frontiers in Energy Research

REVIEW
published: 27 August 2018
doi: 10.3389/fenrg.2018.00083

The Impact of Information Provision on the Social Acceptance of Shale Gas Development: A Review-Based Inclusive Model

*Dilge G. Kânoğlu[1] and Uğur Soytaş[2]**

[1] Department of Earth System Science, Middle East Technical University, Ankara, Turkey, [2] Department of Business Administration, Middle East Technical University, Ankara, Turkey

Social acceptance is critical to the market penetration of new products and technologies as well as the successful implementation of policies, including those concerning energy demand. The hydraulic fracturing technique employed in the development of shale gas has been followed by controversy and this has resulted in the emergence of heterogeneity in attitudes toward the process. This review-based perspective surveys selected contributions of psychology to the literature on social acceptance. While not comprehensive, it aims to identify the factors that determine the acceptance of shale gas development. The proposed model for understanding acceptance encompasses the factors: perceived benefits, risks and costs, procedural and distributional fairness, trust, outcome efficacy, problem perception, knowledge and experience. The study then discusses adequate means of modulating distinguished responses to the same impulse and proposes information provision as an effective methodology. This has become a viable option because survey data and numerous opinion polls have underlined the deficiency of knowledge and the lack of a clear understanding of the risks associated with and benefits to be derived from shale gas development. Moreover, unlike experience, that is much more difficult to regulate, knowledge provides us with three channels namely the source, content and means of communication that allow for spatial divergences in policymaking.

Keywords: social acceptance, shale gas, trust, risk, information

OPEN ACCESS

Edited by:
Monjur Mourshed,
Cardiff University, United Kingdom

Reviewed by:
Meysam Qadrdan,
Cardiff University, United Kingdom
Luca Coscieme,
Trinity College, Dublin, Ireland

Correspondence:
Uğur Soytaş
soytas@metu.edu.tr

Specialty section:
This article was submitted to Energy Systems and Policy, a section of the journal Frontiers in Energy Research

Received: *31 January 2018*
Accepted: *02 August 2018*
Published: *27 August 2018*

Citation:
Kânoğlu DG and Soytaş U (2018) The Impact of Information Provision on the Social Acceptance of Shale Gas Development: A Review-Based Inclusive Model. Front. Energy Res. 6:83. doi: 10.3389/fenrg.2018.00083

INTRODUCTION

While technologies such as the use of climate-friendly alternatives to ozone-depleting hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs), and energy-efficient lighting have been embraced by society, others like nuclear power plants, wind turbines, and carbon capture and storage have encountered substantial amounts of resistance (Huijts et al., 2012). This resistance has stemmed from the prevalence of societal concern either due to the environmental, social or health impacts associated with the technology or from the impression that common resources could have been utilized in a different manner.

Recent advances in the precision and efficiency of the horizontal drilling and hydraulic fracturing techniques employed in the development of shale gas have resulted in the experience of an energy renaissance in the United States. Regions that have previously endured extended periods of economic decline have revitalized, energy security has been ensured at the national level, and a transition toward less carbon-intensive electricity generation has taken place (Considine et al., 2010; Hultman et al., 2011; Small et al., 2014). These developments have been followed by controversy. Presently, more individuals oppose the expansion of shale gas development than support it (Funk and Rainie, 2015; O'Hara et al., 2016). Therefore, it is crucial for planners to provide incentives for research, and to adopt necessary measures to diminish, if not eliminate, the adverse impacts of shale gas development. This will ensure that social consensus is reached while extensive amounts of resources are made available.

It is social acceptance that provides us with a measure of the extent to which people are "willing and prepared to adopt the applications in their own contexts when presented with an opportunity" (Heiskanen et al., 2008). In scrutinizing the social acceptance of shale gas, one may refer to Pennsylvania, Illinois, and New York, which are three states that have adopted legislative measures regarding unconventional gas development in recent years. They are comparable socioeconomically and have substantial opportunity to achieve economic development. The act in Pennsylvania (2012) endorsed a confined system of disclosure of chemicals involved in the process, did not necessitate water testing prior to drilling and did not account for seismic events linked to drilling (Rabe, 2014). On the other hand, policymakers in Illinois favored a more flexible system that allowed public health authorities and family members to access chemical information, required that drilling commence following the completion of tests for water surrounding the site of drilling by an independent third party and safeguarded individuals from seismic events through expanding monitoring and mitigation requirements "when they (seismic events) are of sufficient intensity to result in a concern for public health and safety" (Rabe, 2014). New York has portrayed a more conservative approach toward shale gas development. The New York Department of Health advocated for a ban on hydraulic fracturing in March 2015, due to its potential to result in the emission of methane and volatile organic compounds to the air, its impact on water management, its potential public health threats, and of primary consideration, its impacts on communities that encompass noise and encumbered resources (Zucker, 2014). This ban was to prevail until scientific assessments provided sufficient background to determine the level of risk to public health and when the risks could be adequately managed (Zucker, 2014). This particular heterogeneity in new and expansive legislation emphasizes the significance of social acceptance in terms of the successful implementation of energy policy: even if a proposal is put forward, if society does not intend to support it, an advancement may be delayed, may have to be modulated or may not take place at all. Hence, it is of substance to follow how people form opinions on energy technologies, and to understand the underlying reasons of distinguished responses to the same impulse so that we identify adequate means of modulating these responses.

National and state-level opinion polls have offered valuable insight into the way people perceive shale gas development, but they have mainly concentrated on either the significance of sociodemographic factors (Boudet et al., 2014), on a limited set of factors that include the economic benefits or social or environmental risks singularly (Quinnipiac University, 2012b; Brasier et al., 2013; Ferrar et al., 2013), or on the balance of risks and benefits (Rabe and Borick, 2011; Quinnipiac University, 2012a,b; Schafft et al., 2013).

One study that is crucial to this review-based perspective is the University of Nottingham survey that has scrutinized the public's attitude toward shale gas development in the United Kingdom. The survey has traced changes in knowledge of shale gas, what the public perceived to be the environmental impacts of development, and the technology's acceptability since 2012 (O'Hara et al., 2013, 2014, 2015, 2016). One of the most important contributions of this survey has been to record how the responses evolved through numerous notable events that include the highly publicized Balcombe protests against a proposed test drilling by Cuadrilla for oil in August 2013, and the election of a majority conservative government in May 2015 (O'Hara et al., 2014, 2015, 2016).

The information gathered as part of this survey suggests that the media coverage of shale gas development has been increasing since 2011 (O'Hara et al., 2013), and that the increment in peoples' reception to information about shale gas development, particularly relating to its potential deleterious impact on drinking water, has been accompanied by a change in the way the technology is perceived. While concerns about the contamination of water supplies due to shale gas development had been declining prior to the Balcombe protests, the trend reversed between July 2013 and September 2015 (O'Hara et al., 2015). This change points to a probable relationship between information provision and attitude formation. Yet, to date very little work has explored the validity of this relationship in the context of shale gas development. Whitmarsh et al. (2015) studied this relationship by presenting participants with texts concentrating on economic or environmental factors, and for each factor the information was either framed in loss or gain terms (Kahneman and Tversky, 1979). However, as noted by the authors, there is considerable scope to analyze changes in acceptance by changing the media, source and framing of information related to shale gas. In line with this recommendation, building upon the sustainable energy technology acceptance framework of Huijts et al. (2012), this study presents a model suitable for the social acceptance of shale gas development. It specifies relationships among measurable and meaningful factors that explain the social acceptance of shale gas development. The proposed model for understanding acceptance encompasses the factors: perceived benefits, risks and costs, procedural and distributional fairness, trust, outcome efficacy, problem perception, knowledge and experience.

The main contribution of this study to the literature is to provide a framework that will allow stakeholders to evaluate the social acceptance of shale gas development in different countries, through time.

As research in the United Kingdom has shown (O'Hara et al., 2013, 2014, 2015, 2016), social acceptance is a continuous process. Once the concerns of the public are identified, projects or policies could be adjusted to account for the opinions and evaluations of the public. Therefore, the paper proceeds by presenting considerations regarding the amelioration of communication between professional actors and citizens. In this sense, the source and content of information, and the means of its provision are important aspects. This paper concentrates on the former two and accounts for the interaction between the technology, professional actors and features of the technology's application in order to understand how the provision of information may impact the social acceptance of shale gas.

The following steps are followed in the remainder of this review-based perspective. In section Method for Article Inclusion, we elaborate on the methods for article inclusion. In section Background, we provide background information about the development process of shale gas, and hence the risks and benefits associated with it. In section Motives that Impact Acceptance, we discuss the motives suggested by psychological theories, that impact attitude toward energy technologies. In section Perceived Context that Impacts Acceptance, we evaluate the impact of contextual factors in relation to shale gas development. Following this, in section Knowledge and Experience that Impacts Acceptance, we refer to the channels of knowledge and experience, that would impact many factors that explain acceptance, though most of them indirectly. This section is important in that it allows us to understand how the provision of information would translate into changes in acceptance, which is the aim of this research. Finally, we conclude by presenting a summary of the conceptual model that we proposed in line with a review of literature.

