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UK public perceptions of shale gas hydraulic fracturing: The role of audience, message and contextual factors on risk perceptions and policy support

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HIGHLIGHTS

- First UK experimental online survey of public perceptions of shale gas fracking.
- The public is ambivalent about shale gas, but also sees more risks than benefits.
- Demographics, politics and environmental values exert strongest influence on perceptions.
- Impact of shale gas information is greatest on attitudinally ambivalent respondents.

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ABSTRACT

There is growing recognition of the need to understand public attitudes to energy sources, such as shale gas, and to feed these into decision-making. This study represents the first detailed UK experimental survey of public perceptions of shale gas fracking, including analysis of the effects of different messages and the relative influence of different audience, message and contextual factors on support and risk perceptions in respect of shale gas fracking. Using an online survey ($N = 1457$) of the UK public, we find considerable ambivalence about shale gas, but also greater awareness of potential risks than benefits. Prior knowledge is associated with more favourable attitudes, although demographics, political affiliation and environmental values are strongest influences on perceptions. When provided with environmental or economic information about shale gas, participants became more positive – irrespective of their prior values or whether information is framed in terms of losses or gains. As expected, prior attitudes predict how information is received, with more attitude change amongst the most ambivalent respondents. We conclude that additional information about shale gas is more likely to be effective changing attitudes if focussed on this 'undecided' group. Studies of this type are important for policy makers and industry alike.

1. Introduction

Economic pressures and environmental targets are leading to significant changes to UK energy systems. DECC [1] refers to an energy 'trilemma', the challenge of ensuring secure supply, at an affordable price, while decarbonising the power system. This trilemma has major ramifications for the public, who will be asked to accept new energy infrastructure and technologies and to change patterns of demand. Shale gas is the latest energy source to be suggested by the UK government as providing a key component of the nation's energy mix, particularly in helping reduce reliance on energy imports [2]. However, various uncertainties remain surrounding the benefits and risks associated with shale gas extraction.[1]

While policy-makers have stressed the energy security and affordability benefits of shale gas, estimates of the scale of such benefits have varied substantially [3–5]. Furthermore,

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[1] Hydraulic fracturing ('fracking') is the process used to extract shale gas, which involves injecting water, sand and chemicals at high pressure into the shale, cracking it open and allowing the gas to escape. The water is then allowed to flow back to the surface where it is collected and treated or reused.

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environmental groups have highlighted the risks associated with hydraulic fracturing, including water contamination and induced seismicity [6]. The Royal Society [7, see also 8] concludes the safety and environmental risks of hydraulic fracturing are low and manageable through best practice and enforcement of UK regulations. They also recommend understanding public acceptability of shale gas extraction and use in the context of energy, environmental and economic policies be considered a priority for UK research. Similarly, the International Energy Agency [9, p. 15] concludes shale gas operators require a 'social license to operate'. These recommendations reflect high-profile public protests and concerns about the risks associated with the technology [10,11].

Understanding public attitudes to new energy sources like shale gas is vital for several reasons [12]. From an instrumental perspective, social acceptability can represent a major potential barrier to developments of new energy sources and technologies, as indicated by protests and moratoria on hydraulic fracturing in several countries and US states [7]. Indeed, public opinion is seen as a major challenge for European shale gas development [13]. There are also strong substantive and normative arguments for considering public perceptions and values in relation to energy options: broadening the range of perspectives included in decision-making can lead to better and fairer decisions, and democratic policy decisions should reflect societal views [14]. This normative and substantive argument is particularly strong in relation to decisions about siting of energy developments (e.g., shale gas extraction facilities) where local communities will be directly affected. It is therefore critical to understand public attitudes and the bases of concern about energy technologies, and where possible feed this understanding in at an early stage in decision-making (before attitudes become polarised and decision-makers potentially distrusted [8,12]).

This paper examines the UK public's attitudes to shale gas fracking, including those living in areas where shale gas is being extracted, and in areas where it could be extracted in the future. To date, very little work has explored these perceptions, and no experimental research has been conducted to examine the effects of different messages and the relative influence of different audience, message and contextual factors on support for shale gas extraction. Using an experimental online survey, we address this research need. The following section outlines the relevant empirical and theoretical literatures; Sections 3 and 4 then describe the survey methodology and results, respectively; and Section 5 concludes with inferences for policy.

2. Background

2.1. Attitudes to shale gas fracking

Studies of public attitudes[2] to energy sources and technologies consistently show the public favours renewable sources (e.g., solar, wind) over fossil fuel or other sources [12,15]; and are ambivalent about carbon capture and storage (CCS), nuclear power, biofuels, electrification and demand management [16]. Public values underlying engagement with energy system change include efficiency, nature protection, safety, reliability, affordability, freedom, fairness, and quality of life [16]. Consistent with this, most view fossil fuels as polluting, outdated and finite [16].

Comparatively little work has explored perceptions of unconventional fossil fuels, but many of the public's concerns about conventionals appear to apply here. In contrast to other unconventional fossil fuels [17,18], there has been considerable recent UK media coverage of shale gas [19], leading to relatively high levels of public awareness. Attitudes to shale gas show considerable ambivalence, however: as of June 2014, of the 74% of the British public who have heard of it, half neither oppose nor support it, with support and opposition each accounting for around one-quarter [15]. US research suggests the public is positive about the potential economic opportunities of shale gas extraction, but not at the expense of water quality and local noise pollution and traffic [20,21]. In the UK, concerns about shale gas initially related to earthquakes [22] but have more recently focussed on water contamination, while many also believe it represents a 'cheap' energy source [11]. Women, older people, those with left-of-centre political views, and newspaper readers appear to be particularly concerned about the technology [11,23].

The literature to date on perceptions of shale gas fracking has not sought to make theoretically informed predictions or explanations of public responses to shale gas. However, a sizeable literature exists on attitudes and risk perception, which highlights several technical and non-technical factors likely to predict public views on energy sources and technologies, and explains divergence between expert and non-expert assessment of risks [24,25]. Oltra et al.'s [26] review of the energy siting literature categorises these factors as: (i) characteristics of the technology (e.g., scale, waste outputs); (ii) psychological processes (e.g. place attachment; familiarity with the technology); and (iii) wider social and institutional factors (e.g. trust, ownership, governance). Broadly, this corresponds with models of communication and persuasion from the social psychology literature, such as the Elaboration Likelihood Model (ELM [27]), which highlight the interaction of: audience factors (e.g., level of engagement, prior knowledge, values), message factors (e.g., framing effects[3]); and source and contextual factors (e.g., trust, timing) in shaping the impact of information provision.

The current research draws on this literature to examine the impact of audience, message and contextual factors in predicting public responses to shale gas fracking. We consider both psychological and geographical audience factors, since attitudes to specific, local developments may diverge from attitudes to energy technologies in principle, and individual differences (e.g., values, knowledge, demographics) often predict energy technology attitudes [12]. Critically, little previous work has examined the *relative* importance of audience, message and contextual factors in predicting public responses to energy technologies, or considered whether psychological [e.g., 25,27] or geographical [e.g., 30,31] theories might offer better explanations for these responses. While the current research is primarily intended to provide an empirical exploration of this nascent topic, a further contribution of our paper is to offer a more conceptually integrative view on public responses to novel energy technologies by drawing on several distinct social science literatures (e.g., risk perception, attitude change and persuasion, place identity and attachment). This not only has theoretical value, but can help inform the most appropriate strategy for

[2] Attitudes are hypothetical constructs that refer to an individual's evaluation of, or orientation towards, an 'attitude object' (e.g., thing, person, idea). In this paper, we also use the term 'perception' as a broader concept encompassing 'risk perceptions' (i.e., subjective evaluation of the characteristics and severity of risk) as well as attitudes. For a discussion of relevant theory and measurement of these concepts, see [12].

