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Citation for final published version:

Thomas, Merryn, Partridge, Tristan, Herr Harthorn, Barbara and Pidgeon, Nick 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. 10.1038/nenergy.2017.54 file

Publishers page: <http://dx.doi.org/10.1038/nenergy.2017.54>  
<<http://dx.doi.org/10.1038/nenergy.2017.54>>

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1 **Deliberating the perceived risks, benefits and societal implications of shale**  
2 **gas and oil extraction by hydraulic fracturing in the US and UK**

3

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10 **Short title for mobile devices and RSS feeds:** Perceived risks of shale development in the US and  
11 UK

12

13 **Keywords:** deliberation / risk perception / shale gas and oil / fracking / hydraulic fracturing

14

15 **Author contributions:** MT, TP, NP and BHH designed and performed the research; MT and TP  
16 analyzed the data; MT, TP, NP and BHH wrote the paper.

17

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26

27

1 **Abstract**

2 Shale gas and oil production in the US has increased rapidly in the last decade, while interest in  
3 prospective development has also arisen in the UK. In both countries, shale resources and the method  
4 of their extraction (hydraulic fracturing, or ‘fracking’) have been met with opposition amid concerns  
5 about impacts on water, greenhouse gas emissions, and health effects. Here we report the findings of a  
6 qualitative, cross-national deliberation study of public perceptions of shale development in UK and  
7 US locations not yet subject to extensive shale development. When presented with a carefully  
8 calibrated range of risks and benefits, participants’ discourse focused on risks or doubts about  
9 benefits, and potential impacts were viewed as inequitably distributed. Participants drew on direct,  
10 place-based experiences as well as national contexts in deliberating shale development. These  
11 findings suggest that shale gas development already evokes a similar ‘signature’ of risk across the US  
12 and UK.

1 The development of hydraulic fracturing ('fracking') techniques, by which pressurized liquid and  
2 sand are injected into wells to fracture shale rock and extract oil and gas, has led to rapid increases in  
3 US domestic fossil fuel production. Other countries, including in Europe, are looking to emulate this  
4 lead. In some US states the commercial development of shale has accelerated rapidly in the last  
5 decade, leading to full-scale extraction industries (e.g., in Pennsylvania, Colorado, Texas). In the UK,  
6 as conventional reserves decline, the government is looking for new sources of fossil fuels, arguing  
7 that shale gas production could reduce dependency on imports. However, in both countries shale  
8 development has attracted significant environmental and legal controversy, with fracking proposals in  
9 some US states leading on occasion to local, regional or state-wide moratoria. In addition, scientists  
10 forecast that most of the world's known fossil fuel reserves must remain in the ground if global  
11 warming is to be limited to 2°C above pre-industrial levels[1], while more localized concerns about  
12 hydraulic fracturing include potential risks of water contamination and induced seismicity[2, 3] as  
13 well as social impacts and health effects[4].

14

15 An important means of understanding how controversy arises in the case of energy technologies is to  
16 investigate how ordinary citizens themselves interpret the issues involved[5]. While a mix of  
17 empirical, primarily survey approaches has been used to explore citizen perceptions to date[6], there  
18 have been recent calls for greater public engagement and deliberation regarding hydraulic  
19 fracturing[7]. Such engagement is important because potentially affected people have a right to be  
20 heard and to have their values taken into account in decisions about risky technologies, while  
21 participation can also increase legitimacy and improve confidence in decision makers[8]. The US  
22 National Research Council has developed a detailed set of 'analytic-deliberative' proposals for public  
23 engagement with risk issues[9]. They argue that failure to attend to dialogue at the early stages of the  
24 emergence of an issue, where problem definition is critical, can be particularly costly in subsequent  
25 stages of risk characterization. The value of early public engagement is also elucidated in discussions  
26 of 'upstream' public participation[10], which involves the consideration of uncertainties and  
27 social/ethical issues prior to significant research being conducted or decisions to deploy a technology  
28 at scale. Salient questions for upstream engagement include: What is a technology for? What is the  
29 need? Who owns it? Who will be responsible if things do go wrong? Who will lose and win from the  
30 technology, and will unintended or unanticipated consequences follow? By encouraging an 'opening  
31 up' of debates, and allowing new themes and directions to emerge unprompted[11], such engagement  
32 processes offer insight into co-produced meanings and in particular the deeper social discourses  
33 underlying people's perceptions, including moral, ethical and other societal concerns. Debating such

1 issues early in a technology's life, or as here prior to large-scale 'downstream' deployment in a study  
2 location, serves to elicit extant citizen values[12][13] and national level issues[14] that underlie  
3 concerns, while also insulating the discussions from some of the more acrimonious disputes about  
4 process equity that often dominate debates when proposals are advanced for siting a technology  
5 locally[15].

6

7 We hypothesized that divergent national contexts in the US and UK (of energy history and supply,  
8 land and mineral ownership rights, cultural values, etc.) might have important implications for how  
9 shale development risks and benefits come to be perceived. Although comparisons of media  
10 discourses in different countries have been conducted[16], cross-national comparisons of public  
11 deliberations are lacking. The current study comprised one-day workshops in locations not yet subject  
12 to extensive shale development: Los Angeles (LA), Santa Barbara (SB), London (LN) and Cardiff  
13 (CF). Engaging with such a 'liminal' case[17] for deliberation – through convening workshops in  
14 locations without development, but linking the discussions to both 'upstream' (i.e. extant and  
15 national-scale) and 'downstream' (deployed, localized, and site-based) issues – draws attention to how  
16 citizen concerns can vary across different social and geographical locations, levels of technology  
17 maturity, and over time. The findings focus on the range of perceived risks and benefits of shale  
18 development, and illustrate how participants provided meaning to these in relation to broader  
19 considerations of local contexts, skepticism and equity. While we report data from quantitative tasks,  
20 our core observations are based upon a detailed analysis of in-depth qualitative data elicited  
21 throughout the workshop discussions.

