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Public perception of the relationship between climate change and unconventional gas development ('fracking') in the US

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Title: Public perception of the relationship between climate change and unconventional gas in the US

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Key Policy Insights

- Beliefs about several effects associated with unconventional gas development ('fracking') affect support for and opposition to development to a greater extent than beliefs about development's effect on global climate change do.
- Communication tailored to increase awareness of development would likely be most effective when focusing on local level, as opposed to national or global, impacts.
- Messaging about development's relationship with carbon emissions would have more effect in national-level discourse, as opposed to messaging targeted at communities experiencing or potentially experiencing development.
- To maintain credibility and societal trust, communication on the global climate impacts of unconventional gas development needs to be informative but non-persuasive.

General Academic Abstract

'Fracking', or unconventional gas development via hydraulic fracturing (hereafter 'UGD'), has been closely tied to global climate change in academic discourse. Researchers have debated the lifecycle emissions of shale gas versus coal, rates of methane leakage from wellhead production and transmission infrastructure, the extent to which coal would be displaced by gas as a source of energy, the appropriate time-scale for accounting for the global warming potentials of methane and carbon dioxide, surface versus airborne methane measurements, and the effect of lowered energy prices on gas consumption. Little research, however, has examined the degree to which these potential connections between UGD and climate change are relevant to the general public. This article presents two surveys, one of a representative national (US) sample and one of a representative sample of residents in the Marcellus Shale region of Pennsylvania and New York. It examines relationships between whether respondents associated UGD with climate change and their support for or opposition to UGD. The results reveal that beliefs about many other potential impacts of UGD explain more variation in support and opposition than do beliefs about UGD's association with climate change. Furthermore, most other impacts of UGD are viewed as having more effect on quality of life if they were to occur, at least amongst the Marcellus Shale survey sample. The article concludes with implications of the findings for policy and communication on UGD.

Keywords: shale gas, hydraulic fracturing, climate change, risk perception, communication

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1. Introduction

The last half decade has seen a proliferation of scholarship on the connection between unconventional gas development via hydraulic fracturing ('UGD') and climate change. This research has become contentious and highly politicised, both due to the complexity of UGD and the energy industry as a whole, and due to the enormity of the potential disruption that UGD could bring to the energy industry and the global climate. As such, most of the research is piecemeal, in that it focuses on a particular aspect or scale of UGD. Researchers have debated: (1) the lifecycle emissions of shale gas versus coal (Howarth et al. 2011, Jenner & Lamadrid 2013, Weber & Clavin 2012, Wigley 2011), (2) rates of methane leakage from wellhead production and transmission infrastructure (Allen et al. 2013, Alvarez et al. 2012, Sanchez & Mays 2015, Schwietzke et al. 2016), (3) the extent to which gas actually displaces coal use globally (Sovacool 2014), (4) twenty versus one-hundred year time frames for warming potential (Cathles et al. 2012; Howarth et al. 2012),

(5) surface versus airborne methane measurements (Zavala-Araiza et al. 2015), (6) the effect of lowered energy prices on gas consumption (Newell & Raimi 2014), (7) competition between low-cost gas versus renewables or carbon capture and storage (Schrag 2012), and (8) the economics of natural gas production and trade (Paltsev et al. 2011).

Whilst significant scientific and academic debates on the link between UGD and global climate change (GCC) are manifold, there are still fundamental unanswered questions pertaining to the public perception of UGD and GCC. First, are members of the general public aware of this potential connection? Then, if so, what do they think that relationship looks like (i.e., is UGD positive or negative for GCC)? Finally, does this connection matter to them? The answers to these questions could affect public awareness and support for policies and regulations related to UGD as well as influence the types of communication about UGD that could be most effective. Few studies examine public perceptions of the linkage between UGD and GCC; a recent meta-analysis of public perceptions of UGD noted that the benefits and/or risks that UGD presents in relation to GCC are rarely commented on by research participants (Thomas et al. 2017b). Studies on other energy technologies, such as nuclear power, for example, reveal that connections between reduced carbon emissions and an energy technology can instigate reluctant acceptance of the technology, even if that technology is not generally preferred (Corner et al. 2011; Spence et al. 2010).

One study explicitly on UGD, a cross-sectional panel survey of a national UK sample, repeated twelve times, has shown that from 2012-2016, consistently 40-50% of respondents did not know whether UGD would increase or decrease greenhouse gas emissions (O'Hara et al. 2016). Another online survey of the UK public revealed that climate scepticism (as measured by a 14-item scale assessing beliefs about the reality, causes, and impacts of climate change; scale from Corner et al. [2012]) is the most important correlate of support for or opposition to UGD (Whitmarsh et al. 2015). More climate scepticism equates to more support for UGD. The study did not, however, examine perceptions of whether UGD contributed to or mitigated GCC. Whitmarsh and colleagues (2015) do show that the public perceives a potential indirect effect of UGD on GCC, in that over four times as many of their survey respondents agreed rather than disagreed that politicians who think 'shale gas fracking' is a possibility will be less likely to pursue other policies to tackle climate change. A survey in the US, which asked respondents to discuss any concerns they associated with UGD in an open-ended format, revealed that 23% mentioned GCC-related items (Israel et al. 2015) – this was less than for concerns about water, air, social systems, private economic impacts, and health, but more than for concerns relating to quality of life, ecological impacts, and social disruptions. This survey was, however, of individuals in organisations active on the issue of UGD, not with the general public.

