Title: Growing importance of climate change beliefs for attitudes towards gas

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Abstract (70 words)

Tense global politics, spikes in gas prices, and increasingly urgent warnings about climate change raise questions over the future use of natural gas. UK longitudinal survey data reveal beliefs about climate change increasingly reduce support for gas extraction between 2019 and 2022. Mounting connections between climate and gas use suggest growing opportunities for climate communication to lower support for all fossil fuels, not just the more carbon-intensive oil and coal.

Main text (1,690 words)

Russia's invasion of Ukraine and continued war there has led to massive political and public pressure worldwide to rethink energy security. The European Union has pledged to become entirely independent of Russian fossil fuels before 2030[1]; the United Kingdom (UK) – which imports far less natural gas directly from Russia (4%) – has currently halted any imports of Russian oil and coal, and seeks to become completely independent of Russian liquefied natural gas (LNG) as soon as possible[2]. The United States (US) has agreed to dramatically increase LNG exports to Europe to help reduce the heavy European dependence on Russia[3].

The approaches to reducing Russian reliance, however, vary considerably: (1) speed up the transition to renewables (whilst electrifying heat and transport)[4,5], (2) increase nuclear energy for electricity production[6,7], (3) identify alternate, preferably domestic, sources of gas[8,9], (4) consider hydrogen as a methane substitute for heating, and (5) reduce the need for energy by focusing on energy efficiency and behaviour change[10,11]. Although the direction of travel is towards increased renewables long-term, near-term increases in domestic hydrocarbon production[12] and expanded infrastructure to accommodate LNG imports[13] could frustrate timelines for emissions reductions identified in the IPCC Assessment Report 6[14], locking in extraction and gas use for decades. Gas constituted 42% of overall inland energy consumption in the UK in 2020 – the highest of any fuel. Replacing gas in electricity (e.g., renewables, especially wind) seems more feasible in the short-term compared to the large role of gas in heating; domestic use accounts for 37% of UK gas consumption[15].

In this changing energy landscape, with rising urgency of emissions reduction[16], understanding the relationship between public views about natural gas extraction and climate change could help reveal how the public will respond to policies seeking to expand gas extraction in a carbon-constrained world. Prior research has offered conflicting assessments, with some findings showing little connection between beliefs about climate change and support for gas development[17], whilst other findings point to strong relevance of climate change for informing attitudes towards gas extraction[18]. A recent US study reveals notable support for natural gas use as a 'bridge fuel', but opposition to some specific approaches for extracting gas, such as hydraulic fracturing[19]; this comes as other research questions the role of gas as a 'bridge fuel'[20] and highlights the increasing policy debates over the 'bridge fuel' status[21]. The UK is currently heavily reliant upon gas for electricity production (36% of production in 2020 – the highest from any source, followed by wind at 24%)[15] and heat (74% of all heating and hot water demand in buildings from gas)[22].

We conducted a longitudinal panel survey of a representative sample of 1,000 UK residents (see methods), surveyed in 2019, 2020, 2021, and 2022 examining their views on energy and climate issues. This allowed us to explore evolution in climate change beliefs, support for natural gas production, and the relationship between these two. The dramatic increase in climate activism, in media, political, and scientific attention to climate change, and increased focus on the need to reduce use of all fossil fuels over this period[23-26], led us to hypothesise that climate change beliefs might increasingly shape views on natural gas production over time.

Our data reveal support for domestic gas extraction clearly declines from 2019 to 2020, then again to 2021, but it increases somewhat in 2022 (Table 1). We asked about three types of gas extraction; support varied substantially across the different approaches to extraction, but over time we observe similar patterns in how support changed for each type of gas extraction from one year to the next. For offshore drilling and traditional onshore drilling, this amounts to support waning in 2020 and 2021; for shale gas extraction, which consistently received far less support, opposition increases. Conversely, very little movement occurs in beliefs about climate change over time. Perceived seriousness of climate change differs slightly, but significantly from Time 1 (T1) to T2 ($p = 0.033$), but not between T2 and T3, between T1 and T3, between T3 and T4, or between T1 and T4. Similarly, belief that the evidence for climate change is unreliable does not differ between any set of two time periods.