[3] Message 'framing' refers to the selection and presentation of information through choice of words, images, problem definition, inclusion and omission of information, and so on, that provides context and meaning [28]. How information is framed and questions are posed are likely to influence public views on shale gas. Compare, for example, surveys in May/June 2014 by (a) the industry body UK Onshore Oil and Gas [29], who provided a brief description of shale gas and its benefits including 'to meet the UK's demand for natural gas for nearly 50 years or to heat the UK's homes for over 100 years' and found 57% supported extraction and 16% opposed it; with (b) DECC's [15] survey which provided no information about shale gas (relying on extant understanding) and found, of those (74%) who had heard of it, 24% supported and 24% opposed shale gas extraction.

understanding and potentially overcoming divergence in lay and expert views and involving publics in decision-making about shale gas policy and developments. For example, claims that ignorance about shale gas risks and benefits belie public protests and opposition [32] assume a 'deficit model' of risk communication, whereby provision of accurate, scientific information is assumed to lead to public support. This model has repeatedly been shown to be flawed, with factors such as trust and values more predictive of public support than knowledge [12]. Other claims that protests are merely 'NIMBYism' (i.e., rejection of local developments, irrespective of attitudes to the technology in the abstract) [33] imply location is the key predictor of public attitudes. This paper seeks to provide evidence to explain diverse public responses to fracking and to inform appropriate public engagement strategies.

In respect of geographic audience factors, the literature on place identity and attachment highlights that the relationship between proximity to energy developments and public views is not obvious, and undermines any assumption that communities will inevitably reject local developments. Rather, it seems that if developments are perceived to threaten a local area's inherent character or identity, they will be resisted; but perceptions of place identity vary widely and may be compatible with industrial development [30]. Further, communities with experience of particular industries are likely to have different views than those without such experience. These experiences may be coloured by whether there are local benefits (e.g., employment) associated with the particular industry, as well as trust in local operators and regulators [31]. Consequently, Venables et al. [34] found that place identity, followed by trust in the nuclear industry, were the strongest predictors of support for new local nuclear development amongst communities living close to existing nuclear facilities. The salience of such contextual and place-based factors in predicting responses to fracking will be examined here.

In relation to psychological factors, the ELM particularly highlights the importance of audience and message characteristics (e.g. values, prior knowledge, framing) in shaping public responses. Importantly, audiences are not homogenous, so will respond differently to novel information. For example, knowledge and prior attitudes can serve to polarise views on technical issues [35]. Due to pervasive confirmation bias (i.e., the tendency to seek out confirmatory evidence and disregard or downplay contradictory evidence [36,37]), attitudes can polarise as a result of reading mixed information [38], although this effect is not uniform: those who have not yet made up their minds about an issue or hold mixed views (i.e., attitudinal ambivalence) will process information in a less biased and deeper way. The role of prior knowledge, attitudes and ambivalence will therefore be examined in the current research. Furthermore, the way in which information is framed interacts with audience values and beliefs, such that particular frames (e.g., environmental benefits) will only be meaningful or persuasive for certain audiences [39].

2.2. Research questions and hypotheses

This study aimed to explore how risks and benefits of shale gas fracking are perceived by the UK public; how these perceptions vary by known predictors of risk perception (e.g., location, knowledge, trust, values, message factors); the relative importance of key geographical and psychological audience factors in predicting perceptions; and how messages about shale gas fracking may be received and interpreted differentially according to the audience's prior attitudes or values. Drawing on the literature outlined above, we propose the following hypotheses:

H1. Both geographical and psychological audience factors, including gender, environmental attitudes, location, and place attachment, will predict shale gas attitudes and risk perceptions. Specifically, males, those living in areas with extant fracking, those with lower place attachment, and those with lower environmental values will be more positive about shale gas.

H2. Prior knowledge will influence shale gas attitudes. Specifically: those with more knowledge will have stronger attitudes – both positive and negative – towards shale gas.

H3. Prior attitudes will influence response to shale gas information. Specifically, those who are most ambivalent will experience the greatest attitude change when given information.

H4. There will be an interaction between message (benefit frame) and environmental values. Specifically, those with higher environmental values will be more influenced by the environmental benefit frame than the economic benefit frame.

3. Methodology

3.1. Design

Following a series of in-depth public interviews (reported elsewhere), an online survey was conducted during August 2014 to investigate factors predicting shale gas acceptability and the impact of different information frames. Using a 2×2 design, participants were randomly assigned to one of four conditions, in which the information provided on shale gas was varied (see below).

3.2. Participants

Participants ($N = 1457$) were drawn from a UK online market/-social research panel. We sampled three regions: one where shale gas fracking has already commenced (Lancashire, focussed on Weeton, Elswick, Roseacre Wood, Preston New Road, Westby, Banks[4]; 32%); one with potential for (but so far no exploitation of) shale gas fracking (South Wales, focussed on Pontrhydyfen, Cwmafan and Llandow; 34%[5]); and one where there are no shale deposits (Mid/North Wales, including neighbouring English towns; 34%). A demographic breakdown of the sample is shown in Table 1. In terms of political preferences, this is broadly representative of the UK public[6]; demographically, the sample is somewhat older and better qualified than the general public.[7]

3.3. Measures and materials

The questionnaire's first section included location and demographic measures (see Table 1), followed by baseline (pre-information) measures (item order within each scale was randomised to avoid order effects):

- *Place attachment:* adapting previous scales [40,41], a 12-item measure ($\alpha(12) = .826$) included items assessing place attachment along general (e.g., 'The place where I live is very special to me'), social (e.g., 'I believe my neighbours would help in an

[4] This region (PEDL 165) has been granted a gas extraction license under the Petroleum Act 1998: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/391803/Landfields_Lics.pdf. There is an active gas field here that was fracked in 1993. Cuadrilla have since fracked one well (in 2011), drilled several appraisal wells, conducted geophysical surveys and installed microseismic arrays.

[5] This region includes PEDLs 100, 148, 149, 214–220.

[6] http://www.electoralcommission.org.uk/our-work/our-research/electoral-data.

[7] 2011 census data shows 11.9% are 16–24; 6.8% are 25–34; 20.5% are 35–44; 19.4% are 45–54; 6% are 55–64; and 8% are 65–74. In terms of highest qualifications, 23.2% have no qualifications; 29.3% have GCSE/O-Levels; 12.1% have A-Level/Higher/BTEC; 5.1% have vocational/NVQ; and 27% have a degree or higher.

Table 1
Demographic breakdown of sample.

