Energy Research & Social Science 20 (2016) 63–72

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

Looking through the prism of shale gas development: Towards a holistic framework for analysis

Juan Roberto Lozano-Maya

Asia Pacific Energy Research Centre (APERC), Inui Bldg.-Kachidoki 11F, 1-13-1 Kachidoki, Tokyo 104-0054, Japan

ARTICLE INFO

Article history:
Received 31 December 2015
Received in revised form 18 May 2016
Accepted 20 May 2016
Available online 16 June 2016

Keywords:
Shale gas development
Unconventional gas risks
Policy framework
Governance
Canada
China
Mexico

ABSTRACT

In consideration of the size and geographic concentration of proved conventional gas reserves and the potential role of natural gas to reduce the carbon intensity of energy demand, unconventional gas resources have become increasingly important to expand natural gas supplies. Shale gas in particular has gained international relevance in recent years, largely due to its rapid development and game-changing effects in the United States and its wider and larger distribution worldwide over conventional gas reserves; nonetheless, developing shale gas in other countries has been much slower, as it presents increased risks that span multiple interlinked dimensions and differ across the perceptions of an ample array of stakeholders in diverse contextual settings. The premises presented in this paper attempt to advance a holistic framework for shale gas development which comprises several factors grouped in three major interlinked domains: access to natural resources, industry capabilities and governance. To empirically test its premises under contextual variations, the framework is further used to consistently analyze the cases of Canada, China and Mexico. Findings confirm the interdisciplinary nature of shale gas development and suggest that governance is the most critical domain to bring about changes that improve the management of underlying risks.

1. Introduction

The energy landscape has changed rapidly and drastically in the last decades. In addition to the robust growth of energy demand, especially in developing countries, the rising importance of climate change has called for the use of fuels that emit less greenhouse gases, in particular carbon dioxide. To meet these goals, one of the major actions implemented in many countries consists of an increased use of natural gas in the primary energy balance, as it leads to lower carbon dioxide emissions over other fossil fuels and its use along with certain renewable energy sources fosters an energy mix less reliant on coal and oil and more supportive of cleaner technologies.

However, a larger natural gas supply in the world is currently constrained by the geographic concentration of proved reserves of natural gas in a small number of countries and by the economic and energy security trade-offs resulting from the growing dependency on imported supplies. In recent years, however, the outlook for natural gas markets was dramatically affected by the advent of gas volumes produced in the United States at an unprecedentedly large and rapid scale. These supplies are predominantly the result of shale gas, or unconventional natural gas produced from shale formations, which has transformed the economy of the United States and has brought about several positive effects that include lower carbon emissions, economic spillovers in local communities where development of this resource is taking place, and energy security benefits manifest in the country's emergence as an exporter of natural gas in the form of liquefied natural gas (LNG).

This experience in combination with preliminary geological assessments [15,16] indicating a more extensive and abundant global distribution of shale gas over current proved reserves of conventional gas spurred avid interest across the world in the last five years, with several countries embracing the potential development of their own shale gas resources. Nevertheless, considerable uncertainty remains, particularly in Asia and Europe [5,55], and by the end of 2015, shale gas production outside of the United States only entered commercial stage in Argentina, Australia, Canada and China [6]. In all these countries, shale gas was produced at insufficient low growth rates and volumetric magnitudes to produce any positive energy or economic effects, let alone to similar levels to the United States.

To date, the study of shale gas development predominantly follows two broad research lines. One strand centers on the analysis of single countries [11,13,34,64], but the outcomes of these studies

E-mail address: lozzano@ymail.com

http://dx.doi.org/10.1016/j.erss.2016.05.014

are usually too specific and idiosyncratic to allow comparisons and identify common lessons and points of convergence among them. Given the role of the United States as the earliest, the most successful and the best documented example of shale gas production in the world, another major strand of research attempts to identify the underlying drivers of this experience that would facilitate its reproduction in other countries [55,58,60], notwithstanding the drastically different settings in the other jurisdictions interested in or already engaged in shale gas development. In consequence, the study scope of worldwide shale gas development remains too limited and fragmented, and a reconciliation of all these insights into a cohesive framework with validity beyond the United States is notably absent from the academic literature.

This paper aims to unify these approaches by examining the development of shale gas from a more consistent perspective. In so doing, this paper rests on the main premise that shale gas development is fundamentally an interdisciplinary activity; for which, its study must be inclusive, especially for comparative purposes. The development of this argument not only addresses the main topic of this special issue, but also several of the key areas pointed out by Sovacool [50] in the field of energy research and social sciences, namely about the effects on energy systems from social, political and economic configurations, from institutions and non-state actors, and from diverse social groups and stakeholders.

Section 2 of this paper examines the multidimensional nature of shale gas development and the challenges in devising a homogeneous view applicable worldwide, in order to propose in Section 3 a systemic and holistic approach in the form of a generic framework. Section 4 tests the framework empirically through its application in the brief analysis of shale gas development in Canada, China and Mexico, while Section 5 concludes with the main findings and implications.

2. The multidimensionality of shale gas development

Shale gas is generally more complex and multifaceted to produce than conventional gas, and although the first commercial natural gas well drilled in the United States in 1821 was actually a shale gas well [12], the technology and production methods at the time could not make the extraction of shale gas economical, particularly when compared with relatively inexpensive, easy-to-extract and abundant conventional gas. The advent of horizontal drilling and hydraulic fracturing and their parallel deployment in the 1980s finally helped to release the gas in the shale formations in a cost-effective manner.

Despite these advances, shales show ample geological heterogeneity and a steeper declination rate, with shale gas wells typically exhausting more than half of their gas output in the first few years [10]; additionally, the quality and quantity of shale resources inferred in resource assessments and the exact location of the zones with the highest productivity ('sweet spots') or richer content in liquids of higher economic value remain uncertain until actual exploratory drilling occurs [7]. In order to maintain or increase gas production levels cost-effectively, developers must drill and hydraulically fracture a larger number of wells over shorter lead times, which exceeds the amount of technology inputs, water, chemicals, surface facilities and human resources typically observed in conventional gas production, demanding in turn the creation of agile supply chains formed with external suppliers of specialized services [20]. In sum, because of this profile, early shale gas development generally presents more intricate technical and operational challenges, with higher economic costs and lower profitability margins [2,5].

More relevant, a faster pace and larger scale of development amplifies land, water and environmental impacts, and even though some of these impacts are common with conventional gas development, what makes shale gas distinctive is that the intensity, magnitude and extent of its operations pose cumulative risks with effects still not fully understood that are insufficiently addressed by conventional risk management and regulatory approaches [18,62]. Performed at a large scale as in shale gas production, even a long-established industry practice like hydraulic fracturing creates a non-point source effect whereby the density and length in the rock fractures complicates the accurate traceability and assignment of liabilities to incumbent operators in case of groundwater pollution [24]. Furthermore, shale resources are more widely dispersed, for which development stretches over more extensive areas and tends to take place in proximity to communities with high population densities that had little to no previous involvement in equivalent activities. These issues increase social tensions and the potential to result in conflicts.

