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Health Risk Perception and Shale Development in the UK and US

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Abstract

In this paper we examine discourse in public deliberations in pre-development locales in the UK and US about advantages and disadvantages of future shale development ('fracking'). We aimed to understand how people anticipate potential health effects, broadly construed, of environmental toxicity and disturbance in the context of planned, but not yet implemented, energy development.

In day-long deliberations with small, diverse groups in two cities in each country (London, Cardiff in the UK; Los Angeles, Santa Barbara in the US), participants discussed impacts on health and wellbeing using three main rubrics: '*It's money or health*,' '*Why take chances?*' and '*Beyond the tipping point*.' Throughout, participants framed health as an intrinsically *moral issue*, with *collective responsibility* as a dominant normative frame. We identify the concept of *compound risk* to underscore effects of multiple risks and hazards on people's sensibilities about anticipated future health and environmental harm. The findings demonstrate how and why diverse publics in pre-impact sites in both countries saw shale extraction as high stakes development that poses significant, often unacceptable, risks to human and environmental health and wellbeing. Risks extended beyond toxicity to broad threats to health, including, for some, the end of life as we know it on the planet. Overall, participants' discussions of health were more connected to social categories and their underlying moral principles than to technological details. This work contributes evidence of blurred boundaries between environment and health as well as the importance people place on social risks in the context of proposed energy system change.

Keywords: health risk perception; shale development; fracking; deliberation; environmental and bodily health; social risk

1. Introduction

A number of studies of shale development (often referred to colloquially as ‘fracking’), primarily in the US, have reported varying public views on environmental and economic effects in high impact areas and in larger national samples (Thomas, Pidgeon, et al., 2017), but surprisingly few have examined potential health issues (exceptions include Perry, 2013; Sangaramoorthy et al., 2016). Consistent with precautionary goals of responsible research and innovation that stipulate public consultation before development takes place (Guston & Sarewitz, 2002; Owen, Bessant & Heintz, 2013; Rip, Misa & Schot, 1995), we designed this study to explore perceived risks of future shale development. Based on data from day-long deliberative workshops with diverse groups of citizens in two sites each in the UK and US, we argue that participants made emergent connections between environmental hazards and human bodily health risk concerns in areas of planned but not yet implemented development. We used content analysis of workshop narratives to identify a set of rubrics or tropes people used to draw close connections between environmental and health risks. We found that compared with people in post-impact sites, our participants used constructs of embodied environmental health and wellbeing that are more diffuse and abstract, less tied to specific bodily symptoms, and rather strongly linked to intensely personal threats to self and community, and even planet--future wellbeing was primarily framed as a moral condition rather than a physical state.

Environmental and industrial disasters around the globe have provoked extensive discussion of perceived risks, beliefs, and health concerns about industrial contamination among diverse publics. In many cases environmental hazard exposures have most profoundly shaped health risk perceptions of those in direct contact or proximity (Irwin, Simmons, & Walker, 1999), including

those with disproportionate harmful exposures by race, class, and gender (Brulle & Pellow, 2006). In other cases, such as the Chernobyl nuclear accident of 1986 or the Fukushima Daiishi nuclear disaster of 2011, toxic effects--physical, political and social—have extended spatially far beyond local and national boundaries and socially through risk amplification processes (Pidgeon, Kasperson, & Slovic, 2003). Our goal in this study is to understand how people in differing urban contexts in the UK and US anticipate potential health effects, broadly construed, of environmental toxicity and disturbance in the context of planned, but not yet implemented, unconventional oil and gas development.

Research on public views of fracking/shale development has until very recently focused primarily on aspects of economic gain and environmental harm rather than health or wellbeing (Boudet et al., 2014; Evensen, Stedman, O’Hara, Humphrey, & Anderson-Hudson, 2017; Thomas, Pidgeon, et al., 2017; Williams, Macnaghten, Davies, & Curtis, 2015). The main work on health risk perceptions has focused on qualitative studies in areas of the US with intense commercialization and high impacts (for example, Eaton & Kinchy, 2016; Perry, 2013; Sangaramoorthy et al., 2016). Missing from this record is in-depth qualitative data on emergent views and attitudes before direct impacts have been experienced (see Williams, Macnaghten, Davies & Curtis, 2015, in the UK, for a notable exception). Deliberative methods such as the one used in this study aim to generate nuanced understanding of the logics, sentiments, and contradictions represented by the full range of people’s attitudes and beliefs about technological development (Macnaghten, 2017a; Pidgeon & Rogers-Hayden, 2007) and to provide social intelligence on health aspects of shale development before development takes place. The

comparative UK-US methodological model we apply here allows consideration of how different national policy contexts impact formative views on the ground.

2. Context

Risk perceptions and health effects of shale development

Social scientists, primarily using survey methods, have examined public awareness and attitudes concerning shale development across national contexts, including the US and UK. While levels of acceptability and awareness vary considerably across regions (Thomas, Pidgeon, et al., 2017), US surveys have found that even in close proximity to shale operations, about half of the potentially impacted public are unaware of shale development activities. This awareness contrasts notably with the UK, where 75% overall and 81% of rural residents are estimated to be aware of the extraction process (Bradshaw, 2016). Bradshaw concludes: 'In both regions [UK and US] the benefits are largely seen as economic in nature, while the risks are seen as both environmental and social' (2016, p. 2). Surveys on shale development perceptions in the US have found more polarized views in areas of intense development, with prolonged rural poverty a key factor in support for shale development (Simonelli, 2014). Environmental values, gender, worldviews, media use, and political ideology all are factors in polarization and contestation over the social and ecological impacts of shale development (Boudet, et al., 2014; Clarke et al., 2015).

Until very recently, survey research has focused on environmental and social effects of shale development rather than associated health risk perceptions (see Thomas, Pidgeon, et al., 2017 for a review). In contrast to large-scale national surveys, qualitative social and behavioural researchers have reported that people in some areas of intensive shale development in the US

express great concern about health effects of shale extraction (see Eaton & Kinchy, 2016; Perry, 2013; Sangaramoorthy, et al., 2016; Wylie, 2018). Adverse community health concerns in these downstream studies include: psychosocial stress and powerlessness, disruption to place-based identity, relationships, and meanings, and reduced ability to take protective action. In the UK, Bradshaw and Waite (2017) reported on the first shale development wells in Lancashire, England, and noted that at public meetings most local people voiced opposition and mistrust, raising major health concerns about pollution (air, water, noise, and light) and seismic activity. However, how such views in high impact areas align with views in areas of future development is unknown.

As with many new industrial toxicity cases, the absence of epidemiological studies has created great uncertainty about health outcomes (Finkel & Hays, 2015; Saunders, McCoy, Goldstrin, Saunders, & Munroe, 2018). Potential adverse human health effects of exposure to chemicals used in shale development include clinical and subclinical dermal, respiratory, neurological and immuno-symptoms, and possibly cancer, endocrine disruption, cardiovascular and kidney disease, as well as negative reproductive health effects (Sangaramoorthy et al., 2016). In addition to physical effects of toxic exposures, shale development in the US has raised numerous societal issues that contribute to health concerns, including stress and trauma, uncertainty, loss of control of critical resources, noise and light pollution from production sites and related traffic, crime, and widespread community disruption from boom and bust cycles (Davidson, 2018; Jacquet, 2014).

Comparative studies of health risk perceptions

Comparative studies can highlight how social, cultural, and political contexts shape public perception of health risk issues. Studying health risk perceptions using a comparative methodological design thus allows for analyses that are sensitive to local regulations, assumptions, and practices (Boholm, 2015). Within societies, risk scholars have developed a comparative body of research on gender differences in sensitivity to environmental health risks. For example, Davidson and Freudenberg (1996) found that women typically express higher concern for health risks associated with pollution from nuclear technologies. In the US, belonging to racially and economically marginalized groups was also associated with higher perceptions of technological and environmental risks associated with nuclear power (Vaughan & Nordenstam, 1991). These findings of differences in health risk perceptions among social categories like race, gender, and class highlight the importance of comparative studies.