To explore how climate change beliefs affect support for gas production, and whether this relationship changed over time, we estimated a set of latent growth models. Our first model (see methods), included only the three measures of natural gas support entered at each time (T1, T2, T3, and T4), and estimates of the intercept and slope means and variance. This model indicated an average reduction in support for natural gas extraction of 0.02 per month (intercept mean of 1.010 [$p < 0.001$], with a slope mean of -0.020 [$p < 0.001$]). This baseline model had adequate fit (RMSEA = 0.070, CFI = 0.964, SRMR = 0.061)[27].

We then included five time-varying predictors of support for natural gas extraction (political orientation, *Daily Mail* and *Guardian* readership, and two climate change beliefs), and two time-invariant covariates (age and sex) in a conditional growth model (Figure 1 and Table S1). The most interesting results come from the effect of climate change beliefs on support for gas extraction in the UK. At T1, neither perceived seriousness of climate change for the UK nor certainty of climate change has a significant effect on natural gas support (Figure 1). Nevertheless, over time, the effect of climate change beliefs on gas support grows notably (unstandardised beta values grow from -0.02 to -0.09 to -0.12 to -0.16 for seriousness, and from 0.01 to 0.04 to 0.06 to 0.08 for unreliable science).

The T4 (year 2022) value for climate change seriousness (-0.16), for example, means that for every one-unit increase in perceived seriousness, gas support will decrease on average by 0.16 units. This is eight times larger of an effect than in the 2019 data. Thinking that climate change is serious for the UK has an increasingly negative effect on support for gas extraction each year. Believing that climate science is unreliable has an increasingly positive effect on gas support (the converse is also true – believing that climate science in *not* unreliable has an increasingly negative effect on gas support).

It is unsurprising that support for natural gas extraction declined in the UK from 2019 to 2021, but then rose in 2022. High profile events, such as the rise of climate action movements in the summer and autumn of 2019 (between T1 and T2) and then the public discourse in advance of the UK's hosting of COP26 (between T2 and T3) understandably drew attention to climate-related concerns about fossil fuel use[28]. Climate consciousness has remained high, even with COVID-19 competing for attention[28,29]. An influential IEA report[30] released in May 2021 (the same month as T3) states that a key milestone in the pathway to net zero by 2050 is no new oil and gas fields being approved for development as of 2021. Nevertheless, between T3 and T4, Russia's invasion of Ukraine and the attendant spikes in gas costs fostered much rhetoric about the need for domestic energy security and for reliable sources of gas and oil in the UK.

Although support declined for the three forms of natural gas extraction that we asked about, even in May 2021 (the low point) the mean value was still approximately 'slightly support' for both offshore drilling and conventional onshore drilling (4 on a scale of 1-6). Shale gas extraction conversely fell to a level between slightly and moderately oppose (2020-2022).

The effect of climate change beliefs on support for gas extraction increased markedly. It is possible the UK public has made clearer connections between gas extraction of all kinds and the detrimental effects of this energy source for climate change. Climate activism[23-26] and even policy debates[20] have increasingly painted gas's status as a transition fuel as problematic, and have drawn attention to the role of gas in accelerating (rather than mitigating) climate change. For many years, gas was simultaneously presented as a fuel that could help climate action (e.g., if substituted for coal) and as a fuel causing climate change (due to methane and CO_2 emissions).

Over the recent wave of climate action in Europe, that framing has been increasingly challenged; perhaps this contributed to the rising importance of climate beliefs on support for gas. Viewing gas as something bad for climate change does not necessarily mean, however, that people would perceive climate change as any more certain or serious; it merely highlights what may and may not be viable approaches for addressing climate change. This could explain how even though climate change beliefs remained stagnant, the relationship between climate change beliefs and support for natural gas progressively strengthened. Support for gas has also become more polarised – with politics and left

(*Guardian*) vs right (*Daily Mail*) newspaper readership increasingly predicting support for gas over time (Figure 1, Table S1).

