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Community perceptions of carbon sequestration: insights from California

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Abstract
Over the last decade, many energy experts have supported carbon sequestration as a viable technological response to climate change. Given the potential importance of sequestration in US energy policy, what might explain the views of communities that may be directly impacted by the siting of this technology? To answer this question, we conducted focus groups in two communities who were potentially pilot project sites for California's DOE-funded West Coast Regional Partnership (WESTCARB). We find that communities want a voice in defining the risks to be mitigated as well as the justice of the procedures by which the technology is implemented. We argue that a community's sense of empowerment is key to understanding its range of carbon sequestration opinions, where 'empowerment' includes the ability to mitigate community-defined risks of the technology. This sense of empowerment protects the community against the downside risk of government or corporate neglect, a risk that is rarely identified in risk assessments but that should be factored into assessment and communication strategies.

Keywords: public perceptions, carbon sequestration, community

1. Introduction

Burning fossil fuels is the largest source of energy for electricity generation in the US, and is projected to remain so until at least 2030 (EIA 2008). However, this large-scale combustion of fossil fuels presents a large-scale problem for global climate change mitigation. The US electricity sector contributes nearly one-quarter of all greenhouse gas emissions (EIA 2009). Given the growing political and social impetus for US action on climate change (NETL 2006, WESTCARB 2008), how does the US deal with the environmental challenge of fossil fuels, and in particular with coal?

The answer put forth by many policymakers, both in the USA and internationally, is 'clean coal technologies' (e.g., Parson and Keith 1998, IPCC 2005, DOE 2008b). These technologies, which include integrated gasification combined cycle, circulating fluidized bed coal combustors, and carbon sequestration, are being promoted as 'one of the most promising ways for reducing the buildup of greenhouse gases in the atmosphere' (DOE 2008a). Since 2000, the US DOE has invested heavily in the research and development of these and other energy-related technologies. As part of this effort, DOE developed seven regional research partnerships to develop technology, infrastructure, and regulations through pilot tests, including community outreach and education efforts, to implement large-scale carbon sequestration projects in different regions and geologies in the US (DOE 2006, 2007a, 2007b, 2008c).

The successful deployment of carbon sequestration will be a major endeavor that requires technical know-how, innovative regulations, financial incentives, and public acceptance. Many professionals argue that public acceptance remains one of the most challenging barriers to this technology, at least in the US (e.g. Parfomak 2008). Research shows that public opinion so far varies from slightly in favor of CCS to opposition to it, and that carbon sequestration is sometimes seen as a stalling tactic compared to addressing the 'real' issue of fossil fuel use (Palmgren *et al* 2004).

It can be argued that public opinions, and eventually acceptance, matter for two reasons. First, public acceptance of large-scale infrastructures, and their attendant costs, benefits and risks, could be considered intrinsically important in a democratic nation. Second, public acceptance could be of instrumental importance in that organized protests could slow down, increase the transactions costs of, or even block, sequestration projects. The latter is a real possibility; past projects with potentially negative environmental impacts, such as hazardous waste disposal facilities, have faced social resistance and public protest (Beierle 1999, Shively 2007, Endres 2009). Thus far, most of the research on public perceptions of carbon sequestration has focused on how the general public views the risks of this technology and on how to garner acceptance of it (de Coninck *et al* 2008, Ha-Duong *et al* 2007, Huijts *et al* 2007, Miller *et al* 2007, Palmgren *et al* 2004, Shackley *et al* 2004, Sharp 2000). However, actual deployment of carbon sequestration will directly impact not 'the public' but specific communities.

How host communities themselves understand and define the risks of being host sites remains an understudied question. Host community opinions may differ from those of the public at large because their perceptions are based on the concrete rather than the abstract, particularly when the benefits of hosting are widespread but the risks are locally concentrated. If carbon sequestration needs public acceptance, the directly impacted public is arguably the most important segment to understand and accommodate[1]. This paper asks: what do communities located near actual or potential sequestration sites view as the risks of carbon sequestration? What factors explain community perceptions of the risks of carbon sequestration?

To answer these questions, we conducted focus groups and interviews in two communities that could have been pilot project sites for California's DOE-funded West Coast Regional Partnership (WESTCARB). Pilot projects are by definition not 'real' projects, but they reveal a number of challenges and possibilities, both technological and social, that scaled-up implementation could face[2]. We chose a low-income largely Hispanic community as our first study site and compared its responses to those of a relatively well-off mainly Caucasian community.

