Energy Policy 70 (2014) 106–114

Contents lists available at ScienceDirect

Energy Policy

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

Public perceptions of CO_2 transportation in pipelines

Clair Gough*, Laura O'Keefe, Sarah Mander

Tyndall Centre for Climate Change Research, University of Manchester, Pariser Building, University of Manchester, M13 9PL, UK

HIGHLIGHTS

- Lay publics express good general knowledge of CO_2 but not of its specific properties.
- Key concerns relate to risk and safety and 'first of a kind' nature of CO_2 pipeline.
- Group participants are sceptical about motivations of CO_2 pipeline developers.
- Communities' trust in developer is a major element of their risk assessment.

ARTICLE INFO

Article history:
Received 11 December 2013
Received in revised form
19 March 2014
Accepted 28 March 2014
Available online 24 April 2014

Keywords:
CCS
Deliberative focus groups
CO_2 pipeline

ABSTRACT

This paper explores the response by members of the lay public to the prospect of an onshore CO_2 pipeline through their locality as part of a proposed CCS development and presents results from deliberative Focus Groups held along a proposed pipeline route. Although there is a reasonable level of general knowledge about CO_2 across the lay public, understanding of its specific properties is more limited. The main concerns expressed around pipelines focused on five areas: (i) safe operation of the pipeline; (ii) the risks to people, livestock and vegetation arising from the leakage of CO_2 from the pipeline; (iii) the innovative and 'first of its kind' nature of the pipeline and the consequent lack of operational CO_2 pipelines in the UK to demonstrate the technology; (iv) impacts on coastal erosion at the landfall site; and (v) the potential disruption to local communities during pipeline construction. Participants expressed scepticism over the motivations of CO_2 pipeline developers. Trust that the developer will minimise risk during the route selection and subsequent construction, operation and maintenance of the pipeline is key; building trust within the local community requires early engagement processes, tailored to deliver a variety of engagement and information approaches.

1. Introduction

The UK Carbon Plan suggests that carbon capture and storage (CCS) is expected to play a significant role in the UK climate change mitigation strategy (DECC, 2011) with a goal for the commercial deployment of the technology during the 2020s (DECC, 2012). The key advantage of CCS is that it would allow the continued use of fossil fuelled power generation with a substantial reduction in the associated atmospheric carbon dioxide (CO_2) emissions, in the short to medium term. However, despite its extensive presence in future energy scenarios in the UK and beyond (IEA, 2013), CCS is yet to achieve widespread commercial deployment, with only 8 large scale projects in operation worldwide, none of which are fully integrated power generation projects (GCCSI, 2013). While work on public perceptions suggests that the general public are not opposed in principle, and could be supportive of the technology (Eurobarometer, 2011; Oltra et al., 2012; Sharp et al., 2009; Whitmarsh et al., 2011), there is limited experience of how local communities respond to actual projects. While some demonstration plants have been successfully installed, a number of CCS projects have encountered opposition from local communities and have, as a consequence, been cancelled or gone ahead in a reduced form (Brunsting et al., 2011b; Oltra et al., 2012).

The CCS process involves the capture of CO_2 from a large point source (such as a power station) which is then transported to a permanent underground storage site (such as depleted oil or gas reservoirs, or saline aquifers). CO_2 can be transported in different ways by, for example, ship, road or rail; however, in the case of CCS, pipeline is the most economic and efficient option (IPCC, 2005). CO_2 has been successfully transported by pipeline, both over- and underground, in the US since 1972 and there are now over 6500 km of pipelines transporting around 50 million tonnes CO_2 (Mt CO_2) per annum (GCCSI, 2013, IEAGHG, 2014). In the UK, although there is an extensive network of pipelines transporting water, natural gas, petroleum products and oil, this experience does not extend to transportation of CO_2 by pipeline.

* Corresponding author. Tel.: +44 161 306 3447.
E-mail address: Clair.gough@manchester.ac.uk (C. Gough).

http://dx.doi.org/10.1016/j.enpol.2014.03.039

A pipeline affects multiple local communities along its route, it is highly conspicuous during its construction and could thus be a focus for expressing opposition to the wider project; it is an extensive representation of a larger system (in this case CCS) that goes beyond a single physical artefact (Sovacool, 2011). This paper explores the potential response by members of the lay public to the prospect of an onshore CO_2 pipeline through their locality. While there is a growing body of research on the public perceptions and social implications of CCS in general (for reviews see Ashworth et al., 2009a; Whitmarsh et al., 2011; IJGGC 2013), there is very little relating specifically to CO_2 transportation by pipeline, yet public responses to this element of the CCS chain could be critical. A study into public acceptance of the different components of the CCS chain in Switzerland found that the prospect of a CO_2 pipeline in the respondents' locality held a greater influence on acceptability than storage or plant type but that CO_2 pipelines were viewed less negatively than natural gas pipelines (Wallquist et al., 2012). These findings contrast with those of other studies which have found that CO_2 storage is the element of the CCS chain that typically causes greatest concern to lay publics when they are first introduced to the CCS concept (Hammond and Shackley, 2010; Mander et al., 2010; Upham and Roberts, 2011).

In the UK, National Grid is proposing a transportation and storage system to support the provision of CCS technology in the Yorkshire and Humber region. The Humber pipeline would pass from an area that is an existing centre of power generation, through the sparsely populated Yorkshire Wolds to the east coast. The proposed route corridor, discussed in the following research, was selected following an initial consultation process and both technical (National Grid, 2012) and environmental assessments (National Grid, 2013). Prior to the empirical research described below, National Grid had conducted an open consultation process providing information about the construction and operation of the pipeline and opportunity for feedback on the proposed pipeline route, holding a series of open events[1] within the local communities alongside more formal negotiations with affected landowners. The research was planned in consultation with National Grid, to ensure that information provided was accurate and that the group sessions were designed to deliver relevant insight to community views. The aim was to provide an independent academic assessment of existing knowledge and gaps in understanding of CO_2 and its transportation in pipelines. No representatives of National Grid were present at either of the deliberative focus groups; one out of the nineteen individuals participating in the groups had attended one of the National Grid consultation events, however, they remained unfamiliar with the topics covered during the event.

The overall aim of the research was to explore the issues around public perceptions of CO_2 transportation by pipeline, specifically to:

(i) Assess individuals' understanding of CO_2 and identify their existing perceptions of it: what do people know and understand about CO_2 and its properties;
(ii) Explore perceptions of risk and key areas of concern with respect to pipeline transportation of CO_2 for the purposes of CCS.

These objectives were pursued through deliberative focus groups involving residents along the proposed pipeline route. The paper continues with a short description of the transportation of CO_2 in pipelines, followed by a brief review of the literature relating to risk and public acceptance, community responses to energy infrastructure and public attitudes to CCS. The methods section is followed by a presentation of results from the deliberative focus group process, brought together to inform the concluding sections.

