

# But They Told Us It Was Safe! Carbon Dioxide Removal, Fracking, and Ripple Effects in Risk Perceptions

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Reaching net-zero for global greenhouse gas emissions by the year 2050 will require a portfolio of new technologies and approaches, potentially requiring direct removal and sequestration of atmospheric carbon dioxide using negative emissions technologies (NETs). Since energy and climate systems are fundamentally interconnected it is important that we understand the impacts of policy decisions and their associated controversies in other related technologies and sectors. Using a secondary analysis of data from a series of deliberative workshops conducted with lay publics in the United Kingdom, we suggest that perceptions of CO<sub>2</sub> removal technologies were negatively impacted by risk perceptions and recent policy decisions surrounding shale gas and fracking. Using the social amplification of risk framework, we argue that heightened risk perceptions have extended via “ripple effects” across these technologies. Participants’ attitudes were underpinned by deeper misgivings regarding the actions and motives of experts and policymakers; a pervasive discourse of “but they told us it was safe” regarding fracking negatively affected people’s trust in assurances of the safety and efficacy of CO<sub>2</sub> removal. This has the potential to undermine attempts to build societal agreement around future deployment of CO<sub>2</sub> removal technologies.

**KEY WORDS:** Carbon capture and storage; climate change; greenhouse gas removal; negative emissions technologies; risk amplification; shale gas

## 1. INTRODUCTION

Meeting global climate change mitigation targets, as enshrined in the 2015 Paris Climate Agreement, will require a broad portfolio of technologies capable of meeting energy demand while reducing emissions. This portfolio will almost certainly require capturing emissions from energy and industrial production using carbon capture and storage (CCS), as well as removing some previously emitted carbon dioxide from the atmosphere (National Academies of Sciences, Engineering and Medicine, 2019). CO<sub>2</sub> removal refers to any technique that can *remove and sequester* CO<sub>2</sub> directly from the atmosphere,

as opposed to conventional mitigation that *reduces* the amount of CO<sub>2</sub> emitted into the atmosphere. CO<sub>2</sub> removal techniques are many and varied, and include established practices such as planting trees, “nature-based” solutions such as restoring peatlands, and novel “engineered” techniques including bioenergy with carbon capture and storage (BECCS) and direct capture of CO<sub>2</sub> from the air. The difficulty of fully decarbonizing certain sectors means that adoption of CO<sub>2</sub> removal at scale, alongside early and stringent emissions reduction, may be required to limit the catastrophic impacts of climate change (Royal Society & RAEng, 2018). For example, projections indicate that in order to meet its target of net zero emissions, the United Kingdom will require the removal of 90 million tonnes of CO<sub>2</sub> from the atmosphere every year by 2050 (Committee on Climate Change, 2019). However, such technologies

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and proposals do not exist in isolation; energy and other industrial systems are fundamentally interconnected, and it is therefore important to understand the impacts that policies and interventions in one part of the system may have elsewhere.

Research has also emphasized the importance of attending to public attitudes, because these will be a fundamental component of any effective, timely, and ethical low-carbon transition (Boudet, 2019; Fiorino, 1990). Indeed, establishing a “social license to operate” has been a key challenge for CCS in much of Europe (Gough, Cunningham, & Mander, 2018), and in Section 1.2 we discuss public opposition to shale oil and gas extraction (or “fracking”), which has created severe delays and cost overruns across much of Europe. Significant research has gone into understanding public attitudes to and perception of the risks from fracking, and how these might be influenced by various events, including policy actions and how they are perceived (Thomas, Pidgeon et al., 2017). Adopting a whole-systems approach, we use this case to suggest that policy decisions in one area can have significant secondary knock-on or “ripple” effects on attitudes to seemingly dissimilar technologies, potentially creating public acceptability constraints across multiple sectors, which could jeopardize attempts to adequately mitigate climate change.

The purpose of this article is to discuss the possibility that negative public attitudes to fracking may have impacted public perceptions of other technologies, using a secondary analysis of transcripts from a series of public deliberative workshops on technologies for CO<sub>2</sub> removal. These workshops were originally intended to explore public perceptions of CO<sub>2</sub> removal via three negative emissions technologies, and the analysis of that research question is covered in detail in Cox, Spence and Pidgeon (2020). However, qualitative transcripts sometimes yield interesting insights, which are not what the researchers were originally looking for, in addition to the original research question; thus secondary analysis of transcripts can contribute to literatures beyond the field of the previous research (Henwood, Pidgeon, & Parkhill, 2014; Hinds, Vogel, & Clarke-Steffen, 1997; McLaren, Parkhill, Corner, Vaughan, & Pidgeon, 2016). Importantly, our qualitative deliberative approach allows us to explore in depth *why* certain patterns might have emerged, using an in-depth discourse analysis of relevant passages within the workshop transcripts. The following section introduces the theoretical literature on processes of “social amplification of risk,” showing that ripple ef-

fects to other technologies have been relatively underexplored in the empirical literature.

### 1.1. Social Amplification and Secondary Ripple Effects

Secondary effects on public attitudes have been examined in the literature on the social amplification of risk, a conceptual framework first proposed by Kasperson et al. (1988). That paper noted that publics sometimes display strong reactions to relatively minor risks as judged by experts, for instance during the Three Mile Island nuclear accident, which harmed few people but which had an enormous impact on risk perceptions of nuclear power. Risk amplification leads to behavioral responses, which in turn create second- and third-order impacts such as enduring mental images and perceptions, political and social pressure, impacts on businesses, increased liability and costs, and repercussions on other risk issues and technologies. In this way, the impacts “ripple” out to other parties and places not initially involved. Direct impacts need not be large to trigger huge indirect effects; for example, the Tylenol controversy in 1982 only killed seven people, but inflicted losses of more than \$1.4 billion on the company responsible (Kasperson, Kasperson, Pidgeon, & Slovic, 2003). In another example, Barnett, Menighetti, and Prete (1992) report a one-third decline (albeit temporary) in the use of the DC-10 airliner for domestic U.S. flights following a serious and heavily publicized crash of this type of aircraft at Sioux City, Iowa in 1989. The nature of the risk is also important: ripple effects may be much smaller if the risk is associated with a familiar system such as rail transport (Chilton et al., 2002), as opposed to an unfamiliar one such as a nuclear waste store or a lab (Slovic & Weber, 2002).

