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Sustainability lessons from shale development in the United States for Mexico and other emerging unconventional oil and gas developers

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ABSTRACT

Mexico's recent energy reform (2013) has provided the foundations for increased private participation in attempts to offset or reverse the country's continued decline in fossil fuel production. This country is currently on path to becoming a net energy importer by 2020. Conversely, in 2015, and for the first time in over 20 years, the United States (US) became a net oil exporter to Mexico. One of the strategies being pursued by Mexico to prevent an impending supply–demand energy imbalance is the development of shale resources using horizontal drilling and hydraulic fracturing techniques. Hence, an evaluation of the inherent risks associated with hydraulic fracturing is crucial for Mexico's energy planning and decision-making process. This paper draws lessons from the recent 'shale boom' in the US, and it analyzes and summarizes the environmental, social, economic, and community impacts that Mexico should be aware of as its nascent shale industry develops. The analysis seeks to inform mainly Mexican policy makers, but also academics, nongovernmental organizations, and the public in general, about the main concerns regarding hydraulic fracturing activities, and the importance of regulatory enforcement and community engagement in advancing sustainability. Furthermore, using the US as a case study, we argue that development of unconventional oil and gas resources in Mexico could lead to a short-term boom rather than to a dependable and sustainable long-term energy supply. Our analysis concludes with a set of recommendations for Mexico, featuring best practices that could be used to attenuate and address some of the impacts likely to emerge from shale oil and gas development.

1. Introduction

With the advent of hydraulic fracturing (fracking), the use of natural gas has increased considerably. As a result of the 'shale boom' in the United States (US), and the development of new fracking technology, other countries such as China, the United Kingdom, Turkey, Argentina, and Mexico are all evaluating the potential for exploitation of their indigenous shale resources [1–4] In 2013, the US became the largest producer of natural gas, which has led to some of the cheapest natural gas and oil in over two decades [5]. It is estimated that by 2020 the US will be producing 4.8 thousand barrels per day (4.8 mb/day), which will continue to support the growth of fossil fuel supply from regions not part of the Organization of Petroleum Exporting Countries (OPEC) [6]. While shale exploitation can provide some short-term localized economic benefits for resource-endowed nations, evidence from the US suggests these might be accompanied by a variety of environmental, social, and community-related problems [7]. Hence, the objectives of this paper are to shed light on the impacts of hydraulic fracturing, and to provide recommendations for best practices for consideration by Mexican policy makers as they endeavor to succesfully regulate this industry. We summarize the literature that explores these impacts and the best practices adopted in the US for their mitigation, while evaluating this information in the context of Mexico's desire to exploit its own shale resources.

In the US, the advent of hydraulic fracturing combined with horizontal drilling has changed the oil and gas industry dramatically [7]. Since 2008, the US has increased its production of oil and natural gas by almost 85 billion m^3/year, and crude oil by over 3 million barrels/day [10]. There are indications the US has received short-term localized economic benefits in areas of shale development. Communities sited near shale operations have experienced increases in employment, salaries, and per capita income during the initial stages of such operations [9]. However, the economic instability associated with price volatility and the panoply of environmental, social, and community impacts that emerge due to shale

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development, complicate decision-making processes over whether unconventional oil and gas resources should be developed fully. Massive land clearing, water consumption, waste management issues, community impacts, and emissions of greenhouse gases and volatile organic compounds (VOCs) are only some of the many concerns that surround the exploitation of unconventional resources [10].

The rapid rise in drilling activity together with the adoption of new drilling methods in the US has meant that regulations have been slow to catch up [11]. Consequently, controversy arose over whether the existing oil and gas regulatory structure was sufficiently robust to avoid severe environmental impacts and to protect public health [12]. In effect, the existing rules and regulations were insufficient for these purposes. However, the Federal Government largely avoided the problem and it was left to the states to fill the regulatory gap, which has resulted in the implementation of different regulatory approaches for hydraulic fracturing across the US [13].

In the US, industry and operators have compiled considerable information regarding hydraulic fracturing processes, but they have usually been unwilling to disclose it given trade-secret concerns and the competitive benefits they derive from such practices [14]. Recently, academics, nongovernmental organizations (NGOs), and the government have all begun developing research to address the information asymmetry that exists between developers and the public.

1.1. Brief history of hydrocarbon development in Mexico

Mexico began intensive development of its hydrocarbon resources in 1904 [15]. At the turn of the 20th century, foreign oil companies, mainly from the United Kingdom and the US, commenced significant operations that led to Mexico becoming the second-largest oil producer in the world by the 1920s [16]. In 1938, President Lazaro Cardenas expropriated all the assets of the foreign oil companies operating in Mexico at the time. This action was prompted by constant threats from these foreign companies to leave the country and take their capital if the government forced them to sign a collective agreement with the "Petroleum Workers Union of Mexico," which, among other things, demanded fair working conditions for the employees of the foreign companies [17]. The rationale advanced by the government was that oil, as an energy source, belonged to "all Mexicans," and as such, government entities alone should exploit them for the sole purpose of benefiting the country [18]. Nevertheless, "Petroleos Mexicanos" (PEMEX), continued to engage in service contracts with some US oil companies until a 1958 regulatory law implementing Article 27 of the Mexican constitution definitively banned the practice [16].