In addition to comparative work across social categories, other scholars have used cross-national or regional comparative studies to analyze place-based perceived health risks. Cross-national health risk studies are particularly important for illustrating how politics, government, and policy shape health risk perceptions. For example, a comparative study of six European countries showed how EU policy was instrumental in shaping citizens' policy priorities, but that generally risk priorities varied across national contexts (Bröer, Moerman, Spruijt, & van Poll, 2014). Comparative work can also highlight cases of interesting similarities in health risk perceptions. In a US/UK comparative study of citizens' risk perceptions of climate change, Lorenzoni, Leiserowitz, de Franca Doria, Poortinga, & Pidgeon (2007) found that respondents in both countries viewed risks associated with climate change to be personally distant, and neither group

associated climate change with threats to human health. The study presented here builds on the context-sensitive approach to studying health risk perceptions by utilizing cross-national comparative methodological design.

US and UK contexts for shale development

Hydraulic fracturing for extraction of oil and gas from shale involves injecting high volume pressurized water and chemicals into shale rocks to fracture them and release otherwise inaccessible oil and gas resources. While rapid scale up of high-volume shale extraction in the US has produced significant economic growth (EIA, 2018), risk assessment experts have identified seven types of associated risks and hazards: operational risks; impacts on water supply and quality; local, regional, and global air pollution; global climate change; ecological effects of habitat disruption and toxicity; human health effects; and socioeconomic impacts on affected communities (Stern, Webler, & Small, 2014).

The US and UK are particularly suitable for comparative research on shale development. In terms of similarities: 1) both share similar dependency on fossil fuels for electricity generation (DECC, 2017; EIA, 2018); and 2) both are experiencing increasing contestation over ‘fracking’ (Clough, 2018). However, they also differ notably: 1) the US and UK present differing histories and geographies of fossil fuel development and regulation; 2) compared with the US, the UK has established more aggressive climate change goals, accompanied by more public debate about energy system change; and 3) past high-profile technological risk controversies in the UK have also generated distinct attitudes toward precaution, science values, and deliberative processes to enhance public participation (Stilgoe, Irwin, & Jones, 2006). The UK’s precautionary/

participatory political environment has resulted in extensive past public deliberations and input to policymakers on a range of technological developments, including GM food (Horlick-Jones et al., 2007), geoengineering (Pidgeon, Parkhill, Corner, & Vaughan, 2013), among many others. This project is based on a UK model of public deliberation as a form of public participation.

Studying downstream health effects and health risk perceptions of populations impacted by shale development is critical (see Wylie, 2018). However, waiting until populations have first-hand experiences of harmful effects of technological development to understand their views and incorporate them into governance has been shown to present normative/ethical, instrumental, and substantive problems (compare with Dietz, 2013; Fiorino, 1990; Renn, 1999; Stilgoe, Owen & Macnaghten, 2013). In addition, methods for gaining nuanced understanding of everyday people's views in conditions where they may not yet have extensive knowledge or awareness of the technologies require particular methodological care to avoid overdetermining outcomes. The work presented here reflects an anticipatory format for deliberative engagement, designed to focus on earlier stages of development when different kinds of choices and courses of action may still be possible (Wilsdon & Willis, 2004). We use the term 'pre-impact' to describe our study sites and design but acknowledge shale development to be a downstream, post-impact issue in other regions and locales, particularly in some parts of the US.

This paper examines how public views on potential health effects, broadly construed, of environmental toxicity and disturbance in the context of planned future energy development via fracking emerged and were articulated in diverse deliberative groups in the UK and US in areas that face potential future development but have not yet experienced any direct exposures. To this

end, we held open-ended deliberative conversations to explore these issues and designed our research methods and materials accordingly.

3. Methodology

Research design and data collection

For this comparative study, we selected two global mega-cities (London and Los Angeles) and two smaller coastal cities (Cardiff in the UK, and Santa Barbara in the US) as our research sites. All sites represented pre-impact locations--where potential shale development is under discussion but not yet in full commercial development (Partridge et al., 2017). Shale extraction in the UK is still at exploratory stages (Bradshaw, 2016), but Petroleum Exploration Development Licenses are located near both London and Cardiff (OGA, 2015). In the US, although there is full deployment of high-volume shale development in other parts of the country and a form of fracking is already in use in shallower, vertical wells in Central California (CCST, 2015), deep onshore horizontal drilling into shale is still in the exploratory stages there (Hughes, 2013; Kiparsky & Foley Hein, 2013). Thus, all four sites were deemed roughly similar distance from anticipated, but not yet implemented, shale development, and discussions in all four sites focused on participants' views of potential future impacts, both positive and negative, if shale development were to scale up in their locales.

We designed this deliberative protocol to present carefully vetted technical information to all participants and refined it over three pilot workshops, two in Cardiff (UK), and one in Santa Barbara (US). Facilitation was extensively prepared and piloted to minimize facilitator and framing effects and produce comparability across sites. We convened four groups (two in each

country) of 10-16 participants each, for a total n of 55, concurrently over two subsequent weekends.

Our day-long workshops began with balanced information provision in several forms; participants then engaged in a series of interactive discussion-based tasks in smaller groups; each workshop concluded with a reflexive group dialogue. Discussion topics over the course of the day focused on advantages and disadvantages of shale development, and societal issues of responsibility, governance and decision-making. A summary of our workshop protocol is provided in Figure 1, and the full protocol and elicitation materials, as modified for the two different country contexts, are available in Supplementary Materials. Participants were also asked to complete a short (11-item) survey at the beginning and a longer (35-item) post-survey at the conclusion. Health-focused prompting in the workshops was primarily indirect and took the form of information provision about potential radiation from unearthened waste, toxicity of fracturing fluids, water contamination, and earthquakes.

Pre-workshop survey

Introductions, ice-breakers, and top of mind associations, 40 mins.

Introduction to the research team and project, followed by top of mind associations for five terms: hydraulic fracturing ("fracking"); technology; energy; environment; climate change.

Presentation and discussion, 50 mins.

20 min. PowerPoint presentation describing the differences between conventional and unconventional oil/gas, the formation and extraction of shale oil/gas, history and context of shale oil/gas development, and an overview of national energy sources and uses.

Advantages and disadvantages poster task, 75 mins.

Participants discuss six potential advantages and six potential disadvantages, and were asked to rank what they believed to be the top three advantages and disadvantages

Quotes task, 30 mins.

Participants read and respond to a selection of 17 quotations concerning fracking drawn from members of the public, politicians, NGOs, scientists, energy sector employees.

City Council game, 50 mins.

Participants were asked to assume the role of city council members for a fictional town presented with six energy development proposals, where they ranked the proposals in order of preference.

Final discussion and reflections, 65 mins.

Participants concluded the deliberation with a discussion of risks, benefits trade offs, responsibility, values and governance, trust, deliberation, and the role of emotions in decision making.

Post-workshop survey

Figure 1. Summary of workshop protocol

Our aim was to recruit diverse groups to engage in day-long deliberations in a community setting, in contrast to focus group research that tends to use relatively shorter duration protocols and more homogeneous groups (Lehoux et al., 2014). Diversity was supported by rigorous application of group composition criteria, aimed at composing 'mini-democracy' (Renn, 1999), 'quasi-representative' (Pidgeon, Harthorn, Bryant, & Rogers-Hayden, 2009) groups that were gender balanced and reflected local demographics as closely as possible in terms of age, race/ethnicity, socioeconomic status, occupation, and education, and were drawn from different parts of the cities. Recruitment was topic blind (focused on 'Technology and Society'),

performed by independent market research firms in each country, with compensation for participants. Minimum requirements for participation were sufficient English fluency and no oil or gas industry employment.