Our research finds that communities want a voice in defining the specific risks to be mitigated as well as the justice of the procedures by which the technology is implemented. Consistent with existing work on individual risk perceptions of large-scale technologies, we found that the community-defined risks of sequestration are as much social in nature as they are technological (EPA 2008, Fischoff *et al* 1978, Freudenburg and Pastor 1992, Morgan *et al* 1992, Slovic 1987). In this literature, the social risks of technologies such as sequestration have been related, for example, to how the community is perceived by outsiders (will it be stigmatized?) or to political structures (is the risk voluntary or involuntary, and who is imposing a risk on whom?). Another risk factor cited is the 'trustworthiness' of the project information provider—people sometimes distrust safety information provided by government or companies (Rousseau *et al* 1998, Siegrist and Cvetovich 2000). Our findings extend this important work to include the risk of government and corporate neglect, meaning the risk of no compensation or damage mitigation, should the technology not perform as expected. We argue that this risk should be included in assessing the overall set of risks faced by a community when hosting any large-scale infrastructure, including carbon sequestration.

We find that while both communities were reluctant to host CCS sites a community's sense of empowerment is key to understanding its range of carbon sequestration opinions. 'Empowerment' includes (i) the ability to mitigate community-defined risks of the technology, and (ii) the ability to ensure that just procedures would be followed in implementing the technology. We argue that a community's sense of empowerment is rooted in its history and its material and social asset base. This sense of empowerment allows its members to exercise 'voice' (Hirschman 1970) and to seek redress if they think they are being harmed; it thus gives the community some protection against the downside risk of government or corporate neglect. It is the perception of this risk, more than that of technology failure associated with carbon sequestration, and that is rarely discussed in the sequestration literature, that distinguished our two study communities from each other.

In the rest of the letter, we first recount the data collection methods followed for this research. We then report and interpret our findings on each of our two questions: how communities view the risks of hosting carbon sequestration sites and what factors might explain the range of these perceptions. We highlight in particular a community's history with local industries and its experience of past environmental harm and its mitigation. Finally, we conclude with some thoughts on the implications of our findings for CCS-related risk identification and risk communication.

2. Study sites and methods

Underlying the Sacramento Basin, which spans over 60 miles from the Coast Ranges to the Sierra Nevada, and 140 miles from south of Stockton to just north of Black Butte, are the largest deposits of natural gas west of the Rocky Mountains. Although some deposits are still extractable, and a few new sites are found every year, most are depleted. Such are the formations that underlie Rio Vista and Thornton (figure 1). It is in these depleted gas fields, among other geologic formations such as deep saline aquifers and depleted oil fields, where WESTCARB planned to test carbon sequestration. WESTCARB originally selected the Thornton gas field as an appropriate test location. Before any outreach effort had begun, while WESTCARB was still in the process of negotiating with the owners of the land overlying the proposed site, an article about the Thornton site appeared in the *Los Angeles Times* (Wilson 2006). To mitigate any community concerns, WESTCARB decided to hold a town hall meeting to present the details of carbon sequestration and of the test

[1] This would hold true whether public opinions were valued for intrinsic or for instrumental reasons.

[2] It is widely accepted that pilots are necessary as trial runs for the implementation of new technologies or infrastructure. But they also offer the opportunity to test social responses to such projects. Of course, pilots cannot perfectly predict the social or the technological impacts of projects at scale.

Figure 1. Map of the locations of the two study communities, Thornton, CA and Rio Vista, CA. Thornton is located 30 miles south-east of Sacramento, California's state capital. Rio Vista is located 13 miles from Thornton. (Map of Northern California is from google.maps.com and the pictures were taken by Gabrielle Wong-Parodi in February 2007.)

project. Despite their efforts, WESTCARB could not reach an agreement with the landowners, and its cost-share partner pulled out of the project. Thornton was therefore a potential, but is not as of now an actual, project site.

We conducted three focus groups in Thornton in the spring of 2007. Thornton is an unincorporated, 'tree-lined woodsy'[3] farming community of about 1500, and is located 30 miles south-east of Sacramento, the state capital. The community is largely Latino and has low socio-economic status, where fewer than half of all adults hold a high school diploma and the median household income is \$30 469 yr^{-1} (\$1999) (The comparable median household income for all of California is \$47 493.) According to our interviewees, Thornton's legal US residents have been leaving due to a sagging local economy, while its undocumented population has been increasing with the demand for (cheap) labor in the agricultural sector. A much-cited outcome of the economic downturn is the recent closure of Thornton High School. Students now commute some 8 miles away to a high school in the larger community of Galt.

To compare Thornton's concerns with those that might be voiced by a better-off population, we also conducted two focus groups and sixteen one-on-one interviews[4] in a nearby town, Rio Vista. Rio Vista is a small tight-knit rural community of 4500. Unlike Thornton, the community is largely white, with an educated population and a median household income of \$44 534 yr^{-1} (\$1999). Also unlike Thornton, the community has experienced a period of rapid population growth: 'I think a lot of people are moving here to get away from the smog and all that hustle and bustle and stuff like that in the city' (Interview; business owner). Only 13 miles from Thornton and geologically very similar, Rio Vista had also been considered as a sequestration host site. The complicated negotiations that its numerous landowners would have required WESTCARB to go through removed it as an actual site early in the process.

