

# Journal of Engineering Research

Acceptance date: 20/05/2025

## SYSTEMIC ANALYSIS OF THE TECHNICAL- ECONOMIC DIMENSIONS OF NATURAL GAS BETWEEN PRE-SALT AND VACA MUERTA

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**Abstract:** This work analyzes the energy resources of natural gas for its technical-economic scope to point out energy integration. Also, for offshore production, consolidated in the Argentine and Brazilian markets. The study regions are: Campo de Lula and Sapinhoá in Bahia de Santos and Campos, and also Vaca Muerta in Neuquén, Argentina. The possibilities of cross-border implementation of gas pipelines, use and their interference will still be evaluated, such as the GASBOL line in relation to the Pre-Salt and Vaca Muerta and the application, in the established regions. This analysis verifies that public or private investments are necessary to make this energy resource viable in common agreement. That is why the necessary resources and tools can be explored, as both countries have investments in this sector. In this way, the technical-economic interest in the analysis of electricity production and expansion of gas pipelines can consolidate market influences and political relations.

**Keywords:** Energy resources, Energy integration, Natural gas, Pipelines, Technical-economic dimensions.

## INTRODUCTION

Around the year 2000, the Pre-Salt province emerged as one of the main commercial discoveries of oil and natural gas in the world. Located on the Brazilian coast, between the south of Espírito Santo and the north of Santa Catarina, it is delimited by a polygon with an area of approximately 160,000 km<sup>2</sup>. The reservoirs can reach depths of up to 7,000 m and are sealed by a thick, plastic rock layer of salt that, for many years, was the object of study to make exploratory technologies viable [12].

The reservoirs are characterized by light, high-quality oil, but they contain excessive amounts of contaminants, mainly carbon dioxide (CO<sub>2</sub>). In addition to being able to contribute to Brazil's energy demand, the natural

gas contained in the Pre-Salt reservoirs, depending on the CO<sub>2</sub> level, can be competitive with regional competitors in South America, such as *shale gas* de Vaca Muerta and Bolivian natural gas [12].

The analysis of the panorama of the natural gas industry in Argentina with a view to seeking opportunities to increase the integration of this country with Brazil is of great strategic and economic importance for both countries, due to the following factors: Argentina's greater proximity to natural gas consumers in the South of Brazil would facilitate service in the scenario of reduced Bolivian imports that occur through the Bolivia-Brazil gas pipeline (GASBOL); and the existence of notable estimates of unconventional natural gas reserves (shale and tight gas) in Argentina that subsidize plans to increase production in the Neuquina Basin and export surplus volumes of gas, during the Argentine summer, to Brazil through, for example, pipelines, ships carrying liquefied natural gas (LNG) or trucks powered by this fuel [1].

As for economic integration agreements and protocols, the most relevant are the Iguaçu Declaration (1985); the Brazil-Argentina Integration Act (1986), which created the Economic Integration and Cooperation Program (PICE); and the Treaty of Asunción, signed between Argentina, Brazil, Paraguay and Uruguay in March 1991, creating the Southern Common Market (MERCOSUR). Thus, trade between Brazil and Argentina began to be carried out in accordance with the Economic Complementation Agreement No. 18 (ACE 18). The contents of the documents cited are available at the Ministry of Economy [1].

An initiative was recently drawn up in public consultation based on guidelines between the Ministry of Mines and Energy (MME), the National Agency of Petroleum, Natural Gas and Biofuels (ANP) and the Energy Research Company (EPE) to seek improvements

through changes in business environments. The Gas for Growth Program proposed a new framework to unlock the development of the natural gas sector in Brazil through new investments and agents [12].

In Brazil, there are three regasification terminals in operation and two more in the final stages of construction, expected to be operational in 2020, in addition to dozens of other new projects with implementation under analysis.

## STATE OF THE ART

According to the production of electricity from energy resources with energy integration, we can mainly identify in this study:

I) Energy integration between Brazil and Argentina, according to the study scenario, Santos Basin, in the Lula and Sapinhoá fields and the Neuquén, Vaca Muerta region.

II) Systemic analysis of the technical-economic aspect of both regions, under a panorama of international and political agreements;

III) Market influences of these regions, according to transmission lines, gas pipelines;

While Brazil faces obstacles in opening its market, Argentina has made progress in modernizing its sector. The actions to open the Argentine market included auctions to purchase natural gas to supply thermal power plants and bidding to expand the gas pipeline network. One of the factors that differentiates the Argentine natural gas market from Brazil is free access to infrastructure in the neighboring country, which is already a reality. In addition, access contracts in Argentina are short-term, ranging from one to three years, making gas purchase and sale operations more dynamic. Another difference is the number of suppliers in Argentina, while in Brazil 75% of production is carried out by Petrobras [8].

