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Energy-Environmental Implications Of Shale Gas Exploration In Paraná Hydrological Basin, Brazil

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ABSTRACT

Brazil is amongst the ten nations with the greatest shale gas reservoirs in the world. Despite that, the knowledge regarding hydraulic fracturing (*fracking*) technique for the exploration of shales in the Brazilian territory is still unquestionably new. The environmental and socio-economic consequences of shale gas extraction by fracking are far from being completely understood in that country. In Brazil, concomitantly to the exuberance of forests, rivers and biodiversity, many important mineral resources are present across protected areas. For instance, it is well known that the Paraná Basin, a reference in terms of biodiversity in South Brazil, is one of the three greatest shale gas reservoirs in the country. In this respect, the present review analyzes the case of shale gas extraction at Paraná River Basin sites, inside the geographical location of western Paraná. Very recently, 240 Paraná blocks in total, with 14 of them located in western Paraná, have been auctioned. It may come as no surprise that such fact has provoked social opposition in many western Paraná municipalities. As consequence, public discussions on the negative environmental attributes spanning air, water, public health, and climate were promoted both by the scientific community as by civil organizations. Such concerns are generating an innovative legislation, unprecedented in Brazil. This review article is intended to present the background issues that triggered such discussions, introducing current aspects concerning shale gas exploration within the contours of Paraná River Basin. The methodology presented here is investigative, containing a bibliographical survey of previous cases, and its focus resides in the analysis of socio-environmental aspects, with the evaluation of documents, legislation and civil actions. The methodology also covers the qualitative investigation of the hydraulic fracturing process, the chemical composition of the shale gas and the quantitative study of the energy potential of the Paraná block, presenting, as result, comparisons between shale gas potential and the specific case of biogas production by current agroenergy facilities in the region, specifying the possible benefits, impacts and costs to produce energy from both sources.

1. Introduction

In Brazil, the challenges related to the implementation of a dedicated range for alternative sources of energy are present in levels of intensity proportional to the continental dimensions of its territory. One of those challenges is associated to the use of natural resources that are unevenly spread across the country. Brazil is often recognized as a reference in power generation from renewable resources, highlighted the case of the hydroelectric generation. However, due to unfavorable hydrological conditions, there was recently a reduction of this hydraulic power supply that corresponded to 65.2% of the domestic supply in 2014 and 64.0% in 2016, compared to 76.9% in 2009 [14,15]. Consequently, there was a decrease in the share of renewable energy in the Brazilian energetic matrix for electric power, from 84.5% in 2012 to 74.6% in 2014, with a slight upward trend in 2016 (75.5%) [14,15,30]. In this aspect, Brazil has intensified the use of thermal power plants and has grown dependence on other sources for power generation, such as natural gas and petroleum diesel. The electricity generation from non-renewable fossil fuels accounted for 25.5% of the total in 2016, compared to the 23.3% usage in 2013 [14,15,30].

At the end of 2015, after 18 years of negotiations, about 195 nations that are part of the UN Convention on Climate Change were gathered in COP 21 in Paris to develop a new agreement, the unanimous commitment of the countries on greenhouse gas emissions, favoring and encouraging changes in their energy matrices, pledging that the temperature increase stays below 2 °C [21]. Despite that, energy from fossil sources continues to gain prominence in the world [130,131], and particularly in Brazil [14,15,44]. For example, since 2008 the exploration of pre-salt oil and the prospecting of high potential shale basins are changing substantially economic activities connected to the energy sector at the Brazilian territory.

Especially in the case of the exploration of Brazilian shales, the perspective to extract a great amount of natural gas are coming from recent technological advances of unconventional methods to extract the

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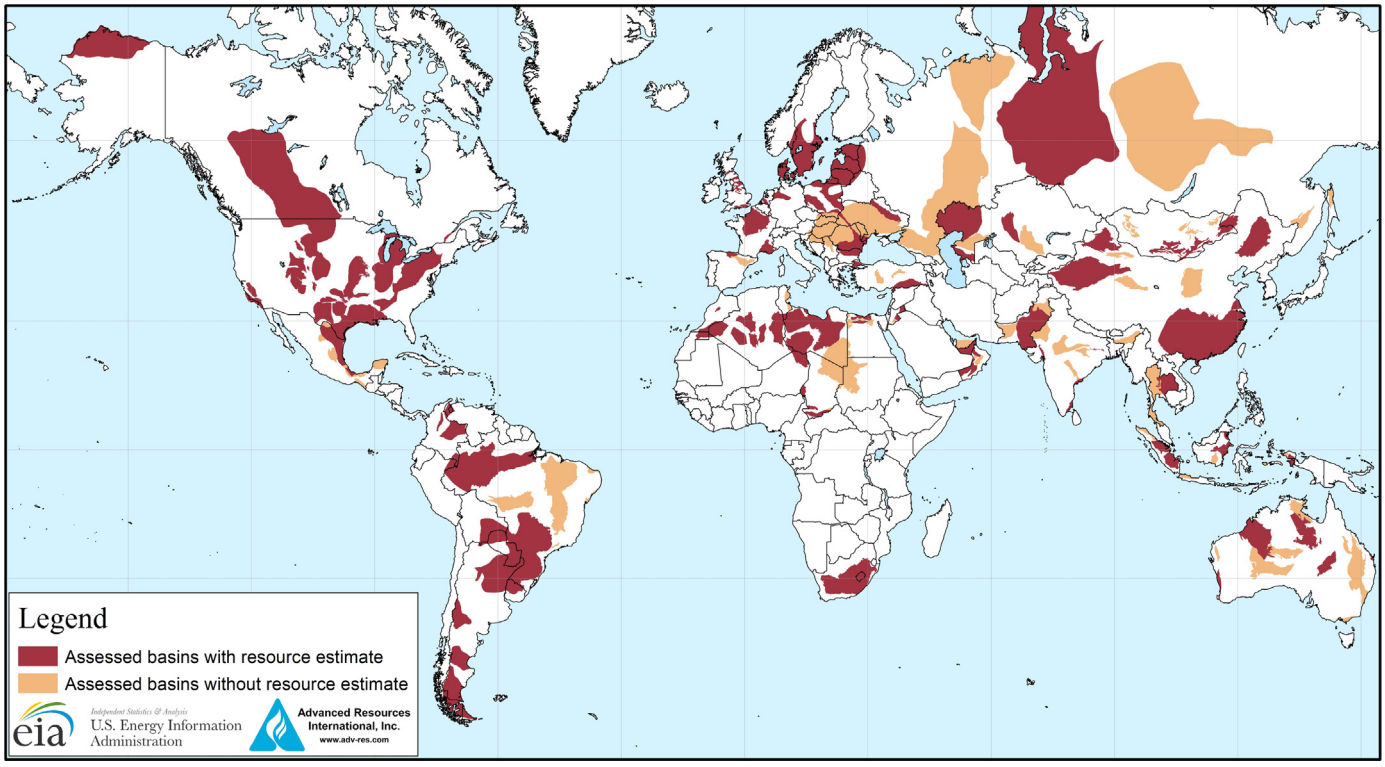