	%
Gender	
Female	56.9
Male	42.6
Missing	0.5
Age	
16–24	4.3
25–34	11.9
35–44	13.8
45–54	19.4
55–64	27.7
65–74	20
75 or over	3
Missing	0.1
Highest qualification	
No formal qualifications	5.9
GCSE/O-Level	21.5
A-Level/Higher/BTEC	19.2
Vocational/NVQ	17.4
Undergraduate degree	22.6
Postgraduate degree	12.1
Missing	1.2
Highest science qualification	
No formal qualifications	23.1
GCSE/O-Level	44.3
A-Level/Higher/BTEC	12.9
Vocational/NVQ	5.2
Undergraduate degree	9.7
Postgraduate degree	4.1
Missing	0.7
Political party most likely to support	
Conservative	22.0
Labour	28.2
Liberal Democrats (Lib Dems)	4.7
Green Party	3.5
UK Independence Party (UKIP)	11.8
British National Party (BNP)	0.5
Scottish National Party (SNP)	0.1
Welsh Nationalist Party/Plaid Cymru	4.1
Democratic Party	0.1
Other	0.5
Undecided	15.3
Would not vote	5.9
Prefer not to say	3.2
Missing	0.1
Rurality	
Urban	25.7
Sub-urban	39.2
Rural	34.4
Missing	0.7
Years living in this area	
Less than 1 year	2.8
1–3 years	7.7
4–6 years	10
7–10 years	9.3
More than 10 years	69.9
Missing	0.3
Employment in energy industry	
No	94.0
Yes, in the past	3.6
Yes, currently	1.9
Missing	0.5

emergency') and natural (e.g., 'I would feel less attached to my area if the native plants and animals that live here disappeared') dimensions, with response options on a five-point scale from Strongly agree (5) to Strongly disagree (1).

- *Environmental identity:* a two-item measure ($\alpha(2) = .858$), adapted from [42], included the items: 'I think of myself as someone who is concerned about the environment'; and 'Being environmentally-friendly is an important part of who I am', with responses again on a five-point agreement scale.
- *Climate change scepticism:* A 14-item scale ($\alpha(14) = .950$), adapted from [38], was used to assess beliefs about the reality, causes and impacts of climate change and views on the reliability of climate change evidence and information sources (e.g., 'I do not believe climate change is a real problem'; 'Claims that human activities are changing the climate are exaggerated') again on a five-point agreement scale.
- *Knowledge about energy sources and technologies:* Participants indicated how much they knew about exemplar energy sources/technologies: gas (also known as 'natural gas'); coal; shale gas or 'fracking'; underground coal gasification; carbon capture and storage; nuclear power; offshore wind power; solar photovoltaic/solar energy; and bioenergy on a five-point scale of 'A lot' (5), 'A fair amount' (4), 'A little' (3), 'Nothing – have only heard the name' (2), and 'Nothing – have never heard of it' (1).
- *Favourability of energy sources and technologies:* Participants provided a personal evaluative assessment of the exemplar energy sources/technologies with the item 'how favourable or unfavourable are your overall opinions or impressions of the following energy options currently' on a five-point scale of 'Very favourable' (5) to 'Very unfavourable' (1).
- *UK energy budget:* Support at national level for the exemplar energy sources/technologies was elicited with: 'What proportion of the UK's budget for energy do you think should be invested in supporting each of the following?' with a total budget of 100% to be assigned to each option.
- *Risks versus benefits of shale gas:* A multiple-choice item ('From what you know or have heard about using shale gas fracking in Britain, on balance, which of these statements most closely reflects your own opinion?') with seven response options from 'The benefits of shale gas fracking far outweigh the risks (1)' to 'The risks of shale gas fracking far outweigh the benefits (5)' (plus 'None of these (6)'; 'Don't know (7)' not used in regression analyses) measured perceived risks/benefits of shale gas.
- *Attitudes to shale gas fracking:* 13 items (adapted from [11,43,44]) assessed attitudes to shale gas fracking, including dimensions known to predict risk perceptions, such as trust in regulators (e.g., 'I feel confident that the British Government will adequately regulate shale gas fracking'), concern about risks (e.g., 'I am concerned about the risks of earthquakes from shale gas fracking'), perceptions of benefits (e.g., 'Shale gas is a clean energy source') and moral hazard (e.g., 'If politicians think shale gas fracking is a possibility, it will make them less likely to pursue other policies to tackle climate change'). Again, a five-point agreement scale was used. A further item asked 'Do you think that in the next 20 years, shale gas fracking will... improve our lives (1); ... make our lives worse (−1); ... make no difference either way (0); Not sure (9).
- *Attitudinal ambivalence towards shale gas fracking:* A three-item measure ($\alpha(3) = .842$), adapted from [45], assessed ambivalence (e.g., 'I have mixed feelings about shale gas'; 'I am undecided about shale gas').
- *Acceptance of shale gas extraction:* Participants were asked 'Should shale gas extraction be allowed in the UK?' with 'Yes', 'No', or 'Don't know' as response options.
- *Perceptions of public acceptance:* In addition, participants were asked 'What percentage of the UK public do you think would agree that shale gas extraction should be allowed in the UK?' with numeric responses permitted from 0 to 100.
- *Preferences for locating shale gas extraction:* Using a UK map of shale gas deposits (from [46]), participants were asked where they thought 'shale gas fracking should take place by clicking

on a region once for places you think it should occur, or twice for places that you think it should not occur'. Six regions could be selected: Marros Group; Weald Basin; Gainsborough Trough; Bowland Shale; Upper Cambrian Shales; and Liss Shale. If respondents did not feel extraction should occur in any of these locations, they were asked to select this option below the map ('I do not think shale gas fracking should occur anywhere').

After this, information was provided about shale gas fracking. We varied the information that was provided, such that there were four experimental conditions: two texts focussed on economic benefits and two on environmental benefits; for each, the information was either framed in loss or gain terms [47]. The information gave a short description of shale gas fracking (see Appendix A) followed by an environmental/economic and loss/gain[8] benefit framing:

- *Conditions 1–2: Economic gain [loss]:* "One of the main benefits is that fracking could generate substantial quantities of gas in the UK, contributing to energy self-sufficiency. This means that widespread extraction of shale gas across the UK could reduce household energy bills. [This means that, without widespread extraction of shale gas across the UK, households could face higher household energy bills]."
- *Conditions 3–4: Environmental gain [loss]:* "One of the main benefits is that, as natural gas burns more cleanly (releasing less CO_2 and other pollutants) than other fossil fuels, it is considered a viable alternative to coal and oil. This means that widespread extraction of shale gas across the UK could help reduce climate change. [This means that, without widespread extraction of shale gas across the UK, we could see increased climate change.]"

After reading the text, participants were asked 'What thoughts came to mind when you were reading the text' (open-ended) to ensure message elaboration. A manipulation check confirmed the manipulation was largely successful.[9] Finally, several shale gas perception measures were again administered to examine any impact of the information provided: Shale gas favourability; Shale gas risks versus benefits; and two of the shale gas attitude statements (clean, cheap) which most directly related to the information provided.

4. Results

4.1. Knowledge and favourability of energy technologies/sources

Most respondents claimed to know only 'a little' about most of the technologies (Fig. 1). Participants were most familiar with coal, followed by natural gas, nuclear, wind and solar; and least familiar with CCS and underground coal gasification (UCG), both scoring highly for 'never heard of it'.

Turning from knowledge to attitudes, participants rated solar energy as most favourable, followed by offshore wind (Fig. 2). Other technologies were rated considerably lower. UCG and CCS were consistently rated as 'neither favourable nor unfavourable', a likely reflection of the lack of knowledge about them. Shale gas was rated most unfavourable, followed by nuclear. However, more participants rated shale as 'neither favourable nor unfavourable' than any other option, with ambivalence also high for bioenergy and nuclear.

Consistent with personal favourability ratings, when asked to allocate a national energy 'budget' for the different energy sources/technologies, the highest proportion was allocated to offshore wind and solar (Fig. 3). However, personal favourability and preferences for national budget are not entirely consistent. Along with natural gas, nuclear was also rated fairly high – perhaps reflecting a 'reluctant acceptance' that this technology is necessary despite its risks. UCG and CCS were allocated the least in the budget allocation exercise, perhaps more reflecting lower knowledge than disapproval. Correlations (see Supplementary Material) between favourability and UK budget assignment show respondents were consistent in their responses – i.e., energy options with highest favourability ratings were given higher percentage of UK energy budget.

