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Development of Shale Gas in Brazil: A Business-Oriented Analysis

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Abstract
Brazil figures amongst the top 10 countries with greatest technically recoverable shale gas resources around the globe. However, shale gas business has not yet taken off. This paper aims to provide a business-oriented analysis on the drivers and opportunities for developing shale gas in the country. Methodology consists of going through critical non-technical factors (above the surface issues) of each one of the Brazilian basins with technically recoverable shale gas resources. Results show that from a business perspective the potential development of unconventionals in Brazil over the next decade or so will most likely be linked with the production declining faced in some conventional gas fields, and hence, a mechanism to extend asset life cycle and sustain existing jobs.
Keywords: Brazil; Oil and gas exploration; Unconventional resources; Unconventional gas; Shale gas; Brazilian sedimentary basins; Market development.
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1. Introduction

The debate around developing shale gas got momentum in Brazil when it was perceived it could foster local and regional development by increasing decentralized supply of gas, inducing the construction of new gas pipes, investment on gas-to-power projects, allowing the establishment and development of local E&P companies, generating new jobs and income (Delgado, 2018).

The Brazilian Oil and Gas Regulator (ANP), the Brazilian Energy Research Office (EPE, 2019) and the U.S. Energy Information Administration (EIA) estimate that, all together, Parecis, Parnaíba, Recôncavo and São Francisco basins could reach to a total of 533 trillion of cubic feet (Tcf) of shale gas, 15.1 trillion of cubic meters (ANP, 2013). EIA estimates Brazil figures among the 10 top countries with regards to shale gas reserves, taking

into consideration technically recoverable resources at Amazonas, Solimões, Parnaíba, Recôncavo and Paraná basins (EIA, 2013).

This paper aims to provide a business-oriented analysis on the drivers and opportunities for developing shale gas in Brazil by going through specifics of each one of the basins analysed by EIA. At the end of the analysis, it will become clear that the potential development of unconventional in Brazil over the next decade will most likely be linked with the production declining faced in some conventional gas fields, and hence, a mechanism to extend asset life cycle and sustain existing jobs.

2. Unconventional development

Different regions and countries around the globe saw their energy landscape pass by a significant revolution through the development of hydrocarbons at low permeability reservoirs over the last decades (Feng et al., 2020). USA, Canada, and Argentina are examples on how the exploration of those resources can boost local oil and gas production, developing new companies and respective supply chain, reducing imports and/or increasing exports, generating thousands of jobs and income (FGV Energia, 2019) (Ramos et al., 2020). At the USA, for instance, the development of shale gas reserves allowed the country to shift from an importer position to a net gas exporter status, shifting not only USA' balance of trade but also oil and gas geopolitics around the globe.

Shale gas is one of several forms of "unconventional gas," which also includes coalbed methane, tight sand gas and methane hydrates. Shale gas, the focus of this study, is trapped within shale formations, which is fine-grained sedimentary rock that is both its source and reservoir (Carnegie Mellon University, 2013). Shale formations are characterized by low permeability, with more limited ability of gas to flow through the rock than is the case with a conventional reservoir (IEA, 2013).

The economic boom from unconventional developments observed in those countries prompted other regions, including Brazil, to consider whether existing unconventional resources and potential could lead to a similar social and economic successes. A series of studies developed by the Oil and Gas Regulator (ANP, 2013) were reinforced by the U.S. Energy Information Administration's research (2013) that shown Brazil figures among the top 10 countries with regards to the size of technically recoverable shale gas resources:

Table 1. Top 10 countries with technically recoverable shale gas resources

Rank	Country	Shale gas (Tcf)
1	China	1.115
2	Argentina	802
3	Algeria	707
4	United States	665
5	Canada	573
6	Mexico	545
7	Australia	437
8	South Africa	390
9	Russia	285
10	Brazil	245
World total		**7.299**

Source: U.S. Energy Information Administration: Technically Recoverable Shale Oil and Shale Gas Resources, 2013