The purpose of such rigorous recruitment efforts was to provide groups of participants with varied perspectives, experiences, positions and vulnerabilities (Conti, Satterfield, & Harthorn, 2011), and in particular to study emergent attitudes and perceptions with careful consideration of diverse socio-political and cultural contexts (Felt & Fochler, 2010; Macnaghten, Davies & Kearnes 2015; Partridge et al., 2017). Some scholars have questioned whether such small, intensive public deliberation groups engage a sufficient number of people (Besley, Kramer, Yao, & Toumey, 2008), but others (Corner & Pidgeon, 2012) have argued that the range of views represented in such diverse groups and the opportunity for interaction are also of critical research value. Thus, we aimed not for strictly representative samples in a statistical sense, but rather the qualitative equivalent (Pidgeon, Demski, Butler, Parkhill, & Spence, 2014). The end result was imperfect quota samples, due to sample attrition after recruitment, but the groups provide acceptable insight into the diversity of views in each city.

Table 1. Workshop participants

City		Los Angeles	Santa Barbara	London	Cardiff*
Number of participants		16	15	10	14
Gender (percent women)		50	67	50	71
Age profile (percentages)	18-34	44	27	40	43
	35-54	38	27	30	21
	55+	19	46	30	28
Ethnicity (percent non-white)		75	53	30	7
Education (percent university degree or above)		31	53	70	57
Total $n=55$. Percentages may not be 100 percent due to rounding effects. * One participant in Cardiff withheld age, ethnicity, and education information.					

We audio and video recorded workshops and made verbatim transcriptions. The UK and US collaborating universities obtained Research Ethics and Institutional Review Board approvals respectively for the ethical treatment of human subjects in each country and followed approved procedures to obtain participants' informed consent. All utterances in the transcripts were anonymized, and all personal names in this paper are pseudonyms.

Data analysis

The main data analysis method was thematic content analysis of workshop transcripts. The cross-national team collaborated in developing a coding manual with many nodes, and used NVivo qualitative data analysis software to systematically code transcripts, using cross-validated reading and coding to ensure comparability. The main aim of analysis was to identify salient themes, capture consensus views, and note divergences. We primarily used an inductive 'grounded' approach that sought to identify participants' own emergent categories and meanings (Charmaz, 2008), following a set of 'sensitizing concepts' (Bowen, 2006) informed by previous research. Examples of such ideas were risk/downside, benefit/advantage, trust, responsibility, uncertainty, and equity.

We used this approach to develop health as an analytic category and code its conceptual elements iteratively. Our initial analysis examined participants' ideas about likelihood and severity of potential threats to health by examining discussion of health hazards, exposure pathways, and health impacts, which led to the formulation of our core rubrics in this paper. We also explored cultural ideas about the connections between health and morality, voluntary and involuntary exposures, controllability, and vulnerability.

We coded all topical discussions of health concerns between participants and refer to these exchanges as *dialogues*, which vary considerably in duration and number of speakers. Dialogues illustrate the prevalence of health concerns throughout the deliberative process and how and why participants explicitly connected environmental factors with bodily health and social risk. We note the importance to risk research of such interpretive discursive social science (Henwood & Pidgeon, 2016). Comparative analysis across all four sites was conducted to discern differences and similarities in views

4. Findings

Perceptions of health hazards and impacts

Table 2 shows the kinds of health hazards that emerged in discussion, aggregated across sites and ranked by frequency of occurrence. Concerns about health hazards linked to shale development identified in this study in some respects mirrored those reported in downstream areas.

Participants saw many human and animal health problems as resulting directly or indirectly from

environmental degradation or disturbance via contamination of air, water, or soil or induced seismicity.

Table 2. Summary of Health Hazards Discussed by Participants

Health hazard or concern in descending order of frequency cited
1. Fresh water contamination 2. Earthquakes 3. Depletion or loss of natural resources 4. Contamination of food, agriculture, and livestock 5. Radiation 6. Air pollution 7. Climate change 8. Sinkholes

Fresh water contamination, earthquakes, and depletion of resources were the most prevalent concerns people cited in relation to health and harm across all sites. They discussed sinkholes (a risk dismissed by scientists), climate change as a health threat, and air pollution less frequently. However, participants did discuss climate change extensively in relation to energy system change (see Partridge et al., 2017; Thomas, Partridge, Harthorn, & Pidgeon, 2017). Post-test data in Figure 2 indicate that a large majority of participants (80 percent) thought that *shale oil/gas and hydraulic fracturing ('fracking')* would pose either moderate or high *health and safety risks* to them and their families. People's views on health risks alone are well formed and largely negative at the end of the day. In discussions about benefits versus risks, participants also expressed considerable ambivalence and unwillingness to trade-off perceived health risks against benefits (see below and Thomas, Partridge, et al., 2017).

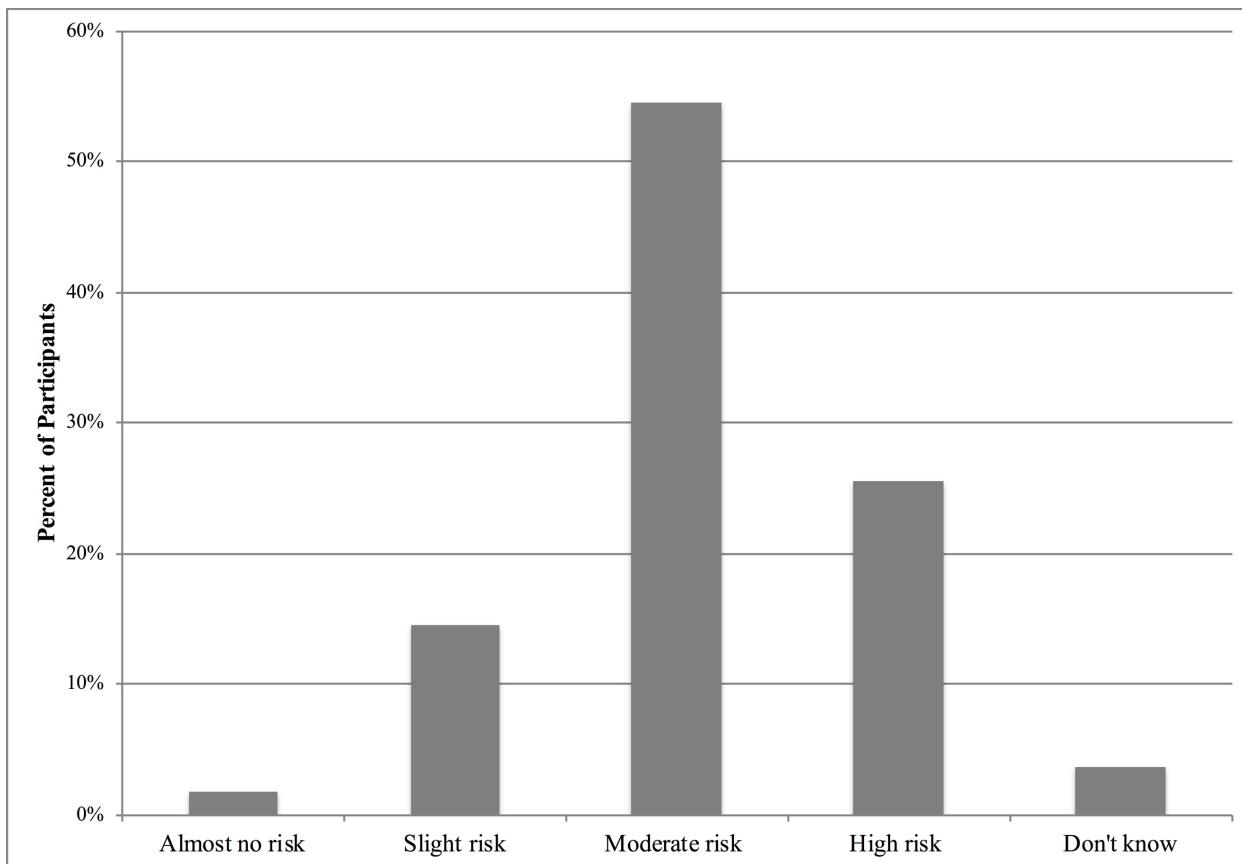


Figure 2. Post-test survey aggregate responses across all 4 sites (n=55): almost no risk (2%); slight risk (15%); moderate risk (55%); high risk (25%); don't know (4%)

In contrast to this clear articulation of specific worrisome health *hazards*, participants' discussions of health *impacts* were significantly more generalized. Compared with health risk concerns downstream, discussions in these groups of potential future health outcomes were often nonspecific, lacking detailed health diagnoses—instead they described shale development more generally as an insult to human health and bodily integrity. For example, Bea (F/18-24/White) in London responded to information about shale development's intense use of fresh water by voicing concern about '*health and quality of life*'.

