SHALE GAS EXPLOITATION IN MEXICO: SOME TECHNICAL CHALLENGES

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ABSTRACT

The energy reforms which have taken place in December of 2013 in Mexico allow foreign companies for the first time since the nationalization of the oil in 1938 to operate in the exploration and production stage of hydrocarbons. This reform will allow them to tap deep water oil and shale gas, both of which until the moment have only just been explored by the national oil company PEMEX. The experiences of shale gas exploitation from other countries have been studied to carry out an analysis of the measures needed in Mexico to develop shale gas in a responsible and environmentally friendly manner. It also sets out the areas which need special attention due to the particular social and legal conditions which are present in Mexico.

KEYWORDS

Shale gas; Mexico; Infrastructure.

NOMENCLATURE

CFE : Comision Federal de Electricidad

CENEGAS : Centro Nacional de Control de Gas Natural

EIA: Energy Information Administration

OECD: Organisation for Economic Co-operation and Development

OPEC: Organization of Petroleum Exporting Countries

PEMEX: Petroleos Mexicanos

TDS: Total Dissolved Solids

TSS: Total Suspended Solids

SEMARNAT: Secretaria de Medio Ambiente y Recursos Naturales

INTRODUCTION

The first well for shale gas extraction was drilled in the United States in 1821 in, New York, U.S. The amount of gas recovered was small since the wells were vertical and where in contact with small portions of shale. These gas quantities were insufficient in comparison to conventional wells and therefore no further investment was carried out since it was not commercially viable. Certain events encouraged the U.S to pursue and develop other energy sources in order to achieve energy independence. In 1979 there was a change of regime in Iran, the Monarchy was replaced by a Republic and during this transition a strike in their oil industry stalled production which led to an oil crisis worldwide. The absence of Iranian oil led to much speculation and fear which fuelled the cancelation of oil contracts and cause general panic. OPEC also used this opportunity to increase the price of oil, the price of a barrel of Saudi Arabian oil increased from $13 to $34 during that time. The U.S. was very dependent on Iranian oil and was affected by the prices and lack of oil, all of which hit their economy provoking long queues for cars to fill their tanks with public discontent. This was already the second oil crisis the U.S. had suffered, thus making them realised they could not rely on a foreign supply of energy for their domestic needs. Hence they decided to work towards an energy independence agenda. As a result of the energy crisis, the U.S. senate passed the Crude Oil Windfall Profit Tax Act in 1980; it provided tax credits for the production of unconventional fuels which in turn encouraged investment on behalf of companies. At the same time Research and Development programmes were started which led to three main technological innovations. The first one was horizontal drilling which permitted a better access to the shale rock strata. In second place fracturing methods were greatly studied and improved in order to break the rock and release the natural gas. Finally, the last most relevant improvement was the creation of a 3-D seismic imaging system to visualise the fractures which had been created and the precise location where the gas was coming from thousands of metres underneath the surface [1].

The successful development of shale gas in the U.S. and the proximity to its southern neighbour has awakened an interest on behalf of the Mexican government which hopes to make good use of the resource as has been done on the other side of the border. The reforms approved in Mexico on December 2013 are the first step to diversify the domestic energy mix and develop the sector with contribution from the private sector. For the first time since 1938 the participation of individuals will be allowed in the areas of exploration and production with new types of contracts. The energy market in Mexico will change, more deep-water oil will be available, gas from shale will be explored and produced and the electric grid connectivity will be improved in order to harness renewable energy sources which tend to be far from consumption areas. It is predicted that the reform will have a positive impact on the country and its population. Jobs will be created, the infrastructure expanded, an influx of new technology will arrive and less expensive oil, gas and electricity will contribute towards building a more developed, energy independent country.

These are amongst some of the reasons because it is so important for Mexico to develop a reliable energy basis on current resources, especially with the development of shale gas systems. However, how these developments and legislations will impact on the revenues and usage of the resources, reaching all population, is still the big debate that needs to be solved.

