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Who is the 'public' when it comes to public opinion on energy? A mixed-methods study of revealed and elicited public attitudes to shale gas extraction

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ABSTRACT

Shale gas is a contentious energy source. Yet, 'imagined' notions of the public (for example, NIMBYs) rarely reflect the reality of public opinion. We use an inductive, empirical approach to define UK publics in relation to shale gas extraction, drawing on multiple data sources (social media, a national survey, and two local surveys) and composite measures. Cluster analyses and thematic coding reveal a diversity of responses ranging from active opposition, through ambivalence, to active support. The number of communities varies by data source and analytical method, but across all datasets we see more opposition than support. Across all datasets, political views were an important lens through which shale gas was understood. Our findings have implications for how developers and policy-makers engage with the public, and expose limitations of pre-defined notions of the public that may not reflect empirical realities.

1. Introduction

Energy systems need to be transformed to address growing socio-economic and environmental pressures, including inflation and climate change. While pressure to move away from fossil fuels grows, in many countries there remains widespread interest in exploiting domestic gas, coal and oil reserves, particularly at a time of rising energy prices and political instability. Shale gas extraction (SGE), for example, has been pursued in several countries (e.g., USA, China, Argentina, Canada, Poland, Australia, South Africa), whilst others have implemented bans or moratoria (e.g., France, Germany, Ireland, Bulgaria; [1]). Extracting natural gas from shale rocks involves hydraulic fracturing or 'fracking', i.e. pumping water at high pressure to create fractures in the rock that allow the gas to be released, and potentially used for electricity and heating. Possible economic and energy security benefits from SGE clash with concerns about induced seismicity and impacts on local communities and environments [2,3], as particularly evident in the UK where SGE policy has varied across time and place. Initial support for development in England from the UK government was replaced by a moratorium in 2019, then withdrawn in 2022, but since reinstated; and differing policies have been implemented across Northern Ireland, Wales, and Scotland [4,5]. In 2019, the UK also became the first major economy to commit to reaching net zero emissions by 2050, making it an important case study for understanding public response to energy system change.

Understanding public opinion about energy sources and technologies is essential for effective and democratic policy-making [6]. Moreover, there is a need to challenge 'imaginary lay publics' [7,8] – representations of 'the public' held by experts/policy-makers that imply or legitimise policy or engagement positions (e.g., public education to foster support for new technologies), typically diagnosed by certain tools (e.g., opinion polls) yet belying heterogeneity and complexity in public

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opinion revealed through different methods. Shale gas has been a particularly contentious energy source [9]. Yet, while polls show a divided public [10], less is known about what being 'for' or 'against' different energy sources, like shale gas, really means: are there only two groups (for/against) or is the picture more complex; what sort of people are in these different opinion groups; what do they believe and do; and what do different data sources reveal about them? This paper seeks to address these questions by applying multiple methods to identify different attitude segments (communities) within the UK public and ultimately provide a deeper understanding of public opinion on SGE. Importantly, we offer an inductive, empirical view of who the 'public' is in relation to shale gas development – in contrast to a pre-defined notion of the public, as may exist within industry or government for example, as those living close to a proposed development site, those with particular interests/views, or as consumers [11,12].

2. Literature review

2.1. Public attitudes to energy

Understanding public attitudes to new energy sources like shale gas is vital for several reasons. 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 [1]. 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 [13]. 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 [14]. It is therefore critical to understand public attitudes and the bases of concern about energy technologies, and feed this in early to decision-making (before attitudes become polarised and decision-makers potentially distrusted [15]).

Studies of public attitudes to energy sources and technologies consistently show the public favours renewable sources (e.g., solar, wind) over fossil fuels; and are ambivalent about carbon capture and storage, nuclear power, biofuels, electrification, and demand management [16,86]. Public values underlying engagement with energy system change include efficiency, nature protection, safety, reliability, affordability, freedom, fairness, and quality of life [17]. Consistent with this, most view fossil fuels as polluting, outdated and finite [17], although some see them offering economic and security benefits [16]. Comparatively little work has explored perceptions of unconventional fossil fuels (i.e., those trapped in low-permeability reservoirs, requiring advanced extraction methods), but many of the public's concerns about conventionals appear to apply here [10].

In contrast to other unconventional fossil fuel technologies (e.g., underground coal gasification), there has been greater media coverage of shale gas hydraulic fracturing [18,19], leading to growing levels of public awareness in recent years. Whereas 42% had heard of shale gas in the UK in 2012, this had risen to 86% by 2022 [16]. Views on shale gas are mixed [9,10], although opposition has grown over time [20–22]; in Autumn 2022, opposition to fracking in the UK was at 36%, with support at 25% (28% undecided; [16]). Men, older people, and those with few/no qualifications are more supportive [16], but demographic factors explain far less variation in SGE attitudes than psychological or geographical factors. Climate change attitudes and political affiliation particularly shape shale gas support, with those holding left-of-centre political views and more concerned about climate change being less supportive of SGE [23,24]. Accordingly, changes in shale gas policy (e.g., UK moratorium) have been interpreted through a political lens by different groups within the public [25,26].

Shale gas attitudes also vary geographically, but when controlling for political affiliation, they are not a function of proximity to SGE development sites though may relate to place attachment [24]. Other research similarly shows attitudes to energy sources and technologies are not well-predicted by proximity; while it is commonly assumed that those living close to developments may be more opposed (i.e., NIMBYism), in fact attitudes can be both more positive *and* more negative (i.e., more polarised) in local compared to distant communities, depending on factors such as perceived risks and benefits (e.g., pollution, job creation), trust in developers, place disruption, resource legacies, and symbolic values attached to local areas [27,28]. Importantly, though, attitudes can vary according to whether the issue is defined as a local development (siting) or a more abstract (policy) issue [29]. In the abstract, acceptance of energy sources tends to be higher than local scheme acceptance [22,30,31], but different factors may also affect support at different scales: for example, Clarke et al. [32] found SGE support amongst the US public was shaped more by political ideology when it was an abstract issue than when it was a specific siting one.

2.2. Defining the public

Pre-defined notions of the public – for example, as a single homogenous 'public'; or as binary 'for' or 'against'; or narrow (mis-)categorisations based on place or role (e.g. NIMBYs, consumers) – have long been acknowledged as a problem for fair and effective policy-making, including within energy policy [2,33]. In relation to hydrogen, for example, studies reveal that publics are often unrecognised or misrecognised in policy documents, resulting in distributive and procedural injustice in policy, technology, and infrastructure [34]. Likewise, wind farm opponents are often dismissed as NIMBYs by the renewable energy industry, who have sought to address presumed public knowledge deficits through education [35]. Often these simplistic or inaccurate imaginary conceptualisations of the public are produced through opinion polls and rely on unidimensional measures of 'support'/'opposition', rather than capturing the complex reality of public opinion [15,36,37]. In relation to shale gas extraction, specifically, government polling of the UK public is reported as percentages supporting or opposing it [16,38], with campaign groups likewise focusing on total support/opposition [39]. These imaginaries have direct consequences on energy policy and how government and industry engage with the public. For example, common assumptions of the public as objectors or NIMBYs driven by narrow-minded selfishness have resulted in recommendations for engaging with local communities through financial payoffs rather than substantive engagement or participation in decision-making [40].

The evidence reviewed above highlights 'the energy public' is in fact highly heterogeneous – there are many 'publics' with different views on energy, which are shaped by both individual and contextual factors [37]. These sub-groups, or segments, within the public can be identified through a range of data sources, each of which can shed different light on public opinion. Polling alone has suggested three main public opinion groups exist in the UK in relation to SGE: strong objectors, strong supporters, and those without a firm opinion [9]. However, social media analysis suggests a more complex picture. Analysis of UK public attitudes to the 2019 moratorium on shale gas extraction using Twitter and survey data found these two sources not only offered different insights onto public opinion (e.g., Twitter data provides granularity of evolving public responses across hours and days; survey data reveals how individual and place-based factors shape opinion), but also exposed different kinds of public. Social media users were more actively involved in the shale gas debate, and interpreted it more in political terms, than survey respondents [25,41]. Moreover, research indicates advantages of social media analysis for capturing historical perceptions: since those opposed to fracking may leave a region before fracking starts, subsequent surveys may present a biased view of public perceptions of SGE [42], whereas social media reveal perceptions over time.

