Local perceptions of the QICS experimental offshore CO_2 release: Results from social science research

Journal Item

Accepted to International Journal of Greenhouse Gas Control 17/10/2014

Local perceptions of the QICS experimental offshore CO_2 release: results from social science research

Leslie Mabon*, Simon Shackley, Jerry C Blackford, Henrik Stahl and Anuschka Miller

*Corresponding author:

Tel: +0044 (0)1224 263210 / +0044 (0) 7864 006 762

Fax: +0044 (0) 1224 263222

E-Mail: l.j.mabon@rgu.ac.uk

Abstract: This paper explores the social dimensions of an experimental release of carbon dioxide (CO_2) carried out in Ardmucknish Bay, Argyll, United Kingdom. The experiment, which aimed to understand detectability and potential effects on the marine environment should there be any leakage from a CO_2 storage site, provided a rare opportunity to study the social aspects of a carbon dioxide capture and storage-related event taking place in a lived-in environment. Qualitative research was carried out in the form of observation at public information events about the release, in-depth interviews with key project staff and local stakeholders/community members, and a review of online media coverage of the experiment. Focusing mainly on the observation and interview data, we discuss three key findings: the role of experience and analogues in learning about unfamiliar concepts like CO_2 storage; the challenge of addressing questions of uncertainty in public engagement; and the issue of when to commence engagement and how to frame the discussion. We conclude that whilst there are clearly slippages between a small-scale experiment and full-scale CCS, the social research carried out for this project demonstrates that issues of public and stakeholder perception are as relevant for offshore CO_2 storage as they are for onshore.

Keywords: carbon dioxide capture and storage (CCS); environmental risk; environmental uncertainty; offshore energy; public engagement.

Research highlights

- Analysis of social dimensions of real-world CO_2 release event;
- Social issues as relevant for offshore CO_2 storage as onshore;
- Analogues helpful for publics in understanding CO_2 storage;
- Non-specialists can quickly grasp complex ideas and make sophisticated points;
- Ongoing challenge of when/how to engage with communities on CCS-related projects.

1. Introduction

1.1 Background to the study

In spring and summer 2012, an experimental release of carbon dioxide (CO_2) was carried out in Ardmucknish Bay, Argyll, United Kingdom. The experiment was an integral part of the Natural Environment Research Council (NERC)-funded Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage (QICS) project, and sought to understand detectability and potential effects on the marine environment should there be any leakage from a CO_2 storage site. Over a thirty-seven day period, CO_2 was pumped into the sediments at 12 metres below the seabed, 350m offshore, via a horizontally-drilled pipeline connected to a pumping station on land. Various monitoring devices were placed around the release site and observations and samples were taken before, during and after the release (for examples of research results, see Blackford and Kita (2013) and the other papers in this issue).

In addition to the physico-chemical and biological science findings, the experiment also presented a rare and valuable opportunity to study the social dimensions of a real-world carbon dioxide capture and storage (CCS)-related event. With the release being conducted in a lived-in environment, public and stakeholder engagement was of the utmost importance in order to avoid potential negative reactions that could have prevented the experiment from taking place or running successfully, or at least threatened the good relationships and trust between the local research laboratory - Scottish Association for Marine Science (SAMS) - and its local community.

SAMS co-ordinated the CO_2 release experiment at the top of Ardmucknish Bay close to Benderloch village, including the installation and operation of the release facility and sampling activities (for more details about the experiment see Taylor et al (this volume)). SAMS was also responsible for acquiring the appropriate permits and consents to conduct the experiment from local- (Argyll and Bute Council, Marine and Coastal Development Unit) and government regulatory bodies (Marine Scotland and The Crown Estate), as well as from landowners (Lochnell Estates), land users (Tralee Bay Holiday Park) and non-governmental organisations. In addition to formal permissions, consent was also sought from the general public and other local stakeholder groups (e.g. local fishers) through various open meetings and public outreach activities.

A public information meeting was held prior to commencement of the work in Benderloch Village Hall in early December 2011, at which the lead local scientist gave a forty-minute presentation on the rationale behind and workflow of the experiment, followed by a forty-minute question and answer session with the audience. An information stand about the project was set up at a farmers' market day in the local village in March 2012. An 'open day' and a school visit were held at the release site whilst the experiment was in progress, where some of the monitoring equipment was displayed, a video of bubbles emitting from the seabed was shown, an experiment with carbonated water and litmus paper was used to demonstrate acidity, and two project scientists answered questions from visitors. Initial findings were presented at SAMS in November 2012 as part of a Winter Lecture series. During the experiment, information posters were displayed around the release site, and one of the responsibilities of the 'on site' scientists was to answer questions about the project from the public. Articles were run in local and later national print and web media, the lead local scientist gave interviews on local radio and television stations, and a group was set up on social media (Facebook) giving continuous updates on the project progress to members. A central webpage (www.bgs.ac.uk/qics, accessed 12/09/2014) was also created containing detailed information and images about the QICS project as a whole.

1.2 Social science research on real-world CCS events

Low public awareness and understanding of CCS (Eurobarometer, 2011) presents a challenge for social scientists seeking to understand the social dimensions of CCS. de Best-Waldhober et al (2009) note that in such situations of low awareness, people's opinions are unstable and subject to change. Daamen et al (2006) refer to such opinions as 'pseudo-opinions', Malone et al (2010) arguing that surveying or 'polling' publics for opinions on CCS may be of limited value when people have not even had the opportunity to form an opinion. Even when people do receive initial information, Upham and Roberts (2011) and Howell et al (2014) find that different people change their views differently in response to learning about CCS. In some cases, people's perceptions towards CCS can become more negative as further information is provided, Howell et al (2014) suggesting this may be because the extra information allows publics to more fully think through the uncertainties associated with CCS.