The original amplification framework article (Kasperson et al., 1988) hypothesized four major pathways or mechanisms that bear upon the secondary stage of risk amplification: heuristics and values, social-group relationships, signal value, and finally stigmatization. High or growing social distrust of risk-managing institutions, and in particular of policymakers, is now realized to be a fifth pathway (Frewer, 2003; Wirz et al., 2018). In conceptual terms Renn and Levine (1991) argue that trust has a number of core determinants: competence (appropriate technical expertise); objectivity (messages free from bias); fairness (all points of view acknowledged); consistency (of statements and behavior); and faith (a perception of good will). Trust could operate in

relation to ripple effects in one of several ways. First, and most directly, in light of an accident or other prominent risk signal the immediate blame may well, rightly or wrongly, be placed with regulatory institutions, who as a result become distrusted (Hood & Jones, 1996). Risk perceptions might then be amplified in other issues and sites that the distrusted organization(s) are responsible for. The extent to which different technologies share (or are thought to share) the same risk governing institutions and policy processes therefore brings a potential for secondary amplification across technologies under such a scenario. Second, in an inverse of this relationship, we know that risk perceptions and distrust can themselves be strongly driven by our more fundamental negative emotional responses, or affect, toward an issue (Poortinga & Pidgeon, 2005; Slovic, 2010). Hence, if we have a prior strong negative response toward something we are unlikely to trust those who manage it, whatever the evidence to the contrary. If such negative associations from one technology transfer across to associated technologies, these might thereby engender both distrust and secondary ripples of risk amplification. Other research notes the important role of traditional and social media in risk amplification (Ng, Yang, & Vishwanath, 2018), the importance of power and agency in risk controversies (Pidgeon, Simmons, & Henwood, 2006), and the importance of procedural dynamics: concerns tend to escalate when information about potential hazards is kept secret, when citizens are not allowed to participate, and when the experts are seen as “too close” to the project (Graham, Rupp, & Schenk, 2015; Lofstedt, 2015). Process-based factors have shown themselves to be crucial in the case of energy and infrastructure projects. Perceptions of procedural justice—that is, that individuals have equitable access to decision-making processes—may even be more important for shaping public perceptions than the actual costs and benefits (Boudet, 2019; Cotton, 2013; Evensen & Stedman, 2017).

There is now extensive empirical evidence demonstrating secondary social amplification of risk within a number of technology sectors and risk issues, and exploring the roles of various actors (Kasperson & Kasperson, 2005; Pidgeon, Kasperson, & Slovic, 2003). Yet there is very little empirical work exploring “ripple effects” *across* issues, sectors, and technologies. What solid evidence there is on the latter comes from studies on novel food technologies. We know that people make use of past associations and analogies to previous risks to make

sense of and interpret new or unfamiliar technological risk issues (Pidgeon et al., 2012; Visschers, Meertens, Passchier, & DeVries, 2007). Work on perceptions of genetically modified food (GM) during the “crisis” in Europe in the late 1990s showed how concerns about the then recent BSE (mad cow disease) disaster was a familiar association raised in focus group discussions of GM agriculture risk. Concerns about the safety of industrialized food production, messing with nature, and a perceived lack of regulatory honesty and transparency in the BSE case all combined to fuel public concerns about GM agriculture (Marris, 2001). More recently, evidence has emerged to show how attitudes toward food applications of nanotechnology (atomic-scale science and engineering) might have been impacted by people’s views on GM food (Ho et al., 2020), although as a technology category more generally nanotechnology seems not to suffer from major social amplification effects in public perceptions (Pidgeon, Harthorn, Bryant, & Rogers-Hayden, 2009; Satterfield, Kandlikar, Beaudrie, Conti, & Herr Harthorn, 2009). It seems that shared category associations (in this case “food technology”) are driving perceptions across the two rather different technology approaches (Visschers et al., 2007).

Importantly, such ripple effects are often overlooked in policy making, which as this article seeks to argue can have damaging consequences where systems and issues are highly interconnected. We demonstrate this using data from a U.K. study on public perceptions of carbon dioxide removal, during which risk perceptions relating to three major CO<sub>2</sub> removal proposals stemmed from participants’ unprompted discussions about unconventional oil and gas (“fracking”), and the policies for promoting it. The following section describes fracking and public attitudes toward it, in particular the stigmatization that appears to have occurred in the minds of the U.K. public, and the social amplification of fracking risk perceptions. However, this literature tends to focus on fracking in isolation from other technologies, with much less research on ripple effects to other technologies and sectors.

## 1.2. Fracking, Risk Amplification and Stigmatization

Shale oil and gas are unconventional hydrocarbons found in low-permeability rocks, which can be extracted by hydraulic fracturing or “fracking.” Fracking typically involves injecting water, sand, and

chemicals under high pressure into a bedrock formation; this creates fractures in the rock which allows the hydrocarbons to be extracted (US Geological Survey, 2019). Fracking in Europe has had a tumultuous journey, with public opposition leading to restrictions or bans on licensing activity in many European countries (Van de Graaf, Haesebrouck, & Debaere, 2018). In the United Kingdom, opposition has increased over time, in line with the "stigmatization" effect noted in the social amplification of risk framework (Bradshaw & Waite, 2017; Flynn, Slovic and Kunreuther, 2001; Thomson, 2015), with a recent survey finding that 56% of the U.K. public are opposed to fracking, compared to 32% who support (Evensen, Devine-Wright, & Whitmarsh, 2019). Deliberative research finds that U.K. publics perceive fracking as very risky, especially regarding effects on drinking water and habitability, and that any benefits are perceived to be inequitably distributed (Thomas, Partridge, Harthorn, & Pidgeon, 2017). Yet, for successive administrations, the U.K. government signaled strong political support for fracking, which was increasingly at odds with growing public opposition (Bradshaw & Waite, 2017). Continued attempts by central government to develop the U.K. shale industry contributed toward growing public distrust (Gough et al., 2018; Williams, Macnaghten, Davies, & Curtis, 2017). In November 2019 the U.K. government unexpectedly issued a moratorium on fracking (Department for Business, Energy and Industrial Strategy, 2019), a decision that was widely seen as politically opportune following years of public opposition and protests. The data collection and analysis for this article was carried out before the fracking moratorium was issued, in a context of strong political support for fracking.