Our analysis identified three rubrics, detailed in the sections below, that we believe reveal shared moral and cultural frames drawn on by participants across sites to articulate concerns about human health within the context of shale development, '*It's money or health*,' '*Why take chances?*' and '*Beyond the tipping point*.' We use 'rubrics' here to describe recurring socio-cultural narratives (Davies, Macnaghten, & Kearnes, 2009), schemata (Casson, 1983), or frames (Benford & Snow, 2000) that mediate participants' ideas about the health hazards and outcomes associated with shale development.

'It's money or health'

Given that economic profits, employment, and affordable energy are seen as the primary benefits of shale development (Jacquet, 2014; Thomas, Partridge, et al., 2017), money was an important topic in all the deliberations. However, discussions of money also often provoked conflicted discussions of health.

For some, potential *health risks were a reasonable trade-off for money* in the form of economic incentives like jobs and affordable energy. In Cardiff, Samantha contrasted advantages as economic gains for society or investors and disadvantages as decreased individual health:

Samantha (F/25-34/White): *I just think there's a clear difference between the advantages and disadvantages.. So--energy supply, jobs, creating jobs, local benefits, money, money, money, money. Disadvantages like health and wellbeing.*

Ellie (F/ 25-34/White): *But then doesn't energy aid our health and wellbeing? ... You know, we need energy, don't we, to function and, you know, so that does, can aid our health and wellbeing I guess.*

In this exchange, Ellie questions Samantha's stark distinction between money and health, suggesting that energy, and perhaps energy security, could be a necessary trade-off for maintenance of health and wellbeing.

In Los Angeles, some participants described uncertain, ambivalent feelings about economic advantages and health disadvantages. Victoria (F/ 25-34/White) felt '*much more mixed about*' weighing economic benefits against shale development's health risks because health is '*a risk that hasn't even been determined*', and Natalie (F/25-34/White) felt more '*torn*': '*I feel like we need to support this, the oil and everything, to have like more money for the country and everything, but our health suffers for it. But I mean our country is in debt and we need to make money, but in the end it's still--I don't know. I'm kind of in between still.*' These expressed uncertainties and ambivalence suggest that economic benefits are enticing, whereas some are considering that against a potential trade-off of unknown health risks.

Others, mostly men, felt less conflicted about the idea that affordable or secure energy systems were worth potential risks. In London, Tony (M/55-64/White) described the importance of affordable energy, even in light of potential risks to human and environmental health: '*Well, there's several things. There is the issue of contamination of the water supply and the ground water. There's the issue of what chemicals are being used and their effects on human health. And I don't think that's well known or investigated. But there are also, one thing, which hasn't*

been mentioned thus far, which is a big driver, is the amount of people in this country in fuel poverty... it's energy security but the cost of that is a real issue for many people.' Both Eric and Aaron in Los Angeles reiterated the idea that the economic advantages of shale development outweigh the risks:

Facilitator: *I think the importance of economic stimulation is something we're kind of largely agreeing on. Do we feel that the advantages outweigh the disadvantages?*

Eric (M/25-34/White): *I think they do.*

Aaron (M/25-34/African-American): *I do. I think they do.*

Facilitator: *Yeah? There's a couple of people shaking their heads on the other side of the table.*

Michelle (F/18-24/ African-American): *I'm very against it. The way I think of it **is money or health** (emphases added).*

Facilitator: *Money or health.*

Michelle: *What's more important? Health... Mm-hmm [yes]...especially since it's coming so close to home... it's pretty morally wrong, but when it is further away, you're physically further away from it, and mentally it's not, I don't think, presented as much to you. So, you're not thinking about it.*

Here, Michelle rejects the idea that shale development's economic stimulation compensated for its risks. This illustrates an alternate framing of the potential health impacts of shale development, also found across all four deliberative sites, that *money is a catastrophic trade-off for health*. For example, when a facilitator in Los Angeles asked what the group would have to

trade for cheap energy, both Michelle and Sally (F/35-44/Hispanic) responded, ‘*our souls*.’ As Sally explained, a company’s pursuit of profit is morally wrong ‘*if it’s at the cost of someone’s health and life*.’ Participants in Cardiff shared these sentiments, where Rhiannon (F/25-34/White) prioritized ‘*quality of life*’ over economic gains and Tammy (F/45-54/Unspecified) stressed that her ‘*health’s more important than money*.’

In contrast to some who saw potential for economic gains through shale development, others anticipated that this new technology would map onto existing systems of inequality. Equity issues were particularly evident in the most diverse and lowest SES group, Los Angeles.

Although some members argued that harm from earthquakes would be equitably distributed: ‘*[with] earthquakes, it’s going to affect anybody in LA whether you’re rich or poor*’ (Scott, M/35-44/White), others (notably people of colour) argued that ‘*old people don’t recover the way people with money do*’ (Frank, M/55-64/Hispanic). Participants saw social class and privileged access to resources as providing disproportionate insulation from the harmful health effects of natural or man-made disasters.

‘Why take chances?’

Throughout the deliberations, as participants grappled with the health risks of shale development, many of them unknown, some feared that lack of regulation and data would make local communities a test case for shale development’s effects, and the unknowns provoked questions. For example, in Cardiff when presented with reports from Texas (US) linking shale development with poor health effects on both humans and livestock, Ellie asked how ‘*strong the link is between fracking and an increase in health problems in the local area*,’ wanting to know ‘*what is the illness or what are the symptoms?*’

In a similar vein, Susan (F/55-64/White) in Santa Barbara raised questions about the safety of shale development in Pennsylvania, where shale development is widespread:

Well, what I know about fracking is that I lived on a farm in Pennsylvania where there is a lot of shale, and so there's a lot of oil in the ground under that...Well, the concern now is that there's a great quantity of water used in order to frack, and there's a lot of chemicals used also, and what happens to that waste when it's done? The area where I lived was considered a very pristine area and a lot of natural water, and it's a big concern for the residents there that their water sources are going to be polluted. A lot of the farmers there were offered a lot of money to sell their mineral rights so that the oil companies could come in and start fracking, and a lot of people there had no knowledge of it. They didn't really care. They just wanted the money, and it's already started there. ... Then all of a sudden, they thought they were prepared, just like the tidal wave that knocked out the nuclear plant in Japan. They thought they were prepared until it actually happened, and then they realized they weren't. That's my concern... I'm not aware of all the research that has been proven to make this a safe way to extract more oil.