One of the biggest reasons for low awareness and understanding of CCS may be the limited number of full-scale integrated CCS projects currently in operation. Nonetheless, a small body of empirical research has been done around 'real world' CCS, focusing mainly on pilot projects trialling part of the CCS chain, or on proposals for future projects. What is widely acknowledged within such studies is that publics' perceptions of CCS are highly contingent on the broader social context into which specific projects are deployed. Dütschke (2011) links the successful deployment of the CO_2Sink project at Ketzin in Germany to the perception of the developer as a research organisation not standing to gain financially from the project, and Terwel et al (2012) consider how questions of trust in the developer affected publics' responses to the Barendrecht proposals in the Netherlands. Bradbury (2012) examined community responses to six CCS project proposals in the USA, suggesting that the nature of previous community experience with large infrastructure could affect the level of support for a project. In France, Ha-Duong et al (2011) found the developer's role as a key employer in the community, and flexibility in responding to early concerns over risk management and landscaping, to be an important factor in the ultimately successful deployment of Total's Lacq development.

The key way in which a study of the QICS project can contribute to this work is that it stands as an example of a pilot study around *offshore* CO_2 storage. The emerging preference for offshore storage sites - in Europe at least - means building an understanding of the differences in public perception that may exist between onshore and offshore storage is vital. Exploration of public and stakeholder issues around the QICS experimental release is thus a valuable opportunity to get an early indication of some of the issues that may arise with CO_2 storage in a marine environment.

2. Method

Social science research around the QICS project was carried out under a wider programme of work being undertaken in Scotland, north England and Italy by the public perceptions work package of the EU FP7-funded ECO_2 project (www.eco2-project.eu, accessed 15/09/2014). A Memorandum of Understanding between ECO_2 and QICS allowed ECO_2 researchers to observe some public engagement activities being carried out around the release site, with the results feeding in to the ECO_2 social science work package (for example Mabon et al, 2014; Mabon and Shackley, 2014).

The research design for the QICS social science study was to a certain extent determined by the nature of the project as a whole. The experimental release was inherently controversial in that it could be viewed as deliberate, albeit well planned and controlled, pollution of a high-quality marine environment. The experiment was both technologically risky, nothing similar having been attempted previously, and involved significant expense in engineering a gas delivery pipeline from shore to the release point 350m off-shore at 12m depth in the sediment. There is already a precedent of environmental groups opposing open ocean iron fertilisation experiments, which has contributed to the abandonment of expensive scientific projects (Mayo-Ramsay, 2012). For QICS, there was thus motivation not only to minimise risk of experimental failure, but also to communicate effectively and transparently so that bodies and individuals could make an informed decision and/or allow the project to take account of any local issues that might require some modification of the experimental plan. To this end, in addition to obtaining formal permission for the CO_2 release from the relevant regulatory bodies, the project took a considered and early decision to go beyond these formal legal obligations and consult with a wide range of potentially affected bodies and individuals, mainly at the local level. Accordingly, QICS developed a locally-centred communications strategy, consulting regional government, environmental groups, marine users and the public. In order to allow any concerns among the community and local stakeholders to be identified and suitably addressed before they became distorted or amplified by other spatially distant actors, national publicity was deliberately left until after all local issues had been considered.

Given these potential sensitivities, it was crucial (especially at the early stages of the project) not to give local citizens the impression that they were being observed to study how they would react to the proposals in order to trial out publicity and marketing strategies for deployment of commercial CCS elsewhere, as if they too were part of an ‘experiment’. Additionally, the aim of forming an in-depth understanding of why people expressed particular perceptions – and the associated need to probe participants and data further on occasion - meant that a qualitative approach was more suitable. Taking both of these factors into account, the first phase of social research involved passive observation at two specific QICS public engagement events – the public information meeting held in Benderloch village hall close to the release site in December 2011; and the ‘open day’ held at the release site in May 2012. ECO_2 social scientists attended both these events, observed the questions publics and stakeholders asked the presenting scientists, and wrote up detailed field notes based on their observations. The public information meeting was also video recorded (with the camera pointing at the presenting scientists), and transcribed.

Following the completion of the main part of the experimental CO_2 release, in-depth interviews were carried out with key SAMS staff involved in the project, and with local stakeholders and community members aware of the experiment (see Table 1 for further details). Seven such interviews were conducted, however given the aim of examining in depth the contextual factors driving perceptions of offshore CO_2 storage, the quality and content of the interviews was deemed more important than the size or statistical representativeness of the sample. Chase (2005:667) notes that “any narrative is significant because it embodies – and gives us insight into – what is possible and intelligible within a specific social context.” It was hence deemed possible to get sufficient analytical purchase on the context of the QICS release by working intensively with a few key locally-based respondents who had a close relationship to the experiment (see Table 1), as they would be well placed to give insight into the wider social context of the QICS release due to their in-depth understanding of how the project had developed over time. In any case, the small local population would have made the construction of a representative sample difficult. The interviews were audio-recorded and transcribed. These formal interviews were supplemented with informal, unrecorded conversations held with members of the general public at a farmers’ market close to the release site, at which one of the ECO_2 social researchers had a stall with basic information about the experimental CO_2 release and the ECO_2 project. The aim of setting the stall up was to find out people’s perceptions at an informal level, whilst continuing the project’s community presence. By and large (with the exception of one member of the public who expressed particular interest in energy and environmental issues, and agreed to take part in a longer interview whilst visiting the stall), publics spoken to in informal conversations showed some interest in but little concern over the experiment, usually admitting to low awareness of CO_2 storage and CCS more widely (we discuss the implications of this at the start of Section 3.2).