The use of Argentine gas will depend on political interests and international market conditions. In 2020, the international oil and natural gas scenario was shaken by disputes between Russia and Saudi Arabia (with increased price volatility) and by the decrease in global energy demand due to the Covid-19 pandemic (disease caused by the new coronavirus). The price of Brent oil fell from US\$ 67/barrel on 02/01/2020 to US\$ 25/barrel on 27/03/2020, amid the lack of an agreement within OPEC+ for new production cuts and the spread of the pandemic to Europe and the USA [1].

The participation of natural gas and renewable energy in the Argentine energy matrix until 2050 has been one of the main topics in the dialogues between public and private agents in that country [1].

The gas coming from Neuquén, the basin where the Vaca Muerta area is located, comes from shale gas. Unconventional gas is extracted using two production technologies: hydraulic fracturing and directional drilling. With the production from Vaca Muerta, Argentina intends to reduce its dependence on gas imported from Bolivia and export the surplus. Argentina is among the four countries that produce the highest commercial volumes of tight gas/oil and shale gas [8].

## BRAZILIAN SCENARIO

Currently, approximately 80% of Brazilian natural gas production is associated gas from offshore sources. Thus, most of Brazil's natural gas reserves are associated with oil reserves (associated gas) and both are produced simultaneously, which means that natural gas needs to be produced and used regularly, contributing to oil production [1].

With the discovery of pre-salt oil in Brazil, it is estimated that the potential supply of natural gas in Brazil could double in the next 15 years. For this to become a reality, challenges

must be overcome. Pre-salt gas production is approximately three hundred kilometers away from the coast, which will require large investments in infrastructure and gas pipelines to transport gas to these fields. In addition, pre-salt gas is rich in CO<sub>2</sub>, which will require an additional cost in its separation [7].

With the increasing production rates of associated natural gas in Pre-Salt and in the marginal areas, several obstacles arise and, to a certain extent, require technical and economic alternatives to make the field development projects viable. One of the main issues under discussion at the moment concerns the production flow segment to the coast. The issue, in addition to economic points, essentially depends on technical factors such as infrastructure and mainly demand for a consumer market.



Fig. 1. Map of the pre-salt region between the Santos and Campos Basins.

In Fig. 1, the Santos basin can be seen specifically, where the reserves of Pré-Brasil are also located, specifically those analyzed in the Lula and Sapinhoá studies. The Brazilian oil and gas sector, in its modern phase, was re-configured after the Petroleum Law in 1997, with the opening of the market and the breaking of Petrobras' operational monopoly. Recently, the obligation that the state-owned

company held as the exclusive operator in the Pré-Salt came to an end, allowing new companies to enter exploration and production activities in the polygon.

With the diversification achieved through the participation of new companies operating in the Pre-Salt layer, new changes in other sectors are currently the subject of intense discussion. In the region, several blocks are in an area that is still unexplored and far from the existing gas pipeline network. Another important point of analysis is that the existing gas pipeline infrastructure, known as Routes 1, 2 and 3, in addition to having a limit on operational capacity, belongs to Petrobras, which could become a problem for consortiums without the participation of the state-owned company.

As in other segments of the oil chain, the natural gas transportation and distribution sectors also developed through Petrobras, characterizing a vertically integrated monopoly arrangement with approximately 95% control in the national market. *Offshore* environments, the methods are constantly employed by means of exploration vessels that use compressed air cannons (SERCEL, 2018). A scheme seismic survey in a maritime environment, exemplifying the exploration campaign through the Pre-Salt reservoirs.

## ARGENTINE SCENARIO

Likewise, Argentina is the Latin American country with the largest share of natural gas in its energy matrix, a result of almost double the region's promise of around 26.4%.

With approximately 3% of the Vaca Muerta area currently under exploration, and the decline in production from conventional wells, domestic energy demand cannot yet be met by natural gas. Therefore, Argentina depends on imports of this resource, which is used not only to heat homes and as input for production, but also to produce electricity.

The exploitation of Vaca Muerta thus took the form of a megaproject. As Álvarez Mullally, Arelovich, Cabrera and Di Risio point out, defining it as such implies that a) The value chain is organized from the processes prior to drilling to the refinery, passing through pipelines, specific inputs for each stage and culminating in wastewater treatment plants; b) It requires investment and development of infrastructure, such as roads, housing, services and the reorganization of towns and cities; c) A multiplicity of companies of different sizes, both national and transnational, are involved [13].