This relates to long-standing critiques of how public opinion has been

constructed and used [36,43,44]. Public opinion polls can reinforce dominant power relationships [45] and project monolithic notions of opposition [46]; in contrast, qualitative and deliberative approaches shed light on the 'intricacies of local disputes' [11], expose typologies of resistance [47], and open up opportunities for more active and diverse involvement of the public in shaping energy developments or policies [48,49]. The public (or publics) from this perspective are not pre-existing or stable in relation to a particular issue, but emergent [50] and 'co-produced' through relations (e.g., between state and citizen; [51]) and discourse [11]. This contrasts with how the 'public' is often defined in policy contexts as 'consumers' or 'non-experts', often with the concomitant assumption that public engagement means education to foster technology acceptance and address 'information deficits' [52,53]. Other constructions of the public emerge from policy consultations [85] or deliberative engagement [54] which elicit informed views from actively engaged citizens, but may not reflect wider (unengaged) publics. Similarly, 'acceptance' of energy technologies tends to imagine the public as either 'society' as a whole or local 'communities' of place, ignoring communities of interest/practice that operate across spaces [55].

It is clear, then, that certain methods (e.g., polls) may have limitations when it comes to defining the public in relation to issues (e.g., static, decontextualised); but equally, other methods (e.g., interviews, citizen's juries, social media analysis) have different limitations (e.g., non-representativeness, knowledge-based). Using multiple methods may help overcome their respective limitations and shed more light on the public's attitudes to energy [56]. Moreover, using different data sources not only provides deeper insights into diverse attitudes, but also reveal *different* sub-groups within the public. As yet, however, no studies have attempted to explore how the public in relation to SGE may be constructed in different ways according to alternative data sources, including comparing those that 'elicit' opinion (surveys, etc.) with those that 'reveal' opinion (social media, etc.).

Public attitude surveys are widely relied on by institutions (e.g., governments; [16]) to reveal opinion (indeed, they are the dominant method of public engagement in energy and climate; [57]). Polling offers important advantages, being relatively quick to administer and analyse, providing representative insights, and allowing for segmentation (at national or local scales). On the other hand, surveys tend to be static and decontextualised [29], and elicit or 'invite' public opinion on issues that respondents may not have articulated views on before. As such, responses may be (artificially) constructed through survey completion and not accurately reflect real-world decisions (due to 'hypothetical bias'; [58]). Survey responses can also be influenced by framing and language [56]; for example, the term 'fracking' elicits more opposition than 'hydraulic fracturing' [10]. Polling then should not be seen as methodologically unproblematic, or the only way to understand public opinion. Moreover, where polling is used, it should avoid relying on single items to measure public sentiment (e.g. support), and ideally draw on multiple items and explore how these coalesce (e.g. using cluster analysis).

Public opinion can also be examined in more naturalistic ways, such as through social listening (monitoring online conversations). Digital spaces and social media allow for 'uninvited citizen engagement' with energy [57], not only shedding light on spontaneous public attitudes to energy but also on how the public may be actively mobilising in relation to energy issues. Social media has revolutionised activism, allowing groups and individuals to share information with vast audiences, readily organise events or protests [59], and confer a sense of belonging to a larger cause [60]. In this sense, social listening can reveal sub-groups within the wider public that may reflect meaningful identities to those within them. It is estimated that in the UK alone there are over 300 individual shale gas activist groups that use a social media platform (e.g., Twitter, Facebook) for information sharing and organisation [61]. Most (84%) of the UK population now actively engage with one or more social media platform [62], although social media users tend to be younger and more educated than non-users [63]. Social media analysis has been used to investigate public engagement with various topics [64,65], but of the limited research on online shale gas debates, most has been conducted in the US and are largely small-scale qualitative studies (e.g., [66,67]). Furthermore, while previous research focusing on UK Twitter data has offered insight into public opinion on shale gas [25,41], this has primarily focused on spatial patterns across the UK rather than what might be ascertained about public attitudes towards SGE from the analysis of the contents of Twitter messages. Social media therefore offers a valuable additional source of data on public opinion (albeit not using a representative sample) on SGE from which to identify potential sub-groups and their associated attitudes, and which can be compared with survey data.

2.3. Research aims and approach

This research aims to identify who the 'public' is in relation to shale gas extraction, using an inductive, empirical approach and drawing on multiple data sources (social media, national and local surveys). Contrasting pre-defined notions of the public in relation to SGE (e.g., as local communities, consumers, activists, NIMBYs), we respond to calls to reflect the diversity of public engagement with energy [57]. We also go beyond polling alone, the most common public engagement method, and using unidimensional survey items to demonstrate how SGE publics can be constructed in different ways using alternative data sources and methods (i.e. methodological determinism). Specifically, we apply (a) cluster analyses of a representative survey of the UK public undertaken in 2019 and of two local surveys undertaken in 2020 and 2021 at sites of proposed SGE development in Northern England; and (b) thematic analysis of Twitter data from the six largest communities of UK users in 2019 identified using a network-based cluster analysis approach.

We explore the following research questions:

1. How many attitudinal sub-groups (segments) can be identified within the datasets, and what beliefs and actions characterise these groups?
2. What are the socio-demographic, political and geographical characteristics of these sub-groups?
3. What are the similarities and differences between the sub-groups identified within the different datasets, and what does this tell us about using different data sources to examine (reveal) public opinion?

3. Methods

3.1. UK and local surveys

3.1.1. Participants

A survey of a representative sample of the UK public[1] ($N = 2777$) was administered in April 2019 by the online panel provider YouGov to measure public attitudes to energy development. Two local surveys were also conducted in April 2020 (Great Altcar) and June 2021 (Woodsetts) in areas where SGE has been proposed: Great Altcar, Lancashire ($N = 102$); and Woodsetts, South Yorkshire ($N = 83$; Fig. 1). Ethical approval for the survey research was granted by the Ethics Committee of the School of Social and Political Sciences at the University of Edinburgh. Informed consent was obtained from participants. See Supplementary Material for demographic details of each sample.

3.1.2. Measures

A range of measures was taken to capture attitudes to SGE, each of

[1] The survey was constrained with quotas to represent the UK population on: age, sex, UK census region of residence, social grade, education, party vote in the 2017 general election, vote in the 2016 EU (Brexit) referendum, and attention paid to politics.

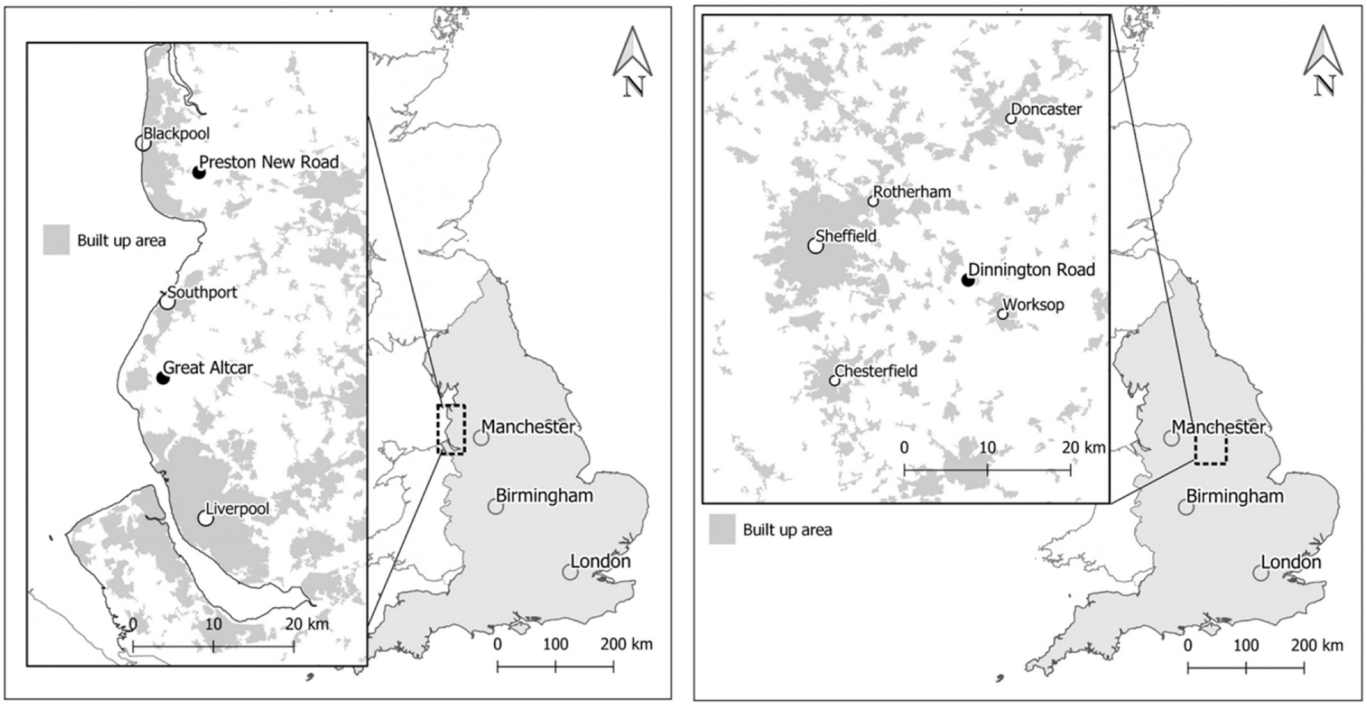

Fig. 1. Map of Great Altcar (left) and Woodsetts (right).