This story illustrates how health hazards result from lack of regulatory and industry precaution, placing local residents at risk of fresh water contamination. Susan questioned why safety concerns arose only after past accidents and wonders if the risk is worth the consequences. Unknowns and potential unintended consequences of shale development also came up again in

Santa Barbara, where participants struggled to assess potential health and safety impacts with unknown risk factors and missing data:

Miriam (F/45-54/Hispanic): *Well, how do we know that earthquakes in Oklahoma that were stimulated by fracking are not going to affect the earthquakes that we have here?*

Susan: *Well, I can just say that in Florida, the water aquifers, as they are being used they create sinkholes, and sometimes people's houses fall into the earth because the water's all gone from the cavity. That happens. ...*

Kim (F/45-54/White): *I think the problem is that we haven't seen the consequences and we had to see to believe things in our country and I think in the world—human nature. And because we haven't really seen... I mean on a personal level... to really want to do something and be motivated because people are motivated by consequences, and we haven't seen those consequences yet, right?*

Olivia (F/45-54/Other): *I'm also wondering has there been any studies or any kind of reports on health impacts? And because it says that it raises the radiation levels. So, there's some correlation, and so yeah. [Laughs]*

Ron: *Yeah, that is a concern.*

In this dialogue, the first four participants ask probing questions about shale development's known effects on earthquakes, sinkholes, and radiation and wanted more research done on the health effects of shale development before implementation.

Amid this series of questions about shale development's potential health risks, Kim suggested that first-hand experience of the risks is key to understanding the consequences. However, others worried that by the time someone experiences the effects of shale development, it could be too late. In contrast to Kim's wait-and-see approach, Jess (F/18-24/White) in Cardiff discussed proactive monitoring of shale development as a way to prevent adverse exposures: '*how do they know if, if it's like, if there's a small, I'd say like hole or something in the area that they're storing it in, when do they become aware that it's leaking? Do they have people checking on it all the time or do they just leave it to its own devices and hope for the best? Like how do they monitor, ... whether it's actually leaking into some other area and we're consuming it without even knowing in small quantities?*' These deliberations elicited concern over not just the form of shale development's health risks, but also who would bear the burden of risk, who would be responsible for risk management/mitigation, and whether they could be trusted.

Some participants distinguished between risk-makers and risk-takers. In Santa Barbara, Isabel (F/25-34/Hispanic) expressed unease about how one mistake from an oil company could put all the residents of California at risk: '*if you polluted an entire aquifer that serves like the entire state of California, that would be a huge issue.*'

Beyond concerns about the threat of health hazards to local and wider communities, there were also discussions of how shale oil and gas development could harm future generations. Gloria, (F/25-34/Hispanic), in Los Angeles, raised questions about the necessity of shale development with a concern for preserving families:

Gloria: *I mean I know we're not okay as we want to be, but we're doing fine. We're doing good. We have jobs. And then doing something that—okay, I'm not trying to be negative. Maybe it's going to happen or maybe it's not. You never know. But something—why take chances?... let's all help each other try to make things better for each other.* [emphasis added]

Frank: *Yeah, in a perfect world. But in this country, ... no matter what happens, we move forward. ... I mean you're absolutely right. In a perfect world, yeah. We worry about our children and our grandchildren. If something doesn't affect us but it might affect them, then we should be opposed to it. But in America, we move forward whether it's—[going to affect them or not]*

Here, Gloria and Frank discussed the potential consequences of shale development, asking ‘why take chances’ with things like families and future generations. These comments, often raised by women, reflect a concern about involuntary exposure of future generations as morally wrong.

Focus on the involuntary exposure of future generations was also often gendered: ‘...these are massive decisions that affect all of us, especially our children. We're ruining [the] world for our children and we don't get a kind of say in it’ (Bea, London).

‘Beyond the tipping point’

Throughout the deliberations, risks to natural resources that were seen as essential for sustaining life provoked the greatest health concern in both the US and UK, where participants expressed worry about individual and collective survival. Most often people linked these concerns to contamination, eroded quality, and excessive consumption of fresh water, an effect of deep

horizontal shale extraction. Participants observed that shale development threatened other essential resources as well, through environmental degradation and disturbance in the form of earthquakes, air pollution, and climate change. *'Beyond the tipping point'* reflects a concern that shale development could damage or permanently destroy natural resources essential for maintaining human health and sustaining life.

Risks to fresh water quality and quantity provoked the greatest concerns in both the US and UK (Evensen, 2016; Thomas, Partridge, et al., 2017), but there were nuances to this discussion across sites. In drought-afflicted Los Angeles, participants often defined health and safety and life itself as directly tied to a *clean and abundant water supply*: *'My first thought is... to keep healthy, stay healthy, and you need clean water for that'* (Marion, F/55-64/White). In the UK, risks associated with shale development's excessive water consumption were viewed as likely to be inequitably distributed: *'in areas where there are high levels of poverty and there's already a lot of industry going on that's taking up a lot of local water... it's just another drain on the resource that is already not quite available to people in the area'* (Laurel, F/35-44/White/Cardiff). Water shortages were seen as potentially threatening collective survival: *'water's a finite resource and it's one which we all will need in order to stay alive'* (Nadia, F/18-24/Other/London). Again, participants, particularly women, expressed moral concern for wider impacted national or global populations and potentially lethal effects.

Among Californians, earthquake risk from shale development and attendant risks of injury and/or death were viewed with palpable concern. Fears about the impacts or safety of shale development mixed with earthquakes were summed up by Frank (M/55-64/Hispanic) in Los

Angeles: ‘*What concerns me in terms of health is if they do it here in California with all the seismic activity here, ..., if they hit the whopper in the San Andreas, we’re all going to be up shit creek without a paddle.*’ In Santa Barbara, Ron argued that: ‘*Nobody likes earthquakes... [if people] would believe that fracking is going to cause even one major earthquake in the next five years or ten years, everybody here would go: Hey, we don’t need fracking. It’s not worth it*’.

Seismic effects of shale development to date have been limited in scale, but have occurred in areas with little or no prior history of seismicity in both the US and UK. The scale of potential earthquake effects in a seismically active such as California is unknown, but participants extrapolated their assessment of scale and scope of effects from this much higher level of baseline seismicity. Some UK participants also expressed considerable concern about earthquakes.

In workshops in both countries, some participants saw shale development as a ‘red line’ issue—one that people oppose pursuing under any circumstances: ‘*I still think there are some things we have to say no to*’ (Ellen F/55-64/White/London). In Los Angeles. Sally stated: ‘*We’re talking about our life. We’re talking about earthquakes. We’re talking about we’re going to die*,’ and Gloria (F/25-34/Hispanic) added: ‘*A lot of families are going to be destroyed... I’d rather just leave it alone.*’ Elsewhere, water quality and habitability have been described as a ‘protected value,’ meaning an aspect of the environment that ‘could not be compensated for by any level of benefit’ (Thomas, Partridge, et al., 2017, p. 5), leading to such ‘red line’ views. We argue here that these views are intricately connected as well to ideas about bodily health and harm.

Although these precautionary feelings are found in the context of many other technological issues (Stirling, 2007), the emphatic form they took in this one was notable.

This study reveals a surprising degree of consonance about the perceived health risks of fracking, given the divergent political and regulatory context for shale development. Although numerous subtle differences arose across national contexts, and particularly between our most diverse group (Los Angeles) and the other three groups, our findings reveal marked similarities across all four workshops on these 3 dominant themes. More subtle differences are woven through the comments above which include concerns in the US over familiar environmental disasters like earthquakes, and how participants' perceived health risks were shaped by social categories and inequalities within each national context. Overall, US and UK participants' conceptions of likely health impacts appear to be critical to judgments people in both countries make about risks associated with shale development.

5. Discussion

These three core analytic rubrics indicate greater concern over societal issues than technological risks among participants in both the US and UK. '*It's money or health*' reflects trade-offs people considered in weighing advantages versus disadvantages, such that potential for economic growth and employment opportunities could also put participants and communities at risk of bodily/environmental harm. '*Why take chances?*' specifies how participants grappled with unknowns about shale development's impact on human health and worried that governments and industry would be negligent with safety of individuals, communities, and future generations, preferring a precautionary approach. '*Beyond the tipping point*' indicates how participants saw shale development as messing irrevocably with the minimal requirements for sustaining life

(access to safe and clean water, air, and land), with human health seen as directly reflecting environmental health.