22

### 23 **Perceived Benefits and Risks of Shale Development**

24 Figure 1 summarizes participants' aggregate importance rankings for each of six proposed advantages  
25 and disadvantages of shale development presented in the poster task (see Methods for an explanation  
26 of each workshop task, and Supplementary Data 1 for the detailed protocol). Potential energy  
27 security/independence, as well as economic and employment benefits tended to be perceived as the  
28 most important, reflecting policy language and media discourse in both countries[16][18]. The notions  
29 of energy independence (US) and energy security (UK) (i.e. reduced dependence on imports) were  
30 viewed positively, for reasons including increased control over national energy prices, avoiding being  
31 'dictated to' by other countries (Ken, CF), and acquiring oil and gas without '*destroying someone*  
32 *else's environment for our benefit*' (Isabel, SB). It is notable that Los Angeles participants prioritized

1 potential energy price cuts over energy independence, reflecting widespread worries in this group  
2 about energy bills. Another important benefit was the potential for mitigating climate change, often  
3 used as a proxy for risks to health and the environment more generally. However, as discussed below,  
4 people in all groups expressed skepticism about whether benefits were realizable.

5 [Figure 1]

6

7 Risks to water, particularly to water quality, were among the greatest concerns identified in the US  
8 and UK, echoing previous research in both nations[6][19][20], aligning with media coverage of  
9 risks[21], and reflecting wider negative public reactions to chemical contamination[22]. For some  
10 participants the risk to water seemingly outweighed any benefits of shale extraction operations and  
11 were perceived as long-lasting and irreversible – characteristics widely documented to produce  
12 amplified risk perceptions[23] – and with the potential to affect the *habitability* of a place: ‘*if your*  
13 *water quality is ruined, you actually can’t live here*’ (Susan, SB).

14

15 Localized impacts such as traffic and noise from oil and gas development tended to be ranked low  
16 across all workshops; being viewed as less significant or ‘*not as bad as the rest*’ (Andrew, LN) and  
17 more of a nuisance than something that ‘*really impacts your life*’ (Frank, LA). This was due partly to  
18 people’s perceptions of having greater control over (and ability to avoid) impacts like traffic and noise  
19 – reflecting theories that voluntary and controllable risks are more acceptable than involuntary and  
20 uncontrollable ones[23]. Drawing on direct personal experiences, Londoners described the urban  
21 context as a place where people already experience manifold disturbances, where ‘*there’s all the*  
22 *vibrations from the tubes and everything – you just accept everything*’ (Lois, LN). Similarly, in Los  
23 Angeles, some felt that such impacts would be negligible in the wider context of existing everyday  
24 pressures of traffic, noise and air pollution – things that are ‘*an everyday thing out here*’ (Scott, LA).  
25 This low prioritization of localized risks likely reflects the current upstream state of shale  
26 development in the four study locations: with impacts such as increased traffic (alongside advantages  
27 such as local jobs) expected to gain in importance in places already experiencing  
28 development[24][25].

29

30 Climate change was discussed primarily as a global issue. Cardiff participants also commented that  
31 they themselves were not yet acutely experiencing climate impacts, situating it as a ‘distant’ risk[26].

1 However, there was concern that while shale development might constitute a short-term insurance  
2 against diminishing energy supplies it simultaneously deflects attention and action from long-term  
3 steps towards more sustainable energy sources, by taking ‘*people’s eye off the ball in developing*  
4 *renewable energy sources*’ (Ken, CF). This is important because participants in all groups – and  
5 particularly Cardiff, London and Santa Barbara – expressed a strong preference for renewable energy  
6 over finite fossil fuels, echoing other research in both countries[13][27].

7

## 8 **Balancing Discourses of Risk and Benefit**

9 Risk more than benefit framed shale perceptions in both the California and UK discussions, even  
10 though information regarding potential benefits was readily available. This persisted despite little  
11 direct experience of risks or benefits in either region. When surveyed at the end of the workshop, in  
12 all four cities more participants felt that risks outweighed benefits than vice versa (Figure 2[a]).  
13 Although initially most participants were neutral or undecided about how fracking made them feel,  
14 when asked again about this at the end of the workshops (Figure 2[b]) only two out of 55 participants  
15 felt ‘good’, while 22 felt bad or very bad (40%).