1.1. CO_2 transport in pipelines

Conventional natural gas pipelines have been designed and operated safely in the UK for many years with well-specified standards (HSE, 2008a, 2008b; IGEM, 2008). However, CO_2 has different properties to natural gas and requires additional standards beyond the prevailing codes and standards. Under normal atmospheric conditions of temperature and pressure, CO_2 exists as a gas. However, to achieve sufficient flow rates and to minimise the pipeline diameter, CO_2 is transported in its dense phase—i.e. at a sufficient pressure that it becomes liquid (Eldevik, 2008); the proposed CO_2 pipeline will operate at a pressure up to 150 bar. The preferred material for CO_2 pipeline construction is carbon steel, as it is highly resistant to corrosion and cost effective (Heggum et al., 2005). Other factors to be considered in the design of a pipeline include: pipe thickness (determined by factors such as operational pressure), resistance to internal and external degradation, protection from damage, incorporation of appropriate monitoring facilities and pipeline routing (Vandeginste and Piessens, 2008; Serpa et al., 2011).

Onshore pipelines are built according to defined standards and are subject to regulatory approval to assure a high level of safety, particularly in densely populated areas, although specific codes and standards are still being developed for CO_2 pipelines in the UK (HSE, 2008a, 2008b). Land use planning zones around the pipeline and associated Above Ground Installations (AGIs) are used in conjunction with separation distances which specify minimum distances from normally occupied buildings to ensure the safety of surrounding communities (HSE, 2008a). These are based on a Quantitative Risk Assessment (QRA) according to the pipeline specification (i.e. pipeline diameter, pipe wall thickness, the maximum operating pressure, type of steel and its depth of burial) and the substance being transported (ibid). Pipelines in operation are closely monitored for changes to pressure and flow rates, which could indicate occurrence of a leak. They are also monitored externally, including corrosion monitoring and visual inspections for leaks, local groundworks and maintaining pipeline "waymarkers" and internally, by pipeline inspection gauges or 'pigs' (piston-like inspection devices that are driven through the pipeline by fluid pressure) which detect potential damage, corrosion or failures of the pipe. In the event of a leak, the pipeline is shut down ensuring that any release is limited.

Unlike a natural gas pipeline, the risk of a fire or explosion is absent from a CO_2 pipeline, however, CO_2 presents other risks. Pure CO_2 is colourless and odourless and, despite being present in ambient air at a concentration of around 380 parts per million (ppm), it is potentially both toxic and an asphyxiant. Relatively low concentrations of CO_2 can be hazardous to human health; inhaling CO_2 at concentrations above 7% (or 7×10^4 ppm) represents a significant toxicological hazard to humans, although a concentrations necessary to present an immediate danger of death are 50% for asphyxiation and 15% for the toxicological effects from inhalation (Harper, 2011; DNV, 2008). The most commonly-cited CO_2 incident occurred as a result of natural processes at Lake Nyos in the Cameroon. The lake is naturally saturated with CO_2 due to the existence of a magma chamber underneath it which continually leaks CO_2; it has been estimated that 1600 kt CO_2 was unexpectedly released in 1986 killing in excess of 1700 people and injuring many more (Kling et al., 1987). The quantity of CO_2 released at

[1] The research study and National Grid's consultation process were entirely separate and independent, however, the researchers did observe a number of the consultation events.

Lake Nyos is vastly greater than the volumes associated with CO_2 transportation for CCS, which are unlikely to be more than 10 s of kt CO_2 (Harper, 2011). Of more relevance as an analogue is an accidental release of about 15 tCO_2 from a fire extinguishing installation factory in Monchengladbach, Germany in 2008. Coincidental failure of door seals resulted in a CO_2 release outside, very still air conditions led to the intoxication of 107 people, of whom 19 were hospitalised and all of whom recovered (HSE, 2011).

1.2. Risk and public acceptance

Renn has described two paradigms of risk, the 'realist' perspective and 'social constructivist' perspective, which are often pitted against each other as technical assessment of risk versus social perceptions (Renn, 1998). This tension between the technical, social and cultural dimensions has been widely recognised in the literature on risk management and communication (e.g. Parkhill et al., 2009; Bradbury et al., 2011); the challenge is to achieve both professional (technical) and social accuracy and fairness (Renn, 1998).

From a technical perspective, risk is the product of the likelihood and severity of an adverse event occurring. When deciding on a pipeline route, and appropriate design measures to reduce any associated risks, a Quantitative Risk Assessment (QRA) is performed to calculate the individual and societal risks arising from the pipeline route proposed, prioritising physical risks. Lay assessments of risk, however, go beyond the immediate physical risks and include wider and more abstract risks as well as the local, direct and tangible. Studies into the public acceptance of new technologies have found that public acceptance is, in part, influenced by how perceptions of associated risks are balanced against perceived benefits (Frewer et al., 1998). Other, qualitative characteristics which can influence tolerance of risk include personal control, institutional control, voluntariness, familiarity, dread, distributional equity, artificiality of risk source and blame (Renn, 1998). Social representations theory (SRT) considers the processes through which socio-cultural influences are embedded in individual responses, avoiding the notion of "erroneous perceivers" of risk (e.g. Joffe, 2003). SRT is a non-predictive approach which describes how risk becomes represented through duel processes of anchoring (by which, for example, a new risk becomes associated with a known danger) and objectifying (whereby an unfamiliar concept becomes transformed to a more concrete construct).

Trust in organisations involved in any development is a critical component of its public acceptability (Midden and Huijts, 2009; Terwel et al., 2009; Terwel et al., 2011) and is closely related to how both the competence and intentions of those organisations are perceived (Huijts et al., 2007). People are not naïve and understand that companies need to make profit—and may question claims that companies are investing in something for purely environmental protection reasons. Previous research suggests that arguments presented by organisations need to be congruent with the type of organisation—a more positive response to statements by private companies is generated when the economic case is presented alongside the environmental case than when the environmental case alone is presented (Terwel et al., 2011). Furthermore, the local community must also trust that the developer will take every step possible to minimise risks during the route selection and subsequent construction, operation and maintenance of the pipeline. The role of trust in public acceptance extends beyond trust in organisations and their representatives, to trust in the underlying technical scientific, managerial and regulatory competence (Gough and Boucher, 2013)—that they are both adequate and enforceable.

The notion that opposition to a new development or technology is simply a result of a lack of knowledge and understanding about the development on the part of lay communities (often referred to as an "information deficit") has been widely contested in the social science literature (see for example Irwin and Wynne, 1996). Research into previous controversies has identified a wide range of factors that can contribute to a community opposing a technology. These may be related to specific physical characteristics, symbolic or ideological associations, local, personal or contextual issues or other political, institutional and socioeconomic factors that influence how individuals and communities respond to a particular development (see for example Devine-Wright, 2005; Roberts et al., 2013; McLachlan, 2009).

Other research suggests that, with time, communities may become familiarised with living near to a 'hazardous' facility (such as a nuclear power station, for example), to the point where there is very little routine engagement with any associated risk issues (Parkhill et al., 2009). Whereas a nuclear power station is a highly visible presence in the landscape, a pipeline is hidden (buried) such that the transition to familiarity may be realised as awareness of the pipeline moves from the conscious to the sub-conscious.

