



Original research article

# Accounting for taste? Analysing diverging public support for energy sources in Great Britain

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## ABSTRACT

Public acceptance of energy technologies is an important area of energy and social science research. However, few studies utilise large datasets which include spatial and temporal dimensions, as well as the demographic and attitudinal characteristics of survey respondents. In this paper, we analyse twenty-five waves of the UK Government's Energy and Climate Change Public Attitudes Tracker: a large, nationally representative dataset spanning six years (2012 - 2018). This enables unique insights into trends in public acceptance across time, space and social groups, covering eight energy sources. We find differing profiles in terms of who supports which types of energy, with a key division between support for renewable technologies on the one hand, and nuclear and fracking on the other. We also identify a growing gap between public and policymakers' attitudes to energy technologies which we argue must be bridged to ensure a smooth rapid transition that is acceptable to all.

## 1. Introduction

Given the widespread risks presented by climate change [1], there is an imperative to transition from fossil fuels to low carbon energy sources. It is recognised that public acceptance is important for the effective implementation of energy policies and technologies [2,3], and, conversely, a lack of public acceptance can act as a barrier to their uptake [4,5]. Public acceptance of energy sources, and how this can be explained, has thus become a prominent topic for energy social scientists in recent years [6,7].

Against this backdrop, several research organisations and government bodies have started to measure public attitudes towards energy sources. Examples include the Eurobarometer (in the European Union); the Afrobarometer (a pan-African series of attitudinal surveys); and the UK Government's Energy and Climate Change Public Attitudes Tracker

(PAT). The PAT was established in 2012 to 'understand and monitor' public attitudes towards energy and climate change (BEIS, [78]). Surveys such as these provide rich datasets for exploring the underlying patterns behind support and opposition to energy sources across societies. However, there has been limited use of such datasets in energy and social science research to date.

Early studies of public acceptance of energy sources and technologies used broad quantitative approaches such as opinion polls, capturing a 'snap-shot' of general trends and concerns at national or sub-national scales [8]. More recently, there has been a shift to case-study based research methods to gain deeper insights into rationales behind public responses to energy sources and specific projects (e.g. [9–12]). These studies indicate that a variety of factors shape public acceptance of energy sources and projects at local scales, including visual impacts, economic benefits, demographic characteristics, and environmental

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attitudes.

However, the localised geographic scales of such case-based studies limits wider understanding of broader national trends, and subsequent relevance to national policy. Thus, as countries progress further into their implementation of low carbon transition plans, it becomes valuable to utilise the large-scale datasets that have been gathered over time, and to apply more advanced quantitative techniques to identify what shapes public support for energy sources at a national scale. This type of analysis is valuable to researchers and policymakers alike who are interested in energy policy and technology implementation across time, space and social groups.

In this paper, we develop and test five hypotheses to understand which variables explain public support for a range of energy sources at the national level. Our hypotheses are informed by the conceptual framework proposed by Roddis et al. [13], in which they identify eight categories relating to community acceptance of renewable energy projects: aesthetic, geographical, temporal, demographic, political, economic, environmental, and project details. We apply this framework to consider 'socio-political acceptance' i.e. support for energy sources or policies at a general level, typically gauged by large-scale surveys [14]. Community acceptance, on the other hand, refers to the 'specific acceptance of siting decisions and renewable energy projects by local stakeholders' ([14], p. 2685). We therefore exclude the 'project details' category as it describes variables relating to the acceptance of individual energy projects, rather than support for energy sources at the socio-political level i.e. general attitudes.

Whilst some existing studies do explore factors shaping socio-political acceptance of energy sources (e.g. [15,16]), there are a lack of studies investigating this topic using large-scale datasets that include spatial and temporal dimensions, as well as the demographic and attitudinal characteristics of respondents. This paper contributes to this research gap by analysing twenty-five 'waves' (i.e. quarterly surveys) of the UK PAT: a large, nationally representative dataset spanning from July 2012 to April 2018 ( $n = 52,525$ ). Data on the location of respondents were made available to the authors at the regional level, enabling unique geographical insights into this dataset. We cover eight energy sources: renewable energy (in general), onshore wind, biomass, offshore wind, wave/tidal, solar, nuclear, and fracking. Given that much of the existing public acceptance literature focuses on wind energy [7,17], our study thus contributes timely evidence from across the energy technology spectrum.

### 1.1. Research hypotheses

A key debate in the literature on public acceptance of energy sources is on the effect of familiarity on people's attitudes. It has traditionally been assumed, particularly outside of academic debates, that opposition can be explained by NIMBYism (Not In My Back Yard-ism) [18]. This assumes that although people may support an energy source in principle (socio-political acceptance), they are opposed to hosting projects in their local area (community acceptance). However, the concept of NIMBYism has been widely critiqued (e.g. [19]) and there is limited empirical evidence to support it. Whilst some studies find substantiating evidence for NIMBY attitudes (e.g. [20]), many studies find that living close to energy projects, and thus having increased familiarity with that energy source, actually increases general support (e.g. [10,21,22]). This has been dubbed the 'inverse NIMBY' syndrome by energy social science researchers [22].

We are interested in whether increased familiarity with energy technologies and sources is linked to public attitudes, and what this means for NIMBY or inverse NIMBY theories. Our first hypothesis is therefore that support for energy sources is associated with people's familiarity with that technology, estimated through visual exposure, geographical location of the respondent (urban/rural), and exposure over time. This falls into the aesthetic, geographical and temporal categories of the Roddis et al. [13] framework, given that familiarity is

primarily a function of visual exposure, which is in turn influenced by spatial location of the respondent and the relevant energy infrastructure, as well as exposure over time.

Our second hypothesis relates to the effect of demographic characteristics on support for energy sources, belonging to the demographic category of the Roddis et al. [13] framework. Several studies have found sociodemographic characteristics such as age, gender and social class to be important predictors of attitudes to energy sources. In general, research suggests that younger people and women are more likely to support renewable energy [23–26], whilst older people and men are more likely to support nuclear and fracking [11,27,28]. However, there is some disagreement in the literature in terms of gender effects [15]. Higher social classes have been found to be associated with greater support for renewable energy, nuclear and hydrocarbons [8,11,28]. We will use the PAT dataset to test the hypothesis that sociodemographic characteristics can predict socio-political acceptance of energy sources, and explore to what extent this matters over other variables.

A number of studies highlight the role of political values in accounting for public acceptance of renewable energy sources (e.g. [29–31]). However, there is relatively little empirical evidence for this. A key exception is Bidwell [32], who finds that support for wind energy is strongly linked to traditional values as opposed to altruistic values. He therefore suggests that opposition to wind energy is 'fueled by conservatism' (p. 197), rather than by local concerns as suggested by NIMBY theories. Klick and Smith [33], on the other hand, find no correlation between political party affiliation and support for wind energy. Other studies find that conservative political ideology is associated with greater support for nuclear power and hydrocarbons (e.g. [21,34]). Our third hypothesis is therefore on the effect of political orientation on support for energy sources, which falls into the political category of the Roddis et al. [13] framework. We predict that people living in more politically conservative regions (i.e. regions with greater numbers of parliamentary constituencies represented by the UK's Conservative Party) are less likely to support renewable energy sources, and more likely to support nuclear and fracking.