These three factors – the extent to which the general public links UGD and GCC, the direction of that relationship (does it mitigate or increase GCC?), and the importance of those beliefs for affecting support for or opposition to GCC – each have substantial policy relevance. For example, in nations such as the UK and European Union member states – which have legislatively mandated commitments to reduce carbon emissions and high levels of public support for climate-relevant regulation (Lorenzoni & Pidgeon 2006, Brügger et al. 2016, McCright et al. 2016) – viability of UGD could depend on public perceptions that it will not harm GCC mitigation efforts, whether or not these perceptions reflect scientific understanding. In the US, President Trump's contentious proposals to open additional federal lands for oil and gas extraction, much of which could be unconventional extraction, could meet with more or less political resistance and legal action depending on links people make between GCC and UGD – does a relationship exist, is it positive or negative, and do they care? A number of industry actors, non-profit organizations, and government entities in the US and Europe have sought to communicate both informatively and persuasively about UGD. In the persuasively-oriented camp are actors on both sides that benefit from confusion, misrepresentation, and prolonging the political debate. Knowing better the perceived relationships between UGD and GCC in the minds of the public could help inform communication efforts and make them increasingly effective.

To explore the relationship between (1) support for or opposition to UGD and (2) associations between UGD and GCC amongst members of the general public, this article presents results from two surveys in the US – one each of a national and a regional sample. In each survey, respondents were asked whether they associated lower 'greenhouse gas (carbon) emissions' with UGD or not. Both surveys also asked about (1) associations between UGD and a range of other impacts and (2) overall support for or opposition to UGD.

Whilst the aforementioned research reviewed leaves open the question of what effect beliefs about UGD's association with climate change has on support and opposition, qualitative interviews conducted in the Marcellus Shale region with people engaged with the issue of UGD suggest that GCC would not be an important predictor of overall views of UGD, and that more localised concerns would dominate (Braiser et al. 2011; Evensen 2015; Evensen and Stedman 2017b; Morrone et al. 2015; Perry 2012; Sangaramoorthy et al. 2016; Schafft & Biddle 2015).

The data analysis explores four research questions:

1. To what extent do members of the public in the US link UGD and GCC?
2. Does the public perceive UGD as mitigating or exacerbating GCC?
3. To what extent do beliefs about UGD's effect on GCC correlate with support for or opposition to UGD? How does the strength of this correlation compare to correlations between beliefs about other impacts and support/opposition?

2. Methods

2.1. Marcellus Shale region survey

Two surveys measured public attitudes and beliefs about UGD. These surveys were not designed for the purposes of direct comparisons across the samples, but both included questions about beliefs about the association between UGD and GCC and included questions on support for or opposition to UGD. This presented an opportunity to examine our research questions independently within a broad, national survey sample and within a sample of individuals close to UGD and heated discussions about UGD.

The first survey was mailed to a stratified random sample of residents in 34 municipalities in the Marcellus Shale region of southern New York and northern Pennsylvania (17 municipalities in each state, total N=1202). To design the questions for the first survey, a content analysis of regional newspaper coverage in the Marcellus Shale region and 47 interviews with individuals heavily involved in discourse on UGD were conducted. Particularly, we sought to identify beliefs about impacts, values, and personal attributes that might be associated with attitudes about support for / opposition to UGD. Study communities for the survey were selected by expanding the regions surrounding the six communities used for interviews (see Figure 1). The sample included a range of urban and rural areas within each of the six regions and across regions. We included communities that varied on a range of variables that could affect views on UGD (e.g., passage of legislation on UGD, number of wells drilled, amount of land leased, demographic statistics, political leaning). The broad spectrum of communities across these variables ensured that a range of factors potentially affecting perspectives on UGD would be reflected. Nevertheless, the sample was randomly drawn from the 34 communities and should be seen as representative of these communities as opposed to reflecting the larger Marcellus Shale region or the states of New York and Pennsylvania. We did also apply proportional weights to the data to control for variation of the sample from population demographics (see below).

With an output of 18.5 million cubic feet of natural gas per day as of February 2017, the Marcellus Shale is the largest natural gas producing region in the USA (with more than double the output of the next highest producing shale basin) (US EIA 2017). Ninety-two percent of gas reserves in the basin are estimated to lie under Pennsylvania and New York (US EIA 2012).

The survey was mailed to a random sample of 147 households in each of the 34 selected municipalities. In July 2013, we obtained a random sample of names, addresses, and telephone numbers for residents in the selected municipalities. The sample was compiled by cross-referencing the most recently available US Postal Service records with telephone book white pages. Following best practice in Dillman and colleagues' (2014) tailored design method, surveys were mailed in a four-wave mailing (i.e., survey, reminder, second survey, second reminder). Data collection occurred between late September and mid-November 2013.