4.2. Attitudes to shale gas fracking

When asked to rate the risks and benefits of shale gas, almost a quarter of participants (24.8%) answered 'don't know' to this question. However, more seem to feel that the risks outweigh the benefits, than vice versa (Fig. 4), with water contamination and earthquakes amongst the most commonly identified risks (see Table 2).

When asked whether they felt shale gas would make a difference to their lives in the next 20 years, almost half of participants indicated they were unsure. The remaining responses were fairly evenly distributed across making their lives better, no difference and worse. Similarly, when asked whether widespread shale gas extraction should be allowed in the UK, the highest proportion (40%) of participants indicated they did not know; while 31% responded affirmatively (Fig. 5). In respect of perceived public acceptance of shale gas, responses ranged from 0% to 100% with a mode of 30% (7.7% of all participants selected this amount). The mean estimate was 37.4% – which compares with 31.1% of the sample who *actually* agreed that shale gas extraction should be allowed in the UK (i.e., participants' estimates of public opinion are reasonably accurate). However, consistent with the false consensus effect [48], disaggregating by opinion, we found that those who said it should be allowed estimated 50.6% of the public would agree; while those who did not think it should be allowed only estimated 29.8% of the public would agree. This difference is significant ($t(844) = -15.5$, $p < .001$).

For the mapping exercise, respondents were asked to indicate whether they thought shale gas should be extracted ('like') or not ('dislike') in UK regions where deposits have been identified. As shown in Fig. 6, most participants were neutral for each region, while the smallest percentages selected 'dislike'. Higher proportions selected dislike for the shales closest to them.[10] However, almost half of participants (42.8%) selected 'I do not think shale gas fracking should occur anywhere'.

[8] We found virtually no differences between loss/gain frames, so the results discussed here focus only on comparing the environmental versus economic framing.

[9] Participants were asked: 'Which of the following was mentioned in the information you read?' with response options: 'Widespread extraction of shale gas could increase climate change'; 'Widespread extraction of shale gas could increase energy bills'; 'Widespread extraction of shale gas could reduce climate change'; 'Widespread extraction of shale gas could reduce energy bills'. The results indicate most respondents had read the text: 81.3% in condition 1 and 79.3% in condition 2 correctly selected 'Widespread extraction of shale gas could reduce energy bills'; while 59.8% in condition 3 and 62.5% in condition 4 correctly selected 'Widespread extraction of shale gas could reduce climate change' ($\chi^2(9, N = 1427) = 468.86$; $p < .001$). While the proportion of incorrect responses was somewhat higher in conditions 3 and 4, it is noteworthy that most of these selected the bill reduction option (i.e., the economic benefit), while very few in any conditions selected the two risk-related response options.

[10] For example, 18.1% in South Wales selected 'dislike' for the Marros Group, compared to 13.3% in Mid/North Wales & Midlands and 11.1% in Lancashire $\chi^2(4, N = 1437) = 20.57$, $p < .001$. In Lancashire, 18.2% selected 'dislike' for the Bowland Shale, compared to 16.3% in Mid/North Wales & Midlands and 11.8% in South Wales $\chi^2(4, N = 1437) = 20.93$, $p < .001$. In Mid/North Wales & Midlands, 9.3% disliked the Cambrian Shales, compared to 5.3% in South Wales and 4.3% in Lancashire $\chi^2(4, N = 1437) = 13.67$, $p = .008$. With respect to the Lias Shale, 12.7% selected 'dislike' in Mid/North Wales & Midlands, while 11.8% did in South Wales and 10.1% in Lancashire $\chi^2(4, N = 1437) = 14.60$, $p = .006$. There were no significant differences for Gainsborough Trough and Weald Basin.

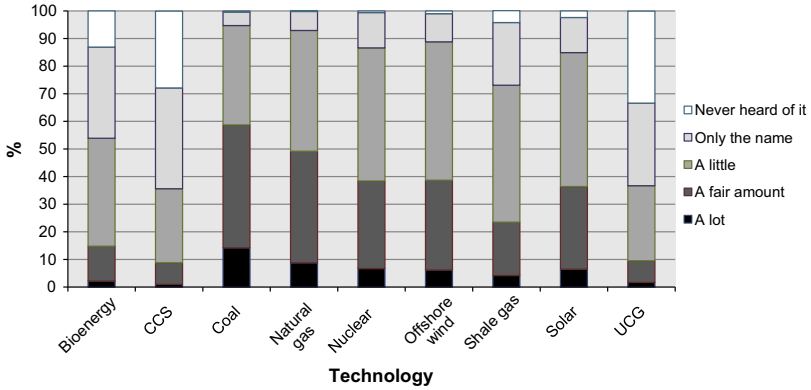

Fig. 1. Knowledge of energy sources/technologies.

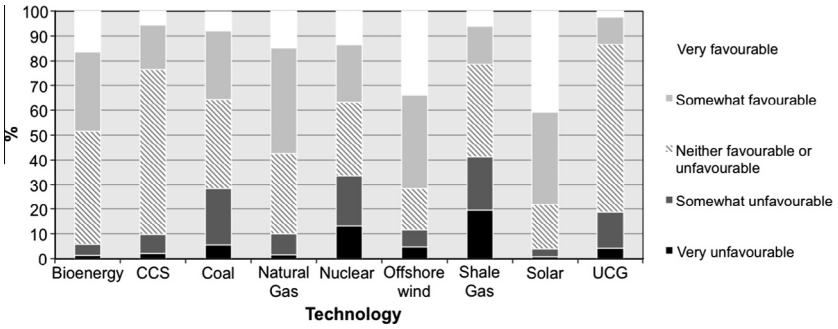

Fig. 2. Favourability towards energy sources/technologies.

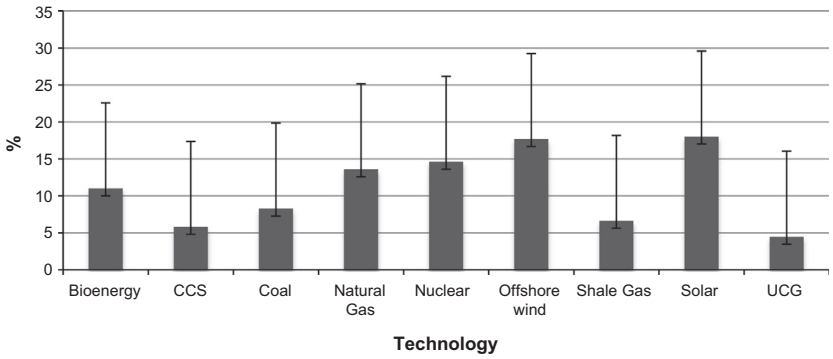

Fig. 3. UK budget assigned to energy sources/technologies.

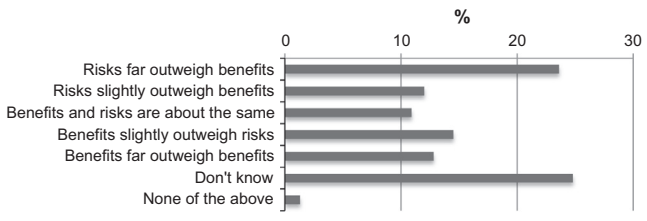

Fig. 4. Perceptions of risks versus benefits of shale gas fracking.