A relatively under-studied aspect of public acceptance is the effect of employment in the energy sector on support for energy sources, belonging to the economic category of the Roddis et al. [13] framework. If there is high employment in a particular energy sector within a geographical region (e.g. offshore oil and gas in North East Scotland), we might reasonably assume that people who live in that region are more likely to support that type of energy source due to the increased likelihood of affiliation(s) to that energy sector, such as direct employment or employment of a family member or friend. Jones et al. [35] include this as a variable when investigating onshore wind in Northern England, but do not find it to be a significant predictor of support. However, qualitative research on wind, solar and biodiesel in Spain finds that local employment opportunities enhanced public support for these energy sources in some circumstances [36]. Our fourth hypothesis is therefore that support for energy sources is positively associated with regional employment in the related energy sector.

Finally, given the significant role of energy generation in contributing to greenhouse gas emissions, we intuitively expect concern about climate change to contribute to socio-political acceptance of energy sources. Our fifth hypothesis therefore relates to beliefs about climate change on support for energy sources, falling into the environmental category of the Roddis et al. [13] framework. Given their differing carbon emission profiles, we predict that people with higher concern for climate change are more likely to support renewable energy sources and less likely to support fracking (i.e. hydraulic fracturing to extract shale gas, a type of fossil fuel). In terms of nuclear power, in line with other studies (e.g. [37,38]) we predict that people with higher climate concern are less likely to support nuclear, despite it having lower carbon emissions than fossil fuels, due to wider environmental and ethical concerns such as radioactive waste disposal.

## 2. Materials and methods

### 2.1. The PAT dataset

The PAT is a quarterly survey of UK residents (aged 16+) established by the UK Government in 2012. Topics covered include energy bills, energy security, energy technologies, and energy saving.<sup>1</sup> Each ‘wave’ of the survey contains approximately 2100 observations. Data is collected using face-to-face in-home interviews, conducted by computer assisted personal interviewing. A central set of questions is asked annually and a subset of questions is asked quarterly where attitudes are subject to greater variability e.g. if they may vary between seasons [39]. The survey uses a random sampling quota method, in which respondents are drawn from a small set of homogenous streets in sample areas. Sample areas are selected by their similar population sizes identified through UK census small area statistics, and sampling points must be contained within a single UK region.<sup>2</sup> Quotas are set in terms of characteristics known to influence the likelihood of being at home in order to minimise sampling bias [39]. Different sampling points are used for each wave of the survey i.e. the same participants are not returned to in each wave, as they would be if the data collection was following a longitudinal design.

PAT data are available on the website of the UK Department of Business, Energy and Industrial Strategy (BEIS). Our analysis includes all waves up to and including Wave 25, spanning the period July 2012 to April 2018. Sociodemographic data is collected for all survey respondents, including age group, gender, working status, tenure, social grade, household income, and area type (urban/rural). The region where the respondents were sampled from was obtained by permission of BEIS under the UK Office for National Statistics (ONS) Approved Researcher Scheme. Whilst this allows for spatial analysis of the data, it should be noted that UK regions are relatively large geographical areas meaning the granularity of the spatial analysis is quite low. Despite this limitation, the dataset is one of the most extensive of its kind containing geographical data, meaning it is uniquely placed to offer spatial insights into support for energy sources, as well as how other variables are associated with support.

The PAT measures attitudes to energy sources on a five-point scale, ranging from ‘Strongly support’ to ‘Strongly oppose’. It also allows a ‘Don’t know’ response. To avoid small sample sizes, which could potentially compromise the confidentiality of respondents, we collapsed these categories into three levels: Support (including ‘Support’ and ‘Strongly support’), Neutral (including ‘Neither support or oppose’), and Oppose (including ‘Oppose’ and ‘Strongly oppose’). Reducing the responses from a five-point to a three-point scale, whilst necessary to avoid breaching stringent confidentiality rules of the ONS, meant that some nuance was lost in terms of predicting the likelihood of *strong* feelings of support or opposition. Reducing categories was also necessary to create a ‘balanced’ dataset (Section 2.2).

PAT respondents who answered ‘Don’t know’ were excluded from the analysis of that energy source as this does not provide relevant insights for our hypotheses. Respondents from Northern Ireland were also excluded from our analysis as low sample sizes from this region could again compromise confidentiality. The extent of the analysis is therefore Great Britain (i.e. England, Scotland, and Wales). Not all waves of the PAT survey asked the questions relevant to our analysis, meaning our sample size varies between the energy sources (Table 1

<sup>1</sup> The content of the PAT was changed in August 2018 to reflect the expanded remit of BEIS (Wave 26 onwards).

<sup>2</sup> There are 12 UK regions (formerly known as Government Office Regions in England): North East, North West, Yorkshire and Humber, East Midlands, West Midlands, Eastern England, London, South East, South West, Wales, Scotland and Northern Ireland. The latter three are not Government Office Regions, but are used as equivalents.

**Table 1**  
Number of waves (quarterly surveys) of the UK Government’s Energy and Climate Change Public Attitudes Tracker between July 2012 and April 2018 (Waves 1–25) asking relevant questions to this study; sample sizes for each question; and original wording of the questions.

	Q3. Renewable energy	Q13a. Onshore wind	Q13b. Biomass	Q13c. Offshore wind	Q13d. Wave/Tidal	Q13e. Solar	Q14a. Nuclear	Q15b. Fracking	
No. waves	25	19	19	19	19	19	23	18 <sup>a</sup>	
Total responses	52,525	39,859	39,859	39,859	39,859	39,859	48,304	37,801	
Original wording in PAT	Do you support or oppose the use of renewable energy for providing our electricity, fuel and heat?	Generally speaking, do you support or oppose the use of the following developments: a) On-shore wind b) Biomass – this includes any plant or animal base material such as wood, specially grown energy crops, and other organic wastes that can be used in the process of creating energy c) Off-shore wind d) Wave and tidal e) Solar	Generally speaking, do you support or oppose the use of the following renewable energy developments: a) On-shore wind b) Biomass – this includes any plant or animal base material such as wood, specially grown energy crops, and other organic wastes that can be used in the process of creating energy c) Off-shore wind d) Wave and tidal e) Solar	Generally speaking, do you support or oppose the use of the following renewable energy developments: a) On-shore wind b) Biomass – this includes any plant or animal base material such as wood, specially grown energy crops, and other organic wastes that can be used in the process of creating energy c) Off-shore wind d) Wave and tidal e) Solar	Generally speaking, do you support or oppose the use of the following renewable energy developments: a) On-shore wind b) Biomass – this includes any plant or animal base material such as wood, specially grown energy crops, and other organic wastes that can be used in the process of creating energy c) Off-shore wind d) Wave and tidal e) Solar	Generally speaking, do you support or oppose the use of the following renewable energy developments: a) On-shore wind b) Biomass – this includes any plant or animal base material such as wood, specially grown energy crops, and other organic wastes that can be used in the process of creating energy c) Off-shore wind d) Wave and tidal e) Solar	Generally speaking, do you support or oppose the use of the following renewable energy developments: a) On-shore wind b) Biomass – this includes any plant or animal base material such as wood, specially grown energy crops, and other organic wastes that can be used in the process of creating energy c) Off-shore wind d) Wave and tidal e) Solar	Generally speaking, do you support or oppose the use of the following renewable energy developments: a) On-shore wind b) Biomass – this includes any plant or animal base material such as wood, specially grown energy crops, and other organic wastes that can be used in the process of creating energy c) Off-shore wind d) Wave and tidal e) Solar	From what you know, or have heard about, extracting shale gas to generate the UK’s heat and electricity, do you support or oppose its use?

