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A systematic quantitative review of the perceived environmental and natural resource-related impacts of unconventional oil and gas development

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1. Introduction

Over the past 15 years, an expansive social science literature has accrued on a variety of issues associated with unconventional oil and gas development (UOGD).¹ Embedded within this extensive body of research is a strand of empirical social scientific studies dealing specifically with the perceived and objective local impacts of UOGD reported and encountered by people who live in or near places hosting upstream UOGD (Jacquet et al., 2021; Walsh et al., 2020). Local impacts, which “can be experienced as a risk, a benefit, or a combination of both” (Haggerty et al., 2018: 621), include effects pertaining to a wide range of economic, social, public health, and environmental/natural resource-related topics.

To date, several scoping and narrative-style review papers have summarized key social science findings pertaining to the various local impacts of UOGD (e.g., Deziel et al., 2020; Evensen, 2018; Haggerty et al., 2018; Jacquet et al., 2018; Luke et al., 2018; Measham et al., 2016; Theodori, 2018; Thomas et al., 2017). Perusal of these reviews revealed that authors have tended to emphasize the results from selected studies that have examined primarily the *social and economic impacts* of UOGD. Less scholarly attention has been given to summarizing the research findings published in social science journals from studies focused on the other types of impacts, particularly the perceived and/or observed environmental and natural resource-related impacts. In a recently published systematic review, Fernando, Ulrich-Schad, and Larson (2021) provided an in-depth evaluation of the research methods used by social scientists to gather data on issues related to UOGD. The authors highlighted various benefits and constraints of using qualitative, quantitative, or mixed methods approaches to data collection. They then argued for an increased use of longitudinal research designs in social scientific studies on UOGD.

¹ In this paper, the term unconventional oil and gas development (UOGD) refers to the production of oil and/or natural gas from unconventional reservoirs (e.g., shales, tight sands, coal seams).

In this article, adhering closely to the methods proposed by Pickering and Byrne (2014) to undertake a systematic quantitative assessment of the literature, we provide a targeted, systematic quantitative review of a robust sample of the international peer-reviewed human-subjects literature in which social science researchers incorporated environmental and natural resource-related variables into their scholarship on the local impacts of UOGD. We first explain the procedures we employed to select our literature sample. Next, we describe the locations and timing of these studies. We then detail the researchers' methods of data collection and the number and types of stakeholders upon which data were gathered. Following that, we summarize the perceived environmental and natural resource-related impacts of UOGD as expressed by the stakeholders or measured by the researchers. We conclude by offering a few comments on the current state of knowledge in the social science literature surrounding the perceived environmental and natural resource-related impacts of UOGD. We also draw comparisons between our findings and the potential risks and benefits highlighted in the environmental science scholarship.

2. Methods

The literature upon which we drew to conduct our targeted, systematic review consisted solely of original social science research articles published in peer-reviewed academic journals.² Our search for relevant journal articles began with the Web of Science Social Sciences Citation Index (SSCI). Building upon the four environmental and natural resource-related topic areas covered in the 2017 state of research and knowledge summary report on shale development in Texas

² Our decision to include only social science journal articles ensured that they were original, peer-reviewed research papers (cf. Pickering and Bryne, 2014). Book chapters, conference proceedings, theses and dissertations, reports that relied on analyses of secondary data, and grey literature publications—while often useful and informative—were not included this review.

(TAMEST, 2017), we searched the Web of Science SSCI in early July 2021 for UOGD literature pertaining to “water,” “air,” “induced seismicity,” and “land.” For each environmental/natural resource topic, Boolean expressions were used to conduct searches with the following terms: shale gas; unconventional gas; natural gas; shale oil; oil shale; tight oil; unconventional oil; hydraulic fracturing; fracking; coalbed methane; and coal seam gas. These terms capture the sources of UOGD and the industrial well stimulation/completion process associated with UOGD, as well as the framings of UOGD across geographies globally. Searches were limited to peer-reviewed journal articles written in English that were published between January 1, 2000, and June 30, 2021.³ Results of the searches produced the following number of journal articles for each of the key topic areas: water = 547; air = 479; induced seismicity = 23; and land = 241.