which came after a short definition of SGE was provided.[2] 'Don't know' responses were removed for further analyses.

- *Familiarity* was assessed with one item: "Overall, how much have you read or heard about shale gas extraction", with responses from 1 (*nothing at all*) to 5 (*I know a great deal*).
- *General support* was assessed with "If the UK continues to use gas in the future to generate heat and electricity, to what extent do you support or oppose each of the following options for how we obtain that gas? Shale gas" on a scale from 1 (*strongly oppose*) to 6 (*strongly support*).
- *UK support:* Participants were shown a map of the UK with five areas of potential SGE activity coloured and asked "the extent to which you support or oppose shale gas extraction in each region of shale gas licences" on a scale from 1 (*strongly oppose*) to 6 (*strongly support*); the mean of all areas was used to calculate UK support ($\alpha(5) = 0.98$).
- *Local support* was then assessed with the item: "Irrespective of whether you live near any of the coloured areas on the map, would you support or oppose shale gas extraction in your local area (i.e., within 3 miles of your home)" on the same 6-point response scale.
- *Psychological proximity:* Perceived psychological distance of shale gas extraction was measured with responses from 1 (*strongly disagree*) to 6 (*strongly agree*) to three items: "My local area is likely to be affected by extraction", "Extraction is likely to have a big impact on people like me", and "Extraction will mostly affect areas far away from here" (reversed; $\alpha(3) = 0.66$). The final item was not included in the local surveys.
- *Negative emotions:* Participants were asked "To what extent do you experience the following emotions when thinking about shale gas extraction?" followed by five emotions on a scale from 0 (*not at all*) to 3 (*very much*). Three negative emotions – "Anxious", "Tense" and "Fearful" – were used to construct a negative emotion scale ($\alpha(3) = 0.92$).
- *Perceived costs and benefits* were measured with the question "How likely do you think the following effects are from shale gas extraction?" followed by a list of positive and negative impacts on a scale from 1 (*not at all likely*) to 4 (*very likely*). In the local survey, the question wording specified the local development.[3] Perceived benefits included job protection and creation, reduction of dependence on gas imports, and (UK survey only) reduced energy bills; $\alpha(5) = 0.81$. Perceived costs included increased traffic, negative health impacts, reduced property values, industrialisation of countryside, water contamination, tremors or earthquakes, decreased local beauty, and (UK only) reduced greenhouse gases; $\alpha(7) = 0.91$.
- *Public involvement* was measured with agreement on two items: (a): "I believe people like me can have a say in affecting decisions about *shale gas extraction* (for example, where wells are sited)"; and (b) "The public needs to have a voice in decisions such as those related to approving or refusing an application for a shale gas well". For the UK survey, the items did not scale reliably so were analysed separately. In local surveys, involvement was measured with a two-item scale: "Local people have been given sufficient opportunity to participate in decision-making" and "Local people have been able to influence decision-making on the proposal", with responses ranging from 1 (*strongly disagree*) to 6 (*strongly agree*); $\alpha(2) = 0.67$.
- *Action:* In the UK survey, participants were asked to "select any of the following actions you would engage in if shale gas extraction were proposed near where you live?" followed by 11 actions e.g., "Attended a meeting organized by the fracking company", "Signed a petition related to the proposal", "Contacted one of my elected officials about the proposal", with a score derived from the sum of actions. For the local survey, participants were asked "How often have you engaged in the following, with a specific focus on the

[2] "Throughout this survey, we will ask you several questions about a way to produce gas, which we will term *shale gas extraction*. It involves removing gas (methane) from shale formations a mile or more below ground, by using hydraulic pressure to pump water, sand, and chemicals into the shale to create microscopic fractures, allowing the gas to return to the surface. This is sometimes called 'hydraulic fracturing' or 'fracking'."

[3] "Please read the following list of potential benefits related to the proposed shale gas project at [Woodsetts/Great Altcar]. For each, indicate the degree to which you think these benefits are likely to occur if the proposed project goes ahead."

proposed shale project in Woodsetts/Great Altcar" and responded on a scale of 1 (*never*) to 5 (*more than 10 times*) for nine items similar to the above; $\alpha(9) = 0.78$.

Additional predictors included: age, gender, education, numeracy,[4] household income, region, ethnicity, religion, newspaper readership, national identity (English, Scottish, Welsh), and rurality. Perceived climate change risk was measured on a four-item scale ($\alpha(4) = 0.93$); participants were asked how serious they think climate change poses a threat to themselves and their family, to the UK as a whole, to people in developing countries, and to the wildlife and ecosystems, responding from 1 (*not at all serious*) to 5 (*extremely serious*). Political ideology was measured on a 7-point scale from very liberal (1), to very conservative (7). Participants were also asked which political party they voted for in the 2017 general election (e.g. Labour, Conservative, Liberal Democrat). Finally, place attachment was measured with six items (e.g., "I would regret having to move to another place"; "This place is a part of me"; [69]) on a 6-point agreement scale (see above).

3.1.3. Cluster analysis

Cluster analysis is commonly used to identify sub-groups, or segments, within publics, and has been used in previous analysis on public energy attitudes [70]. To identify patterns in the SGE attitudes, we applied hierarchical cluster analysis using the Ward method with squared Euclidian distance. We defined the clusters based on 11 shale gas attitudinal variables measured in our UK surveys, and then compared (using ANOVA) whether clusters varied in terms of demographic and political factors. As discussed below, dendrograms indicated a six-cluster solution optimised differences across groups for the UK sample. For the local samples, cluster analysis was performed separately for Woodsetts and Great Altcar given our interest in geographical context. All scales above (except Local Involvement, due to excessive missing data) were used to create the clusters. In contrast to the UK analysis, we were unable to generate six clusters due to the relatively low sample, which would create very uneven cluster sizes (e.g., only one participant in one of the clusters). Hence, dendrograms were inspected to identify the maximum number of clusters which allowed for more even cluster size distribution, and a four-cluster solution was identified. While guidance varies on minimum cluster sample size, groups of at least 20 are often considered acceptable [71]; some of our clusters reached this threshold but others did not, so caution should be exercised in interpretation.

3.2. Social media analysis

3.2.1. Twitter

Within the UK, the microblogging service Twitter has the third largest user base (16.7 million users) and permits users to post up to 280 characters including emojis in a single tweet. Users can retweet the message contents of other users and allows for sharing of external information sources, making it more accessible for public communication than other platforms [72]. Twitter users tend to be younger and more educated than the general public; moreover, not all Twitter users post about shale gas, so the sample for this analysis is specific sub-set of the UK population, and not representative.

We used a network-based cluster analysis approach [88], utilising retweets and mentions, to investigate how the UK public engaged on Twitter with SGE. Tweets were gathered over the course of the entire year of 2019 from the Twitter Streaming API using the Tweepy Python Package, which is a live streaming service. This package filtered messages containing the key terms: 'frack', 'hydraulic frac' and 'shale gas' and included messages which contain these character sequences e.g., 'fracking', '#frackoff', 'hydraulic fracturing'. Live streaming was chosen over legacy service as the preferred method of data collection to mitigate the potential for loss from deleted Twitter accounts and tweets. Due to restrictions with the Twitter API, the tweets collected came from the global user population and not restricted to the UK. This resulted in just over 1.4 million tweets collected for 2019 from the English-speaking world. Any account which tweeted less than twice during the year was removed, and considered a dormant account, resulting in 1.03 million tweets. This number was further reduced to 381,364 through the analysis and filtering processes outlined below.