Compared with conventional gas, the risks derived from shale gas development span quantity and quality issues in groundwater and surface aquifers, including those apt for human use; emissions of toxic pollutants and greenhouse gases (most noticeably methane) that affect overall air quality; induced seismicity; ecological damage to natural habitats and wildlife; occupational hazards for workers and personnel adjacent to production sites; public health effects; and impacts to community life from the increased noise, dust and road traffic generated by ongoing operations. Other negative externalities refer to boom-and-bust cycles, and losses in the quality of life, property value and visual aesthetics [22,47,62].

In essence, shale gas development transcends purely technical and economic domains, to interweave environmental, social, and political risks that interlink a larger number of stakeholders. Therefore, to sever any of these links from shale gas development renders incomplete the prism of risks and stakeholders involved, which has deleterious effects, especially for comparative, strategy-making and policy-making purposes. In spite of this, the academic discussion about shale gas development largely centers on specific attributes that only capture part of these risks, overlooking several relevant domains and their corresponding interrelations. A study of the academic literature devoted to shale gas between 1990 and 2014 confirms that most research has been highly concentrated on engineering, technical and geological subjects [59].

In line with these arguments, scholars have stressed the need for a multidisciplinary approach different from that applicable to conventional gas, in order to overcome the multiple challenges and risks associated with shale gas development [2,47] and favor the shift of energy research from a few specific domains towards a more inclusive problem-based approach [51]. In addition to this fragmented scope, the majority of academic studies, including those attempting to identify the major forces behind shale gas development [1,5,58,60,53] are usually restricted to the discussion of single countries, which has further contributed to hamper the applicability of their findings to other settings.

In particular, deliberately or tacitly, the United States became the reference for shale gas development around the world. Deliberately, the United States federal government formally launched in 2010 its 'Global Shale Gas Initiative' to provide help to countries looking forward to developing their own unconventional gas resources for energy security and environmental reasons [43]. Tacitly, the pioneering experience of the United States became a role model in countries like Mexico [33] and the United Kingdom [22].

Empirical evidence however, has demonstrated the increasing difficulty in making shale gas production commercially viable beyond the United States. Despite the early positive expectations about shale gas, the experiences in the last few years in a number of countries with significant inferred volumes of shale gas have yielded poor results and have presented more considerable risks than conventional gas production. Examples of challenges spanning

multiple dimensions include Argentina [34], China [26,57], Mexico [13,33], Poland [28] and the United Kingdom [11,22]. These experiences have also questioned the use of the United States experience as a 'template' or 'benchmark' of shale gas development success, given the structural and contextual divergences throughout the world. In Europe, several countries had embraced the replication of the successful shale gas 'revolution' in the United States as a means to reduce their dependence on Russian pipeline gas imports, yet as soon as they faced the challenges involved in such task, many of them pulled out indefinitely from their strategy to develop their unconventional gas resources [25,55].

To begin with, one of the most distinctive characteristics in the United States refers to the private ownership of petroleum rights, which has helped reduce the social tension produced by shale gas development through the economic incentives that many landowners perceive [53,60] but which is highly unlikely to be replicated, given the predominance of state-owned rights in most other jurisdictions worldwide. Secondly, the United States shale gas boom is far from being a spontaneous occurrence, as it is the result of economic incentives, industry capabilities and extensive infrastructure systems developed over long timespans and under different institutional arrangements [1,58]. Lastly, due to the diversity of legal, regulatory arrangements, policy priorities at different government levels and the social questionability and evolution of certain environmental practices across jurisdictions, there are no uniform shale gas pathways from which to portray a single model absolutely representative of the United States [9].

Besides, scholars have noted an intrinsic flaw in the natural use of the United States as an 'international benchmark' of shale gas development, insofar as the adaptability of such benchmark and its derived aspirational goals are poor in countries with fairly different settings [33,38]. This is also consistent with some views that claim shale gas production to be an overly exaggerated or 'hyped' phenomenon, since it is largely limited to the United States due to the unique characteristics of that country and the timing of favorable external events to foster such a large scale of production [30,58]. These considerations suggest that there is no one-size-fits-all approach for the development of shale gas resources, and lead the academic discussion to question whether this activity is unique enough in every case to prevent the use of any reference based on common attributes [36].

Interestingly enough, more than two decades ago, in light of the works at the time in the United States towards the commercial development of different types of unconventional gas resources, not only was that country suggested as the most likely pioneer of shale gas production, but particularly as a source of learning for other countries to follow suit [36]. In this sense, this paper adheres to the argument that valuable knowledge can be assimilated from the examination of the United States and of those countries at an early stage of commercial shale gas development, albeit not in the form of a rigid template but as a knowledge source to design transferable policies [33,38] and illustrate actual negative examples and major risks to avoid in the development of shale gas for other settings [9,22]. The following section strives to condense these notions into a cohesive systemic framework.

3. Introducing a generic perspective for shale gas development

The design of a single approach to shale gas development is not a straightforward task, as it involves differing, and sometimes opposing views between major stakeholders that include the oil and gas industry, the government, local communities, non-governmental organizations (NGOs) and the general public. Contextual settings at a country or regional level are likely to influence a richer diversity of subgroups and interests within these major stakeholders.

Prior efforts to reflect the interdisciplinary nature of shale gas development for comparative purposes fell short in capturing this complexity. These attempts include a SWOT analysis on China's experience [63] that blurred the distinction between the macro and micro levels of analysis and between the perspectives of the diverse stakeholders embedded; similarly, a robust approximation to potential risks was presented by Wiseman [62], nevertheless, it was based on and applied only to particular jurisdictions in the United States.

The framework presented in this section strives to provide a multidisciplinary and more consistent perspective following the main assumption that the pace and magnitude of shale gas development will vary across countries and possibly between the jurisdictions within them [6,21]. This statement aligns with other views underscoring that shale gas development will tend to diverge as it is influenced by different considerations, especially of political nature [5], and includes the values of different stakeholders in response to their perception on the distribution of benefits and risks [49]. The overarching premise is that scarce as they are, energy issues are fundamentally entrenched in an indissoluble nexus with multiple dimensions that in turn, exert asymmetrical influence over diverse stakeholders and settings and occur at different spatial and physical scales [4,19].

Therefore, shale gas is not exclusively a geophysical, technical or economic endeavor, but a set of higher interrelated multidimensional constructs that contingent on their context, reflect a political position concerning shale gas resources, involve the industry proficiency to develop those resources, and affect the perceptions and the formal and informal relationships of the actors involved. These three domains are respectively denoted in the framework as Access to Natural Resources; Industry Capabilities, and Governance.