In our Thornton focus groups we informed the community that they were under consideration as a pilot site, which they then were, but that no final decision had been reached. We found that, other than some of our Chamber of Commerce participants, no one knew this: our focus group members, at least, had not read the earlier *Los Angeles Times* article. In Rio Vista we informed the community that their gas fields were viable sites for geologic sequestration, and that the DOE had seriously considered them as CCS pilots. We asked our participants in both communities to imagine that they had actually been selected as a host. In both cases we made clear the small and experimental nature of WESTCARB's test injections.

Our sampling method was purposive so that the first focus group in each town comprised people of local standing, such as the Fire Chief and Chamber of Commerce members. We

[3] This was the description offered by one of the participants in our study.

[4] We did not conduct one-on-one interviews in Thornton, which, at the time of our research, was under consideration as a CCS test site. The DOE approved our focus group protocol, but did not permit individual interviews. Rio Vista had already been discounted as a CCS site; therefore no restrictions on our research activities were in effect.

wanted to ensure that these groups would welcome us, and our research agenda, in their towns. Some of these early individuals continued to act as key informants for our study. Other participants were recruited through snowball sampling—a non-probabilistic sampling method in which participants already in the study recommend other persons to be invited to participate. Considerable effort was made, through flyers and radio messages, to ensure that participants for the focus groups and interviews were demographically representative of their communities. To ensure that all participants would be comfortable in sharing their views, we kept the focus groups internally homogeneous (by standard socio-economic measures such as household income, level of education and primary language) but heterogeneous across groups (Bryman 2008)[5].

We chose focus groups as our main data collection method for two reasons. Investigating host community opinions of carbon sequestration is a relatively new area of research, and focus groups allow multiple dimensions important to participants to emerge through discussion. Because focus group participants are self-selected, their views may not represent those of the larger community and should not be treated as doing so. Rather, a series of focus group discussions reveal and clarify the range of perspectives held in the community on the focal theme; for emergent research areas this is especially valuable. Second, focus groups are an excellent way to pilot and refine surveys for any subsequent larger-scale studies (Richards and Morse 2007); we plan to conduct these in several sequestration sites in the future.

Our focus group materials were developed and piloted during the summer of 2006 in collaboration with the education and outreach teams from the Southwest Regional Partnership and the Midwest Regional Carbon Sequestration Partnership. After half of the focus groups had been conducted, we used the results from the group discussions to develop a one-on-one interview protocol. We conducted interviews so that additional views could be solicited, and to test the focus group responses for robustness[6]. The focus group instrument covered four areas: (a) community concerns overall; (b) climate change (c) carbon sequestration; and (d) alternatives to carbon sequestration. Our main interest was sequestration, but in order to help respondents to understand why sequestration was an issue at all, we embedded the sequestration questions within the context of climate change as well as other energy policy options. The interview protocol covered similar themes. Examples of questions we asked are 'Where do you think these [carbon sequestration] projects will be sited?' and 'In California we live with risk (e.g. earthquakes and flooding). Given the scale of these risks, how much does the additional risk of CCS (carbon sequestration) matter?' Each focus group comprised 6–8 participants and ran up to 3 h in length. The individual interviews ranged from 25 to 60 min depending on the time constraints of the participant. At the end of the data collection period, we organized a Town Hall style meeting in each community and shared our main observations with interested residents.

[5] Rio Vista's two focus groups comprised influential members of the town and lay community members respectively. The final town hall meeting was attended primarily by the second group. Thornton's three focus groups were composed of the influential, teachers and educators, and lay community members (documented and otherwise) who mainly spoke Spanish. The final town hall style meeting attracted a mix of the first two.

[6] Interviews were performed to assess the opinions of community members who did not choose to participate in the focus groups. These were used to validate the opinions expressed during the focus groups as being reflective of the community at large. As explained earlier, we conducted individual interviews in Rio Vista only.

3. What do host communities view as the risks of carbon sequestration?

In this section we report the range of risks with respect to hosting a CCS site that our participants expressed in the course of our discussions. As with most small-*n* qualitative studies, we use quotes from our participants to illustrate our findings. We mainly report quotes that were reflective of opinions commonly expressed during our focus groups and interviews. Across focus groups within each community (including our interview results in Rio Vista) our results were remarkably similar.