Identification of Twitter communities comprised two stages. The first stage involved constructing a network graph of users where nodes represent user accounts and edges model the interactions between those accounts based on messages (i.e. retweets, mentions). Retweets were identified through the string pattern 'RT @username'; mentions were identified through the string pattern '@username' (RTs were omitted first to avoid duplication). During this process hashtags (#) and URL links were also extracted.

The second stage involved determining statistically significant clusters ('communities') within the graph. Assignment of communities was performed on the 2019 directional network using the Louvain algorithm (De Meo et al., 2011). Only retweet connections within the Twitter network graph were used in this analysis as retweets show endorsement of ideas [89]. The Louvain method is one of the faster clustering algorithms utilising modularity to identify areas in the network with high connection densities [90]. For each new community a number was assigned, with manual inspection of the top 20 user details, corresponding to those having the highest number of retweets.

Location data for Twitter users within each community was ascertained by extracting user account location registration details using the Twitter API and use of the OpenStreetMap geocoding API (https://nominatim.org/) to convert placenames into geographic coordinates. Location data was only retained if it was within the UK and the centroid of each polygon was taken as the final location and any broad level descriptions (e.g., 'United Kingdom', 'Great Britain', 'England', 'Wales', 'Northern Ireland', 'Scotland') were omitted. Users that could not be located were removed from further spatial analysis. This filtering process left approximately 5% of usable account locations. UK tweets were then separated from other English-speaking countries by reviewing Twitter account information of these 20 users. For efficiency, communities with less than five accounts were omitted from further analysis. This further reduced the total number of tweets in the sample; however, these groups were deemed too small to further investigate (for example there were hundreds of groups with a handful of users identified by the clustering algorithm). UK groups were manually assigned if over 90% of the top user accounts were identified as being from the UK. The decision to focus on the UK tweets from the larger groups only, was also justified on the basis that the aim was to better understand the larger groups that were driving the UK shale gas conversation on social media.

3.2.2. Thematic analysis

Whilst network-based clustering identifies communities of users connected to each other, it does not provide information about what topics are being discussed or shared within these communities. Thus, manual thematic analysis of the contents of a sample of 1800 tweets from across the six largest communities identified from the network-clustering analysis process was conducted using NVivo 20. Thematic analysis identifies patterns (themes) within data and is recognised as a rigorous methodological approach to inductively analysing qualitative data and giving meaning to important patterns within data ([73,91]. Inductive, thematic analysis was chosen owing to its usefulness for identifying public perceptions of social phenomenon on social media [92,93]. Using an inductive approach also lessened the risk of imposing researcher-driven conceptual understandings upon the data [73].

Analysis was undertaken in six stages [73], with the aim of

[4] Measured as the number of correct responses to three questions, e.g.: "Imagine that the chance of getting a disease is 1 %. If there were 1000 people, about how many would be expected to get the disease?" [68].

discerning topics/themes of interest and/or attitude(s) towards SGE expressed within each tweet. The unit of analysis was the whole tweet. The first phase involved data familiarisation to generate ideas for codes. The second stage consisted of manually assigning codes to each tweet, using a data-driven approach to develop thematic categories (codes) using NVivo 20. Each tweet could have been assigned multiple codes based on the thematic topic(s) to which it mentioned or referred to. The third phase involved grouping codes into overarching organising thematic categories and searching for themes within codes (sub-themes). Stage four involved reviewing the identified data to ensure the best possible code and theme assignment; stage five was defining and naming themes. Stage six compared the proportion of each theme across communities identified through the cluster analysis. Coding was undertaken independently by two researchers; manual coding was used to capture linguistic nuances and implied sentiments (e.g., sarcasm, irony; [74]). Analysis allowed themes and motivations for tweeting to be compared across communities.

4. Results

4.1. Survey results

4.1.1. UK-level

Mean scores for the UK and local surveys are shown in Table 1. Respondents in all are somewhat familiar with SGE but not very supportive, perceiving more costs than benefits. Participants in Woodsetts and Great Altcar are more familiar with shale gas than the general UK public, but somewhat less supportive and more negative. From the UK survey, people feel they should have a say in SGE decisions but the local surveys suggest this is not yet happening as much as communities would like.

For the UK survey, dendrograms indicated a six-cluster solution optimised differences across groups. The six groups comprised three anti-shale groups (55% of total sample), one ambivalent group (21%), and two pro-shale groups (25%; see Fig. 2). As well as SGE support and associated SGE perceptions, willingness to act (e.g., protest) on SGE and the belief that 'people like me can have a say on shale' appear to most distinguish the groups (Supplementary Materials). As such, the groups can be labelled: 1:Anti-Shale & Active ($N = 418$); 2:Anti-Shale & Inactive ($N = 283$); 4:Anti-Shale & Empowered ($N = 166$); 5:Ambivalent ($N = 329$); 3:Pro-Shale & Active ($N = 129$); and 6:Pro-Shale & Inactive ($N = 265$).

MANOVA and Chi-square analyses (Supplementary Materials) indicate socio-demographic factors (age, gender, education, numeracy, marital status), politics (political party, liberalism-conservatism values, newspaper readership) and climate risk perceptions significantly differ across groups; however, no place-based variables (place attachment, region, rurality) are significant. Specifically, SGE supporters are more likely to be older, male, (marginally) wealthier, less educated, more conservative, with lower climate risk perceptions (see Table 2).

4.1.2. Local-level

At the local level, four clusters were preferred for each local sample. Expert judgment based was exercised for the justification of choosing the four clusters, as it seemed to classify participants well into (i) Active Opposers, (ii) Inactive Opposers (with more ambivalent attitudes), (iii) Weak Supporters (with more ambivalent attitudes) and (iii) Strong Supporters. Further analysis to validate this judgment is described below.

4.1.2.1. Woodsetts. Mean scores for all variables used were plotted against their clusters (Fig. 3). Moving from Cluster 1 to Cluster 4, we observe support for SGE on all levels decreases, whilst psychological proximity increases. Clusters 2 and 3 see more ambivalent attitudes and responses for negative emotions, perceived costs and perceived benefits. Action taken was relatively low, except for Cluster 4. Accordingly, Clusters 1–4 were named Strong Supporters ($N = 9$, 13%), Weak Supporters ($N = 17$, 25%), Inactive Opposers ($N = 29$, 43%), Active Supporters ($N = 13$, 19%). MANOVA confirmed clusters significantly differed across all variables (Supplementary Material). Most importantly, Strong Supporters showed significantly higher support for SGE than Weak Supporters, whilst support was significantly lower for both Active and Inactive Opposers. Action taken was similar across Strong Supporters, Weak Supporters and Inactive Opposers, but significantly higher for Active Opposers.

4.1.2.2. Great Altcar. Similar results were found for Great Altcar. As seen in Fig. 3, support for SGE decreases from Cluster 1 to 4, whilst psychology proximity increases. Clusters 2 and 3 showed more ambivalent emotions, and perceived benefits/costs. Action was relatively low, except for Cluster 4. Accordingly, Clusters 1–4 were named Strong Supporters ($N = 18$, 23%), Weak Supporters ($N = 16$, 20%), Inactive Opposers ($N = 25$, 32%), Active Supporters ($N = 20$, 25%). MANOVA confirmed clusters significantly differed across all variables (Supplementary Material). As with Woodsetts, Strong Supporters showed significantly higher support for SGE than Weak Supporters, whilst support was significantly lower for both Active and Inactive Opposers. Action taken was similar across Strong Supporters, Weak Supporters and Inactive Opposers, but significantly higher for Active Opposers.

4.1.2.3. Cluster classification. Overall, results for Great Altcar showed a similar trend to the Woodsetts sample, where Cluster 1 showed the highest level of support for SGE, higher perceived benefits than costs, lower psychological proximity to their area, lowest negative emotions, and minimal action taken in respect of SGE. Cluster 2 showed a similar

Table 1
Descriptive Statistics for All Variables.