Table 1: summary of interviewees

Interviewee	Gender	Role and relationship to project	How interviewee was selected
Communications officer (SAMS)	Female	Responsible for liaising with media and local community about all SAMS’ activities.	Identified as key SAMS member – responsible for communications.
Farm manager	Female	Farm manager close to experiment site, also key figure in community sustainability group.	Identified through initial media analysis as key environmental stakeholder in area.
Journalist at local newspaper	Male	Reporting on local news, including the QICS release.	Identified through initial media analysis as key source of media information on QICS.
Informed member of public	Male	Lives close to sea, occasional sailor in experiment bay.	Opportunistic sampling at farmers’ market based on expression of interest.
Professor (SAMS)	Male	Senior figure in SAMS, oversees research in institute and acts as public ‘face’ for activities.	Identified as key SAMS member – overarching view of institute’s role in community.
Research scientist (SAMS)	Male	Working on QICS project as part of research programme.	Identified as key SAMS member – physical involvement in

			experiment.
Senior research scientist (SAMS)	Male	Chief local scientist for QICS experiment.	Initial point of contact for social scientists planning research on QICS.

Finally, articles published on online news sites about the experiment were read (both editorial content and reader comments) as a means of providing additional contextual information. These articles were used initially to help identify key stakeholders to interview, and were then reviewed after the analysis of the in-depth interviews and qualitative observations were completed as a means of checking whether the themes emerging in the small-scale data set were representative of wider thinking within the community and beyond. The key themes emerging from the interviews and observations mapped well onto the concepts raised in online articles – in particular the contextualisation of risk and the use of analogues to understand unfamiliar concepts. As these online sources were used mainly as a cross-check for the other data in the study and offered little extra in the way of thematic content, in the interests of space this paper will focus on the interview and ethnographic observations in order to explore these as fully as possible within the space available.

Topics of energy and environmental change can elicit strong and emotive responses (Cass and Walker, 2009). With this can come the risk of researchers – perhaps unconsciously – 'cherry picking' the most exciting or contentious quotes for further investigation (Mabon et al, 2014), even if these do not necessarily represent the views of the wider community. Data analysis was therefore based on an adapted version of the Doucet and Mauthner (2008) ‘listening guide’. This entailed reading the interview and meeting transcripts four times – once for the researcher’s own initial responses; once for the way the speaker talks about themselves; once for identifying how the speaker talks about relationships; and once for the wider themes the speaker raises. The aim was to acknowledge that the researcher’s own interests and values can affect the way qualitative data is processed, and to try to separate this out from what participants themselves said. The field notes and online media were then read in light of the emergent themes, looking for additional topics or additional nuances. The results discussed below reflect the themes that emerged most clearly from the whole analysis process.

3. Results and implications for CCS

3.1 How people learn – experience and analogues

The first theme emerging from the study concerns how people learn about CO_2 storage, climate change, and the environment around them. It became apparent during both the public engagement sessions and interviews that whilst both publics and stakeholders can remember some things well, they may remember other things in a vague, superficial or partial way:

I was aware, certainly in Asia there were a few trials […] *And I think as well I’d heard about earthquakes etc, I think in America if I remember correctly, and also England as well from carbon capture experiments.* (interview with local journalist, Oban, October 2012)

There has been experiments that you intend to carry out, there has been these done already, isn't there? […] *in America they tested inland, there, do it there and actually contaminate fresh water to the point that humans couldn't drink it.* (participant, public meeting, December 2011)

From the data available to the authors, it cannot be ascertained with certainty whether or not the events the speakers describe above actually relate to CO_2 storage. Given the timing of the public information meeting, it is likely the second speaker is referring to the leakage allegations at the Weyburn-Midale project in Saskatchewan, Canada, in which a local farming couple situated on the perimeter of the injection area made allegations of excessive CO_2 levels, abnormal plant growth and animal mortalities on their land. Investigations subsequently found that the high CO_2 levels were real, but because they were seasonal, and related to rainfall in the area were most likely biogenic in origin and not associated with the injected CO_2 (Beaubien et al, 2013). The allegations received some headline media coverage, but the refutations did not make such extensive headlines (Boyd et al, 2013). However, there is also a chance that both speakers are confusing CO_2 storage with the well-documented controversies around hydraulic fracturing in the USA and UK. Regardless, the fact remains that things the speakers recall seeing or hearing elsewhere inform their initial perceptions of CCS, even if they cannot remember specific details. In the case of the second speaker, this prior understanding pre-dispositions him to be more cautious towards the whole idea of CO_2 storage, and thus towards the experimental release. Whilst the second speaker explicitly refers to an 'inland' experiment in the USA (note also that Weyburn-Midale is in fact situated in Canada), he carries this concern over to an offshore experiment in the UK – suggesting that perceptions of risks people understand from onshore ventures may transfer to their perceptions of offshore CO_2 storage.

Even when publics did fully understand the underpinning science behind the experiment, personal understandings and experiences of the local environment in some cases contributed to a more cautious stance towards offshore CO_2 storage – if not to the local experiment itself (we explore this distinction between the experiment and CCS as a climate change mitigation technology more fully in Section 4). As a farm manager with a background in biological science explained:

The full concept of the bigger, the big scale version, it would be better if we could reduce the amount of CO_2 we were doing rather than, you know, finding unusual places to dump it! I have, I still have my doubts about whether that's as well thought through as it could be, glad it's the North Sea and not on the west coast but it's still a bit too close. You know, we have, we have interesting earthquakes in this part of the world on occasions, because, well because we're at the bottom of the Great Glen, so anything that messes about with the- Well that's the point you see, is, geology's not just local, in fact geology's almost never local, geology does work rather, over rather large distances, so, so yes messing about with one bit would go, can have repercussions for the rest of us. (interview with farm manager, near Oban, October 2012)

Here, experience of small earthquakes in the locale are used as a starting point for the interviewee - who explained earlier on in the interview she had a background in biological science - to think about the complexity of geology. Concepts such as tectonic plates are drawn in to argue that even something happening across a great spatial distance could have localised implications for communities. The use of the phrase 'messing about' perhaps also implies the limitations of human knowledge (see Section 3.2), and the potential for unknown or unexpected effects to arise from sub-seabed CO_2 storage. Additionally, this stands as another example of a situation where experiences or understandings of activities taking place onshore can affect perceptions of activities taking place 'far away' and offshore. Offshore activities like sub-seabed CO_2 storage are not necessarily perceived as being less risky because they are taking place out at sea, rather people may use more familiar 'on land' understandings to conceptualise what could go wrong and how it could affect them.