<sup>a</sup> The PAT first asked question 15b in 2014; all other questions relevant to this study were asked since 2012.

shows sample sizes for each energy source and original wording of the questions in the PAT questionnaire).

## 2.2. Data analysis

Our analytical approach falls into the ‘data analysis and statistics’ category of research method for energy social science, as classified by Sovacool et al. [40]. To begin, we mapped the spatial variation in support for energy sources across Great Britain in order to visualise the PAT dataset. To do this, we calculated the mean percentage of support for each of the eight energy sources in our study between April 2012 and July 2018 for the whole of Great Britain. We then calculated the average difference from this mean in each of the geographical regions of the study area. To display this information, we created eight choropleth maps sharing the same colour ramp so that the difference between overall levels of support for energy sources was immediately clear (Fig. 2). We then labelled each region with the difference from the mean of Great Britain to show whether support in that region was higher or lower than the average, and to show the variance between regions.

We ran Mann-Kendall (MK) tests on annual time series of support between 2012 and 2018 (i.e. the percentage of PAT respondents answering support or strongly support for the energy source in each year) to identify whether there was a statistically significant monotonic trend, either increasing or decreasing. We chose to use MK tests as they are non-parametric, which is appropriate due to the limited number of data points when the data was disaggregated by year, meaning that normal distribution of the data cannot be confidently determined [41]. We added a time series plot to each of the choropleth maps to show how support for each energy source changed over the study period, and whether the trend was statistically significant at the 5% level. The spatial and time series analysis (as well as the regression analysis described below) was carried out using weighted data, applying the weighting provided by BEIS which is designed to make the data representative of the entire UK adult population [39].

To directly address our research hypotheses (Section 1.1), we used ordinal logistic regression (henceforth referred to as ordinal regression). Ordinal regression is a type of statistical analysis which assesses the relationship between an ordinal dependent variable, such as a Likert scale, and one or more independent variables. The type of ordinal regression used in this analysis is a generalised ordered logit model with partial proportional odds. Unlike the more common proportional odds model, this type of model does not assume that the effect (i.e. slope coefficient) of each independent variable is the same across all categories of the dependent variable [42]. Instead, it tests the assumption of proportionality for each independent variable: for those which meet the assumption, a single slope coefficient is estimated; for those which do not, separate slope coefficients are estimated for each cumulative dichotomous categorisation of the response variable. We chose this type of model as diagnostic tests (following [43,44]) showed that the assumption of proportional odds was not met by our data in many cases. The models were run in Stata 14 using the user-written program `gologit2` [45].

A regression model was calculated for each of the eight energy sources in the study: renewable energy (in general), onshore wind, biomass, offshore wind, wave/tidal, solar, nuclear, and fracking. The dependent variable was the PAT respondent’s aggregated level of support for the energy source in question (either support, neutral or oppose). The independent variables were selected based on the hypotheses being tested (Table 2). The data for the independent variables were either obtained directly from the PAT itself, or calculated from external data sources (Supporting information contains full details). Social grade (a measure based on occupation, collected in the PAT) was used as a proxy for social class. Category A was treated as the highest social grade (referring to higher managerial, administrative or professional workers) and category E as the lowest social grade (referring to

unemployed people, state pensioners and casual workers). All variables were matched to the appropriate survey year as far as data availability allowed. For example, to calculate parliamentary constituencies represented by the UK’s Conservative Party, percentages were assigned to each region based on the most recent general election data (either 2010, 2015 or 2017). Multicollinearity between independent variables was measured using variance inflation factors (VIF); following Kock and Lynn [46] the VIF values deemed acceptable were those less than 3.3.

Initial analysis of the dataset showed that, for several energy sources, the levels of support are strongly skewed (Fig. 1). The dataset can therefore be described as ‘imbalanced’ i.e. the frequency of observations in each response category are not comparable. Imbalanced datasets can cause problems in statistical analyses such as ordinal regression as their underlying algorithms expect balanced class distributions [47]. For this reason, an informed under-sampling approach was taken to subsetting the data. This has been shown to reduce the problems associated with imbalanced data in a variety of studies (e.g. [48–51]). Specifically, we generated five random subsets for each energy source, based on the size of the minority class i.e. classes within each subset were created to be approximately the same size as the smallest class [52]. By taking this approach (bootstrap aggregating or ‘bagging’), we could train the models on a large number of samples whilst removing as the problem of class imbalance. The results of the models estimated for each of the random subsets were then combining by taking the average (mean) across the five models. This technique has been shown to provide substantial gains in model accuracy and helps to reduce variance error [53]. The generalised ordered logit model with partial proportional odds can be written as below, where  $M$  is the number of categories of the ordinal variable:

$$P(Y_i > j) = \frac{\exp(\alpha_j + X_i\beta_j)}{1 + [\exp(\alpha_j + X_i\beta_j)]}, \quad j = 1, 2, \dots, M-1 \quad (1)$$

Eq. (1) Generalised ordered logit model with partial proportional odds

The outputs of ordinal regression models are odds ratios (ORs). For continuous variables, ORs greater than one indicate that the odds of a higher score of the dependent variable increase by this amount per one unit change; ORs less than one indicate decreased odds of a higher score per one unit change. For categorical variables, each category is compared to a reference or ‘baseline’ category (Table 2). The dependent variable was coded so that higher scores relate to increased support for an energy source (oppose = 1, neutral = 2, support = 3). Because of how generalised ordered logit models with partial proportional odds are calculated, ORs are generated for each cumulative dichotomous categorisation of the dependent variable (similar to a series of binary logit models). Therefore, the ORs generated by our regression models refer to the odds of being in the support category (vs neutral/oppose), and the neutral/support categories (vs oppose) i.e. the odds of getting a ‘higher’ score on the dependent variable scale.