The survey was mailed to 4,998 households; 629 of those surveys were returned as undeliverable (345 in NY and 284 in PA). Therefore, with 1202 respondents (637 from NY and 565 from PA), the adjusted response rate for the entire sample was 28%. The rate for the NY municipalities was 30%; the rate for the PA municipalities was 26%. The sample varied from population means in terms of age, sex, and education. The sample was more educated, more male, and older than the general population. Therefore, we used 2010 US Census data for the six counties in NY (averaged across these counties) and four counties in PA (again, averaged) to generate proportional weights which were applied to the data set for all analyses below (see Supplemental Table 2).

2.2. National (USA) sample survey

The second survey was a nationwide Internet survey administered via the online survey firm Qualtrics (N=1625). The survey approximated the US national population with respect to sex, regional distribution (by state), and age (of individuals 18 years and older). Qualtrics draws respondents from online panels; therefore, quotas were applied to responses to ensure that the resulting responses match the national averages demographically. Because the sample was nationally representative based on population distribution across the US, areas with low population had very little representation in the survey (e.g., states such as the Dakotas, Wyoming, and Montana, and all rural areas). This means that areas with UGD (or potential for UGD) contributed few respondents. The survey should be viewed as reflecting national views on this topic, not the views of communities exposed to development or with potential for development.

Data was collected from 16-19 September 2014. To ensure that data quality was maintained, Qualtrics only included in the final data set respondents who spent at least eight minutes responding to the survey. A pre-test established that this was a reasonable threshold to exclude respondents who were likely engaging in strong satisficing. Response rates are not indicative when using online quota-sampling as non-response cannot be easily defined and demographic information should be consulted instead (Dillman, 2007). Fifty-seven people exited the survey prematurely; this equates to an adjusted completion rate of 97%.

2.3. Survey questions

This article reports on two questions from each survey. One measured attitudes about UGD by asking respondents, in the Marcellus Shale region survey, ‘Considering everything, do you support or oppose shale gas development in the USA?’ (evaluated on a

6-point Likert-type scale, strongly oppose to strongly support). In the US survey we asked, 'Do you think that extracting natural gas from shale in the United States should or should not be allowed?' (evaluated on a 4-point Likert-type scale, strongly oppose to strongly support). Slightly different wording and different scales were used; therefore, our analyses below do not compare data across the two samples. Rather, we use each data set independently to address the research questions specified earlier.

The second question in the Marcellus Shale region survey asked, 'How likely do you think the following effects of shale gas development are (in areas with development)?' (response options: not at all likely, not very likely, likely, very likely). The national sample survey asked, 'For each of the following, please state whether you do or do not associate it with shale gas' (response options: do associate, do not associate, don't know). The Marcellus Shale region survey included twenty-four impacts, whilst the US survey included six. Tables 1 and 2 list all the impacts included. Again, whilst question wording differences and differences in the impacts listed do not allow for direct comparisons of each impact across samples, each survey independently allows for comparisons of beliefs about GCC with beliefs about other impacts of UGD *within* the survey.

2.4. Data analysis

Data analysis consisted of, within each survey individually, comparisons of the Pearson correlations (r) between beliefs about various impacts with support for UGD. In each case, we separate out the correlation between beliefs about UGD's relationship with decreased carbon emissions and support for UGD; we then compare this to correlations between beliefs about the other impacts and support for UGD. The greater the absolute value of a correlation, the stronger association between a belief and support. Whilst we do not assert causality, the greater the correlation, the more likely beliefs about that impact are relevant for communication to public audiences and policy on UGD that aims to respond to public perspectives (see Evensen and Stedman [2017a] for a discussion of the causal relationship between beliefs about UGD impacts and support/opposition). In the Marcellus Shale region survey, we report correlations: (1) between perceived likelihood of an impact occurring and support for UGD and (2) between perceived effect on quality of life if that impact were to occur and support for UGD. In the US survey, we report correlations between whether each impact is associated with UGD or not and support for UGD. In all multivariate analysis, we excluded the 'don't know' responses in the US survey to make this variable dichotomous, as opposed to nominal.

We also conducted regression analysis to reveal the relationship between demographic variables included in each survey and the beliefs about carbon emissions that we associated with support in the correlational analysis. For the Marcellus Shale survey, we conducted two OLS linear regressions (due to the two dependent variables being linear – likelihood of an impact occurring and effect on quality of life if it were to occur). Independent variables included: age, sex, education, satisfaction with one's family's financial situation, political views, urban residence (vs. rural), state (NY vs. PA), and whether the respondent had a gas lease or not. For the US survey, we conducted a binary logistic regression due to the dependent variable (whether an impact was associated with UGD or not) being dichotomous. Independent variables differed somewhat from those in the Marcellus region survey and included: age, sex, education, annual family income, and political views.