Conversely, personal and embodied experience can help publics to understand new and complex phenomena. Another attendee at the initial public information meeting rationalised the small scale of the experimental release thus:

Another parallel might be the discharge of septic tanks into Ardmucknish Bay, which has been going on for, well, as long as we've been discharging urine and faeces into Ardmucknish Bay. That presumably, I mean, I see urea mentioned there bringing down the pH […] *we've been able to swim near to a sewage outcrop for many years without hitting the worst of the rubbish, so it's no big a problem, is it?* (participant, public meeting, December 2011)

The participant's own understanding of the environment in which he lives helps him to understand how small quantities of 'pollutants' released into a relatively healthy marine environment need not have disastrous consequences for humans living nearby. Visitors to the open afternoon at the release site made a similar point, suggesting that the environmental impacts from effluent released by a nearby caravan site could be greater than those from the experimental

CO_2 release. In both cases, analogues are used to compare the unfamiliar concept of CO_2 storage to what is known locally. There is thus the possibility that small-scale, localised 'pollution' (rather than more scientific discourses around climate change) can be used as an analogue to help publics and stakeholders understand that CO_2 storage takes place against a much wider backdrop of humans having effects on the marine environments around them.

A key implication of all of this for engaging with publics and stakeholders on CCS is that people's understandings and perceptions of new phenomena are based very much on their ability to find appropriate analogues, primarily from direct experiences of the environments around them but also from media coverage and/or wider public discussions about energy and environmental change. This fits well with Gigerenzer's (2008) advocacy for the use of analogues as powerful heuristics, since they allow someone to make rapid progress in identifying and characterising a 'new thing' by reference to something more familiar. Likewise, Riesch (2012) discusses Moscovici's work on social representations of risk, suggesting that new and abstract concepts are conceptually anchored to topics that are already understood and made sense of via associated reasoning. From a cognitive psychology perspective, Palmgren et al (2004) suggest a 'mental models' approach can demonstrate how understandings of new phenomena relate to people's wider beliefs. In short, the idea of CCS being evaluated in relation to previous experiences people have had fits well with thinking across a range of social theories.

People may of course come to understand things in a partial and piecemeal way, remembering some things well but mis-remembering or mis-interpreting others. Equally, however, experiences of processes like earthquakes and environmental pollution can help people to contextualise the potential risks and benefits of an unfamiliar new technology like CO_2 storage. As such, rather than 'starting from scratch' with a narrative of climate change and the need for CO_2 emission cuts that assumes limited public knowledge, an alternative starting point for public and stakeholder engagement on CCS may be to have a discussion about how people experience environmental change around them more generally, and situate CO_2 storage within this much larger picture of human and natural activities driving change in the marine environment. It is important to register, though, that this rationale still rests upon the understanding that CO_2 is somehow problematic and that carbon reduction is necessary.

3.2 Dealing with uncertainty and risk

The second emergent theme relates to how publics (and local stakeholders) evaluate questions of uncertainty and risk. Carr et al (2013) argue in the context of climate engineering that the public are ready for discussions of high technical, moral and ethical complexity, and can participate in such discussions without a huge amount of scientific information. This certainly seemed to be the case for the community members engaging with the experimental CO_2 release in Ardmucknish Bay. Consider some of the questions asked by audience members at the public information evening following a presentation on the experiment by the lead scientist:

[I]*n ecological terms it's impossible to ever scale up, because the reactions are all so completely different. Is this caprock the same as what we have in Ardmucknish Bay? I mean this looks like, what you're looking at under, you know, the North Sea is your deep sea, large empty wells or vacant areas. What you're doing in Ardmucknish is just pumping the gas into the mud.*

What's to stop [storage formation] *water absorbing the CO_2 and then coming out? Because the water presumably displaces when it goes somewhere, and what's to stop that water absorbing the CO_2 and going out as it wishes?*

[Y]*our presentation appears to be maybe four or five things that are quite key to dealing with people's perceptions, you know the small scale, short-term experiment, a minimal area being affected, small quantities of CO_2 being released and what is the, you know, the equivalent in real life etc.*

(participants, public meeting, December 2011)

One of course has to bear in mind the possibility that community members willing to attend a public information talk – and asking questions thereafter – could well be more scientifically engaged than the community at large. Indeed, members of the public spoken to informally at the farmers' market appeared somewhat interested in but generally unconcerned by the experiment, often professing to having low awareness of the concept of CO_2 storage. This relates to the suggestion of Howell et al (2014) that as knowledge of CCS and related processes increases, so too can perception of potential risks and uncertainties – hence it may be the case that those attending the meeting were more engaged and informed than 'average' or lay members of the public, and thus more likely to perceive shortcomings or limitations. Many of these questions may also have come from those who were attending the evening in a semi-professional role as stakeholders. However, these quotes still stand as a good illustration of two related issues: how publics and stakeholders conceive of uncertainty in science; and how they come to interpret the risks of CO_2 storage more specifically.

In terms of uncertainty in science more broadly, the first participant's questioning of the wider relevance of the release reflects very well Wynne's (1992) observation on how technical risk assessment is 'extended' beyond a limited context and assumed to have relevance more widely. What was especially interesting about the QICS release was that, because of the experimental nature of the work and the huge timescales involved with full-scale CO_2 storage, project scientists were sometimes unable to give straight and unequivocal answers to questions posed by the public:

[I]*n any research project you do not know one hundred percent what the outcome is going to be. So you put something in the environment that you think is safe, that will not have a long-term implication, what if you're wrong and you do have a long-term implication, what are you going to do about it then?* […] *So that I think was a genuine open question that we just couldn't answer, and that nobody can, and that is a matter of research.*[…] *I mean we would, I think our main, main answer was then to look at the amount of gas we were going to release and how small it was.* (interview with communications officer, SAMS, October 2012)

Uncertainty here is conceived of as an integral and inevitable part of scientific enquiry. The nature of research and experimentation is such that the outcomes cannot be determined beforehand – however, through existing knowledge, understanding and experience it is possible to get a sense of the parameters within which the outcome of this 'experiment' will be located.