Previous research has demonstrated that risk amplification has been important for perceptions of fracking, particularly in North America and the United Kingdom where the concept evokes a powerful, amplified "signature" of risk (Bharadwaj & Goldstein, 2015; Harthorn et al., 2019; Thomas, Pidgeon et al., 2017). Graham et al. (2015) note that fracking is vulnerable to risk amplification because its potential hazards can trigger a variety of factors that are known to elevate risk perceptions, including unfamiliarity, involuntary exposure, and lack of personal control over risk. Fracking also raises all of the sensitive questions of procedural and distributional equity, as well as potential distrust of the motives of powerful outside actors and organizations, that we know from other issues can lead to

intense risk siting controversies (e.g., Kunreuther, Fitzgerald, & Aarts, 1993; Pidgeon & Demski, 2012). One of the main public concerns around fracking is contamination of drinking water (Thomas, Partridge et al., 2017), which gives it a high "dread" factor (Thomson, 2015), shown to be instrumental in nuclear and other risk perceptions (Slovic, 1987). A cross-national study in the United States and the United Kingdom found that the concept of fracking evokes for people multiple high-risk, high-salience perceived hazards relating to seismicity and water supply, which has resulted in "intensification" of risk perceptions (Harthorn et al., 2019: 51). Risk amplification has been a common feature of the fracking debate in some states of the United States, partly because of a failure on the part of policymakers and industry to address public concerns directly, combined with selective and sensational reporting of risks in the media (Thomson, 2015). In the United Kingdom, communities in Lancashire at the center of a controversy over exploratory drilling were found to have experienced a breach of trust between them and local government, negatively impacting their perceptions of fracking and also of analogous CCS technology (Gough et al., 2018). That study remains (to our knowledge) the only existing examination of the cross-cutting impacts of fracking on other technologies, although it did not directly address risk amplification effects. This article does not aim to reiterate the process of risk amplification and stigmatization of fracking, but rather focuses on the second- and third-order impacts of this onto other publics, sectors, and technologies.

## 2. METHODS

The data for this study come from a secondary analysis of transcripts from a series of deliberative workshops, which were designed to interrogate public attitudes to carbon dioxide removal, conducted in locations in England and Wales in September–November 2018. These technologies bear little relation to fracking, except that both have been positioned as key technologies in relation to climate change, and some CO<sub>2</sub> removal proposals require CCS which includes a subsoil component (cf. Partridge, Thomas, Pidgeon, & Harthorn, 2019). We conducted four workshops in three locations: two in Cardiff (a large diverse capital city), one in Norwich (a small university city), and one in rural

Norfolk (an arable agricultural area).<sup>1</sup> Previous work has found differences in public perceptions between rural and urban populations (Boudet, 2019), therefore we chose urban, semiurban, and rural locations, with participants recruited from the local area. We targeted Norwich and Norfolk because grain agriculture is the predominant economic sector in that part of the U.K.: arable land could be a prime deployment location for several types of CO<sub>2</sub> removal in the U.K. and other countries. Our choice of locations was unrelated to fracking, and none have been proximate to any of the recent U.K. licensing or drilling activities. Each workshop comprised eight participants, recruited from the general population using a professional recruitment company and broadly representative of the demographic characteristics of the location. Participant details are given in Supporting Information Appendix A.

Each workshop lasted around five hours in total, and was split across two evenings one week apart. Deliberative workshops such as these are a tried and tested qualitative social science research method, particularly suited to exploring in a group setting how citizens come to make sense of the risks, benefits, and uncertainties of initially unfamiliar environmental or technology issues (see e.g., Pidgeon, 2020; Pidgeon, Demski, Butler, Parkhill, & Spence, 2014; Renn, Webler & Wiedemann, 1995). The aim is to enable participants to discuss unfamiliar issues among themselves, forming views and perceptions through an extended period of discussion and debate, supported by a range of activities and balanced stimulus materials provided by the research team. This can help to “open up” to a more diverse range of perspectives, encouraging citizens to introduce their own imaginaries and raise new questions which might not have been considered by the research team (Macnaghten, 2017). As well as generating research insights into public perceptions and new hypotheses for future empirical work, this approach has been shown to yield valuable insights for policy making (Climate Assembly UK, 2020; Devaney, Torney, Brereton, & Coleman, 2020). For this study, workshops were conducted initially to explore public perceptions of carbon dioxide removal, the results of which are reported in Cox, Spence, and Pidgeon (2020). The

evidence presented in the current article did not feature in that previous analysis, since it explores a new research question, which emerged from our initial coding of the transcripts and which appeared interesting and novel enough to warrant a secondary analysis of this topic.