Shale Gas

Shale is one of the most common types of sedimentary rocks; they have been formed by the deposition of different sediments and as a result vary in colour from red to green or black and in properties. Their two main characteristics are their very low porosity and their laminations. The latter means they can very easily be broken into layers. In the last couple of decades a specific type of shale has been identified for its capacity to produce high quantities of natural gas and/or oil, they are referred to as an organic rich shale. High levels of organic matter and low levels of oxygen are the main requirements for this type of rock to be created. The organic matter is deposited gradually and as the time passes more material accumulates which then results in an increase in pressure and temperature. This process is called lithification and means the sediments are transformed into rock under these conditions over a long period of time. During this process the organic material is transformed into kerogen, which resembles a type of wax like material. Kerogen is formed through a process called diagenesis which occurs when organic compounds such as humin and other organic acids, lipids, proteins and carbohydrates are broken down with heat and pressure to form geopolymers which are long hydrocarbon chains [2].

Hydraulic fracturing is the most widely used method to fissure shale to permit the release of gas. Hydraulic fracturing consists of several stages and the number of stages depends on the composition of the shale. Sometimes certain minerals need a specific treatment to improve the extraction method. Usually, the first stage consists of inserting an acid solution which involves a mix of water with a dilute acid that could be either muriatic or hydrochloric. By inserting this into the wellbore it will dissolve the natural carbonate minerals present and thus creates fissures, also clearing any debris present. The second stage is to inject several thousands of litres of slick water. It is generally composed of water and different chemicals such as biocide (to prevent the growth of bacteria which may foul the system), a scale inhibitor (which allows the carbonate and sulphate minerals to remain in suspension in the mixture), iron control agents such as citric or hydrochloric acid (in order to prevent iron from precipitation of iron compounds), friction reducing agents (to reduce the pressure needed to pump fluid into wellbore and the tubular friction), and corrosion inhibitors (used to prevent corrosion of the steel well casing). The slick water is then pressurized with pumps at the surface and subsequently the fracturing of the shale begins; the rock underneath breaks. Sometimes there is a previous stage to increase the size of the fractures created during the pressurization, which consists in using explosives which are detonated at regular intervals in the layer of shale. The third stage consists of a pumping down into the well a fluid with proppant. This refers to any material such as sand or ceramic which can keep the fractures open in order to allow time for the gas to flow. The final step consists of a volume of fresh water to flush the surplus proppant [3].

There are other methods to perform fracking [5]. However, these will not be considered for this paper

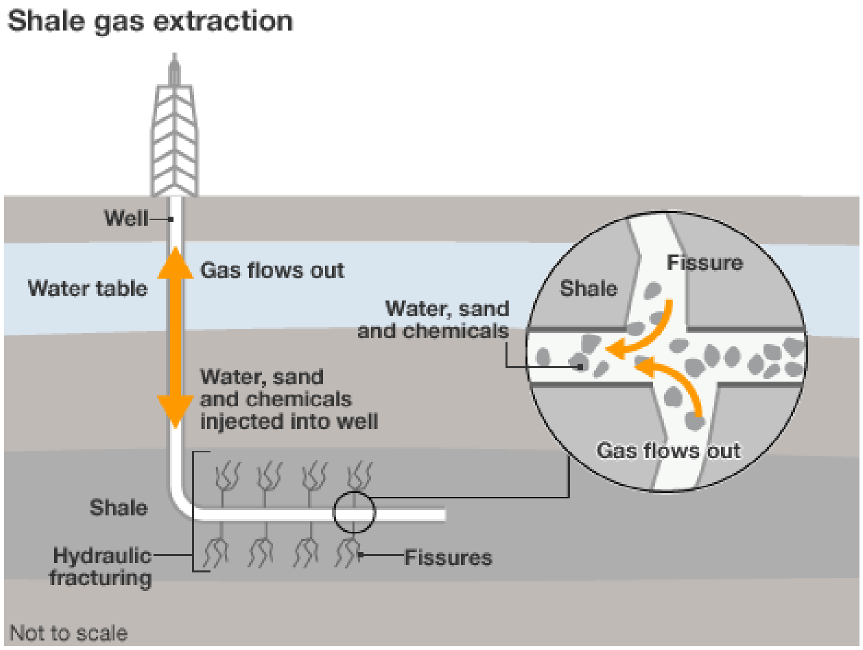

Fig. 1. Shale gas extraction. Fracking [4].