Nonetheless, this conception of uncertainty in science – and an experiment as a controlled way of refining existing knowledge - had potential to run up against alternative views of experimentation and uncertainty. This bigger issue of uncertainty on occasion manifested itself in the form of more specific concerns over the environmental risks of CO_2 storage and the experimental release:

You can't guarantee it's not going to stay within that 200 metres, the effects, what are the effects if it does come onto the beach? […] *I happen to know three or four folk who do fish in the area all the time, and there is a lot of people who visit, divers go to the marina etc, and I would say that's a massive recreational area, and it's a fishing area, and basically, potentially, and you can't answer the question is how much damage could that do in that short period of time?* (participant, public meeting, December 2011)

In this case, the member of the public takes the notion of uncertainty and the need for experimentation, and translates it into the possibility that absolutely anything could happen as a result of CO_2 being released into Ardmucknish Bay. People thinking in this way about risks specifically associated with the QICS release were in the minority, however the project scientists (and some more supportive publics) responded to concerns of this type mainly by putting the size and scale of the experiment into a wider context – as with the communications officer emphasising the small volume of gas being released. Two scientists present at the open day at the release site likewise related the controlled CO_2 release to the much larger and uncontrolled 'experiment' humans are doing on a daily basis by releasing vast quantities of CO_2 into the environment through the consumption of fossil fuels. The scientists also used a 'Soda Stream' machine to inject CO_2 into drinking water, thus creating carbonated water of the kind drunk on a daily basis and illustrating that CO_2 in water was not necessarily harmful to humans.

As for what this says for CCS communication and engagement, it illustrates a much bigger issue over communicating uncertainties. As some of the extracts above indicate, more than reassurances that a CO_2 storage site will *not* leak (or that site operators know exactly what will happen), what publics and stakeholders want is to see that researchers and developers have given adequate thought to the limitations of their knowledge, and that adequate monitoring and remediation procedures are in place *should* any unexpected event like a leak of CO_2 occur (Scott et al, 2014). This is closely linked with the concept of 'resilience' in risk management, where 'success' can be viewerd as the ability of organisations, groups and individuals to anticipate the complexity of the real world before failures and harm occur (Hollnagel et al, 2006). Fitting with the responsible innovation agenda proposed by Stilgoe et al (2013), there is thus the importance of building anticipatory capability into projects by asking and taking seriously 'what if' questions, bringing a range of knowledges and experiences into project development at as early a stage as possible. By starting from the premise of what would happen were a sub-seabed CO_2 storage site to leak, the QICS experiment itself could even be seen as an example of building this kind of anticipatory capability.

3.3 When and how to engage?

The final emergent theme concerns the timing and framing of engagement. One of the lead scientists describes the dilemma that existed within the QICS project thus:

[T]*he problem is, what do you start with? It's a little bit like the chicken and the egg! Before we knew we had a site where we actually had to get permission from the land owner, we had to do all the surveys before and then say okay we've got a couple of sites, and then before asking the public if, I mean some might have said that we should have gone out and asked the public first, what do you think about this? But then we just realised this is going to take far too much time, and there are just so many, so we thought at first it was best to just find a site, and get permission from the landowner, and the end user, and then engaged the local community in that area and work in that way.* (interview with research scientist, QICS project, October 2012)

The project management decided on balance that selecting one site with agreement of land owners and relevant authorities, and only then engaging the wider community, was the only economical and practicable approach when compared to sounding out eight or nine different communities at potential sites. With necessary consents from land owners/users and regulatory bodies, the public information evening thus served the purpose of informing the local community about what would be happening rather than seeking their consent. This elicited surprise from several (but not all) people at the information meeting:

Is it not nice to ask folk rather than just saying by the way, coming here tonight, this thing's happening and you're paying for this thing? You know, it's not, like, it's like me telling you that I don't agree with totally, and I don't have all the facts about it tonight, and I just feel like you've turned up here, and you've said this is what's happening, you can object as much as you like, but it's a done deal. (participant, public information meeting, December 2011)

This concern over activities being a ‘done deal’ – perhaps aided by the way in which the workflow of the QICS release inevitably had to be presented as imminent and definitely going ahead - is mirrored in other CCS-related social science research, where publics have expressed discomfort over the way in which decisions about the environments around them are made without their consultation or consent. In work carried out for the EU FP7 SiteChar project in north-east Scotland, it was this perception that a decision had already been taken to proceed with CO_2 storage that concerned some participants, even though the proposed storage site was far out at sea and not on the land under people’s homes (Brunsting et al, 2012; Mabon and Shackley, 2014). This suggests that the concerns publics can have about CCS-related developments being forced on them from on high may not necessarily relate to worries about exposure to immediate technical and scientific risks, but rather dissatisfaction with the process through which decisions about places meaningful to them are made. The value of process in reaching outcomes amenable to all is likewise understood as part of the basic guidelines of consensus building and alternative dispute resolution (Susskind and Crukishank, 2006). An implication of this for governance of sub-seabed CO_2 storage sites is that it should not be assumed the potential for public concern will be reduced by increasing the physical distance between storage sites and centres of population, as bigger questions about process, justice and ‘ownership’ of environments may arise (Mackinnon and Brennan, 2012).

Nonetheless, the dilemma faced by the experiment organisers – a limited number of sites with the right physical characteristics, and restrictions on time and resources to carry out public engagement activities - somewhat mirrors the conditions that will affect full-scale CCS deployment. Storage sites will initially be identified largely by geological suitability as opposed to 'social fit', and the locations of existing power stations, pipelines and associated infrastructure may constrain the flexibility of deployment. Further, whilst more deliberative processes bringing in a range of perspectives at an early stage are certainly desirable, it may be the case that decisions about renewing energy systems and mitigating climate change do ultimately have to be taken, and that some people may not be happy with these. Under such conditions, strategies for reducing the potential for opposition may include being clear from the outset about what can and cannot be achieved through participation in engagement. The QICS experiment organisers also expanded their communications strategy in response to feedback from community members, taking part in a radio interview, having a presence at a farmers' market, and feeding back initial results to the community through a free public lecture organised soon after the conclusion of the experiment.