The full records for the results of each search were exported to an Excel file. We employed an iterative process to determine which papers would be selected for inclusion in our sample. First, each paper’s abstract was read to determine whether human-subjects data were used in the study. Criteria for human-subjects data eligibility included data collected through the use of qualitative data collection methods (i.e., interviews, focus groups, facilitated group discussions, and/or participant observations) and/or survey questionnaire research techniques. Papers that did not use human-subjects data were discarded. Those papers that employed human-subjects data were read in their entirety. Articles in which the author(s) examined one or more perceived environmental or natural resource-related risk and/or benefit were deemed eligible for inclusion in the sample. Specifically, for a paper to be included in our sample, the author(s) had to: (1) explicate the perceived environmental or natural resource-related impact(s) identified by stakeholders during their qualitative data collection efforts, or (2) measure one or more perceived

³ We replicated the start date of January 1, 2000, used by Walsh et al. (2020) in their systematic review of research on unconventional oil and gas development in the United States.

environmental or natural resource-related impacts in their survey questionnaire. With respect to the latter, the item(s) used to assess the perceived impact(s) may have been utilized either as an independent or dependent variable, or the item(s) may have been included in some type of attitudinal scale.

In August of 2021, we replicated our initial search process using three additional databases—Agricola, SocINDEX, and Social Sciences Full Text. Search results produced the following number of journal articles for each of the key topic areas (minus the duplicates across the three databases): water = 286; air = 162; induced seismicity = 4; land = 130. Many of the papers uncovered while searching these three additional databases were found in the previous searches using SSI. The same iterative process was used to determine whether or not each article met the eligibility criteria for inclusion in our sample.

As per the criteria stated above, a total of 60 papers were selected upon completion of the literature searches within the four databases. In mid-September 2021, we conducted an additional search of the literature using the same four databases to check for pertinent papers we may have missed or overlooked. We paired the word “risk” with each of the aforementioned search terms (i.e., shale gas; unconventional gas; natural gas; shale oil; etc.). Together, the results of this search yielded a total of 780 papers. Using the same iterative reduction process, we reduced the number of eligible papers to 36. Those 36 papers were combined with the other 60 papers to produce a sample of 96 peer-reviewed journal articles.⁴

3. Analyses

3.1. Sample of papers and number of unique studies contained therein

⁴ The complete list of 96 papers can be found in the Appendix.

Our sample of 96 papers included data collected in 84 unique studies.⁵ For purposes of presentation in this article, a unique study refers to the full suite of data collection efforts used by an investigator or team of investigators within a particular spatiotemporal research project.⁶ These 96 papers were published in 50 different journals. Slightly more than one-third of these papers were published in four journals—*Energy Research & Social Science* (17 papers); *The Extractive Industries and Society* (6 papers); *Journal of Rural Social Sciences/Southern Rural Sociology* (6 papers); and *Rural Sociology* (5 papers).⁷

3.2. Locations and timing of studies

Human-subjects data collection on the perceived local impacts of modern, large-scale UOGD commenced in 2006 with studies designed to examine elected officials' and local residents' attitudes and behaviors toward the rapid energy development occurring in the Barnett Shale region of north-central Texas (Anderson, 2007; Theodori, 2007a, 2007b). Roughly three years after those original investigations, human-subjects data collection events occurred in three unique studies within two states in the Marcellus Shale region—New York and Pennsylvania. Shortly thereafter, as UOGD activities began and substantially increased in additional U.S. states—or, concomitantly, as the talk of potential development amplified in various other geographic locations—so too began a flurry of human-subjects research activities across the U.S. and then around the globe.

⁵ Critical appraisal of the quality of the studies—which varied considerably—did not occur.

