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NATURAL GAS AS A GENERATING SOURCE IN THE DIVERSIFICATION OF THE BRAZILIAN ELECTRIC MATRIX

GÁS NATURAL COMO FONTE GERADORA NA DIVERSIFICAÇÃO DA MATRIZ ELÉTRICA BRASILEIRA

EL GAS NATURAL COMO FUENTE GENERADORA EN LA DIVERSIFICACIÓN DE LA MATRIZ ELÉCTRICA BRASILEÑA

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ABSTRACT

Energy consumption grows annually, requiring an increase in the production and distribution standards of available energy sources. One of the main energy consumptions is linked to the electricity sector, which is globally dependent on fossil fuels such as oil and coal. In Brazil, more than 60% of electricity consumption comes from hydroelectric plants, and the lack of variability in generating sources generates instability and energy insecurity in the country. In this sense, it is necessary to evaluate an alternative source of electricity that can work together with hydroelectric plants and guarantee the stability of generation. Natural gas presents itself as an alternative, as it is a safe source and less aggressive to the environment when compared to other non-renewable sources. Through data collection and bibliographic research on proven reserves, processing capacity and distribution of natural gas, this work analyzed the Brazilian potential for the use of natural gas and the biggest gaps in the sector. The results showed that, despite the great potential in proven natural gas reserves, Brazil is stagnant in its processing and distribution capacity. In addition, there are challenges related to high rates and taxes on the use of natural gas.

RESUMO

O consumo energético cresce anualmente exigindo um aumento no padrão de produção e distribuição das fontes de energia disponíveis. Um dos principais consumos de energia está atrelado ao setor elétrico, mundialmente dependente de combustíveis fósseis, como o petróleo e o carvão. No Brasil, mais de 60% do consumo de energia elétrica é proveniente das hidrelétricas e, a falta de variabilidade de fontes geradoras gera instabilidades e insegurança energética no país. Nesse sentido, faz-se necessário avaliar uma fonte alternativa de energia elétrica que possa atuar em conjunto com a hidrelétrica e garantir a estabilidade da geração. O gás natural se apresenta como uma alternativa, por ser uma fonte segura e menos agressiva ao meio ambiente quando comparado com outras fontes não renováveis. Por meio de levantamento de dados e pesquisa bibliográfica sobre as reservas provadas, capacidade de processamento e distribuição do gás natural este trabalho analisou o potencial brasileiro para utilização do gás natural e as maiores lacunas do setor. Os resultados mostraram que, apesar do grande potencial em reservas provadas de gás natural, o Brasil está estagnado na sua capacidade de processamento e distribuição. Além disso, há desafios relacionados com altas taxas e impostos sobre o uso do gás natural.

RESUMEN

El consumo de energía crece anualmente, lo que requiere un aumento en el estándar de producción y distribución de las fuentes de energía disponibles. Uno de los principales consumos energéticos está vinculado al sector eléctrico, que depende globalmente de los combustibles fósiles, como el petróleo y el carbón. En Brasil, más del 60% del consumo eléctrico proviene de centrales hidroeléctricas y la falta de variabilidad en las fuentes de generación genera inestabilidad e inseguridad energética en el país. En este sentido, es necesario evaluar una fuente alternativa de energía eléctrica que pueda trabajar en conjunto con la central hidroeléctrica y garantizar la estabilidad de la generación. El gas natural se presenta como una alternativa, ya que es una fuente segura y menos dañina para el medio ambiente en comparación con otras fuentes no renovables. A través de la recopilación de datos y la investigación bibliográfica sobre reservas probadas, capacidad de procesamiento y distribución de gas natural, este trabajo analizó el potencial brasileño para el uso de gas natural y las mayores brechas del sector. Los resultados mostraron que, a pesar del gran potencial de las reservas probadas de gas natural, Brasil está estancado en su capacidad de procesamiento y distribución. Además, existen desafíos relacionados con las altas tarifas e impuestos sobre el uso del gas natural.

INTRODUCTION

It was estimated by the International Energy Agency (IEA) that the world population will approach 9 billion in 2040, and to meet this demand, an increase in energy supply will be necessary (IEA, 2015). Linked to the need for more sustainable consumption, this demand will require greater diversification of energy resources and more efficient technological innovations with less environmental impact. One of the energy resources available to expand the supply of energy and meet the world's demand is natural gas. Increased use of natural gas will help reduce dependency on oil and coal, which can result in greater energy security and reduced environmental impact (Aguilera, 2012; Pedroso et al., 2018).