## 3. Results

Our results show that the energy source with the highest level of support in Great Britain between July 2012 and April 2018 was solar, with a mean score of 80.1%. This was followed by renewable energy (in general) which scored 76.8%, wave and tidal (74%), offshore wind (73.6%), onshore wind (66.7%) and biomass (62.5%). Nuclear and fracking had notably lower levels of support, with mean scores of 37.1% and 22.1% respectively. Support for all renewable energy sources is increasing over time (Fig. 2). These trends were statistically significant in the case of onshore wind, biomass, offshore wind, and wave/tidal energy ( $p < 0.05$ ). Support for nuclear and fracking, on the other hand, was found to be decreasing over time. The trend in relation to nuclear was statistically significant ( $p < 0.05$ ); the trend for fracking was very slightly short of statistical significance ( $p = 0.08$ ), perhaps due to the fewer data points for this technology given that the PAT only

**Table 2**

Variables included in the ordinal regression models to predict support for eight energy sources: renewable energy (in general), onshore wind, biomass, offshore wind, wave/tidal, solar, nuclear, and fracking.

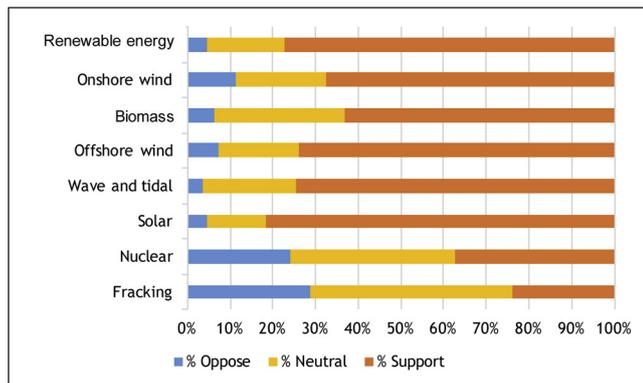
Hypothesis	Category of the conceptual framework	Independent variable	Data source for the variable
Familiarity effect (exposure to energy sources)	Aesthetic	Percentage of region where energy technology is visible (estimated using viewshed analysis techniques)	UK Renewable Energy Planning Database (REPD), Digest of UK Energy Statistics (DUKES), UK Oil and Gas Authority (OGA) <sup>a</sup>
	Geographical	Area type (urban area was compared to rural area)	UK Energy and Climate Change Public Attitudes Tracker (UK PAT) <sup>b</sup>
Effect of demographic characteristics	Temporal	Year of the PAT survey	UK PAT
	Demographic	Age group (ages 16–24, 25–34, 35–44, 45–54, and 55–64 were compared to age 65+)	UK PAT
		Gender (male was compared to female)	UK PAT
		Social Grade (A, B, C1, C2, and D were compared to E)	UK PAT
Effect of political orientation	Political	% parliamentary constituencies in region represented by the UK Conservative Party	UK Electoral Commission
Effect of employment in energy sector	Economic	% jobs in the related energy sector in region (of total regional employment) <sup>c</sup>	Renewable Energy Association (REA), Nuclear Industry Association (NIA), Oil and Gas UK (OGUK)
Effect of climate change concern	Environmental	Level of concern ('very', 'fairly', and 'not very' were compared to 'not at all')	UK PAT

For renewable energy sources, the whole renewable energy sector was used as the 'related energy sector' rather than disaggregating employment to the specific renewable technology sectors e.g. wind, solar, biomass.

<sup>a</sup> April 2018 monthly extract of the REPD; DUKES 2017; OGA Onshore Wells (OGA Open Data, 30/05/2018).

<sup>b</sup> Waves 1–25 (July 2012–April 2018). Includes survey questions 3, 13a, 13b, 13c, 13d, 13e, 14a, and 15b.

<sup>c</sup> Employment figures refer to direct employment (as estimated by REA, NIA and OGUK industry reports). Total regional employment obtained from UK Labour Force Survey (A07: Regional Labour Market Summary).



**Fig. 1.** Levels of support for energy sources in Waves 1–25 of the UK Government's Energy and Climate Change Public Attitudes Tracker (July 2012–April 2018). All statistical results remain Crown Copyright.

began tracking its support in 2014, whilst the other energy sources began in 2012.

In terms of geographical variation, our results show an approximate North-South divide whereby more southerly regions of Great Britain (other than London) tend to have higher average support for energy sources than more northerly regions (Fig. 2). Most notably, the South West and Eastern England have consistently above average support for most types of energy, whilst Scotland and London show consistently lower levels of support for all energy sources than other regions (Fig. 2). This perhaps indicates that the familiarity effect follows a non-linear trend, given that London has the lowest rates of installed capacity for many energy technologies due to its high population density, whereas Scotland has consistently high rates of installed capacity (Table S4 in Supporting information). In other words, people *least* familiar and *most* familiar with energy technologies appear to have the lowest levels of support. Wales has notably low support for onshore wind, and the second highest level of installed capacity (after Scotland), supporting the idea of very high levels of exposure reducing support, perhaps due to perceptions of distributional injustice.

If urban and rural respondents are mapped separately (Fig. S2 in

Supporting information), similar patterns to those described above continue to pertain. Support for renewable energy (in general), biomass, wave/tidal and solar was found to be higher in rural areas, whilst support for nuclear, fracking and wind energy (both onshore and offshore) was found to be higher in urban areas. A notable outlier is that rural respondents in North West England have much higher average levels of support for nuclear than their urban counterparts. This is potentially due to the elevated levels of rural employment in the nuclear sector in this part of Great Britain, which hosted the world's first industrial-scale nuclear power facility (Calder Hall, opened in 1956) and continues to host several nuclear power stations and the Sellafield nuclear reprocessing facility [54].

As shown, mapping public attitudes to energy sources by region and area type can provide some insights into how attitudes vary geographically, and potential reasons why. In general, however, we found that the age group of the PAT respondent and their level of concern for climate change were stronger and more consistent predictors of support for energy sources than spatial variables (Fig. 3). Our regression results indicate a divide between younger people, women and those with higher climate concern (who are more likely to support renewable energy sources) and older people, men, and those with lower climate concern (who are more likely to support nuclear and fracking). The other independent variables used to test our hypotheses, particularly political and economic variables, had a less apparent and consistent effect on PAT respondents' likelihood of support for energy sources.

The regression models were best able to explain support for offshore wind, accounting for 19% of the variance (Nagelkerke R<sup>2</sup>). This was followed by solar (18%), onshore wind (17%) and renewable energy (17%). The models were weakest for wave and tidal energy (13%), fracking (13%), and nuclear (11%). All models were statistically significant ( $p < 0.001$ ). Thus, although the independent variables included in our modelling clearly do have some explanatory power, a key finding of this paper is that they do not fully explain people's attitudes to energy sources (at least when these variables are calculated at the regional level). This is an important limitation to our analysis, and suggests that regional-scale analysis is too coarse a resolution to fully explain people's attitudes. Alternatively, the lack of variance explained by our models could indicate that there are other factors influencing people's attitudes to energy sources which we have not modelled, or