⁶ In our sample of papers, some researchers published more than one paper using the same data or a subset of the data collected in a unique study. Given the different foci of the authors' inquiries, all papers were analyzed independently.

⁷ The *Journal of Rural Social Sciences*, the official publication of the Southern Rural Sociological Association, was known as *Southern Rural Sociology* prior to 2010. Two of the six papers were published in 2009 prior to the name change.

Information on the locations and timing of the 84 studies in our database of 96 papers is shown in Table 1. Within the studies, data collection efforts on the perceived environmental and natural resource-related risks and/or benefits of UOGD occurred in ten countries between 2006 and 2018. These countries (listed in alphabetical order) included: Australia, Canada, China, the Netherlands, Poland, South Africa, Spain, Switzerland, the United Kingdom, and the United States of America. As reflected in our sample of papers, the country that hosted the largest number of studies focused on the perceived local impacts of UOGD was the United States of America. Data were collected on U.S. human subjects in 55 unique research projects (54 projects located solely within the U.S. plus the one study conducted within both the U.S. and the UK). Australia, with data collection efforts on its citizens in 11 studies, ranked second, followed by the United Kingdom (7 studies), and then by China (4 studies) and Canada (3 studies). Poland, South Africa, Spain, Switzerland, and the Netherlands hosted one study each.

[Table 1 about here]

Within the U.S., eight studies analyzed data from nationwide samples and 47 studies used data drawn from samples in 19 different states (see Table 2). As with the larger body of scholarship on the impacts of UOGD (Walsh et al., 2020), research studies that have gathered and assessed data on perceived environmental and natural resource-related issues have been disproportionately concentrated in a few locations across the U.S. Of the 19 states in which researchers collected data, the four states that overlay the Marcellus and Utica Shale formations—New York, Ohio, Pennsylvania, and West Virginia—were represented in roughly 72% of the studies (34 of 47 studies). Within those four states, data collection efforts in

Pennsylvania occurred just over four times more than in New York or Ohio and seven times more than in West Virginia.

[Table 2 about here]

3.3. Methods of data collection and the number and types of human subjects

A variety of qualitative and survey questionnaire research methods were employed to collect the human-subjects data on perceived impacts of UOGD in the 84 unique studies represented in our sample. In 44 studies, qualitative methods were used to collect data from approximately 1,822 human subjects (1,178 U.S. human subjects; 644 non-U.S. human subjects).⁸ Findings from the analyses of the qualitative data collected in these 44 studies were published in 48 papers.

Twenty-eight papers (using data from 26 studies) reported results of human-subjects research conducted in the U.S., 16 papers (using data from 15 studies) disseminated research findings from non-U.S. stakeholders, and 4 papers (using data from 3 studies) presented the results obtained from combined samples of U.S. and non-U.S. human subjects.

Interviews were the most common qualitative method of data collection used in the studies (35 studies). Interviews were conducted in person or using a combination of in-person and telephone or online communication platform techniques. In 15 studies, the researchers did not specify the interview style. The use of focus groups (8 studies) was the second most common qualitative data collection method, followed by the implementation of deliberative and inclusionary processes (4 studies). Among the different deliberative and inclusionary processes

⁸ Not all researchers reported the exact number of human-subject participants in their studies. In those studies, the total number of human subjects counted is based upon the most conservative estimate using the information provided by the authors. We also recognize that the possibility exists that some human subjects may have contributed to multiple qualitative data collection efforts, thus inflating the approximate total number.

that were used, facilitated discussion circles/groups were employed in two studies, a deliberative focus group methodology was utilized in one study, and day-long deliberative workshops were held in one study. Data collection using some form of fieldwork (e.g., ethnography or participant observation) was mentioned in nine of these studies.