16 [Figure 2]

17

18 Our concluding survey did not differentiate between indifference, ambivalence[28] and need for  
19 additional information[29]. However, the qualitative data indicates that ‘neither good nor bad’  
20 responses in Figure 2[b] – which represented at least 50% in each group – largely reflected  
21 ambivalence about perceptions of both high benefits and high risks, as previously identified in  
22 responses to other emergent technologies[30]. Ambivalence often reflects not only an unwillingness  
23 to trade-off perceived risks against uncertain benefits, but equally that the acceptability of any  
24 uncertain new technology is conditional; e.g. on assurances that appropriate risk governance is in  
25 place[31]. The Los Angeles group expressed the most ambivalence. In this group more than any other,  
26 there was a notion that while shale development is bad, it is nevertheless necessary for the economy –  
27 a pattern similar to responses to nuclear power characterized in other studies as ‘reluctant  
28 acceptance’[32]. There was also a feeling amongst some Los Angeles participants that they had  
29 already lost the battle for protecting their environment and were powerless to intervene, while for  
30 some, familiarity with extant oil extraction operations resulted in risk attenuation: ‘*growing up here in*  
31 *LA, I’ve seen those oil pumps... all over Southern California. It never bothered me, and so I wouldn’t*  
32 *think twice if they started fracking*’ (Carlos, LA).

1

2 UK participants, by contrast, have much less experience with onshore oil and gas development.  
3 Instead, Cardiff participants referred to historical experiences of coal extraction from the extensive  
4 Welsh coalfields, and to a lesser extent heavy industries, in making sense of potential shale  
5 development. For example, when comparing shale gas/oil with other energy options, Ellie (CF) noted  
6 that *‘in Wales we see the coal mining industry, that’s part of our heritage [...] we don’t necessarily*  
7 *see it as a negative thing.’*

8

### 9 **Skepticism, Distrust and Equity**

10 When citizens are given the opportunity to debate technical risk issues, their judgements of what  
11 counts as ‘risk’ and ‘benefit’ invariably go beyond those included in formal assessments. For  
12 example, people may worry about social impacts such as threats to local community cohesion or  
13 identity that are poorly modelled in technical assessments[19]. In our workshops, these issues  
14 coalesced around themes of skepticism, distrust and equity. In all four workshops, participants  
15 critically questioned claims made for shale development, particularly the likelihood of future benefits  
16 materializing[31]. Although some skepticism was also expressed in Los Angeles about whether risks  
17 would materialize, with Scott stating *‘for all you know, a lot of the disadvantages, they may never*  
18 *appear’*, skepticism emerged in all groups surrounding potential advantages, particularly those related  
19 to climate change and the economy. For example, shale oil and gas were seen as constituting a short-  
20 term fix leading to an unwanted dependency on finite fossil fuels at the expense of renewables,  
21 consistent with other evidence on preferences in both countries for moving away from fossil  
22 fuels[13][27]. Participants also stated that economic and employment benefits were not unique to  
23 shale development and would equally apply to significant investment and scaling-up of renewable  
24 technologies. More specific doubts were expressed about the reliability of economic forecasts.  
25 Participants, particularly in LA, were concerned about the number and types of jobs, the longevity of  
26 contracts, worker safety and whether labor would be sourced locally – issues that have surrounded  
27 shale development elsewhere in the US[33].

28

29 Participants were skeptical that energy price cuts would be passed onto consumers (see also Figure 1),  
30 particularly in the UK where the ‘advantages’ information outlined potential limits to price benefits  
31 due to Britain’s connectivity with the European gas market[34]. Some also argued that selling gas to

1 Europe was inconsistent with the goal of increasing UK energy security. Indeed, while energy security  
2 / independence were viewed favorably in all workshops, there was skepticism in both countries about  
3 the feasibility of this in a globalized economy. Finally, and in contrast to some research that suggests  
4 economic incentive packages for host communities increases support for shale development[35], we  
5 found that such incentives were often interpreted as ‘*bribes*’ (Jess, CF). In other areas of siting  
6 controversy such an interpretation is found to be likely if people simultaneously distrust the party or  
7 institution offering that incentive[36].

8

9 In all groups a desire was expressed for more certainty. Before making a judgment on shale  
10 operations, participants called for ‘*black and white answers*’ (Bea, LN), research that is ‘*really*  
11 *conclusive*’ (Isabel, SB), ‘*confirmed facts*’ (Frank, LA) and ‘*statistics*’ (CF, Samantha). Much of the  
12 desire for more certainty stemmed from a lack of trust in those who provide information – including  
13 government officials, industry representatives and, to a lesser extent, scientists – and in both countries  
14 there was a suggestion that the public are sometimes deliberately misled by government and industry.

15

16 More respondents in both countries disagreed or strongly disagreed that the national government is  
17 taking appropriate measures to regulate fracking than those who agreed (Figure 2[c]), and participants  
18 in both countries called for more *independent* regulation. Different concerns in the US and UK  
19 reflected different models of governance of extractive industries. In the US, some participants wanted  
20 more standardized federal guidelines and long-term accountability, calling for this to be done with  
21 ‘*tailoring to the unique situation of each state*’ (Julia, SB). Conversely, in the UK, where regulation is  
22 predominantly at the national level, participants were concerned that ‘*local authority powers are*  
23 *vetoed by central Government powers*’ (Paul, LN), and there were calls for more local control.  
24 Skepticism was also voiced in both countries with regard to the motives of corporations, with a  
25 majority of participants disagreeing that gas/oil and energy corporations can be trusted to ensure that  
26 ‘fracking’ is done safely (Figure 2[d]). Some referred to historical events and disruption linked to the  
27 extractive industries and other technologies [c.f. 37] and suggested corporations act out of  
28 responsibility to shareholders rather than the public good.