In common with several studies on the siting of infrastructure projects (Kearney and Smith 1994, Lober and Green 1994), both communities in our study were overall negatively disposed towards hosting a CCS site. This reluctance was, as we show below, partly but not wholly a result of the NIMBY[7] phenomenon (Heiman 1990, Piller 1991, Takahashi 1998). Also in common with studies cited above we found that the community-defined risks of hosting a sequestration site were both technological and social in nature. In our study, the social risks appeared to be of greater concern; indeed, the risks of the technology and the risks of being a host site appear to be quite distinct issues. The expressed risks were related to technical problems that might arise with the sequestration process as well as to procedures to be followed during project implementation.

Both communities defined technological risks as actual physical harm and linked it to their suspicion of deficiencies in the quality of expert knowledge: 'We are concerned. If we bubble up this CO_2, we cannot live in it, we cannot breathe it. What could you do? ... You (experts) do not know, we do not know' (Thornton). Participants' concern about unknown technical problems led some to fear that injection of CO_2 could result in a catastrophic leak or induced seismicity, which then could result in injury to people or things. For example, one Thornton resident said, 'It would kill people ... it is a silent gas. That is pretty scary'. Both communities also expressed doubts about either the government or companies as trustworthy sources of information, and preferred to receive information from multiple sources. Neither community felt differently about hosting a large and permanent injection project as compared to a small and temporary one; their view was that they would have 'more of a problem with it if it lasted five years. They did (DOE) go through all the disruption to get it started and it would be short term' (Rio Vista).

On the social front, participants were concerned that the (actual or imagined) technological risks of a carbon sequestration project would change the nature of the town: 'We

[7] 'Not in my back yard'. This is sometimes modified to NUMBY ('not under my back yard') for CCS (Huijts *et al* 2007).

would have to be forever vigilant' (Rio Vista). Some believed that the quality of life in the community would be adversely impacted, for example through increased traffic or reduced property values for their homes. The property value concern was especially strong in Thornton, a town that has experienced economic stress and de-population.

Participants in each community were equally interested in the procedures of sequestration site selection, deployment and redress in case of damages. During site selection, participants would want to know 'what advantages there were for (them)' (Thornton, Rio Vista). Sequestering carbon is a global public good, and most respondents argued that some local benefits such as better school buildings or new jobs were due to them if they were to serve as host sites. During and after project deployment, our respondents wanted transparency and participation: 'Thornton wants to see (what) their reports are of gas leaking, or whatever'. It was clear that information posted on the DOE website was not what the communities wanted; they wanted consultation and information at regular intervals. Finally, if something should go wrong with the project, residents wanted to know: 'is not there some law or something that says they have to explain or inform . . . (and) is there something that we can respond to?' (Thornton).

Although just implementation procedures such as the granting of local benefits and transparency were important to both communities, our interviews revealed that residents of Thornton did not expect to have voice or redress during the lifetime of a project, while most Rio Vista residents did. Although both communities had similar concerns about the technological risks of carbon sequestration, they did not have similar perceptions of the social risks of hosting a site. Thornton residents displayed resignation and powerlessness: 'Because they say right here that they are going to test, right? They are going to do it. So you do not think that regardless of what we say it is going to happen? It is going to happen' (Thornton). This community, whose material and social assets were relatively low, was convinced that it would be unable to exercise voice or have recourse to mitigation in case of future harms. They somewhat feared the risks of sequestration per se, but feared even more the risk of being neglected or ignored if the sequestration project turned out to be more harmful than currently expected.

In contrast, Rio Vista residents believed in their power of voice and redress. For example, one resident said '(if carbon sequestration proponents) were to come to Rio Vista and *shove* their way in here, we would shove them right back out'. Another person, during the final town hall meeting, told us: 'we will keep watching. We know what to do if we do not like what's going on; there are people of influence here in this room'.

Thus we found Thornton to be more concerned than the relatively well-endowed Rio Vista when it came to hosting the technology. Many residents were strongly opposed to it; during one discussion, a teacher's aide was particularly angry about the (then-planned) Thornton project and about everything else that gets 'pulled over' poor people. Another participant noted that most of the pilot projects were taking place in rural but populated locations: 'Why are not they doing this in the desert where they cannot hurt nobody. Why is it here?'[8] Another chimed in saying that these projects were likely to be placed in mostly poor and Latino communities. Overall, there was considerable anger at being close to selection as a sequestration site without any degree of consultation, and at what was seen as yet another marker of their low status.