The full workshop protocol is shown in Supporting Information Appendix B. The workshops began with an icebreaker, followed by a facilitator-delivered presentation about “ways of reducing the risk of climate change,” which used images of familiar techniques on the energy supply-side, energy demand-side, and climate adaptation. Following a very brief introduction to the topic and rationale of CO<sub>2</sub> removal, participants learnt about three major CO<sub>2</sub> removal technology proposals, selected on the basis of their potential ability to sequester very large quantities of CO<sub>2</sub> over a very long time-frame (Friedmann, 2019; Fuss et al., 2018). These are as follows: BECCS, in which bioenergy crops are grown and burned for fuel, with the resulting CO<sub>2</sub> captured and stored using CCS technology; Direct Air Capture, in which CO<sub>2</sub> is captured from ambient air using fans and chemical processes and stored using CCS; and Enhanced Weathering, in which silicate rocks are finely crushed and spread, absorbing CO<sub>2</sub> through weathering processes and sequestering it in the form of stable bicarbonate. Information on these was presented using three posters, comprising an image, a brief description in simple terms, and information on risks and benefits (Figures C.1, C.2, and C.3 in Supporting Information Appendix C). Participants were free to move among the posters to reduce ordering bias, and made anonymous comments on sticky notes to reduce discomfort in a situation of low prior knowledge. The comments were then discussed as a group. At no point was the topic of fracking or unconventional oil and gas exploration introduced by the research team, either verbally or in the materials presented.

At the end of the first evening, we gave participants a homework task to speak to family and friends about what they had learnt. In this way, our methodology broadened the discussions to include people’s broader peer groups, and as a result sought to reflect more accurately the opinion-forming processes which occur in everyday life. Focus groups and workshops have been criticized for creating an artificial or controlled environment (Degeling, Carter, & Rychetnik, 2015); by including participants’ peers and allowing them to explore issues in places they felt most comfortable such as their homes, this

<sup>1</sup>Two workshops were conducted in Cardiff, because the first was originally intended as a pilot study; however, following a highly successful final pilot (the last of four), we decided to keep the methods exactly the same and to use the data arising.

technique forms a logical extension of our “opening up” approach, and aims to reduce participant bias.<sup>2</sup> On the second evening, we started with a 30-minute discussion of the homework task, during which all participants reported back and others were invited to comment. All workshops were facilitated by Cox and Spence; there was no technical expert present, because previous research suggests that this can divert and bias discussions (Macnaghten & Szerszynski, 2013). The workshops were video and audio recorded and professionally transcribed and anonymized, and participants were given aliases, which are used in this article.

Previous research with “upstream,” or emerging technologies has shown that people often use analogies to other issues to first make sense of an unfamiliar technology (Pidgeon et al., 2012). During the workshops we noticed that fracking was mentioned unprompted by participants many times, prompting the research team to ask whether ripple effects could be occurring across technologies. We also wondered whether ripple effects might be limited to techniques with a substantial underground component: our stimulus materials presented two techniques involving deep geological storage (BECCS and Direct Air Capture), and one which does not (Enhanced Weathering). We therefore decided to conduct a secondary analysis of the transcript data with this specific research question in mind. We first conducted a keyword search of the transcripts (cf. Seale & Charteris-Black, 2010), using the keywords “fracking,” “frack,” “shale,” and “unconventional.” We then analyzed the resulting excerpts and surrounding conversations in more depth using thematic coding analysis to identify cross-cutting themes with which to describe and understand the excerpts (Braun & Clarke, 2006; Macnaghten, 2017), as well as insights from discourse analysis to analyze the way in which participants interacted and debated with one another (e.g., Goldberg, 1990).

### 3. RESULTS

The keyword search identified 13 segments of text, all of which were quite lengthy and involved multiple participants. The term “fracking” or “frack” was mentioned unprompted by 11 out of 32 participants, and a further 11 participants joined in during the surrounding conversations,

shown in Supporting Information Appendix A. The terms “shale gas,” “shale oil,” and “unconventional gas/oil/hydrocarbons” did not appear at all. As can be seen from the excerpts presented in this section, multiple participants quickly became engaged when the discussion turned to fracking, generally supporting rather than disputing with one another. During the poster task and the homework task, several participants immediately made a connection with fracking, and used this to draw generally negative connotations to the techniques proposed. Although the aim of the workshops was to discuss CO<sub>2</sub> removal, all groups mentioned this topic to approximately the same degree, showing that the fracking discourse was well distributed across multiple locations and diverse groups of participants. Among the individuals who mentioned fracking, from the demographic details in Supporting Information Appendix A it is difficult to discern any patterns relating to gender, age, ethnicity, or socioeconomic class. We did note that those who specifically mentioned fracking were more likely to be in socioeconomic grades B or C1 (i.e., the middle classes); however, this is complicated by the fact that it is not possible to draw a clear line between those who specifically mentioned the term, and those who joined into the conversation, as shown by the excerpts below.

Using thematic analysis, we identified themes that appeared to explain the reasons underlying participants’ responses. These generally fell into two overarching categories: concerns relating to specific attributes of fracking (mainly impacts to ecosystems and the underground); and deeper underlying concerns regarding scientific assurances of safety, constraints to our ability to adequately predict and control unintended consequences, and trust in experts, regulators, and government. We address those two categories in turn, although themes are highly overlapping, with specific concerns often rooted in deeper cross-cutting ones. The final results section focuses on whether we noticed ripple effects occurring for technologies without an underground component. In general, the themes we identified were voiced by all the groups. However, we found that the Norfolk Rural group voiced fewer ecosystem concerns and a very strong anti-elites discourse, discussed in Section 3.2.

#### 3.1. Ecosystems and the Underground

During the discussions, fracking was connected to damage to ecosystems and leakage of harmful chemicals, with participants across all groups

<sup>2</sup>Participant bias: where participants respond or act in a way which they feel corresponds with what the researchers are looking for.

drawing similarities to CO<sub>2</sub> storage underground. For example:

Peter: You've got things like with... is it with fracking now and all sorts of things where you... how will that disrupt the ground? Not so much earthquakes, but will it poison water? Will it be able to seep out? Will it be detrimental to the...

Ruby: Sea life and...

Peter: Yeah, anything. Yeah.

Tom: It's kind of, another just sweeping something under the carpet, isn't it?