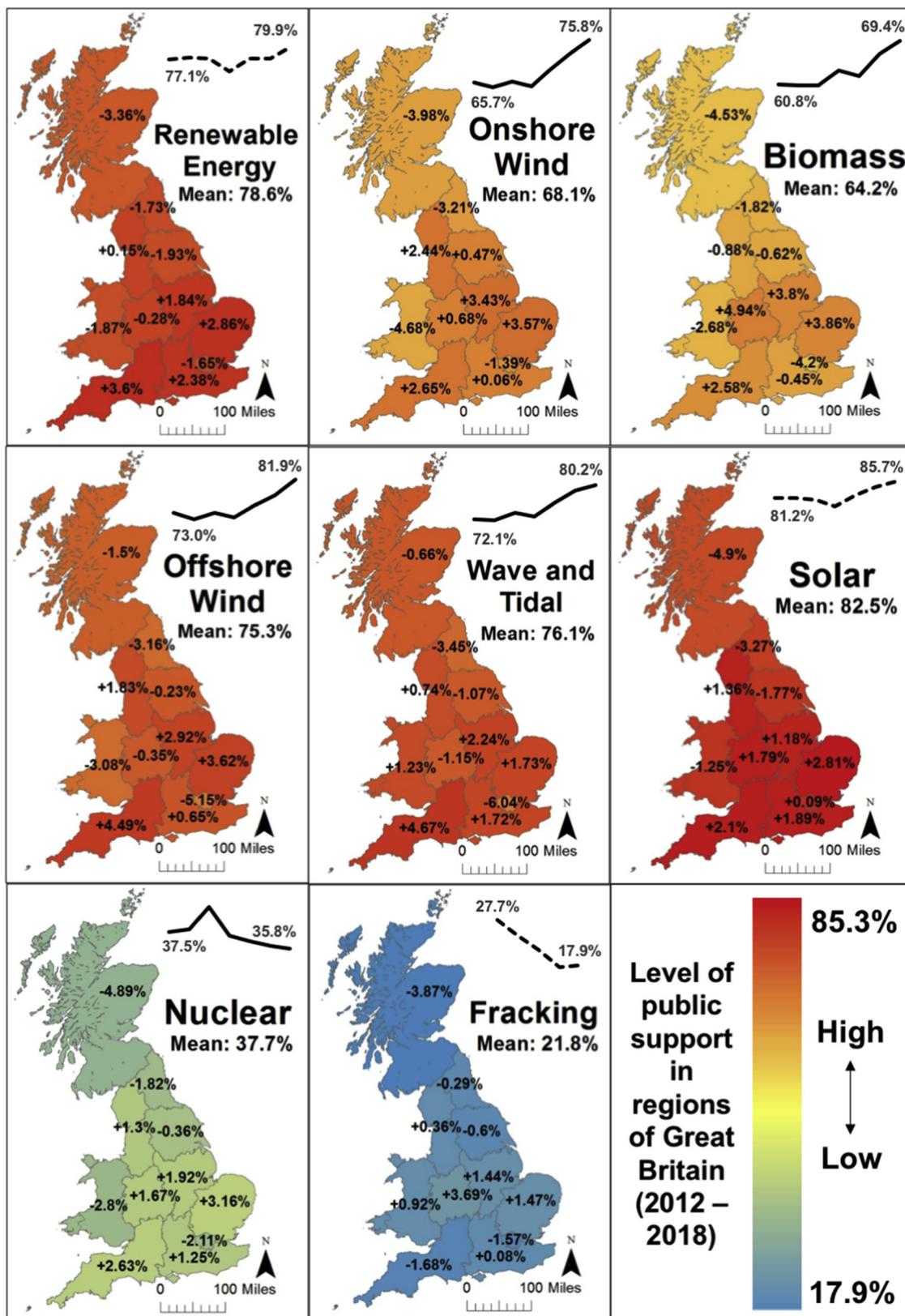


Fig. 2. Support for energy sources in regions of Great Britain (2012–2018). Shetland Islands have the same results as the rest of Scotland. Labels show the difference from the mean level of support. Solid lines indicate time series has a statistically significant monotonic trend ( $p < 0.05$ ). Data is from the UK Government’s Energy and Climate Change Public Attitudes Tracker (Waves 1–25). All statistical results remain Crown Copyright.