29

30 It is well documented that different communities are divided in terms of unequal exposure to risk –  
31 particularly along lines of race and class – with technological hazards more likely to be located in

1 minority communities[38]. In our workshops, participants saw the impacts of shale development as  
2 likely to be inequitably distributed in space, time and across social divides. In both countries, it was  
3 noted that the majority of proposed benefits would be relatively short term (e.g., jobs of limited  
4 duration) while the risks would almost certainly be longer term (e.g., environmental degradation).  
5 Benefits would be reaped by those who hold power – governments and politically powerful  
6 corporations – leading to feelings of inefficacy amongst participants who felt *‘very small and*  
7 *insignificant in the whole process’* (Miriam, SB). In some parts of the US where shale development is  
8 established, landowners can profit from leasing their property for oil/gas extraction[39], but  
9 participants in Santa Barbara and particularly in Los Angeles saw themselves as unable to access such  
10 benefits. Indeed, the strongest feelings of inequality were voiced in Los Angeles, where participants  
11 argued that companies don’t answer to poor people (‘like us’): *‘[corporations] don’t answer to me.*  
12 *They’ve got to answer to shareholders, [and] poor people don’t buy corporate shares.’* (Frank, LA).  
13 Here, there was also a palpable feeling of being members of targeted or ‘sacrificed’ communities: *‘the*  
14 *people that are most likely going to suffer are going to be the less fortunate, the ones that we don’t*  
15 *know how to fix this, the ones that we don’t have control over a lot of things.’* (Sally, LA).

16

## 17 **Cross-Nation Similarities and Differences**

18 Comparing the California and UK data we found similarities pertaining to: the ambivalent nature of  
19 risk ‘acceptability’; discourses around risks rather than benefits; skepticism about potential benefits;  
20 and concerns about inequitable distribution of risks and benefits. Such themes persist despite different  
21 regulatory contexts, extraction histories, mineral and land ownership patterns, risk and deliberation  
22 histories, and different cultural values existing between the US and UK, consistent with other  
23 comparative research on US and UK perceptions of energy[40] and some emerging technologies[41].  
24 We also find common ground where cultural divergences might otherwise have been expected. In  
25 both countries participants expressed a desire for concrete statistical evidence alongside a reluctance  
26 to accept expert knowledge entirely at face value – styles of objectivity previously described as  
27 characteristic of US civic epistemologies[42]. Furthermore, deep-seated distrust of government and  
28 institutions characteristic of the US[43] also emerged amongst UK respondents, corroborating  
29 findings from other deliberative research of future shale development in the UK[31]. The authors of  
30 the latter study conclude that citizen views in the UK have been affected by a climate of political and  
31 media discourse that has consistently misrepresented the ‘public’ view (as simply uninformed about  
32 the ‘true’ risks), thereby further alienating public sentiment.

1

2 Despite these similarities, important national-scale differences were also present. One stemmed from  
3 the greater visibility of onshore gas and oil in California (as is the case also in other areas of the US),  
4 which may have resigned our US participants to new shale developments, and another, as noted  
5 above, to divergent concerns relating to the level at which governmental control is exercised  
6 (reflecting different modes of governance in each country). Direct, place-based experiences provide  
7 an important vehicle for anchoring unfamiliar risks in more concrete terms, expressing learning from  
8 recent history, and empathizing with those exposed to risks. In some cases, past and current  
9 experiences with the regional oil industry in California served to minimize concern about future risks  
10 from potential shale development. In others, personal experiences of water shortages and earthquakes  
11 amplified this sense of risk. In the UK, where onshore oil and gas extraction is less common – and far  
12 less visible where it does exist – participants drew on tangential experiences of coal and heavy  
13 industries when making sense of what shale development might mean for them in the future. There  
14 were also marked differences between the US and UK responses to the potential risk of increased  
15 seismicity, which is to be expected considering California’s extensive earthquake history and the  
16 UK’s comparatively benign seismological context. Both California groups drew on past direct  
17 experiences of earthquake events in their localities, with earthquakes the primary concern amongst  
18 Los Angeles participants, who were worried that fracking operations could trigger a major earthquake.  
19 Conversely, in the UK earthquake risk received less attention, although there was some concern that  
20 earthquake impacts could be exacerbated in Britain due to high population density, aging  
21 infrastructure and a poor history of emergency response. Notably, however, participants in both the  
22 US and UK felt that if shale development were to cause earthquakes, however small, it should not be  
23 pursued.

24

## 25 **Discussion**

26 This study offers unique insights into commonalities and differences in public perceptions of shale  
27 development in both the US and UK. The deliberative approach facilitates exploration of underlying  
28 dimensions of perceptions of shale development when citizens are given access to extensive  
29 information and the opportunity to deliberate the issues as they saw them. Participants in both  
30 countries tended to value potential benefits to the economy, jobs and energy independence/security,  
31 and conversely the most significant risk perceptions related to water, particularly water contamination.  
32 While these findings are consistent with existing evidence from the US[6][19] and UK[20], the added

1 value of our in-depth discussions lies in the ways in which we can explore some of the underlying  
2 reasons for these attitudes. For example, the importance assigned to energy independence and security  
3 reflected the complex, polysemic nature of this concept[44], but stemmed primarily from concerns  
4 about dependence upon other countries and concerns over energy bills. In contrast, anxieties about  
5 water quality were often related, fundamentally, to the perceived impacts of shale development on  
6 habitability. The deliberative format allows exploration of attitude ambivalence and, conversely,  
7 particularly troubling trade-offs (both issues that are more difficult to investigate solely with  
8 quantitative survey methods). Regarding the latter, water quality and habitability could be  
9 characterized in our data as a ‘protected value’[45][46]. That is, a valued aspect of the natural  
10 environment that, if compromised, could not be compensated for by any level of benefit; thereby  
11 ultimately rendering shale development unacceptable to many workshop participants.

