphasis on the role of IP protection for the industry consortium that would win the competition for funding. During the competition process, the emphasis on knowledge sharing has increased somewhat. Locally, the project has also attracted support because of its potential contribution to the economy.

Table 3 summarizes the main differences in economic framing. In the projects, a focus on long-term economic benefits has been coupled with a framing of technological progress and leadership, whereas a short-term focus has involved expectations about more immediate effects on industry and competitiveness. The table also suggests a correspondence between the economic framing and the arrangements made to shape the learning processes, with a short-term focus favoring IP protection over knowledge sharing.

The shifts in the relative focus on research versus near-market activities in the projects illustrate the tension in demonstration projects between the need to learn from testing and development and the need to promote and sell a successful technology. These shifts are further evidence for the continued uncertainty about the maturity of the technology and they demonstrate the need for further learning.

5.2.3. Governance context

Each of the three cases has been associated with high hopes for national benefit and commercial returns on the projects, either in the near or in the distant future. The high levels of government subsidy for each project, ranging from 50 to 100%, have influenced social learning in several ways.

With FutureGen and Longannet, government support has been distributed in the form of competitions between projects/sites. In the Longannet case, the competition limited knowledge sharing with other projects, but the government competition simultaneously helped raise the profile of the project and attracted collaboration interest. With FutureGen, competition also resulted in state-level investment in education, raising awareness and social learning at multiple locations throughout Texas and Illinois in particular. The close collaboration between industry and government and the absence of open competition for funding in the Yubari case reflect a more technocratic model of governance that limits social learning to a sparse, one-way exchange of information with the wider society.

These examples show that the ways in which demonstration is designed, structured and organized have strong implications for the learning that occurs. The combination of market forms of governance and government coordination is clearly important and it raises multiple issues, including the balance between protecting intellectual property rights and free knowledge sharing. The governance arrangements observed in these cases in part reflect government intentions regarding learning, e.g., the FutureGen policy of open knowledge sharing. Other factors, however, also influence the governance arrangements. The choice of competitive versus non-competitive funding, for example, represents the need in at least some countries to avoid the political sensitivity associated with 'picking winners'. Moreover, the role of and engagement with civil society influences the extent and type of social learning associated with any project. The Yubari case suggests that technocracy is perhaps the least favorable mode of governance for facilitating broad social learning processes, but additional research could explore this suggestion further.

6. Conclusions

This paper explores social and political aspects of the learning processes related to CCS demonstration projects by comparing three different cases. The comparative analysis has shown that major differences in the framing of the projects, as well as key socio-political factors, can impact the learning associated with CCS demonstration projects.

This analysis represents an initial, exploratory effort to develop a conceptual framework for considering the multiplicity of factors that influence social learning in CCS demonstration projects. The analysis suggests that these factors include the way in which alignment of interests is achieved, mechanisms for communication among stakeholders, project framing, governance structures and the national contexts within which projects are designed and implemented.

Although some of the factors influencing social learning will remain constant throughout the project and the learning processes, others may change as the project progresses. For example, whereas early framing is likely to shape the design and subsequent development of the project, projects may also come to be reframed in the light of insights gained. Initial high hopes for quick commercialization with Longannet, for example, appear to have given way to more realistic longer term framing. Similarly, the way in which interests align initially may influence who learns what, but the situation may also change as more is learned about the project. Insights about rising costs with FutureGen, for example, led to restructuring and subsequent withdrawal of support by a local community. Framing and interest alignment can thus both be factors that shape learning and be outcomes of it. We propose that such processes of coevolution of framing, interest alignment and learning represent an important topic for future research on CCS social learning.

The research presented here also suggests that further work on 'learning about learning', sometimes called 'deutero-learning' in the organizational learning literature (Argyris and Schön, 1996), should be part of further development of a conceptual framework for analyzing CCS social learning.

This analysis highlights a broader range of actors and types of knowledge than is typically considered. The analysis also confirms that there is need to direct more attention than is presently paid to the different types of learning that take place in CCS demonstration projects (e.g., ZEP, 2008). Integrating consideration of these factors into planning, design and implementation of demonstration projects is likely to enhance the potential and actualization of social learning. This preliminary study highlights the value of applying more in-depth social science research to questions of social learning associated with future demonstration projects. Given the unique context for each specific project, however, we caution that those involved in CCS demonstration projects should not look to social science researchers for a recipe for maximizing social learning. Social learning involves multiple, complex context-specific processes. Social science research may provide insights into ways of facilitating and enhancing these projects, but no generalizable guiding checklist to optimize social learning can be developed. The initial findings presented here could be applied and further developed by a more comprehensive comparative analysis of emerging and proposed CCS demonstration projects around the world to assess in more depth whether CCS demonstrations are designed to deliver effectively on policy expectations of learning outcomes.

Given recent public protests against CO_2 storage projects in the Netherlands (Vergragt, 2009), Germany, Denmark and USA, it is interesting to note the civil society's support for the three projects explored in this study. These cases were characterized primarily by aligned interests, rather than by dispute or public opposition. As a consequence, minimal learning about confronting and delivering public opposition has occurred. Interest alignment was achieved in different ways in the three projects and the influence of local publics, ENGOs and the private and public sectors was different in each case. Additional case studies on other CCS demonstration projects would be helpful in understanding this diversity. In particular, studies of cases in which serious opposition has emerged would provide different kinds of insights than those offered by this analysis. Studies of cases involving conflicts among other stakeholders are also likely to offer further insights into learning processes. Learning takes place both in consensual and in conflictual processes; in both cases, it is shaped by local contexts and contingencies.

Acknowledgements

Thanks to those who were interviewed for their time and the valuable information they provided. Thanks also to the MISTRA Foundation for supporting this international collaborative project and to the editors of this special addition, Karin Bäckstrand, James Meadowcroft and Michael Oppenheimer for their feedback and suggestions that have greatly improved the quality of this paper. Appreciation is also given to the other researchers involved in this MISTRA project on CCS who through several workshops have also contributed to the development of this work. Earlier versions of this paper have been presented at the 35th Annual Meeting of the Society for the Social Studies of Science and at the 10th International Conference on Greenhouse Gas Technologies, and we thank the audiences for their useful feedback. Finally, we thank the anonymous reviewers for their insights and constructive critique.

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