The electrical matrix, which encompasses the sources used to generate electricity, is one of the most widely used forms of energy consumption in the world. The electricity sector is based on high levels of capital investment, production density, and mechanization and automation of production processes. As an industrial branch, the energy sector has a pronounced effect on the performance of all other industries, both manufacturing and services. Therefore, there is a link between a country's economic progress and the development of its electricity sector, as industry and domestic lifestyles are highly dependent on this sector. On a global scale, the industry and transport sectors are the largest consumers of electricity, and about 40% of this energy comes from coal.

In recent decades, the use of water resources in Brazil has been discussed due to the increase in demand for electricity, linked to the scarcity caused by the lack of rain in many states, which leads to low volumes of water in reservoirs. As a result, there is a drop in energy supply, requiring the use of other alternative forms of supply (Galvao and Bermann, 2015).

The Brazilian dependence on electricity from water resources reinforces the importance of diversifying the matrix in Brazil, which would guarantee a strategic position and greater security in the electricity supply for the country (Pereira and Silva Neto, 2021). In this context, natural gas presents itself as a complementary source in the Brazilian electricity matrix, operating as one of the energy sources that are the basis for the operation of thermoelectric plants (Lima and Souza, 2015).

According to the projection of EIA (2019), natural gas and renewable sources will be responsible for approximately 70% of electricity generation in 2050. For the same year, projections indicate stagnation in hydro generation due to the depletion of potential and environmental issues related to this resource.

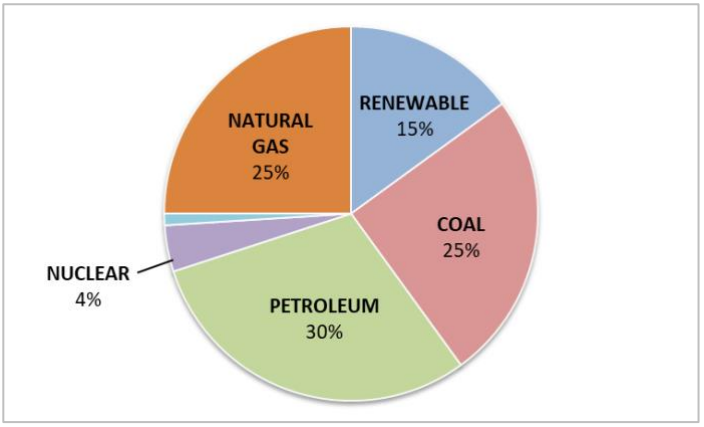
The general objective of this work was to list the existing and observed incentives in the main countries that consume and produce natural gas in the world, which lead to better development of gas in the electrical matrix, to compare with the incentives found in Brazil. The energy scenario in Brazil was analyzed, in which the energy industry contributes to the increase in the use of energy, in addition to the challenges and disadvantages encountered by the sector in the country.

THE ELECTRICAL MATRIX AND THE NATURAL GAS INDUSTRY

THE ELECTRICAL MATRIX IN BRAZIL AND IN THE WORLD

The electrical matrix is composed of renewable and non-renewable energy sources. Due to this diversity of sources available in the matrix, electricity consumption varies greatly from country to country. According to the latest EIA publication (2021), an average of world consumption was calculated, as shown in Figure 1.

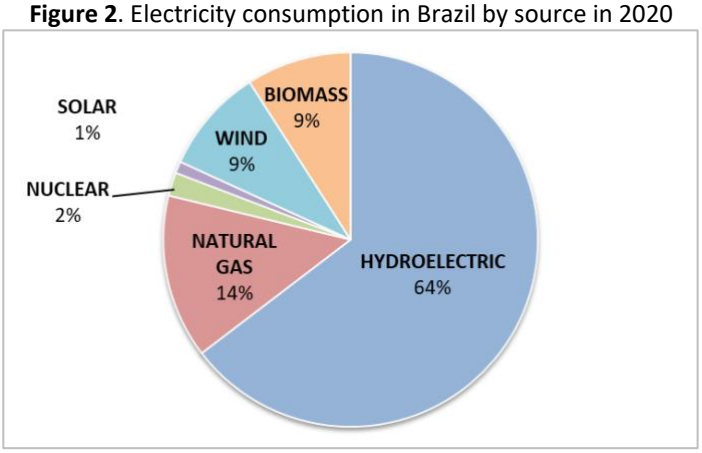
Figure 1. Electricity consumption in the world by source in 2020



Source: Authors (2022). Prepared according to EIA (2021)

It is noticed that renewable energy sources still represent a small share of the matrix, with the most predominant non-renewable sources being oil (30%), coal (25%), and natural gas (25%). In Brazil, however, this scenario is different. In Figure 2, it is possible to observe the distribution of energy sources in the Brazilian electrical matrix.