These arguments use and refine the guidelines of the 'RIG' model presented in APERC [6], through the support of an extensive literature review and case studies that included semi-structured interviews with industry experts and government officers visited in Mexico City, Mexico; Alberta, Canada; and Pennsylvania, United States during June 2014. The insights about global shale gas development condensed in this framework also benefited from the author's participation in several international academic and institutional events on the subject held during 2013 and 2014 and from his visit to several communities affected by shale gas activities in Denton City and across the Eagle Ford Shale in Texas in February 2016. This framework elaborates on the principles of an integral petroleum resource management system posited by Al-Kasim [3], with the addition of the concept of governance from the arguments that emphasize its role as a vehicle to support more effective outcomes in the development of natural resources among the different stakeholders involved and their respective interests [4,52]. In this framework, governance is conceived as the distribution of authority between state and non-state actors at multiple parallel levels [4,48].

The framework assumes a systemic relationship whereby its three major domains are interdependent and necessary for shale gas development, but among them governance comprises the elements that significantly affect the incentives in the interactions of the diverse stakeholders involved, which in turn affects the other two domains. According to this assumption, governance issues are then expected to influence the industry capabilities and credibility, to affect operations and recovery factors in the shale gas resource base, including the subset of resources with potential to be produced on a commercial scale. This influence on the industry's capabilities and the resource base has the potential to influence the conditions and extent of the access to shale resources and also to feed back into the social response and the political position towards

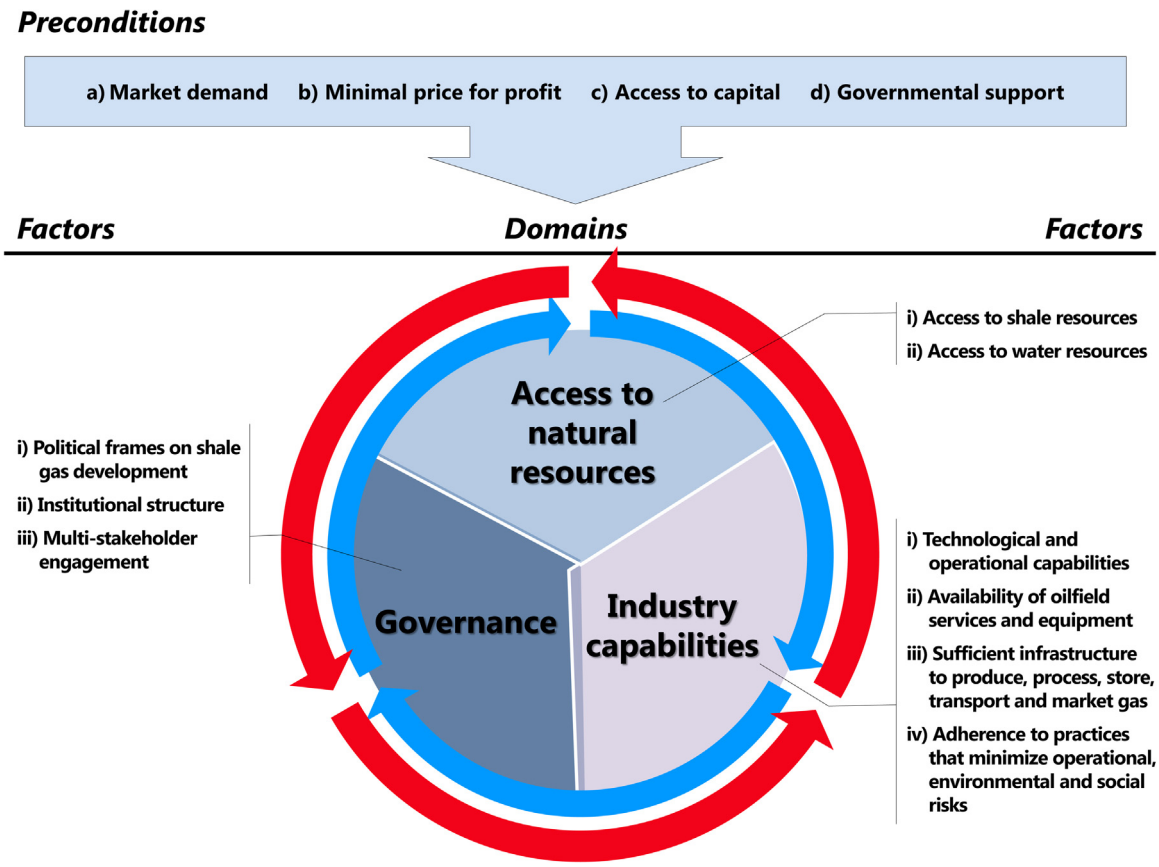

Fig. 1. Generic framework to assess shale gas development.

Source: Adapted from Ref. [6].

shale gas in the governance domain, either in the vein of a 'virtuous cycle' of interlinked positive effects leading to improved operations, enhanced recovery factors increased participation and social trust [32] or as a 'vicious cycle' that undermines the authority and expectations of stakeholders to prevent reciprocal agreements and spur radically opposing stances. Fundamentally, the factors in this domain converge with the position that shale gas can bring overall positive benefits if done responsibly through adequate governance mechanisms [5,27,52].

The design aims to make the framework widely applicable, while also keeping it sufficiently detailed to have an insightful analysis in which the relevant issues for a particular context fit in. Owing that the three major domains in the framework could be largely applicable to other type of energy and even non-energy undertakings, their subdivision into finer factors helps to account for contextual granularity specific to shale gas development. As the multiple risks of shale gas development are systemically linked with each other, the three domains in the framework influence and overlap each other, for which their respective factors may not be totally discrete, spanning more than one of these domains. As described in more detail below, a main premise in the framework is that a dynamic process permeates across its three domains whereby stakeholders perceive risks and react differently, depending on their set of values, information and expectations; their spatial, geographical and institutional context; and the iteration and evolution of their interactions over time [37,56].

It must be stressed that the framework is comprehensive but not exhaustive, which implies that it cannot include every possible element involved in the development of shale gas, for which some level of abstraction is inevitably necessary. Likewise, the framework only comprises those elements concerning shale gas development which a country can fairly influence or modify; in consequence, external variables such as geopolitical events or international price fluctuations lie beyond its scope, notwithstanding their relevance and influence. In addition, although the framework outlines the potential risks and interdisciplinary considerations in a broad array of contextual settings, its objective is to provide a consistent and holistic view of shale gas development, not to promote it. For the sake of clarity, Fig. 1 depicts a visual representation of this tripartite framework with its overlapping dimensions. The subsections below describe the interactions and finer factors in the tripartite framework.

3.1. Access to natural resources

The founding domain of the framework refers to the access to natural resources, which includes (i) the shale gas resources to be extracted, along with the (ii) water resources required to perform the required methods to produce the gas economically from the shale formations. In line with the multidisciplinary approach embedded in the framework, this notion of access transcends geophysical, technical and economic constraints to emphasize the legal right to extract shale and water resources, including the degree of control and the extent of access embedded [38]. This access is largely dependent on the political and institutional trade-offs in the governance domain described below.

This is a fundamental consideration, inasmuch as the existence of shale gas resources is a necessary, but not sufficient condition to their development whenever there are blanket restrictions to their extraction. Legal access explains why countries presumed to have a large shale gas potential such as France has declined to pursue the development of those resources due to legal restrictions.