12

13 The study also highlights the importance of localized context in perceptions of risk: not surprising  
14 considering shale development is both a place-based and national issue. In engaging a diverse public  
15 sample, and in regions where shale development is at an early stage, we have been able to examine  
16 how both national as well as local factors influence perceptions. Given the importance highlighted  
17 here of local social, geographical and political context it would be unwise to extrapolate the findings  
18 of this study directly to locations where shale gas extraction is already underway (see Methods). This  
19 suggests a need for further in-depth and systematic public engagement experiments in such places, for  
20 which the current study serves as a methodological template.

21

22 Renn[47] shows that citizen deliberation can lead either to attenuation or amplification of risk  
23 perceptions, depending on the issue involved and deliberative methods adopted. Here, when presented  
24 with risk and benefit information, we found that participants in both the US and UK tended to focus  
25 on the negative aspects of shale development. This could be for many reasons. It may be that,  
26 regardless of information source, individuals are more likely to believe information that reports  
27 something is riskier than previously believed rather than safer[48]. Alternatively, this may be because  
28 pro-shale development is presently advanced primarily by actors (governments and corporations) who  
29 are little trusted by the public[49]. Taken alongside the strong negative reactions to water  
30 contamination risk in all workshop locations, along with preferences for renewable energy sources  
31 over fossil fuels as part of a long-term approach to meeting national energy needs, we are led to our  
32 core conclusion from this study - that the very concept of shale gas development, both as a specific

1 technology and a system of resource extraction, already evokes a powerful, amplified ‘signature’ of  
2 risk that is shared across cultural divides. Understanding the complexities underlying this signature  
3 will be the first step in more informed dialogue between the varied stakeholders to the shale debate in  
4 the US, Europe and elsewhere, and through this to promoting better decision-making on behalf of all  
5 concerned.

6

7 **[word count main text = 3726]**

8

## 9 **Methods**

10

11 **Sample.** We build upon existing deliberative approaches that have been used in past US-UK research  
12 to gain understanding of views of emerging technologies in both countries[41]. The study aimed to  
13 explore perceptions in the context of shale development in both California and the UK, both places  
14 not yet extensively affected by shale development. Following three pilot workshops in the UK and  
15 US, we held four full-day deliberative workshops in October 2014: two in California (Los Angeles  
16 and Santa Barbara) and two in the UK (London and Cardiff). These cities were chosen because they  
17 are of comparative size and scale, represent diverse demographics, and are located in areas that have  
18 not yet experienced shale development activities and associated high degrees of social or media  
19 amplification of risk concerns. Of the limited hydraulic fracturing that has taken place in California,  
20 most has been concentrated in shallow vertical wells in the San Joaquin Valley accessing conventional  
21 resources rather than shale, at considerable distance from our workshop locations. UK shale  
22 development is also emergent, with one shale well to date drilled and hydraulically fractured[34], and  
23 no shale development currently underway in or near either London or Cardiff, although there is  
24 potential close to both.

25

26 **Workshop Composition.** Each workshop involved between 10 and 16 participants (total N=55).  
27 Thus far, qualitative research in this field – in the US and UK – has tended to focus on interested and  
28 affected parties, groups representing ‘theoretically significant interests’ and stakeholders[50] [51]  
29 [52], with only one study to date engaging more representative publics[31]. Our ‘quasi-representative’  
30 groups were designed to be gender balanced and to match local demographics as closely as possible,  
31 though group composition was subject to unpredictable variance in final attendance. The groups were

1 designed to allow researchers and participants to explore a diversity of perspectives, drawing on  
 2 different kinds of experience, vulnerabilities and identities, from which emerge varying outlooks [53].  
 3 Recruitment was carried out by neutral third parties and was topic-blind; participants knew only that  
 4 the workshop would be about ‘technology and society.’ A summary of the demographic  
 5 characteristics of each group is shown in Table 1.

6 **Table 1: Summary demographics** (percentages may not sum to 100 due to rounding effects; \* one participant  
 7 in Cardiff withheld age ethnicity and education information).

City		Los Angeles	Santa Barbara	London	Cardiff*
Number of participants		16	15	10	14
Gender (female %)		50	67	50	71
Age profile (%)	18-34	44	27	40	43
	35-54	38	27	30	21
	55+	19	46	30	28
Ethnicity (non-white %)		75	53	30	7
Education (university degree or above %)		31	53	70	57