Scale name (range)	UK			Woodsetts			Great Altcar		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Familiarity (1–5)	2777	2.65	0.95	83	3.20	1.02	102	3.44	0.78
General support (1–6)	2121	3.01	1.70	76	2.08	1.48	98	2.37	1.73
UK support (1–6)	2098	2.87	1.63	75	2.15	1.46	93	2.42	1.65
Local support (1–6)	2269	2.36	1.58	77	1.84	1.34	97	2.02	1.53
Psych. proximity (1–6)	2206	3.28	1.20	76	4.45	1.32	97	4.66	1.19
Neg. emotions (1–4)	2777	2.11	0.90	83	2.70	0.99	94	2.61	0.98
Perc. benefits (1–4)	2340	2.58	0.66	75	2.20	0.88	93	2.43	0.83
Perc. costs (1–4)	2430	3.19	0.65	80	3.49	0.67	100	3.30	0.71
People can have say (1–6)	2398	3.19	1.63	–	–	–	–	–	–
Public need a voice (1–6)	2464	4.98	1.24	–	–	–	–	–	–
Local involvement (1–6)ˆ	–	–	–	58	2.48	1.32	97	2.74	1.21
Action (0–11)*	2777	3.13	3.25	83	1.35	0.53	102	1.32	0.39

ˆremoved from Cluster Analysis for local surveys below due to excessive missing data.
* Question wording differs across UK and local surveys: hypothetical versus actual actions, respectively.

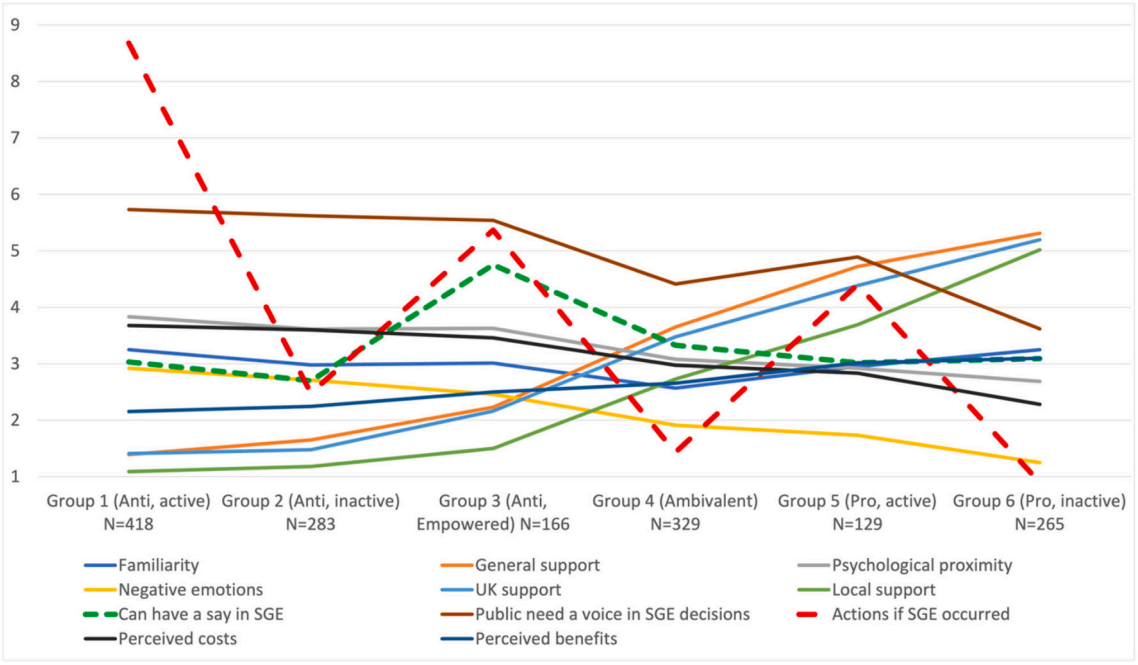

Fig. 2. Cluster analysis for UK survey.

trend as Cluster 1, but had lower levels of support, more negative emotions, and higher perceived costs than Cluster 1. Clusters 3 and 4 showed lowest support for SGE, higher psychological proximity, greater negative emotions, greater perceived costs and lower perceived benefits, as compared to Clusters 1 and 2. However, Cluster 3 was distinct from Cluster 4 on Action, as Cluster 4 showed more action on SGE. Hence, the MANOVA and follow-up contrasts provide evidence to support the classification of participants into Strong Supporters (Cluster 1), Weak Supporters (Cluster 2), Inactive Opposers (Cluster 3), and Active Opposers (Cluster 4). Chi-square tests showed distribution of Supporters (both Strong and Weak) and Opposers (both Inactive and Active) did not differ significantly between Woodsetts (62% Opposers) and Great Altcar (57% Opposers), $X^2 = 0.35$, $p = .56$. This suggests that relative opinions on SGE are similar across the (potentially) affected areas of Woodsetts and Great Altcar.

Moreover, the effect of physical proximity can be tested within the Great Altcar sample, as it consists of two distinct geographical regions: Rural Great Altcar and East Formby region ($N = 51$, 50%) which was very close to a proposed site for SGE, and the Rest of Formby region (N = 51, 50%) which was far from the proposed site, at the time of the study. Despite this, both regions have similar numbers of people for Strong Supporters $N = 7$ vs. 11), Weak Supporters ($N = 10$ vs. 6), Inactive Opposers ($N = 9$ vs. 16) and Active Opposers ($N = 8$ vs. 12), and the minor differences were not significant, $X^2 = 3.18$, $p = .37$. Overall, results suggest that the distribution of opposers and supporters of SGE may not be a factor of physical proximity to proposed extraction sites.

When looking at the socio-demographic and political characteristics of the local clusters (Table 3), as with the UK sample, we see the SGE-supportive clusters have a higher proportion of males, are more conservative, and have lower climate risk perceptions. Neither age appears nor place attachment appear to differentiate local clusters locally. There are some differences between the two areas; income, rurality, and minority ethnicity tend to be higher in Woodsetts than Great Altcar.

4.2. Social media

4.2.1. Communities identified through network-based cluster analysis

The clustering algorithm identified over 2000 communities within the global retweet network, with only 48 having five or more users. Nineteen communities of these 48 were identified as having a significant presence in the UK's online shale gas debate. In total 37,004 nodes were associated with UK's shale gas debate, representing approximately 36.6% of the global English-speaking users in 2019. In total 322,290 RTs (re-tweets) and 176,844 @ (mentions) were made, accounting for 50.2% and 45.5% respectively of the global network, of which 381,364 (25.5%) tweets were identified as being about the UK shale gas debate. This suggested that a significant proportion of global tweets about shale gas extraction were from the UK. Of the 19 UK communities, the six largest were analysed using thematic coding.

4.2.2. Thematic analysis of social media data

Thematic analysis generated six over-arching themes, each with several sub-themes. Theme 1 relates to environmental issues and climate change; theme 2 to risks and hazards from SGE (e.g., tremors); theme 3 to energy policy and politics; theme 4 covers wider political issues; theme 5 is about science and evidence; and theme 6 action and activism.

- Tweets grouped within theme 1 (environmental issues and climate change) were those referring to the relationship between shale gas and climate change, including references to renewable energy, shale gas and climate change, and uncertainties concerning SGE for sustainability. This revealed important insights about environmental concerns of social media users.
- Tweets in theme 2 were concerned with risk and seismic activity and included references to seismic activity at Preston New Road, fear of seismic activity risks more generally, concerns about contamination, and risk of destruction to local areas and conservation sites.
- Theme 3 (energy policy and politics) consisted of tweets about SGE in relation to UK energy politics debates. This included responses to Scottish Politician Jo Swinson's involvement, as well as concern over the UK Conservative party's links with shale gas lobbyists in election campaigns.
- Theme 4 contained tweets that explored SGE in relation to wider political topical issues, including Brexit, Scotland's future, and debates about localism in governance, revealing how Twitter users frame and communicate SGE in relation to political issues beyond energy politics debates.

Table 2
Summary of UK survey cluster characteristics.