Although members of single-stakeholder groups were targeted in a few investigations, researchers in most of these studies gathered data on perceived impacts of UOGD from people across multiple stakeholder groups. Our assessment of the human subjects from which qualitative data on perceived impacts of UOGD were collected produced a list of 37 stakeholder types.⁹ The ten most-frequently targeted groups included: community residents¹⁰ (17 studies); local or community leaders/officials (17 studies); farmers/ranchers (13 studies); landowners/property owners (11 studies); business owners/operators (11 studies); industry personnel (10 studies); university faculty/researchers/scientists (9 studies); public school educators/administrators (7 studies); economic development agents (7 studies); and NGO employees/representatives (7 studies).

Data collected on 42,859 human subjects (23,635 U.S. individuals; 19,224 non-U.S. individuals) via survey questionnaire research methods in 47 studies were analyzed by researchers and reported in 54 papers.¹¹ In roughly two-thirds of those papers (n = 35), the authors used survey data collected from human subjects in the U.S. In 18 papers, the authors reported on survey data gathered from individuals in countries other than the U.S. And, in one

⁹ The complete list of stakeholder types is available upon request from the first author.

¹⁰ Individuals without any specific identifying titles/characteristics were placed in this category.

¹¹ In seven studies, researchers used mixed methods to collect human-subjects data, employing both qualitative methods and survey research techniques. These seven studies were included in the total count for studies employing qualitative methods and for studies employing survey research techniques. Hence, the total number of studies appears to exceed 84. In total, 37 unique studies employed only qualitative methods, 40 unique studies employed only survey research techniques, and seven employed mixed methods. The number of human subjects upon which data were collected using qualitative methods and survey research techniques were distinguished in the mixed-methods studies.

paper, the authors combined the survey data collected as part of two previously conducted unique studies in two countries (one study in the U.S. and one study in the UK). The human subjects in the latter paper were not included in the aforementioned tally as they were already counted once in our sample. Online surveys represented the most common mode of survey questionnaire data collection (n = 22). Researchers used mail surveys to collect data in seven studies, telephone surveys in six studies, and in-person surveys in five studies. Mixed-mode surveys were used to collect data in six studies. The mixed modes included: mail and online (n = 4), telephone and online (n = 1), and mail, telephone, online, and in-person (n = 1).

Our appraisal of the survey respondents produced a list of nine distinct yet overlapping categories of human subjects who provided data on perceived environmental and natural resource-related impacts of UOGD. In just over half of the studies (25 of 47), researchers surveyed “general population residents.” In roughly one quarter of the studies (n = 12), samples were comprised of “opt-in online panel members.” The remaining seven categories of human subjects and the number of studies in which they were surveyed included: “non-expert interested and affected parties/stakeholders” (n = 3); “landowners/property owners” (n = 2); “city and county governmental officials/community leaders” (n = 2); “farmers/ranchers/agricultural operators/rural residents” (n = 2); “public school educators/administrators” (n = 1), “oil and gas industry personnel” (n = 1), and “experts (academia, governmental regulatory agencies, industry, and environmental NGOs)” (n = 1).¹²

¹² Members of single-stakeholder groups were surveyed in 45 of the 47 studies. Two separate stakeholder groups were surveyed in two studies. Hence, the tally for the number of studies in which the different categories of stakeholders were surveyed exceeds 47.

3.4. Perceived environmental and natural resource-related impacts of UOGD as expressed by respondents or measured by researchers¹³

3.4.1. Studies employing qualitative methods. Empirical analyses of the papers in which researchers analyzed human-subjects data collected via qualitative methods revealed that stakeholders in all 44 studies (results reported in 48 papers) expressed uneasiness about one or more possible environmental and natural resource-related impacts. In five studies (results published in five papers), when stakeholders mentioned potential negative environmental/natural resource-related impacts, those individuals downplayed the potential associated risks. For the stakeholders in these five studies, the perceived magnitude of such impacts was low compared to the potential economic and/or service-related benefits they anticipated would occur. Such findings were uncovered in one study conducted in Illinois and Kentucky and separate studies conducted in Kansas, Montana, Ohio, and South Dakota. For purposes of presentation, the findings presented in these five papers were not included in the summaries below.