8  
 9

10 **Protocol.** The workshops consisted of carefully staged and sequenced activities (see below, and  
 11 Supplementary Data 1-6 for the full protocol and workshop materials) designed to engage participants  
 12 in full consideration of the advantages/benefits and disadvantages/risks of shale operations, as well as  
 13 additional issues such as values, trust, governance and energy preferences (for methodological  
 14 orientation see [12][14][54]). Throughout the day, participants were provided with information in  
 15 English in both written and spoken format. We composed materials with a neutral effect by providing  
 16 a range of types and sources of information inviting participants to select freely among them, and by  
 17 focusing our discussions and informational materials on ‘shale gas and oil extraction’ rather than  
 18 ‘fracking’ since the latter term has been linked to more negative associations[55]. Quantitative  
 19 surveys indicate that knowledge of shale development is relatively restricted in both the US and UK,  
 20 and the qualitative research that has been conducted so far has tended to focus upon locations with  
 21 developed plays, particularly the Marcellus region in the northeastern US[6]. Accordingly, the  
 22 workshop format and materials described here aimed to elicit ‘informed’ preferences and views  
 23 through the provision of balanced information, careful attention by moderators to issues of problem  
 24 framing and group dynamics, and by providing varied opportunities throughout the day for discussion  
 25 and deliberation (posters, small groups, plenary sessions)[14]. Longstanding and extensive evidence  
 26 testifies to the fact that citizens are, as a result, perfectly capable of learning, debating with each other  
 27 and facilitators both critically and respectfully, and arriving at well-founded positions about what  
 28 were initially unfamiliar science and technology topics[56] [57] [14] [31].

1

2 The workshop format was as follows. The day started with a two-page survey, which consisted of 11  
3 questions relating to familiarity with and feelings about hydraulic fracturing for shale gas and oil. This  
4 was followed by a welcome introduction and ice-breaking before participants were asked to provide  
5 ‘top-of-mind’/free associations for five terms: hydraulic fracturing/fracking, technology, energy,  
6 environment, and climate change. The team then delivered a twenty-minute PowerPoint presentation  
7 providing an introduction to shale gas and oil development, including processes, guidelines and an  
8 overview of national energy sources and uses. This presentation was followed by a whole-group  
9 discussion.

10 Next, half of the group discussed a poster about six potential advantages of shale and oil extraction  
11 (e.g. reduced dependence on imports, job creation, climate change mitigation, increased energy  
12 supply, local tax revenues, reduced energy bills), while the other discussed a poster about six potential  
13 disadvantages (e.g. impacts on water quality, climate change exacerbation, water usage, earthquakes,  
14 waste and by products, local impacts such as increased traffic). Participants were asked to rate the  
15 most important advantages/disadvantages, and place comments or questions on the posters. The  
16 groups then swapped to do the same with the other poster, before participating in a whole-group  
17 discussion about the task. ‘Climate change’ was included on both posters because it has been used to  
18 argue both *for* and *against* shale development: shale gas produces lower CO<sub>2</sub> emissions than coal; but  
19 greenhouse gases are emitted from burning the gas and from leaks, and shale development may reduce  
20 demand for renewable energy.

21

22 After lunch, in half-size groups, participants were asked to discuss quotes attributed to different  
23 sources (e.g. industry spokesperson, scientist, environmental non-governmental organization). This  
24 was followed by a role-playing task, also in half-size groups, whereby participants assumed the role of  
25 city council members asked to discuss and choose between six energy development proposals, two of  
26 which were shale oil/gas developments. Final plenary discussions included feedback from each group,  
27 reflections and then a debriefing session by the moderators. The workshop concluded with a seven-  
28 page survey consisting of 35 questions (some repeated from the initial survey) to explore final views,  
29 attitude change during the workshop, values and demographics.

30

1 **Deliberation Dynamics.** Deliberative workshops are intensely social activities where the participants  
2 interact to share and challenge opinions, as well as seek agreement amongst themselves. Deliberation  
3 theory and methodology has a well-developed literature which we drew upon to guide both the  
4 protocols and the facilitator instructions. In theoretical terms our overarching aim was to generate  
5 ‘fair’ (equal) and ‘competent’ (informed) discussions and discourse amongst the participants[56]. By  
6 this means a relatively small number of participants can quite quickly generate rich discussions and  
7 conclusions that span the range of values and social representations circulating more widely about a  
8 topic within a society and its media, express the emotions that a topic raises, and generate novel ideas  
9 and solutions. Workshop discussions were facilitated in several ways, but primarily: by the avoidance  
10 of strong prior problem framings within the information presented, which might otherwise have  
11 inadvertently closed-down debate and options[11] [54]; by seeking to allow all participants to share  
12 information freely, and on an equal basis[58], in both plenary and small group breakout sessions; and  
13 through repeatedly using facilitator prompts (such as ‘can you say a little more about why you might  
14 hold that view?’) and other methods to explore people’s fundamental values, preferences and trade-  
15 offs[14]. We also deployed techniques to minimize the effects of facilitation practices and design of  
16 elicitation materials on participant views, or to make these effects uniform across workshops were  
17 they to occur. Materials were developed from a wide range of scientific literature to present a  
18 carefully calibrated range of risk and benefit information, and materials were reviewed by a panel of  
19 five topical experts in both countries (see Supplementary Data 1-6). We conducted extensive piloting  
20 (in both Cardiff and Santa Barbara) to standardize facilitation practices and materials. A member of  
21 the research team was on hand with supporting literature to answer technical questions, and the group  
22 dynamics between members were carefully observed throughout the process, with the aim of ensuring  
23 that all participants had opportunities to both hear and express views.

24

25 **Data Analysis.** All discussions were audio- and video-recorded and transcribed professionally,  
26 checked against recordings to ensure accuracy, and then anonymized. They were then thematically  
27 coded using a grounded approach to explore emergent themes in the data[59]. This paper reports the  
28 overarching findings of these analyses, pertaining to risk and benefit perceptions -and their drivers- in  
29 US and UK samples. A separate analysis of themes specifically pertaining to climate change and the  
30 compatibility of shale development with desired energy systems is reported by Partridge et al [17]. In  
31 accordance with the study ethical protocol, all names reported here are pseudonyms.