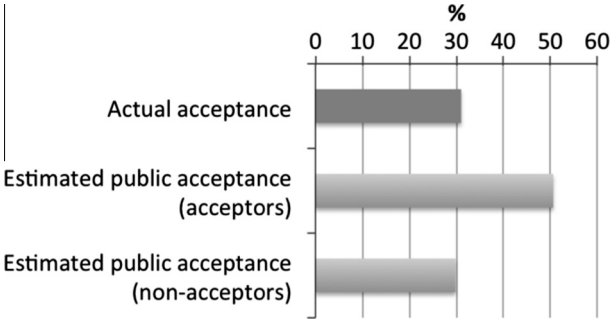

Fig. 5. Acceptance (and perceived acceptance) for widespread extraction of shale gas across UK.

4.3. Knowledge analysis

We found a non-linear relationship between (self-assessed) knowledge and shale gas favourability, but not indicating polarisation in the expected direction: those who claimed to have no knowledge and those claiming to have high knowledge of shale gas had the most favourable attitudes (Fig. 7; $F(1, 4) = 3.16$, $p = .01$). Furthermore, perceptions of risks versus benefits were much higher for those claiming to have no knowledge of shale gas ($F(1, 4) = 3.70$, $p = .01$). Following information provision, however, the relationships between knowledge and shale gas perceptions disappear: favourability ($F(1, 4) = .91$, $p = .46$); risk

Table 2
Attitudes to shale gas fracking.

	Strongly Agree	Agree	Neither	Disagree	Strongly Disagree	*Mean*	*SD*
I am concerned about the risks of water contamination from shale gas fracking	19.4	31.4	36	9.6	3.6	*3.53*	*1.02*
Producing energy from shale gas will reduce reliance on foreign energy sources	13.5	33.4	42.4	7.3	3.4	*3.46*	*0.93*
If politicians think shale gas fracking is a possibility, it will make them less likely to pursue other policies to tackle climate change	13.1	31.7	45.1	8.4	1.7	*3.46*	*0.89*
I am concerned about the risks of earthquakes from shale gas fracking	13.2	27.2	38.7	14.9	5.9	*3.27*	*1.06*
Producing energy from shale gas will ensure a reliable source of energy for the UK in the future	9	23.8	47.8	12.3	7	*3.16*	*0.99*
Shale gas is a cheap energy source	5.7	20.3	53.4	14.1	6.5	*3.05*	*0.91*
When people find out about shale gas fracking, it will reduce their motivation to make changes in their own behaviour to tackle climate change	5.1	16.7	58.2	15.7	4.3	*3.03*	*0.84*
Producing energy from shale gas will reduce the UK's greenhouse gas emissions	2.7	15	57.9	16.5	8	*2.88*	*0.85*
Producing energy from shale gas will reduce energy bills	4.3	16.6	48.9	18.7	11.4	*2.84*	*0.98*
Shale gas is a clean energy	3.1	14.8	54.2	18	10	*2.83*	*0.91*
I feel that current rules and regulations are sufficient to control any risks from shale gas fracking	3.7	16.2	42.5	21.5	16.1	*2.70*	*1.04*
I feel confident that the British Government will adequately regulate shale gas fracking	4.6	18.1	35.4	22.8	19.1	*2.66*	*1.11*
Knowing shale gas fracking is a possibility makes me feel less inclined to make changes in my own behaviour to tackle climate change	2.3	5.4	46.4	29.6	16.3	*2.48*	*0.91*

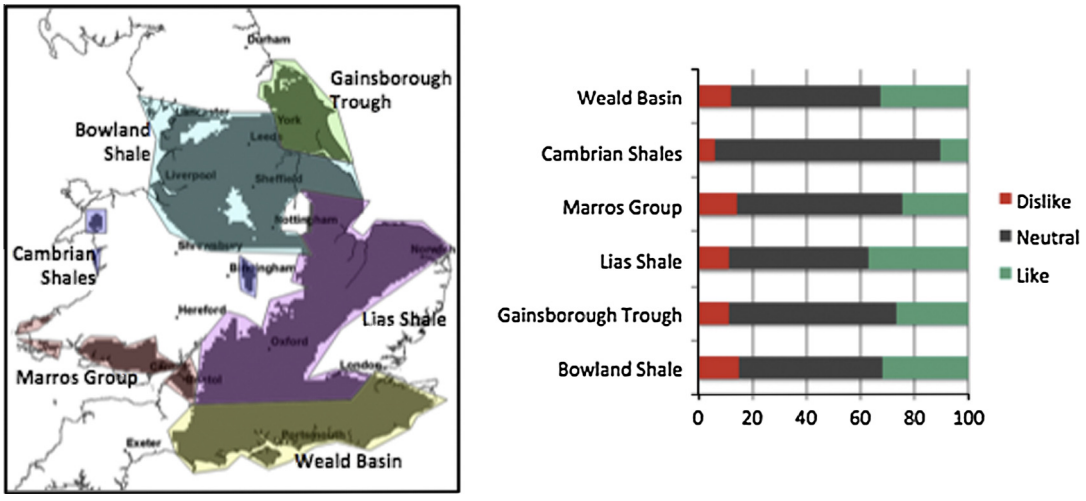

Fig. 6. Preferred locations for shale gas extraction.

versus benefits ($F(1, 4) = .46$, $p = .77$). There was no statistically significant relationship between knowledge and acceptance of shale extraction $F(1, 4) = 1.26$, $p = .28$).

4.4. Location analysis

Fig. 8 shows differences in attitudes between the three regions surveyed (i.e., Lancashire, South Wales and Mid/North Wales & Midlands). Shale gas favourability showed a significant relationship with location $F(2, 1434) = 4.95$, $p = .01$ (but see Section 4.5). Participants from Lancashire (i.e., where fracking has been ongoing for some years) rated shale gas as a more favourable energy source ($M = 2.77$, SD = 1.14) than those from Mid/North Wales & Midlands ($M = 2.54$, SD = 1.12) where fracking is not viable, a statistically significant mean difference of $M = .22$, 95% CI[0.05, 0.40], $p = .01$.

There was also a marginally significant relationship between viewing shale as a 'cheap' energy source and respondents' location: Welch's $F(2, 941.56) = 2.60$, $p = .075$. Participants from Lancashire rated shale gas as a cheaper energy source ($M = 3.13$, SD = .99) than those from Mid/North Wales & Midlands ($M = 3.00$, SD = .853), a difference of $M = 0.13$, 95% CI[−0.01, 0.27], $p = .085$). Similarly, there was a statistically significant relationship between seeing shale as clean and location $F(2, 1422) = 3.53$, $p = .03$. Participants from Lancashire rated shale gas as a cleaner ($M = 2.92$, SD = .93) than those from Mid/North Wales & Midlands ($M = 2.78$, SD = .85), a statistically significant difference of, $M = .145$, 95% CI [0.00, 0.29], $p = .04$.

Consistent with the more favourable attitudes amongst those in Lancashire, we also found a statistically significant relationship between location and shale risk perceptions $F(2, 1422) = 7.08$, $p = .001$. Participants from Mid/North Wales & Midlands rated shale gas as more risky ($M = 4.40$, SD = 2.03), than those from Lancashire ($M = 3.93$, SD = 2.06) a statistically significant difference of, $M = .467$, 95% CI[0.15, 0.79], $p = .002$. Participants from South Wales rated shale gas as more risky ($M = 4.33$, SD = 2.12), than those from Lancashire ($M = 3.93$, SD = 2.06) a statistically significant difference of, $M = .41$, 95% CI[0.08, 0.73], $p = .008$.