Another related issue pertains to the framing of the experimental release, and of CCS more generally. Many publics attending the engagement events organised by SAMS – and many people posting comments to news articles – viewed the experiment as a piece of 'science' rather than a trial of energy technology. SAMS staff involved in the experiment situated the QICS release in this context of scientific endeavour:

I think there's a huge degree of confidence developing about our operation. People feel it's to their benefit so we get a lot of public support. So when we propose something we're not seen as coming from some distant planet and doing something terribly suspicious, we're probably seen *as a bunch of scientists who are wanting to achieve something new, which as a starting position is not bad!* (interview with professor, SAMS, October 2012)

[M]*ost people, whether, whether they necessarily think CCS is a good thing or a bad thing is less relevant, they're more curious to find out what we are, what results we're going to get. I mean, different people are approaching it from very different directions, but once we explain all we're doing is generating the results, analysing the results, and interpreting them, then they're actually very curious to find out what the results are going to be.* (interview with researcher, SAMS, October 2012)

The primary focus on the QICS release as a piece of scientific research – with decisions about its implications for the viability of CO_2 storage being made elsewhere – seemed to garner support from most residents and stakeholders. The emphasis on building knowledge to allow developers and policy makers to make an informed decision about CO_2 storage and CCS (the word 'evidence' appeared frequently in interview transcripts) perhaps helped to side-step the range of views within the community on whether or not full-scale CCS was a 'good thing'. Linking back to the points made in Section 3.1, additional strategies used by scientists at both the public information evening and the open day to rationalise the experiment – in many cases suggested by publics and stakeholders themselves – centered around the release as just one of many human impacts affecting the marine ecosystem of the bay, and the very small size of the experiment compared to some of these other emission sources. In particular, the samples of monitoring equipment on display at the open day, and the use of experiments with carbonated water to contextualise the scale of the release, seemed to keep to the fore this idea of QICS as a small-scale scientific endeavour.

The QICS experimental release offers some suggestions as to how to widen out the discussion on CCS. The commonly used narrative in CCS communication is one of the need for deep cuts in anthropogenic CO_2 emissions to avert dangerous climate change, with CCS being the only realistic way to deliver this in the time frame available (Mabon and Shackley, 2014). However, this is problematic for those who may never accept the anthropogenic climate change argument, and for those who may not view large-scale fossil fuel infrastructure as a fitting solution in any case. The framing of CO_2 not as a greenhouse gas but more generally as a pollutant that needs to be controlled is one possibility in this regard, and has already proven successful with the Decatur project in the USA (Ibarolla et al, 2012). Particularly with offshore projects where the marine environment is already a focus of discussion, it may be possible to couch the need to reduce the amount of atmospheric CO_2 in terms of a drive to mitigate ocean acidification – indeed, a discussion on water acidity formed part of the scientists' presentations at the release site 'open day'. A focus on building the evidence base for assessing viability of storage may also prove helpful with early projects, and could even be tied into reasons other than energy production for why CO_2 may need to be 'stored', such as emissions from industrial sources.

4. Cautions – what might the QICS release *not* tell us about CCS and society?

Whilst we have aimed above to sketch out some areas in which the QICS experimental release might contribute to the body of research on public perceptions of real-world CCS-related project, it is important to acknowledge the limitations of our findings. Although the CO_2 release did involve interaction with other activities in a populated, working marine environment, it was ultimately a small-scale scientific experiment. In addition to having a long-standing reputation for producing quality scientific research, SAMS is one of the biggest employers in the Argyll area, especially in the communities around which the release took place. About 160 people are employed locally at the organisation's Scottish Marine Institute (SAMS, 2014). Many researchers themselves live in these communities (indeed, the institute director commented at the end of the first public information meeting that his own house overlooked the bay in which the release would take place), and the familiarity of the communities with the scientists carrying out the research may have contributed to the generally high levels of support and trust. Whilst it was not possible to conduct a 'baseline' analysis of public perception before the experiment due to potential sensitivities within the community and the concern with not jeopardising the physical science research that had been planned in advance, it is true that SAMS has conducted large-scale research in the local marine environment previously. An example of this is the installation of an artificial reef system (Sayer and Wilding, 2002), hence there is already precedent for activities similar to the QICS release being carried out in the community to broad support. Whether an external developer coming in to the area without these relationships would have been able to carry out a similar piece of work is open to question.

Public support for a piece of scientific research may also not equal support for full-scale commercial CCS. A number of people did make their scepticism about CCS known during the engagement events and interviews, even if they could understand the need to generate a strong evidence base to allow decisions to be made about CO_2 storage. The extent to which findings from experimental and pilot studies like these can be transferred to projects being operated for profit by private developers thus ought to be examined further. On the other hand, comments from publics during the engagement events, and also on from other CCS social research projects (Mabon and Shackley, 2014), suggest publics do not necessarily view science as 'objective' and impartial and can be suspicious about the effects of science funding sources on results.

When applying the lessons of experiments like QICS to commercial CCS-related trials, it is also important to note potential limitations to framing CCS as 'pollution control'. Stressing the control of pollution when the key aim is still to produce electricity could be seen as an example of Schwarz and Thompson's (1990) 'stolen rhetoric', which could back-fire if publics and stakeholders already sceptical towards the development get a sense they are being lied to or told half-truths about the real purpose of CCS. As outlined earlier, the conceptualisation of CO_2 as pollution does still rely on people believing that CO_2, or pollution generally, is a problem for them.