These restrictions might be indirect, imposed on the use of water resources or on the deployment of certain production methods such as hydraulic fracturing. Thus, access to natural resources will vary in every country and even within the internal jurisdictions in a single country, largely because of political considerations; however, the framework acknowledges four essential preconditions to allow the development of shale resources.

These preconditions refer to (a) market demand, whether internal or external, to absorb the potential incremental gas supply; (b) a minimal price level at which massive shale gas production would become profitable and (c) access to capital, necessary to fund the activities associated, whether in the form of financial markets in free-market economies, public investments prevalent in command-driven economies or a combination of both. Another precondition refers to (d) governmental support in the form of subsidies, research programs, more accurate and publicly accessible geologic information or other incentives. On this last precondition, subsidies and incentives are deemed necessary to support the introduction of technologies widely available but not yet fully commercial for a certain geographic reach, at least until they reach a scale-up stage [54] and gain acceptance at the political, social and industry levels [30].

3.2. Industry capabilities

The profitability of companies producing shale gas hinges on their strategies to enhance knowledge, flexibility and cost-efficiency capabilities, to leverage the linkages with other external providers, and to effectively mitigate potential environmental and social risks in anticipation of the uncertain changes in the oil and gas markets. These characteristics are fairly reminiscent of the concept of 'dynamic capabilities' which firms deploys in order to sense their environment, seize potential business opportunities and adapt themselves adequately and timely to remain competitive [46].

The complexity embedded in the development of shale gas is calling for a new business model that demands more sophisticated technical and organizational capabilities with technological prowess, increased flexibility, cost-efficiency and competitiveness [7], especially under the recent period of continued low oil (and gas) prices. Industry capabilities thus determine the adaptability and potential timespans associated in the activity of producing shale gas. In some contexts, a legacy oil and gas industry will represent an advantage in terms of the existing wealth of human and physical assets that might be better adapted to the task of shale gas production, contingent on the quality and quantity of those assets and their experience in the commercial production of other type of unconventional gas resources or even in early stages of shale gas development.

In step with the critical role that technological applications and capabilities play in the production of shale gas [2,7], the industry capabilities domain encompasses four specific factors: (i) the industry's technological and operational capabilities, including an adequate workforce in terms of size and skills and the presence of international oil and gas companies with previous experience in the production of shale gas; (ii) the availability of providers of specialized oilfield services and equipment; (iii) sufficient infrastructure necessary to produce, process, store and transport the gas produced up to the markets; and (iv) the adherence to practices, including industry standards, to minimize the risks to industrial safety, to the environment and to local communities, in order to affect the way in which the general public perceives shale-gas-related operations.

Beyond economic criteria, the factors in this domain acknowledge that oil and gas firms looking for a sustained competitive advantage must legitimate their operations through a genuine commitment that balances their commercial profitability with the interests, perceptions and expectations from other stakeholders, in what is generally known as a 'social license' [41]. In line with the framework's premises, energy technology and infrastructure are conceived as socio-technical systems that involve, depend on, and evolve with the socio-economic context and the interests of the different stakeholders involved [30,47]. This means that potential technology progress allowing the eventual abandonment or reduction in the use of water, a necessary- and controversial-input in the development of shale gas, would certainly also affect the associated perceptions of risk and acceptance among stakeholders. These social perceptions pertain as well to the next domain.

3.3. Governance

The governance domain in the framework concerns the way in which different state and non-state stakeholders involved in the development of shale gas articulate their interactions and relationships based on their interests, expectations, benefits and risks over time and across contextual situations. Governance is critical because at heart, shale gas development is a political undertaking and creates asymmetrical benefits and risks in different spatial and temporal scales, leading to disputes among stakeholders which are guided by their respective 'narratives' or 'storylines', since facts and data are no longer relevant for them owing to their divergences in values, benefits, risk perceptions and reciprocal trust [8,23,37].

Accordingly, the governance domain encompasses three factors: (i) the political frames and their narratives regarding shale gas development at different levels; (ii) the institutional structure including the arrangements between owners and developers of shale gas, applicable regulations and legal issues; and (iii) a multi-stakeholder engagement. Implicit in this domain is a fair degree of political stability allowing polycentric governance, whereby the participation of empowered local communities in the management of natural resources is more appropriate due to their better knowledge of social and environmental risks and the government's ineffectiveness to act on behalf of the public interest due to moral, informational or intellectual reasons [40].

The first factor alludes to the position or frame of meaning devised by major stakeholder groups to help their own positions on shale gas dominate the public opinion for policy-making purposes. Because shale gas interlinks several scales of action (national, regional, local), plausible benefits and risks are perceived differently, producing mixed societal responses and irreconcilable conflicts that push stakeholders not to look for a rational dialogue, but rather to create their own views of what shale gas development is about, in order to impose those views with the aid of coalitions formed with other like-minded actors [11,23,49]. The aim evidently, is to increase the discursive dominance of these partisan views by creating compelling narratives that encourage large audiences to interpret shale gas development in just the same way.

To be successful, these narratives seek to connect to their audience values by building storylines that underpin certain arguments through selective meanings, evidences and sense of urgency, to be then delivered by trustworthy actors [37,61]. These narratives are usually antagonistic, conceiving on one hand shale gas as an 'opportunity' to bring benefits like energy security, reduced carbon emissions and economic growth, with typical supporters being the industry, governments and media. On the other hand, there are narratives of shale gas as a 'threat', which leverage the negative impacts on public health and the environment, mostly at the local level, although at a broader scale, they also argue that shale gas development locks-in economies into a higher use of gas that hinders the opportunities to expand renewable energy and introduce low-carbon energy systems. Typical supporters of this narrative include local communities, NGOs, the renewable energy industry and media [8]. Recent empirical research stresses for instance, that

contexts with prior oil and gas activities seem to be more favorable to the development of shale gas [61] and that a dominant industry voice in shale gas development, makes regulation lag behind [18]. Irrespective of the tone supported, a shale gas narrative is closely connected to the political position underlying the access to shale and water resources, which further reflects the cross-linkages among the framework's domains.

The second governance factor recognizes the different risks of shale gas over conventional gas in terms of the incumbent institutional arrangement rooted in a set of geophysical, economic, environmental, legal and social trade-offs that affect the distribution of costs and benefits [4]. This second factor includes the considerations that articulate the relationships between owners and developers of shale gas resources, as manifest in legal rights and fiscal regimes [38] along with the regulatory approaches to acknowledge and avoid the cumulative effects in several dimensions areas, most noticeably environmental [47].

The third and last domain factor refers to a permanent multistakeholder engagement that includes the efforts by shale gas companies to interact with local communities and influence their perceptions to gain (or lose) social acceptance. Also included are the governmental efforts to involve other stakeholders in the governance of shale gas development. Again, as per the framework's premises, these factors have strong links with others in the industry capabilities and access to natural resources domains.