4.5. Relative importance of demographic, value, location and knowledge factors

While we found location correlated with shale attitudes, other factors (e.g., sector of employment) may be driving these effects. Consequently, we ran regression analyses of the dependent variables (DVs) to examine the relative influence of location and other place-based audience factors, relative to attitudinal, value, knowledge and demographic variables. As shown in Table 3, males, those with higher science education, Conservative voters, urban

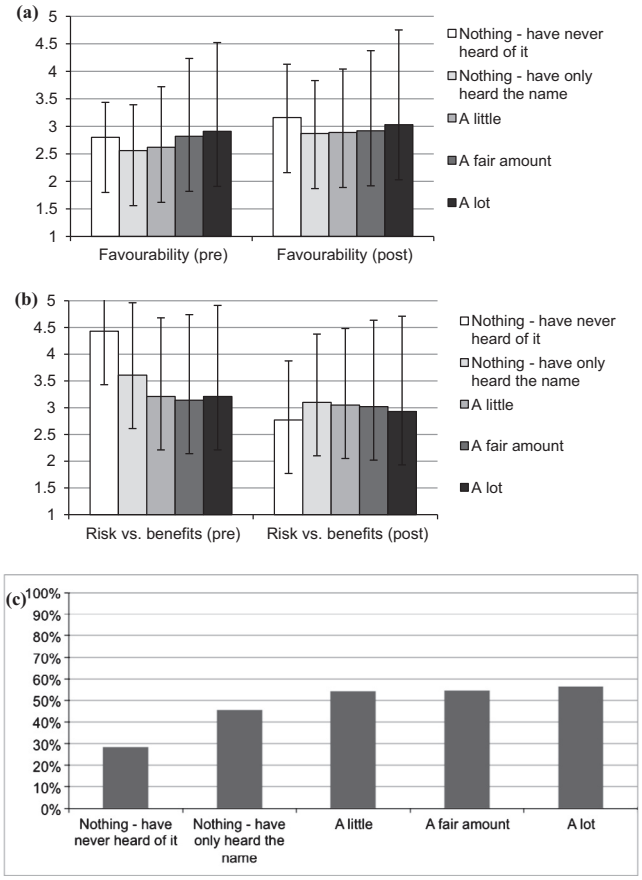

Fig. 7. Relationship between self-assessed knowledge and (a) shale gas favourability, (b) shale gas risk perceptions, and (c) acceptance of shale gas extraction.

residents, those more attached to place, those with lower environmental identity and those with higher climate scepticism scores were more favourable towards shale gas.[11] Political affiliation and climate change attitudes were the strongest predictors. However, location was no longer a significant predictor, suggesting that the effects described above were associated with other factors.[12] When different types of predictors are grouped according to more geographical (e.g., location, employment in energy sector) versus psychological (e.g., knowledge, environmental identity, attitudes) audience factors, they account for very similar levels of variance (Fig. 9), with attitudinal/value and knowledge variables together accounting for 18% and place-based/geographical factors for 16%.

4.6. Information framing (experimental component)

We next examined the impact of different forms of information provision on shale attitudes. We first included environmental identity as an additional independent variable (IV), as we expected from previous work [38] that people who considered themselves to be 'green' would perceive the information differently to those who do not.

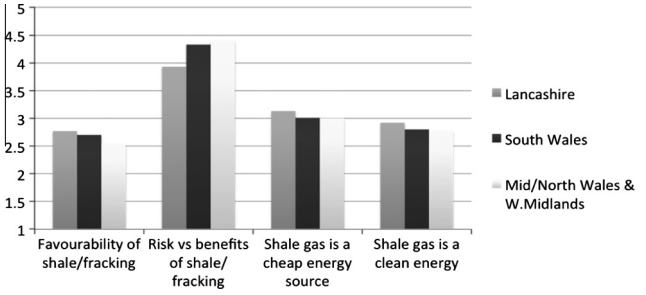

Fig. 8. Perceptions of shale gas across different locations.

As shown in Fig. 10, favourability towards shale gas changed after information provision $F(1, 1414 = 129.68$, $p < .001$, partial $\eta^2 = .084$. Participants rated shale gas as more favourable post-information ($M = 2.91$, SD = 1.20) compared to pre-information ($M = 2.67$, SD = 1.13).[13] There was also a significant impact of information on perceptions of shale gas as a 'cheap energy source', $F(1, 1405) = 84.87$, $p < .001$, partial $\eta^2 = .058$. Participants rated shale gas as cheaper post-information ($M = 3.24$, SD = 1.02) than pre-information ($M = 3.05$, SD = 0.91).[14]

Similarly, there was a statistically significant impact of information on seeing shale as a 'clean energy source' $F(1, 1394) = 300.01$, $p < .001$, partial $\eta^2 = .177$. Participants rated shale gas as cleaner post-information ($M = 3.19$, SD = 1.03) than pre-information ($M = 2.83$, SD = .92). There was a significant main effect of environmental identity, $F(1, 1394) = 5.25$, $p = .022$, partial $\eta^2 = .004$. Participants with low environmental identity rated shale gas as cleaner than those with high environmental identity both pre- (Low, $M = 2.96$, SD = .81; High, $M = 2.70$, SD = .98) and post-information (Low, $M = 3.28$, SD = .92; $M = 3.09$, SD = 1.13).

In respect of risk perceptions, there was a statistically significant influence of information $F(1, 1410) = 113.59$, $p < .001$, partial $\eta^2 = .075$. Participants rated shale gas as less risky/more beneficial post-information ($M = 3.75$, SD = 1.98) compared to pre-information ($M = 4.22$, SD = 2.08).[15]

Next, we included prior attitudes (favourability) as an IV, along with condition, to explore the possible effects of attitude polarisation. While we found prior attitudes (recoded as a median-split binary variable) exerted a main effect on post-information favourability $F(1, 3) = 1031.07$, $p < .001$, there was no interaction effect with condition $F(1, 3) = .32$, $p = .808$. Similarly, prior attitudes exerted a main effect on post-information risk perceptions $F(1, 3) = 941.44$, $p < .001$.[16] There was also a main effect on both perceptions of shale as clean $F(1, 3) = 332.89$, $p < .001$[17]; and shale as cheap $F(1, 3) = 275.52$, $p < .001$.[18]

Finally, we included ambivalence as an IV, along with condition, to see whether those more ambivalent changed attitudes more than those with firmer beliefs [49]. This showed significantly greater attitude change amongst the more ambivalent respondents – specifically, less risk perception $F(1, 3) = 4.09$, $p < .05$,

[11] Similarly, acceptance of extraction of shale across the UK was higher for males, those with higher levels of science education, higher scepticism, and lower environmental identity, as well as those with higher place attachment (see Supplementary Information).

[12] Indeed, those living in Lancashire are more likely to vote UKIP (15.1%) and Conservative (24.0%) than those living elsewhere (10.3% and 21.0%, respectively; $\chi^2(12, 1455) = 43.78$; $p < .001$). Those living in Lancashire also have lower environmental identity ($M = 3.49$, SD = .95) than those living elsewhere ($M = 3.70$, SD = .95; $t(1449) = -3.89$; $p < .001$); they also have higher climate change scepticism ($M = 2.96$; SD = .91) than those living elsewhere ($M = 2.78$; SD = .87; $t(1448)=3.49$; $p < .001$). There were also more males (51.1%) in the Lancaster sample than elsewhere (38.9%; $\chi^2(1, 1449) = 19.16$; $p < .001$); and a lower proportion in Lancashire living in rural areas (23.6%) compared to those living in other regions (39.9%; $\chi^2(2, 1447) = 37.57$; $p < .001$). There was no significance in science education or place attachment between regions.