Figure 2. Electricity consumption in Brazil by source in 2020



Source: Authors (2022). Prepared according to EIA (2021)

Currently, hydroelectric plants account for 64% of the country's electricity consumption, and the second most used source is natural gas, with a 14% share. On the positive side, Brazil stands out in the use of renewable sources, an important situation in the current transition to a more sustainable scenario. However, the country faces some setbacks regarding the use of energy from water on a large scale. Among them, one can list the political scenario, low rainfall, and delays in investments in the sector (Araujo and Oliveira, 2020).

The decrease in rainfall and reservoir levels shows that Brazil needs to create alternatives to face times of drought without having to resort to dispatching thermal power plants whose operation is very expensive, passing on their costs to consumer tariffs (Fuhrmann, 2016). Thus, it is important for a country to have a diversified electrical matrix to meet energy demand and avoid crises in the sector. One option that has been proven to be favorable in this regard is the use of natural gas as a secondary source, due to its low cost and wide availability compared to other available sources (Gillingham & Huang, 2019).

The Natural Gas Industry in the World

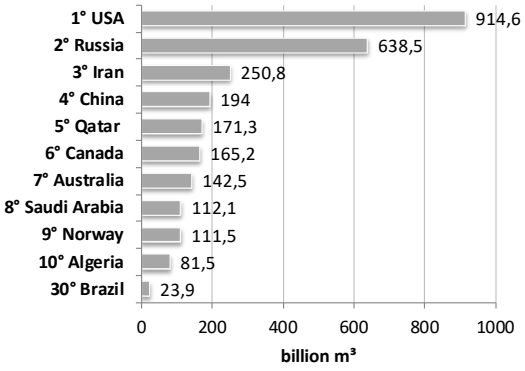
Due to its low-carbon and high-efficiency characteristics relative to oil and coal, natural gas is occupying an increasing position in the global energy structure and is expected to overtake oil as the dominant fuel shortly (Kan et al., 2019). According to the latest statistics published by British Petroleum (BP), through the annual Statistical Review of World Energy, the largest producer of natural gas in the world is the United States, with 914.6 billion m³. Brazil appears in 30th position with 23.9 billion m³ of annual production. Figure 3a presents the top ten natural gas producers in 2020.

However, according to the magazine, although the United States is the largest producer of natural gas in the world, the country appears in 5th place with 12.6 trillion m³ of reserves, with Russia having the largest proven reserves in the world with 37.4 trillion m³. Other countries are among the top 10 worldwide for natural gas reserves, according to Figure 3b, but are not among the top 10 producers, according to Figure 3a. These countries are Turkmenistan, in 4th place, with 13.6 trillion m³; Venezuela, in 7th place, with 6.3 trillion m³; the United Arab Emirates, in 9th place, with 5.9 trillion m³; and Nigeria, in 10th place, with 5.5 trillion m³.

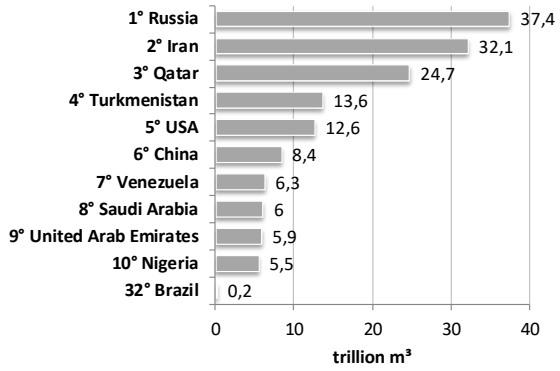
In Brazil and the rest of the world, there is an acceleration of the increase in demand for natural gas due to environmental concerns, as it is considered a clean energy compared to other fossil fuels. (Santos et al., 2017). According to the IEA (2020), there will be a growth of 1.27% per year in the demand for natural gas in the world, mainly in the Asia-Pacific region. This growth is mainly linked to the replacement of other fuels for electricity generation in China, in addition to meeting the increase in Asian demand, preferably through natural gas and other sources with lower Greenhouse Gases (GHG) emissions than those historically used (EPE, 2020).

Also, according to the Statistical Review of World Energy magazine (Figure 3c), the United States is the country that most consumes natural gas in the world, followed by Russia and China. Brazil occupies the 28th position. The total world consumption of natural gas in 2020 was 3822.8 billion m³. This value, if compared to the previous ten years (2010), when consumption was 3160.5 billion m³, represents an increase of approximately 20.95%. The data refer to industrial and household consumption.