3. Results

3.1. Linkage of UGD and GCC

Respondents to the Marcellus Shale region survey displayed a fairly normal distribution in how likely they thought it to be that UGD would lead to 'decreased greenhouse gas (carbon) emissions' (15% very likely, 26% likely, 37% not very likely, 23% not at all likely; N=1089, standard deviation = 0.99) and in terms of their perceived effect on their quality of life if UGD were to lead to decreased emissions (13% no effect, 29% little effect, 33% some effect, 25% a large effect; N=1034, standard deviation = 0.99). In the US survey, 36% of respondents associated UGD with 'lower greenhouse gas (carbon) emissions' (Table 2); 21% associated it with higher emissions (N=1625). Notably, a plurality of the US respondents – 42% – stated that they 'don't know' whether UGD would increase or decrease carbon emissions. This is similar to levels of indecision on this question captured in surveys of the British public (O'Hara et al. 2016).

In terms of overall likelihood of decreased carbon emissions being associated with UGD, this was viewed as a relatively unlikely impact in the Marcellus survey, with 21 of the other 23 impacts being assessed as more likely on average (Table 1). With respect to the question, 'If it [the impact] were to occur, how much of an effect would it have on your quality of life?', the respondents collectively assigned a higher mean (thus, more impact on quality of life) to nine of the twelve social impacts listed in the survey and to all three of the other environmental impacts listed, than to decreased emissions (Table 1). In the US survey, 36% of respondents associated lower greenhouse gas emissions with UGD; this was less than for all other impacts, save earthquakes (Table 1).

Our regressions examining the relationship between demographic covariates and beliefs about UGD's effects on carbon emissions in the Marcellus Shale region survey (Table 3) and US survey (Table 4) revealed that beliefs are largely constant across a range of demographics. In the Marcellus Shale region survey, beliefs about the likelihood of UGD decreasing carbon emissions were only predicted ($p < 0.05$) by political views (scale of 1-7 for liberal to conservative; more conservative = more likely to decrease emissions) and education (more formal education = less likely to decrease emissions). Age, sex, satisfaction with family's financial situation, living in an urban versus rural area, living in NY versus PA, and having a gas lease on one's property were all nonsignificant in the model. In that same survey, beliefs about the effect on quality of life of UGD decreasing carbon emissions again saw education and political views as significant predictors, with the addition of sex as significant (Table 3). In the US survey, association of UGD with lower carbon emissions was only predicted ($p < 0.05$) by political views (same scale as in the other survey; more conservative = higher odds of associating UGD with lower emissions). Age, sex, annual family income, and education were all nonsignificant in the model.

3.2. Effect of GCC beliefs on support for UGD

Out of the twenty-four potential effects of UGD included in the Marcellus Shale region survey, beliefs about the likelihood of decreased emissions coming from UGD had the fifth lowest correlation (absolute value) with support/opposition (Table 1). Beliefs about carbon emissions from UGD could alone explain less than 10% of the variation (R^2) in support/opposition; yet, beliefs about the likelihood of each of seven other impacts, by themselves, could explain over 50% of this variation (i.e., decreased water quality, decreased fish and wildlife health, long-term local economic growth, decreased quality of outdoor recreation, decreased air quality, decreased local beauty, and decreased human / public health).[a] In terms of effect on quality of life if UGD did reduce emissions, this effect

[a] Correlations in which the beliefs about impacts were treated as binary variables (i.e., with 'not at all likely' and 'not very likely' pooled, and 'likely' and 'very likely' pooled), produced very similar results. The association between beliefs about UGD's relationship to decreased carbon emissions and support for UGD changed little when compared to correlations with the other beliefs (see Supplemental Table 1).

had the fourth lowest correlation with support/opposition out of the twenty-four effects (Table 1).

In the US survey, public perceptions of the association between UGD and lower emissions had the fourth strongest correlation with support/opposition of the six impacts included (r = 0.43; Table 2). By itself, associations of UGD with lower carbon emissions explained 19% of the variation (R^2) in support/opposition. The three beliefs about impacts with higher correlations each individually explained between 22-28% of this variation (Table 2). Therefore, whilst still not at the top of the list in terms of impacts that associated closely with support and opposition, the association between beliefs about UGD's effects on GCC and support for UGD was not dwarfed by the correlations between other beliefs and support. Note, however, that whilst the correlation between beliefs about UGD's linkage to GCC and support/opposition was relatively close to correlations between the other variables and support/opposition in the US survey, this was amongst respondents who answered this question affirmatively or negatively (only 58% of all respondents, due to the high percentage of 'don't know' responses).

4. Discussion

The empirical data from the two surveys suggest that whilst connections between UGD and GCC are not unimportant for explaining support for or opposition to UGD, this is far from the impact that is most linked to support/opposition on this issue. These results raise the question of why beliefs about associations between UGD and GCC matter relatively little, both in an area where UGD is occurring and in the US at large. A plausible response is that GCC is a psychologically distant, and largely abstract, potential impact of UGD (Brügger, Dessai, Devine-Wright, Morton, & Pidgeon 2015; Brügger, Morton, & Dessai 2015; Haden et al. 2012; Jones, Hine, & Marks 2017; Spence & Pidgeon 2010;