During the 1980s, PEMEX consolidated and became one of the main contributors to Mexico's public finances, providing around 30% of the Federal Government's total income [19]. This was achieved largely because of the discovery in 1979 of Cantarell, the world's third largest oilfield at the time (just behind the Ghawar and Burgan oilfields of Saudi Arabia and Kuwait). This newfound bounty came with promises of jobs, technological development, commitment to industrialization, and sustainable city building. Above all, Lopez Portillo (and his team of experts) stressed that this windfall of wealth would be reinvested in Mexico to guarantee a future "beyond oil." However, it took just 24 years for Cantarell to reach peak oil status. By 2004, Mexico's largest oilfield had reached its maximum rate of petroleum extraction, after which it entered a state of terminal decline [20,21].

Since its peak in 2004, Mexico's total oil production has declined by 27%. In 2014, Mexico produced an average of 2.8 million barrels/d of petroleum and other liquids, crude oil accounted for 2.4 million barrels (87% of the total output), with the remainder attributable to lease condensate, natural gas liquids, and refinery processing gain. Notably, crude oil production in 2014 was at its lowest level since 1986 and it has continued to decline [22]. This is evidenced by the fact that during 2015 the US became a net exporter of oil to Mexico, a situation that had not happened for over 20 years [23].

1.2. Current state of shale development in Mexico

The decline in hydrocarbon production has spurred support for the development of Mexico's unconventional resources as a means of reversing the situation. In 2011, the US Energy Information Administration reported that Mexico has the second-largest shale gas potential in Latin America and the fourth largest globally. With technically recoverable shale resources estimated at 545 tcf of natural gas, and 13.1 billion barrels of oil and condensate, Mexico's unconventional resources are potentially larger than its proven conventional reserves [24].

According to a public information petition made to PEMEX in 2014, at least 924 wells have been fractured hydraulically in Mexico since 2003 [25]. These wells are in the states of Coahuila (47 wells), Nuevo León (182 wells), Puebla (233 wells), Tabasco (13 wells), Tamaulipas (100 wells), and Veracruz (349 wells). However, the "Proyecto Aceite Terciario del Golfo: Primera Revisión y Recomendaciones" document (prepared in 2010 by the Mexican Ministry of Energy and National Hydrocarbons Commission) stated that 1323 wells have been fractured hydraulically in the specific areas of "Paleocanal" and "Chicontepec" in Veracruz and northern Puebla [26]. This inconsistency highlights the urgency for transparency in information, while illustrating the pressing need for a comprehensive regulatory framework aimed at protecting the local communities and the environment.

2. Lessons from hydraulic fracturing operations in the US

In this section, we provide a review of the literature and an analysis of the panoply of impacts associated with hydraulic fracturing in the US. Land impacts, atmospheric impacts, water impacts, community impacts, public health concerns, crime considerations, waste management, and administrative and environmental violations are evaluated.

2.1. Land impacts and issues

Oil and gas drilling activities require extensive use of land [27]. Hence, the primary major environmental impact of unconventional oil and gas development is associated with the requirement for land. This is estimated to be roughly 30,000 m^2 per well pad, including roads and associated infrastructure (i.e., equivalent to about seven football fields placed together) [28].

Hydraulic fracturing sites often intrude into forested land, agricultural land, and grassland [29]. Deforestation associated with this intrusion has been found to cause loss of habitat for animals and plants, and to increase the impacts of climate change because of associated land use changes [29].

The total infrastructure requirements are a function of the number of well pads and the size of the overall development; thus, the total impact is determined by the total number of well pads in a play [30]. In addition to direct impacts related to land clearance, there might also be indirect effects on ecosystems near the affected area due to the "edge effect" [31]. This edge effect relates to an ecosystem reducing its spatial "buffer zone" as a shale development encroaches.

Apart from issues associated with land clearance, spills of toxic hydraulic fracturing fluids can have severe environmental impacts in neighboring areas. Adams [32] focused on simulating a spill of hydraulic fracturing fluid in an experimental forest. This study found the forest experienced significant mortality: "Two years after fluid application, 56% of the trees within the fluid application area were dead."

In lieu of permanent infrastructure, many operators dig pits in the ground, line them with plastic or vinyl sheets, and use them to store water both before and after the hydraulic fracturing activity [33]. These pits can leak and subsequently kill aquatic life [34]. In addition to the massive volumes of fluids stored on site, chemicals and other additives