Mexican Situation

For Mexico, the extraction of shale gas needs a deep study regarding its impacts on environmental, technical and social aspects, looking for efficient and prosperous benefits out of the extraction and usage of the resource. The shale gas potential of Mexico has been studied by the Energy Information Administration (EIA) of the U.S., the Advanced Resources International company and PEMEX, all concerned with the viability of the shale wells drilled. Until now the technically recoverable shale gas resources are close to 545 trillion cubic feet (Tcf) which places Mexico in sixth place behind China, Argentina, Algeria, U.S. and Canada. With regards to the shale oil reserves Mexico also occupies an important place, with the 7th largest reserves [6].

The location of the known and explored reserves can be seen in Fig. 2. As it can be appreciated they are close to areas which are also known to have traditional oil and gas fields. The north of Mexico is probably a continuation of the U.S. Eagle ford formation where shale gas is also extracted. Mexico has mostly marine deposited shale which until now has shown to possess good qualities and have the ability to produce gas. However in comparison to the U.S. their structure is more complex. For instance in most parts of Texas the shale strata have a minor inclination with respect to the surface; however the shale close to the Gulf of Mexico is narrower, with more discontinuities and generally of a less consistent structure. These characteristics are also consistent with the topography of the region of the Sierra Madre Mountain while the coastal plain has been compressed, creating uneven subsoil strata [7].

Fig. 2. Potential Shale Basins in Mexico [7].

Challenges

As previously seen, Mexico is a country with extremely rich shale resources. Although the shale can be easily extracted compared to other regions such as Europe, there are still some difficulties that need to be considered as follows.

Water. Water is employed during the hydraulic fracturing process; the amounts vary according to the geology and properties of shale. In a single drill site between 11,000 to 19,000 m3 of water may be needed. In the U.S. it is sourced from rivers and creeks or bought directly from the local water company. For shale gas production in Mexico it is important to understand the availability of this resource. Close to eighty million cubic metres of water are used every year in Mexico. The consumption of water is broken down into the following sectors: 77% for agriculture, 14% for public consumption, 4% for self-supplying industry and 5% for power stations. The public consumption includes human use and certain industries which are connected to the water distribution system. The self-supplying industries are mainly mining, electricity generation, construction, manufacturing industries and oil and gas extraction [8-9].

Mexico is divided into hydrological administrative regions, Fig. 3, and each one rated according to the availability of this resource. It is possible to see that large areas in the country suffer from high water stress which means the sources are becoming depleted. The north coincides both with areas of shale gas potential, Fig. 2, and low water availability [10].

Fig. 3. Water stress in Mexico [10].

The scarcity of water in certain regions has pushed the Comision Nacional de Agua (CONAGUA) to identify which areas will not be exploited in order to allow the replenishment of underground aquifers. Some of these areas also coincide with shale gas potential areas which limits the options for shale companies, Fig. 4. Thirty-seven percent of the water used in Mexico comes from underground sources. The new companies entering the shale gas market will have to comply with the water regulations both for the sourcing of water and for its treatment. PEMEX has its own water treatment facilities for the water used in exploration and production of hydrocarbons with considerable investment to clean crude oil and gas [11].

Water treatment is another important parameter. In the U.S., the Josephine Brine Treatment facility has been functioning for several years to clean up waste water from fracking. After 2 years of analyses, it was found that the water quality and sediments downstream the injection point were lower than those observed upstream the plant. Therefore, it was concluded that municipal water treatment plants cannot cope adequately with the cleaning up of waste water from fracking. This is a point that needs to be considered for the infrastructure required to exploit the resource in Mexico [12].