Local communities are becoming more relevant in the governance of shale gas development, demanding meaningful information, decision-making and benefits; likewise, developing companies are increasingly aware of the favorable role that early social licenses gained through legitimacy, credibility and trust have in the mitigation of the business risks that social conflicts pose to operations, including delays and eventual project cancellations [11,41]. For governments, multistakeholder engagement in energy projects improves decision-making and risks mitigation in a more integrated and equitable manner [41,48] but demands in turn the governmental ability to empower those stakeholders and better manage of their expectations about risks, developers, processes and benefits [56]. A more inclusive governance of shale gas development, especially involving those whose voice is less likely to be heard, helps governments stay away from partisan narratives to strengthen their own political autonomy and credibility, and ultimately, avoid the 'coalmine canary effect' whereby unfulfilled social demands and excluded local communities will first impact a reduced number of local actors but eventually will expand and create much stronger social and environmental effects with broader implications (Willow, 2010 cited in Ref. [18]).

4. Case studies

In line with the notions on the multidisciplinary nature of shale gas development and the need to design a more consistent view of this activity across the world, this section presents three brief country cases analyzed with the framework presented in the previous section. The first criterion used to select Canada, China and Mexico as case studies referred to the inferred existence of shale gas resources in all of them as per EIA [16], the relative size of those volumes over the remaining countries assessed, as well as evidences of early shale gas development. To enhance the comparative analysis, the selection of Canada and Mexico responded to the assessment of countries within a single geographical region (North America), especially against their neighboring exemplar the United States. Canada and China were also selected as they represent some of the most advanced experiences of commercial shale gas production beyond the United States.

4.1. Canada

4.1.1. Access to natural resources

Canada has huge shale gas resources that put it at the fourth largest place worldwide [16], but because of the primary legal powers vested in the Canadian provinces, oil and gas issues differ across the country. Thus, this brief analysis centers on the western Canadian provinces of Alberta and British Columbia where shale and water resources have been accessible thus far under the competitive premises of a free market.

As for the preconditions to this domain, despite the continued low market prices since late 2014, commercial shale gas development has been underway in these provinces leveraging robust financial and capital markets, with province governmental support that encompasses incentives embedded in the royalty regime, as well as repositories that by legal mandate provide open access to an exhaustive inventory of geological samples collected across the provinces over decades, from nearly every well ever drilled [6]. Market demand is weak, however. The United States became the most important market for Canadian gas and the only one for exports, providing stable growth for decades, but due to the rising self-sufficiency of that country, Canadian natural gas production, especially of shale gas, greatly depends on finding other export markets overseas [35].

4.1.2. Industry capabilities

In these western Canadian provinces there is a long-established oil and gas industry that grew in deep integration with the United States market and which is also experienced in the production of other unconventional gas resources such as coalbed methane, tight gas and shale gas, that have rested on sufficient experienced personnel and oilfield service providers [42]. Infrastructure faces certain gaps concerning the age of some pipelines, but especially on the lack of lateral transport systems that connect these provinces with the rest of Canada, mostly due to the traditional focus on north-to-south gas transport flows from Canada to the United States [35]. In terms of the adherence to practices, industry associations and operators have progressively become more aware of environmental impacts, although the discussion of the full risks embedded continues, as supported by different levels of government, universities and research bodies [42,47].

4.1.3. Governance

While some Canadian provinces do not allow shale gas development and have current legal bans, the political position in the provincial governments of Alberta and British Columbia is clearly favorable to the development of shale gas. The significance of the oil and gas industry in the province economies in combination with the competitiveness between upstream gas projects on a global scale has tied provincial governments to offer attractive conditions for developers with the aim of keeping them operating in their jurisdictions, much at the expense of a powerful narrative stressing the macro-level benefits of shale gas development and providing dedicated fiscal measures to this activity contingent on the age, type and output of each well [18]. Given the institutional arrangement between the different levels of government, the oil and gas industry and its significance in the economic activity, and the rights granted to aboriginal groups like the First Nations, social and environmental risks are major concerns in shale gas development. In this regard, the legacy of oil and gas production in Alberta and British Columbia provided a wide scope of regulations; nevertheless, management of shale gas development risks is not comprehensive, and although specific regulations are in progress, studies suggest that the management of risks substantially lags behind actual projects, that enforcement and monitoring are loose, and that despite the consultation processes established in these regulations, many projects

started operations without the prior feedback of local communities to identify critical risks [42,45].

Due to these issues, communities and aboriginal groups in particular, perceive their engagement in consultations as superfluous, regulations as not enough demanding of the industry, and their demands and concerns as overlooked by authorities and regulators, who are increasingly sensed as deliberately favoring shale gas on the fear of losing the investments associated, much to the expense of social welfare [45]. More important, these issues have resulted in a serious distrust in the government which has triggered a proactive shift of decision-making whereby local First Nations groups in British Columbia are bypassing authorities to inform their concerns and negotiate current projects directly with developers, who in turn have responded favorably in their interest of securing a social license [18]. If not addressed efficiently, governance issues, could greatly block the advance of shale gas production in western Canada. What is more important is that these incidents seem to have eroded the credibility of the provincial governments and have prompted an emergent governance of shale gas development in which aboriginal groups are empowered and have shaped regulation proactively in the face of the regulatory gaps and ineffectiveness perceived.

4.2. China

4.2.1. Access to natural resources

China has the largest inferred resource base of shale gas in the world [16] and manifested its interest in shale gas from 2009. After significant technical and financial efforts, by the end of 2013, the Fuling field in southeastern Sichuan Basin entered the commercial stage of production [6]. A centralized economy, the majority of oil and gas operations in China are held by a few dominant national oil companies; however, in light of the complexity to produce shale gas at a large scale, the Chinese government has thus far conducted two tenders for the exploration of several shale gas blocks which were granted to Chinese private and state companies; and it has allowed a modest participation of international oil companies that include Shell from 2012 and BP from March 2016 to participate in the development of shale resources [14,39]. Currently, there is access to water resources for shale gas extraction, although many Chinese shale basins are located in arid and semi-arid regions with high water stress levels, and even in those regions with relatively more abundant water resources like the Sichuan basin, other competing human and agriculture needs pose a major risk to a larger scale of shale gas production [26].

Regarding the framework's preconditions to access these natural resources, energy sustainability and energy security reasons sustain a growing demand of natural gas and the efforts to increase domestic gas supplies. Funding of these projects is present mainly through the capital of Chinese development agencies and state-owned oil and gas companies, and producers enjoy a progressively decreasing subsidy to help them with the profitability of their operations [26]. The Chinese government has been fully supportive of shale gas through a broad array of initiatives that besides production subsidies have included ambitious production targets, research and development programs, special mineral status to shale gas, and international cooperation strategies to accelerate the production of these resources [54,64].

4.2.2. Industry capabilities

The Chinese gas industry is evolving to harness the technical challenges of shale formations, but to a large extent, it lacks the technological and operational capabilities to substantially increase the pace of production, in consideration of the drastically different geological properties of the Chinese shale formations against those in North America where current technologies were successfully proven [54]. Furthermore, none of the winners of the shale tenders had previous experience developing these resources [14]; and the combination of bold production targets with incipient regulations does not help to effectively manage the safety and environmental risks associated [29].