Spence et al. 2012; Weber 2016). Psychological distance typically has four components: social distance (i.e., affects others more than people like me), spatial distance (i.e., affects those far away more than those close by), temporal distance (i.e., affects the future [or past] rather than the present), and experiential distance (i.e., is the effect imagined or experienced?). The influence of psychological distance is theoretically consistent with construal-level theory (Hart et al. 2015; Trope & Liberman 2010; Zwickle & Wilson 2014), which some research has suggested is relevant for understanding public perceptions of UGD (Evensen, Jacquet, Clarke, & Stedman 2014; Evensen & Stedman 2016; Clarke et al. 2016; Thomas et al. 2017b). Our findings offer further evidence that this theory applies to perceptions of UGD. One could hypothesise that for people living near areas with UGD, decreased carbon emissions would be distant on all four aspects of distance, whereas impacts such as decreased fish and wildlife health, air quality, local beauty, and road quality would be proximate on each dimension. Even in areas not directly exposed to UGD, many of the other impacts are more concrete, tangible, and easily comprehended in relation to one's own life than a decrease in carbon emissions is.

Perhaps some people might find it unsurprising that likelihood of decreased carbon emissions was not too strongly associated with UGD in the Marcellus Shale region survey. They might offer this as evidence that people thought UGD would, rather, increase carbon emissions. Whilst possible, we think a more accurate interpretation is that respondents were uncertain about or ambivalent to the relationship between UGD and GCC. This is likely a reflection of the complexity of the UGD literature, as well as the contentious political and scientific debate over issues of energy use, fossil fuels, and climate change. The mean on the likelihood scale placed the average response between 'likely' and 'not very likely'; the most common response was 'not very likely'. The data does not evince strong beliefs either way about UGD decreasing or not decreasing carbon emissions.

Unlike effects of GCC, the vast majority of the impacts in Table 1 are local impacts that would be observed and experienced in the near term in the survey respondents' home communities. Because the Marcellus Shale region survey was distributed to residents in New York and Pennsylvania living close to development (and in 2013, before NY instated its 2014 ban on UGD), residents could have tractably linked these impacts closely to their own experience in the foreseeable future. Indeed, responses to the question about impact on quality of life (Table 1) showed that, in addition to Marcellus respondents not linking UGD closely to effects on GCC, even if this relationship were presumed to exist, they did not care much about it. Furthermore, their level of care about the presumed effect asserted little influence on their support for or opposition to UGD.

Some scholars have contended that beliefs about UGD's effects on GCC do importantly affect attitudes about UGD (Mazur 2016), but this is based on mass media coverage of academic debates, and not on direct evidence of public perceptions. Furthermore, this supposition comes from analysis of national mass media outlets. Research has shown that local newspapers are much more important information sources on this topic than national newspapers in areas affected by UGD, particularly in the Marcellus Shale region (Ashmoore et al. 2016; Theodori et al. 2014), where local newspapers afford little attention to the linkage between UGD and GCC (Evensen, Clarke, & Stedman 2014).

5. Communication and policy implications

Although more research in this area could be useful – for example, to what extent are the findings in southern NY and northern PA mirrored in other areas exposed to UGD and to what extent is the link between GCC and UGD important for public perceptions of UGD in other nations – the data analysed herein do suggest initial approaches to communicating about UGD. Apropos messaging, of course, depends on one's goal. For individuals concerned about UGD and hoping to foster opposition, or minimally a critical eye towards development, they might avoid highlighting the link between UGD and GCC, at least in areas close to development, in favour of discussing local impacts that could more strongly affect attitudes. The first nine associations with UGD listed in Table 1 (after decreased carbon emissions), each individually explain more than 40% of the variance in overall support/opposition; seven associations correlate with opposition, two correlate with support. Communication could focus on whether these potential effects are likely to occur. Furthermore, the effect of each of the eight impacts with the highest correlations listed in Table 1 on quality of life could individually explain more than 30% of the variance in overall support/opposition. Communication that highlights these impacts would speak more clearly to public perspectives on this issue than would attention to GCC implications of UGD. Whilst it is unclear whether beliefs about these impacts lead to support/opposition or stem from this general attitude (or both), targeting communication towards these impacts would likely have more effect on overall attitudes than attending to GCC's relationship with UGD.

The foregoing suggestion might seem unsatisfying to individuals convinced of the importance of UGD's effects on GCC (either as helping or hindering action to mitigate GCC). Such individuals would appreciate recent research that reveals that providing additional information about impacts of UGD, even explicitly about UGD's connection to GCC, does seem to affect overall attitudes about UGD (Whitmarsh et al. 2015). In the US survey, 42% of respondents answered that they did not know whether or not they associated UGD with higher or lower carbon emissions. This suggests that there is some opportunity for additional information sharing, whether in communication about GCC broadly or specifically about energy development or UGD (Kahan et al. 2012; Weber & Stern 2011). Construal-level theory would suggest that because most impacts of UGD are potentially at least somewhat abstract (e.g., spatially, experientially, and temporally distant) in areas not yet exposed to UGD, focusing on an abstract impact such as UGD's effect on carbon emissions and GCC might be best targeted to populations outside of areas directly exposed to development or areas experiencing heavy conversation about UGD. In such areas, deliberative, two-way public engagement processes could be effective means for sharing information with the public and learning of public concerns (Thomas *et al.* 2017b).