Throughout discussions, and across all four sites, participants introduced ‘health’ as a stable, non-problematized category, suggesting an assumption of shared meanings about health and its broader concept of wellbeing—they notably did not discuss potential health impacts in terms of specific symptoms or diagnoses or other immediate impacts—rather they referenced ‘health’ in a broad way, linked to ‘wellbeing’. This absence of detailed physical and mental health symptoms is a key difference to findings in downstream studies of shale development in the US, where stress and crime, traffic, noise, and light pollution (Jacquet, 2014; Sangaramoorthy et al., 2016) and other lurking ‘toxic uncertainties’ (Goldstein, 2014) threaten health. Instead, participants focused on the degradation and disturbance of the environment itself as the source of anticipated adverse health effects. We did identify in the workshop materials documented ‘disadvantages’ of adverse impacts on water quality and water quantity, earthquakes, and radiation, so it is possible that our framing contributed to people’s focus on environmentally induced health impacts. But the information on those disadvantages was carefully counterbalanced with information on economic and energy security benefits, so we argue that these dialogues reveal distinctive, selective ways people in both countries made sense of potential hazards as threats to health and wellbeing, the relative qualitative weights they placed on them (see Thomas, Partridge, et al., 2017 for quantitative data on these weightings), and how they anticipated embodying them (Lock, 2017). As noted above, for some participants shale development emerged as a ‘red line’ issue, one that should not go forward under any conditions.

Moral issues underlie all three analytic rubrics. Key normative, ethical, moral principles about health identified in dialogues include: that it is essential to protect the health of wider populations (even extending around the globe), not just one's own family and community; that the health of future generations is precious and fragile, and it is morally wrong to make decisions in the present that affect those whose interests would be so directly impacted; that governments and industry cannot be trusted to safeguard the public's health (see also Thomas, Partridge, et al., 2017); and that publics are entitled to full knowledge about the safety and/or adverse health impacts of new technologically based developments *before* they are asked to accept them. In addition to such human rights, informed consent, and other procedural justice issues, distributional justice issues regarding exposure to risks arose strongly. Environmental and social justice concerns have been noted across many downstream studies of shale development's societal implications (Clough, 2018). These ideas resonate with Gilligan's (2011) idea of a feminist 'ethics of care,' which she argues is a fundamental human ethic, anchored in core democratic values, that gives equal voice to all in experiences of moral conflict. Another critical moral concern that troubled our participants was the idea of *going forward with avoidable harm* (Prüss-Ustün et al., 2014), which is at odds with the precautionary principle (Evensen, 2016) and foresight (Guston et al., 2014). Together, participants' discussions of health were more connected to social categories and their underlying moral and ethical principles, that is, to social risk, than to technological details.

Although we cannot quantify this effect, there is compelling qualitative evidence that the politics of difference permeate people's views of the physical and nonphysical hazards of shale development, their likelihood of suffering health consequences, and their anticipated access to

resources necessary for protection, treatment, or cure. Social class and privileged access to resources were seen as providing insulation from the harmful effects of disasters, just as their absence signalled vulnerability. Women and people of colour in the most diverse group by race and class, in Los Angeles, more readily articulated their geospatial and social locations as constituting a type of ‘sacrifice zone’ (Lerner, 2010), a damaged environment with multiple toxic chemical (and social) exposures. We found clear evidence of ‘white male effect’ (WME) patterns of risk acceptance that contrast with the risk concerns and ideas of collective responsibility and mutual assistance articulated by many women and people of colour (Satterfield, Mertz, & Slovic, 2004). Earlier analysts have argued that such differentiated concerns by race, class, and/or gender arise in connection with local, direct contamination experiences (Davidson & Freudenburg, 1996) and vulnerability (Satterfield et al., 2004). However, our study also found deeply moral, collective responsibility that extends far beyond the local to wider impacted national or even global populations (Henwood, Parkhill, & Pidgeon, 2008).

Another feature that pervades the discussions we refer to as *compound risk*. Although this term has been used quantitatively elsewhere, here we use it to reference the way additional contextual information on co-occurring risks may result in overall social amplification of risk perception or a shift in perceived *prominence* of one risk over another (Pidgeon et al., 2003). The combined risk effects of known hazards such as radon exposure and smoking have been well studied, and the analysis of how hazards combine to present ‘synergistic risks’ has begun to be studied in health risk message contexts (Dawson, Johnson & Luke, 2013). However, in this case, we analyse the way emergent views incorporate multiple hazard information. In this study, the co-occurrence of multiple high salience and high-risk hazards, such as freshwater contamination,

excessive water consumption in conditions of scarcity, and seismic disturbance, even in the context of considerable possible economic benefit, resulted in intensification and acceleration of risk perception that is characterized by uncertainty and perceived uncontrollability, as well as fears for future generations. These compounded risks led to a pronounced theme of fear about mortality and bodily vulnerability in the case of future shale development. This was not individualised nor merely additive—it reflects an intensification of collective risk amplification: Sally's comment in Los Angeles, '*We're talking about we're going to die*' (see above) was a recurrent theme in one form or another.

While such 'narrow but deep' approaches facilitate rich discussions about complex and conditional viewpoints (Henwood & Pidgeon, 2016), they have limitations. Unlike a nationwide survey, the findings are in part constrained by the specific places in which we conducted them--our two California locations should not be taken to represent every part of the US, nor do Cardiff and London reflect the whole of the UK. The results must therefore be interpreted in relation to the specific circumstances in which they have been conducted. This includes the pre-impact context of our workshops; we might expect different conversations in downstream, high impact locations where shale development is established. We also note that unpredictable variations in final attendance resulted in our samples being imperfect representations of the cities from which they were drawn: particularly, the London group had higher than average levels of education and were less ethnically diverse than our quota, and the Cardiff and Santa Barbara samples were overrepresented by women (see Table 1). As our research focused exclusively on urban areas of varying size, we also believe future research could profitably be extended to explore the views of rural residents who are more commonly impacted by shale development.

Conclusion

Participatory public engagement to discuss shale development's likely future effects provides a method for systematic qualitative research that serves the mandates of responsible research and innovation (Stilgoe et al., 2013). While acknowledging rising critical analysis of some public engagement (Wynne, 2006), carefully constructed and fairly managed deliberations such as those reported here keep framing effects on the part of researchers to a minimum (Macnaghten, 2017b). These pre-impact deliberations provide a space for open reflection among diverse citizens and create a possibility for foresight and setting a new course, if called for. Using such a qualitative approach to understand people's environmental and cultural values, considering their social locations, *prior to* exposure to shale development's hazards, enables us to analyse people's deeper reflections on the innovation's policy implications and to argue that considerations of health can and should be part of governance procedures before decision-making. If 'non-mobilization' results from shale development exposures in some downstream locales (Eaton & Kinchy, 2016), then pre-impact engagement becomes imperative. This study demonstrates how even a liminal pre-impact context opens up the possibility of discussion of issues within wider communities of impact and responsibility.