METHOD FOR ARTICLE INCLUSION

In our systematic review of the literature, we have utilized both the extensive library catalog of Middle East Technical University, and journal databases to search the concepts of "social acceptance," "public acceptance," and "shale gas." While the search for social, otherwise entitled public acceptance allowed us to identify the factors relevant for the conceptual model, the search for shale gas constituted the foundation for the indicators of the antecedents of acceptance. Moreover, following the determination of factors that would impact the acceptance of shale gas development, we did separate searches for the relationship between each factor and shale gas. For instance, for the risks and benefits sections we searched for "shale gas risks" and "shale gas benefits." While including articles about acceptance in this review, we chose the identification of unobserved, latent factors that impact acceptance as the selection criteria. On the other hand, while including articles about shale gas development in this research, we chose their referral to the latent factors as the selection criteria.

BACKGROUND

Shale Gas Development Basics

Natural gas has constituted an important component of the global energy mix and unconventional natural gas reserves, that include shale gas reservoirs, have recently been regarded as alternative natural gas sources (Kok and Merey, 2014). Shale gas reservoirs are defined as organic-rich and very fine grained sedimentary rocks (Kok and Merey, 2014). They consist of matrix and natural fracture systems. Shale gas then refers to natural gas stored in pore spaces of the shale matrix and natural fractures (Pashin et al., 2010). The characteristic that differentiates shale gas from conventional gas is that it does not naturally flow into a well. This is because it has extremely low permeability (Cipolla et al., 2010) and low porosity values (Sunjay and Kothari, 2011). Shale gas can be forced to flow by artificially incrementing its permeability through fracturing the system containing gas. This is accomplished by the technique hydraulic fracturing (Sovacool, 2014). The process serves to reactivate and reconnect natural fractures in shale, that are generally closed as a result of overburden pressure (Sunjay and Kothari, 2011).

To have a better understanding of the risks and benefits associated with shale gas development one may have a closer look at the process of producing natural gas in shale formations. The process begins with drilling. Drilling initially follows a vertical path, which may then be gradually curved so as to reach a 90° angle. Entitled horizontal drilling, this process enables access to the horizontal strata of the reservoir (Rotman, 2009). During the drilling stage a steel pipe is placed into the hole, and cement casing is utilized to keep the structure of the wellbore intact and to isolate it from contact with fresh water aquifers. Following this, the completion phase that allows the well to produce natural gas begins. Hydraulic fracturing occurs during this stage. Through pumping a mixture composed of water, proppant (generally sand), and chemicals along and across the drilled formation, subsequent fractures are propagated in the rock layer (Ground Water Protection Council (GWPC) and ALL Consulting, 2009). While the role of sand is to prevent fractures from closing, chemicals preserve the well and ameliorate its operation. The final stage production comes next. The top of the well is outfitted with a collection of valves and gas flow is connected to a distribution network. Once the well reaches its economic limit, all pipes are removed from it, it is filled with cement and abandoned (Maugeri, 2013).

Shale Gas Risks and Benefits

Shale gas development has been associated with a number of benefits. The most commonly cited benefit relates to economic development. This encompasses employment opportunities, infrastructure, revenues, and taxes shale gas development promises (Sovacool, 2014). House (2013) notes that production in Texas at the Barnett Shale created 100,000 jobs and generated annual output of $11.1 billion in 2011. Similar results were observed in Pennsylvania (Kargbo et al., 2010), and in the Marcellus Shale that goes across West Virginia and Pennsylvania (Scott, 2013). It is reasonable to envision that this impact will continue since an assessment of 48 basins around the world in 32 countries by the US Energy Information Administration (2011), suggests that the estimated recoverable shale gas potential is almost equivalent to conventional natural gas (US Energy Information Administration, 2011). This result was also confirmed by the business-information firm IHS, that postulated that the potential could amount to 42 trillion cubic meters, a value almost 65 times the current annual consumption of the United States (Engelder, 2011). The abundance of shale gas, combined with its 50–66% approximate lower production cost when compared to conventional gas development implies that continuing shale gas operations bears the potential of depressing global prices of natural gas and breaking longstanding monopolies through facilitating global competition (Deutch, 2011).

One of the most debated aspects of shale gas development has been the greenhouse gas emissions related to it and hence, its global warming potential. Several studies have estimated figures in this respect (Ground Water Protection Council (GWPC) and ALL Consulting, 2009; Burnham et al., 2011; Howarth et al., 2011b; Hultman et al., 2011; Jiang et al., 2011; Stephenson et al., 2011; Cathles et al., 2012; Weber and Clavin, 2012; Newell and Raimi, 2014; Small et al., 2014; Stamford and Azapagic, 2014). The most commonly disputed work is that of Howarth et al. (2011a) that concluded that the global warming potential of shale gas is higher than that of coal. To the contrary, other authors have claimed that shale gas has driven out the "dirtier" fuel, namely coal, from the electricity sector (Argetsinger, 2011; Logan et al., 2012; Jenner and Lamadrid, 2013). Moreover, future scenarios in Jacoby et al. (2012) that compared emissions from the sector with and without accelerated utilization of shale gas discerned that shale gas reduces the US national emissions 17% when compared to the business as usual scenario. For a detailed criticism of Howarth et al. (2011b), and a discussion of the impacts of shale gas development on climate change readers are directed to Ground Water Protection Council (GWPC) and ALL Consulting (2009), Burnham et al. (2011), Hultman et al. (2011), Cathles et al. (2012), and Weber and Clavin (2012). What is of consequence here is that the suggested impacts vary significantly depending upon assumptions of authors. When the impact of supply increase on energy consumption and fuel substitution is accounted for, the figures change (Shoemaker and Schrag, 2013). When the impacts are analyzed for different end uses such as heating and electricity (Hultman et al., 2011; Newell and Raimi, 2014) the results change again. Therefore, more comprehensive studies should be conducted in relation to this matter.

There are also a number of concerns raised about shale gas development. The first concern relates to leakage and accidents. As the production process of shale gas consists of numerous steps, malfunctions are difficult to detect. This results in instances of natural gas escaping into the atmosphere as reported in the Uinta Basin in Utah (Maffly, 2013), in the Denver-Julesburg Basin (Tollefson, 2012), and in the Barnett Shale region (Logan et al., 2012). Another important study related to such events is that of Holzman (2011), where he notes that 50% of the inspected novel natural gas wells in Quebec leaked methane. Water availability and quality are notable concerns, too (Small et al., 2014). As clarified in the previous section, shale gas operations are substantially water intensive. That is to say, in an environment where "the groundwater resources and ecosystems are under threat" (Gleeson et al., 2012), proper water treatment and disposal measures should be taken. The hydraulic fracturing technique employed in the development of shale gas can also contribute to seismic events. Still, one should note that these are of the scale of insignificant disturbances, rather than disastrous instances (Sovacool, 2014). Nevertheless, other factors such as the deep well injection of wastewater have been shown to have caused earthquakes (Kerr, 2012; Kim, 2013). Kerr (2012) states that the injection of wastewater from shale gas development under the Dallas/Fort Worth International Airport generated more than 180 earthquakes between 2008 and 2009, each ranging up to the magnitude 3.3 on the Richter scale. The causality was evident as the earthquakes stopped once injections were ceased. Similar observations have been made in the Guy-Greenbrier region, as well (Kerr, 2012).

Researchers often underline the potential of shale gas to displace cleaner forms of energy, including renewable energy sources (Jacoby et al., 2012). Logan et al. (2012) suggest that the drop in natural gas prices achieved through shale gas development has been followed by the resurgence of the hunt for oil liberated through the improved technology of hydraulic fracturing. Howarth et al. (2011b) support this standpoint by claiming that: "shale gas competes for investment with green energy technologies, slowing their development and distracting politicians and the public from developing a long-term sustainable energy policy." Furthermore, the profitability of shale gas production is also questionable. This is a result of a combination of factors: the hardship of measuring reserves, low profit margins of current fields, the economic impacts on traditional natural gas producers, and the cost of externalities (Sovacool, 2014). In terms of low depletion and recovery rates, it is important to note that while conventional wells can maintain production at an increasing rate up to 40 years (Jacoby et al., 2012), the output of shale gas drops 80–95% within the first 3 years (Hughes, 2013). In terms of impacts on traditional natural gas producers, the repercussions in the liquefied natural gas (LNG) market are already observable. Wright (2012) states that increased shale gas production has resulted in the stagnation or decline of traditional LNG production in all but 3 major countries, namely Australia, Nigeria and Russia.