Cluster 1. Anti-Shale & Active (*N* = 418)	- Mean age = 51.5 - Female = 51.9% - Median household income = £30,000–£34,999 - White ethnicity = 88.8% - No religion = 61.7% - Urban residence = 72.2% - Married = 49.6% - Highly educated and numerate (graduate =38.5%, numeracy = 2.42/3)	- Most liberal of all clusters (M = 3.0; 1 = *very liberal*, 7 = *very conservative)* - Most likely to have voted Labour in the general election (52.8%) - Small readership of Telegraph (12.2%) but highest readership of Guardian (26.1%) - Highest perceived climate risk (M = 4.3/5); - Feels relatively attached to their area (M = 3.9/6).
Cluster 2. Anti-Shale & Inactive (N = 283)	- Mean age = 50.8 - Female = 52.3% - Median household income = £25,000–£29,999 - White ethnicity = 91.2% - No religion = 57.4% - Most likely cluster to live in urban area (80.2%) - Married = 41.7% - Moderately educated and numerate (graduates = 26.2%; numeracy = 2.2/3)	- Fairly liberal (M = 3.6) - Tending to vote Labour (49.1%) - Smallest readership of the Telegraph (8.5%) but also fairly low readership of the Guardian (11%) - Fairly high perceived climate risk (M = 3.9) - Feels relatively attached to their area (M = 3.8).
Cluster 3. Anti-Shale & Empowered (N = 166)	- Mean age = 52 - Female = 56.6% - Median household income = £30,000–£34,999 - White ethnicity = 93.4% - Religious = 51.4% - Urban residence = 78% - Married = 47.6% - Highly-educated (36.7% graduates) and numerate (2.31/3)	- Fairly liberal (M = 3.5) - Similar proportions voting Conservative (40.4%) and Labour (41.8%) - Low readership of Telegraph (10.8%), high Guardian readership (16.3%) - High perceived climate risk (*M* = 4.1) - Feel relatively attached to their area (M = 3.9).
Cluster 4. Ambivalent (N = 329)	- Lowest mean age of all clusters (48.5) - Male = 55.9% - Median household income = £25,000–£39,999 - White ethnicity = 90% - Religious = 51.2% - Urban residence = 76.8% - Married = 41.9% - Moderately educated (30.4% graduates) with lowest numeracy (2.1/3)	- Slightly liberal (M = 3.9) - More likely to vote Conservative (47.9%) - Fairly low Telegraph (11.6%) and Guardian readership (11.6%) - Moderate climate risk perceptions (M = 3.5) - Feel relatively attached to their area (M = 3.7).
Cluster 5. Pro-Shale & Active (N = 129)	- Mean age = 54.5 - Male = 57.4% - Median household income = £35,000–£39,999 - White ethnicity = 89.9% - Religious = 53% - Urban residence = 78.2% - Married = 61.2% - Fairly highly-educated (31.8% graduates) and numerate (2.4/3)	- Fairly conservative (M = 4.12) - Likely to vote Conservative (60.2%) - Highest readership of Telegraph (21.7%) and low Guardian readership (13.2%) - Moderate climate risk perceptions (M = 3.6) - Feel relatively attached to their area (M = 3.9).
Cluster 6. Pro-Shale & Inactive (N = 265)	- Older than other clusters (M_{age} = 57.7) - Highest proportions of males (75.5%), - Joint highest median household income (£35,000–£39,999) - Highest proportion of White ethnicity (95.8%) - Not religious = 52% - Urban residence = 75.1% - Married = 58.3% - Not very highly-educated (26.1% graduates) but highly numerate (2.4/3)	- Fairly conservative (M = 4.4), - Most likely cluster to vote Conservative (64.7%) - High readership of Telegraph (20.8%), lowest readership of Guardian (9.1%) - Lowest climate risk perceptions (M = 3.0) - Feel relatively attached to their area (M = 3.8)

- Theme 5 evidenced how Twitter users utilised scientific information in their social media communications about shale gas debates and included tweets on SGE and its impacts on climate change. It also included expressions of concern over the availability and reliability of scientific information, the use (or lack) of scientific information in political communications, trust and distrust of scientific information, and use of evidence in calls to action, e.g., encouraging protest.
- Theme 6 contained tweets relating to calls to action on SGE, including calls for a ban on shale gas development, opinions about protestor actions, and calls to sign petitions or participate in demonstrations and protests.

Distribution of these themes across the six communities identified through the network-based cluster analysis is shown in Fig. 4. All communities discuss energy policy/politics more than other topics, but this is particularly the case for communities 1, 4 and 5. Activism is the next most common theme, and is particularly discussed in communities 2, 3, 5, and 6. Community 2 has the highest occurrence of climate discussions; while community 3 has most risk discussion. The least discussed topic was wider political issues, but this is more present in community 5 than in other communities.

Analysis within themes sheds light on the differences between communities and suggests possible labels for characterising each community. Labels were ascertained by examining tweet numbers relating to each sub-theme for each community and differences in distribution across communities. A full breakdown of the analysis within themes is available in the supplementary materials but the possible labels for each community were defined as following:

1 – Left-Wing/Environmentalist: Concerned about climate, favours renewables. Political corruption with shale operators, moratorium as a political tool, wider political distrust. Brexit and austerity policies.

This community had the highest occurrence of tweets relating to three of the sub-themes within the theme of Politics, Policy and Governance Issues (Theme 3): the Scottish Liberal Democrat Leader's Involvement with Shale Gas Companies (Sub-theme 3d); Political Distrust in relation to Shale Gas Governance (3e) and Distrust of the Conservative Party Government (3f), out of the six communities. It also had the highest occurrence of tweets relating to concerns over Brexit and the EU, Austerity, NHS, and People's Issues (sub-theme 4a), and Lack of Political Openness or Communication in Relation to Shale Gas (sub-theme 5f). Tweets from this community also revealed concern with Environmental Issues and Climate Change (Theme 1), particularly in relation to the roles of shale gas and renewables in relation to tackling climate change (Sub-themes 1a and 1b).

2 – Anti-Shale Activists: Distrust and lack of information. Call for shale ban. Signing or posting a petition.

This community's anti-shale stance and support for activism was ascertained from its having the highest occurrence of tweets across all communities calling for a ban on shale gas extraction (Sub-theme 6e) and about signing or encouraging others to sign a petition (Sub-theme 6e), as well as a high proportion of tweets concerned with a perceived lack of political openness or communication (Sub-theme 5f).

3 – Seismic Risk Concerns: Seismic risk (including at Preston New Road)

Community 3 had the highest occurrence of tweets regarding risks associated with shale gas development (Theme 2). Tweets revealed concerns about multiple forms of risk, including risk of seismic episodes in general (Sub-theme 2a) as well as the risks of these episodes at the

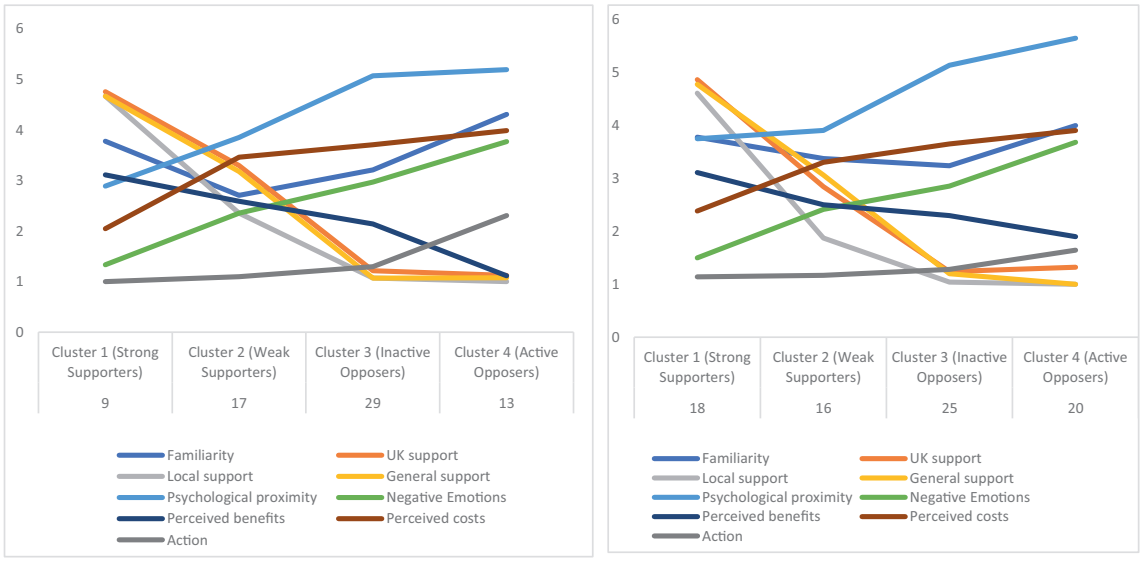

Fig. 3. Cluster analysis for Woodsetts (left) and Great Altcar (right).