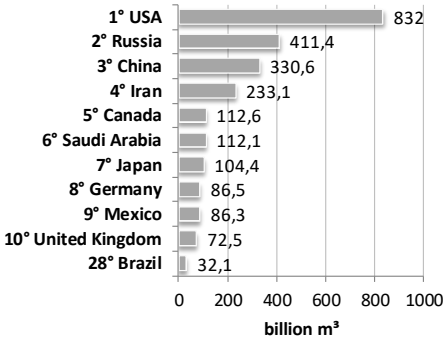
Figure 3. Overview of the largest producers, reserves and consumers of natural gas in the world and the position of Brazil



a - The ten largest natural gas producers at the end of 2020 and production in Brazil.



b - The ten largest natural gas reserves at the end of 2020 and Brazil's reserve.

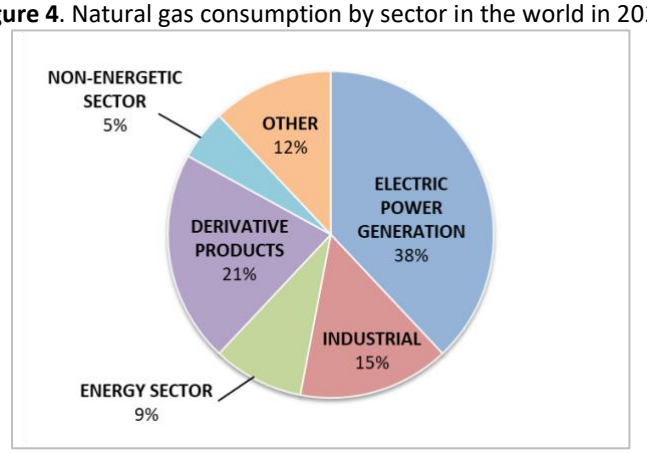


c - The ten largest consumers of natural gas at the end of 2020 and consumption in Brazil.

Source: Authors (2022). Prepared according to BP (2022)

In 2020, natural gas occupied the third position in total primary energy demand in the world, with approximately 30% of total demand (IEA, 2021). In general, the global demand for natural gas is focused on the electricity generation sectors (38%), derivative products (21%), and the industrial sector (15%). Figure 4 presents the structure of world natural gas demand by sector in 2020.

Figure 4. Natural gas consumption by sector in the world in 2020



Source: Authors (2022). Prepared according to EPE (2021)

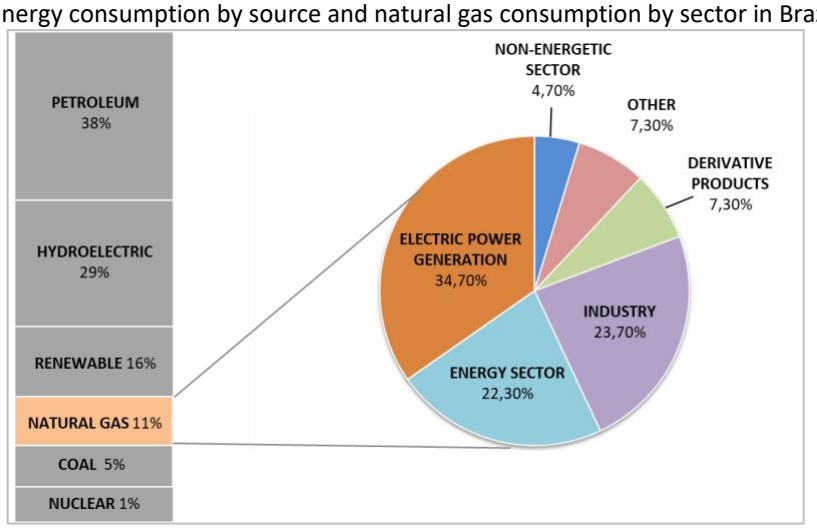
According to the data, it is noted that the top five natural gas producers in the world are the United States, Russia, Iran, China, and Qatar. Therefore, the consumption and legislation in force in each country were analyzed to carry out a comparative analysis with the Brazilian legislation and the incentives carried out in the country.

THE NATURAL GAS INDUSTRY IN BRAZIL

According to the last National Energy Balance (EPE, 2021), the consumption of natural gas in Brazil in 2020 took place mainly in the generation of electricity, with a share of 11.8% in the national energy matrix. There was a 6% decrease compared to the previous year due to the drop in industrial consumption, which may be linked to the Coronavirus pandemic that started in 2019. The low dependence on gas demand in certain sectors and regions is mainly due to the predominant role of hydroelectricity and sugarcane products, underdeveloped gas infrastructure, low demand for heating, and lack of investment and regulatory frameworks (Kerdan et al., 2019). Figure 5 presents energy consumption in Brazil and the percentages of natural gas demands from each sector of the country.