MOTIVES THAT IMPACT ACCEPTANCE

Lindenberg and Steg (2007), categorize three motives or goals in terms of the channel of their impact on behavior: gain, normative, and hedonic goals.

Gain Motives and Acceptance

The theory of planned behavior (Ajzen, 1991) suggests that the intention to exert a particular behavior is based on attitudes, subjective norms and perceived behavioral control. While attitudes correspond to the degree of agreeableness of the behavior in question, subjective norms correspond to the social hardship or ease to perform the behavior, and perceived behavioral control to the facility to perform the behavior (Ajzen, 1991).

In this study, we are not exploring acceptance in the context of numerous actions, but only in expressing an opinion on shale gas development through answering a questionnaire. Concentrating on the single deed of answering a questionnaire anonymously ensures that there is no difficulty in performing the behavior. Similarly, there is no social pressure that urges individuals not to perform the behavior. Finally, in terms of the degree of agreeableness of the action, in line with Tokushige et al. (2007a), we suggest capturing this through the inclusion of an indicator for "deployment promotion" among the indicators of acceptance. This indicator will measure the degree of active promotion of the technology the respondent finds suitable. Overall, none of the identified variables, namely attitudes, subjective norms or perceived behavioral control remain in our model.

While we remove these three factors from our model we account for outcomes that influence attitudes. These outcomes can be divided into benefits, risks and costs (see **Figure 1**). When gain goal is focal, individuals weigh the values of these outcomes and select alternatives that provide them with the maximum gain, or the minimum risks or costs. Regardless of the type of the energy technology, the variance in the levels of opposition or support both at the individual and social level, can mainly be attributed to two factors: perceived risks and benefits (Lesbirel and Shaw, 2005; Tokushige et al., 2007b; Pidgeon and Demski, 2012; Visschers and Siegrist, 2013).

For shale gas development, costs could include monetary costs to the society such as subsidies required to guarantee the cost-effectiveness of investments or non-monetary costs such as the exertion to apprehend the technology. Risks could include rapid industrialization, community conflict, social-psychological stress, and disruption (Jacquet, 2014), surface and groundwater contamination, deterioration of air quality and induced seismic events (Small et al., 2014). Benefits of the technology could relate to collective benefits such as the reduction of natural gas prices, contribution to economic growth, the diminution of the energy intensity, and the solution of energy security problems (Sovacool, 2014). One should however state that only perceived and salient benefits, risks and costs, that materialize through intuitive judgments would influence attitudes toward shale gas development at a specific moment (Slovic et al., 1985; Ajzen, 1991).

Normative Motives and Acceptance

When normative goals are central to decision making, individuals base their choices on their moral evaluations, that is, on the extent they feel they are morally obliged to act in a peculiar manner or refrain from doing so (Schwartz and Howard, 1981). Labeled as personal norms, these moral evaluations are stimulated when individuals sense that there will be ramifications to their not behaving in the socially desired way, and when they acknowledge their ability to contribute to the mitigation of problems. In our analysis, we are only concentrating on the action of clarifying a stance toward shale gas development through responding to an anonymous questionnaire. In line with this reasoning, personal norms will not be present as a factor in our model, but in cases where differential actions should be accounted for, readers may refer to Huijts et al. (2012).

While we have excluded personal norms from our model, we account for its antecedents. In the context of energy technology acceptance personal norms are influenced by perceived benefits, risks and costs, outcome efficacy and problem perception (Schwartz, 1977; Schwartz and Howard, 1981), see **Figure 1**. Since we have clarified the impact of perceived benefits, risks and costs in the gain motives section, we will elaborate on the remaining factors here.

Related to the social acceptance of shale gas development, awareness of adverse consequences of human interference with the environment could be influential. This concept referred to as problem perception encompasses climate change, pollution, loss of biodiversity, and resource depletion (Huijts et al., 2007; Tokushige et al., 2007a). The impact of problem perception could be through the following mechanism: the more one thinks we should actively prevent global warming, the more he or she might favor a technology that reduces CO_2 emissions (Tokushige et al., 2007a).

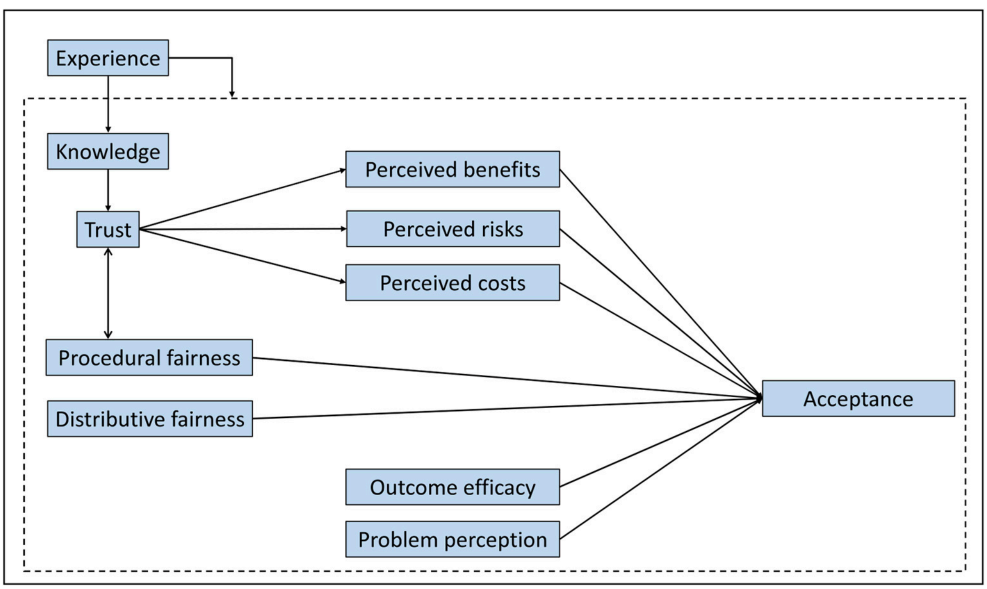

FIGURE 1 | An illustrative representation of the model for the social acceptance of shale gas development.

Outcome efficacy represents the degree of assistance one can provide in effectively solving problems (Steg and Groot, 2010). Two aspects of outcome efficacy are of consequence in the technology acceptance framework. The first one pertains to the potency of the technology to resolve perceived problems. The other one is related to the extent to which one believes that his or her attitude would impact the application of the technology. As to the former, Engelder (2011) asserts that shale gas development has a cleaner environmental footprint when compared to coal, so it may be viewed as an effective way of contributing to the mitigation of the impacts of climate change. As to the latter, in communities such as New York where social agreement upon the dominance of risks of shale gas development over its benefits could possibly result in a ban of the technology, individuals may exert behavior in favor or against a technology much easily. If this action is one against the technology, an advancement may be delayed, may incur higher costs, or not take place at all (Hisschemöller and Midden, 1999).

Hedonic Motives and Acceptance

When hedonic goals are central to decision making, feelings govern behavior (Lindenberg and Steg, 2007). Theories on affect concentrate on the role of anticipated feelings associated with a technology (Midden and Huijts, 2009), or on feelings that result from the aftermath of decisions (Loewenstein and Lerner, 2003) in explaining goals that influence attitudes toward energy technologies. Peters and Slovic (1996), and Montijn-Dorgelo and Midden (2008) showed that positive affect that encompasses feelings like pride, happiness, satisfaction and negative affect that blankets fear, worries, anger are independent and significant factors in predicting the acceptance of energy technologies. Additionally, Lavine et al. (1998) argued that the direction of cognitions and affect were crucial in determining the impact on acceptance. As explained in Huijts et al. (2012) they elaborated on the matter by claiming that "when cognitions and affect point in the same direction (e.g., are both positive or both negative), they equally contribute to attitude, but when they contradict, then feelings tend to dominate over cognitions in the formation of attitudes." However, we propose considering affect in relation with other factors in our model such as risks and benefits, experience, knowledge, and trust in relevant actors associated with the development of energy technologies. This is because in the context of shale gas development these feelings are intertwined with environment or health concerns and with perceived economic benefits. For example, the negative affect of apprehension linked to the prevalence of natural gas in taps (Fox, 2010) could be accounted for through the inclusion of an indicator for safety concern within the perceived risk factor in our model. Moreover, it is probable that this worry be a consequence of a lack of knowledge about the technology, a lack of trust in the people responsible of development, experience of the technology due to proximity to the source, or all enlisted. Thus, our approach of integrating affective imagery with risk and benefit perception will serve useful in capturing these relationships altogether.