The Chinese industry is basically dominated by three vertically integrated national oil companies (CNPC, CNOOC and Sinopec) that hold most of the shale acreage and concentrate the capital, workforce, technology and infrastructure. In the practice, this impedes operators without ties to these three major owned companies from using common infrastructure like pipelines and prevents a richer technological exchange; by the end of 2012, state-owned companies held more than 85% of the Chinese oilfield services market, with international companies accounting for less than 5% [57]. Additionally, with the exception of Sichuan, the extension of China's gas pipeline network does not effectively connect potential shale producing basins and markets [21]. Adding up to this complexity, China's legacy oil and gas industry stretched into the production of other unconventional gas resources like coalbed methane since the late 1990s; however, production is still low, mostly because of several remaining challenges very similar to those of shale gas [63].

4.2.3. Governance

The central government's power and its omnipresence in the industry back the leading narrative to produce shale gas massively. China's rising energy needs and current coal use at approximately two-thirds of its primary energy supply have prompted a strategy to expand the use of natural gas, with the increased production of domestic gas resources being set to reduce its reliance on external supplies. Because of this, shale gas has become a priority in the governmental agenda, aided by the top-down nature of the Chinese institutional system and its authoritarian politics [57]. This shale gas narrative puts economic drivers ahead of environmental concerns, and has led the Chinese government to grant shale gas special 'independent mineral' status in 2011 in order to provide stronger economic support and foster the participation of private capital that rushes large-scale production [21,26]. China's institutional arrangement is also multi-layered, with numerous agencies overlapping or bypassing others at different administrative levels and blurring the distribution of risks and benefits among stakeholders, with central-made legislations that must be enforced by the provinces, which in turn greatly depend on the revenue and employment provided by national oil companies owned by the central government. This results in regulatory ambiguity which in combination with the lack of transparency in all the government levels leads to environmental risks being greatly overlooked, but most notably, stakeholder engagement, happens if at all, only when projects are operating and when environmental impacts are most likely to have occurred [21]. Along with this lack of meaningful engagement, some social protests were reported over the nuisances and environmental effects of the shale gas activity in Sichuan [14,29] and could grow if unattended.

4.3. Mexico

4.3.1. Access to natural resources

Mexico's potential shale gas resources are considered the sixth largest in the world, with formations that are shared with the United States [16]. Mexico is a remarkable example of access to shale resources and energy as a whole. For more than 75 years, the Mexican oil and gas industry remained strictly closed to nearly every form of private investment, carrying out all the activities in the oil and gas value chain exclusively through its monopolistic national oil company Pemex, but in 2013 an overhauling energy reform granted private operators legal access to produce oil and gas

along with Pemex, including the eventual development of shale gas resources through competitive tenders [38]. There is legal access to water resources to perform hydraulic fracturing, although Mexico's northeastern territory, where most shale gas activities are taking place, is arid and prone to droughts [33].

4.3.2. Industry capabilities

Mostly because of its long-lasting monopolistic structure, Mexico's oil and gas sector suffered from chronic underinvestment, overstaffing and financial pressures that seriously eroded the industry's capabilities and infrastructure, more so for the eventual development of unconventional resources like shale gas. Serious infrastructure bottlenecks like the 22 'critical alerts' in 2012 that asked consumers to curtail their natural gas consumption due to the saturated capacity in the main transmission pipelines [13] blocked an expanded use of gas, and although they triggered new pipeline projects, these will take some years more to come online.

4.3.3. Governance

Mexico's federal government built an official narrative that not only supported shale gas development but also, at a broader level, its overhauling 2013 energy reform. Aided by heavy media coverage, this narrative was notorious because the administration at the time touted the economic prosperity and game-changing effects from embarking on shale gas development, nearly taking for granted that once reforms were passed, Mexico would follow suit the shale gas experience of the United States, without any prior consideration of potential risks [13,33]. Shale gas activities led by Pemex commenced in 2010, and despite originally ambitious plans and the presence of international and domestic oilfield service companies in Mexico, by the end of 2014 only 17 shale wells had been drilled, most of them with mixed performance results [6]. Furthermore, by the end of 2015 no tenders had been yet conducted and in May 2016 it was announced that the unconventional resources (including shale gas) tender scheduled for that same year was further postponed, on the grounds of low oil prices and specific regulations still in progress [17].

In this regard, no fiscal regime specific to shale gas exists in Mexico as tenders have not yet occurred, although the new legal instruments provides an economic incentive in the form of a royalty exemption for non-associated natural gas whenever prices remain under USD 5 per million BTU [38]. Mexico's evolving regulations in shale gas development demand the institutional ability to enforce them effectively through a number of incumbent federal agencies that were created as a system of check and balances to increase transparency and avoid the deeply embedded corruption history in the oil and gas sector [31].

In Mexico, petroleum rights belong to the federation, for which states and local communities get no more benefits than economic spillovers. With the reform passed, the law now considers a small economic retribution to landowners from developers, but in parallel it grants oil and gas activities the highest priority over other land uses, which in the practice forces landowners to monetize their potential risks [6]. Although public consultation processes for oil and gas projects were also included in the laws, their importance is relegated, and social demonstrations could increase under a scenario of larger production, especially as tenders and actual development are further delayed and NGOs and local communities gain time to strengthen their actions and arguments to change the current governance and offset the government's narrative. Last but not least, key to sound shale gas governance is political stability, but organized crime activities, especially in the northeast Mexican territory where exploratory shale occurs [44], threaten the other key factors that support shale gas development, especially in the industry capabilities domain.

5. Conclusions and implications

Largely inspired by the game-changing experience of the United States and by the promise of sustaining larger gas consumption with expanded domestic supplies, many countries have pursued the development of shale gas, with modest results at best in few of them. As the academic study of shale gas development has either centered on specific dimensions for certain countries or on the experience on the United States, there is a fragmented scope that overlooks spatial and contextual variations and the interdisciplinary nature embedded in this activity.

In an analogy with a prism, the numerous risks underlying shale gas development are further amplified by the interrelations and perceptions of the different stakeholders involved, for which this paper proposed a holistic study in the form of a tripartite framework that condenses the systemic relationships of different factors pertaining to the domains of access to natural resources, industry capabilities and governance. The arguments in the framework converge with the position that the risks of shale gas development vary across actors, spaces, times and context; therefore, this activity entails diverse trade-offs that accommodate certain narratives, for which it is essentially a political undertaking.

While access and industry proficiency are fundamental to extract the gas from shale formations, it is governance, and particularly a multi-level inclusive governance, which is likely to significantly affect the incentives that bring about mutually beneficial outcomes for the stakeholders involved, which in turn affect the other two domains. This is critical since empirical experiences illustrate that whenever a narrative is imposed on those stakeholders who do not receive direct benefits but endure the risks, states can undermine their political autonomy and credibility and stir more antagonist positions. More important, in their narrative to deliberately favor shale gas in exchange for overall economic benefits at the expense of more vulnerable social groups, governments may fall prey of the 'coalmine canary' effect, undermining the risks involved and triggering much larger social and environmental impacts once shale gas development advances.