However, despite having great applicability in the Brazilian energy sector, there are still many difficulties for the insertion of natural gas in the energy matrix. According to IBP (2019), the main challenge is to create a competitive market in the country. Furthermore, even though the pre-salt has contributed to the advancement of natural gas production in Brazil, it is still necessary to face the challenge of making the energy source economically viable, improving the country's gas pipeline network, and developing and applying technologies that enable/improve the separation of CO_2 and promote its reuse (Santos, 2020).

Figure 5. Energy consumption by source and natural gas consumption by sector in Brazil in 2020



Source: Authors (2022). Prepared according to EPE (2021)

METHODOLOGY

Once the exploratory search and data analysis were performed, a case study was carried out for Brazil to compare the Brazilian scenario with the analyzed countries. For the case study, it analyzed the proven reserves, production capacity, processing capacity, share of electricity generation by natural gas, and electricity consumption. Based on these data, the percentage

of electricity demanded in the country coming from natural gas and whether there is a possibility of growth for the sector were analyzed.

The states that most produce and consume natural gas as a secondary source of electricity were analyzed. Also, the incentives that collaborate to increase electric production by natural gas were evaluated.

To carry out the case study, a survey of data was elaborated regarding the proven reserves of natural gas, production, processing, and use of natural gas in the generation of electricity in the previously selected countries (USA; Russia; China; Iran; Qatar; and Canada). These data were evaluated to correlate the presence of incentives regarding the use of natural gas in the electrical matrix. Such data were taken from websites, manuals, standards, and reports prepared by official bodies that deal with natural gas in each country. This relationship served to confront these parameters with the data obtained through the case study in Brazil.

After this data analysis, a comparison was made between the results obtained from the countries studied and the results obtained for Brazil. With this, it was expected to evaluate what has been done in Brazil in relation to natural gas so that it is more used in the electrical matrix; and what the incentives observed in other countries are that collaborate for the use of this source in the matrix that can be applied to the Brazilian electrical matrix.

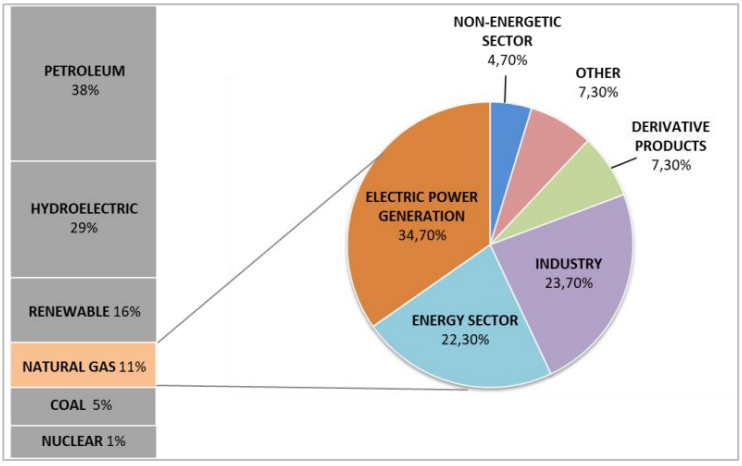
RESULTS AND DISCUSSION

RESERVES, PRODUCTION, AND CONSUMPTION OF NATURAL GAS IN THE BRAZILIAN ELECTRIC MATRIX

According to ANP (2022), in 2021, 378,653 MMm³ of proven reserves, 491,919 MMm³ of proven + probable reserves, and 560,396 MMm³ of proven + probable + possible reserves were declared. These numbers represented an increase of 11.7%, 20.3%, and 24.0% compared to 2020, respectively. This shows that there is a movement in commercial projects for additional natural gas (NG) exploration.

Out of all net natural gas production in the country (100%), natural gas goes through a few stages before it becomes available on the market. In 2021, 15.63% of the total volume of gas produced was sent to the Natural Gas Processing Unit (UPGNs) to be processed or transformed into LPG and C5+ (natural gasoline). The 14.06% corresponds to the volume that is not yet available for the integrated network; that is, it constitutes isolated systems to serve specific sets of consumers. The 70.31% corresponds to the integrated network to be added to imports and serve the domestic market. From this total production, it is possible to observe the contribution of each producing state in Brazil (Figure 6).