PERCEIVED CONTEXT THAT IMPACTS ACCEPTANCE

Trust and Acceptance

Trust can be defined as the extent to acknowledge susceptibleness on one's part, that is founded upon a positive anticipation of the intention or behavior of the another (Rousseau et al., 1998). This susceptibleness has been identified as a factor that impacts acceptance directly in two studies (Siegrist et al., 2007; Terwel et al., 2009), indirectly through the channel of perceived benefits, risks and costs in five (Siegrist et al., 2007; Tokushige et al., 2007a; Montijn-Dorgelo and Midden, 2008; Midden and Huijts, 2009; Bronfman et al., 2012) and both directly and indirectly in one study (Soland et al., 2013). Following the most frequently modeled relationships, we link trust and acceptance through perceived benefits, risks and costs (see **Figure 1**).

Relying on government organizations, the industry, environmental organizations, scientists and the ideas that they convey to us through media could be perceived as a substitute to acting upon full knowledge (Luhmann, 1979; Siegrist, 1999; Siegrist and Cvetkovich, 2000; **Figure 1**). Since it is challenging for individuals to select, comprehend and evaluate all information available to them, and they may not have the experience that would allow them to form an objective standpoint, trust provides a foundation for one's opinion (Siegrist, 1999; Siegrist and Cvetkovich, 2000; Midden and Huijts, 2009). When trust is excessive, people may tolerate uncertainties or insufficiency of information, and be more overt to accept novel technologies. Contrarily, a lack of trust in actors implementing or regulating projects, may create prejudice and diminish cooperation (Huijts et al., 2012).

The substance of trust brings into question how trust in professional actors is cultivated. Some authors have concentrated on two key factors, the perceived intentions and competence of professional actors (Johnson, 1999; Metlay, 1999; Huijts et al., 2007), and have suggested that the belief that the actor is concerned about and capable of safeguarding the interests of the citizens and the environment increments the individual's willingness to conform. In addition to these aspects, numerous characteristics have been suggested in relation to trust. These include the reliability, predictability, transparency, ability to act without private or political pressures and obligations, tendency to disclose information about alternatives to the technology (Frewer et al., 1996; Peters et al., 1997; Tokushige et al., 2007a; Musall and Kuik, 2011). The factor trust in our model accounts for all listed aspects.

The implementation of an energy technology is generally a multi-actor process. Therefore, while trying to formulate a model for the social acceptance of shale gas development it is crucial that we clarify whether trust should be considered as a composition of trust in the participating actors, or as separate entities with respect to the specific roles of each actor in the process. Huijts et al. (2007) adhered to the latter approach and found that trust in actors who are responsible for the planning and implementation of carbon capture and storage (the government and the industry) resulted in more positive and less negative affects. This in turn altered the perception of risks and benefits toward the energy technology such that acceptance increased (Huijts et al., 2007). On the other hand, if actors other than those in charge of the technology [namely non-governmental organizations (NGOs)] were trusted, their negative stance against the technology decreased acceptance (Huijts et al., 2007). In this sense, trust becomes important in evaluating which source of information has more considerable impact on shale gas acceptance.

In our model for shale gas development we utilize a similar approach to Huijts et al. (2007) and treat trust in each actor independently since the roles of each actor is distinct in the process, as well. In terms of concern for safety for example, while trust in the industry is related to the intention and capability to take necessary precautions to limit associated risks, trust in the government is linked to the propensity to interfere when a problem arises during shale gas development.

Fairness and Acceptance

Neoclassical economics assumes that choices are founded on monetary gains and consumption (Pesendorfer, 2006), but experimental games have delineated the opposite, and have underlined the significance of fairness in decision-making. Kahneman et al. (1986) for example, showed that the perception of fairness of a firm's short-run price decisions impacted consumer behavior and thus precluded firms from exerting full monopoly power.

Attitudes toward energy technologies are similarly impacted by the perceived fairness of the distribution of benefits, risks and costs: distributive fairness, and the fairness in contribution to the decision process that results in the actualization of the technology: procedural fairness (Bernheim and Rangel, 2007; Gross, 2007; Wolsink, 2007). This relationship is depicted in **Figure 1**.

Fairness of procedures is related to the consideration of opinions. When individuals from different groups all feel that their opinions are sufficiently regarded in the planning and implementation of projects, procedures are considered to be fairer (Lind and Van den Bos, 2002). In the framework of environmental risk management, Earle and Siegrist (2008) suggest that fairness can instill a sense of trust when it is the primary consideration or when there is an absence of information relating to trust. They further elaborate on the matter by stating that the relationship is generally the exact opposite, trust leads to perceived fairness (Earle and Siegrist, 2008).

In terms of distributive fairness, research has shown that "fairness based on collective outcomes," that is to say fairness relating to the distribution of benefits and drawbacks between groups, is the predominant antecedent of acceptance of travel demand management strategies (Schuitema et al., 2011). In the context of shale gas development, the distribution of economic benefits has not been as broad as promised. Hardy and Kelsey (2015) found that while activity in the Marcellus Shale resulted in an increase in the lease and royalty income of Pennsylvania residents, the revenue distribution was concentrated among a miniscule section of the population.

KNOWLEDGE AND EXPERIENCE THAT IMPACTS ACCEPTANCE

Knowledge and Acceptance

De Best-Waldhober and Daamen (2006) claim that reaching a reasoned judgment requires a sufficient amount of knowledge. The main issue regarding knowledge is that its exigency encourages people to base their intention to accept on intuitive feelings. This underlines the importance of the subjective component of knowledge, as noted by House et al. (2005). Thus, we concentrate on self-rated knowledge in the following sections.

A survey conducted to analyze Americans' indicated familiarity with and perceptions of hydraulic fracturing concluded that among the sample of 1061 respondents "13% did not know how much they had heard about the technology; 39% had heard nothing at all; 16% heard a little; 22% heard some; and 9% heard a lot" (Boudet et al., 2014). Although there was a total of 47% that possessed some amount of knowledge about shale gas development, only few of them could specify its impacts on water quality (7%); economic or energy supply that encompass "job creation" and "cheap energy" (3%); and social impacts that include "effects on property and people" (1%) (Boudet et al., 2014).

The lack of familiarity with shale gas development raises the question whether we can develop awareness and modulate attitudes toward this energy technology. The first issue to account for in this sense is the credibility of the source of information. Craig and McCann (1978) showed that when the letterheads of distributed letters that provided advice on energy conservation changed while the content remained the same, the letter from the local energy commission had a higher impact on behavior when compared to the letter from the local utility. We will not elaborate more on the substance of this change in this part of the paper as it has been discussed in detail in the trust section.

The second characteristic of information that is significant in explaining differences in social acceptance is its content. How the type of information impacts social acceptance was discussed by Tokushige et al. (2007a). A survey conducted among 423 Japanese university students on the perception of geological storage of carbon dioxide revealed that information concerning the scientific process did not necessarily influence attitudes. On the other hand, information on natural analogs incremented the level of public acceptance through diminishing the perceived risks. Similarly, on field demonstrations increased public acceptance through enhancing visions of human interference with the environment in the process of implementation (Tokushige et al., 2007a). This is also an important consideration for shale gas development. Individuals may not be susceptible to change their attitude toward shale gas development through the provision of scientific information. If that is the case, going on about the level of isolation that the casing of the drilled hole provides will be counterproductive. Hence, understanding which content would modulate acceptance should be an imperative consideration for policymakers.

An important note here is that the studies mentioned above concentrate only on the impact of a single change regarding information, ceteris paribus. However, it is often too difficult to differentiate the source and the content since each actor has a different approach toward the technology in question and presents this attitude in the information they disseminate through diverse means of communication. In line with this reasoning, Huijts et al. (2007) chose to interview members of the government, industry and environmental NGOs to discern their approach toward carbon capture and storage. The results of surveys conducted before and after individuals were provided with realistic information from these actors showed that NGOs were trusted the most, and the industry least by respondents.

In the context of shale gas development, we identified the government, the industry, environmental NGOs and scientists as actors that could influence acceptance because they are involved in policymaking, the implementation of projects, the provision of information on environment-related issues, and in the formulation of a shared fact base for the technology. We may elaborate on the perceptions of these actors to elucidate the ways through which these actors could influence acceptance.

The representatives of the United States government see shale gas development as an economic opportunity that generates government revenue via taxes, creates new jobs and contributes to the Gross Domestic Product (US Department of Energy Office of Fossil Energy, 2013). They claim that the energy released during hydraulic fracturing is generally not likely to initiate a seismic event, but that groundwater contamination remains a risk mainly because of the human factor. These spokespersons underline that requirements from numerous laws apply to shale gas development, and that this ensures that the process is highly engineered, controlled and monitored (US Department of Energy Office of Fossil Energy, 2013). The significance of this viewpoint is that it attempts to instill a sense of security to individuals about the environmental risks linked to shale gas development. This may in turn reduce the level of risk perception or increment the level of benefit perception (see **Figure 1**).