Preston New Road site (Sub-theme 2b), risk of contamination (Sub-theme 2d), and risk of destruction to local areas (Sub-theme 2f).

4 – Pro-Shale: Benefits outweigh risks. Lack of political openness on shale

The pro-shale label of this community was ascertained on the basis that it had the highest occurrences of tweets suggesting the benefits of shale gas development outweighed the risks (Sub-theme 2e), in addition to tweets relating to the UK's energy mix and which indicated a stance favourable to shale gas (Sub-theme 3c). Tweets from this community also revealed concern over a lack of political openness and communication in relation to shale gas (Sub-theme 5f), but lower levels of concern about risk due to availability of scientific information (Sub-theme 5d).

5 – Scottish Anti-Shale: UK energy policy. Political distrust. Scotland's future. Scottish efforts to ban shale. Call for shale ban.

This community had the highest occurrence of tweets concerned with Scotland's future (Sub-theme 4b) and Scottish efforts to ban shale gas extraction (Sub-theme 6b). However, despite having greater focus on Scotland, this community also had the highest number of tweets expressing an anti-shale gas stance towards the UK's energy mix (Sub-theme 3b) as well as high incidences of tweets expressing distrust over the UK Conservative Government's over shale gas development activities (Sub-theme 3f).

6 – Seismic Risk Activists: Seismic risk (including at Preston new road). Call for shale ban.

Community 6 had the highest occurrence of tweets specifically relating to induced seismic episodes at Preston New Road in Lancashire (Sub-theme 2b), as well as comparatively high calls for a ban on shale gas extraction (Sub-theme 6c) and expressions of opinion about shale gas protests or calls for actions (Sub-theme 6d).

5. Discussion, conclusion and policy implications

Understanding public opinion about energy sources and technologies is essential for effective and democratic policy-making [14]. Shale gas has been a particularly contentious energy source, dividing public opinion and contributing to political ambivalence [1,20]. Yet, predefined notions of the public – for example, as a homogenous 'public'; or 'for' or 'against' shale gas; or NIMBYs – rarely reflect the complex reality of public opinion (e.g. [37]). Often these simplistic or inaccurate imaginary public are produced through opinion polls and rely on unidimensional measures of 'support'/'opposition' (cf. [15]). Our research used an inductive, empirical approach to defining the UK public in relation to SGE, drawing on multiple data sources (social media, a national survey, and two local surveys) and composite measures.

The three data sources reveal different levels of understanding and opinion about SGE. Our UK survey indicated the public is somewhat familiar with SGE but relatively ambivalent (albeit seeing more costs than benefits), feel they should have a say in SGE decisions, and would participate in some actions on SGE. In contrast, both local surveys indicate more familiarity but also more opposition than the UK sample, and show more desired than actual involvement in SGE decision-making. The social media analysis likewise shows more opposition than support for SGE, and several distinct bases for this opposition. In this sense, there is some consistency across the methods: on balance, they show more opposition than support for SGE, in line with previous studies (e.g., [9]); but the absolute levels and reasons underlying these positions vary across the datasets. Importantly, while at first glance the greater opposition to SGE in the local samples than the UK sample might appear consistent with 'NIMBYism', when we compared levels of opposition between residents living very close to the proposed SGE site in Great Altcar and those living much further away, we found no significant difference. Spatial proximity alone therefore appears not to explain opinion about SGE, as we discuss further below.

However, our research aims here were not to report on aggregates and averages for each of the datasets but to explore variation and diversity within them (i.e. to expose the number and characteristics of subgroups). Consistent with recent scholarship on public engagement with energy [57], we find a diversity of responses ranging from active opposition through ambivalence to active support. The number of segments or communities within the public varies according to the data source and analytical method used. In our nationally representative UK survey, we identified six segments, differentiated by support vs. opposition but also by levels of activism and feelings of empowerment. In our two local surveys, sample size limited the number of segments we could identify to four, similarly distinguished by support vs. opposition and the level of action taken in relation to SGE. Our social media analysis identified six segments, differentiated by support vs. opposition but also by politics, other social concerns, risk perception, use of evidence, and activism.

Characteristics of these segments differ by data source, with more similarity between the UK and local surveys than between surveys and social media. Across both the national and local scales, segments were distinguished demographically and psychologically in important ways: clusters opposed to SGE were more likely to be female, liberal, and more

Table 3
Summary of local survey cluster characteristics.

Cluster:	Woodsetts	Great Altcar
1: Strong Supporters	N = 9 Mean age = 62.7 Male = 89% Median household income = £70,000–£99,999 White ethnicity = 89% Christian = 44% Urban residence = 44% Married = 67% Relatively conservative (M = 4.3) Some readership of Telegraph (33%), no Guardian readership (0%) Lowest climate risk perception (M = 2.8) Moderate place attachment (M = 3.5).	N = 18 Mean age = 64.3 Male = 72% Household income = £45,000–£49,999 White ethnicity = 100% Christian = 50% Urban residence = 83% Married = 67% Relatively conservative (M = 4.0) Some readership of Telegraph (39%) and Guardian (17%). Lowest climate risk perception (M = 3.2) Moderate place attachment (M = 4.0).
2: Weak Supporters	N = 17 Mean age of 55.8, Male = 59% Median household income = £40,000–£44,999 White ethnicity = 88% Not religious = 65% Urban residence = 77% Married = 65% Most conservative cluster (M = 4.5) Small readership of Telegraph (6%), no Guardian readership (0%) Moderate climate risk perception 1 (M = 3.5) Moderate place attachment (M = 3.6).	N = 16 Mean age = 66.3, Male = 44% Household income = £35,000–£39,999 White ethnicity = 100% Christian = 44% Urban residence = 88% Married = 69% Moderate political leaning (M = 3.5) Some readership of Telegraph (31%) and Guardian (25%) Moderate climate risk perception (M = 3.7) Moderate place attachment (M = 3.8).
3: Inactive Opposers	N = 29 Mean age = 48.7 Male = 55% Median household income = £30,000–£34,999 English ethnicity = 90% Not religious = 79% Urban residence = 66% Married = 31% Moderate political leaning (M = 3.2) No readership of Telegraph (0%), small Guardian readership (7%) Relatively high perceived climate risk (M = 4.1) Moderate place attachment (M = 3.5).	N = 25 Mean age = 59.2 Female = 76% Household income = £40,000 to £44,999 White ethnicity = 100% Not religious = 48% Urban residence = 92% Married = 64% Most liberal cluster (M = 3.1) Some readership of Telegraph (20%) and Guardian (36%) Relatively high perceived climate risk (M = 4.1) Moderate place attachment (M = 3.9).
4: Active Opposers	N = 13 Mean age = 62.6 Female = 62% Median household income = £50,000–£59,999 White ethnicity = 100% Non-religious = 69% Urban residence = 38% Married = 62% Most liberal cluster (M = 2.7) No readership of Telegraph (0%) or Guardian (0%) Highest perceived climate risk (M = 4.4) Moderate place attachment (M = 3.7).	N = 20 Mean age = 62.4 Male = 55% Household income = £40,000- £44,999 White ethnicity = 95% Christian = 50% Urban residence = 80% Married = 70% Relatively liberal (M = 3.5) Small readership of Telegraph (10%), and Guardian (25%). Highest perceived climate risk (M = 4.4) Relatively high place attachment (M = 4.5).