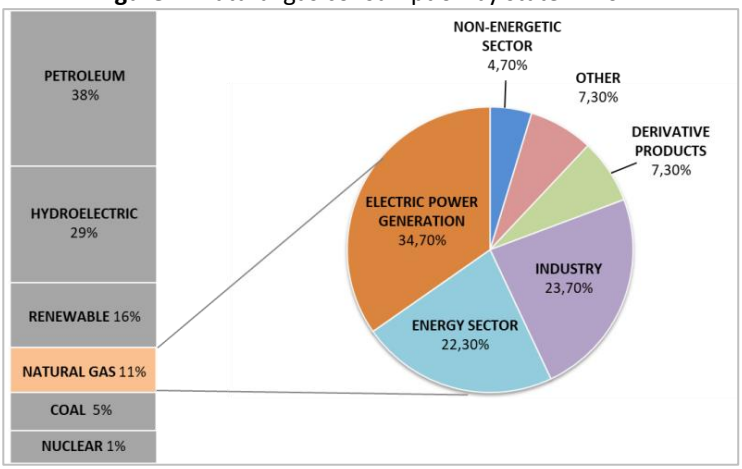
Figure 6. Natural gas production in Brazil by state in 2021



Source: Authors (2022). Prepared according to ANP (2021).

The consumption of natural gas in Brazil occurs through the national supply added to the imported volume of Bolivian gas through GASBOL, and Argentine gas through TSB. Regarding consumption in Brazil, the graph in Figure 7 shows consumption in 2021 for each of the states.

Figure 7. Natural gas consumption by state in 2021



Source: Authors (2022). Prepared according to ANP (2021).

The state of Rio de Janeiro is the largest consumer of natural gas and represents the largest share of consumption with 74.09%. Espírito Santo is the second-largest consumer. In total, the Southeast region consumes 93.90% of the natural gas available in the country. Regarding the use of NG, Table 1 shows the movement of the source, in 2021, according to the destination.

Table 1. Natural Gas handling by destination in 2021 (Mm^3/d)

Month	Production	Intern consumption	Burn	Available	Injection
January	135,929	14,021	2,901	61,192	57,815
February	131,087	13,449	3,475	55,066	59,096
March	126,086	13,426	3,173	50,177	59,310
April	131,432	14,028	2,888	53,495	61,021
May	134,554	13,734	2,948	57,898	59,974
June	135,750	13,370	3,128	58,909	60,343
July	139,178	14,040	3,516	56,087	65,536
August	136,594	13,698	3,102	55,322	64,472
September	133,373	13,568	3,986	48,785	67,034
October	131,703	12,930	4,343	57,084	57,346
November	136,585	13,647	3,790	61,730	57,418

December	132,239	13,747	3,329	54,465	60,698
AVERAGE	133,709	13,638	3,382	55,851	60,839

Source: Authors (2022). Prepared according to ANP (2022).

The volume produced in 2021 reached an average of 133,709 Mm^3/d, representing a 5% growth compared to 2020 (ANP, 2022). Of this produced volume, NG was destined for internal consumption, availability for use, and injection into wells. A smaller portion of this volume was burned or lost. Note that the volume of all NG movements remained stable throughout the year, with no major fluctuations over the months.

INFRASTRUCTURE FOR NATURAL GAS IN BRAZIL

Regarding the refining stage, Brazil had 14 UPGNs to separate the heavy fractions existing in NG in 2021. Table 2 shows the list of UPGNs and their respective locations. In all, the UPGNs had an operating capacity of 104,710 Mm^3/d, with the Cabiúnas hub having the highest installed capacity. According to the ANP (2022), the oldest UPGN in operation is Santiago[2], which started operations in 1962, and the most recent is the UPGN of Alvopetro, starting operations in 2020.

Table 2. Natural Gas Processing Units in Brazil

Producing Poles	Municipality (State)	Start of Operation	Normal Capacity (Mm^3/d)
Santiago[2]	Catu (BA)	1962	2000
Candeias	San Francisco do Conde (BA)	1972	2900
Reduc	Duque de Caxias (RJ)	1983	5000
Guamaré	Guamaré (RN)	1985	5700
Lubnor	Fortress (CE)	1987	350
Cabiúnas	Macaé (RJ)	1987	25160
Urucu	Coari (AM)	1993	12200
RPBC	Cubatão (SP)	1993	2500
Alagoas	Abutment (AL)	2003	1800
Vandemir Ferreira Station	San Francisco do Conde (BA)	2007	6000
Cacimbas	Linhares (ES)	2008	18100
Sul Capixaba	Anchieta (ES)	2010	2500
Caraguatatuba	Caraguatatuba (SP)	2011	20000
Alvopetro	Forest of São João (BA)	2020	500

Source: Authors (2022). Prepared according to ANP (2022).

The transport pipeline network in Brazil comprises 9,400 kilometers of pipelines. Of this total, 96.1% is currently controlled by Petrobras. In addition, the gas pipeline network has remained stagnant since 2012 (FGV, 2019).