5. Conclusions

The QICS experimental CO_2 release provided a valuable opportunity to study public and stakeholder responses to a CO_2 storage-related event taking place not on paper or in the laboratory, but in an inhabited and working environment. Of perhaps more importance than whether the local communities ultimately thought the experiment was a 'good' or 'bad' thing was building an understanding of what the factors are that drive perception of sub-seabed CO_2

storage, and also getting a sense of where the possible gaps and slippages might lie in going from a small-scale science ‘experiment’ to a large-scale commercial development.

The first main finding is that people do not enter engagement processes like these with no *a priori* knowledge of energy or environmental change. Rather, they bring with them knowledge gained from experiences of living (and sometimes working) in environments around them, learning in embodied, ad hoc and occasionally piecemeal ways. As a result, things may be mis-remembered or mis-understood in a way that leads to a very cautious stance to things like CO_2 storage, but equally these experiences can help people to contextualise and rationalise otherwise obscure and opaque ideas. In any case, all of this demonstrates the value for project operators in tapping in to analogues to more familiar processes as a means of opening up a discussion on a new and unfamiliar concept like CO_2 storage.

The second main finding relates to dealing with uncertainty. Although awareness of CCS remains low among the general public, this does not mean that people cannot quickly grasp new ideas and ask complex and in-depth questions. Some of the points raised in the information meetings and interviews by stakeholders and informed publics serve only to reiterate the idea that people do not want to be told by researchers and developers that CO_2 storage sites will *never* leak, rather that adequate procedures are in place *if* there is a leak and that sufficient attention has been given to ‘worst case’ scenarios. QICS as a whole project may have a key role to play in building such knowledge of what would happen should a sub-seabed storage site for whatever reason leak.

The third main finding concerns how and when to engage. The dilemma around early engagement for the Ardmucknish CO_2 release exemplifies well the tension between wanting to have a full, fair and open deliberation process on one hand, versus the harsh reality of needing to avoid paralysis and make decisions within a certain time frame and budget on the other. Managing expectations from an early stage, having flexibility in governance processes, and feeding back results to the community can be helpful in this regard. Although maybe excessive for a project on the scale of QICS, the ‘stage gating’ approach developed by Stilgoe et al (2013) might be useful for larger projects, bringing in publics and stakeholders at key decision points during the project planning and execution. The QICS release has also illustrated some alternative ways in which CO_2 storage can be framed (at the research and development stage at least), for example the need to create an evidence base and the concept of CO_2 as a general pollutant.

We finish with an observation on perceptions of offshore versus onshore storage. There is ample evidence in this study to call into question assumptions that offshore CO_2 storage will always be ‘easier’ from a public acceptance perspective. The marine environment can be a major source of employment and income for coastal communities like those in Argyll, so anything perceived as affecting this marine environment may be viewed as exposing coastal communities to risk – albeit risk to livelihood and valued biological diversity instead of the techno-scientific risk usually associated with onshore storage. Furthermore, a number of participants in this study used their knowledge of physical processes on land to envision what the risks of offshore storage might be, and did not always see physical distance as insulating them from problems like groundwater contamination or induced seismicity. Finally, concern over how decisions are taken about what happens in and under waters shows that publics’ place values and attachments can easily extend beyond land to include the sea and seabed. If nothing else, this social study into the QICS release has illustrated that issues of public and stakeholder perception are just as relevant to offshore CO_2 storage as to its onshore counterpart.

Acknowledgments

The research leading to these results has received funding from the European Union Seventh Framework Programme [FP7/2007-2013] under grant agreement n° 265847 - ECO_2: impacts of sub-seabed CO_2 storage on marine ecosystems. This research was possible thanks to a Memorandum of Understanding with the NERC-funded QICS project (Grant no.NE/H013962/1). The authors are especially grateful to staff at Plymouth Marine Laboratory and Scottish Association for Marine Science for allowing this social science research to take place alongside the experimental work on QICS, and to local community members and stakeholders who participated in the research.

References

Beaubien, S.E., Jones, D., Gal, F., Barkwith, A.K.A.P., Braibant, G., Baubron, J-C., Ciotoli, G., Graziani, S., Lister, T.R., Lombardi, S., Michel, K., Quattrocchi, F., Strutt, M.H., 2013. Monitoring of near-surface gas geochemistry at the Weyburn, Canada, CO_2-EOR site, 2001–2011. International Journal of Greenhouse Gas Control. 16 (Supplement 1), S236-S262.

de Best-Waldhober, M., Daamen, D., Faaij, A., 2009. Informed and uninformed public opinions on CO_2 capture and storage technologies in the Netherlands. International Journal of Greenhouse Gas Control. 3(3), 322-332.

Blackford, J., Kita, J., 2013. A novel experimental release of CO_2 in the marine environment to aid monitoring and impact assessment. Energy Procedia. 37, 3387-3393.

Blackford, J., QICS Project, 2014. QICS – Project Website. www.bgs.ac.uk/qics/, accessed 12/09/2014.

Boyd, A., Liu, Y., Stephens, J.C., Wilson, E.J., Polak, M., Peterson, T.R., Einsiedel, E., Meadowcroft, J., 2013. Controversy in technology innovation: Contrasting media and expert risk perceptions of the alleged leakage at the Weyburn carbon dioxide storage demonstration project. International Journal of Greenhouse Gas Control. 14 (Supplement 1), 259-269.

Bradbury, J.A., 2012. Public understanding of and engagement with CCS. In: The Social Dynamics of Carbon Capture and Storage (Eds. Markusson, N., Shackley, S. Evar, B.) Earthscan, London, pp. 172-188.

Brunsting, S., Mastop, J., Pol, M., Kaiser, M., Zimmer, R., Shackley, S., Mabon, L., Howell, R., 2012. SiteChar Deliverable 8.2: Trust building and raising public awareness. ECN, Amsterdam. http://www.sitechar-co2.eu/FileDownload.aspx?IdFile=590&From=Publications, accessed 15/09/2014.