The increasing effect of climate change beliefs on natural gas support has implications for public reactions to government policies that include a notable role for natural gas. This is particularly relevant with the UK's publication in April 2022 of a new energy security strategy[31] that opens up opportunities for expanded domestic gas production, stating 'There is no contradiction between our commitment to net zero and our commitment to a strong and evolving North Sea industry'. Although the 'evolving' industry could include gas for hydrogen and using depleted fields for carbon sequestration, our data suggest a growing contradiction between domestic gas production and net-zero in the minds of the UK public. The data also portend that if communication and activism efforts are able to negate the presumption of gas as a transition fuel, and rather frame gas as a fossil fuel like any other, they could likely cause increased opposition to gas extraction.

In the quickly shifting global energy landscape following Russia's war against Ukraine, some rhetoric/policy is strongly in favour of expanding renewables, some for nuclear, some for decreasing demand, and some for new approaches to obtaining gas[32]. Our research suggests that despite major geopolitical shifts over the last few years (e.g., responses to the pandemic, effects of the Ukraine war), the link between climate change and gas has strengthened; climate change beliefs increasingly predict opposition to gas.

Data availability statement:

The datasets used and analysed during the current study are available from the corresponding author upon reasonable request. The data sets will be deposited with the UK Data Service and the UK's National Geoscience Data Centre in February 2023.

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DE, LW, PDW, JD, PB, MB, and AV designed the surveys for data collection; DE, LW, and PDW conducted the data analysis; all authors (DE, LW, PDW, JD, PB, CF, MB, SR, AM, and AV) contributed to writing the article and interpreting the results and implications of the findings; DE, LW, PDW, JD, PB, and MB collaborated on the application for the funding secured for this research.

Competing interests statement:

No authors declared competing interests.

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<u>Methods</u> (1399 words)

Data collection

The data come from four waves of a longitudinal survey of a representative sample of the UK general public, run in April 2019, June 2020, May 2021, and May 2022, administered by the online survey panel provider YouGov, via their own proprietary software. The survey was designed to measure public attitudes and responses to energy development in the UK. The first wave of 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. Although attrition occurred between waves, the samples varied little on the quota variables; only age differed notably (more attrition amongst younger respondents; mean age, as of 2019, for the samples was 49.4 years in wave 1, 53.0 years in wave 2, 54.5 years in wave 3, and 55.6 years in wave 4).

Respondents received incentive points from YouGov for their participation, which they could redeem for cash or prize entries. The 2,777 respondents to the initial survey were invited to a follow-up survey 14 months later, which attracted 1,858 respondents (67% from 2019). The respondents to the second survey were invited to another follow-up survey 11 months later, attracting 1,439 respondents (52% from 2019). Finally, of the wave 3 respondents, 1,000 responded 12 months later (36% from 2019).

Herein, we examine change over time in support for natural gas extraction, and the effect of climate change beliefs, political orientation, mass media consumption, age, and sex on support for domestic gas extraction. Each variable was measured in all four surveys. Our dependent variable, in which we sought to model change over time, was a latent variable constructed from the following three measured items:

> 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?
>
> - Offshore drilling in the North and Irish Seas (not using 'fracking')
> - Traditional onshore drilling in the UK (not shale gas and not using 'fracking')
> - Shale gas extraction onshore in the UK (using 'fracking')

Response options included a 1-6 scale (strongly oppose, moderately oppose, slightly oppose, slightly support, moderately support, strongly support) and 'don't know'. Initial reliability scaling (Cronbach's alpha) for the three forms of support of natural gas extraction revealed single constructs at each time ($\alpha = 0.71$ [T1], 0.73 [T2], 0.76 [T3], 0.82 [T4]). We treated support for each of the three forms of gas extraction as a single latent variable due to: the reliability values, the fact that these three measures all conceptually capture the same broad concept of feelings towards gas extraction, and their subsequent high factor loadings onto one latent variable in the confirmatory factor analysis (figure 1).