Emma: We don't really know the damage we could do by doing this, 'cos it's... to my knowledge we've never done anything like this before with anything, so... it does bring fracking back to mind and thinking, you know, that it can cause all sorts of issues in the Earth's make-up in that we might be storing problems for future. [Cardiff 2]

In this exchange in Cardiff, Peter expresses concern about risks to water supplies, as discussed in the risk amplification literature on fracking. Word-ing his comments as a series of questions, he conveys a sense of unresolved uncertainty around the techniques under discussion. Ruby then interrupts to voice concerns about wildlife and ecosystems; in this context, her interruption appears to convey her rapport with what Peter is saying, demonstrating enthusiastic interest for the topic and active involvement in the discourse (Goldberg, 1990). Emma then brings the discussion back round to fracking, voicing her concerns that CO<sub>2</sub> removal technologies could be creating unexpected problems in the future similarly to generally-accepted risks of fracking, thus showing that amplified risk perceptions regarding fracking may be impacting attitudes toward the technologies under discussion.

In the exchange below from the other Cardiff group, Elliot voices similar concerns about interfering with the underground, and offers an understanding of the earth system as inherently interconnected (see also Partridge et al., 2019), a sentiment voiced by participants in all workshops. Elliot and Katie see fracking as a failure to fully understand and predict the consequences of human actions, a discourse also evident in Peter and Emma's comments above, thus implying that other technologies could result in similar deleterious impacts:

Elliot: It changes the composition of what's underground. At the end of the day, if it changes something then it's going to have an effect. We might not like to think about it but we need to have a really good idea of what the change will be before we start to do it really, similar to fracking.

(...)

Facilitator: So if someone said, we're going to do this but it's not going to have any impact on the water supply, it will be fine, would you believe that?

Elliot: Every new technology at the time it's created is fine. We only start to find out retrospectively about the impact it has, so often, there's not a considerable amount of research or development or understanding done before we roll it out, which could have sort of reflections on different motives really (...).

Katie: And the terrifying thing is, with technology, we can't control it. We recall products, we put new ones out. This is just uncontrollable. [Cardiff 1]

Katie's response to Elliot is highly emotive, describing technology as "terrifying," and suggesting that the risks are uncontrollable. Elliot's statement links fracking and CO<sub>2</sub> removal so tightly that it is unclear here whether Katie is referring to fracking, CO<sub>2</sub> removal, or both. Underlying both of these Cardiff discussions is a discourse about the ability of scientists to accurately predict the future and to protect against unintended and uncontrollable consequences. In our thematic analysis of the broader workshop discussions on CO<sub>2</sub> removal, we found this discourse to be prevalent throughout all four of the workshops.

### 3.2. Responses to Scientific Assurances

Technology development and deployment will rely to some extent on scientists being able to deliver their research to publics in a trusted manner, particularly for highly novel, engineered proposals such as the three CO<sub>2</sub> removal technologies we discussed. Trust in scientists is generally high among U.K. public (Ipsos Mori, 2018). Yet fracking was associated with skepticism about scientific assurances of safety across all groups; in fact, when asked how they would

react to such assurances on CO<sub>2</sub> storage, Norfolk rural participant Shaun responded with one word: “fracking.” Williams et al. (2017) found something similar in their deliberative work on fracking discourses: they identified a “sheer paucity of trust and goodwill toward industry and government” (p. 95). In the exchange below (Norwich), fracking is again mentioned unprompted in the midst of a discussion about the abilities of scientists to predict and control against unintended consequences. Then, when questioned directly by the facilitator about scientific assurances, Amy responds with strong statements of distrust:

- William: Until these things happen, nobody knows do they, if it’s in its infancy, you know, once these problems come to fruition, everybody then starts worrying about it. People are worried about fracking, and they’re showing gas coming out of the taps in America and stuff. It’s all...
- Amy: They’re doing it here, and it’s proved to be causing earthquakes.
- William: Yeah, and there’s been lots of minor earthquakes, haven’t there.
- Amy: And they’re gonna have that anyway, so what, what luck do we- do we have?
- Facilitator: I’m interested in- cos, obviously, as we said, research is being done into these, and so if a little bit down the line the people who are researching it said, “Right, we’ve looked into the storage thing and it’s completely safe. We can put it under the ground, and it’s fine. There’s gonna be no explosions. There’s gonna be no earthquakes.” How would you react to that?
- Amy: I wouldn’t believe it.
- Facilitator: Why not?
- Amy: I just don’t see it as safe.... And I don’t think they’d tell us the whole truth anyway. I sound like a conspiracy theorist, I know, but I just - they just tell us what they want us to know.
- William: Would you not have thought that about natural gas 60, 70 years ago? And this piping gas around the streets? Would you said that’s dangerous?
- Amy: It is dangerous. [Laughs] [Norwich]

Here, Amy voices her concerns that “they wouldn’t tell us the whole truth anyway,” although this is then countered by William with an example of technologies which are now considered safe. Throughout the rest of the discussions, Amy and the Norwich group were actually quite favorable toward CO<sub>2</sub> removal and toward the scientific process in general; yet this exchange suggests that for some people, ripple effects stemming from risk perceptions of fracking might spark a perception of scientific information as untrustworthy and nontransparent. The exchange below (Cardiff 2), discussing all three CO<sub>2</sub> removal technologies, shows how participants navigated these issues of trust via group discourse, sometimes countering and sometimes reinforcing one another. Emma and Tom voice suspicion about the assurances received regarding fracking and the potential for profit motives to be the real driving force behind scientific advice:

- Peter: It’s like the whole fracking, anti-fracking movement. So, I’m not too concerned about... because if there are any issues, I think they’ll be found out, because it will be something that’s so invasive and so... well people will be studying it from all sides to see whether... what the consequences are. You can’t sort of just hide things away. People will find out if there’s a big issue. I’d like to think...
- Emma: But it might be too late.
- Facilitator: What makes you think about it being too late?
- Emma: I suppose, it’s just... the argument about fracking, you know, it’s safe apparently and it doesn’t cause earthquakes, apparently. It’s been stopped three times now in about a week, because it has caused earthquakes. So that, sort of, makes me really suspicious. Who is saying that it doesn’t cause earthquakes, because quite clearly it does? Do you know what I mean?
- Tom: Well, the motivation for that is capital gain, isn’t it?
- Emma: But it’s supposed to be clever people who are telling us that it doesn’t cause earthquakes.
- Tom: Not impartial scientists though.