Cruz and Guerra (2022) reinforce that, in terms of extensions of transport pipelines, Brazil is lagging regarding the distribution of gas to the population, in addition to the lack of new pipelines built in its geographic area. For comparison, Argentina has approximately 16,000 kilometers of transport pipelines, almost twice as many as Brazil, even with a smaller land area.

MAIN WORLD POWERS IN NATURAL GAS ELECTRICITY VS BRAZIL: COMPARATIVE ANALYSIS

An analysis of the amount of natural gas consumed in the electricity matrix of each country, shown in Table 3, shows that Brazil uses 50.80% of all-natural gas produced and imported to generate electricity. However, when analyzing the volume produced, Brazil, which produced 24.3 bcm in 2021, is still far from the average production of other countries, which was 408.52 bcm.

Table 3. Share of natural gas in the energy matrix of the countries under study in billions of cubic meters 2021

Country	Production (bcm)	Consumption (bcm)	Import (bcm)	Export (bcm)	GN in the Electrical Matrix (bcm)	Percentage of NG in the Electrical Matrix
U.S	934.2	826.7	76.5	179.3	355.0	38%
Russia	701.7	474.6	15.1	241.3	266.6	38%
Will	256.7	241.1	-	17.3	66.7	26%
China	209.2	378.7	109.5	-	46.0	22%
Canada	172.3	119.2	26.2	54	53.4	31%
Qatar	177	40	-	106.8	42.5	24%
Brazil	24.3	40.4	17.2	0.1	12.3	50.80%

Source: Authors (2022). Prepared according to Enerdata (2022), CEIC (2021) and BP (2022).

Table 4 presents a list of bodies responsible for regulating the natural gas production chain in the countries; companies responsible for the extraction and production of natural gas; types of fees charged for these companies to participate in the production chain; and the incentive policies in force in the country to increase the participation of natural gas in the energy chain.

Table 4. Regulation and Incentives in the natural gas chain in the countries under study

Country	Body Responsible for Regulation	Extraction and Production Companies	Legislation and Taxation	Incentive Policies
U.S	State Governments	Most: private properties. Other parties: federal government, state governments or native tribes	There are no federal taxes. Rates depend on the taxation of the state where the natural gas is being produced	Repeal of regulations that may have caused a disincentive to natural gas production in the country
Russia	Federal Subsoil Use Agency	State Enterprises; especially Gazprom	Participation fees in bids or auctions. One-off payments for granting the subsoil license and other instances provided for in the subsoil use license and geological study	Government offers tax incentives for energy companies to invest more in refineries
China	National Development and Reform Commission; National Energy Administration and its branches in different provinces and cities	State-Owned Enterprises: PetroChina, Sinopec, CNOOC and Shaanxi Yanchang Petroleum Group	VAT; Consumption rate; Customs Law; Income tax	Policies aimed at the insertion of new companies for gas exploration and production in China
Iran	Ministry of Petroleum of the Islamic Republic of Iran	Private companies	Federal taxes.	Drafting of the Iran Oil Contract
Canada	Canadian Energy Regulator, Canadian Environmental Assessment Agency, Department of Fisheries and Oceans	Private companies	Canadian Exploration Expense; Canadian Development Expenditure; Canadian Oil and Gas Ownership Expenses	Currently, there are no specific federal or territorial policies that encourage gas exploration and production in the country
Qatar	Ministry of Energy Affairs	Private companies	The tax rate applicable to contracts to which the government or other public entity is a party is determined in the terms of the contract but must be a minimum of 35% of taxable income	Currently, there are no specific federal or territorial policies that encourage gas exploration and production in the country
Brazil	National Agency of Petroleum, Natural Gas and Biofuels, Ministry of Mines and Energy, National Council for Energy Policy	Most: state-owned company, Petrobras. Other parties: private companies	Signing Bonus; Royalties; Special participation; Annual occupancy or retention rate	Currently, there are no specific federal or territorial policies that encourage gas exploration and production in the country

Source: Authors (2022). Prepared according to IEA (2022) and Thomson Reuters Practical (2022).

SCENARIO AND PROSPECTS FOR NATURAL GAS IN THE BRAZILIAN ELECTRICITY SECTOR

Although the Brazilian electricity matrix is predominantly hydro, the share of this energy source has fallen over the last few years. Data from the National Electric System Operator—ONS—indicate that, in 2009, hydroelectricity accounted for 80.8% of the installed capacity in Brazil. In 2021, this number dropped to 63.2% (Taets, 2021). This reinforces the need for other energy sources to supply the demand in the country.