1.3. Community responses to energy infrastructure

The response of local communities to new infrastructure projects can be critical to the successful delivery of those projects; a hostile response from the host community may fatally impact a project (and leave a legacy which may affect future projects elsewhere). In Barendrect, a full chain CCS demonstration project which included onshore CO_2 storage in a densely populated area, was eventually cancelled amidst a high level of public opposition. Barendrecht is a well-documented and well-studied case, which delivers valuable insights relating to how the public engagement process is conducted and the specific local factors that contributed to its unsuccessful outcome (Brunsting et al., 2011a, 2011b).

While the opportunity for opposition and debate is an essential part of the democratic process, providing learning opportunities and ultimately a check on inappropriate developments, avoiding unnecessary hostility can support a more positive outcome for all parties: achieving "fewer, but better conflicts" (Fischoff, quoted in Bradbury et al., 2011). A pipeline can be subject to "interpretive flexibility", representing different meanings to different stakeholders; a study looking at oil and gas pipelines in central and south east Asia found representations well beyond their fuel distribution role, extending to notions of progress, modernity and economic wealth but also human rights and development issues (Sovacool, 2011).

In the context of CCS projects, during its construction a pipeline is a very visible component of the CCS process and provides an "access point" for opponents of the broader context of CCS in association with coal fired power generation. Widener (2013) describes how local environmental justice issues combined with wider climate activism in the US during the early stages of the Keystone pipeline and the refinery which it connects. In this case, the debate focused around the issue of fossil fuel proliferation and alternative energy sources but did not receive conventional media coverage—the "quiet conflict" was played out locally and communicated primarily through the web (ibid). Furthermore, issues relating to justice may become important when a community does not identify any local benefits from a project which is seen to deliver benefits elsewhere. For example when a local community does not have access to the resource being transported by the pipeline; or identifies others profiting while the local community bears the burden.

With any new infrastructure the potential physical risks must be minimised and key to any discussion of physical impacts is the way that scientific arguments are used and framed within the debate. McLachlan and Mander (2013) have described how different ways in which knowledge is framed and applied influences how it is used to support different arguments within a controversy. Both local and larger protest groups increasingly have access to scientific and expert resources, whether through the resources to commission consultants, for example, as a group of local residents did in support of their opposition to the Milford Haven gas pipeline (Groves et al., 2013; Yakovleva and Munday, 2010), or through the skills of individuals within the campaign. A recent controversy relating to the Weyburn-Midale CCS project was framed entirely around conflicting scientific analyses relating to the causes of observed effects and the sources of alleged pollutants (PTRC, 2011; Lafleur, 2010).

1.4. Public attitudes to CCS

In an analysis of previously planned CCS projects, Oltra et al. (2012) found that local opposition is not solely a function of risk characteristics or proximity and identified six commonly active factors: characteristics of the technology or project; planning/public engagement process; risk perceptions; stakeholder actions; characteristics of the host community; socio-political context. The importance of trust recurs throughout the literature on responses to CCS (e.g. Huijts et al., 2007; Terwel et al., 2009, 2011). Local opposition to a project is not solely a function of the risk presented by the technology; distrust of the key actors is often a key driver (Oltra et al., 2012). When a new project is unfamiliar, the developer is identified as the main beneficiary of the project and is also the main source of information about the project; trust in the company is both essential and easily eroded by opposition from influential stakeholder groups, such as media, environmental NGOs etc (ibid.). Furthermore, recognition of the specific social characteristics of host communities have been identified as holding a significant influence on community perspectives of a planned development (Bradbury et al., 2009).

A number of studies have looked at the public understanding of CO_2 as part of an assessment of opinions and the understanding of CCS in general (Wallquist et al., 2009; de Best-Waldhober et al., 2012; de Best-Waldhober and Daamen, 2011; Itaoka et al., 2012). Itaoka et al. (2012) explored the relationship between the understanding of CO_2 and acceptance of CCS in three countries but not how it relates to CO_2 transportation by pipeline specifically (Itaoka et al., 2012). Finding a correlation between misperceptions of CO_2 and misperceptions of CCS, the authors highlight the importance of providing information about CO_2 as part of all CCS communications, not just with respect to pipelines, and found low levels of understanding and familiarity with the physical and chemical properties of CO_2 or its everyday uses (ibid). In another study, interview respondents in Switzerland related atmospheric release of CO_2 (from a power station or from part of the CCS process) to a reduction in the local air quality—comparing it to "exhaust gases" (Wallquist et al., 2009), similar associations were expressed in the former study in which CO_2 was associated with "soot" or "air pollution" (Itaoka et al., 2012).

A large scale survey into perceptions of CCS in the Netherlands (de Best-Waldhober et al., 2011, 2012) found a proportion of respondents were unsure about whether CO_2 was a cause of cancer, was harmful if it came into contact with the skin, or whether it made the earth's climate habitable. A positive correlation was found between respondents with a good understanding of CO_2 and those with a positive view of CCS (ibid).

The basic properties of CO_2, its sources and sinks, were identified as key topics requiring explanation delivered through Briefing Notes on CCS in a study assessing information needs surrounding CCS (Shackley et al., 2013). A special Eurobarometer survey on CCS found that 30% of all respondents did not know what "CO_2" was; the number correctly identifying it as carbon dioxide ranged from only 29% (France) to 75% (Poland), the figure for the UK was 54% (Eurobarometer, 2011). In the same survey, 74% of respondents (UK: 67%) identified CO_2 as being "unhealthy" and 16% (UK: 13%) thought that it was flammable or explosive; the survey did not include questions specifically relating to pipeline transportation. Understanding that CO_2 is not flammable or explosive could be a critical factor in local responses to CO_2 pipelines, since any previous serious accidents involving natural gas pipelines, although rare, are often associated with an explosion.

2. Material and methods

2.1. Deliberative focus groups

Focus groups have been successfully applied within other studies examining the public understanding of CCS (Bradbury et al., 2009; Oltra et al., 2010; Shackley et al., 2005; Upham and Roberts, 2011). Given the low levels of existing knowledge of CCS technology (Wallquist et al., 2009; de Best-Waldhober et al., 2011, 2012; Itaoka et al., 2012), we describe empirical research in which members of the public participated.

in deliberative focus groups. A deliberative focus group is a process through which a group of people are provided with detailed briefing on particular topics before being asked in an interactive and deliberative setting about their attitudes (see Morgan, 1993; Macnaghten and Szerszynski, 2013). The deliberative focus groups within this study each took place over one full day and involved a mix of presentations, activities and facilitated discussions, allowing for an in-depth exploration of attitudes, opinions and concerns around the topic of CO_2 transportation in pipelines (Morgan, 1993; Therwell, 1999; Krueger and Casey, 2000). Responses to this new technology can be categorised in two ways: firstly a response to the principle of CCS in the abstract and secondly the response to specific projects (Stephens et al., 2011); much of the previous research into the public perceptions of CCS falls into the first category. The deliberative focus groups described below capture both types of response—participants are confronted with the new concept of CCS technology and with the possibility that their region might be host to one of the first demonstration projects in the UK.