Emma: Oh, aren't they? Oh, okay. I thought they would have been using experts to...

Tom: Probably, and you know, maybe lining their pockets.

Denise: But we're supposed to trust experts, aren't we? We're supposed to be able to trust in them, aren't we? [Cardiff 2]

Like Denise and Tom above, participants sometimes voiced a sense of betrayal on the part of those driving technology development and deployment. This was particularly prevalent in our Norfolk Rural group, who often voiced a strong anti-elites discourse regarding policymakers and capital flight to nearby metropolitan London. In the exchange below, Trev refers to a conversation he had with his wife during the homework task, illustrating the way in which participants used these conversations with their peers to reinforce (and in some cases question) their own perspectives:

Trev: The things, like the big fans [referring to Direct Air Capture], she said, whatever we say, are they gonna do that anyhow? They've done a similar sort of thing with fracking. You know, people were campaigning against it, they still went ahead and done it.

Facilitator: How do you react to that, when people say "no" and then people kind of go ahead and do it all the same?

Trev: I think it's the same as, you know, it isn't just that, it's a lot of other things as well going back to a long time ago, they just do anything they want to, that they like really. And we just have to go along with it. [Norfolk Rural]

Trev's wife uses the example of fracking to voice concerns that even if people object to these technologies, "they" will go ahead and do them anyway. Thus, fracking is used as an illustration of the failure of U.K. policy at that time to give publics a meaningful voice in decision making, showing that for these participants, trust was a strong factor in the ripple effect from fracking to CO<sub>2</sub> removal.

### 3.3. Ripple Effects across Technologies

Importantly, we found evidence that ripple effects are not confined simply to the CO<sub>2</sub> storage components of BECCS and Direct Air Capture, as

one might predict. Carbon capture with deep geological storage can be seen as somewhat analogous to fracking because both involve drilling and transporting liquids deep underground, despite the fact that they are technically quite different (Gough et al., 2018). Certain risks of fracking, such as aquifer contamination and induced seismicity, were applied extensively by our participants to the deep geological storage component of BECCS and Direct Air Capture. However, participants in all groups also applied the fracking analogy to dissimilar techniques, including Enhanced Weathering and the air capture component of Direct Air Capture. In the poster task in the Norfolk Rural group (below), a participant writes "similar to fracking" on the Enhanced Weathering poster, a technique which does not require CO<sub>2</sub> storage and which does not include an underground component:

Facilitator: Someone's put, similar to fracking? Who was that?

Elizabeth: I did.

Facilitator: So, what was it that made you think of fracking when you looked at this?

Elizabeth: I think the giveaway was the heavy machinery and the rocks and that put me in mind of fracking process, which nobody wants.

Shaun: No.

Elizabeth: That's all right if you're in Arizona in the desert and there's no communities around you. That's not great for the U.K.. And even in America I think they have a lot of objection to it and opposition. [Sounds of agreement from the group]. [Norfolk Rural]

In several of the exchanges, references to public opposition to fracking are used to imply that CO<sub>2</sub> removal technologies could also be expected to encounter public opposition, with a possible inference that similar efforts will be made to override public opinion in U.K. technology policy. Again, this shows that the fracking analogy is not necessarily limited to technological similarities, but rather a deeper set of discourses about trust in science and institutions, assurances, and the policy process. However, the analysis presented here, as an exploratory secondary study, is of necessity limited and hence would benefit from further research, particularly into other

climate/energy technologies without an underground component.

We originally expected that ripple effects might be limited to techniques with a substantial underground component, yet our data provides evidence that this is not necessarily the case. While the majority of fracking comments were indeed made in relation to deep geological storage, they might also have been influenced by our initial climate change framing for the workshops. This is because our stimulus material positioned CO<sub>2</sub> removal within a similar energy/climate discourse as is often adopted by proponents of fracking and natural gas. Had this study focused purely on agricultural and soil-sequestration techniques, for example afforestation and Enhanced Weathering, the fracking analogy may have been less likely to arise spontaneously. The vast majority of research and policy on CO<sub>2</sub> removal frames it as a climate/energy technique; therefore, the observation of ripple effects even with dissimilar technologies if they are framed in this way points to the need for further experimental study of this hypothesis using framing studies.

#### 4. DISCUSSION

Our results indicate that perceptions of fracking may have impacted attitudes to non-fracking technologies, in communities spatially and socially distant from any shale industry activity. Individuals with no direct experience of the fracking controversy used its negative connotations to draw similar negative conclusions about CO<sub>2</sub> removal technologies, despite the fact that (technically speaking) the similarities between fracking and the three technologies we discussed are very limited. This is in line with an important, yet somewhat underresearched, point in the literature on social amplification of risk—that ripple effects can spill over to completely different technologies (Kasperson et al., 1988). Such a finding would have significant policy implications, because a broad portfolio of approaches will be required to meet challenging emissions targets, and the U.K. net zero target requires considerable CO<sub>2</sub> removals by 2050. The failure to find grounds for common public consent for fracking may therefore unintentionally constrain the U.K.'s energy transition and broader climate goals in ways which extend beyond a single technology.