Energy companies consider shale gas as an opportunity that has stimulated economic activity through lowering power and materials costs (American Petroleum Institute, 2017). Representatives of the industry claim to take earthquakes that may be related to shale gas development seriously, and regarding groundwater contamination they state that "there have been no such confirmed cases in the at least 2 million wells fracked over the past 68 years" (American Petroleum Institute, 2017). They further assert that existing standards, regulations protect communities from adverse impacts of the process, and that on field experience and industry practices have allowed methane emissions from hydraulically fractured natural gas wells to fall by nearly 65% between 2012 and 2015 (American Petroleum Institute, 2017). The approach of industry representatives is therefore such that it reinforces their intentions and capabilities. This may serve to formulate trust in the actors. If such trust is established, it is probable that people undermine the risks associated with the technology (see **Figure 1**).

Environmental NGOs have grave concerns about shale gas development because they consider it as a temporary fix. While shale gas is presented as means of reducing greenhouse gas emissions since natural gas emits 50% less carbon dioxide when compared to burning coal (Engelder, 2011), environmental NGOs suggest that relying on this source will be at the expense of long-term solutions to the issue that should build upon the transition to renewable energy sources (Greenpeace, 2012). Additionally, they underline the possibility of surface and groundwater contamination particularly that of drinking water, through leaks of toxic chemicals in fracking fluids. Therefore, they advocate for holding off shale gas activities "until all these problems are adequately addressed" (Greenpeace, 2012). If NGOs are perceived to have been trustworthy, the definitive language presented here may impact social acceptance through incrementing the risk perception. To represent this relationship, we have formulated a direct association from knowledge to trust and through trust to perceived risks in our model (**Figure 1**).

Scientists that assessed the overall impact of shale gas development noted that 1.5% of the gas produced in the Barnett Shale region is emitted to the atmosphere prior to being transmitted to the power plant (Logan et al., 2012). Radioactive pollutants could persist in this produced gas traveling through pipelines, enter households and eventually lead to lung cancer. Similarly, spills and leaks and the disposal of inadequately treated wastewater or hydraulic fracturing fluids can result in the contamination of both surface and groundwater (Small et al., 2014). Moreover, the benefits to be derived from shale gas development remain uncertain. The net effect on greenhouse gas emissions should account both for direct emissions and for the economic aftermath of fuel substitution due to diminished natural gas prices (Small et al., 2014). Again, the economic benefits predicted to be derived from shale gas development should account for the negative externalities on traditional natural gas producers (Sovacool, 2014). According to scientists, these synergies may "amplify risks and produce cumulative effects" (Small et al., 2014) and since the understanding of these amplification mechanisms is limited more weight should be placed on doing a thorough life-cycle assessment. Overall, scientists are skeptical about the impact of shale gas development. What this implies for this research is that information from scientists can reduce bias (both in favor and against) toward the technology (**Figure 1**).

The method of information provision is also effective in modulating the social acceptance of an energy technology. It consists of the medium of communication, frequency and content of the provided information, and the language used in this process.

Thaler and Sunstein (1999) claim that the accuracy of information is secondary to the method of explanation. Visual cues and vivid descriptions emerge as more effective means of communication when compared to verbal representations. The authors founded their argument upon an experiment that showed that customers of an energy company who were provided with an "Ambient Orb" that generated a salient red-light signal when energy consumption was high, diminished their peak energy demand by 40% (Thaler and Sunstein, 1999). Henceforth, technological advancements that provide us with novice ways of conveying ideas will become consequential in managing social acceptance through the knowledge channel.

According to Heberlein and Baumgartner (1985) how one explains a particular incentive influences its effectiveness. Stern

(1999) supports this position through discerning that consumers who received an enhanced information package with frequent reminders about time-of-use rates, and recommendations on the means to regulate home energy use, diminished their peak-period electricity consumption to a level 16% below that attained when one message that explained the rates was utilized. The implication of this in terms of shale gas development is that it accentuates the necessity to adjust strategies such that desired changes be achieved.

The word choice is crucial in communicating ideas that could impact acceptance. Evensen et al. (2014) found that using the phrase "shale gas development" instead of "fracking" in a questionnaire produced significantly distinctive results in terms of the attitude of respondents. "Fracking" appeared to have more negative connotations and respondents were three times more inclined to resort to positive expressions while describing "shale gas development" when compared to "fracking." Nonetheless, in analyzing the impact of changing the source of information, it is usually difficult to control the language employed, particularly in the case of shale gas development. This is because actors adopt a language that strengthens their argument. NGOs for instance, prefer to utilize the phrase "fracking" in their statements (Greenpeace, 2012) most probably, because it carries negative connotations (Evensen et al., 2014). Alternatively, regulators use the phrase "shale gas development" (US Department of Energy Office of Fossil Energy, 2013), possibly in order to avoid bias (Evensen et al., 2014).

Whether the cultivation of knowledge brings about more positive acceptance or not is uncertain. Yet, research suggests that it can result in the formulation of more stable opinions (Daamen et al., 2006). Thus, we strongly encourage policymakers to gather information about how the public perceives the technology starting from the very early stages of the process, and to analyze the impact of information provision through time so that policies are as effective as possible.

Experience and Acceptance

Experience has two pillars in our model of shale gas development. First of all, it encompasses the impacts associated with the technology directly. This experience may stem from proximity to the source, or from substantial media coverage. In either way, experience serves as a means of accumulating knowledge and this may influence how people weigh benefits, risks and costs and develop a stance about the development process (**Figure 1**). An example that would clarify this approach relates to nuclear energy technologies. A study conducted in Switzerland 5 months prior to and immediately after the Fukushima incident showed that both the public's acceptance of nuclear power and the trust society places in reactor operatives were more negative following the accident (Visschers and Siegrist, 2013). Again, opinion polling in Pennsylvania, a state where shale gas development actively takes place, showed that 48% of the respondents followed news pertaining to drilling activities in the Marcellus Shale either "somewhat" or "very" closely (Rabe and Borick, 2011). This reinforces the idea that experience influences knowledge and raises the question whether experience can constitute a barrier for further activities in the region.

The second pillar is personal experience unrelated to the particular energy technology. In the case of shale gas development this may be the experience of a natural disaster, more specifically the experience of an earthquake. Individuals who have previously experienced an earthquake unrelated to shale gas development may be more susceptible to oppose the technology if they are informed that it bears a seismic risk.

We depicted the large-scale effect of experience by two arrows: one that points at knowledge and another that points at all variables in our model (see **Figure 1**). We have not internalized experience as in the case of knowledge, because neither can we limit peoples' exposure to the technology nor can we establish full security from external impacts.

CONCLUSION

Recent developments, especially conflicts associated with energy technologies, have delineated that social acceptance has become an imperative consideration in the planning and implementation of energy policies. Fortunately, it is not a challenge, but instead an indicator that can be measured and managed.

In predicting a model that adds up to a complex portrait of the social acceptance of shale gas development, we have concentrated on the psychological factors that were suggested by and tested in literature. As previous research has shown, other factors such as sociodemographic variables or situational factors that include the location and scale of projects can impact social acceptance. Yet, it is reasonable to assert that these factors are likely to influence acceptance through the factors in our model. The model we proposed for understanding acceptance encompasses the factors: perceived benefits, risks and costs, procedural and distributional fairness, trust, outcome efficacy, problem perception, knowledge and experience.

In line with the theory of planned behavior we accounted for benefits, risks, and costs as antecedents of acceptance. We argued that only the perceived values of these factors would influence attitudes toward shale gas development. In the context of problem perception we suggested that the more one thinks we should actively prevent global warming, the more he or she might favor shale gas development. For outcome efficacy we initially stated that individuals who believe that shale gas has a cleaner environmental footprint, may favor the technology over another. Following this, we argued that individuals who think that they reside in regions where their attitudes have a more significant impact on decision making would be more willing to express an opinion in favor or against the technology.

Trust was one of the main factors that impacted acceptance. We stated that relying on government organizations, the industry, environmental organizations and scientists could be viewed as a substitute to acting upon full knowledge. While discussing the measurability of the factor we underlined that trust in each actor should be treated independently since the roles of each actor is distinct in the process.

The fairness in the distribution of benefits, risks and costs and the fairness in contribution to the decision process of the technology were important considerations. We claimed that perceived fairness could formulate trust in actors when there is an exigency of information relating to trust. Furthermore, once an actor is trusted, an illusion of fairness could follow.

For the experience factor we asserted that experience serves as a means of accumulating knowledge that would allow individuals to arrive at a reasoned judgment. We considered experience as exogenously given because it is difficult, if not impossible, to limit peoples' exposure to the technology and to establish full immunity from external impacts.