As only small samples of respondents can be accessed, conclusions from deliberative focus group studies are more useful for understanding *how* and *why* members of the lay public might respond to and form opinions about a particular project or technology than for *predicting* the response of the wider population. The aim of this study is to gain a greater insight into the level of existing knowledge and the nature of issues that inspire concern or reassurance amongst people living within the local community, recognising that the wider response is formed by multiple 'publics' (Pidgeon et al., 2008). Furthermore, the reach of a focus group extends beyond the immediate participants to their network of family, friends and acquaintances as they go on to discuss their experience (Roberts and Mander, 2011).

Participants were recruited using a purposive sampling approach targeting individuals in close proximity to the proposed Yorkshire and Humber CCS pipeline and, as such, are not necessarily representative of the whole population (Carson et al., 2001). Previous research suggests that individuals living in closer to a planned CCS project have a greater level of knowledge and awareness of the technology (Reiner et al., 2010). Following a poor response from advertisements placed in local papers and web-based community fora, a mailshot was delivered to households in the selected areas ($n=1000$), including the offer of a cash incentive of £75 for taking part. In order to recruit a wide cross section of people, and to avoid deterring people unfamiliar with the topic, the mailshot did not reveal that the discussion related to energy, CCS or pipelines. Nevertheless, response rates were low, potentially due to the restricted dates and duration of the focus groups. In addition, all respondents to the mailshot were screened to ensure a spread of participants, consistent with the demographic profile of the area.

In total, 19 participants took part in one day deliberative focus groups in two village locations along the proposed pipeline route. The first location, Barmston, is situated on the east coast close to the proposed landfall site, and the second, Holme-on-Spalding-Moor, is further inland and hence is nearer to the CO_2 capture site; the groups took place on the 13th and 14th October 2012 respectively. Each six hour session was structured around four topics–CO_2, CCS, pipelines and risk assessment. Each topic included a presentation by an expert, followed by a facilitated in-depth group discussion, using a topic guide designed to explore the specific research questions outlined above and, in the case of the CCS and pipeline sessions, additional interactive activities.

The CO_2 presentation, made by a science communicator independent of the project team, incorporated a variety of interactive experiments designed to demonstrate the particular properties of CO_2. Topics on CO_2 included: natural occurrences, the greenhouse effect, uses, as a product of combustion, physical and toxicological properties. In the CCS session, a presentation by a member of the project team provided an overview of UK electricity generation, fossil fuels and climate change, climate policy, a description of CCS, its global status and local project plans. Participants then worked in small groups to summarise the key pros and cons of CCS. The two pipeline session included presentations by an academic pipeline engineer; the first session described substances transported by pipeline, pipeline materials, pipeline dimensions, operating pressures, safety measures and pipeline routes. The second pipeline presentation covered risk issues, including a description of risk and how safe levels of risks are defined and a description of how pipeline routing decisions are made. A map of National Grid's proposed route corridor (National Grid, 2013) was used as a means of prompting discussions, focusing on the risks that participants associated with the CO_2 pipeline proposed. More detail on the content of the expert presentations, discussion prompts and activities can be found in O'Keefe et al. (2013). Great care was taken to ensure that the expert presentations provided balanced information as far as possible. While it is recognised that provision of information in this way can influence individuals' perceptions, given the lack of familiarity with the topic, the presence of three independent experts, each knowledgeable about different aspects of the technology, enabled discussions to be structured around accurate information and allowing immediate answers to questions, ensuring discussions on key issues did not become unnecessarily speculative. Discussions were led by a facilitator, the expert only participated when answering specific questions, participants were encouraged to discuss any issues that they felt important to them. Discussions were audio-taped using digital recorders, transcribed verbatim and verified by the researchers before being entered into a qualitative data analysis software package (Atlas.ti). The transcripts were then coded using the topic guide for preset codes and new codes as they emerged.

3. Results

Participants' responses to the discussion topics introduced during the deliberative Focus Groups are described below.

3.1. Carbon dioxide

In order to assess individual understanding of CO_2 and to initiate the discussions, participants were asked to list their associations with CO_2 prior to the presentation. Positive associations included "trees", "plants", "photosynthesis", "natural"; negative associations included "poisonous", "faulty heaters", "global warming", "electricity generation", "pollution", "industrial", "invisible". Participants initially lacked confidence in discussing CO_2[2] and, although expressing some awareness of it, they were not all familiar with its sources or properties. Prior to the CO_2 presentation, some participants associated it with carbon monoxide (chemical formula, CO) poisoning, although any confusion was clarified in discussions with other participants. Different ways of referring to CO_2 were discussed: "carbon dioxide" was considered by participants to be a familiar term, known to the majority of people; for some, the use of the chemical formula "CO_2" was considered to sound more technical—possibly more "dangerous". No-one from either group, volunteered the idea of CO_2 being either explosive or flammable. Participants were reasonably clear that CO_2 played a role in natural plant processes and about some of the anthropogenic aspects of CO_2 but a discussion about whether it is a man-made or natural substance revealed some ambiguity and confusion:

> It pollutes the environment and things like that, which is really bad or whatever (….) But then it can't be so bad because plants use it and things like that.
>
> Female (F4), Holme-on-Spalding Moor

> It didn't register at all to start with, I just thought carbon dioxide, it's a negative gas, we breathe it out, it's waste, and it isn't, there's more to it than that.
>
> Male (M1), Barmston

Participants responded positively to practical demonstrations about the properties of CO_2 and in particular were reassured that it is denser than air (seen as making it more "manageable"); by the way in which CO_2 is formed through the combustion process and the conditions that produce CO_2 (which could not occur in a power station). The potential for the utilisation of CO_2 was raised as an alternative to its storage and also in relation to whether stored CO_2 could later be recovered and used.

3.2. Carbon capture and storage

Previous research suggests that support for CCS as a climate change mitigation strategy is likely to be a major factor in the way that specific projects are received (see for example (Shackley et al., 2005; Sharp et al., 2009; Terwel et al., 2011)). There was very limited awareness of CCS amongst participants—only one of whom could describe what CCS was. Following the presentation, participants described their positive and negative reactions to the technology.

Positive reactions included:

- CCS is seen as actively "doing something" about the problem of climate change;
- A sense of pride that Yorkshire could be seen as a leader (although concerns were also expressed that the area already supports an excessively high concentration of energy infrastructure);
- Identifying benefits in terms in terms of local jobs;

[2] The term "carbon dioxide" was used throughout the sessions however, for the sake of brevity we refer to it as "CO_2" in this article.

The following two quotes capture the flavour of support for the technology:

> It's not going to really directly affect you emotionally or physically.
>
> Female (F4), Holme-on-Spalding Moor

> I just think the CO_2 is better down where it can be monitored and not floating around.
>
> Male (M1), Barmston

None of the participants in the present study were opposed to CCS (or the proposed pipeline) and any negative local impacts were considered not to be significant. However, terms such as "dumping" were used rather than 'storing' CO_2 (reinforcing aforementioned conclusions suggesting that the main concern expressed around the impacts of CCS relates to storage). In an unprompted discussion, participants in the Holme-on-Spalding Moor group also made a connection with the process of fracking for oil shale production and queried whether CO_2 storage could cause earthquakes. The following negative aspects of CCS were raised:

- That CCS perpetuates the use of coal fired power stations;
- That eventually storage sites will be filled and at that point we will need alternative power generation options;
- The investment in CCS would be better directed to a longer term solution raising the question whether the UK should be concentrating on renewable energy instead (tidal, wind, solar all mentioned);
- Lack of confidence in modelling of the fate of stored CO_2;
- The implications of interfering with nature, including potential for inducing earthquakes.