This was an exploratory study, using a secondary analysis of existing transcripts to understand factors driving participants' risk perceptions. One of the

strengths of qualitative as opposed to quantitative social sciences research is that it can be generative of new hypotheses or theoretical observations, as here, which is a necessary if sometimes overlooked component of the scientific method and scientific progress as a whole (Henwood & Pidgeon, 1992). The data does not, however, enable us to demonstrate conclusively that fracking created a "ripple effect" to other technologies, and an alternative explanation could be that workshop participants held other preexisting attitudes, which acted as drivers of skepticism toward both fracking and CO<sub>2</sub> removal. For example, it has been shown that perceptions of "messing with nature" are important for understanding attitudes toward many novel technologies (Corner, Parkhill, Pidgeon, & Vaughan, 2013; Siegrist & Sütterlin, 2014), and it may be that participants who felt more strongly about this extended similar concerns to both fracking and CO<sub>2</sub> removal. Similarly, participants with particular worldviews or values might be expected to be more skeptical toward both fracking and novel CO<sub>2</sub> removal; for example, people with egalitarian cultural worldviews might be generally more skeptical of scientists' abilities to predict and control future risks (Bellamy, Lezaun, & Palmer, 2017; Douglas & Wildavsky, 1983).<sup>3</sup> As such, further quantitative research is needed to test whether a direct causal relationship does indeed exist between fracking perceptions and amplified risk perceptions of other technologies. That said, our data appears to suggest that skepticism toward fracking, occurring as a result of its stigmatization in the public mind, was a core frame which participants used to make sense of and form attitudes toward the novel CO<sub>2</sub> removal techniques. This would suggest a direct ripple effect rather than a simple correlation based upon background worldviews or beliefs. Clearly there is a need for more focused hypothesis-led research to explore these two competing explanations. In this sense, we have not used the social amplification of risk framework here as a predictive theory, but as a heuristic framework for interpreting the complex and interconnected stories and imaginaries that our participants provided.

<sup>3</sup>We searched the qualitative data for patterns regarding values and worldviews expressed by individuals elsewhere in the workshop, particularly pro-environmental sentiment, egalitarian worldviews, and "messing with nature." From the participants who referred to fracking (Appendix A), no such patterns were readily apparent. However the small sample size means we cannot rule this out.

A key linkage drawn by participants between fracking and CO<sub>2</sub> removal was a generic lack of trust in the abilities and motivations of scientists, experts and policymakers. Our participants conceptualized “risk” broadly, relating it not only to technological risks such as induced seismicity, but also to perceived shortcomings in the way the risk was handled and sociopolitical concerns regarding the controllability and voluntariness of the risk (Renn, 1985; Slovic, 1987). This had a very negative impact on our participants’ perceptions of assurances from experts—there was a sense that fracking advice had been shown to be flawed or influenced by vested interests, for example where Amy (Norwich) points out that induced seismicity had occurred despite assurances to the contrary. In essence, several of the exchanges above can be summed up in the phrase “but they told us it was safe.” The “they” to which participants refer is not clearly defined but appears to reflect misgivings about an imbalance of power involving vested interests. As pointed out by Pidgeon et al. (2006), the risk amplification framework as originally proposed pays relatively limited attention to power, agency, and political processes, and yet we would argue that these are critical for our case here, appearing throughout our data. Political processes appear to have played a pivotal role in the ripple effect occurring here, because as demonstrated by Bradshaw and Waite (2017), the U.K. fracking controversy has revolved around particular policy decisions which have left the public feeling that their concerns are being ignored or overridden, and that solutions are being “imposed” on them from above. This type of anti-elites discourse was especially strong in the Norfolk Rural group, which also happened to be the group with the lowest average income and education level (Supporting Information Appendix A). Whilst our sample size is too small to draw firm conclusions from this, it is in line with the observation of Frewer (2003) that perceptions of social exclusion and disenfranchisement may result in increased sensitivity to risk messages and increased risk amplification among certain individuals.

Of course, much of the public opposition to fracking in the U.K. was based around concerns about environmental impacts, as well as the noise, disruption and traffic associated with drilling and setting up the sites. These concerns have been found for multiple types of infrastructure, including many of those required to meet a net zero emissions target, and would seem to imply that people are opposed to disruption of any kind. Yet experience demonstrates

that such concerns can be ameliorated if there is a strong perception that the project adheres to principles of procedural and distributional justice (Boude, 2019; Thomas, Demski, & Pidgeon, 2020). Our data suggests that our participants felt strongly that procedural justice was lacking in the case of fracking in the U, and that this impacted how they felt about the potential for adequate procedural justice for other technologies, exemplified by the comment from Trev’s wife, who felt that “they” would just go ahead and do it anyway. Again, this is a question of power: procedural justice can be said to be lacking when solutions are imposed by those with more power than others.

Of course, multiple factors influence public attitudes to CO<sub>2</sub> removal, and may well have influence over and above the ripple effect we have noticed here (Bellamy, Chilvers, & Vaughan, 2016; Bellamy, Lezaun, & Palmer, 2019; Cox, Pidgeon, Spence, & Thomas, 2018; Jobin & Siegrist, 2020; Thomas, Pidgeon, & Roberts, 2018). There is also a wealth of understanding about public attitudes to CCS, which the results of our workshops generally support (L’Orange Seigo, Dohle, & Siegrist, 2014; Mabon & Shackley, 2015). However, within the CCS literature, risk amplification is also an underresearched phenomenon which may have a nontrivial impact. Our small sample size obviously limits the generalizability of our results: deliberative methods enable in-depth understanding of *why* publics respond in a certain way but cannot generalize to the whole population or to other locations or types of public. Furthermore, secondary analysis is an inherently exploratory and tentative approach, because the data being analyzed was originally collected to answer a research question which is different from the one currently in focus (Hinds et al., 1997). Therefore further survey or experimental work using large samples would be needed to test our ripple effects hypothesis. Further work is also needed to assess whether the effect is similar across different locations and publics. The locations of our workshops, and the fact that the fracking analogy appeared consistently and completely unprompted in all of our groups, suggests that heightened risk perceptions now occur in locations distant from the sites of the fracking controversy, in line with social amplification theory which posits that risk perceptions ripple across spatial scales (Kasperson et al., 1988). However, an important limitation of our choice of location is that we focused on areas with connections to farming and the countryside and did not explicitly include an industrial area. Previous research in Teesside has found that CCS

could be well-placed to establish a social license to operate there, partly due to local pride in the area's industrial past (Gough et al., 2018). Many policy changes have occurred in the years since that study was carried out, therefore it would be interesting to see whether the ripple effect we found now extends to industrial areas proposed for large-scale CCS deployment.