In spite of noted limitations, this study shows that *health concerns are prevalent in pre-impact locales*. Furthermore, those ideas are socially situated in ways that reflect structural issues of inequality/privilege and disproportionality in environmental exposures (Brulle & Pellow, 2006). However, we note some differences from reported downstream patterns of shale development

health risk perception. In these pre-impact contexts, people conceptualized harms to health without emphasis on physical, clinical symptoms or morbidity. They also were concerned less with ‘local impacts’ of boomtown effects as sources of stress and health risk concern (see Thomas, Partridge, et al., 2017). Instead, they focused on the (unspecified) *situated embodiment* of environmental health (Lock, 2017), and in many cases find the compound risks of the shale development environmental health nexus to form a redline issue, a ‘tipping point’ for massive, unstoppable destruction. We find this consistent with other recent studies demonstrating the emergence of a ‘new politics of environmental degradation’ (Willow, 2014) and similar increasingly blurred boundaries between environment and health (Larrea-Killinger et al., 2017). However, a notable difference from widespread health research on increasing individualisation of risk and responsibility (for example, Mackendrick, 2014) is the emergence in both UK and US deliberations of a strong moral discourse about environment, health and the future, particularly in reference to collective responsibility for those living at a distance and for future generations. Health in this anticipatory approach thus serves as a springboard to vital discussions about the societal implications of new technologies and development, pathways to their responsible governance, and enhanced understanding of how diverse publics make them intelligible in the context of political, social and risk uncertainty.

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No financial interest or benefit has arisen from the direct applications of our research.

References

- Besley, J. C., Kramer, V. L., Yao, Q., Toumey, C. (2008). Interpersonal discussion following citizen engagement about nanotechnology: What, if anything, do they say? *Science Communication*, 30(2), 209-235.
- Benford, R. D., & Snow, D. A. (2000). Framing processes and social movements: An overview and assessment. *Annual Review of Sociology*, 26(1), 611-639.
- Boholm, Å. (2015). *Anthropology and risk*. London: Routledge.
- Boudet, H., Clarke, C., Bugden, D., Maibach, E., Roser-Renouf, C., & Leiserowitz, A. (2014). 'Fracking' controversy and communication: Using national survey data to understand public perceptions of hydraulic fracturing. *Energy Policy* 65, 57-67.
- Bowen, G. (2006). Grounded theory and sensitizing concepts. *International Journal of Qualitative Methods*, 5(3), 12-23.
- Bradshaw, M. (2016). *Integrated review of public perceptions of shale gas impacts*. Project report D20.1. European Union Horizon 2020 research and innovation program: M4ShaleGas Consortium. <http://www.m4shalegas.eu/reportsp4.html>
- Bradshaw, M., & Waite, C. (2017). Learning from Lancashire: Exploring the contours of the shale gas conflict in England. *Global Environmental Change*, 47, 28-36.
- Bröer, C., Moerman, G., Spruijt, P., & van Poll, R. (2014). Risk policies and risk perceptions: a comparative study of environmental health risk policy and perception in six European countries. *Journal of Risk Research*, 17(4), 525-542.
- Brulle, R. J., & Pellow, D. N. (2006). Environmental justice: Human health and environmental inequalities. *Annual Review of Public Health*, 27, 103-124.

- Casson, R. W. (1983). Schemata in cognitive anthropology. *Annual Review of Anthropology*, 12, 429-462.
- CCST. (2015). Well stimulation technologies and their past, present, and potential future use in California. California Council on Science and Technology, Sacramento No. 1.
- Charmaz, K. (2008). Grounded theory as an emergent method. In S. Hesse-Biber & P. Leavy (Eds.), *Handbook of emergent methods* (pp. 155-172). New York, NY: Guilford Press.
- Clarke, C., Hart, P., Schuldt, J., Evensen, D., Boudet, H., Jacquet, J., & Stedman, R. (2015). Public opinion on energy development: The interplay of issue framing, top-of-mind associations, and political ideology. *Energy Policy*, 81, 131-140.
- Clough, E. (2018). Environmental justice and fracking: A review. *Current Opinion in Environmental Science & Health*, 3. doi: 10.1016/j.coesh.2018.02.005
- Conti, J., Satterfield, T., & Harthorn, B. H. (2011). Vulnerability and social justice as factors in emergent US nanotechnology risk perceptions. *Risk Analysis: An International Journal*, 31(11), 1734-1748.
- Corner, A., and Pidgeon, N. (2012). Nanotechnologies and upstream public engagement: Dilemmas, debates and prospects? In B. Herr Harthorn & J. Mohr (Eds.), *The Social Life of Nanotechnology*, 169-194. New York, NY: Routledge.
- Davidson, D. (2018). Evaluating the effects of living with contamination from the lens of trauma: A case study of fracking development in Alberta, Canada. *Environmental Sociology*, 4(2), 196-209.
- Davidson, D., & Freudenburg, W. (1996). Gender and environmental risk concerns: A review and analysis of available research. *Environment & Behavior*, 28, 302-339.

Davies, S., Macnaghten, P., & Kearnes, M. (Eds.) (2009). *Reconfiguring responsibility: Lessons for public policy (Part 1 of the report on Deepening Debate on Nanotechnology)*.

Durham University, Durham, UK.

Dawson, I., Johnson, J., & Luke, M. (2013). Helping individuals to understand synergistic risks:

An assessment of message contents depicting mechanistic and probabilistic concepts.

Risk Analysis 33(5), 851-861.

DECC (UK Department of Energy and Climate Change). (2017). *Energy Trends: electricity*.

<https://www.gov.uk/government/collections/electricity-statistics>

Dietz, T. (2013). Bringing values and deliberation to science communication. *PNAS*, 110,

14081–14087.

Eaton, E., & Kinchy, A. (2016). Quiet voices in the fracking debate: Ambivalence, nonmobilization, and individual action in two extractive communities (Saskatchewan and Pennsylvania). *Energy Research & Social Science*, 20, 22-30.

EIA (US Energy Information Administration). (2018). *United States remains the world's top*

producer of petroleum and natural gas hydrocarbons. Retrieved from:

<https://www.eia.gov/todayinenergy/detail.php?id=36292>

Evensen, D. (2016). Ethics and ‘fracking’: A review of (the limited) moral thought on shale gas development. *WIREs Water*, 3(4), 575-586.

Evensen, D., Stedman, R., O’Hara, S., Humphrey, M., & Andersson-Hudson, J. (2017).

Variation in beliefs about ‘fracking’ between the UK and US. *Environmental Research Letters*, 12(12), 124004.

Felt, U., & Fochler, M. (2010). Machineries for making publics: Inscribing and de-scribing publics in public engagement. *Minerva*, 48(3), 219-238.

- Finkel, M. L., & Hays, J. (2015). Environmental and health impacts of 'fracking': Why epidemiological studies are necessary. *Journal of Epidemiology and Community Health*, 70(3), 221-222.
- Fiorino, D. J. (1990). Citizen participation and environmental risk: A survey of institutional mechanisms. *Science, Technology & Human Values*, 15(2), 226-243.
- Gilligan, C. (2011). *Joining the resistance*. Oxford, England: Polity Press.
- Goldstein, D. M. (2014). Toxic uncertainties of a nuclear era: Anthropology, history, memoir. *American Ethnologist*, 41(3), 579-584.
- Guston, D. H., & Sarewitz, D. (2002). Real-time technology assessment. *Technology & Society* 24, 93–109.
- Guston, D. H., Fisher, E., Grunwald, A., Owen, R., Swierstra, T. & van der Burg, S. (2014). Responsible innovation: motivations for a new journal. *Journal of Responsible Innovation*, 1(1), 1-8.
- Henwood, K., & Pidgeon, N. (2016). Interpretive environmental risk research: Affect, discourses and change. In J. Crichton, C. Candlin & A. Firkins (Eds.), *Communicating risk: Communicating in Professions and Organizations*, (pp. 155-170). London: Palgrave Macmillan.
- Henwood, K. L., Parkhill, K., & Pidgeon, N. (2008). Science, technology and risk perception: From gender differences to the effects made by gender. *Equal Opportunities International*, 27, 662-676.
- Horlick-Jones, T., Walls, J., Rowe, G., Pidgeon, N., Poortinga, W., and O'riordan, T. (2007). On evaluating the GM Nation? Public debate about the commercialization of transgenic crops in Britain. *New Genetics & Society*, 25, 3, 265-288.

Hughes, J. D. (2013). *Drilling California: a reality check on the Monterey Shale*. Post Carbon Institute.