[13] There were no statistically significant differences between conditions $F(3, 1414) = .62$, $p = .603$, nor by environmental identity $F(1, 1414) = 1.988$, $p = .114$.

[14] This did not vary between conditions $F(3, 1399) = 1.22$, $p = .302$, nor by environmental identity, $F(1, 1399) = 1.342$, $p = .247$.

[15] There were no significant differences between conditions $F(3, 1410) = 1.28$, $p = .279$ nor by environmental identity $F(1, 1410) = .003$, p=.958.

[16] However, there was no interaction effect with condition $F(1, 3) = .96$, $p = .413$.

[17] However, there was no interaction with condition: $F(1, 3) = 1.10$, $p = .35$.

[18] However, there was no interaction with condition: $F(1, 3) = 1.15$, $p = .33$).

Table 3
Regression analysis of favourability towards shale gas.

		B	Std. Error	Beta	t	B	Std. Error	Beta	t	B	Std. Error	Beta	t	B	Std. Error	Beta	t
1	(Constant)	2.37	0.12		19.41***	2.54	0.17		15.29***	0.51	1.15		0.44	0.36	1.16		0.31
	Gender	0.33	0.07	0.13	4.82***	0.31	0.07	0.13	4.48***	0.22	0.07	0.09	3.30***	0.22	0.07	0.09	3.20***
	Age	0.02	0.02	0.02	0.71	0.02	0.02	0.03	1.06	−0.04	0.02	−0.05	−1.65	−0.04	0.02	−0.05	−1.69
2	Education					−0.06	0.03	−0.08	−2.31*	−0.05	0.03	−0.06	−1.84	−0.04	0.03	−0.05	−1.73
	Science education					0.08	0.03	0.09	2.80**	0.09	0.03	0.10	3.21***	0.09	0.03	0.10	3.13***
	Knowledge of shale gas/fracking					−0.05	0.04	−0.04	−1.28	−0.02	0.04	−0.02	−0.59	−0.03	0.04	−0.02	−0.86
	Environmental identity									−0.08	0.04	−0.06	−2.15*	−0.11	0.04	−0.09	−2.90**
	Climate scepticism									0.27	0.04	0.20	6.70***	0.25	0.04	0.19	6.26***
	Politics_conservative									2.24	1.12	0.77	2.00*	2.30	1.12	0.79	2.06*
3	Politics_labour									1.65	1.12	0.62	1.48	1.71	1.12	0.64	1.53
	Politics_libdem									1.85	1.13	0.33	1.64	1.91	1.12	0.34	1.70
	Politics_green									0.98	1.13	0.15	0.87	1.07	1.13	0.16	0.95
	Politics_UKIP									1.89	1.12	0.50	1.68	1.96	1.12	0.52	1.75
	Politics_plaidcymru									1.68	1.13	0.28	1.50	1.74	1.12	0.29	1.55
	Politics_undecided									1.69	1.12	0.51	1.51	1.77	1.12	0.53	1.58
	Politics_wouldnotvote									1.48	1.13	0.29	1.31	1.60	1.12	0.31	1.43
	Politics_other									1.85	1.13	0.31	1.64	1.92	1.13	0.32	1.71
4	Location_SWales													0.02	0.08	0.01	0.27
	Location_NEngland													0.00	0.08	0.00	0.06
	Length of residence in area													0.00	0.03	0.00	0.13
	Rurality													−0.09	0.04	−0.06	−2.17*
	Employed in energy industry													0.17	0.10	0.04	1.70
	Place attachment													0.14	0.05	0.07	2.59**

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

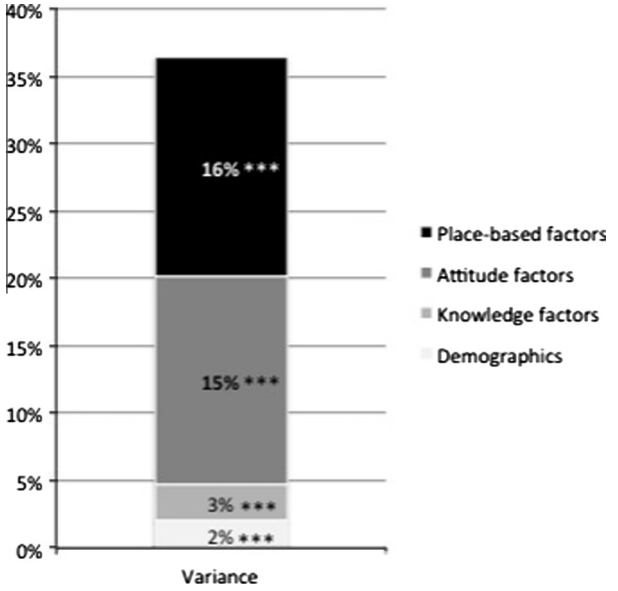

Fig. 9. Variance explained in shale gas favourability by different predictors. 'Demographics' includes gender and age. 'Knowledge factors' includes knowledge of shale gas/fracking, highest qualification, and highest qualification in a science subject. 'Attitude factors' includes political affiliation, environmental identity, climate scepticism. 'Place-based factors' includes location, rurality, employment in energy industry, length of residence in area, and place attachment. ***$p < 0.001$ change in variance.

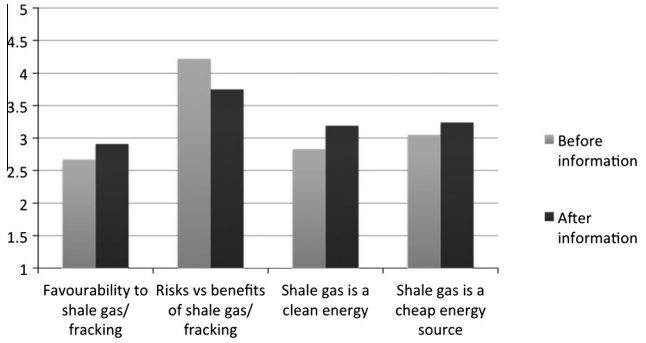

Fig. 10. Impact of information on shale gas perceptions.

(marginally) more favourability $F(1, 3) = 3.39$, $p = .066$, and higher agreement that shale is clean $F(1, 3) = 6.71$, $p < .01$ (but not that it is cheap $F(1, 3) = 1.08$, $p = .299$; Fig. 11).[19]

5. Discussion and conclusions

5.1. Discussion

There is growing recognition of the need to understand public attitudes to energy sources, such as shale gas, and to feed these views into policy-making. This study represents the first detailed UK experimental survey of public perceptions of shale gas fracking, including analysis of the effects of different messages and the

[19] There were no main effects of condition on any DV.