The decision to undertake the development of shale resources is in the end contingent on the particular actors, interactions and context involved, meaning that depending on the circumstances, the best collective decision may be not to undertake shale gas development at all, at least until there is a balanced, inclusive approach that results in the creation of economic opportunities while still protecting the land, environment and rights of local communities. In regions where shale gas is being produced commercially like western Canada, the dominant narrative imposed by provincial governments is showing that local and aboriginal communities are losing trust in regulators and empowering themselves as effective interlocutors with the industry, shaping regulations proactively. In China and Mexico, social and environmental issues could spur similar dynamics, especially if a unilateral narrative is not willing to listen to other voices.

Nevertheless, whenever shale gas development is pursued, the framework concurs with the position that it must bring net positive benefits to all stakeholders through appropriate governance mechanisms and meaningful dialogue that promote a socially and environmentally responsible production of these resources locally, while also looking for macro-level benefits associated to energy security and economic competitiveness.

The premises presented in this paper attempted to advance a common reference framework for the analysis and comparison of shale gas development around the world, and while this framework is only an initial approximation to capture the complexity surrounding shale gas development, it provides an interdisciplinary perspective with generic characteristics that ascertain the key domains and interactions involved, as well as those lying beyond

its control. The insights and empirical cases presented highlight the study of shale gas development as a fertile field for the convergence of several disciplines, with robust opportunities for an enlarged participation of social sciences. Hopefully, this study will instill more research that refines the framework's premises, in particular in countries other than the ones presented here, especially in those which have banned this activity. Ultimately, this paper could help policy-makers and countries across the world to understand the risks underlying shale gas development, and to devise more inclusive strategies with balanced governance approaches in those cases where political will is favorable to such goal.

Acknowledgment

The author expresses his deepest gratitude to three anonymous referees whose thorough and valuable insights improved this paper.