An important proviso to the ability of communication to effect attitudinal change is that the information must come from a trusted source (Thomas *et al.* 2017b, Jacquet 2014). Mrozowska *et al.* (2016) demonstrated from surveys in Poland and the US that, after controlling for several factors including political views, scientific knowledge, and a range of personal values and attitudes, trust in the entity providing information about shale gas was repeatedly a lead predictor of general evaluations of UGD. Several studies have measured trust in a variety of actors who might share information on UGD (for a review see Thomas *et al.* 2017b). Consistently, regulatory agencies, industry, and environmental groups benefit from little trust; scientists and 'experts' perceived as being independent, competent, and not politically motivated are one of the few categories of information sources regularly afforded high levels of trust.

Even if additional information about the connection between UGD and GCC could be useful for increasing public awareness and/or concern on the issue of UGD, scientists, in particular, need to exercise caution in how they provide information, should they choose to do so. In light of the large percentage of 'don't know' responses and relatively low importance of beliefs about the connection between GCC and UGD for explaining support/opposition, advocacy from scientists might seem helpful or even necessary; indeed, some such advocacy is already practiced by scientists engaged in the aforementioned atmospheric research on UGD and GCC. Fischhoff (2007), however, points out how such advocacy on GCC can damage credibility of the scientific enterprise. He recommends non-persuasive communication in a 'credible, comprehensive form' (p. 7208).

In terms of policy, UGD's potential connections to GCC need to be carefully considered. This sentiment is independent of the findings herein; it is based on our personal commitment to seeing action on GCC and the overwhelming support worldwide for action to mitigate GCC (Clayton et al. 2015). Beyond the limited importance of connections between GCC and UGD, the general public also has difficulty processing GCC as a morally-relevant dilemma (Markowitz & Shariff 2012). Nevertheless, this does not necessitate avoiding ethical considerations when forming policy on GCC (Wardekker, Petersen, & van der Sluijs 2009). Indeed, perhaps policy must focus even more heavily on concerns neglected by the public due to the reduced likelihood that the public will demand action on such issues. Explicit consideration of UGD's connection to GCC in concert with other, more local environmental, economic, and social impacts in regulation on this issue could work towards this goal.

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Table 1: Relationships between various impacts and support for UGD (Marcellus survey)[b]

Potential effect of UGD	**'Likelihood of effect occurring' (mean)**	**'Effect on quality of life' *if it did* occur (mean)**	**Correlation of 'likelihood of effect' with support**	**Correlation of 'effect on quality of life' with support**
Decreased greenhouse gas (carbon) emissions	2.33	2.69	**0.29**	**-0.25**
Decreased water quality	2.87	3.05	**-0.76**	**-0.62**
Decreased fish and wildlife health	2.80	2.88	**-0.75**	**-0.60**
Long-term local economic growth	2.61	2.64	**0.74**	**0.41**
Decreased quality of outdoor recreation	2.65	2.74	**-0.73**	**-0.58**
Decreased air quality	2.62	2.81	**-0.72**	**-0.60**
Decreased local beauty	2.87	2.90	**-0.71**	**-0.62**
Decreased human / public health	2.47	2.62	**-0.71**	**-0.61**
Increased stress	2.65	2.67	**-0.68**	**-0.58**
Increased jobs for locals	2.91	2.63	**0.67**	**0.31**
Lowered property values	2.43	2.69	**-0.63**	**-0.42**
Decreased peace and quiet	3.03	3.04	**-0.59**	**-0.56**
Less tourism locally	2.32	2.11	**-0.56**	**-0.32**
Decreased road quality	3.10	3.11	**-0.55**	**-0.46**
Changes in community character	3.02	2.87	**-0.53**	**-0.49**
Landowner income from leases/royalties on gas	2.65	2.34	**0.49**	**0.46**
Increased energy independence	2.66	2.66	**0.48**	**0.32**
Increased crime	2.69	2.76	**-0.44**	**-0.39**
Short-term local economic growth	3.21	2.67	**0.39**	**0.39**
Lower taxes locally	2.07	2.64	**0.33**	*0.07*
Increased traffic	3.56	3.25	**-0.22**	**-0.33**
Increased industrialization	2.94	2.83	**-0.13**	**-0.20**
Increased rental housing prices	3.38	2.36	**0.12**	0.05

[b] Values in **bold** are significant at $p < 0.001$; values in *italics* are significant at $p < 0.05$. Impacts with Pearson correlations with absolute value higher than for 'decreased greenhouse gas (carbon) emissions' are written in black type; impacts with lower absolute value correlations are in grey type. Likelihood of effect occurring was measured on a 4-point scale (not at all likely, not very likely, likely, very likely); effect on quality of life if the impact did occur was measured on a 4-point scale (no effect at all, little effect, some effect, a large effect). Sample sizes for the correlations are between 974-1023 for the 24 'likelihood' correlations and between 929-989 for the 'effect on quality of life' correlations.