The discussions in Brazil started to get momentum in 2017, when the National Energy Policy Council (CNPE) established the Oil and Natural Gas Exploration and Production Policy "to maximize the recovery of in situ resources in the reservoirs, the quantification of the national oil potential and the intensification of exploratory activities in the country, as well as promoting the adequate monetization of existing reserves, safeguarding national interests" (CNPE's Resolution number 17/2017). At the same year, the Federal Government launched its Public Policy Program for Revitalization of Onshore Oil and Gas Exploration and Production Activities (REATE), aiming to advance the development and implementation of a national policy to strengthen the oil and gas exploration and production sector in onshore areas, including unconventional resources. As part of these efforts, the project "Support for environmental licensing of the implementation of the Transparent Well Project in a low permeability reservoir" ("Poço Transparente") was conceived to give wide publicity about hydraulic fracturing techniques and help to disseminate geological, environmental, technical information on the progress of projects for the exploitation and production of unconventional natural gas (PPI, 2020).

According to EIA (2013; 2015) and EPE (2019), the greatest unconventional potential in Brazil can be found in five different basins:

Table 2: Brazilian basins with technically recoverable shale gas resources

Basin	Technically Recoverable (Tcf)	Technically Recoverable (Billion cubic meters - bmc)
Amazonas Basin	100	2832
Solimões Basin	65	1840
Parnaíba Basin	64	1812
Recôncavo Basin	20	566
Paraná Basin	80	2265
Brazil total	**329**	**9315**

Source: EIA (2013; 2015) and EPE (2019)

In-place and technically recoverable resource values for each shale gas and shale oil basin have been risked by EIA (2013) to incorporate: (1) the probability that the shale play will (or will not) have sufficiently attractive flow rates to become developed; and (2) an expectation of how much of the prospective area set forth for each shale basin and formation will eventually be developed.

Undoubtedly Brazil has a great potential of technically recoverable reserves to be considered. Nevertheless, history shows that different drivers may apply in different countries and hence other critical factors in addition to the size of those potential resources must be considered.

Several studies have been developed over the last years evaluating the technical aspects of each of the basins, such as geological and geophysical aspects of those formations (below the surface issues) and can be found on the literature, such as Feng et al. study (2020). However, shale gas business has not yet taken off. In this study, we will consider critical non-technical factors (above the surface issues), some of them proposed by Accenture (2014), for analyzing the Brazilian basins with greater shale gas potential from a business development perspective:

- Established oil and gas distribution networks, that could be used to distribute the produced unconventional gas to consuming markets;
- Competition from conventional development: producing unconventional hydrocarbons is more costly than producing from a conventional reservoir, which can present a major barrier to investment when there is still conventional potential to be explored without using advanced and costly recovery methods;
- Land access and operability: the road infrastructure that exists, water availability, population density and other non-technical factors that impact how easy it would be to access and set-up operations to develop the resources;
- Public perception: views of Non-Government Organizations (NGOs), public bodies, policymakers, regulators and the local community with regards to development of unconventionals, including, eventually, existence of bans and/or moratoria;
- Existence of an unconventional services sector that could supply operators, providing services and materials for drilling and fracturing activities;
- Presence of skilled oil and gas workforce whose capabilities could be adjusted to serve the unconventional resource operations.

The experience in other countries shows that there are at least two other critical non-technical factors for developing unconventionals, which will apply equally to all basins in Brazil and hence won't be used to differentiate them:

- Environmental licenses: the hydraulic fracturing method used for producing unconventional, including shale gas, requires the use of significant volume of water and may affect ground and surface water resources, including water quantity and water quality (Carnegie Mellon University, 2013). A clear, unified, and mature process to obtain environmental permits, based on a set of regulations defining minimum criteria to be followed, would incentivize the activity. Nevertheless, different federal entities carry out the environmental licensing process in Brazil as for exploration and production of hydrocarbons, making the process, from a non-technical perspective, time consuming and particularly challenging.
- Enabling tax regime: tax incentives were essential for the unconventional development in the United States and in Argentina (Gomes & Brandt, 2016; Lage et al., 2013). The Section 29 production tax credit for unconventional gas, created by the American Congress back in the 1980's is an example, providing an incentive of $0.50 per thousand cubic feet (Tcf) of natural gas produced from unconventional resources. The incentive gave investors a premium that allowed them, among others, to invest in and mature technologies that pushed shale gas into full commercial competitiveness over the years (Trembath et al., 2012). Currently Brazil does not apply any sort of tax incentives favoring unconventional development.