Across the remaining 43 papers (data from 39 studies), potential risks pertaining to “water” were the most pronounced environmental or natural-resource related concerns. In fact, perceived risks associated with water were reported in 100% of the papers (23 papers/21 studies from U.S. samples; 16 papers/15 studies from non-U.S. samples; 4 papers/3 studies from combined U.S. and non-U.S. samples). Open coding processes of the water-related worries

¹³ The first and second authors independently coded the data within the 96 papers into five categories (i.e., water, air, induced seismicity, land, and/or general environmental issue). Upon completion of the initial coding process, the first author compared the coding results, reread papers with disparate codes, then determined final placement of each paper within one or more of the categories. Results of the interrater reliability for the studies employing qualitative methods: 69% (33 of 48 papers) agreement when water, air, induced seismicity, land, and/or general environmental concerns expressed by respondents were coded. Results of the interrater reliability for the studies employing survey research techniques: 78% (42 of 54 papers) agreement with water, air, induced seismicity, land, and/or general environmental impacts were measured by respondents.

resulted in three main categories of perceived risks: water quality (i.e., potential contamination of surface water and/or groundwater), water quantity (i.e., the amount of water used in UOGD), and wastewater disposal.

Potential risks associated with “land” were stated in 67.4% of the papers in which the authors conveyed the results of their qualitative analyses (29 of 43 papers, data from 27 studies). A wide array of land-related topics was uncovered when we coded the concerns expressed by the stakeholders. Included here were issues such as land use change, land degradation, land fragmentation, land/soil contamination, soil erosion, reduced access to forest lands, aesthetics/changes in appearance of natural landscapes, reclamation, and impacts to ecosystems, habitat, and wildlife. Within the U.S., potential risks related to land were reported in at least one study conducted in each of the following states: Colorado, Louisiana, Michigan, North Dakota, Ohio, Pennsylvania, Texas, and West Virginia. Stakeholders in the studies conducted in Australia, Canada, China, and the UK associated UOGD with potential land-related risks.

Perceived risks associated with “air” were raised in 65.1% of the papers that reported findings from qualitative data analyses (28 of 43 papers, data from 25 studies). Open coding techniques revealed stakeholders expressed concerns about general air pollution and air quality issues, as well as specific fears about the release/leakage of methane. Within the U.S., potential air-related risks were documented in at least one study conducted in each of the following states: Colorado, Louisiana, Michigan, Ohio, Pennsylvania, Texas, and West Virginia. Stakeholders in studies conducted in Australia, China, and the UK also perceived that air-related risks accompany UOGD.

Perceived risks associated with “induced seismicity” were referenced in 32.6% of this battery of papers (14 of 43 papers, data from 10 studies). Concerns about potential earthquakes

and seismic activity were recorded in both papers (data from 2 unique studies) on Oklahomans. Potential seismic-related risks were detailed in the two papers from Louisiana (one unique study), in one paper from one study in Texas, in one paper from one study in Michigan, and in one paper from one study in Pennsylvania. Stakeholders in studies conducted in China and the UK also perceived seismic-related risks.

Concerns regarding all four environmental/natural resource-related topics were reported in nine papers (using data from three U.S.-based studies, three non-U.S.-based studies, and the U.S./UK study). General environmental/natural resource-related perceived concerns, as well as potential negative effects of UOGD on climate change, were expressed by respondents alongside the specific water-related, air-related, seismic-related, and/or land-related impacts in 19 papers (using data from 11 U.S.-based studies and six non-U.S.-based studies). Analyses revealed that perceived environmental and natural resource-related benefits of UOGD with potential public implications were reported by stakeholders in two papers. By replacing the use of coal with natural gas, participants in one study in Louisiana and in one in Pennsylvania asserted that CO₂ emissions could be decreased, thus helping reduce air pollution and combat climate change. In Louisiana, another perceived benefit was that the increase in UOGD had forced state regulatory agencies to address water conservation issues in the northern part of the state for the first time.