What we suggested in terms of the management of social acceptance was the provision of information. This became a viable option because survey data and numerous opinion polls have underlined the deficiency of knowledge and the lack of a clear understanding of the risks associated with and benefits to be derived from shale gas development. While there appears to be no exact solution to the problem of low levels of knowledge, providing information may change the way people perceive the technology. In this context, we suggested two channels through which knowledge would allow for spatial divergences in policymaking, namely the source and content of information.

In relation to the source of information we underlined the importance of the credibility of the source in modulating attitudes toward shale gas development. The government, the industry, environmental NGOs and scientists emerged as actors that could possibly influence acceptance. Governments could reduce the level of risk perception or increment the benefit perception through instilling a sense of security to individuals about the environmental risks linked to the energy technology. Industry representatives on the other hand, could undermine the risks associated with shale gas development through underlining their good intentions and capabilities. Environmental NGOs could increment the risk perception through reinforcing the idea that shale gas development is a temporary fix. Dissimilarly scientists could reduce bias toward the technology through presenting balanced stances. In relation to the content, we stated that discerning the relative impact of information of different contents on acceptance should be an imperative consideration for policymakers.

Once a questionnaire developed in line with the model proposed in this paper is administered and data is collected, a confirmatory factor analysis could be conducted to check the validity of the model. The factor loadings obtained from such analysis would have important implications for policymakers as they mirror the opinions, evaluations and behavioral intentions of the public. In line with the factor loadings then, policymakers could make adjustments to the designs of policies or projects. Policymakers could choose to concentrate on improving the moral benefits of the technology, diminishing its environmental damages, distributing the costs and benefits fairly, or on locating operations such that people feel safe. Moreover, tracing the factor loadings through time while exposure to information increases, could allow policymakers to find more effective methods of communication among representatives of the industry, regulatory agencies, environmental NGOs, scientists and members of the general public.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

FUNDING

This study was partially funded by the project Nature4Cities—Nature Based Solutions for re-naturing cities: knowledge diffusion and decision support platform through new collaborative models (EU Project ID: 730468).

REFERENCES

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50, 179–211.

American Petroleum Institute (2017). *Hydraulic Fracturing: Unlocking America's Natural Gas Resources*. Available online at: http://www.api.org/~/media/Files/Oil-and-Natural-Gas/Hydraulic-Fracturing-primer/Hydraulic-Fracturing-Primer.pdf

Argetsinger, B. (2011). The Marcellus Shale: bridge to a clean energy future or bridge to nowhere-environmental, energy and climate policy considerations for shale gas development in New York State. *Pace Environ. Law Rev.* 29:321. Available online at: http://digitalcommons.pace.edu/pelr/vol29/iss1/8

Bernheim, B. D., and Rangel, A. (2007). Behavioral public economics: welfare and policy analysis with nonstandard decision-makers. *Behav. Econ. Its Appl.* 7:28. doi: 10.3386/w11518

Boudet, H., Clarke, C., Bugden, D., Maibach, E., Roser-Renouf, C., and Leiserowitz, A. (2014). "Fracking" controversy and communication: using national survey data to understand public perceptions of hydraulic fracturing. *Energy Policy* 65, 57–67. doi: 10.1016/j.enpol.2013.10.017

Brasier, K. J., McLaughlin, D. K., Rhubart, D., Stedman, R. C., Filteau, M. R., and Jacquet, J. (2013). Risk perceptions of natural gas development in the Marcellus Shale. *Environ. Pract.* 15, 108–122. doi: 10.1017/S1466046613000021

Bronfman, N. C., Jiménez, R. B., Arévalo, P. C., and Cifuentes, L. A. (2012). Understanding social acceptance of electricity generation sources. *Energy Policy* 46, 246–252. doi: 10.1016/j.enpol.2012.03.057

Burnham, A., Han, J., Clark, C. E., Wang, M., Dunn, J. B., and Palou-Rivera, I. (2011). Life-cycle greenhouse gas emissions of shale gas, natural gas, coal, and petroleum. *Environ. Sci. Technol.* 46, 619–627. doi: 10.1021/es201942m

Cathles, L. M., Brown, L., Taam, M., and Hunter, A. (2012). A commentary on "The greenhouse-gas footprint of natural gas in shale formations" by RW Howarth, R. Santoro, and Anthony Ingraffea. *Clim.Change* 113, 525–535. doi: 10.1007/s10584-011-0333-0

Cipolla, C. L., Lolon, E. P., Erdle, J. C., and Rubin, B. (2010). Reservoir modeling in shale-gas reservoirs. *SPE Reservoir Eval. Eng.* 13, 638–653. doi: 10.2118/125530-MS

Considine, T. J., Watson, R., and Blumsack, S. (2010). *The Economic Impacts of the Pennsylvania Marcellus Shale Natural Gas Play: An Update*. The Pennsylvania State University, Department of Energy and Mineral Engineering.

Craig, C. S., and McCann, J. M. (1978). Assessing communication effects on energy conservation. *J. Consum. Res.* 5, 82–88.

Daamen, D., de Best-Waldhober, M., Damen, K., and Faaij, A. (2006). *Pseudo-Opinions on CCS Technologies*. Trondheim: GHGT-8.

De Best-Waldhober, M., and Daamen, D. (2006). *Public Perceptions and Preferences Regarding Large Scale Implementation of Six CO_2 Capture and*

Storage Technologies. Well-Informed and well-Considered Opinions Versus Uninformed Pseudo-Opinions of the Dutch Public. Leiden: Leiden University.

Deutch, J. (2011). The good news about gas-The natural gas revolution and its consequences. *Foreign Aff.* 90, 82–93.

Earle, T. C., and Siegrist, M. (2008). On the relation between trust and fairness in environmental risk management. *Risk Anal.* 28, 1395–1414. doi: 10.1111/j.1539-6924.2008.01091.x

Engelder, T. (2011). Should fracking stop? No, it's too valuable. *Nature* 477, 274–275.

Evensen, D., Jacquet, J. B., Clarke, C. E., and Stedman, R. C. (2014). What's the "fracking" problem? One word can't say it all. *Extractive Industries Soc.* 1, 130–136. doi: 10.1016/j.exis.2014.06.004

Ferrar, K. J., Kriesky, J., Christen, C. L., Marshall, L. P., Malone, S. L., Sharma, R. K., et al. (2013). Assessment and longitudinal analysis of health impacts and stressors perceived to result from unconventional shale gas development in the Marcellus Shale region. *Int. J. Occup. Environ. Health* 19, 104–112. doi: 10.1179/2049396713Y.0000000024

Fox, J. (2010). *Gasland: A Film by Josh Fox*. Milanville, PA: International WOW Co.

Frewer, L. J., Howard, C., Hedderley, D., and Shepherd, R. (1996). What determines trust in information about food-related risks? Underlying psychological constructs. *Risk Anal.* 16, 473–486.

Funk, C., and Rainie, L. (2015). "Chapter 3: attitudes and beliefs on science and technology topics," in Available online at: http://www.pewinternet.org/2015/01/29/chapter-3-attitudes-and-beliefs-on-science-and-technology-topics/

Gleeson, T., Wada, Y., Bierkens, M. F., and van Beek, L. P. (2012). Water balance of global aquifers revealed by groundwater footprint. *Nature* 488, 197–200. doi: 10.1038/nature11295

Greenpeace (2012). *Position Statement on Shale Gas, Shale Oil, Coal Bed Methane And "Fracking"*. Available online at: https://www.greenpeace.org/eu-unit/Global/eu-unit/reports-briefings/2012%20pubs/Pubs%202%20Apr-Jun/Joint%20statement%20on%20fracking.pdf

Gross, C. (2007). Community perspectives of wind energy in Australia: the application of a justice and community fairness framework to increase social acceptance. *Energy Policy* 35, 2727–2736. doi: 10.1016/j.enpol.2006.12.013

Ground Water Protection Council (GWPC) and ALL Consulting (2009). *Modern Shale Gas Development in the United States: A Primer*. U.S. Department of Energy Office of Fossil Energy and National Energy Technology Laboratory, 53.

Hardy, K., and Kelsey, T. W. (2015). Local income related to Marcellus shale activity in Pennsylvania. *Community Dev.* 46, 329–340. doi: 10.1080/15575330.2015.1059351

Heberlein, T. A., and Baumgartner, R. M. (1985). "Changing attitudes and electricity consumption in a time-of-use experiment," in *International Conference on Consumer Behavior and Energy Policy* (Versailles).

Heiskanen, E., Hodson, M., Mourik, R. M., Raven, R. P. J. M., Feenstra, C. F. J., Alcantud, A., et al. (2008). *Factors Influencing the Societal Acceptance of New Energy Technologies: Meta-Analysis of recent European Projects.* Work Package 2.