Although hardly enthusiastic about hosting a project, the residents of Rio Vista were more mixed in their responses. Every participant was unwilling to see his or her town as a host site but few were as hostile as their Thornton counterparts. The community's confidence that it would be able to arrange some local benefits and maintain some oversight made at least some members more open to the idea. One retiree said, 'If I am assured that this is a safe technology then I do not have a problem with it'. Others cited possible benefits such as job creation and 'royalties to the City from mineral deeds'. Rio Vista citizens were generally more aware of climate change than Thornton citizens, and were also aware that some action to halt climate change was necessary. This knowledge had little impact on their willingness to host; they would only consider hosting a site if their local economy saw direct benefits (e.g. royalties) and the local community could exercise some control ('we will keep watching'). No such expectations were raised in Thornton, where residents are pre-occupied with life's basic necessities: 'I think survival is most important. Yeah, absolutely, I think trying to survive on a day-to-day basis'.

Our research suggests that the degree to which being a host community is considered risky is significantly influenced by a community's sense of *empowerment*, or the degree to which a host community believes that it has the power to control its own future. Empowerment partly stems from the community's ability to exercise voice and have recourse to compensation or damage mitigation, as well as its belief in that ability. In this study this sense of empowerment was correlated with a community's affluence, education, connections to the outside world and cohesion as a community. The perceived risk of being a host site is also, as we found, a function of previous histories of environmental damage, its mitigation or lack thereof, and the role of industries in the community. These histories are themselves partly determined by a community's capital endowments. In section 4, we present three examples of our study communities' experiences with industrial harm, environmental harm, and the natural gas industry. These experiences, which were recounted in detail, with mention of specific dates and specific episodes, reinforced a community's sense of empowerment or disempowerment.

4. What factors explain community perceptions of carbon sequestration risks?

4.1. Experience with industrial harm

In general, Thornton's experience with industry-caused environmental damage has been negative. One example of

[8] As one of our anonymous reviewers pointed out, this is an excellent question. In California, depleted oil and gas reservoirs or deep saline aquifers are considered appropriate sites for carbon sequestration. Many of these reservoirs are close to human populations. Why WESTCARB chose or did not choose a particular site was, however, not a focus of our research.

this is water contamination by the (now defunct) Tri-Valley Growers cannery. For a number of years, many residents had suspected that the cannery was polluting their drinking water; these fears were confirmed when tests by the Regional Water Quality Control Board showed that dangerous levels of lead had seeped into the groundwater via the cannery's underground storage units. But before the community could demand abatement or reparations, the company filed for bankruptcy. Today, poor water quality still plagues the community. Many residents cited this and similar examples to explain why a carbon sequestration project, whatever the community felt about it, would go ahead anyway. They all seemed sure that if something were to go wrong during deployment, any demands for recourse would go unheard.

Rio Vista, too, has had negative experiences with industry. However, the community has also had some successes that have bolstered its sense of empowerment. In 1975 DOW Chemical started to build a $500 million petrochemical complex along the Sacramento River near the town, but later dropped the project. Members of the community attributed the failed attempt by DOW Chemical to their protests at not being sufficiently involved, and not to the political 'red tape' cited by DOW (Stammer 1977). Whatever the actual sequence of events, Rio Vista residents felt that they had collectively exercised their voice and that it had been heard. With respect to hosting a sequestration project, a significant segment, while somewhat resistant, nevertheless possessed the confidence that, if necessary, they could act collectively again.

4.2. Experience with environmental harm

Thornton's most pressing environmental problem in the eyes of the community was its poor water quality. The drinking water was allegedly so poor that you could not only taste it, you could also see it: 'If you live over here in the housing where the water drips, it stains the sink brown. Yeah, just yesterday it was coming out brown'. Many in the community were unhappy with their water, and wanted to see improvements. However, the community felt that their voice was not heard nor their fears understood, and therefore insufficient or inappropriate solutions were offered:

> 'I have gone to some of the town meetings where they have (discussions) about this water thing that they say they come out and clean it out every so often. But, I do not think they do . . . I do not think they do it as often as they should . . . A lot of people cannot afford to buy (water treatment) equipment for their house' (Thornton).

The community's failure to get its water cleaned up, even after repeated efforts, clearly contributed to the overall sense of disempowerment. As their experience with the cannery had also shown, they could not trust their local governments or any other entity to help with damage mitigation.

Neighboring Rio Vista also suffered in the recent past from water contamination; their effort for remediation, however, has largely been successful and their water quality has improved. For example, in response to the community's ongoing concern about poor water quality, the city of Rio Vista is planning on developing its own hazardous waste program to identify sources of contamination and possible solutions. Our discussions showed that Rio Vista residents could call upon their collective social and economic capital to organize against perceived environmental harms and to ensure a degree of redress and accountability from the relevant authorities. They did not share Thornton's feeling of powerlessness, and so did not share Thornton's perceived risk of official neglect should 'the gas project leak or something'.