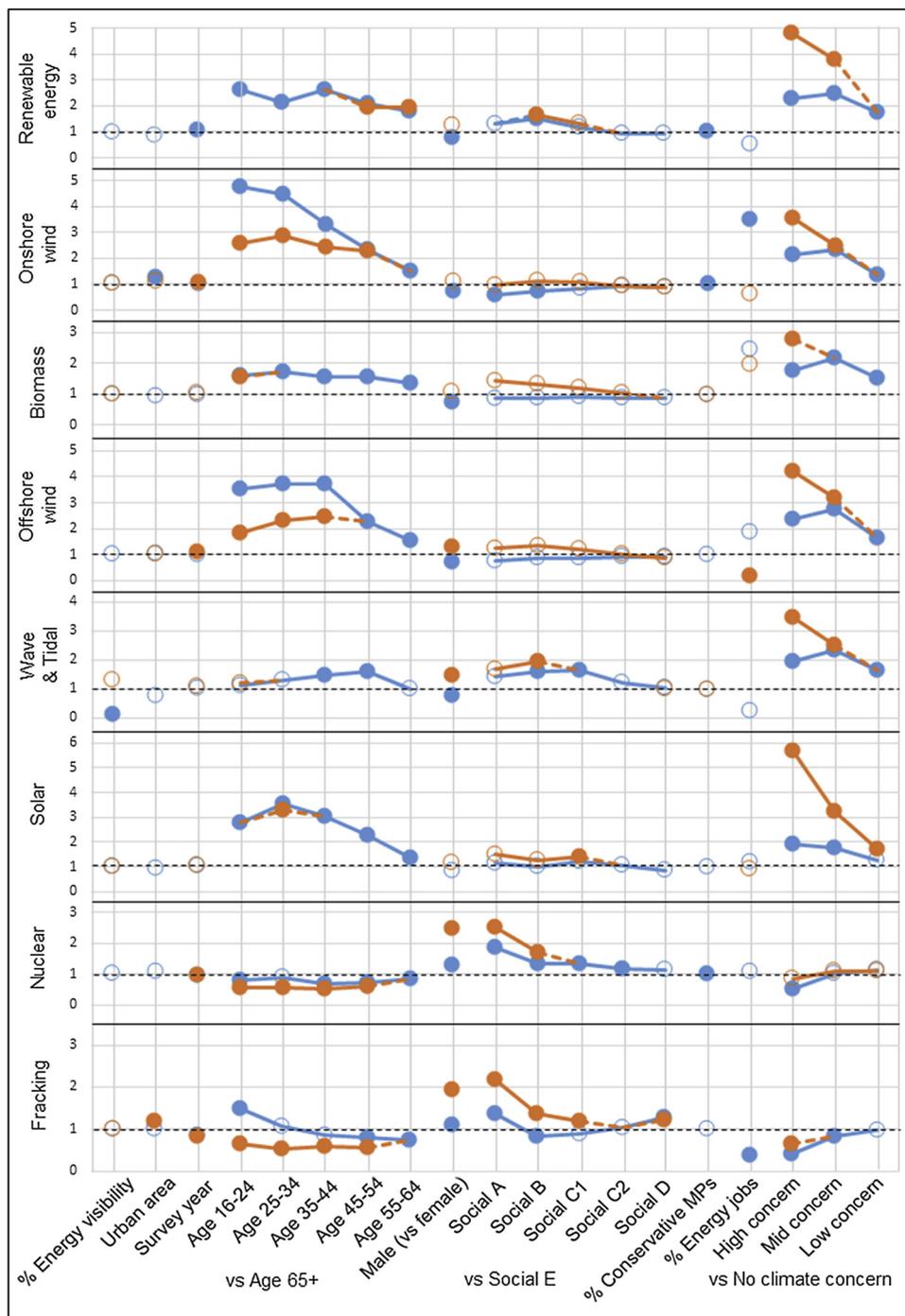


Fig. 3. Scatter plots showing odds ratios (ORs) for variables used to predict support for energy sources. Blue circles show ORs for the support category compared to neutral/oppose categories. Orange circles show ORs for support/neutral categories compared to the oppose category. Where there is one circle, the same OR applies to both outcomes. Solid circles indicate statistically significant ORs ( $p < 0.05$ ). ORs greater than 1 indicate positive effects; ORs less than 1 indicate negative effects. All statistical results remain Crown Copyright.

that there is random heterogeneity in the sample i.e. random individual differences in opinion.

Fig. 3 shows the ORs for the independent variables included in each of the eight regression models. The first set of ORs (indicated by blue circles) refers to the odds of belonging to the support category, compared to the neutral/oppose categories (S vs N/O). The second set of ORs (indicated by orange circles) refers to the odds of belonging to the support/neutral categories, compared to the oppose category (S/N vs O). Where the OR is the same in both sets, the independent variable meets the proportional odds assumption; where it differs, it does not

meet this assumption. As an example, the regression model for onshore wind estimated two ORs for the ‘energy jobs’ variable. The blue circle is above 1 and solid, showing a statistically significant ( $p < 0.05$ ) positive effect for higher employment increasing the odds of being in the support category for onshore wind. The orange circle is below 1 and hollow, indicating a statistically insignificant ( $p < 0.05$ ) negative effect for higher employment increasing the odds of being in the support and/or neutral categories. In other words, having more renewable energy jobs in the region increases the likelihood of support towards onshore wind, but not necessarily of neutrality.

## 4. Discussion

### 4.1. The familiarity effect

We tested the effect of familiarity on people's support for energy sources using three independent variables: visual exposure, urban or rural dwelling, and the year in which the PAT respondent was surveyed. Our results show limited support for the familiarity effect via visual exposure. We predicted that increased visual exposure would have a positive effect on the likelihood of support as people would become accustomed to energy infrastructure being part of the visual landscape. Several studies have found aesthetic concerns to be prominent in explaining public acceptance of energy sources, particularly wind energy (e.g. [19,23,31,55]), indicating the importance of visual impacts in informing attitudes. However, our results do not show that visual exposure had a statistically significant effect on people's likelihood of support for energy sources in either a positive or negative way.

The exception to our findings on visual exposure was in relation to wave and tidal energy. These energy sources are referred to collectively throughout this paper given that the PAT questionnaire collects attitudes to both together, meaning attitudes between them cannot be disaggregated. Our results showed there to be a statistically significant *negative* effect of visual exposure on support for these sources of energy. However, this result should be interpreted with caution given that there is currently very limited deployment of wave and tidal energy in Great Britain (23 MW in South West England and 11 MW in Scotland, resulting in percentage exposure of 0.04% and 0.07% in these regions respectively). Additionally, these types of energy technology are often submerged underwater meaning they are sometimes not visible from land. We estimated an average height of 2 m to account for the likelihood of some infrastructure (e.g. cabling, floats, buoys) being visible above the waterline. It should be noted that there are no tidal range projects in Great Britain, such as dams or barrages spanning bays or estuaries, only tidal stream technologies such as underwater turbines [56].

The lack of significant effects regarding visual exposure could be explained by the low spatial resolution of those data. This analysis could be improved by using more finely grained georeferenced data on respondents' locations and mobility patterns. This would allow a better understanding of their exposure to energy infrastructure, however, such data are not currently available. Using total regional installed capacity as a predictor variable instead of visual exposure in the regression models was also not statistically significant. This analysis could further be improved upon by using more detailed height data (or MW/area) for energy installations, accounting for the trend towards larger infrastructure after 2012, to more accurately model landscape impacts. However, it could be that visual exposure to an energy source does not by itself alter people's attitudes; rather it could be the way in which energy installations change people's perceptions of landscapes and their attachment to places [57], which is very difficult to model at a national level.

Our results show that people living in urban areas were more likely than rural people to support wind energy (both onshore and offshore), nuclear, and fracking. A key exception is in relation to nuclear in the North West of England, which showed higher support in rural areas than urban areas, potentially due to employment effects (Section 3). We found that people in rural areas were more likely than urban people to support renewable energy (in general), biomass, wave/tidal, and solar. The only statistically significant results in our analysis, however, were in relation to onshore wind and fracking, which showed that contrary to our hypothesis on the familiarity effect, people in rural areas were *less* likely to support or be neutral towards these technologies. Given that these are both more suited to rural than urban areas, this suggests that people living closer to the impacts (or potential impacts) of onshore wind and fracking installations are less likely to support these technologies.

These findings somewhat contrast with other studies on this topic, particularly in relation to fracking. Other studies have identified stronger support in places *closer* to fracking sites. For example, Whitmarsh et al. [11] find that out of three areas surveyed in the UK, the area in which fracking was already underway showed significantly more support than areas where it is not viable. Similarly, Boudet et al. [58] find that people in the US who live in closer proximity to fracking sites show greater support for the practice. The key difference between these studies and ours is that fracking has not taken place at a national scale in Great Britain, meaning that socio-political attitudes are informed by hypothetical scenarios rather than direct experience. This could explain why our results do not show the same proximity effect as other studies do, or this may be because the resolution of analysis is coarser than other studies'. Alternatively, our findings may indicate that people in Great Britain are *de facto* opposed to fracking, whether they have direct experience or not, as shown by the low average level of support for this technology (mean = 22%).

Our findings around temporal familiarity reveal a division between renewable energy sources with nuclear and fracking. For renewable energy (in general), onshore wind, and offshore wind, each year that passed between 2012 and 2018 increased people's likelihood of support or being neutral in a statistically significant way at the 5% level. For nuclear and fracking, however, each year that passed decreased the likelihood of people supporting or being neutral towards these technologies (this was statistically significant for nuclear at the 5% level and fracking at the 10% level). In other words, the likelihood of opposition to nuclear and fracking *increased* over this period, whilst it *decreased* for renewable energy and wind energy. This could suggest that people have become more familiar with renewables over time, in line with our hypothesis regarding the familiarity effect. For nuclear, there has not been any significant changes in the level of deployment over this time, meaning that its popularity has decreased despite the same levels of public exposure. Fracking has commenced in Great Britain over this period, though at relatively slow pace, meaning that opposition has increased despite similar levels of public exposure.