Fig. 1. Geographic distribution of the main structural basins with shale gas and oil across the world. From the EIA [30] report.

gas formed in low porosity rocks [41,62,117,129]. One of the most successful mechanisms used to deal with this difficult extraction is called “hydraulic fracturing” or simply “hydraulic fracking”. Hydraulic fracking is almost always performed in combination with horizontal drilling technology, which can exploit resources held in wide areas.

It is well known that in most cases the chemical composition of the shale gas is similar to the conventional natural gas [61]. It is mostly composed of methane (CH_4), but also has in smaller quantities ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}) and other hydrocarbons concentrations. There may also be the presence of water vapor (H_2O), hydrogen sulfide (H_2S) and carbon dioxide (CO_2) [129].

This type of natural gas has increased its share in the energy matrix of many countries, particularly in the United States. In that country, the beginning of exploration of shales introduced new parameters for the gas, going to unlink it from oil, since its offer has become considerably larger [117,129]. Currently, on a global level, the price of oil is actually closely linked to the exploitation of fossil fuels drilled from shale rocks.

It is estimated that the shale gas world reserves have more than 190 trillion cubic meters of gas, while in Brazil it is about 6.9 trillion m^3. This puts Brazil among the ten countries with the largest unconventional gas reserves [30,72]. Brazil has 18 onshore sedimentary basins, of which 14 may be generating oil. On the other hand, since the 1980s, Brazil has focused the exploration of its oil and gas resources from offshore platforms, while onshore basins have seen less activity. The Energy Information Administration (EIA), associated to the Department of Energy of the United States, assessed the potential shale resources of three onshore basins of Brazil (Paraná, Solimões and Amazonas). These basins have sufficient geological data available for many type of scientific analysis. Following that, in recent times, the Brazilian Agency of Petroleum, Natural Gas and Biofuels (ANP) has conducted research explorations, mainly by gravity and magnetism with minimal drilling, in four onshore basins to confirm their shale gas potential: Amazonas (North), Paraná (South), Parnaíba (Northeast), and part of São Francisco (Northeast) basins [13,28,30].

Meanwhile, the Brazilian government recently organized some auctions to sell Paraná Basin exploration blocks. Such auctions generated many public debates about the role of the shale gas in the Brazilian energy matrix and the probable environmental damages related to the technology of the hydraulic fracturing. Concomitantly, biogas projects and facilities are gaining visibility in the same region where shale exploration blocks are being auctioned, especially in western Paraná [20]. Currently, biomass and specially biogas are considered the main renewable resources in such region.

The general purpose of the present review is to report the current status of the hydraulic fracturing method and its implications for the environment and society in the specific case of western Paraná region, Brazil. In this respect, the paper is organized as follows: Section 2 deals with methods to extract shale gas, highlighted the hydraulic fracturing method and in Section 3 it is discussed some of the main environmental, social and health concerns about such method. Section 4 is devoted to review the main environmental and economic aspects of western Paraná region within the geographical contours of Paraná River Basin. It is introduced a discussion on the current status of shale gas extraction in this Brazilian basin and the possible renewable alternatives to the shale gas in western Paraná. In Section 5 some concluding remarks are formulated.

2. Extraction of shale gas by hydraulic fracturing method

In order to maximize the production of hydrocarbons, especially natural gas, oil industries are investing in a relatively new technology of extraction and exploration of natural gas from unconventional reservoirs. Known as “hydraulic fracturing”, or simply “fracking”, this technology was first used in 1947 in the United States. This method allows an increase in the productivity of the oil well and may even double its rate. It is reported that about 60% of the world wells use this technique [22,40,54,55,69,71,81,88,91,93,106,126,134]. Oil and gas from shales are the main products recovered by the hydraulic fracturing method. Fig. 1 shows the geographic distribution of the main shale gas basins across the world according to EIA [28,30].

The sentence “shale gas” refers to natural gas extracted from gas shales, porous rocks that hold gas in pockets. In general, it is reported

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