## 5. CONCLUSION

This article has suggested that controversies around fracking in the United Kingdom have led to second- and third-order social amplification of risk, whereby heightened risk perceptions have extended via “ripple effects” across spatial scales and *across technologies*. We reported the results from a series of deliberative workshops designed to elicit public attitudes to CO<sub>2</sub> removal using negative emissions technologies (NETs). During the course of these workshops, we noticed that fracking was mentioned unprompted in all groups in relation to the risks of the CO<sub>2</sub> removal technologies participants were deliberating. Other analogies were at times utilized to discuss NETs in the workshops, including plastic and nuclear waste (Cox et al., 2020). However, when discussing risks to ecosystems and the underground, and participants' distrust of scientific assurances, fracking was the common analogy utilized across all groups. Our in-depth secondary analysis of this theme in our workshop data showed that this was influenced by deeper misgivings regarding the actions and motives of scientists, experts, and policymakers. This discourse, which can be characterized as “but they told us it was safe,” could have a negative impact on people's trust in assurances of the safety and efficacy of CO<sub>2</sub> removal proposals. Very few empirical papers on social amplification of risk explore ripple effects to other technologies, yet this will be important if our interconnected energy and climate systems are to be transformed in a sustainable way and underlines the importance of taking a whole systems view when assessing the risks and benefits of technologies and policies. Energy policy making in particular is frequently siloed, yet all policy making should assume that action regarding one technology will impact others (Cox, Royston, & Selby, 2019). A lack of social license to operate was instrumental in causing severe delays, cost overruns, and eventually a moratorium for the U.K. fracking industry, hence policy should be extremely wary of similar effects extending to other technologies.

Trust, once lost, is not easily regained (Lofstedt, 2015). One proposed resolution here would be for experts, developers, and industry to take people's concerns seriously, and as a priority ensure that planning procedures are perceived to be fair (Boudet, 2019; Freudenburg, 2003). There is also a need to ensure that people do not feel as if risks are being managed and communicated by vested interests, or that solutions are being imposed from above onto unwilling and ignored communities. Williams et al. (2017) demonstrate that some of the problems facing public perceptions of fracking in the United Kingdom stemmed from industry and government assumptions that people's concerns are a product of ignorance, and therefore led to an ineffective focus on providing more technology-centric “facts.” Bradshaw and Waite (2017) suggested that U.K. shale gas could fail in the same way as genetically modified food, a claim which appears rather prescient in light of the recent moratorium. It also raises significant questions for the future of other technologies which become associated in the public mind.

Reversal of stigmatization, once in place, may be difficult or unlikely (Thomson, 2015). The recent retraction of U.K. policy support for fracking, as a direct result of public concerns, suggests that fracking will be, at the very least, on pause for the foreseeable future. Therefore the more interesting question raised by this article is, how to address ripple effects in order to prevent similar risk amplification occurring in other technologies such as CO<sub>2</sub> removal? Here we would argue that actors with an interest in CO<sub>2</sub> removal (including scientists, developers, industry, and government) should not assume that simply downplaying or obscuring risks is the pragmatic route to take, even though this might seem tempting where scientific uncertainty still exists (Leiss, 2003). Rather, engaging with lay publics early on in technology development using principles of “upstream engagement,” opening up development processes so that more diverse stakeholders are included and problem framings considered, and ensuring that communities are given genuine voice in consultation over issues that affect them, have all been recommended as effective methods to increase the legitimacy, efficacy, and ethicality of technology development and deployment (Bellamy et al., 2016; Chilvers & Kearnes, 2016; Fiorino, 1990; Rogers-Hayden & Pidgeon, 2016; Stirling, 2008).

There are signs that this is being recognized, with increasing pressure from research funders to incorporate public engagement into scientific programs,

through programs of responsible research and innovation (Owen, Bessant, & Heintz, 2013). Yet the real challenge will be to ensure that this generates a genuine two-way dialogue process, in which public concerns are fed into and influence the development of technologies and their associated policies. Importantly for CO<sub>2</sub> removal technologies, this process does not stop at early R&D: technologies and policies co-evolve over time, and the sociopolitical context will be at least as important for determining public attitudes as the technology *per se* (Bellamy et al., 2019). This means that policy will need to remain flexible and responsive to public concerns throughout, as well as sensitive to the power dynamics involved in risk amplification and its secondary impacts. Actors and interests seeking to downplay or ignore risks will sometimes have a disproportionate ability to influence, and our results highlight the fact that publics are aware and distrusting of this. It is only by acknowledging and attempting to mitigate for such power dynamics, for instance by increasing transparency and supporting principles of responsible innovation, that we might hope to minimize the unintended impacts of risk amplification on the transition to a net zero world.

## ACKNOWLEDGMENTS

This work was funded by the Leverhulme Trust under project research grant RC-2015-029. Additional funding for the authors was provided by the UK Energy Research Centre, and by the Wales European Funding Office via the FLEXIS project. We are grateful to the following for their help developing study protocols and materials: Alan Flewker, Tim Kruger, Naomi Vaughan, Gideon Henderson, Darrik Evensen, Duncan McLaren, Victoria Campbell-Arvai, Peta Ashworth, and Michele Ferguson. We are also grateful to the LC3M advisory board and researchers at the Evan de Lucia lab at the University of Illinois, for their design input and ongoing support.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## DATA AVAILABILITY STATEMENT

The workshop audio files and transcripts cannot be made publicly available due to the need to respect participant confidentiality. However, we will consider

individual requests to share the anonymized transcripts (for research purposes only) on a case-by-case basis after an embargo of one year, during which time our analysis continues.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Appendix A:** Participant details

**Appendix B:** Workshop Protocol

**Figure C.1:** Copy of Bioenergy with Carbon Capture and Storage (BECCS) poster

**Figure C.2:** Copy of Direct Air Capture with Storage (DAC) poster

**Figure C.3:** Copy of Enhanced Rock Weathering (ERW) poster