Another explanation for the increase in support for renewable energy sources between 2012 and 2018, and the decrease for fracking, is that concern for climate change has also increased over this time period (Fig. S3 in Supporting information). For nuclear, it could be that the escalating costs of constructing new nuclear power stations such as Hinkley Point C are affecting people's attitudes in a negative way, particularly when the costs of many renewable technologies are falling [59]. There has been significant public debate in the UK about the financial cost of transitioning to low carbon energy, meaning that economic criteria may well be prominent in people's minds when asked about their support for energy sources. Another key socio-political issue which may have affected public attitudes over this period is the adoption of the UN Paris Agreement, which was agreed in 2015 (with much publicity) and ratified in 2016. This is likely to have raised awareness of climate change and the urgency of mitigation measures, such as shifting from fossil fuels to low carbon energy sources [60,61].

In summary, we did not find evidence for the familiarity effect via visual exposure, though this could be due to the limitations of modelling this variable at a regional scale. We found that onshore wind and fracking are *less* popular in rural communities than in cities, but renewable energy (in general), solar, wave/tidal and biomass are *more* popular. Whilst this could be interpreted as NIMBYism in relation to onshore wind and fracking, and inverse NIMBYism for the others, it is difficult to draw firm conclusions on this given that our research design does not allow a strong understanding of *why* people feel the way they do. Indeed, when the results of our regression modelling are considered in conjunction with our spatial analysis (Figs. 2 and S2), it suggests that more subtle considerations may be at play, such as rural employment effects and concerns around distributional (in)justice. Finally, our results show support for the familiarity effect via temporal exposure for renewable energy sources, though this could also be explained by other

trends between 2012 and 2018 such as increasing concern for climate change. We do not find evidence to support the familiarity effect via temporal exposure for nuclear and fracking, for which support is declining despite no major changes in deployment rates.

#### 4.2. The effect of demographics

Demographics were found to have a clear effect on people's likelihood of supporting different energy sources in a statistically significant way (at the 5% level). Younger age groups were more likely to support renewable energy, onshore wind, biomass, offshore wind, wave/tidal and solar. This effect was particularly pronounced in the case of onshore wind and offshore wind, with the odds of someone in the 16–24 age group supporting these energy sources on average four times that of someone in the 65+ age group. Older age groups, on the other hand, were more likely to support nuclear and fracking. For example, the odds of someone aged 16–24 being in the support category for nuclear were approximately 20% less than someone aged 65+. This indicates a divergence in preferences for energy sources between age groups.

One explanation for the effect of age on people's attitudes to energy sources is the concept of 'Shifting Baseline Syndrome' (SBS). SBS was originally coined to describe the phenomenon of each generation perceiving the state of ecosystems they encountered in their childhood as normal [62]. It could also describe people's attitudes towards energy sources, although it has received limited application in the field of energy social science to date. An exception to this is Ladenburg and Dubgaard [24] who find significant differences in attitudes towards offshore wind farms between age groups, with younger people generally more positive than older people. Following Short [63], they suggest this may be explained by the differences in the 'mental landscape' of different generations: 'older respondents might think of a "pristine" mental landscape which does not include wind turbines. On the other hand, the mental landscape of younger respondents might include wind turbines, because they were already present in the landscape from their past (childhood)' (pp. 4067). Because the younger generations in the PAT dataset have renewable energy as part of their 'baseline', this could explain why they are more likely than older generations to support it.

Our findings around gender again reiterate a difference between those likely to support renewable energy sources, and those likely to support nuclear and fracking. While women were more likely to support all types of renewable energy other than solar, men were more likely to support nuclear and fracking (these results were statistically significant at the 5% level). These findings are in line with other studies' findings (e.g. [28,26,10,11]) and could be explained by differing perceptions of risk. Gender has been found to be an important influence on risk perception, with women tending to be more risk averse [64]. Given the various risks associated with fracking and nuclear such as water contamination, earth tremors and nuclear accidents, this may explain why men were more likely to support these energy sources, and women were more likely to oppose them.

In terms of social class, our results support other studies which find higher social class to be associated with greater support for nuclear and hydrocarbons (e.g. [11,28]). This may be because higher levels of education (which are often correlated with higher social class) increases people's awareness of the societal need for energy, or potentially enhances the perception that risks can be handled by technical management solutions. A similar pattern was identified for renewable energy sources, though this effect was quite weak and only statistically significant in a few cases (Fig. 3). Social class therefore does not appear to be a strong determinant of support for renewable energy sources.

In summary, our results show that younger age groups and women were more likely to support renewables, whilst older age groups and men were more likely to support nuclear and fracking. These findings are broadly in line with other studies, and support our original

hypothesis (Section 1.1); existing studies have somewhat varied findings around gender, meaning that our results help to add clarity to this area. However, our hypothesis was not supported by our results on social class, other than in relation to nuclear and fracking. These energy sources were significantly more likely to be supported by higher social grades than lower social grades (which are used in this study as a proxy for social class). We had predicted that people of higher social classes would be more likely to support *all* energy sources in this study.

#### 4.3. Political and economic effects

Our hypothesis on the effect of political orientation was partially supported and partially contradicted by our findings. We predicted that people living in areas with higher levels of representation by the UK Conservative Party were less likely to support renewable sources, and more likely to support nuclear and fracking. Our findings, however, show that people living in more politically conservative regions were marginally more likely to support nuclear, onshore wind *and* renewable energy (statistically significant at the 5% level). Our results therefore support the literature which finds that conservative political ideology is associated with greater support for nuclear power (e.g. [34]), but do not support the literature which finds that conservatism is associated with lower support for renewable energy (e.g. [32]). It should be noted that these conclusions are subject to substantial uncertainty given that we did not have data on the political orientation of individual PAT respondents, only regionally aggregated election data. This analysis could be improved if a more accurate measure of the political orientation of survey respondents were available.

Interestingly, support for all types of energy in the PAT survey was consistently below average in Scotland and London, and frequently in Wales and the North East. This could suggest that being politically isolated from central decision-making bodies (in the case of Scotland and Wales, which historically have a tense relationship with the central UK government in London) influences citizens' likelihood of supporting policies and technologies proposed centrally. On the other hand, people living within London (and therefore theoretically 'close' to centralised institutions) are also below average in terms of support, perhaps because of a lack of familiarity and exposure. Following Batel and Devine-Wright [65], we recommend further research into how political beliefs interact with public support for energy transitions, particularly given the context of a rise in populism and major political developments such as Brexit which have implications for energy policy and planning.

Similarly, our results also partially support and partially contradict our fourth hypothesis: the effect of employment in the related energy sector on support for energy sources. We expected to find greater levels of support in regions where there is higher employment in the related industry. In support of this hypothesis, we found that people living in areas with higher employment in onshore wind were more likely to support this type of energy source (statistically significant at the 5% level). Our spatial analysis also identified high support for nuclear in rural North West England, where there is historically high employment in this sector (Fig. S2). Contrastingly, we found that high employment in the oil and gas sector was associated with *decreased* support for fracking (statistically significant at the 5% level), contrary to our prediction that this would boost support. This could suggest that people who already have oil and gas development in their region do not want even more in the form of fracking, despite potential employment opportunities in the locality.