Nevertheless, Table 1 reveals that the mean values differ substantially between shale gas extraction ('fracking') and the other two forms of production. Both offshore and onshore extraction without 'fracking' clearly enjoy majority support whilst shale gas extraction with 'fracking' is subject to majority opposition.

The independent, predictor variables of support for UK gas extraction included:

- The respondents' beliefs about how serious of a threat climate change poses to the UK as a whole (scale of 1-5, not at all serious to extremely serious, with 'don't know' option)
- Beliefs about the extent to which the evidence for climate change is unreliable (scale of 1-6, strongly disagree to strongly agree, with 'don't know option)
- Political orientation (scale of 1-7, very liberal to very conservative)
- *Daily Mail* readership (read a print version in the last 12 months; yes/no)
- *Guardian* readership (read a print version in the last 12 months; yes/no)
- Age (in years)
- Sex (male, female)

The *Daily Mail* and *Guardian* were chosen to operationalise polarised media discourse on climate change, due to multiple studies showing very strong climate denial discourse in the *Daily Mail* – a highly-read UK tabloid newspaper, and the opposite from the *Guardian* – a leftist broadsheet newspaper that focuses heavily on climate concerns[33-35]. The *Daily Mail* constantly downplays need for action on climate change, whilst the *Guardian* constantly demands it. After excluding survey respondents with missing data and 'don't know' responses, we had a final sample of n=963 for our baseline latent growth model and n=737 for our conditional growth model.

Each of the beliefs about climate change we included in our model were single-item measures. In our surveys, we included multiple indicators of perceived seriousness of climate change and of perceived certainty of anthropogenic climate change. We asked about seriousness of climate change for: you and your family, the UK as a whole, people in developing countries, and wildlife and ecosystems. We then asked about agreement with statements that: claims about human activities changing the climate are exaggerated, the evidence for climate change is unreliable, climate change is just natural fluctuation of the earth's temperature, and the media is often too alarmist about issues like climate change.

The results of exploratory factor analyses for the two sets of climate change beliefs in our survey are presented in Table S2. The four measures of climate change seriousness, and separately the four measures of anthropogenic climate change certainty, pooled very well onto single factors in all four waves of the longitudinal survey. To keep our conditional latent growth model parsimonious, however, we only included perceived seriousness of climate change as a threat to the UK in general, and belief that evidence for climate change is unreliable, as the two metrics to represent these constructs in the final model. We considered the UK level most relevant to policy on both climate and natural gas. We chose unreliability as the construct most tied to uncertainty due to research showing questioning of evidence of as a dominant discourse in the UK related to climate scepticism[36].

Data analysis

To investigate our hypothesis, we conducted two latent growth curve models designed to analyse change in support for natural gas extraction within our longitudinal survey sample. Curran *et al.*[37] define latent growth modelling as a set of 'statistical methods that allow for the estimation of inter-individual variability in intra-individual patterns of change over time'. The models fundamentally allow researchers to estimate differences in within-person change over time across a population.

We modelled latent growth via structural equation modelling (SEM), as opposed to via multilevel modelling, due to our inclusion of support for natural gas extraction as a latent variable constructed from three measured items. SEM has more capacity for incorporating comprehensive measurement models into latent growth modelling[37]. We conducted initial analyses in SPSS (version 27) and then the latent growth model in Mplus (version 8.3).

Our first latent growth model was a baseline model in which we only included the three measures of support for gas production, collapsed onto a latent construct, at each of the four times the survey was run (T1, T2, T3, T4). In this model we estimated the intercept mean (i.e., the starting point for support for gas extraction), slope mean (i.e., rate of change, per month, in support), intercept variance (i.e., degree of variability in the starting point across the survey respondents), and slope variance (i.e., variability in the rate of change across respondents). Because the surveys were not in the same month each year, we used month rather than year in our latent growth models, with T1 being month zero, T2 month 14, T3 month 25, and T4 month 37.