3.4.2. Studies employing survey research techniques. As noted, survey research methods were employed in 47 studies (results reported in 54 papers) to collect data on the perceived environmental and natural resource-related impacts of UOGD. Experimental designs were utilized in two of the studies (findings described in two papers). In one study in Switzerland, perceived impacts of induced seismicity from geothermal and shale gas developments were

assessed using different risk communication formats. In a survey experiment conducted in the U.S., potential risks associated with water, air, and induced seismicity were used to frame arguments for and/or against hydraulic fracturing.

Within the remaining 45 studies (results reported in 52 papers), an assortment of unstructured and structured questions/items were used to collect data on the perceived environmental and natural resource-related risks and/or benefits of UOGD. In nine papers (data from six U.S.-based studies, two studies conducted in Australia, and one study conducted in South Africa), written comments to one or more open-ended questions asking about perceived local impacts of UOGD or the written remarks proffered by survey respondents in an “additional comments” section on the questionnaire were thematically analyzed. Potential risks pertaining to “water” were reported in all nine papers. Perceived risks associated with “air” and “land” were each referenced in seven papers, whereas “seismicity” was perceived as a potential risk in four papers. A perceived environmental/natural resource-related benefit was expressed in only one of the nine papers. In that paper, the authors noted how respondents in the Powder River Basin of Wyoming emphasized the potential positive effects of the water produced during coalbed methane development—water that, when available, is often used for livestock consumption.

In 47 papers (data from 27 unique U.S.-based studies and 14 unique non-U.S.-based studies), researchers presented descriptive findings and/or used inferential statistics to analyze data on respondents’ perceived environmental and natural resource-related risks and/or benefits of UOGD obtained from one or more structured questions/items included in the survey questionnaires.¹⁴ These structured survey questions/items were assessed at the nominal or ordinal

¹⁴ This tally includes the two papers from Australia, the one paper from South Africa, and the one paper from the U.S. in which the authors analyzed responses to unstructured questions asking about perceived local impacts of UOGD.

level of measurement using categorical response options or Likert-type response scales (or similar types of response scales with unipolar or bipolar rank-ordered answer categories). In the papers, the structured survey questions/items measuring perceived environmental/natural resource-related impacts were assessed individually or combined into summated rating scales. The use of these measures—either individually or scaled—as dependent, independent, and/or control variables varied greatly.

Our assessment documented the use of structured survey questions/items measuring at least one perceived water-related, air-related, seismic-related, or land-related impact in 42 of the 47 papers. In the remaining five papers, authors used one or more “general” structured questions/items as the sole measure(s) of perceived environmental/natural resource-related impact(s) (e.g., “fracking will damage the local environment” or “the use of fracking to extract natural gas causes environmental damage”). Structured survey questions/items gauging potential water-related impacts were included in 39 of the 42 papers. In 22 papers each, authors assessed potential air-related and seismic-related impacts using structured questions/items. Structured survey questions/items measuring potential land-related impacts were included in 21 papers. Structured survey questions/items assessing general environmental/natural resource-related perceived impacts, as well as potential global warming and climate change impacts, were included alongside the specific water-related, air-related, seismic-related, and/or land-related impact measures in 24 papers.

4. Concluding comments

This targeted, systematic quantitative review of 96 published journal articles (using data drawn from 84 unique studies) complements previously-published review articles on the local impacts

of UOGD and augments the natural resource social science literature on the topic. In this paper, we delineated the *where* (i.e., geographic locations of studies), *when* (i.e., timing of studies), *who* (i.e., number and types of stakeholders in the studies) and *how* (i.e., methods used to collect data) specified in ~~the social science literature~~ these papers on the perceived environmental/natural resource-related impacts of UOGD. Additionally, we quantified the perceived water-, air-, seismic-, and land-related impacts of UOGD as *expressed* by stakeholders in the qualitative studies or as *measured* by researchers in the studies that employed survey research techniques. We did not, however, synthesize the substantively or statistically significant results reported in either the qualitative or survey research studies. We recognize that providing information on the substantive and statistical significance of the findings in this body of literature would allow for a deeper understanding of the perceived environmental and natural resource-related risks and benefits of UOGD; however, such an endeavor was simply beyond the scope of our review.