Hisschemöller, M., and Midden, C. J. (1999). Improving the usability of research on the public perception of science and technology for policy-making. *Public Understand. Sci.* 8, 17–34. doi: 10.1088/0963-6625/8/1/002

Holzman, D. C. (2011). Methane found in well water near fracking sites. *Environ. Health Perspect.* 119:a289.

House, E. J. (2013). Fractured fairytales: the failed social license for unconventional oil and gas development. *Wyoming Law Rev.* 13:5. Available online at: http://repository.uwyo.edu/wlr/vol13/iss1/1

House, L., Lusk, J., Jaeger, S., Traill, W. B., Moore, M., Valli, C., et al. (2005). Objective and subjective knowledge: impacts on consumer demand for genetically modified foods in the United States and the European Union. *AgBioForum* 7, 113–123.

Howarth, R. W., Ingraffea, A., and Engelder, T. (2011a). Natural gas: Should fracking stop? *Nature* 477, 271–275. doi: 10.1038/477271a

Howarth, R. W., Santoro, R., and Ingraffea, A. (2011b). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Clim. Change* 106:679. doi: 10.1007/s10584-011-0061-5

Hughes, J. D. (2013). Energy: a reality check on the shale revolution. *Nature* 494, 307–308. doi: 10.1038/494307a

Huijts, N. M., Midden, C. J., and Meijnders, A. L. (2007). Social acceptance of carbon dioxide storage. *Ener. Policy* 35, 2780–2789. doi: 10.1016/j.enpol.2006.12.007

Huijts, N. M., Molin, E. J., and Steg, L. (2012). Psychological factors influencing sustainable energy technology acceptance: a review-based comprehensive framework. *Renew. Sustain. Energy Rev.* 16, 525–531. doi: 10.1016/j.rser.2011.08.018

Hultman, N., Rebois, D., Scholten, M., and Ramig, C. (2011). The greenhouse impact of unconventional gas for electricity generation. *Environ. Res. Lett.* 6:044008. doi:10.1088/1748-9326/6/4/044008

Jacoby, H. D., O'Sullivan, F. M., and Paltsev, S. (2012). The influence of shale gas on US energy and environmental policy. *Econ. Energy Environ. Policy* 1, 37–52. doi: 10.5547/2160-5890.1.1.5

Jacquet, J. B. (2014). Review of risks to communities from shale energy development. *Environ. Sci. Technol.* 48, 8321–8333. doi: 10.1021/es404647x

Jenner, S., and Lamadrid, A. J. (2013). Shale gas vs. coal: policy implications from environmental impact comparisons of shale gas, conventional gas, and coal on air, water, and land in the United States. *Energy Policy* 53, 442–453. doi: 10.1016/j.enpol.2012.11.010

Jiang, M., Griffin, W. M., Hendrickson, C., Jaramillo, P., VanBriesen, J., and Venkatesh, A. (2011). Life cycle greenhouse gas emissions of Marcellus shale gas. *Environ. Res. Lett.* 6:034014. doi: 10.1088/1748-9326/6/3/034014

Johnson, B. B. (1999). Exploring dimensionality in the origins of hazard-related trust. *J. Risk Res.* 2, 325–354.

Kahneman, D., Knetsch, J. L., and Thaler, R. (1986). Fairness as a constraint on profit seeking: entitlements in the market. *Am. Econ. Rev.* 76, 728–741.

Kahneman, D., and Tversky, A. (1979). Prospect theory: an analysis of decision under risk. *Econometrica* 47, 263–292.

Kargbo, D. M., Wilhelm, R. G., and Campbell, D. J. (2010). Natural gas plays in the marcellus shale: challenges and potential opportunities. *Environ. Sci. Technol.* 44, 5679–5684. doi: 10.1021/es903811p

Kerr, R. A. (2012). Learning how to not make your own earthquakes. *Science* 335, 1436–1437. doi: 10.1126/science.335.6075.1436

Kim, W. Y. (2013). Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio. *J. Geophys. Res. Solid Earth* 118, 3506–3518. doi: 10.1002/jgrb.50247

Kok, M. V., and Merey, S. (2014). Shale gas: current perspectives and future prospects in Turkey and the world. *Energy Sour. Pt A: Recovery Util. Environ. Eff.* 36, 2492–2501. doi: 10.1080/15567036.2014.943854

Lavine, H., Thomsen, C. J., Zanna, M. P., and Borgida, E. (1998). On the primacy of affect in the determination of attitudes and behavior: the moderating role of affective-cognitive ambivalence. *J. Exp. Soc. Psychol.* 34, 398–421. doi: 10.1006/jesp.1998.1357

Lesbirel, S. H., and Shaw, D. (2005). *Managing Conflict in Facility Siting: An International Comparison*. Northampton, MA: Edward Elgar Publishing Limited.

Lind, E. A., and Van den Bos, K. (2002). When fairness works: toward a general theory of uncertainty management. *Res. Org. Behav.* 24, 181–223. doi: 10.1016/S0191-3085(02)24006-X

Lindenberg, S., and Steg, L. (2007). Normative, gain and hedonic goal frames guiding environmental behavior. *J. Soc. Iss.* 63, 117–137. doi: 10.1111/j.1540-4560.2007.00499.x

Loewenstein, G., and Lerner, J. S. (2003). "The role of affect in decision making," in *Handbook of Affective Science,* eds R. Davidson, H. Goldsmith, and K. Scherer (Oxford: Oxford University Press), 619–642.

Logan, J., Heath, G., Macknick, J., Paranhos, E., Boyd, W., and Carlson, K. (2012). *Natural Gas and the Transformation of the US Energy Sector: Electricity (No. NREL/TP-6A50-55538)*. Colorado State University, University of Colorado Law School, National Renewable Energy Laboratory.

Luhmann, N. (1979). *Trust and Power: Two Works by Niklas Luhmann*. Chichester: Wiley.

Maffly, B. (2013). *Uinta Basin Gas Leakage far Worse than Most Believe; New Study Says up to 12 Percent of Basin's Methane Escapes*. Salt Lake Trib.

Maugeri, L. (2013). *The Shale Oil Boom: A US Phenomenon*. Harvard Kennedy School, Belfer Center for Science and International Affairs.

Metlay, D. (1999). "Institutional trust and confidence: a journey into a conceptual quagmire," in *Social Trust and the Management of Risk*, eds G. T. Cvetkovich, and R. E. Lofstedt (London: Earthscan), 100–116.

Midden, C. J., and Huijts, N. (2009). The role of trust in the affective evaluation of novel risks: the case of CO_2 storage. *Risk Anal.* 29, 743–751. doi: 10.1111/j.1539-6924.2009.01201.x

Montijn-Dorgelo, F. N., and Midden, C. J. (2008). The role of negative associations and trust in risk perception of new hydrogen systems. *J. Risk Res.* 11, 659–671. doi: 10.1080/13669870801967218

Musall, F. D., and Kuik, O. (2011). Local acceptance of renewable energy—A case study from southeast Germany. *Energy Policy* 39, 3252–3260. doi: 10.1016/j.enpol.2011.03.017

Newell, R. G., and Raimi, D. (2014). Implications of shale gas development for climate change. *Environ. Sci. Technol.* 48, 8360–8368. doi: 10.1021/es4046154

O'Hara, S., Humphrey, M., Andersson, J., Jaspal, R., Nerlich, B., and Knight, W. (2014). *Public Perception of Shale Gas Extraction in the UK: Has Balcombe Bottomed Out*. University of Nottingham, Science and Technology Research Priority Group.

O'Hara, S., Humphrey, M., Andersson-Hudson, J., and Knight, W. (2015). *Public Perception of Shale Gas Extraction in the UK: Two Years on from the Balcombe Protests.* Nottingham: University of Nottingham.

O'Hara, S., Humphrey, M., Andersson-Hudson, J., and Knight, W. (2016). *Public Perception of Shale Gas Extraction in the UK: from Positive to Negative.* Nottingham: University of Nottingham. Available online at: at https://www.scribd.com/doc/131787519/public-perceptions-of-shale-gas-in-the-UK-October-2016-pdf

O'Hara, S., Humphrey, M., Jaspal, R., Nerlich, B., and Poberezhskaya, M. (2013). *Public Perception of Shale Gas Extraction in the Uk*: *How People's Views Are Changing.* Nottingham, UK: University of Nottingham.

Pashin, J. C., Grace, R. L. B., and Kopaska-Merkel, D. C. (2010). "Devonian shale plays in the Black Warrior basin and Appalachian thrust belt of Alabama," in *International Coalbed Shale Gas Symposium* (New Orleans, LA).