4.3. Experience with the natural gas industry

Both Thornton and Rio Vista were built up on natural gas fields. Thornton's view of the natural gas industry can best be described as one of indifference. Not many people in the community directly benefited from the gas industry; only a few people hold mineral rights and most of those no longer live in the community. Furthermore, because Thornton is unincorporated, any tax revenues generated from gas extraction royalties went to San Joaquin County and not to the community itself. To many in Thornton, the benefits from a carbon sequestration project were tied to those few who owned mineral rights or land. Hosting the technology was seen as imposing a burden on, but not benefiting, the community as a whole.

Rio Vista had a markedly different relationship with the natural gas industry. Natural gas production was one of the largest sources of town revenue, and several hundred people in town owned land or mineral rights. The discovery of gas deposits and milestones in gas production are prominently featured in the tiny, well-maintained Rio Vista Museum. The industry has had a tremendous influence on the social and cultural makeup of the community (e.g. '. . . most people here get mineral income, which justifies a lot of things'). To many residents of Rio Vista, hosting a carbon sequestration project was seen as imposing a modest burden, but also as a potential financial opportunity for the whole town. Our interviewees admitted that some in the community had benefited enormously from the natural gas industry, but felt that the broader community had shared in those benefits. In short, 'We know them here. We trust them. Let them put the carbon dioxide in the ground. That's a good thing, is not it? I mean, it's not a bad thing, is it?'

5. Discussion

Consistent with previous research on risk perceptions, we found community-defined risks could be both technological and social in nature. Both communities were concerned that inadequate knowledge of carbon sequestration could lead to mistakes during the injection of CO_2. Most of these technology related concerns echoed those reported by other studies on sequestration and the public (e.g. Palmgren *et al* 2004, Sharp 2000). Both communities feared that neither the government nor companies could be trusted as the sole source of safety-related information (e.g. Siegrist and Cvetovich 2000).

Social risks centered on the implications of hosting the technology and the procedures to be followed during project implementation. Common concerns were how the presence of the technology would affect the character of the community

and property values. Just procedures were important to both communities and included local benefits such as jobs or compensation, upgrading school buildings, and a measure of transparency and community participation. But our focus groups revealed that residents of Thornton did not expect to have voice or redress during the lifetime of a project, while Rio Vista residents did. This difference—the downside risk of government or corporate neglect should something go wrong with the technology deployment—is what distinguished the two communities from each other. It can plausibly be argued that softer responses are to be expected when the project in question is hypothetical (Rio Vista) rather than imminent (Thornton). But our research reveals that this risk is related not just to the likelihood of a project in a community's backyard, but to the community's social and material assets, its history and its ensuing sense of empowerment.

The risk of neglect should something go wrong, and the correlation of this risk with a community's past history and experiences with industry, has not been adequately addressed in the literatures on the risks of sequestration or risk communication. But this finding is consistent with Bradbury *et al* (1994) who concluded that individuals evaluate the risks of a technology not with respect to the specific technology but in light of their life histories; and it is consistent with sociological studies arguing that risk perceptions are as tied to broader worldviews and beliefs as they are to actual risks (Freudenburg and Pastor 1992). It also supports arguments in the procedural justice literature that the fairness of the process is central to the legitimacy of the outcome (e.g. Thibaut and Walker 1975, Lind and Tyler 1988, Senier *et al* 2008).

We argue that a community's sense of empowerment, defined as its ability to exercise voice and to seek redress, acts as protection against the downside risk of neglect. To the extent that our communities are representative of other possible sequestration sites, our research suggests that communities that already feel disempowered are likely to resist hosting a site in part because they fear neglect ('. . . they say they come out and clean it out . . . but I do not think they do') and they fear that having a site thrust upon them only cements their low social standing ('why is it here?'). Yet Thornton also knew that any resistance to a potential site would not be effective, that they would have to accept it if they were chosen ('. . . you do not think that regardless of what we say it is going to happen?'). What then, are the implications of our findings for gaining community acceptance of carbon sequestration?

If policy experts assume, as they still often do, that technical risks and inadequate risk communication are the main barriers to public acceptance, they could find themselves reassuring communities on the wrong front entirely. If policy implementers consult only landowners or office bearers in a community—as was the case when Thornton was under consideration as a sequestration site—the broader community and its set of concerns will remain invisible. Such an approach loses the opportunity to make the terms of technology deployment more inclusive. This acceptance this approach leads to can best be described as passive, mainly reflecting the lack of community information, engagement or organized protest. This is the sort of acceptance that the residents of Thornton were ready to bestow on a CCS site.