Chemical injection: Some of the chemicals used in the U.S. are mentioned in Table 1. When companies refuse to disclose information about their chemical mixtures a general distrust is generated among the public. It is vital this information is available for everyone to consult since these chemicals may be spilled in the environment in the case of an accident [13]. Thus Mexican regulations need to ensure this is accomplished.

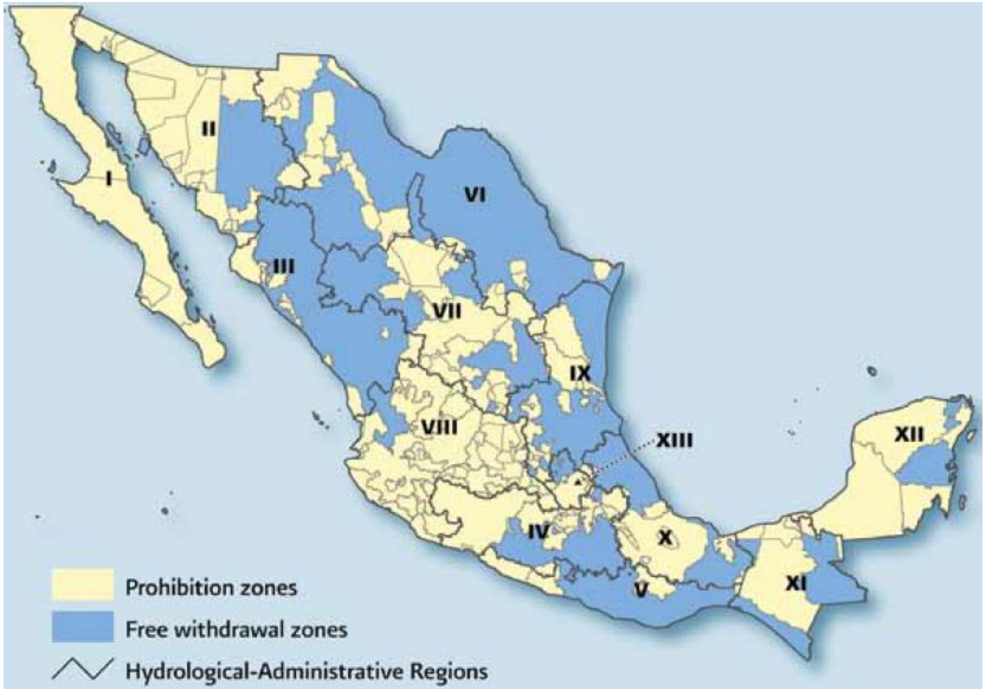

Fig. 4. Prohibited areas of underground water extraction [10]

Table 1. Chemicals commonly used in fracking [14].

Additive	Chemical Ingredient	Purpose
Acid	Hydrochloric acid or muriatic Acid	Helps dissolve minerals and initiate cracks in the rock
Antibacterial agent	Glutaraldehyde	Eliminates bacteria in the water that produce corrosive by-products
Breaker	Ammonium persulfate	Allows a delayed breakdown of the gel
Corrosion inhibitor	Formamide	Prevents the corrosion of the well casing
Crosslinker	Borate salts	Maintains fluid viscosity as temperatures increase
Friction reducer	Petroleum distillate	"Slicks" the water to minimize friction
Gel	Guar gum	Thickens the water in order to suspend the sand
Iron control	Citric acid	Prevents precipitation of metal oxides
Clay stabilizer	Potassium chloride	Creates a brine carrier fluid that prohibits fluid interaction with formation clays

pH adjusting agent	Sodium/potassium carbonate	Maintains the effectiveness of other components, such as crosslinkers
Proppant	Silica, quartz sand	Allows the fractures to remain open so the gas can escape
Scale inhibitor	Ethylene glycol	Prevents scale deposits in the pipe
Surfactant	Isopropanol	Used to reduce the surface tension of the fracturing fluids, to improve liquid recovery from the well after the fracking.