3. Critical factors affecting viability of Brazilian basins for unconventional investment

3.1 Amazonas Basin

The Amazonas Basin is in the Northern region of the country and occupies an area of approximately 620

thousand km², covering part of the states of Amazonas and Pará (Table 3).

Table 3: Amazonas Basin overview

Size of potential resources	• 100 Tcf shale gas
Established oil and gas distribution	• Absolute lack of gas pipelines to transport and connect with consumer markets
Conventional competition	• Relevant conventional reserves still to be produced • Conventional production starting at Azulão field only and was made viable by using small-scale LNG solution for gas transportation due to lack of gas pipelines
Land access and operability	• Reasonable roads available • Low population density • Good water availability
Unconventional services sector	• Insufficient services for conventional oil and gas • Lack of local technical capability; need to import technologies and equipment for developing unconventional resources
Skilled workforce	• Insufficient skilled labor for the oil and gas sector
Public perception	• Conventional development is well perceived • Lack of significant discussions with regards to unconventionals • NGOs opposition have already blocked conventional exploration close to the Amazon River.

Source: Elaborated by authors.

3.2 Solimões Basin

Located in the Northern region of the country, the Solimões Basin occupies an area of approximately 600 thousand km² in the state of Amazonas. Solimões Basin has the largest onshore reserve of natural gas in the country and produces light oil with great quality (Table 4).

Table 4: Solimões Basin overview

Size of potential resources	• 65 Tcf shale gas
Established oil and gas distribution	• Urucu-Coari-Manaus is the only one gas transport pipeline established • One of the most expensive gas pipeline in Latin America.
Conventional competition	• Biggest onshore commercial reserves, with significant volume still to be produced • Existing conventional gas production is stranded by Urucu-Coari-Manaus limited gas transport capacity
Land access and operability	• Remote location and low population density • Good water availability • Lack of good road infrastructure: use of large helicopters is required to move drilling rigs to most of exploration areas, increasing substantially the cost of the activity
Unconventional services sector	• Existing service sector for conventional oil and gas • Lack of local technical capability; need to import technologies and equipment for developing unconventional resources
Skilled workforce	• Insufficient skilled labor for the oil and gas sector
Public perception	• Conventional development is well perceived • Lack of significant discussions with regards to unconventionals • Significant presence of NGOs

Source: Elaborated by authors.

3.3 Parnaíba Basin

The Parnaíba Basin is in the Northeast region of the country, occupying an area of approximately 666 thousand km² in the states of Piauí, Maranhão, Pará, Tocantins, Bahia and Ceará. The basin is currently the second largest gas producer in the continental shelf of the country (Table 5).

Table 5: Parnaíba Basin overview

Size of potential resources	• 64 Tcf shale gas
Established oil and gas distribution	• Absolute lack of gas pipelines for gas transportation
Conventional competition	• Relevant conventional gas volumes still to be produced • Existing conventional gas production is consumed exclusively by thermopower generation
Land access and operability	• Low population density • Reasonable water availability • Reasonable road infrastructure available
Unconventional services sector	• Existing service sector for conventional oil and gas • Need to import technologies and equipment for developing unconventional resources
Skilled workforce	• Insufficient skilled labor for the oil and gas sector
Public perception	• Conventional development is well perceived • Lack of significant discussions with regards to unconventionals

Source: Elaborated by authors.

3.4 Recôncavo Basin

The Recôncavo Basin, located in the state of Bahia, has been the subject of studies since the first half of the 20th century. The basin is part of the history of the oil industry in Brazil: in 1937, the first barrels of oil extracted in Brazilian soil came from there (Table 6).

Table 6: Recôncavo Basin overview

Size of potential resources	• 20 Tcf shale gas
Established oil and gas distribution	• Gas transport and distribution pipelines available • The Recôncavo basin is where the Southeast and Northeast gas grids connect
Conventional competition	• Recôncavo is the first basin that became productive in Brazil. The basin is now considered mature from an exploration and production perspective and conventional gas production and reserves are declining
Land access and operability	• Existing road and air infrastructure available
Unconventional services sector	• Existing service sector for conventional oil and gas • Need to import technologies and equipment for developing unconventional resources
Skilled workforce	• Skilled workforce for conventional operations available
Public perception	• Conventional development is well perceived • A legal injunction was granted in 2014 suspending the effects of the Brazil O&G Round number 12 with regards to exploratory blocks exploration by using hydraulic fracturing technique in the state of Bahia (CNI, 2017).