An alternative approach would be to seek a more active form of acceptance: to consult a range of local stakeholders throughout the site selection process, so that a grounded understanding of risks, concerns and mitigation options can emerge. However, while lauded in theory (Beierle 1999, Chess and Purcell 1999) and in official policy documents (Bradbury *et al* 1994, National Academies Press 2008), this approach is often avoided because it carries the risk of prolonged negotiation or outright rejection of the proposed technology. Of course, the timing and level of community engagement are always open to debate. It is unclear which forms of participation work best, there are no guarantees of acceptance even with early consultation (e.g. Chess and Purcell 1999), and consultation is more expensive than hierarchical decision-making. Nevertheless our research supports Morgan *et al* (1992) in suggesting that open-ended engagement remains the best way to identify the diverse concerns of the intended hosts.

Our conclusions from this research are preliminary; while they do provide insights into community perceptions of the risks of sequestration, they are best viewed as guides to better research on risk perceptions with respect to the siting of any energy (or other large-scale) infrastructures. We believe that they can usefully inform future efforts at risk identification and communication, which previous studies have highlighted as critical to acceptance: we have to understand what each community views as its greatest risks before we know which ones to allay or communicate about.

Our particular findings relate the social risks of hosting climate change mitigation technologies to perceived levels of community empowerment and to the history of community–industry relations. Before attempts are made at public outreach and education in the service of carbon sequestration, it is crucial to understand that there are several 'publics', and that their risk perceptions are specific to their histories and their sense of empowerment. A risk assessment grounded in community perceptions could identify factors (such as the sense of empowerment) that are not identified in conventional risk assessments but should be included in risk assessment, communication and mitigation strategies.

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References

Beierle T C 1999 Using social goals to evaluate public participation in environmental decisions *Policy Stud. Rev.* **16** 75–103

Bradbury J A, Branch K, Heerwagen J and Liebow E 1994 *Community Viewpoints of the Chemical Stockpile Disposal Program: Tooele Army Depot Site Report* (Washington, DC: Battelle Pacific Northwest Laboratories)

Bryman A 2008 *Social Research Methods* (New York: Oxford University Press) p 608

Chess C and Purcell K 1999 Public participation and the environments: do we know what works? *Environ. Sci. Technol.* **33** 2685–92

de Coninck H, Flach T, Curnow P, Richardson P, Anderson J, Shackley S, Sigurthorsson G and Reiner D 2008 The acceptability of CO_2 capture and storage (CCS) in Europe: an assessment of the key determining factors: part 1. Scientific, technical and economic dimensions *Int. J. Greenhouse Gas Control* **3** 333–43

Department of Energy 2006 Sequestration test to demonstrate carbon dioxide storage while increasing oil production Accessed May 26, 2008 http://www.fossil.energy.gov/news/techlines/2006/06037-Carbon_Storage_Test_Begins.html

Department of Energy 2007a DOE awards first three large-scale carbon sequestration projects Accessed on May 26, 2008 http://www.fossil.energy.gov/news/techlines/2007/07072-DOE_Awards_Sequestration_Projects.html

Department of Energy 2007b Energy department awards $66.7 million for large-scale carbon sequestration project Accessed on May 26, 2008 http://www.fossil.energy.gov/news/techlines/2007/07084-Illinois_Basin_Sequestration_Proje.html

Department of Energy 2008a Carbon sequestration Accessed on May 26, 2008 http://fossil.energy.gov/sequestration/

Department of Energy 2008b Clean coal technology and the President's clean coal power initiative Accessed on May 26, 2008 http://www.fossil.energy.gov/programs/powersystems/cleancoal/

Department of Energy 2008c DOE awards $126.6 million for two more large-scale carbon sequestration projects Accessed on May 26, 2008 http://www.fossil.energy.gov/news/techlines/2008/08012-DOE_Funds_Large-Scale_Projects.html

Endres D 2009 Science and public participation: an analysis of public scientific argument in the yucca mountain controversy *Environ. Commun.: J. Nat. Cult.* **3** 49–75

Energy Information Administration 2008 *International Energy Outlook 2008, Report Number: DOE/EIA-0-484(2008)* (Washington, DC: Department of Energy)

Energy Information Administration 2009 *International Energy Outlook 2009, Report Number: DOE/EIA-0484(2009)* (Washington, DC: Energy Information Administration) chapter 8 (Energy-Related Carbon Dioxide Emissions)

Fischoff B, Slovic P, Lichtenstein S, Read S and Combs B 1978 How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits *Policy Sci.* **9** 127–52

Freudenburg W R and Pastor S K 1992 Public responses to technological risks: toward a sociological perspective *Sociol. Q.* **33** 389–412

Ha-Duong M, Nadai A and Campos A S 2007 A survey on the public perception of CCS in France *Working Papers, Centre International de Recherche sur l'Environnement et le Développement. Report Number: halshs-00200894_v1, HAL*

Heiman M 1990 From 'Not in My Backyard!' to 'Not in Anyone's Backyard!' *J. Am. Plan. Assoc.* **56** 359–63