Our second latent growth model was a conditional growth model, meaning we measured the intercept and slope means and variances again, but whilst controlling for the effect of the aforementioned independent variables on support for gas extraction at each time. Age and sex were entered as time-invariant covariates, because sex remains static for each respondent and age increases linearly with time. Climate change beliefs, *Daily Mail* and *Guardian* readership, and political orientation were entered as time-varying covariates, with unique values provided for each survey wave. Time-varying covariates speak to within-person influences, whilst time-invariant covariates speak to between-person influences[38].

Human subjects research

Human subjects approval for the survey research was granted by the Ethics Committees of the School of Social and Political Sciences at the University of Edinburgh and the Geography department at the University of Exeter. Informed consent was obtained from all research participants. All methods were performed in accordance with the relevant guidelines and regulations.

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Table 1. Core survey items, mean values over time

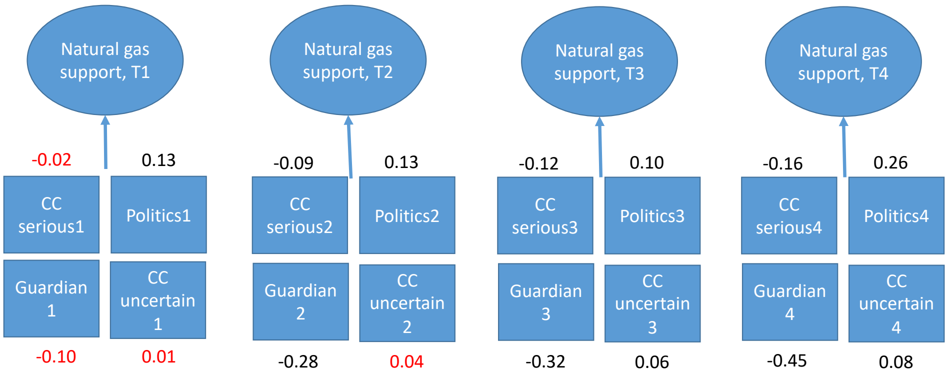
	April 2019	June 2020	May 2021	May 2022
Offshore drilling in the North and Irish Seas (not using 'fracking')	5.07[1] (n=872[2]) (s.d. = 1.14)	4.54 (n=890) (s.d. = 1.35)	4.27 (n=867) (s.d. = 1.45)	4.51 (n=901) (s.d. = 1.54)
Traditional onshore drilling in the UK (not shale gas and not using 'fracking')	4.52 (n=838) (s.d. = 1.33)	4.16 (n=862) (s.d. = 1.39)	3.99 (n=840) (s.d. = 1.46)	4.24 (n=868) (s.d. = 1.53)
Shale gas extraction onshore in the UK (using 'fracking')	3.02 (n=823) (s.d. = 1.78)	2.62 (n=866) (s.d. = 1.65)	2.47 (n=857) (s.d. = 1.61)	2.93 (n=884) (s.d. = 1.79)
Seriousness of climate change for the UK as a whole	3.50 (n=938) (s.d. = 1.15)	3.42 (n=946) (s.d. = 1.10)	3.48 (n=935) (s.d. = 1.12)	3.51 (n=943) (s.d. = 1.09)
The evidence for climate change is unreliable	2.59 (n=891) (s.d. = 1.63)	2.51 (n=911) (s.d. = 1.61)	2.50 (n=896) (s.d. = 1.64)	2.57 (n=898) (s.d. = 1.69)
Political orientation (very liberal to very conservative)	3.81 (n=1000) (s.d. = 1.38)	3.89 (n=1000) (s.d. = 1.38)	3.92 (n=1000) (s.d. = 1.37)	3.82 (n=1000) (s.d. = 1.40)
Read a print version of the *Daily Mail* in the last year	18% (n=1000) (s.d. = 0.38)	15% (n=1000) (s.d. = 0.36)	12% (n=1000) (s.d. = 0.33)	10% (n=1000) (s.d. = 0.30)
Read a print version of the *Guardian* in the last year	11% (n=1000) (s.d. = 0.32)	10% (n=1000) (s.d. = 0.30)	7% (n=1000) (s.d. = 0.26)	6% (n=1000) (s.d. = 0.24)

[1] Scale of 1-6: strongly oppose, moderately oppose, slightly oppose, slightly support, moderately support, strongly support

[2] The sample sizes for 2019, 2020, 2021, and 2022 means are 1000 minus 'don't know' responses for that item. Although initial sample sizes were higher for waves 1, wave 2, and wave 3, we use the sample from wave 4 for all means, to allow for systematic comparison across the panel data.