Preservation of agricultural land	2.55	2.84	**0.09**	**-0.41**

Table 2: Relationships between various impacts and support for UGD (US survey)[c]

Potential effect of UGD	**Associate effect with UGD? (%)**	**Correlation with support**	**R^2**
Lower greenhouse gas (carbon) emissions (N=939)	**36%**	**0.43**	**0.19**
Contamination of drinking water (N=1126)	**41%**	**-0.53**	**0.28**
Clean energy (N=1157)	**43%**	**0.47**	**0.22**
Energy security (N=1114)	**47%**	**0.47**	**0.22**
Earthquakes (N=1118)	**31%**	**-0.39**	**0.15**
Cheap energy (N=1204)	**55%**	**0.27**	**0.07**

Table 3: Linear regression of demographics on beliefs about UGD's effect on GCC (Marcellus Shale region survey)[i]

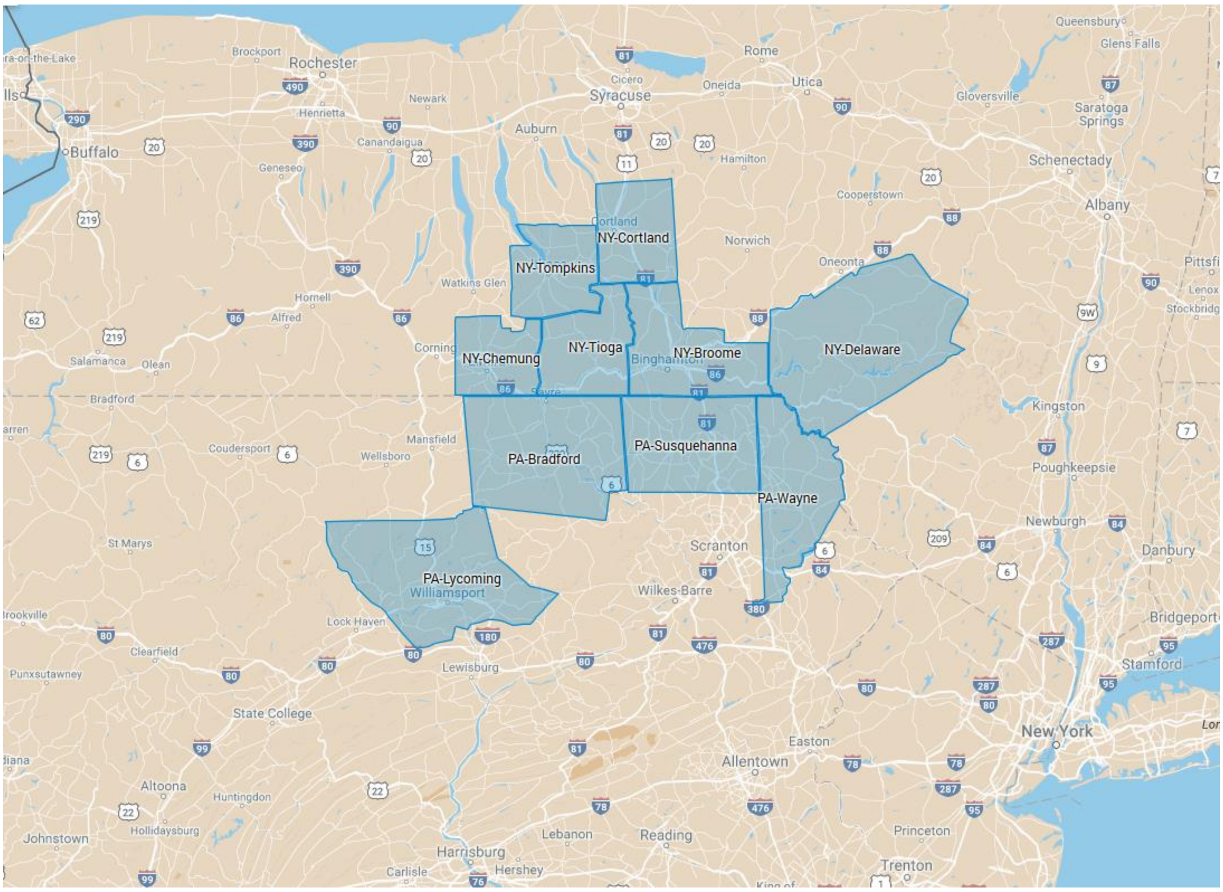
Independent variables	**ß[ii], likelihood (N=797)**	**Sig.**	**ß[b], effect on quality of life (N=766)**	**Sig.**
Sex (0 = female, 1 = male)	-0.04	.302	**-0.12**	**.001**
Age	0.02	.551	-0.04	.283
Education	**-0.09**	**.018**	**-0.08**	**.047**
Satisfaction with family's financial situation	0.04	.230	0.03	.503
Political views	**0.21**	**.000**	**-0.11**	**.004**
Urban (vs. rural)	0.06	.067	0.04	.296
Pennsylvania (vs. New York)	0.02	.613	0.00	.952
Have a gas lease on your property	0.06	.121	-0.02	.682

[c] Values in **bold** are significant at $p < 0.001$. Impacts with R^2 values higher than for 'lower greenhouse gas (carbon) emissions' are written in black type; impacts with lower R^2 values are in grey type. Sample size for all associations with UGD are 1625; sample sizes for the correlations are provided in the table.