Hirschman A 1970 *Exit, Voice, and Loyalty: Responses to Decline in Firms, Organizations and States* (Cambridge, MA: Harvard University Press)

Huijts N M A, Midden C J H and Meijnders A L 2007 Social acceptance of carbon dioxide storage *Energy Policy* **35** 2780–9

IPCC 2005 Summary for policymakers carbon dioxide capture and storage *A Special Report of Working Group III of the Intergovernmental Panel on Climate Change* ed B Metz, O Davidson, H de Coninck, M Loos and L Meyer (Cambridge: Cambridge University Press)

Kearney R C and Smith A A 1994 The low-level radioactive waste siting process in connecticut: anatomy of a failure *Policy Stud. J.* **22** 617–31

Lind E A and Tyler T R 1988 *The Social Psychology of Procedural Justice* (New York: Plenum) p 284

Lober D J and Green D P 1994 NIMBY or NIABY: a logit model of opposition to solid-waste-disposal facility siting *J. Environ. Manage.* **49** 141–61

Miller E, Bell L and Buys L 2007 Public understanding of carbon sequestration in australia: socio-demographic predictors of knowledge, engagement and trust *Aust. J. Emerg. Technol. Soc.* **5** 15–33

Morgan M G, Baruch Fischoff, Ann Bostrom, Lave L and Atman C J 1992 Communicating risk to the public *Environ. Sci. Technol.* **26** 2048–56

National Academies Press 2008 *Public Participation in Environmental Assessment and Decision Making* (Washington, DC: National Academies Press) p 322

National Energy Technology Laboratory 2006 Carbon sequestration: regional partnerships Accessed on December 6, 2006 http://www.netl.DOE.gov/technologies/carbon_seq/partnerships/partnerships.html

Palmgren C R, Morgan M G, Bruin W B d and Keith D W 2004 Initial public perceptions of deep geological and oceanic disposal of carbon dioxide *Environ. Sci. Technol.* **38** 6441–50

Parfomak P W 2008 Community acceptance of carbon capture and sequestration infrastructure: siting challenges. *Congress. Res. Serv. DC Report Number: 31* Washington

Parson E A and Keith D W 1998 Fossil fuels without CO_2 emissions *Science* **282** 1053–4

Piller C 1991 *The Fail-Safe Society: Community Defiance and the End of American Technological Optimism* (New York: Basic)

Richards L and Morse J M 2007 *README First for a User's Guide to Qualitative Methods* (Thousand Oaks, CA: Sage Publications)

Rousseau D M, Sitkin S B, Burt R S and Camerer C 1998 Introduction to special topic forum: not so different after all: a cross-discipline view of trust *Acad. Manage. Rev.* **23** 393–404

Senier L, Hudson B, Fort S, Hoover E, Tillson R and Brown P 2008 Brown superfund basic research program: a multistakeholder partnership addresses real-world problems in contaminated communities *Environ. Sci. Technol.* **42** 4655–62

Shackley S, McLaclan C and Gough C 2004 The public perceptions of carbon capture and storage *Working Paper, Tyndell Centere for Climate Change Research Report Number: 44* Norwich, UK

Sharp J 2000 Public attitudes toward Geological disposal of carbon dioxide in Canada *Masters Thesis* School of Resource Management, Queen's University Kingston, Ontario 148 pp

Shively C 2007 Siting geologic sequestration: problems and prospects *Carbon Capture and Sequestration: Integrating Technology, Monitoring and Regulation* ed E J Wilson and D Gerard (Ames, IA: Blackwell) pp 223–42

Siegrist M and Cvetovich G 2000 Perception of hazards: the role of social trust and knowledge *Risk Anal.* **20** 713–9

Slovic P 1987 Perception of risk *Science* **236** 280–5

Stammer L 1977 DOW Blames Environmental Red Tape: $10 Million Spent, Industrial Plan Dies *Los Angeles Times* Los Angeles. B1

Takahashi L M 1998 *Homelessness, AIDS, and Stigmatization: The NIMBY Syndrome in the United States at the End of the Twentieth Century* (Oxford: Clarendon)

Thibaut J and Walker L 1975 *Procedural justice: A Psychological Analysis* (New York: Halsted Press Division of Wiley) p 150

US Environmental Protection Agency 2008 Vulnerability evaluation framework for geologic sequestration of carbon dioxide *Technical Support Document: EPA430-R-08-009* July 10, 2008

West Coast Regional Carbon Sequestration Partnership 2008 Public Outreach. Accessed on May 26, 2008 http://www.westcarb.org/outreach.htm

Wilson E 2006 Team hopes to drill its way to global warming solution; experiment would keep carbon dioxide out of the atmosphere by injecting it deep under the Central Valley *Los Angeles Times* Los Angeles. California Metro; Part B; Metro Desk. B1