References

[1] R. Aguilera, M. Radetzki, The shale revolution: global gas and oil markets under transformation, Miner. Econ. 26 (3) (2014) 75–84.
[2] R.F. Aguilera, R.D. Ripple, R. Aguilera, Link between endowments: economics and environment in conventional and unconventional gas reservoirs, Fuel 126 (2014) 224–238.
[3] F. Al-Kasim, Managing Petroleum Resources. The 'Norwegian Model' in a Broad Perspective, Oxford Institute for Energy Studies, Oxford, 2006.
[4] P. Andrews-Speed, R. Bleischwitz, T. Boersma, C. Johnson, G. Kemp, S.D. Vandeveer, Want, Waste or War? The Global Resource Nexus and the Struggle for Land, Energy, Food, Water and Minerals, Routledge, New York, 2015.
[5] P. Andrews-Speed, C. Len, The legal and commercial determinants of unconventional gas production in East Asia, J. World Energy Law Bus. 7 (5) (2014) 408–422.
[6] APERC (Asia Pacific Energy Research Centre), Pathways to Shale Gas Development [Online], Asia Pacific Energy Research Centre, Tokyo, 2015.
[7] M. Binnion, How the technical differences between shale gas and conventional gas projects lead to a new business model being required to be successful, Mar. Petrol. Geol. 31 (1) (2012) 3–7.
[8] E. Bomberg, Shale we drill? Discourse dynamic in UK fracking debates, J. Environ. Policy Plann. (2015), http://dx.doi.org/10.1080/1523908X.2015.1053111.
[9] T.J. Centner, L.K. O'Connell, Unfinished business in the regulation of shale gas production in the United States, Sci. Total Environ. 476–477 (2014) 359–367.
[10] C.R. Clarkson, J.L. Jensen, S. Chipperfield, Unconventional gas reservoir evaluation: what do we have to consider? J. Nat. Gas Sci. Eng. 8 (2012) 9–33.
[11] M. Cotton, I. Rattle, J. Van Alstine, Shale gas policy in the United Kingdom: an argumentative discourse analysis, Energy Policy 73 (2014) 427–438.
[12] J.B. Curtis, Fractured shale-gas systems, AAPG Bull. 86 (11) (2002) 1921–1938.
[13] A. De la Vega Navarro, J. Ramírez Villegas, El gas de lutitas (shale gas) en México Recursos, explotación, usos impactos, Econ. UNAM 12 (34) (2015) 79–105.
[14] P. Deemer, N. Song, China's 'Long March' to shale gas production-exciting potential and lost opportunities, J. World Energy Bus. 7 (5) (2014) 448–467.
[15] EIA (Energy Information Administration), World Shale Gas Resources: an Initial Assessment of 14 Regions Outside the United States, United States Energy Information Administration, Washington, 2011.
[16] EIA (Energy Information Administration), Technically Recoverable Shale Oil and Shale Gas Resource: an Assessment of 137 Shale Formations in 41 Countries Outside the United States, U.S. Energy Information Administration, Washington, 2013.
[17] El Financiero, Postergan Ronda 1.5 Para áreas No Convencionales [Online], 2016, Available at: http://www.elfinanciero.com.mx/economia/postergan-ronda-para-areas-no-convencionales.html (accessed 08.05.16).
[18] K.H. Garvie, K. Shaw, Shale gas development and community response: perspectives from Treaty 8 territory, British Columbia, Local Environ. (2015), http://dx.doi.org/10.1080/13549839.2015.1063043.
[19] A. Goldthau, Rethinking the governance of energy infrastructure: scale, decentralization and polycentrism, Energy Res. Soc. Sci. 1 (2014) 134–140.
[20] M. Guarnone, F. Rossi, E. Negri, C. Grassi, D. Genazzi, R. Zennaro, An unconventional mindset for shale gas surface facilities, J. Nat. Gas Sci. Eng. 6 (2012) 14–23.
[21] N. Gunningham, A shale gas revolution for China, Clim. Policy 14 (2013) 302–320.
[22] J. Hays, M.L. Finkel, M. Depledge, A. Law, S.B.C. Shonkoff, Considerations for the development of shale gas in the United Kingdom, Sci. Total Environ. 512–513 (2015) 36–42.
[23] C. Hilson, Framing fracking: which frames are heard in English planning and environmental policy and practice, J. Environ. Law 27 (2015) 177–202.
[24] R. Holahan, G. Arnold, An institutional theory of hydraulic fracturing policy, Ecol. Econ. 94 (2013) 127–134.
[25] M. Hulbert, A. Goldthau, Natural gas going global? Potential and pitfalls, in: A. Goldthau (Ed.), The Handbook of Global Energy Policy, Wiley-Blackwell, West Sussex, 2013, pp. 98–112.
[26] D. Hu, S. Xu, Opportunity, challenges and policy choices for China on the development of shale gas, Energy Policy 60 (2013) 21–26.
[27] R.B. Jackson, A. Vengosh, W. Carey, R.J. Davies, T.H. Darrah, F. O'Sullivan, G. Pétron, The environmental costs and benefits of fracking, Annu. Rev. Environ. Resour. 39 (2014) 327–362.
[28] C. Johnson, T. Boersma, Energy (in)security in Poland the case of shale gas, Energy Policy 53 (2013) 389–399.
[29] A. Krupnick, Z. Wang, Y. Wang, Environmental risks of shale gas development in China, Energy Policy 75 (2014) 117–125.
[30] M. LaBelle, A. Goldthau, Escaping the valley of death? Comparing shale gas technology prospects to nuclear and solar in Europe, J. World Energy Law Bus. 7 (2) (2014) 93–111.
[31] A. Lajous, Mexican Oil Reform: The First Two Bidding Rounds, Farmouts and Contractual Conversions in a Lower Oil Price Environment, Columbia SIPA Center on Global Energy Policy, New York, 2015.
[32] A.M. Larson, F. Soto, Decentralization of natural resource governance regimes, Annu. Rev. Environ. Resour. 33 (2008) 213–239.
[33] J.R. Lozano Maya, The United States experience as a reference of success for shale gas development: the case of Mexico, Energy Policy 62 (2013) 70–78.
[34] J. Martínez de Hoz, T. Lanardonne, A. Máculus, Shale we dance an unconventional tango? J. World Energy Law Bus. 6 (3) (2013) 179–209.
[35] M.C. Moore, An Energy Strategy for Canada, University of Calgary—The School of Public Policy, Calgary, 2015.
[36] M.H. Nederlof, The scope for natural gas supplies from unconventional sources, Annu. Rev. Energy 13 (1988) 95–117.
[37] D.W. North, P.C. Stern, T. Webler, P. Field, Public and stakeholder participation for managing and reducing the risks of shale gas development, Environ. Sci. Technol. 48 (2014) 8388–8396.
[38] G.M. Nülle, Prospects for shale development outside the USA: evaluating nations' regulatory and fiscal regimes for unconventional hydrocarbons, J. World Energy Law Bus. 8 (3) (2015) 232–268.
[39] Oil and Gas Journal, BP, CNPC Ink Chinese Shale Gas PSC [Online], 2016, Available at: http://www.ogj.com/articles/2016/03/bp-cnpc-ink-chinese-shale-gas-psc.html (accessed 01.05.16).
[40] E. Ostrom, Understanding Institutional Diversity, Princeton University Press, Princeton, 2005.
[41] J. Prno, D.S. Slocombe, Exploring the origins of 'social license to operate' in the mining sector: perspectives from governance and sustainability theories, Resour. Policy 37 (2012) 346–357.
[42] C. Rivard, D. Lavoie, R. Lefebvre, S. Séjourné, C. Lamontagne, M. Duchesne, An overview of Canadian shale gas production and environmental concerns, Int. J. Coal Geol. 126 (2014) 64–76.
[43] S.L. Sakmar, The Global Shale Gas Initiative: will the United States be the role model for the development of shale gas around the world? Houst. J. Int. Law 33 (2) (2011) 369–417.
[44] Seelke, C., Villarreal, M., Ratner, M., Brown, P., 2015. Mexico's oil and gas sector: Background, reform efforts and the implications for the United States. Congressional Research Service.
[45] K. Shaw, S.D. Hill, A.D. Boyd, L. Monk, J. Reid, E.F. Einsiedel, Conflicted or constructive? Exploring community responses to new energy developments in Canada, Energy Res. Soc. Sci. 8 (2015) 41–51.
[46] A. Shuen, P.F. Feiler, D.J. Teece, Dynamic capabilities in the upstream oil and gas sector: managing next generation competition, Energy Strategy Rev. 3 (2014) 5–13.
[47] M. Small, P. Stern, E. Bomberg, S. Christopherson, B. Goldstein, A. Israel, R. Jackson, A. Krupnick, M. Mauter, J. Nash, D. North, S. Olmstead, A. Prakash, B. Rabe, N. Richardson, S. Tierney, T. Webler, G. Wong-Parodi, B. Zielinska, Risks and risk governance in unconventional shale gas development, Environ. Sci. Technol. 48 (2014) 8289–8297.
[48] B.K. Sovacool, An international comparison of four polycentric approaches to climate and energy governance, Energy Policy 39 (2011) 3282–3844.
[49] B.K. Sovacool, Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking), Renew. Sustain. Energy Rev. 37 (2014) 249–264.
[50] B.K. Sovacool, What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda, Energy Res. Soc. Sci. 1 (2014) 1–29.
[51] B.K. Sovacool, S.E. Ryan, P.C. Stern, K. Janda, G. Rochlin, D. Spreng, M.J. Pasqualetti, H. Wilhite, L. Lutzenhiser, Integrating social science in energy research, Energy Res. Soc. Sci. 6 (2015) 95–99.
[52] B.K. Sovacool, V. Vivoda, Enhancing the energy security and governance of shale gas Oil, Gas Energy Law Intell. 12 (3) (2014) 1–35.
[53] P. Stevens, The 'Shale Gas Revolution': Hype and Reality, Chatham House, London, 2010.
[54] L. Tian, Z. Wang, A. Krupnick, X. Liu, Stimulating shale gas development in China: a comparison with the US experience, Energy Policy 75 (2014) 109–116.
[55] F. Umbach, The unconventional gas revolution and the prospects for Europe and Asia, Asia Eur. J. 11 (3) (2013) 305–322.
[56] G. Walker, P. Devine-Wright, J. Barnett, K. Burningham, N. Cass, H. Devine-Wright, G. Speller, J. Barton, B. Evans, Y. Heath, D. Infield, J. Parks, K. Theobald, Symmetries, expectations, dynamics and contexts: a framework for understanding public engagement with renewable energy projects, in: P.

Devine-Wright (Ed.), Renewable Energy and the Public: From NIMBY to Participation, Earthscan, New York, 2011, pp. 1–14.
[57] Z. Wan, T. Huang, B. Craig, Barriers to the development of China's shale gas industry, J. Clean. Prod. 84 (2014) 818–823.
[58] Q. Wang, X. Chen, J. Awadesh, H. Rogers, Natural gas from shale formation—the evolution, evidences and challenges of shale gas revolution in the United States, Renew. Sustain. Energy Rev. 30 (2014) 1–28.
[59] Q. Wang, R. Li, Natural gas from shale formation: a research profile, Renew. Sustain. Energy Rev. 57 (2016) 1–6.
[60] Z. Wang, A. Krupnick, A Retrospective Review of Shale Gas Development in the United States. What Led to the Boom? Resources for the Future Resources for the Future, Washington, D.C, 2013.
[61] L. Whitmarsh, N. Nash, P. Upham, A. Lloyd, J. Verdon, M. Kendall, 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 (2015) 419–430.
[62] H.J. Wiseman, The capacity of States to govern shale gas development risks, Environ. Sci. Technol. 48 (2014) 8376–8387.
[63] Z. Xingang, K. Jiaoli, L. Bei, Focus on the development of shale gas in China—based on SWOT analysis, Renew. Sustain. Energy Rev. 21 (2013) 603–613.
[64] J. Yuan, D. Luo, L. Xia, L. Feng, Policy recommendations to promote shale gas development in China, Energy Policy 85 (2015) 194–206.