Air pollution. Once the well has been drilled and the hydraulic fracturing performed, some of the natural gas produced in the well is burned through a process called flaring. This is a common practice in Mexico during maintenance problems or emergency situations. In the U.S., this has raised many concerns about the need to be adequately prepared to process the gas. According to the legislation during the first year companies are allowed to flare in order to help them establish they production cycle. However, they are obliged to pay an amount equivalent to the tax they would be paying if the gas had been marketed from their second year onwards. It is highly important to note that even if methane is not being released, carbon dioxide is and this contributes to climate change too. The economic value of the gas has also being completely lost and wasted if it is not sold in the market. Mexico needs an appropriate policy on how to deal with flares and first steps of extraction to avoid large amounts of emissions and loss of methane gas [15].

Geological leakage. The way in which the methane can migrate from its origin into the aquifers is diverse and still not fully understood. These leakages can increase up to 17 the amount of dissolved methane in the water [16]. It is has been argued that due to hydraulic fracturing the fissures created could extend upwards a considerable distance and allow the methane to migrate directly into an acquirer. However this possibility is very small since the distance between the aquifers and the shale is very long, at least a couple of kilometres and would require extremely high pressures for fracturing. A second option for possible methane leaks is the well casing which may present cracks and permit the flow of methane. It is very likely that the main reason for this relation is faulty cement lining or leaks at joints between the steel tubes.

Radiactivity. There are probabilities of existence of Naturally Radioactive Occurring Material (NORM) in shale gas reservoirs. These elements are located inside the shale rock and rise to the surface with the liquid. In the U.S. the Environmental Protection Agency (EPA) has set its own permissible limits for water intended for human consumption and Mexico has certain overall radiation levels set too, Table 2. The radioactivity should be measured at all times in the flowback and if it needs treatment the facilities have to be designed to cope with this in order to release back into the aquifers water within the permissible standards. Some debris from the well will also contain low levels of radiation, disposal is very important to avoid its migration. Therefore, approved landfills with lining have to be built in order to cope with the incoming waste from this industry. In Mexico, if this activity is not regulated adequately the debris may be left unattended and water may come in contact with the material and make the elements mobile, thus increasing radioactivity in the natural surroundings.

Table 2. Permissible levels of radioactivity in drinking water in U.S. and Mexico [17]

Radionuclides	Maximum concentration level in US	Maximum concentration level (picoCuries/litre) in Mexico
Gross Alpha Emitters	15 picoCuries per liter	15.13
Beta Particle and Photon Radioactivity	4 millirems per year	-
Radium 226 and Radium 228 (Combined)	5 picoCuries per liter	-
Uranium	30 micrograms per liter	-
Gross Beta Emitters	-	50

Seismicity. Earthquakes have been reported to occur as a direct result of hydraulic fracturing by local residents. For instance on the 1st of April 2011 a 2.3 tremor on the Richter scale was measured in Lancashire, England, very close to where the company Cuadrilla was extracting shale gas. The independent report concluded that it was highly probable the earthquake was caused by the hydraulic fracturing. It does specify that the local geological conditions where very important factors which triggered the tremor and the report also predicted that in the future the worst case scenario taking into account this geological information would cause seismic events of 3 on the Richter scale [18]. One of the major problems in Mexico is that half of the country runs next to some of the biggest faults in the world (St. Andreas and the Coco and Caribbean plate). Therefore extensive studies are needed before shale is recovered in shale gas rich regions close to these faults.

Infrastructure. The first issue companies will have to address is obtaining the water and the second one will be to treat the flowback produced. The total amount of dissolved solids in this flowback are very high and therefore require more sophisticated equipment to remove the contaminants. However, the necessary infrastructure to treat water which could come from shale extraction activities is not currently present and new plants would have to be built. Several facilities would be necessary in order for them to be at a reasonable distance from drilling pads to ensure it is cost effective. Transportation of the gas is another important challenge. Mexico has planned to increase the networks of pipelines due to the growing demand of natural gas and the construction of new combined cycle power plants. For the short term there is currently a gas line being built from the U.S. to Mexico in order to import cheap gas. Furthermore, there are planned gas pipes to be developed at the centre and the North West regions of the country, Fig. 5 [19]. These new pipelines should have sufficient capacity to expand the market and in the future take shale gas where it can be sold. Separation of gases is another important topic since shale gas is comprised by methane and ethane essentially. Ethane can be used to produce polyethene (plastic). However, there is still lack of infrastructure in such facilities in Mexico, with most of the plants located in the South Atlantic far away from shale extraction points.