The Neuquén Basin includes the Vaca Muerta and Los Molles sedimentary geological formations, located in the Patagonia region of Argentina (Fig. 1). The Vaca Muerta formation is the primary source rock for hydrocarbons in the Neuquén Basin. It spans four different Argentine provinces and has an estimated prospective area of 30,000 km<sup>2</sup> and an average depth of over 2,400 m [11]. The Basin is bounded to the west by the Andes Mountains and to the north and south by the Colorado River, Neuquén River and Limay River. The Basin has a pluvial regime, with most of the precipitation coming from the eastern Andes. The Limay River and Neuquén River have six hydroelectric plants with a total installed capacity of 5,000 MW, representing 15% of Argentina's electricity supply. The Neuquén Basin has freshwater and brackish or saline aquifers at depths ranging from 0 to 600 m [11].

As can be seen in the map below, which delimits the study concentration area, Vaca Muerta, in the geographic space of the Neuquén region.

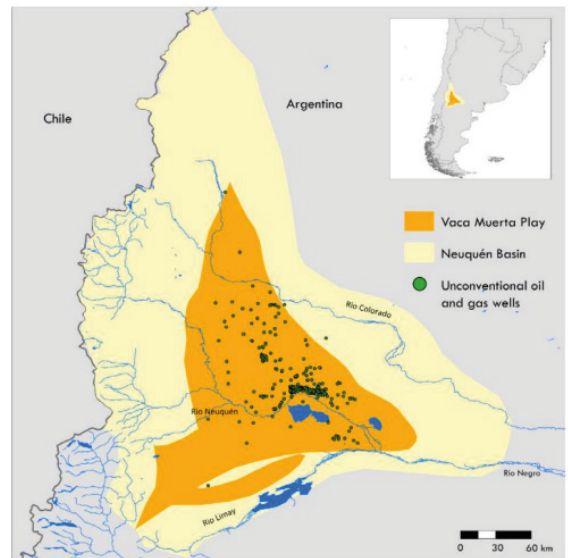


Fig. 2. Map delimiting the geographic space of Vaca Muerta, in the Neuquén region, Argentina.

The region is already producing oil and gas from conventional and tight sandstones and is emerging as the main UOG development in South America. The climate is semiarid with an average annual rainfall of 178 mm [11]. In Neuquén province, most of the agricultural land is irrigated and in 2010 its population was 551,000 people. The region is an important agricultural area with intensive fruit production with 10 million hectares of irrigated land [11].

In the case of associated natural gas production, the issue becomes relevant. Opening the market to existing and future natural gas flow and treatment infrastructure is important to maximize natural gas production and reduce reinjection of the same. In a highly capital-intensive segment, it may not make sense for each operator of a block with associated natural gas to build its own flow infrastructure because the scale may be prohibitive. However, several nearby blocks together may make it possible to build a single flow and treatment infrastructure if they contract a minimum capacity from a third party that will build the infrastructure.



# SYSTEMIC ANALYSIS

In line with the evolution in the use of natural gas in electricity production, in recent years South America has been establishing improvements in this sector, thus, through of-shore production, consolidating itself in the Argentine and Brazilian markets.

Of the attributes established by the PIR (Integrated Resource Planning) model, the infrastructure from production to consumption enables solid and important integration, so that countries can reach agreements and take advantage of them, since technically they look for other resources so that there is no political and financial dependence.

As can be seen in the schematic model in Fig. 3, the analysis of resources and this integration precisely shows the En-In (Involved-Interested) for both countries.

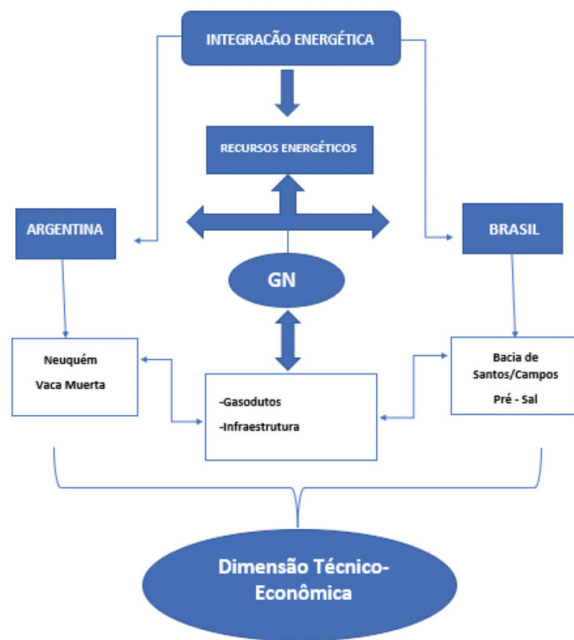


Fig. 3. Flowchart for study analysis among the main actors.

According to the present study, the infrastructure currently available for the transportation of natural gas from the Pre-Salt layer, as presented in the data on the subject, will require new investments in gas pipelines. Fur-

thermore, the scenario of these two countries is being considered and guidelines are being established that allow for the quantification, in an integrated manner, of the gains associated with the scenario of gas exports from the Pre-Salt layer projects. Among them, the knock-on effect caused by the commercialization of gas, including cost reduction in the industry, increased economic activity in the country, job creation, and tax collection.