This moderate scepticism and resigned acceptance are reflected in the following quotes:

> Do they know what timescale have we got, how long can we go on storing the CO_2, what capacity we have to store it once we've outgrown the storage, then what do we do?
>
> Male (M4), Barmston

> Yeah, I don't have any objection to it in principle, I think there are better ways we could look to the future, but if it has to happen…
>
> Female (F2), Holme-on-Spalding Moor

3.3. *Transportation of CO_2 by pipeline*

The afternoon sessions of the two Focus Groups were devoted to CO2 pipelines and the Quantitative Risk Assessment (QRA) process. Here we present the results of these two sessions together; the two presentations were made by the same individual and although separated during the sessions, the discussions flowed across the two topics.

There are currently many 1000s of miles of pipeline in operation in the UK and a map of the UK pipeline network shown to the groups was met with surprise over its extent and coverage. The presentation was seen by participants as providing clear and transparent information; although the presentation reassured participants about the pipelines and the risks they bring, the main concerns, as indicated by the frequency and length of discussion related to: disruption, safety and trust in the companies involved.

Short term disruption during the construction of the pipeline was a particular concern, in terms of both the duration and impacts of the construction process. While some voiced concern about the impacts of a pipeline, for example on local wildlife, historical sites and the rural landscape, and possible impacts on local businesses dependent on tourism, others were confident that things would be restored after the construction phase, although the potential impact on existing coastal erosion remained a concern. An increase in construction traffic was also identified as potentially exacerbating an existing problem given the small roads connecting local towns and villages.

The broader issue of safety was raised in different contexts during the discussions. Initial concerns from participants about the consequences of a pipeline rupture, and the possibility of an explosion were allayed by appropriate information and experts answering questions about pipeline safety and the properties of CO_2. However, because both CCS and CO2 pipelines are new technologies to the UK, participants voiced concerns over whether long- and short-term health and safety could be guaranteed. Particular issues related to pipeline leaks, the speed and accuracy of detection and what steps are taken to both prevent leaks from happening and putting them right in the event that they do. Participants were also concerned about the local environmental impacts of a pipeline leak, for example on plants, wildlife and farm animals. However, the discussions suggest that, despite an initial limited awareness of both CO_2 and pipelines, a certain level of understanding was achieved, as illustrated by the following exchange:

> Well, it would kill whatever was in that area.
>
> Female (F1), Barmston

> If it was concentrated enough and didn't disperse quickly, yeah.
>
> Female (F2), Barmston

The 'first of a kind' nature of the proposed pipeline was a concern to participants, who questioned the rationale for transporting CO_2 by pipeline and the CCS process in general; scepticism expressed towards the pipeline project, extended to the research study itself. Although availability of evidence from other successful projects was identified as an important factor in promoting local acceptance, concerns remained:

> I don't know because I'm not a scientist, but there's always in the future lots of things [that] come back to bite us.
>
> Female (F2), Holme-on- Spalding Moor

> Rather than just letting us be a guinea pig.
>
> Female (F4) Holme-on-Spalding Moor

> Just the fact that there seems to be some glaringly obvious catches that none of us are not quite aware of because we're not quite knowledgeable. I mean the fact alone that you're running a focus group about it, I mean, why?
>
> Female (F4), Holme-on-Spalding Moor

A discussion emerged during the Barmston group on whether the proposed pipeline would be a potential terrorist target. While participants themselves understood that there was no risk of explosion associated with a release of CO_2, concern was voiced that this understanding might not be sufficiently widespread to prevent the pipeline becoming a potential target. Eventually participants concluded that this risk would not be great:

> Regarding the terrorists, gas pipe, yeah, but not a CO_2 pipe. I can't see what they've got to gain.
>
> Male (M4), Barmston

Of greater concern was the possibility of third party damage, which in practice represents the greatest risk to pipeline integrity (Akel, 2011), with participants seeking reassurance that adequate measures were in place to minimise the risk of, for example, accidental damage from farm or construction machinery:

> How many ruthless builders are out there and will ignore it?
>
> Female (F3), Barmston

Some concern was voiced about the companies involved, the management of the pipeline and the storage site, construction and operation, and the motives for involvement in the project. Although recognising National Grid as being responsible for the distribution of electricity and natural gas, participants queried whether it was a private or public sector organisation and its relationship with external regulators. Participants expressed concern over profit making organisations emphasising the wider environmental benefits of a project ahead of the financial benefits they would accrue.

> I think in a perfect world all of this would be getting done just to save the planet or whatever, but at the end of the day you don't get many businesses whose purpose in life is to save the planet.
>
> Female (F5), Holme-on-Spalding Moor

While reassured by information presented on the variety of issues considered in the development of a pipeline, participants continually questioned the benefits offered by CCS and locating it in their region. There was concern that it added to the existing concentration of power generation infrastructure (fossil fuel power stations and wind farms) that residents had to tolerate:

> I think there's definitely a feeling from people in this area that we, in East Yorkshire, are being dumped on a bit.
>
> Female (F1), Holme on Spalding Moor

> I wonder why they have specifically targeted the east coast, is it because the land is flat?
>
> Female (F3), Barmston

4. Discussion

When considering potential responses to a CO_2 pipeline, existing associations, understanding and perceptions of what is being transported are likely to play a large part. The research presented here complements findings from previous studies suggesting that there is a reasonable level of general knowledge about CO_2 among the lay public but a poor understanding of its more specific properties (Itaoka et al., 2012). In an assessment of their initial conceptions of CO_2, participants were aware of the gas, its role in both plant physiology and anthropogenic climate change. In contrast to previous studies, participants did not associate CO_2 with explosive or flammable properties; they did however, raise concerns about the potential for explosions as a consequence of a pipeline rupture. These concerns were allayed through further discussions about pipeline safety and the physical properties of CO_2.

While participants were not initially familiar with the properties of CO_2, an explanation of its basic physical properties supported their understanding of some of the consequences of transporting CO_2 (such as the pipeline design and routing) and of the potential exposure to CO_2 (for example, that it is an asphyxiant). This was evidenced in discussions relating to the relative implications of transporting different substances, revealing an ability to use this new understanding to conceptualise different types of risk. For example, participants appreciated that, unlike natural gas, CO_2 is not explosive but that its high density results in a very different dispersion pattern to that of natural gas.