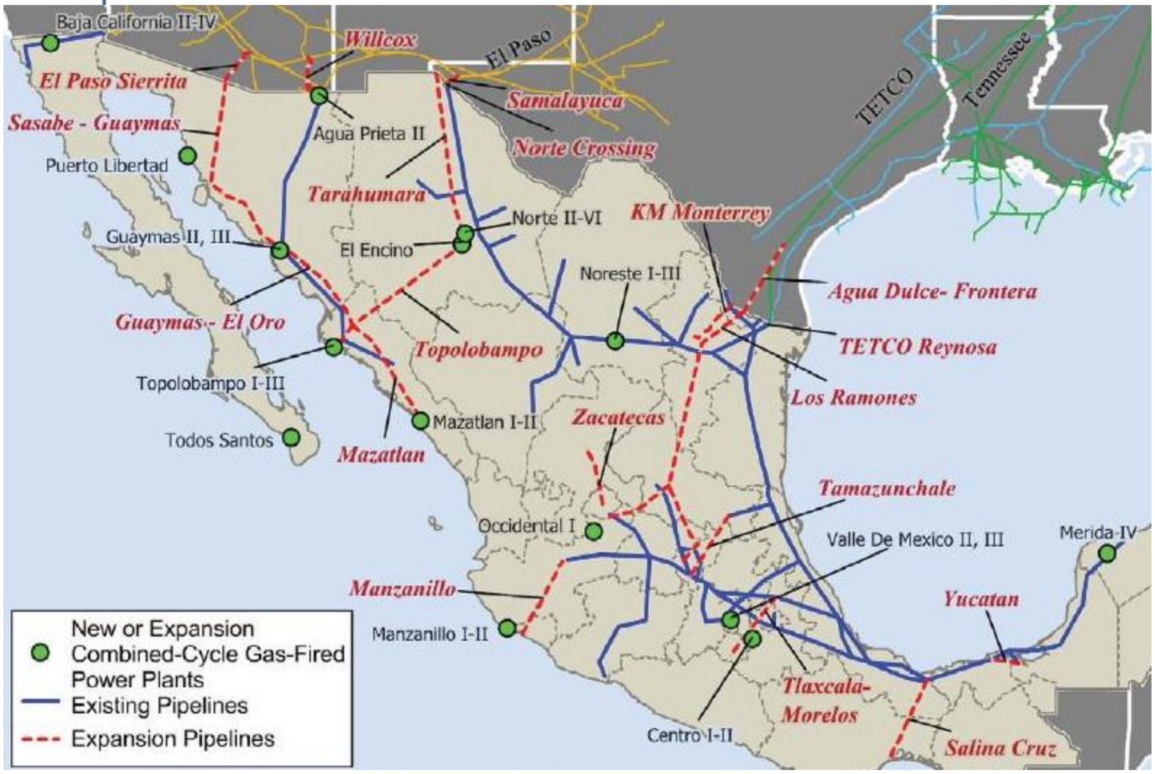

Fig. 5. Expansion Plan For Gas Pipelines In Mexico [19]

CONCLUSIONS

The development of shale gas in Mexico has the potential to benefit people if technical aspects are addressed for its proper exploitation. At the present moment there is a lack of infrastructure to supply water for fracking processes. Moreover, facilities for waste treatment and gas separation will also be needed to achieve the highest profitable margin from these resources. Studies concerning seismicity, leakages, contamination and pollution, radioactivity, legislation on chemical usage and flares will be of the highest importance to allow a sustainable way to exploit shale gas in Mexico. Although social and political parameters will also influence, these have been avoided in this work due to their ambiguity concerning shale gas and the new reforms in Mexico at the moment. However, it is evident that this source of energy could be one of the highest interests for the Mexican economy, society and environment.

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