Irwin, A., Simmons, P., & Walker, G. (1999). Faulty environments and risk reasoning: the local understanding of industrial hazards. *Environment and planning*, 31(7), 1311-1326.

Jacquet, J. B. (2014). Review of risks to communities from shale energy development. *Environmental Science & Technology*, 48(15), 8321-8333.

Kiparsky, M., & Foley Hein, J. (2013). *Regulation of hydraulic fracturing in California: A wastewater and water quality perspective*. Berkeley, CA: University of California Berkeley Law, Center for Law, Energy & the Environment.

Larrea-Killinger, C., Munoz, A., Mascaro, J., Zafra, E., & Porta, M. (2017). Discourses on the toxic effects of internal chemical contamination in Catalonia, Spain. *Medical Anthropology*, 36(2), 125-140.

Lehoux, p., Williams-Jones, B., Miller, F. A., Fishman, J., Yivon, M., & Vachon, P. (2014). Examining the ethical and social issues of health technology design through the public appraisal of prospective scenarios: a study protocol describing a multi-media-based deliberative methods. *Implementation Science*, 9, 81.

<http://www.implementationscience.com/content/9/1/81>

Lerner, S. (2010). *Sacrifice zones: The front lines of toxic chemical exposure in the United States*. Cambridge, Mass: MIT Press.

Lock, M. (2017). Recovering the body. *Annual Review of Anthropology*, 46(1), 1-14.

Lorenzoni, I., Leiserowitz, A., de Franca Doria, M., Poortinga, W., & Pidgeon, N. F. (2006).

Cross-National comparisons of image associations with “global warming” and “climate

- change” among laypeople in the United States of America and Great Britain. *Journal of Risk Research*, 9(3), 265-281.
- Mackendrick, N. (2014). More work for mother: Chemical body burdens as a maternal responsibility. *Gender & Society*, 28(5), 705-728.
- Macnaghten, P. (2017a). Focus groups as anticipatory methodology: A contribution from science and technology studies towards socially resilient governance. In R. S. Barbour & D. L. Morgan (Eds.), *A New Era in Focus Group Research: Challenges, Innovation and Practice* (pp. 343-363). London, UK: Palgrave Macmillan.
- Macnaghten, P. (2017b). Public perception: Distrust for fracking. *Nature Energy* 2.
- Macnaghten, P., Davies, S. R., & Kearnes, M. (2015). Understanding public responses to emerging technologies: a narrative approach. *Journal of Environmental Policy & Planning*, 1-19.
- OGA (UK Oil and Gas Authority). (2015). Retrieved from: <https://www.ogauthority.co.uk/news-publications/news/2015/>
- Owen, R., Bessant, J., & Heintz, M. (Eds.) (2013). *Responsible innovation: Managing the responsible emergence of science and innovation in society*. London: Wiley.
- Partridge, T., Thomas, M., Harthorn, B. H., Pidgeon, N., Hasell, A., Stevenson, L., & Enders, C. (2017). Seeing futures now: Emergent US and UK views on shale development, climate change and energy systems. *Global Environmental Change*, 42, 1-12.
- Perry, S. (2013). Using ethnography to monitor the community health implications of onshore unconventional oil and gas developments: Examples from Pennsylvania's Marcellus Shale. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, 23, 33-53.

- Pidgeon, N., Demski, C., Butler, C., Parkhill, K., & Spence, A. (2014). Creating a national citizen engagement process for energy policy. *Proceedings of the National Academy of Sciences*, 111(Supplement 4), 13606-13613.
- Pidgeon, N., Harthorn, B. H., Bryant, K., & Rogers-Hayden, T. (2009). Deliberating the risks of nanotechnologies for energy and health applications in the United States and United Kingdom. *Nature Nanotechnology*, 4, 95-98.
- Pidgeon, N., Kasperson, R., & Slovic, P. (Eds.) (2003). *The social amplification of risk*. Cambridge, UK: Cambridge University Press.
- Pidgeon, N., Parkhill, K., Corner, A., & Vaughan, N. (2013). Deliberating stratospheric aerosols for climate geoengineering and the SPICE project. *Nature Climate Change*, 3, 451-457.
- Pidgeon, N., & Rogers-Hayden, T. (2007). Opening up nanotechnology dialogue with the publics: Risk communication or 'upstream engagement'? *Health, Risk & Society*, 9, 191-210.
- Prüss-Ustün, A., Bartram, J., Clasen, T., Colford, J. M., Cumming, O., Curtis, V., . . . Cairncross, S. (2014). Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. *Tropical Medicine and International Health*, 19(8), 894-905.
- Renn, O. (1999). A model for an analytic-deliberative process in risk management. *Environmental Science & Technology*, 33, 3049-3055.
- Rip, A., Misa, T., & Schot, J. W. (Eds.). (1995). *Managing technology in society: The approach of Constructive Technology Assessment*. London: Pinter Publishers.

- Sangaramoorthy, T., Jamison, A. M., Boyle, M. D., Payne-Sturges, D. C., Sapkota, A., Milton, D. K., & Wilson, S. M. (2016). Place-based perceptions of the impacts of fracking along the Marcellus Shale. *Social Science & Medicine*, 151, 27-37.
- Satterfield, T., Mertz, C. K., & Slovic, P. (2004). Discrimination, vulnerability, and justice in the face of risk. *Risk Analysis*, 24, 115-129.
- Saunders P. J., McCoy, D., Goldstein, R., Saunders, A. T., & Munroe, A. (2018). A review of the public health impacts of unconventional natural gas development. *Environ Geochem Health*, 40, 1-57.
- Simonelli, J. (2014). Home rule and natural gas development in New York: Civil fracking rights. *Journal of Political Ecology*, 21(1), 258–278.
- Stern, P., Webler, T., & Small, M. J. (2014). Understanding the risks of unconventional shale gas development. *Environmental Science & Technology*, 48, 8287-8288.
- Stilgoe, J., Irwin, A., & Jones, K. (2006). *The received wisdom: Opening up expert advice*. London: Demos.
- Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy*, 42, 1568-1580.
- Stirling, A. (2007). Risk, precaution and science: Towards a more constructive policy debate. Talking point on the precautionary principle. *EMBO Reports*, 8 (4). pp. 309-315.
- <http://sro.sussex.ac.uk>
- Thomas, M., Partridge, T., Harthorn, B. H., & Pidgeon, N. (2017). Deliberating the perceived risks, benefits, and societal implications of shale gas and oil extraction by hydraulic fracturing in the US and UK. *Nature Energy*, 2, 17054.

- Thomas, M., Pidgeon, N., Evensen, D., Partridge, T., Hasell, A., Enders, C., Harthorn, B.H. and Bradshaw, M. (2017). Public perceptions of hydraulic fracturing for shale gas and oil in the United States and Canada. *WIREs Climate Change*, e450. 10.1002/wcc.450
- Vaughan, E., & Nordenstam, B. (1991). The perception of environmental risks among ethnically diverse groups. *Journal of Cross-Cultural Psychology*, 22(1), 29-60.
- Williams, L., Macnaghten, P., Davies, R. J., & Curtis, S. (2015). Framing 'fracking': Exploring public perceptions of hydraulic fracturing in the United Kingdom. *Public Understanding of Science*, 26(1), 89-104.
- Willow, A. J. (2014). The new politics of environmental degradation: Un/expected landscapes of disempowerment and vulnerability. *Journal of Political Ecology*, 21, 237–257.
- Wilsdon, J., & Willis, R. (2004). *See-through science: Why public engagement needs to move upstream*. London: Demos.
- Wylie, S. A. (2018). *Fractivism: Corporate Bodies and Chemical Bonds*. Durham, NC: Duke University Press.
- Wynne, B. (2006). Public engagement as a means of restoring public trust in science—hitting the notes, missing the music? *Community Genetics* 1, 211-220.