The potential public response to CCS technologies has been extensively studied and the results presented here are consistent with previous findings (see for example, Shackley et al., 2005; Ashworth et al., 2010; Fleishman et al., 2010; Oltra et al., 2010; Upham and Roberts, 2010). Participants had very little prior knowledge of CCS – few had even heard of the technology – making it difficult to predict how the debate will evolve as it enters the mainstream. However, on provision of introductory information about CCS, initial responses do not reflect an intuitive opposition to the technology. Participants understood the wider benefits to climate change mitigation, the potential benefits to the local economy and the kudos of pioneering a new technology and were able to rationalise the need to balance risks and benefits across different scales. This consistency with previous studies, suggests that the wider body of social research on CCS remains applicable in the context of the CO_2 pipeline stage of the CCS chain. This is in itself a useful conclusion since, unlike the more geographically contained nature of the capture and storage stages, a pipeline directly affects different communities along its length.

Participants were reassured by and engaged positively with the technical assessments of risks presented to them; visual and practical demonstrations proved to be a particularly effective means of communicating complex scientific concepts. However, other, non-technical, risk factors were afforded equal attention when concerns and views of the CO_2 pipeline were discussed, raising issues related to the themes of institutional control, familiarity and local context in particular.

Participants voiced a high degree of scepticism and questioned the motivations behind the pipeline construction, in line with earlier findings by Terwel et al. (2009). A lengthy discussion relating to the project developer and its relationship with government and shareholders revealed the importance of the reputation of the primary actors, reinforcing previous research findings (Oltra et al., 2012). For the communities along the pipeline route there is no strong local presence or familiarity with the developer and this did appear to affect the response in terms of credibility and trust (Bradbury et al., 2011). Despite the developer's absence from the groups and the stated independence of our research, participants nevertheless were suspicious of the purpose of the groups. Trust also emerged as factor influencing the degree of confidence in institutions to competently implement control, operation and regulation of both the pipeline and the wider CCS process.

Local and contextual issues held a strong influence with a fine balance between a sense of pride in the region's potential role in addressing the climate change problem, alongside economic and employment benefits to the region, weighed against a perception that the area hosts more than its fair of energy infrastructure, both fossil and renewable. The lack of familiarity with the technology also influenced how the pipeline was viewed. This was expressed in terms of CCS being unknown to the participants but also the fact that the development in their region would the first of a kind for the UK, symbolically interpreted in contrasting terms of being "guinea pigs" and "pioneers". With respect to the pipeline itself, the fact that CO_2 is a ubiquitous and, at least superficially, familiar substance clearly has a role in how this tension plays out. Although not central to the research presented here, as participants tried to understand the implications of CO_2 storage, the groups revealed the potential for CCS to be associated with another recent controversial and high profile activity relating to the subsurface, i.e. fracking. Future research by the authors is planned to explore the relevance of fracking in more detail, as people search for something against which to anchor their understanding of CO_2 storage.

Compared with responses to previous pipeline developments, notably those associated with transport of oil and gas, the responses of the local participants to this study suggest two factors that might contribute to a different response to a CO_2 pipeline. First, although the local community gains no immediate direct benefit from hosting the pipeline, attitudes to it do appear to be positively influenced by its role in climate change mitigation. So, where in the past gas pipelines have been targeted by climate activist groups, although CCS is associated with maintaining the use of fossil fuels, arguments relating to fossil fuel proliferation and climate change are likely to be more complex or nuanced in the case of a CO_2 pipeline. Furthermore, although questioning the potential financial benefits to the developer, the wider environmental benefits of reducing CO_2 emissions are global and thus not conferred exclusively on specific communities elsewhere. Second, although a pipeline failure could be hazardous, the fact that CO_2 is not flammable or explosive was recognised by the lay participants to present a different risk profile compared with natural gas.

5. Conclusions and policy recommendations

In the case of a CO_2 pipeline, public attitudes may be influenced not only by any risks or impact associated with the pipeline itself but by a host of other factors such as a lack of familiarity with the technology, local, contextual and institutional factors. Despite expressing a degree of scepticism, participants to this research were open minded and not immediately opposed to the prospect of a CO_2 pipeline. Although the approach described provides insights into the nature of the potential response to a CO_2 pipeline, establishing the extent to which the views of participants are representative of the wider local population would require further research, employing different research methods in order to access a larger sample. As the development proceeds and the debate opens up, bringing in wider influences and other actors, recognising the importance of both socio-cultural and technical risk factors will be crucial in understanding how broader public opinion will evolve.

While a lack of information rarely tells the full story, it does not mean that communities don't need access to clear, transparent and balanced information in order to form an opinion. Participants responded positively to the provision of detailed information explaining the motivations and processes behind the pipeline development and the opportunity to ask questions. While there is some experience of so-called large group processes that suggests a level of engagement equivalent to the deliberative focus group process may be possible on a larger scale (Ashworth et al., 2009b; Howell et al., 2012), a variety of engagement and information approaches is likely to be needed. The challenge of recruiting a sufficient number of participants, both to the focus groups and the wider consultation process, indicates a tension between a claimed desire for information and uptake of the information when it is provided. Different types and levels of engagement will be suitable for different individuals, information materials need to be tailored to different audiences and opportunities to engage provided in a variety of ways.

Participants expressed a high degree of scepticism towards the key drivers of a company planning a CO_2 pipeline, suggesting that if developers focus primarily on the climate change benefits of a project, this may impact negatively on how the developer is perceived. Trust within the local community that the developer will minimise risk during the route selection and subsequent construction, operation and maintenance of the pipeline was seen as key during Focus Group discussions. Impacts that participants associated with the proposed CO_2 pipeline were expressed in terms of the safety aspects but also physical disruption, impact on the landscape and a sense of bearing the burden of energy supply infrastructure in the region (where there is a concentration of both fossil fuel power stations and large scale wind farms).

Existing knowledge of CO_2 is limited within lay publics; the research presented in this paper suggests that there exists both a capacity and willingness to engage with issues around CO_2, its transportation by pipeline and the associated risks. In a densely populated country like the UK, a new pipeline will potentially impact a large number of people—the success of a CCS project will depend on affected communities tolerating the presence of a pipeline in their environs. If the initial route planning and construction of a pipeline has proceeded without unresolved controversy, community focus on a pipeline is likely to fade as its trace on the landscape fades.

Acknowledgements

This research has been progressed with the benefit of co-funding from the European Commission European Energy Programme for Recovery (EEPR) and National Grid as part of the COOLTRANS (Dense Phase CO_2 Pipeline Transportation) research programme. Any opinions expressed in this paper are, however, those of the authors and not of National Grid or its staff.

We are particularly grateful to Dr Julia Race (Newcastle University) and Dr. Mark Lorch (University of Hull) for providing presentations and answering questions during the Focus Groups. We would like to thank the lay members of the Focus Groups for their participation in this study. Finally we gratefully acknowledge the constructive comments from four anonymous reviewers.