Source: Elaborated by authors.

3.5 Paraná Basin

The Paraná Basin is in the central-eastern portion of South America and covers an area of approximately 1.500 thousand km², of which about 1.100 thousand km² are in the Brazilian territory. In Brazil, the Basin includes areas from the states of Paraná, Santa Catarina, Rio Grande do Sul, São Paulo, Minas Gerais, Mato Grosso do Sul, Goiás and the Federal District (Table 7).

Table 7: Paraná Basin overview

Size of potential resources	• 80 Tcf shale gas
Established oil and gas distribution	• Transport pipeline available, with distribution pipelines close to state capital areas
Conventional competition	• Although there is great potential for gas production in the basin, including one gas field declared commercially viable, there is currently no ongoing production
Land access and operability	• Excellent road and air infrastructure available
Unconventional services sector	• Existing service sector for conventional oil and gas in nearby basins
Skilled workforce	• Skilled workforce for conventional operations available in nearby basins
Public perception	• The basin cover areas in several states. In some of them, critical opposition to unconventionals development can be found. Paraná and Santa Catarina states have put in place specific laws[1] prohibiting the exploration of unconventionals by using hydraulic fracking method.

Source: Elaborated by authors.

4. Conclusion

The analysis and key non-technical critical factors detailed here present a snapshot of the current scenario at each of the Brazilian basins with greater shale gas technically recoverable reserves reviewed in this paper. Understanding those factors and their influence on the pace of market development is of great relevance. The factors may develop over time and whilst a single factor can prevent a market from developing today, overcoming it may create the momentum for others to be resolved.

Bans and moratoria prevent markets to develop even when all other critical technical and non-technical factors play in favor. The laws prohibiting the exploration of unconventionals by using hydraulic fracking method currently found in Paraná and Santa Catarina states brings a major barrier for unconventional development consideration in the Paraná basin nowadays.

The challenges related to access and operability at Solimões basin and the lack of adequate infrastructure for gas transport in the region discourages even the investment on conventional production in the region.

The size of conventional reserves still to be produced at Amazonas, Solimões, Parnaíba and Paraná basins seems to be the greatest challenge for exploring unconventionals in those regions over the next years. From a business perspective, the relevant cost difference found between producing from a conventional and an unconventional reservoir makes the second much less attractive, especially in a scenario where there is no stimulus to it such as tax incentives. Until new technologies allow cost reduction of the current advanced recovery techniques, such as hydraulic fracturing, it is expected business to consider unconventionals development only when conventional reserves start to decline, as a mechanism to increase available reserves and extend asset life cycle. This is exactly why we understand Recôncavo basin, even though being the one amongst the analyzed basins with the smaller shale gas technically recoverable reserves potential, is the one with greatest chances for unconventional development in Brazil over the next decade or so from a business perspective: being the first basin that became productive in Brazil, conventional gas production and reserves are now facing declining and shale gas can play a pivotal role sustaining production and jobs in the region over the next decades.

The Recôncavo basin region counts with relevant gas pipelines that could be used to transport and distribute the produced gas, not only to the Northeast, but also to Southeast region through the gas grid connection already in place. In addition to that, a) the existing service sector for conventional oil and gas industry can evolve to support unconventional development, including localizing technologies and equipment required for developing these resources; b) educational and industrial training institutions established in the region can support the existing oil and gas skilled workforce to adjust its capabilities to serve the unconventional resource operations.

Further studies should consider the missing critical stepstone towards the development of shale gas in the region amongst the non-technical factors analyzed in this study: to gather and disseminate technical knowledge with regards to the risks of the hydraulic fracturing technique, including the environmental ones, as proposed by the Transparent Well Project in a low permeability reservoir (“Poço Transparente”) project (FGV Energia, 2021). A greater transparence around them will certainly favor and give confidence to policymakers, public bodies, environmental agencies and regulators to proper analyze the risks related to the development of unconventionals, ensuring the country will have a comprehensive understanding of them and won’t miss the opportunity of exploring this energy source and foster social and economic benefits from it.

[1] Paraná, through Law 19.878/2019, and Santa Catarina, via Law 17.766 of 2019.

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