Pesendorfer, W. (2006). Behavioral economics comes of age: A review essay on advances in behavioral economics. *J. Econ. Lit.* 44, 712–721. doi: 10.1257/jel.44.3.712

Peters, E., and Slovic, P. (1996). The role of affect and worldviews as orienting dispositions in the perception and acceptance of nuclear power. *J. Appl. Soc. Psychol.* 26, 1427–1453.

Peters, R. G., Covello, V. T., and McCallum, D. B. (1997). The determinants of trust and credibility in environmental risk communication: an empirical study. *Risk Anal.* 17, 43–54.

Pidgeon, N., and Demski, C. C. (2012). From nuclear to renewable: Energy system transformation and public attitudes. *Bull. Atomic Sci.* 68, 41–51. doi: 10.1177/0096340212451592

Quinnipiac University, (2012a). *Ohio Voters Divided on Fetal Heartbeat Bill, Quinnipiac University Poll Finds; Voters Say 3-1 Stop Hydro-Fracking Until More Study*. Quinnipiac University. Available online at: http://www.quinnipiac.edu/institutes-and-centers/polling-institute/ohio/release-detail?ReleaseID=1692

Quinnipiac University, (2012b). *New York Voters Nix Pay Raise for Lawmakers 5-1, Quinnipiac University poll finds; Voters Back Higher Taxes for Rich, Health Care Law*. Available online at: http://www.quinnipiac.edu/institutes-and-centers/polling-institute/new-york-state/release-detail?ReleaseID=1780

Rabe, B. G. (2014). Shale play politics: the intergovernmental odyssey of American shale governance. *Environ. Sci. Technol.* 48, 8369–8375. doi: 10.1021/es4051132

Rabe, B. G., and Borick, C. P. (2011). *Fracking for Natural Gas: Public Opinion on State Policy Options.* Center for Local, State, and Urban Policy, University of Michigan.

Rotman, D. (2009). Natural gas changes the energy map. *MIT Technol. Rev.* 112.

Rousseau, D. M., Sitkin, S. B., Burt, R. S., and Camerer, C. (1998). Not so different after all: a cross-discipline view of trust. *Acad. Manag. Rev.* 23, 393–404.

Schafft, K. A., Borlu, Y., and Glenna, L. (2013). The relationship between Marcellus Shale gas development in Pennsylvania and local perceptions of risk and opportunity. *Rural Sociol.* 78, 143–166. doi: 10.1111/ruso.12004

Schuitema, G., Steg, L., and Van Kruining, M. (2011). When are transport pricing policies fair and acceptable?. *Soc. Justice Res.* 24, 66–84. doi: 10.1007/s11211-011-0124-9

Schwartz, S. H. (1977). Normative influences on altruism. *Adv. Exp. Soc. Psychol.* 10, 221–279. doi: 10.1016/S0065-2601(08)60358-5

Schwartz, S. H., and Howard, J. A. (1981). A normative decision-making model of altruism. *Altruism Help. Behav.* 2, 189–211.

Scott, S. (2013). Who shale regulate the fracking industry. *Villanova Environ. Law J.* 24, 189–223. Available online at: http://digitalcommons.law.villanova.edu/elj/vol24/iss1/6?

Shoemaker, J. K., and Schrag, D. P. (2013). The danger of overvaluing methane's influence on future climate change. *Clim. Change* 120, 903–914. doi: 10.1007/s10584-013-0861-x

Siegrist, M. (1999). A causal model explaining the perception and acceptance of gene technology. *J. Appl. Soc. Psychol.* 29, 2093–2106.

Siegrist, M., Cousin, M. E., Kastenholz, H., and Wiek, A. (2007). Public acceptance of nanotechnology foods and food packaging: the influence of affect and trust. *Appetite* 49, 459–466. doi: 10.1016/j.appet.2007.03.002

Siegrist, M., and Cvetkovich, G. (2000). Perception of hazards: the role of social trust and knowledge. *Risk Anal.* 20, 713–720. doi: 10.1111/0272-4332.205064

Slovic, P., Fischhoff, B., and Lichtenstein, S. (1985). "Characterizing perceived risk," in *Perilous Progress: Managing the Hazards of Technology,* eds R. W. Kates, C. Hohenemser, and J. X. Kasperson (Westview), 91–125. Available online at: https://ssrn.com/abstract=2185557

Small, M. J., Stern, P. C., Bomberg, E., Christopherson, S. M., Goldstein, B. D., Israel, A. L., et al. (2014). Risks and risk governance in unconventional shale gas development. *Environ. Sci. Technol.* 48, 8289–8297. doi: 10.1021/es502111u

Soland, M., Steimer, N., and Walter, G. (2013). Local acceptance of existing biogas plants in Switzerland. *Energy Policy* 61, 802–810. doi: 10.1016/j.enpol.2013.06.111

Sovacool, B. K. (2014). Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking). *Renewable Sustain. Energy Rev.* 37, 249–264. doi: 10.1016/j.rser.2014.04.068

Stamford, L., and Azapagic, A. (2014). Life cycle environmental impacts of UK shale gas. *Appl. Energy* 134, 506–518. doi: 10.1016/j.apenergy.2014.08.063

Steg, L., and Groot, J. (2010). Explaining prosocial intentions: testing causal relationships in the norm activation model. *Br. J. Soc. Psychol.* 49, 725–743. doi: 10.1348/014466609X477745

Stephenson, T., Valle, J. E., and Riera-Palou, X. (2011). Modeling the relative GHG emissions of conventional and shale gas production. *Environ. Sci. Technol.* 45, 10757–10764. doi: 10.1021/es2024115

Stern, P. C. (1999). Information, incentives, and proenvironmental consumer behavior. *J. Consum. Policy* 22, 461–478.

Sunjay, B., and Kothari, N. (2011, March). "Unconventional energy sources: shale gas," in *10th Offshore Mediterranean Conference and Exhibition* (Ravenna), 23–25.

Terwel, B. W., Harinck, F., Ellemers, N., and Daamen, D. D. (2009). Competence-based and integrity-based trust as predictors of acceptance of carbon dioxide capture and storage (CCS). *Risk Anal.* 29, 1129–1140. doi: 10.1111/j.1539-6924.2009.01256.x

Thaler, R. H., and Sunstein, C. R. (1999). *Nudge: Improving Decisions About Health, Wealth, and Happiness*. New Haven, CT: Yale University Press.

Tokushige, K., Akimoto, K., and Tomoda, T. (2007a). Public perceptions on the acceptance of geological storage of carbon dioxide and information influencing the acceptance. *International Journal of Greenhouse Gas Control* 1, 101–112.

Tokushige, K., Akimoto, K., and Tomoda, T. (2007b). Public acceptance and risk-benefit perception of CO_2 geological storage for global warming mitigation in Japan. *Mitigation Adapt. Strateg. Global Change* 12, 1237–1251. doi: 10.1007/s11027-006-9037-6

Tollefson, J. (2012). Air sampling reveals high emissions from gas field. *Nature* 482, 139–140. doi: 10.1038/482139a

US Department of Energy Office of Fossil Energy (2013). *Natural Gas from Shale: Questions and Answers*. Washington, DC: U.S. Department of Energy, Office of Fossil Energy. Available online at: http://www.fe.doe.gov/

US Energy Information Administration, (2011). *World Shale Gas Resources: An Initial Assessment of 14 Regions outside the United States*. U.S. Energy Information Administration. Available online at: https://www.eia.gov/analysis/studies/worldshalegas/archive/2011/pdf/fullreport.pdf

Visschers, V. H., and Siegrist, M. (2013). How a nuclear power plant accident influences acceptance of nuclear power: results of a longitudinal study before and after the Fukushima disaster. *Risk Anal.* 33, 333–347. doi: 10.1111/j.1539-6924.2012.01861.x

Weber, C. L., and Clavin, C. (2012). Life cycle carbon footprint of shale gas: review of evidence and implications. *Environ. Sci. Technol.* 46, 5688–5695. doi: 10.1021/es300375n

Whitmarsh, L., Nash, N., Upham, P., Lloyd, A., Verdon, J. P., and Kendall, J. M. (2015). UK public perceptions of shale gas hydraulic fracturing: the role of audience, message and contextual factors on risk perceptions and policy support. *Appl. Energy* 160, 419–430. doi: 10.1016/j.apenergy.2015.09.004

Wolsink, M. (2007). Wind power implementation: the nature of public attitudes: equity and fairness instead of "backyard motives". *Renewable Sustain. Energy Rev.* 11, 1188–1207. doi: 10.1016/j.rser.2005.10.005

Wright, S. (2012). *An Unconventional Bonanza*. Special Report Natural Gas, Economist Newspaper.

Zucker, H. A. (2014). *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development*. Albany, NY: New York State Department of Health 100.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer MQ and handling Editor declared their shared affiliation.