Overall, our review revealed that of the various perceived environmental and natural resource-related impacts of UOGD, potential water-related risks have been expressed most often by stakeholders in both the U.S.-based and non-U.S.-based qualitative studies. Moreover, potential water-related risks have been the most-assessed of any environmental and natural-resource related impact in the studies that employed survey research techniques. From the initial human-subjects work on contemporary shale development to the most recently-published literature, attempts by social scientists to understand and predict perceived water-related impacts of UOGD is one thread on continuity that pervades this extensive body of work. Although rare, potential environmental benefits associated with UOGD were perceived by stakeholders in the qualitative studies and measured by researchers in their survey questionnaires. Potential benefits—regardless if they emerged from stakeholders or were assessed by researchers—dealt

mostly with the perceived positive effects of increased development and use of natural gas (as opposed to other fossil fuels) on issues associated with climate change (e.g., perceived reductions in air pollution and CO₂ emissions). An increase in water availability for livestock consumption during coalbed methane development was perceived as a potential benefit in one specific qualitative study. Taken together, these findings pertaining to the perceived environmental and natural resource-related impacts of UOGD in the social science literature largely mirror those reported in the environmental science literature. Numerous environmental science review papers and meta-analyses have substantiated that concerns associated with water resources—both in terms of water quantity and quality—have been the most consistently-cited risks (e.g., Jackson et al., 2014; Small et al., 2014; Soeder, 2018; Vengosh et al., 2014). Acknowledged environmental benefits of UOGD have been largely limited to potential improvements in air quality, most notably reductions in air pollutants and CO₂ emissions anticipated to occur with the transition from coal to natural gas-fired power plants (Jackson et al., 2014; Small et al., 2014).

Our review further offered insights into how the methods that researchers employ to study the impacts of UOGD specifically, as well as the risks/benefits of energy developments more generally, can be diversified. This review revealed a preponderance of *either* qualitative or quantitative research designs. The implementation of mixed methods research designs—research designs that incorporate *both* qualitative and quantitative methods—in future energy-impacts studies could potentially strengthen the breadth of our knowledge of the perceived and/or objective environmental/natural resource-related risks and/or benefits of energy development (cf. Fernando et al., 2021). Additionally, our review revealed disparities in types of human subjects from which data on perceived environmental/natural resource-related impacts were collected, especially in studies employing survey research techniques with a heavy reliance on general

population samples. Future research that has a clear rationale for collecting data from more narrowly defined stakeholder groups could be particularly useful for suggesting policy recommendations.

Another future research agenda item offered as a result of our review is the need to examine more thoroughly the perceptions of non-U.S. human subjects. The geographic distribution of the studies included in our sample of papers revealed that the vast majority of articles were written using human-subjects data collected in the United States. The overwhelming majority of these data were collected in Pennsylvania and other states where UOGD was already occurring. Perhaps this seems natural, in that perceived environmental and natural resource-related impacts would be more salient in places experiencing UOGD. Perhaps also, fewer studies on the environmental/natural resource-related impacts of UOGD have occurred in countries other than the United States because much of the societal discourse in those countries—particularly countries in Europe—has been on whether or not to allow UOGD rather than on how to manage UOGD over the lifecycle of the industry. This raises additional questions around systematically assessing the relationship between timing and the types of concerns that are raised. Greater attention to longitudinal effects focusing on how perceived environmental risks of UOGD change over the lifecycle of the industry time is needed (cf. Fernando et al., 2021). Perceived impacts occur well before production commences; therefore, we believe it would be beneficial for researchers and policy makers alike to have a more robust understanding of the perceived local impacts of UOGD in countries where UOGD—or any form of energy development—has yet to transpire.

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