32

1 **Methodological Innovation.** There is considerable interest within both scientific and policy spheres  
2 concerned with the future of unconventional oil and gas development, as to how the public and other  
3 stakeholders can be engaged and included more directly in decisions about this technology. Our study  
4 demonstrates one way in which established analytic-deliberative methods[7] [9] can be applied to this  
5 question, alongside the considerable value of engaging citizens early in a systematic way about the  
6 risks and benefits of unconventional oil and gas development. The methodology that we have  
7 described offers a generic framework for future public engagement, but one that would then need to  
8 be adapted to any specific geographical and political circumstances (e.g. in areas where shale gas and  
9 oil production is already extensive) within which it is subsequently used. This does highlight one  
10 sampling limitation of such an in-depth deliberative study, in that (unlike in a nationwide survey, for  
11 example) the findings from the workshops are in part constrained by, and have to be interpreted in  
12 relation to, the specific places in which they have been conducted and the extent of shale development  
13 in play there at the time. Hence, our two locations in California should not be taken to represent every  
14 part of the USA, in the same way that Cardiff and London do not necessarily reflect the whole of the  
15 UK. Our assumption here has to be that, as with any such cross-cultural deliberative work, enough  
16 national context, culture and discourse is reflected amongst the views of the participants selected in  
17 each location to allow for meaningful comparisons to then be drawn. This in turn suggests a need for  
18 further in-depth public engagement experiments in places with a history of shale development, and the  
19 current study serves as a methodological template for systematically designing such future research  
20 and engagement. However, the facility siting literature also clearly indicates that getting the wider  
21 process right (such things as initial community engagement, early timing, independence of  
22 facilitation, attending carefully to community representation and trust issues etc.)(15)(60) are as  
23 important to the success of local deliberative events as is having a good protocol and skilled  
24 facilitation on the day. The findings of this study also clearly caution scientists and regulators against  
25 adopting a simplistic or naïve view of the ‘public’ as simply uninformed (or incapable of becoming  
26 informed) about the risks, benefits and wider implications of this technology. As research in many  
27 other domains of technology perceptions repeatedly shows, when given the right resources to do so  
28 varied public(s) typically generate quite complex and nuanced views about the wider societal and  
29 ethical issues within which the relative acceptability of a specific technology must be evaluated, and  
30 the values that they use to make such judgements.

31 **Ethical Review Statement.** Informed consent was obtained from all participants in the research,  
32 following procedures approved by the UCSB Human Subjects Committee under US Institutional  
33 Review Board procedures and Cardiff University School of Psychology Research Ethics Committee.  
34 No individual identifiers are reported in any phase of this research. The deliberative workshop

1 protocol, slides, posters with additional information, quotes and role-playing task cards are available  
2 in Supplementary Data 1-6. Some images have been removed for copyright reasons – please contact  
3 the corresponding author for more information.

4

5 **Data availability statement.** Audio and visual files from the workshops cannot be made publicly  
6 available due to participant confidentiality. However, we will consider requests to share anonymized  
7 transcripts for research purposes on a case-by-case basis after an embargo of two years, during which  
8 time our own analyses continue. Any other data is available from the corresponding author upon  
9 reasonable request.

10

1 **Acknowledgements.** Funding for this research was provided by the US National Science Foundation  
2 (NSF) in Cooperative Agreement SES-0938099 and grant SES-1535193. Supplemental funding came  
3 from the European Union’s Horizon 2020 research and innovation program under grant agreement No  
4 640715. Views expressed here are those of the authors and do not necessarily reflect the views of the  
5 NSF. We would like to thank all of our participants in the US and UK, without whom this research  
6 would not have been possible, and the members of our expert panel for their time and expertise. We  
7 also thank Ariel Hasell, Louise Stevenson, Catherine Enders, Robert Sposato and Erin Roberts for  
8 assistance in workshops and data analysis.