Carr, W., Preston, C., Yung, L., Szerszynski, B., Keith, D., Mercer, A., 2013. Public engagement on solar radiation management and why it needs to happen now. Climatic Change. 121, 567-577.

Cass, N., Walker, G., 2009. Emotion and rationality: The characterization and evaluation of opposition to renewable energy projects. Emotion, Space and Society. 2. 62-69.

Chase, S. E., 2005. Narrative inquiry: Multiple Lenses, approaches, voices. In: The Sage Handbook of Qualitative Research (3rd edition) (Eds. Denzin, N.K., Lincoln, Y.S.), Sage, Thousand Oaks, CA, pp. 651-679.

Daamen, D., de Best-Waldhober, M., Damen, K., Faaij, A., 2006. Pseudo-opinions on CCS technologies. Paper presented at GHGT-8 (2006) Trondheim, Norway.

Doucet, A., Mauthner, N., 2008. What can be known and how? Narrated subjects and the Listening Guide. Qualitative Research. 8(3), 399-409.

Dütschke, E., 2011. What drives local public acceptance – comparing two cases from Germany. Energy Procedia. 4, 6234-6240.

ECO_2 Project, 2014. ECO_2 – Project Website. http://www.eco2-project.eu/, accessed 15/09/2014.

Eurobarometer, 2011. Special Eurobarometer 364: Eurobarometer survey on public awareness and acceptance of CCS. DG-Research, Brussels.

Gigerenzer, G., 2008. Why heuristics work. Perspectives on Psychological Science. 3(1), 20-29.

Ha-Duong, M., Gaultier, M., de Guillebon, B., 2011. Social aspects of Total's Lacq CO_2 capture, transport and storage pilot project. Energy Procedia. 4, 6263-6272.

Hollnagel, E., Woods, D.D., Leveson, N., 2006. Resilience Engineering – Concepts and Precepts. Ashgate: Aldershot.

Howell, R., Shackley, S., Mabon, L., Ashworth, P., Jeanneret, T., 2014. Engaging the public with low-carbon energy technologies: results from a Scottish large group process. Energy Policy. 66, 496-506.

Ibarolla, R., Shackley, S., Rouillard, J., 2012. EuTRACE Deliverable 1.2: Climate engineering case studies: what lessons can be learned from recent research? University of Edinburgh, Edinburgh.

Mabon, L., Shackley, S., 2014. More than meeting the targets? Exploring the ethical dimensions of carbon dioxide capture and storage. Environmental Values. Advance online version: http://www.erica.demon.co.uk/EV/papers/Mabon.pdf

Mabon, L., Shackley, S., Bower-Bir, N., 2014. Perceptions of sub-seabed carbon dioxide storage in Scotland and implications for policy: A qualitative study. Marine Policy. 45, 9-15.

MacKinnon, I., Brennan, R., 2012. Belonging to the sea. SAMS/Scottish Crofting Federation, Oban/Kyle of Lochalsh.

Malone, E.L., Dooley, J.J., Bradbury J.A., 2010. Moving from Misinformation Derived from Public Attitude Surveys on Carbon Dioxide Capture and Storage toward Realistic Stakeholder Involvement. International Journal of Greenhouse Gas Control. 4(2), 419-425.

Mayo-Ramsay, J., 2012. Environmental discourses in the ocean commons: the case of ocean fertilisation. In: Environmental Discourses in Public and International Law (Eds. Jessup, B., Rubenstein, K.), Cambridge University Press, Cambridge pp. 420-435.

Palmgren, C., Morgan, G., de Bruin, W., Keith, D., 2004. Initial Public Perceptions of Deep Geological and Oceanic Disposal of Carbon Dioxide. Environmental Science and Technology. 38 (24), 6441-6450.

Riesch, H., 2012. Levels of uncertainty. In: Essentials of Risk Theory (Eds. Roeser, S., Hillerbrand, R., Sandin, P., Peterson M.). Springer, New York pp. 29-56.

Sayer, M.D.J., Wilding, T.A., 2002. Planning, licensing, and stakeholder consultation in an artificial reef development: the Loch Linnhe reef, a case study. ICES Journal of Marine Science. 59, S178-S185.

Schwarz, M., Thompson, M., 1990. Divided We Stand: re-defining politics, technology and social choice. University of Pennsylvania Press, Philadelphia.

Scott, V., Haszeldine, R.S., Shackley, S., Gilfillan, S.M.V., Mabon, L., Johnson, G., 2014. North Sea: carbon dioxide storage is secure. Nature. 506, 34.

Scottish Association for Marine Science, 2014. About SAMS. http://www.sams.ac.uk/about-us/visiting-sams/about-the-smi, accessed 15/09/2014.

Stilgoe, J., Owen, R., McNaghten, P., 2013. Developing a framework for responsible innovation. Research Policy. 42 (9), 1568-1580.

Susskind, L., Cruikshank, J., 2006. Breaking Robert's Rules: The New Way to Run Your Meeting, Build Consensus and Get Results. Oxford University Press, New York.

Taylor, P., Stahl, H., Blackford, J., Vardy, M., Bull, J., Ackhurst, M., Haughton, C., James, R., Lichtslag, A., Long, D., Aleynik, D., Toberman, M., Naylor, M., Smith, D., Sayer, M., Widdicombe, S., Wright, I., this issue. A novel sub-seabed CO_2 release experiment informing monitoring and impact assessment for geological carbon storage. International Journal of Greenhouse Gas Control.

Terwel, B.W., ter Mors, E., Daamen, D.D.L., 2012. It’s not only about safety: Beliefs and attitudes of 811 local residents regarding a CCS project in Barendrecht. International Journal of Greenhouse Gas Control. 9, 41–51.

Upham, P., Roberts, T., 2011. Public perceptions of CCS: Emergent themes in pan-European focus groups and implications for communications. International Journal of Greenhouse Gas Control. 5 (5), 1359-1367

Wynne, B., 1992. Uncertainty and environmental learning: reconceiving science and policy in the preventative paradigm. Global Environmental Change. 2 (2), 111-127.