References

Akel, S., 2011. Third-party interference: pipeline survey based on risk assessment. J. Pipeline Eng..
Ashworth, P., Boughen, N., Mayhew, M., Millar, F., 2009a. An integrated roadmap of communication activities around carbon capture and storage in Australia and beyond. Energy Procedia 1, 4749–4756.
Ashworth, P., Carr-Cornish, S., Boughen, N., Thambimuthu, K., 2009b. Engaging the public on carbon dioxide capture and storage: does a large group process work? Energy Procedia 1, 4765–4773.
Ashworth, P., Boughen, N., Mayhew, M., Millar, F., 2010. From research to action: now we have to move on CCS communication. Int. J. Greenhouse Gas Control 4, 426–433.
Bradbury, J., Ray, I., Peterson, T., Wade, S., Wong-Parodi, G., Feldpausch, A., 2009. The role of social factors in shaping public perceptions of CCS results of multi-state focus group interviews in the U.S. Energy Procedia 1, 4665–4672.
Bradbury, J., Greenberg, S., Wade, S., 2011. Communicating the Risks of CCS. Global CCS Institute, Canberra.
Brunsting, S., de Best-Waldhober, M., Feenstra, C.F.J., Mikunda, T., 2011a. Stakeholder participation practices and onshore CCS: lessons from the Dutch CCS case Barendrecht. Energy Procedia 4, 6376–6383.
Brunsting, S., Desbarats, J., de Best-Waldhober, M., Duetschke, E., Oltra, C., Upham, P., Riesch, H., 2011b. The public and CCS: the importance of communication and participation in the context of local realities. Energy Procedia 4, 6241–6247.
Carson, D., Gilmore, A., Perry, C., Gronhauget, K., 2001. Qualitative Marketing Research. Sage, London.
de Best-Waldhober, M., Daamen, D., 2011. Development of CCS awareness and knowledge of the general public between 2004 and 2008. Energy Procedia 4, 6315–6321.
de Best-Waldhober, M., Paukovic, M., Brunsting, S., Daamen, D., 2011. Awareness, knowledge, beliefs, and opinions regarding CCS of the Dutch general public before and after information. Energy Procedia 4, 6292–6299.
de Best-Waldhober, M., Brunsting, S., Paukovic, M., 2012. Public concepts of CCS: understanding of the Dutch general public and its reflection in the media. Int. J. Greenhouse Gas Control 11 (Supplement), S139–S147.
DECC, 2011. The Carbon Plan: Delivering our Low Carbon Future. Department of Energy and Climate Change, London.
DECC, 2012. CCS Roadmap: Supporting Deployment of Carbon Capture and Storage in the UK. Department of Energy and Climate Change, London.
Devine-Wright, P., 2005. Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. Wind Energy 22, 125–139.
DNV, 2008. Mapping of Potential HSE Issues Related to Large-scale Capture, Transport and Storage of CO_2.
Eldevik, F., 2008. Safe pipeline transmission of CO_2. Pipeline Gas J., 235.
Eurobarometer, 2011. Public Awareness and Acceptance of CO_2 Capture and Storage. European Commission, Brussels.
Fleishman, L.A., De Bruin, W.B., Morgan, M.G., 2010. Informed public preferences for electricity portfolios with CCS and other low-carbon technologies. Risk Anal. 30, 1399–1410.

Frewer, L.J., Howard, C., Shepherd, R., 1998. Understanding public attitudes to technology. J. Risk Res. 1 (3), 221–235.

GCCSI, 2013. The Global Status of CCS: Update. The Global CCS Institute, Canberra (January 2013).

Gough, C., Boucher, P., 2013. Ethical attitudes to underground CO_2 storage: points of convergence and potential faultlines. Int. J. Greenhouse Gas Control 13, 156–167.

Groves, C., Munday, M., Yakovleva, N., 2013. Fighting the pipe: neoliberal governance and barriers to effective community participation in energy infrastructure planning. Environ. Plann. C: Govt. Pol. 31 (2), 340–356.

Hammond, J., Shackley, S., 2010. Towards a Public Communication and Engagement Strategy for Carbon Dioxide Capture and Storage Projects in Scotland. Scottish Centre for Carbon Storage, Edinburgh (Working Paper SCCS 2010-08).

Harper, P., 2011. Assessment of the major hazard potential of carbon dioxide (CO2). Health Saf. Executive.

Heggum, G., Weydahl, T., Mo, R., Mølnvik, M., Austergaard, A., 2005. CO_2 Conditioning and Transportation. In: Thomas, D.C., Benson, S.M. (Eds.), Carbon Dioxide Capture for Storage in Deep Geologic Formations, vol. 2. Elsevier.

Howell, R., Shackley, S., Mabon, L., 2012. Public Perceptions of Low Carbon Energy Technologies: Results from a Scottish Large Group Process. GCCSI, Canberra.

HSE, 2008a. Interim Guidance on Conveying CO_2 in Pipelines in Connection with Carbon Capture, Storage and Sequestration Projects. 〈http://www.hse.gov.uk/pipelines/co2conveying-full.htm〉, retrieved 13 March 2014.

HSE, 2008b. Pipeline Design Codes and Standards for use in UK CO_2 Storage and Sequestration Projects. 〈http://www.hse.gov.uk/pipelines/resources/designcodes.htm〉, Retrieved 20 August, 2012.

HSE, 2011. Assessment of the Major Hazard Potential of Carbon Dioxide (CO_2).

Huijts, N.M.A., Midden, C.J.H., Meijnders, A.L., 2007. Social acceptance of carbon dioxide storage. Energy Policy 35 (5), 2780–2789.

IEA, 2013. Technology Roadmap: Carbon Capture and Storage OECD/IEA, Paris.

IEAGHG, 2014. CO2 Pipeline Infrastructure, Report 2013/18, January 2014, IEA Greenhouse Gas R & D Programme, 〈http://www.ieaghg.org/docs/General_Docs/Reports/2013-18.pdf〉.

IGEM, 2008. Defining the End of the Network, a Meter Installation and Installation Pipework. IGEM/G/1. 3rd Impression Communication, 1733.

IJGGC, 2013. Virtual Special Issue: Key CCS Social Science Research Articles.

IPCC, 2005. In: Metz, B., Davidson, O., Coninck, H.C.d., Loos, M., Meyer, L.A. (Eds.), IPCC Special Report on Carbon Dioxide Capture and Storage. Cambridge University Press, Cambridge.

Irwin, A., Wynne, B., 1996. Misunderstanding science?, The Public Reconstruction of Science and Technology. Cambridge University Press.

Itaoka, K., Saito, A., Paukovic, M., de Best-Waldhober, M., Dowd, A.-M., Jeanneret, T., Ashworth, P., James, M., 2012. Understanding how Individuals Perceive Carbon Dioxide: Implications for Acceptance of Carbon Dioxide Capture and Storage. CSIRO, Australia.

Joffe, H., 2003. Risk: from perception to social representation. Br. J. Soc. Psychol. 42, 55–73.

Kling, G., Clark, M., Wagner, G., Compton, H., Humphrey, A., Devine, J., Evans, W., Lockwood, J., Tuttle, M., Koenigsber, E., 1987. The 1986 Lake Nyos Gas Disaster in Cameroon, West Africa. In: Science 10 April 1987: 236 (4798), 169–175.

Krueger, R., Casey, M., 2000. Focus Groups: A practical Guide for Applied Research. SAGE, USA.

Lafleur, P., 2010. Geochemical Soil Gas Survey. A Site Investigation of SW30-5-13-W2M Weyburn Field. Petro-Find Geochem Ltd, Saskatchewan.