Table 4: Binary logistic regression of demographics on beliefs about UGD's effect on GCC (US survey)[iii]

Independent variables	Odds ratio[iv] (N=915)	Sig.
Sex (0 = female, 1 = male)	1.19	.223
Age	1.00	.374
Education	0.88	.107
Annual family income	1.01	.581
Political views	**1.18**	**.000**

Figure 1: Extent of survey coverage in New York and Pennsylvania



The highlighted areas on the map represent the six counties in NY and four counties in Pennsylvania to which we mailed surveys. Two to six municipalities in each county were included in the survey.

Table S1: Relationships between various impacts and support for SGD (Marcellus survey)[d]

Potential effect of SGD	**'Likelihood of effect occurring' (mean)**	**Correlation of 'likelihood of effect' with support**	**Correlation of binary 'likelihood of effect' with support**
Decreased greenhouse gas (carbon) emissions	2.33	**0.29**	**0.24**
Decreased water quality	2.87	**-0.76**	**-0.65**
Decreased fish and wildlife health	2.80	**-0.75**	**-0.64**
Long-term local economic growth	2.61	**0.74**	**0.67**
Decreased quality of outdoor recreation	2.65	**-0.73**	**-0.62**
Decreased air quality	2.62	**-0.72**	**-0.64**
Decreased local beauty	2.87	**-0.71**	**-0.59**
Decreased human / public health	2.47	**-0.71**	**-0.65**
Increased stress	2.65	**-0.68**	**-0.60**
Increased jobs for locals	2.91	**0.67**	**0.57**
Lowered property values	2.43	**-0.63**	**-0.59**
Decreased peace and quiet	3.03	**-0.59**	**-0.46**
Less tourism locally	2.32	**-0.56**	**-0.53**
Decreased road quality	3.10	**-0.55**	**-0.44**
Changes in community character	3.02	**-0.53**	**-0.39**
Landowner income from leases/royalties on gas	2.65	**0.49**	**0.37**
Increased energy independence	2.66	**0.48**	**0.42**
Increased crime	2.69	**-0.44**	**-0.35**
Short-term local economic growth	3.21	**0.39**	**0.22**
Lower taxes locally	2.07	**0.33**	**0.28**
Increased traffic	3.56	**-0.22**	*-0.08*
Increased industrialization	2.94	**-0.13**	-0.06
Increased rental housing prices	3.38	**0.12**	**0.14**
Preservation of agricultural land	2.55	**0.09**	*0.09*

[d] Values in **bold** are significant at $p < 0.001$; values in *italics* are significant at $p < 0.05$. Impacts with Pearson correlations with absolute value higher than for 'decreased greenhouse gas (carbon) emissions' are written in black type; impacts with lower absolute value correlations are in grey type. Likelihood of effect occurring was measured on a 4-point scale (not at all likely, not very likely, likely, very likely). The binary 'likelihood of effect' variables were created by combining 'not at all likely' with 'not very likely' (coded 0) and then combining the other two response options (coded 1).

Table S2: Proportional weights for Marcellus Shale region survey data

NY (N = 637)

	Population %	Respondent %	Weight
Male, 18-44, less than bachelors	0.185	0.052	3.56
Male, 18-44, bachelors+	0.053	0.046	1.15
Male, 45+, less than bachelors	0.182	0.23	0.79
Male, 45+, bachelors+	0.068	0.203	0.33
Female, 18-44, less than bachelors	0.17	0.046	3.70
Female, 18-44, bachelors+	0.06	0.04	1.50
Female, 45+, less than bachelors	0.214	0.203	1.05
Female, 45+, bachelors+	0.068	0.179	0.38

PA (N = 565)

	Population %	Respondent %	Weight
Male, 18-44, less than bachelors	0.178	0.051	3.49
Male, 18-44, bachelors+	0.028	0.026	1.08
Male, 45+, less than bachelors	0.238	0.329	0.72
Male, 45+, bachelors+	0.051	0.172	0.30
Female, 18-44, less than bachelors	0.154	0.037	4.16
Female, 18-44, bachelors+	0.039	0.019	2.05
Female, 45+, less than bachelors	0.264	0.24	1.10
Female, 45+, bachelors+	0.048	0.125	0.38

[i] The first regression column includes perceived likelihood of UGD leading to decreased carbon emissions as the dependent variable; the second regression column includes perceived effect on quality of life if UGD were to decrease carbon emission as the dependent variable. The R^2 (i.e., effect size; amount of variance in the dependent variable explained by the set of independent variables) for the perceived likelihood model is 0.07; for the second model it is 0.03.

[ii] All beta coefficients are standardised. All beta coefficients significant at $p < 0.05$ are in **bold**.

[iii] The dependent variable is whether respondents associate decreased carbon emission with UGD or not (0 = do NOT associate, 1 = do associate). The R^2 (i.e., effect size; amount of variance in the dependent variable explained by the set of independent variables) is 0.03.

[iv] All odds ratios significant at $p < 0.05$ are in **bold**.