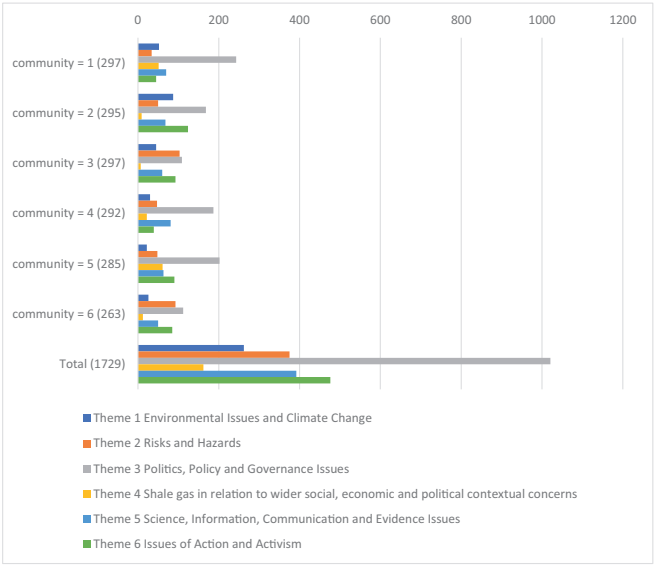

Fig. 4. Main themes (topics) discussed by online communities (number of Tweets).

concerned about climate change; pro-SGE clusters were more conservative, male with lower climate risk perceptions. At national level, SGE supporters were also older and somewhat less educated – consistent with other recent UK polling [16]. However, while gender, political orientation, and climate perceptions consistently correlate with SGE-cluster membership across scales, other demographic factors (education, age) only emerge at UK level.

Geographical factors, including rurality, place attachment, and spatial proximity to proposed SGE sites, tended not to differentiate segments in our surveys at either national or local levels – also consistent with previous SGE research [24] but in contrast to research on other energy sources (e.g., [27]). This is perhaps because SGE remains mostly a proposed energy source, while other energy sources (e.g. wind, nuclear) are more established. On the other hand, geography differentiates some social media groups, with a Scottish anti-shale community and two other communities particularly discussing the Preston New Road site in Lancashire.

Across all data sources, and consistent with previous work (e.g., [23–25]), we find SGE opinion is strongly driven by values and ideology. As expected, UK and local surveys show climate concern and liberal politics predict SGE opposition. Our social media analysis unsurprisingly revealed a strong activist focus of discussions, in line with previous Twitter analysis of SGE [25,41]. Our analysis also builds on this research focusing on spatial patterns across the UK by exploring the insights that can be ascertained by analysing the topics and themes contained within the Twitter messages. Qualitative insights from the thematic social media analysis reveal the multiple ways in which shale gas is interpreted through a political lens by different groups. The most prevalent theme in the tweets related to politics and policy, particularly energy policy, but other themes cover wider political issues including Brexit, Scottish independence, corruption, distrust in government, risk governance, and activism. Values are also implicit in the content relating to risks; environmental (climate) risks are prioritised by some, while others focus on local risks (e.g. seismicity, contamination). Arguments draw on different forms of evidence, with scientific evidence particularly mobilised to support pro-shale arguments.

These themes can also be found in wider literature on social acceptance of energy technologies, which finds publics evaluate energy sources against social values such as efficiency, affordability and security, and that (unconventional) fossil fuels tend to be seen as polluting and finite (e.g. [17]). Our findings show that shale gas, perhaps more

than most other energy technologies, goes beyond immediate social values to become an object of complex *political* meanings for the public [1,75]. Indeed, in contrast to previous (US) studies suggesting political ideology is less relevant for specific SGE scheme perceptions than for abstract SGE views [32], we find political values are important across scales. This, along with the growing importance of climate change perceptions in predicting SGE opposition (see [87]), highlights that efforts to engage the public in discussions and decisions on SGE should recognise the importance of political and environmental framings [76].

Another important novel contribution of our findings is to go beyond unidimensional classifications of survey segments along a support-opposition spectrum to identify an orthogonal (and asymmetric) dimension of empowerment. We found supporters and opponents differ substantively according to the amount of action they do or would take in respect of SGE, and how empowered they feel to act; and that there tends to be more activism amongst opponents. This was evident both from the surveys and the social media analysis: in the local surveys, SGE-related action was low amongst strong supporters, weak supporters and inactive opposers, but higher for active opposers; while online anti-shale communities discussed activism more than the only pro-shale online community. In the UK survey, two of the three anti-shale segments were moderately or highly activist, while the smaller of the two pro-shale segments had modest levels of activism. However, it is noteworthy that the two activist anti-shale segments differ on the extent they feel 'people like me can have a say on shale'; group 1 (Anti-shame & Active) is taking most anti-SGE actions, but feels disempowered, while group 3 (Anti-Shale & Empowered) are taking fewer actions but feel much more empowered. The ambivalent segment (group 4) similarly feel more empowered than they are active, perhaps suggesting they would act if they resolved whether to support or oppose SGE. Taken together, these findings have important policy implications in that they suggest only some groups feel empowered to convert opinion into action, so decision-makers cannot assume public support or opposition based on visible action (e.g., protest). These findings are also consistent with theoretical models of collective action, which highlight the key role for (collective) efficacy, along with emotions, norms and group identity [77]. While we did not measure identity and norms, we did measure emotions and empowerment, and both appear to be important drivers of SGE opinion and action. Future research could test theoretical models of activism in relation to SGE, expanding the range of datasets and methods (e.g. activist ethnographies), and including more emergent forms of public engagement, such as having conversations with others [57,78]. Another avenue for future research could be to identify triggers that push inactive opinion groups to become active.

A significant difference between the survey analyses and social media analysis is the individual-level information available to enable cluster characterisation. Our surveys included demographic, attitudinal and geographical data that enabled a far more detailed picture to emerge of who SGE publics are. On the other hand, surveys constrain and artificially construct opinion, while opinion expressed on social media is more authentic and unconstrained (aside from length). Twitter users, though, are not representative of the general public, and those choosing to tweet about SGE will likely have stronger views than most; while online communities had complex and multi-faceted views, none were ambivalent about SGE (unlike our survey-derived segments). Moreover, activism is a strong theme across several online clusters, differentiating them from those exposed through the surveys. Importantly, however, there may be communities who have not vocally expressed opinions on SGE online, but nevertheless do have views that should be considered in policy and scheme development. As Eaton and Kinchy [79] note, non-mobilised communities do not necessarily consent to shale gas, suggesting it is important to elicit (e.g., via surveys, interviews) as well as reveal (e.g., via social media analysis) public attitudes to ensure inclusive and diverse engagement.

Our research is limited in several ways. First, our local survey samples were small, constraining our cluster analysis and resulting in groups which did not all meet minimum sample size guidance [71]. Some variable measurement also differed across UK and local surveys, although most were comparable. Our data was collected across 2019–2021 so some of the variability between methods could also arise from the timing of data collection though no major shale-related events occurred during that time. Similarly, in light of the recent Russian invasion in Ukraine and its impact on energy, it would be important to replicate this study to explore whether sub-groupings were affected by these developments. Limitations relating to use the of Twitter data also exist as the findings represent only to those who engage with the platform [80]. We also need to avoid making inferential leaps from easily observable social media behaviour to offline public behaviour and attitudes because although digital systems have interfaces with the non-digital world, individuals' online behaviours can differ from their offline behaviour [80]. Additionally, Twitter data typically involves short responses, which poses challenges for identifying the full picture of the context and motivations from which each single tweet arose [81]. More generally, by seeking to identify and reify discrete sub-groups within the wider public, we inevitably underplay variance that exists within groups.

Our findings have implications, nonetheless, for how developers and policy-makers engage with the public, shedding light on the complex range of views and forms of engagement within the public, and exposing limitations of using pre-defined notions of the public that may not reflect empirical realities. We extend past arguments that critique opinion polls as sufficient evidence for policy makers to understand 'public opinion' on energy sources, contrasting our survey findings using other data sources. We demonstrate that the methods and data employed shapes the 'energy public' that is produced and may inform policy. This methodological determinism is evidenced through the divergent findings across methods. All methods are limited when taken on their own to diagnose public opinion; hence the value of a mixed-method approach. The implication for robust, evidence-based policy is that policy-makers use a more diverse suite of methods – not just opinion polls – to diagnose public opinion and produce more complex and diverse 'imaginary publics', making for more effective energy policy-making.

CRediT authorship contribution statement

Lorraine Whitmarsh: Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Yu Shuang Gan:** Writing – original draft, Visualization, Formal analysis. **Patrick Devine-Wright:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Darrick Evensen:** Writing – review & editing, Methodology, Funding acquisition, Data curation. **Jen Dickie:** Writing – review & editing, Supervision, Methodology, Funding acquisition. **Irena Connon:** Writing – original draft, Visualization, Methodology, Formal analysis. **Adam Varley:** Formal analysis. **Stacia Ryder:** Writing – review & editing, Investigation. **Phil Bartie:** Writing – review & editing, Methodology, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2024.103840.

Data availability

Data will be made available on request.

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