9  
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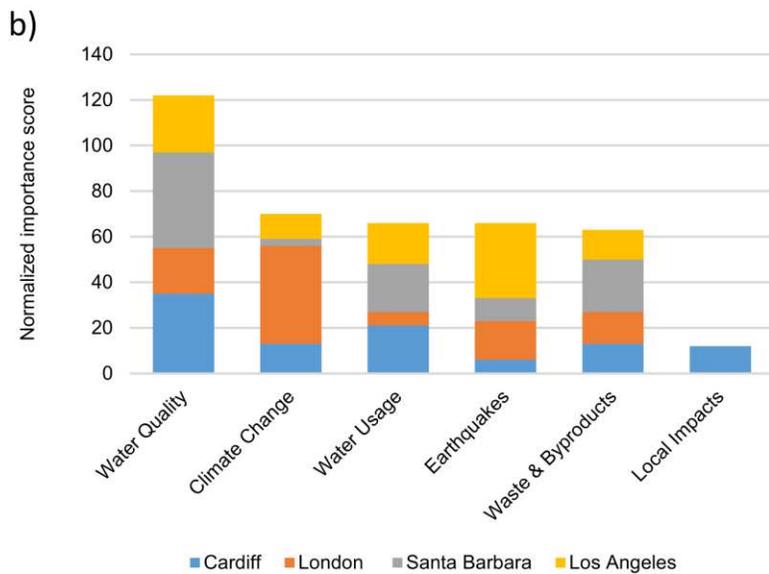
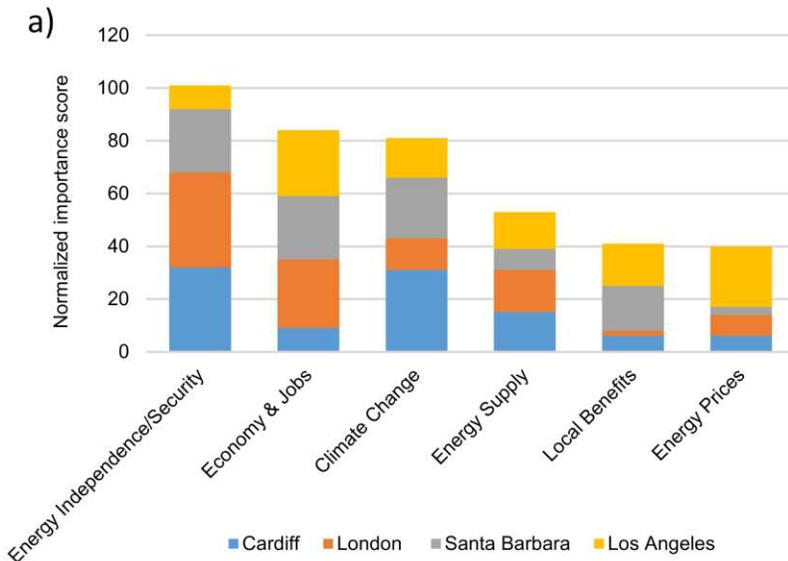
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1 **Figures**

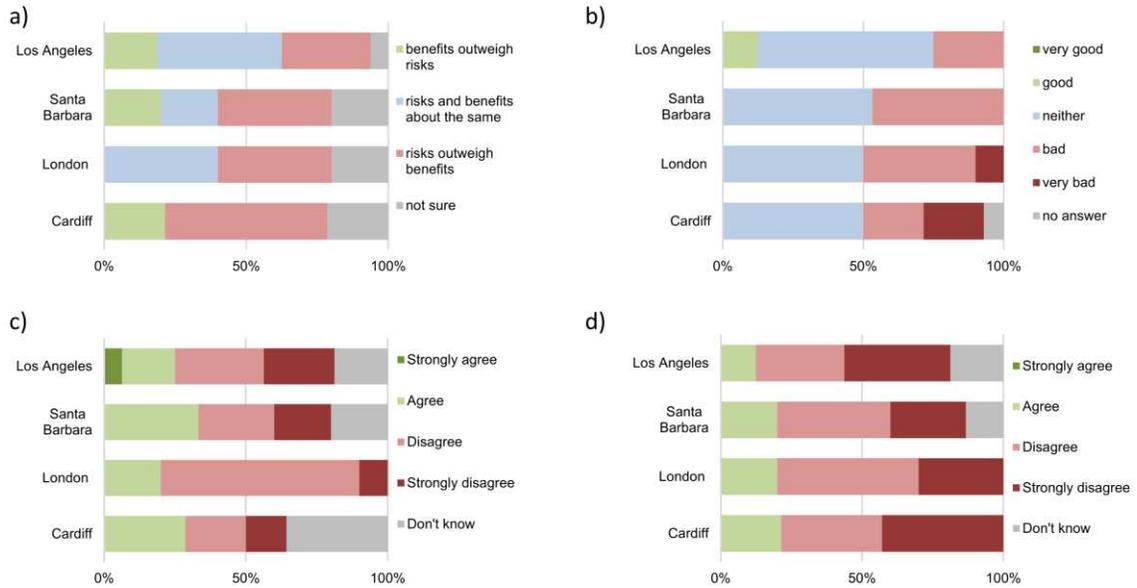
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3 **Figure 1: Summary of importance rankings.** Graphs show participant normalized importance scores for  
4 potential advantages (a) and disadvantages (b) by city, with higher scores indicating greater assigned  
5 importance. Where a participant assigned the topic as their most important it was allocated a score of 3; their  
6 second most was allocated a score of 2, and their third most a score of 1. For each city these scores were  
7 summed for each individual topic, and then a normalized importance score was produced by calculating a  
8 percentage of the total scores allocated in each city. The size of each stack indicates issue importance summed  
9 across the four locations, and within each stack its relative importance in an individual city. Caution should be  
10 exercised when interpreting climate change scores because this topic was included on both advantages and  
11 disadvantages posters (see Methods).



12

1 **Figure 2: Responses to post-workshop survey questions.** Percentage of participants in each city who chose  
 2 each response for the questions: (a) Do you think: the benefits of fracking will outweigh the risks/the risk and  
 3 benefits of fracking will be about the same/the risks of fracking will outweigh the benefits/not sure; (b) How  
 4 would you say hydraulic fracturing ('fracking') makes you feel?; (c) To what extent do you agree or disagree  
 5 with the following statement: The [US/UK] government is taking appropriate measures to regulate hydraulic  
 6 fracturing ('fracking'); (d) To what extent do you agree or disagree with the following statement: Gas/oil and  
 7 energy corporations can be trusted to ensure that 'fracking' is done safely.



8