[2] s.d. = standard deviation

Figure 1. Conditional latent growth model



Model fit: RMSEA = 0.046, CFI = 0.930, Chi^2 = 753.4 ($p<0.001$)

Note: coefficients in red are not statistically significant

Supplemental Information

Table S1. Full conditional latent growth model results

Pathway	Unstandardised parameter estimate	95% confidence interval	p-value
Natural Gas Support factor loadings			
Offshore	1.000	n/a (fixed)	---
Onshore	0.996	0.955 – 1.036	0.000
Shale	0.680	0.609 – 0.750	0.000
Age → Intercept	0.023	0.018 – 0.028	0.000
Sex (female) → Intercept	-0.170	-0.316 – -0.024	0.022
Age → Slope	0.000	0.000 – 0.000	0.969
Sex (female) → Slope	-0.001	-0.006 – 0.003	0.493
Predictors of Natural Gas Support 1			
Climate change serious 1	-0.021	-0.083 – 0.040	0.496
Climate change uncertain 1	0.009	-0.037 – 0.055	0.693
Politics (conservative) 1	0.129	0.080 – 0.178	0.000
Guardian reader 1	-0.103	-0.288 – 0.082	0.276
Daily Mail reader 1	0.141	-0.019 – 0.301	0.084
Predictors of Natural Gas Support 2			
Climate change serious 2	-0.085	-0.141 – -0.030	0.003
Climate change uncertain 2	0.039	-0.004 – 0.082	0.076
Politics (conservative) 2	0.128	0.080 – 0.176	0.000
Guardian reader 2	-0.280	-0.475 – -0.085	0.005
Daily Mail reader 2	0.081	-0.097 – 0.260	0.372
Predictors of Natural Gas Support 3			
Climate change serious 3	-0.120	-0.190 – -0.050	0.001
Climate change uncertain 3	0.055	0.002 – 0.107	0.041
Politics (conservative) 3	0.101	0.045 – 0.156	0.000
Guardian reader 3	-0.323	-0.544 – -0.101	0.004
Daily Mail reader 3	0.237	0.048 – 0.426	0.003
Predictors of Natural Gas Support 4			
Climate change serious 4	-0.155	-0.230 – -0.081	0.000
Climate change uncertain 4	0.083	0.032 – 0.135	0.002
Politics (conservative) 4	0.260	0.203 – 0.317	0.000
Guardian reader 4	-0.454	-0.710 – -0.197	0.001
Daily Mail reader 4	0.347	0.126 – 0.568	0.002
Intercept and slope			
Intercept at T1 (mean)	0.996	0.955 – 1.036	0.000
Slope (mean)	-0.020	-0.044 – 0.004	0.095
Intercept at T1 (variance)	0.657	0.540 – 0.775	0.000
Slope (variance)	0.000	0.000 – 0.000	0.006

Covariance of Intercept and Slope	-0.002	-0.005 – 0.001	0.235

RMSEA = 0.046, CFI = 0.930, Chi-Square = 753.4 (297 d.f., p<0.001)

Table S2. Exploratory factor analyses for climate change beliefs

Latent variable	Lowest factor loading	% variance explained	Cronbach's alpha
Climate change seriousness, T1	0.84	84	0.94
Climate change seriousness, T2	0.83	83	0.93
Climate change seriousness, T3	0.84	84	0.94
Climate change seriousness, T4	0.85	83	0.93
Climate change uncertain, T1	0.79	76	0.89
Climate change uncertain, T2	0.82	77	0.90
Climate change uncertain, T3	0.81	78	0.91
Climate change uncertain, T4	0.85	80	0.92