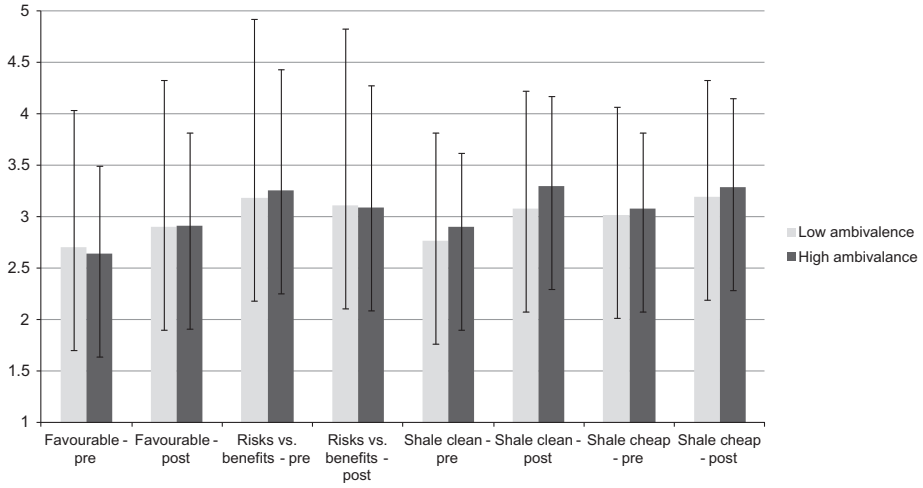

Fig. 11. Influence of ambivalence and information framing on shale gas perceptions.

relative influence of different audience, message and contextual factors on support for shale gas extraction. Our survey of three UK regions revealed relatively low levels of knowledge about energy technologies, although respondents (who were slightly older and more qualified than the UK public as a whole) were most familiar with coal, natural gas and nuclear power. Consistent with previous research [11,15], most people had heard of shale gas or fracking. In terms of favourability, renewables were seen most favourably, while other technologies were rated considerably lower – again, consistent with previous research [12]. Interestingly, shale gas was the most unfavourable of the technologies, followed by nuclear, although the largest proportion of respondents rated shale gas as 'neither favourable nor unfavourable'.

Despite the lower level of favour afforded to fracked shale gas relative to other options, both attitudes and risk perceptions in respect of shale gas do show considerable ambivalence, confirming previous work [11,15].[20] One-quarter of participants answered 'don't know' about the risks versus benefits of shale gas fracking. However, one-quarter also indicated that the risks far outweigh the benefits – double the proportion who said the benefits far outweigh the risks. In respect of most attitude statements, a large proportion selected 'neither agree nor disagree', highlighting considerable public uncertainty about shale. However, many express doubts about the government's ability to adequately regulate shale gas, and there is concern about the risk of water contamination from fracking (cf. [11]). Almost half of participants were not sure whether shale gas would make a difference to their lives in the next 20 years; and 40% did not know if widespread shale gas extraction should be allowed in the UK. Participants have few preferences on where shale gas extraction should occur, many stating that it should not occur anywhere.

Comparison of survey responses by location showed, as expected (H1), that those living in a region where shale gas extraction is already underway (Lancashire) were significantly more positive than those living where shale gas fracking is not viable. However, these location differences disappear when controlling for demographic and value factors. Rather, political affiliation and attitudes to climate change, as well as gender, rurality, place attachment and environmental identity, appear to be more important predictors of shale gas attitudes (cf. [11]). As expected (H1), males and those with lower environmental concern were more positive about shale gas; although contrary to expectations, those with *higher* place attachment were also more positive. The latter is an unexpected finding that merits qualitative follow-up.

While the current research was intended foremost as an empirical exploration of an emerging energy topic, a significant contribution of the paper was to integrate geographical and psychological perspectives on energy communication, by comparing the relative importance of place-based versus attitudinal, value and knowledge factors. Each accounted for around half the variance, highlighting the importance of examining both sets of factors in future audience research. Of course, this distinction is rather arbitrary and non-inclusive; future work might focus on exploring interactions and causal pathways through different predictor variables (e.g., sector of employment, shale knowledge and climate attitudes) as well as additional predictor variables.

Contrary to expectations (H2), we found that knowledge did not polarise attitudes. Rather, those with the highest prior knowledge of shale gas had the most favourable attitudes. However, we acknowledge that our measure of knowledge in this study was self-assessed, and that future work could compare this with more 'objective' knowledge measures. On the other hand, as expected (H3) and consistent with previous work [49], prior attitudes predicted how information was received. We found that attitudinal ambivalence interacted with change in attitudes after reading the information: specifically, there was greater attitude change (becoming more favourable) amongst the more ambivalent respondents.

When provided with information about shale gas, participants became more positive – in most cases this was irrespective of whether environmental or economic benefits were highlighted. Contrary to expectations (H4), environmental identity did not interact with message framing; that is, the environmentally-framed message did not resonate any more with those with higher environmental concern than with other people.

5.2. Conclusion and implications

Our results are consistent with other recent studies that show the UK public is ambivalent about shale gas, although there appears to be greater awareness of the risks than the benefits. However, the public is highly heterogeneous in relation to shale gas attitudes: prior knowledge appears to be associated with more favourable attitudes, although demographics and environmental values are overall strongest influences on perceptions. Recognising

[20] It is likely that the research design of the survey is responsible for the lower level of ambivalence found relative to the DECC public attitudes tracker [15]. The latter is a longitudinal survey tracking UK public attitudes on seven energy-related topics, whereas the present survey is specific to fracking, probing in depth and with the use of variously framed information.

this heterogeneity is important for effective engagement with different audiences; for example, those with strong pro-environmental values are likely to be difficult to persuade of the benefits of shale gas unless shale gas can be successfully framed as relatively environmentally benign.

In the present study, providing information about a particular benefit (economic or environment) of shale gas in general made attitudes more positive, particularly amongst those who are the most ambivalent. It is this undecided group who will be most susceptible to persuasive information, be this from pro- or anti-fracking sources.

When related to relevant theoretical and policy debates around engaging publics with novel energy technologies, these findings do not undermine the deficit model to the extent that other work on related issues, such as climate change, does [50]. Evidently, there is an important role for information provision, but other factors such as values, play at least as important a role in attitude formation. On the other hand, our findings are consistent with other work on NIMBYism [30], which calls into question any straightforward relationship between location and public attitudes.

Future work should include longitudinal analysis pre- and post-development of energy infrastructure to explore the process and mediators of attitudinal change. There is also considerable scope to examine attitude change by varying the media, source and framing of shale gas information. In terms of news media representation of hydraulic fracturing for shale gas, comparative international work is also likely to be instructive: the limited data available highlights national differences that merit further investigation [51]. Work should also focus on the role of trust in government, which recent deliberative work (and communication theory) indicates is likely to be critical for public acceptance [37].

Acknowledgements

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Appendix A. Experimental text (Economic gain condition)

On the next screen, you will see some information about shale gas fracking. Please read the information carefully as you will be asked some questions about it afterwards:

The UK government has announced that it wants to see the widespread extraction of shale gas across the UK. Shale gas is a natural gas that forms within a particular type of rock, formed from clay and other minerals. This rock is known as 'shale'. To extract gas from the shale, a process called 'hydraulic fracturing' is used (known more commonly as 'fracking'). Water, sand and chemicals are injected at high pressure into the shale, cracking it open and allowing the gas to escape. The water is then allowed to flow back to the surface where it is collected and treated or reused. The gas can then be collected and burnt in a power plant to generate electricity. When finished, the sand that has been injected fills and stabilises the cracks in the rock. Shale gas could increase global gas reserves by over 40%.

There are both benefits and drawbacks associated with shale gas fracking. One of the main benefits is that fracking could generate substantial quantities of gas in the UK, contributing to energy self-sufficiency. This means that widespread extraction of shale gas across the UK could reduce household energy bills.

Appendix B. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.apenergy.2015.09.004.

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