## III. Case study

Thus, given the new configurations in the sector, the debate on the proposal to liquefy natural gas production in the Pre-Salt layer comes at an opportune time for both producers and consumers. In addition to presenting itself as an option for monetizing reserves for operators who face the challenge of unavailability of access to the gas pipeline network, liquefaction also offers the possibility of expanding the supply of natural gas to remote areas in the country.

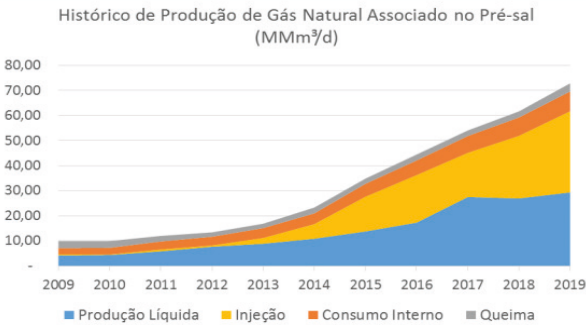


Fig. 4. Graph of the History of NG Production associated with Pre-salt.

As per the graph above, recently the growth through energy resources has been increasing more and more, mainly with a significant number of injections.

The Pre-Salt reservoirs have enormous potential for natural gas production. While natural gas resources represent significant economic opportunities, realizing this potential is a technical and economic challenge. The depth, long distance from the coast and presence of

Bowl	Oil (MMm <sup>3</sup> )			
	1P Reservations	2P Reservations	3P Reservations	Contingent Resources
Alagoas	0.02	0.02	0.02	-
Camamu	3.70	3.83	14.25	0.02
Fields	532.19	751.50	871.83	499.09
Ceara	-	-	-	-
Holy Spirit	0.74	0.82	0.94	2.92
Potiguar	9.62	13,14	14.22	0.01
Recôncavo	0.04	0.04	0.04	0.15
Saints	1,269.83	1,915.08	2,208.51	423.53
Sergipe	1.34	2.43	3.50	-
Total	1,817.46	2,686.86	3,113.32	925.72

Fig. 5. Oil Table in relation to basins and reserves associated with the Pre-salt.

Bowl	Natural gas (MMm <sup>3</sup> )			
	1P Reservations	2P Reservations	3P Reservations	Contingent Resources
Alagoas	213.11	213.11	213.11	-
Camamu	3,747.60	3,997.29	7,419.48	1,148.86
Fields	49,658.90	71,134.22	83,833.13	48,927.99
Ceara	-	-	-	-
Holy Spirit	259.75	270.43	281.95	1,590.39
Potiguar	1,348.94	1,899.47	2,487.59	22.03
Recôncavo	-	-	-	-
Saints	205,580.58	244,605.21	265,463.85	62,400.98
Sergipe	181.99	371.74	451.31	-
Total	260,990.87	322,437.47	360,150.42	114,090.26

Fig. 6. GN table in relation to the basins and reserves associated with Pre-salt.

contaminants in Pre-Salt gas require diverse technological solutions, which increase project costs. At the same time, the debate on how to offer this gas to the consumer market in a competitive manner is also ongoing.

Through the analyses obtained, the perception of not only depending on existing agreements, but also the great influence of GASBOL, both for Brazil and Argentina. When observing Fig. 5, of the table in relation to oil and its reserves.

Since both regions already have the infrastructure and technological resources necessary to produce oil and natural gas, the financial investment seen in both political and economic interests influences the determining actions. Therefore, the viability of a gas pipeli-

ne line is interesting for both countries, Vaca Muerta to further consolidate the market and Pre-Salt for expansion and return, as highlighted in Fig. 6 in relation to natural gas.

## CONCLUSION

Based on what has been presented, it is understood that Argentina has a mature, consolidated market in this study environment, since a large part of its matrix comes from natural gas. Therefore, it is important to analyze the investments that were placed in Vaca Muerta and the procedures that lead to political disputes and the high value of its maintenance.

In Brazil, the growth of natural gas is an important advance not only in studies, but also in its application. The existing gas pipelines,

considered territorially, do not cover the country since many of them are authorized, but depend on political agreements, structure and investment for this application. It is known that there is international interference, mainly by GASBOL, the main access and agreement with the countries under study.

Therefore, for there to be a specific agreement on this transport system, political spheres must intervene so that public or private investments can act and be applied in common agreement, making this energy resource viable.

Therefore, the necessary resources and tools can be explored, as both countries have investments in this sector, to continue the studies, since it is possible to improve and carry out the complete application of the PIR, adopting criteria, exploring the En-In agents, in addition to the application of the PIGT (Indicative Plan for Gas Transport Pipelines) of the concentrated regions to be benefited economically, in the generation of new jobs and in the use of gas, as a renewable source.

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