Mander, S., Polson, D., Roberts, T., Curtis, A., 2010. Risk from CO_2 storage in saline aquifers: a comparison of lay and expert perceptions of risk. Energy Procedia 4, 6360–6367.

McLachlan, C., 2009. 'You don't do a chemistry experiment in your best china': symbolic interpretations of place and technology in a wave energy case. Energy Policy 37, 5342–5350.

McLachlan, C., Mander, S., 2013. What have facts got do with it anyway? Competing knowledge claims in low-carbon energy controversy. In: Roberts, T., Upham, P., Mander, McLachlan, C., Boucher, P., Gough, C., Abi Ghanem, D. (Eds.), Low-Carbon Energy Controversies. Routledge.

Macnaghten, P., Szerszynski, B., 2013. Living the global social experiment: an analysis of public discourse on solar radiation management and its implications for governance. Global Environ. Change 23, 465–474.

Midden, C.J.H., Huijts, N., 2009. The role of trust in the affective evaluation of novel risks: the case of CO_2 storage. Risk Anal. 29, 743–751.

Morgan, D., 1993. Successful Focus Groups: advancing the state of the art. Sage.

National Grid, 2012. Yorkshire and Humber Carbon Capture and Transportation and Storage Project; Feedback Report on Stage 1A Consultation.

National Grid, 2013. Yorkshire and Humber CCS Cross Country Pipeline 10-2574-RPT-0033 Scoping Report.

O'Keefe, L.L., Mander, S.M., Gough, C., 2013. WP5.2.2: Public Perceptions of CO_2 Transport in Pipelines, Interim Report, April 2013. 〈www.tyndall.manchester.ac.uk〉.

Oltra, C., Sala, R., Solà, R., Di Masso, M., Rowe, G., 2010. Lay perceptions of carbon capture and storage technology. Int. J. Greenhouse Gas Control 4, 698–706.

Oltra, C., Upham, P., Riesch, H., Boso, À., Brunsting, S., Dütschke, E., Lis, A., 2012. Public responses to CO_2 storage sites: lessons from five European cases. Energy Environ. 23, 227–248.

Parkhill, K., Pidgeon, N., Henwood, K., Simons, P., Venables, D., 2009. From the familiar to the extraordinary: local residents' perceptions of risk when living with nuclear power in the UK. Trans. Inst. Br. Geogr. 35, 39–58.

Pidgeon, N., Lorenzoni, I., Poortinga, W., 2008. Climate change or nuclear power–no thanks! A quantitative study of pubic perceptions and risk framing in Britain. Global Environ. Change 18, 69–85.

PTRC, 2011. IEAGHG Weyburn-Midale CO_2 Monitoring and Storage Project: Response to a soil gas study performed by Petro-find Geochem Ltd. Petroleum Technology Research Centre.

D. Reiner, H.R., Chyong, C.K., Brunsting, S., de Best-Waldhober, M., Duetschke, E., Oltra, C., Lis, A., Desbarats, J., Pol, M., Breukers, S., Upham, P., Mander, S., 2010. Opinion Shaping Factors Towards CCS and Local CCS Projects: Public and Stakeholder Survey and Focus Groups. NEAR CO_2 Work Package 2 Report Judge Business School, Cambridge.

Renn, O., 1998. The role of risk perception for risk management. Reliab. Eng. Syst. Saf. 59, 49–62.

Roberts, T., Mander, S., 2011. Assessing public perceptions of CCS: benefits, challenges and methods. Energy Procedia 4, 6307–6314.

Roberts, T., Upham, P., Mander, S., McLachlan, C., Boucher, P., Gough, C., Ghanem, D. A. (Eds.), 2013. Low-Carbon Energy Controversies. Routledge.

Serpa, J., Morbee, J., Tzimas, E., 2011. Technical and Economic Characteristics of CO_2 Transmission Pipeline Infrastructure. European Commission Joint Research Centre, Institute for Energy.

Shackley, S., Dowd, A.-M., Scott, V., Howell, R., Markusson, N., Boot, K., Mabon, L., Evar, B., 2013. Key Messages for Communication Needs for Key Stakeholders. IEAGHG, Cheltenham.

Shackley, S., McLachlan, C., Gough, C., 2005. The public perception of carbon capture and storage in the UK: results from focus groups and a survey. Clim. Policy 4, 377–398.

Sharp, J.D., Jaccard, M.K., Keith, D.W., 2009. Anticipating public attitudes toward underground CO_2 storage. Int. J. Greenhouse Gas Control 3, 641–651.

Stephens, J.C., Hansson, A., Liu, Y., de Coninck, H., Vajjhala, S., 2011. Characterizing the international carbon capture and storage community. Global Environ. Change 21, 379–390.

Sovacool, B.K., 2011. The interpretive flexibility of oil and gas pipelines: case studies from Southeast Asia and the Caspian Sea. Technol. Forecasting Soc. Change 78, 610–620.

Terwel, B.W., Harinck, F., Ellemers, N., Daamen, D.D.L., 2009. How organizational motives and communications affect public trust in organizations: the case of carbon dioxide capture and storage. J. Environ. Psychol. 29, 290–299.

Terwel, B.W., Harinck, F., Ellemers, N., Daamen, D.D.L., 2011. Going beyond the properties of CO_2 capture and storage (CCS) technology: how trust in stakeholders affects public acceptance of CCS. Int. J. Greenhouse Gas Control 5, 181–188.

Therwell, D., 1999. Using focus groups as a consumer research tool. J. Marketing Pract.: Appl. Marketing Sci. 5 (4), 102–105.

Upham, P., Roberts, T., 2010. Public Perceptions of CCS: The Results of NEARCO2 European Focus Groups.

Upham, P., Roberts, T., 2011. Public perceptions of CCS: emergent themes in pan-European focus groups and implications for communications. Int. J. Greenhouse Gas Control 5, 1359–1367.

Vandeginste, V., Piessens, K., 2008. Pipeline design for a least cost router application for CO_2 transport in the CO_2 sequestration cycle. Int. J. Greenhouse Gas Control 2, 571–581.

Wallquist, L., Visschers, V.H.M., Siegrist, M., 2009. Lay concepts on CCS deployment in Switzerland based on qualitative interviews. Int. J. Greenhouse Gas Control 3, 652–657.

Wallquist, L., L'Orange-Seigo, S., Visschers, V.H.M., Siegrist, M., 2012. Public acceptance of CCS system elements: a conjoint measurement. Int. J. Greenhouse Gas Control 6, 77–83.

Whitmarsh, L., Upham, P., Poortinga, W., McLachlan, C., Darnton, A., Devine-Wright, P., Demski, C., Sherry-Brennan, F., 2011. Public Attitudes to and Engagement with Low-Carbon Energy: A Selective Review of Academic and Non-academic Literatures, Report for RCUK Energy Programme. EPSRC, Swindon.

Widener, P., 2013. A protracted age of oil: pipelines, refineries and quiet conflict. Local Environ. 18, 834–851.

Yakovleva, N., Munday, M., 2010. Pipeline Development and Community Participation. Cardiff, ESRC Centre for Business Relationships, Accountability, Sustainability and Society (BRASS). University of Cardiff.