#### 4.4. The effect of environmental beliefs

Of all the independent variables included in our regression modelling, concern for climate change was the strongest and most consistent predictor of support for different energy sources. The odds of people who were very or fairly concerned being in the support or neutral categories for all renewable energy sources were, on average, three times

that of those who were not at all concerned about climate change. By contrast, the odds of people who were very concerned about climate change supporting nuclear power and fracking were approximately *half* of those of people who were not at all concerned. These results were statistically significant at the 5% level. These findings are in line with our predictions and other existing studies in this area (e.g. [37,38,26,11]). Our fifth hypothesis on the effect of environmental beliefs was therefore strongly supported by our results.

Importantly, concern for climate change is increasing over time, rising from 63% in 2012 to 71% in 2018 as measured by the PAT (Fig. S3). Over this period, support for all renewable energy sources has been increasing, whilst support for nuclear and fracking has been decreasing. This suggests that as concern for climate change continues to increase, and particularly as climate impacts such as floods and heat waves are felt more frequently and severely in Great Britain [66], the already substantial gap between public support for renewable and non-renewable energy will continue to grow. Interestingly, although nuclear power is advocated by some stakeholders as a response to climate change given that it produces fewer carbon emissions than fossil fuels, this does not result in higher support for nuclear amongst PAT respondents with greater climate concern. This is presumably due to wider environmental and ethical concerns about nuclear energy, such as the safe disposal of waste and associated risks to future generations.

## 5. Conclusion

In this paper, we have conducted quantitative and spatial analysis of a large national dataset spanning six years: the UK Government's Energy and Climate Change Public Attitudes Tracker (PAT), from July 2012 to April 2018. Informed by the conceptual framework developed by Roddis et al. [13] to investigate community acceptance of renewable energy projects, we identified and collated a range of variables to test what shapes public support for energy sources at a national scale. By utilising this dataset, we addressed gaps in the existing literature of how trends in public support have unfolded across time, space and social groups, rather than at localised case study scales. Our findings thus have broader implications and relevance to national policy and the national governance of low carbon energy transitions. They also help to understand and explain socio-political acceptance of eight different energy sources, thereby adding insights to the literature beyond well-studied technologies.

We find that despite commonly held assumptions that public opposition to energy can be characterised as NIMBYism (Not In My Back Yard-ism), the relationship between the amount of energy infrastructure in people's region, as well as the visual impact of this infrastructure, had limited effect on people's support for that energy source. In other words, we did not find a clear link between direct experience of energy developments in a person's region (i.e. at the community level) with their general attitudes towards that type of energy (i.e. at the socio-political level). Whilst we did identify some spatial variation in attitudes across Great Britain, suggesting that geography does play a role to some extent, the strongest predictors of support were demographic characteristics (particularly age and gender), concern for climate change, and time. Our research therefore lends support to other scholars who argue that NIMBYism is not a satisfactory theory for explaining public acceptance (e.g. Burningham, [77]), as well as research suggesting that worldviews and values may be the most important predictors of attitudes [67], something it was not possible for us to consider using the PAT dataset. Indeed, the relatively low variance explained by our regression models suggests that there are other important predictor variables which we did not include. Analysis at a finer resolution may also help to uncover further and more detailed spatial patterns.

Whilst this paper has focused on the public or 'societal' dimension of socio-political acceptance, there is also a need for continued research on the political and policymaking dimension of this topic, and better

integration between these dimensions to understand the broader dynamics of social acceptance of energy sources and transitions as a whole [68,69]. As energy social scientist Maarten Wolsink emphasises, social acceptance can be thought of as a "bundle of dynamic processes instead of a set of actor positions" (2018, p. 287), meaning that integrated approaches are important to provide a full understanding of this complex social phenomenon. Additionally, we cannot be sure that our findings can be generalised to countries other than Great Britain, meaning that similar research designs using comparable national data would also be valuable for deepening understanding of this topic across multiple contexts.

Importantly, our analysis shows that support for renewables has substantially increased from 2012 to 2018, whilst support for nuclear and fracking has markedly decreased. As concern for climate change increases (a trend also demonstrated by the PAT), it seems likely that these diverging levels of support for different energy sources will continue to travel in opposite directions. Given that younger people were found to be more likely to support renewable energy sources, and older people were more likely to support non-renewable nuclear and fracking, it seems likely that in the future the public will increasingly favour renewable over non-renewable energy sources, at least at the 'socio-political' level of acceptance i.e. in terms of generalised public attitudes, though not necessarily in terms of 'community acceptance' of specific energy projects. However, it cannot be ruled out that preferences will change as the current younger generation grows older, meaning that continued research in this area is important in order to monitor these trends.

This raises an important issue around the relationship between public and policymakers' attitudes to energy sources, with implications for national governance of low carbon transitions. Whilst the UK Government is backing a nuclear expansion programme and shale gas development through fracking, it has repeatedly cut subsidies for on-shore renewable technologies and changed planning regulations making it harder to build renewable energy projects [70], citing a lack of public acceptance as a rationale [71]. This highlights a clear conflict between national policymakers' preferences for the UK's energy future, and the preferences of the public (as measured by the UK Government) i.e. the two 'dimensions' of socio-political acceptance, as theorised by Wüstenhagen et al. [14]. If the transition to a low carbon future is to be achieved in a smooth and timely way, and in a way that is acceptable to all stakeholders, it is crucial that these divergent socio-political preferences are somehow aligned. Whether this is achieved through changes to policy and the energy sources that are supported by policymakers, or by targeted campaigns to change public perceptions, there is a clear need for dialogue between stakeholders to bridge this widening gap and to reach consensus on the energy mix that will be used to achieve decarbonisation.

In this context, it becomes increasingly important to have consistent and reliable data to measure trends in attitudes across society. It is critical that there is long-term consistency in the measurement of public attitudes in order to take account of changes in trends over time, and to inform long-term policy development. The PAT is an extremely valuable resource in this regard, making it concerning that BEIS has recently reduced the regularity with which it asks some questions, specifically the questions measuring attitudes on fracking and nuclear [72].

To conclude, there are multiple rationales for policymakers to measure public attitudes towards energy issues, including enhancing the legitimacy of decision-making (instrumental rationale), providing non-expert input to policy decisions (substantive rationale), and increasing democracy (normative rationale) [73]. However, if public attitudes are not seemingly incorporated into decision-making processes, it becomes unclear which of these rationales is being pursued, potentially eroding trust in decision-making institutions and damaging the social license of energy industries to operate if they do not have the backing of the citizenry. Whilst public attitudes are only one of multiple considerations involved in energy policymaking, our findings call on

policymakers to be more transparent in justifying decisions to ensure a smooth and rapid low carbon transition that is acceptable to all.

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.erss.2019.101226>.

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