In this sense, natural gas plays an important role as a secondary source to meet the demand of a country like Brazil, due to the energy security that the source offers compared to hydroelectric power. However, it is important to highlight the need for investment in infrastructure to facilitate access to natural gas and thus encourage its use. As pointed out by the IEA (2022), a project for the construction or expansion of an interstate gas pipeline takes on average, about three years from the moment it is announced until its completion. In addition, project implementers may encounter environmental obstacles or public opposition during their planning.

Another limiting factor that can raise concerns about the use of natural gas in Brazil, as well as any other non-renewable source, is the carbon emission rate. It is necessary to use methods to reduce the emission of CO_2 into the atmosphere. The capture of CO_2 proves to be effective and can collaborate to achieve the goals stipulated to mitigate these gas emissions.

On the other hand, some opportunities may arise to favor the increased use of the source in the country. Campos et al. (2016) raised the issue of the fall in the value of natural gas due to reduced imports from the United States. The country has had recent discoveries of unconventional gas, which has caused its imports to decline. As a result, this drop could promote a reduction in demand for natural gas worldwide, as the United States was one of the largest importers of natural gas. Therefore, a drop in price can result in a good competitive scenario with other lower-priced sources.

Some actions taken by government agencies can also collaborate directly to encourage investments in the country's natural gas industry. The ANP (2022) approved a resolution to regulate the reduction of the royalty rate for small and medium-sized companies. As a result, the government hopes that the useful life of the fields will be extended.

CONCLUSION

Natural gas has favorable advantages to become the main alternative source in an energy matrix. One of the main advantages is the energy security that the source provides because there are no fluctuations in the energy supply, as is the case of the hydroelectric plant in the absence of rain and of the solar plant in times of low radiation. Another important factor is the prospect of increased gas production due to existing exploration and production optimization methods, which help to avoid gas loss in the reservoirs.

This study provided research that involves the analysis of the use of natural gas as a secondary source of electricity generation in Brazil. Studies on the regulations and legislation of the main producers and consumers showed that Brazil applies many tax rates for producing companies and for importing natural gas. This, in a way, may discourage investment in more projects to expand the use of gas in Brazil.

Countries do not have a lot of incentives to use natural gas. It is believed that the low taxes charged are a contributing factor in attracting investment to the main producers and consumers. In the United States and Russia, tax incentives are paramount in dealing with domestic production incentives.

In Brazil, it is possible to observe that the main limiting factor to increasing the share of natural gas, after the high tax rates, is the poor infrastructure available to transport gas in the country. However, there is a prospect of growth in the gas pipeline network, which may contribute to increased NG production. In addition, it was observed that a significant portion of the natural gas produced in the country is still discarded; that is, it is necessary to make greater use of gas in the country.

As noted, Brazil has reserve potential to produce large volumes of natural gas; however, the processing and distribution capacity is still scarce to meet demand. Still, almost half of the NG produced is injected into wells, which shows the low use of natural gas for use in final products, such as fuel to produce electricity.

Even so, it is possible to observe Brazil's potential to invest in natural gas expansion projects in the electricity matrix, as the country has large reserves and producing companies, in addition to having a large territorial extension for possible gas pipeline construction projects.

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REFERÊNCIAS

Aguilera, R. F. (2012). World natural gas endowment as a bridge towards zero carbon emissions. *Technological Forecasting and Social Change*, Perth, 79(3), 579-586.

ANP (2022). *Boletim da Produção de Petróleo e Gás Natural*. Rio de Janeiro: Anp. Available in https://www.gov.br/anp/pt-br/centrais-de-conteudo/publicacoes/boletins-anp/boletins/arquivos-bmppgn/2021/2021-03-boletim-pdf

ANP (2021). *Boletim de Recursos e Reservas de Petróleo e Gás Natural 2021*. Rio de Janeiro: Anp, 2021. Available in https://www.gov.br/anp/pt-br/centrais-de-conteudo/dados-estatisticos/arquivos-reservas-nacionais-de-petroleo-e-gas-natural/boletim_reservas_2021.pdf

Araujo, G. J. F. de & Oliveira, S. V. W. B. de. (2020). Análise de viabilidade econômica-financeira do uso de vinhaça para geração de eletricidade no Brasil. *Cadernos Ebape.Br*, São Paulo, 18(4), 936-955.

BP, British Petroleum (BP, 2020). *Statistical Review of World Energy***.** Online: Bp, 2020. [internet], 68 p. Available in https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf

Campos, A. F., Silva, N. F. da, Pereira, M. G.; Freitas, M. A. V. (2016). A review of Brazilian natural gas industry: challenges and strategies. *Renewable And Sustainable Energy Reviews*, Rio de Janeiro, 75, 1207-1216.

CEIC. *Catar Gás Natural: Exportações.* 2021. Available https://www.ceicdata.com/pt/indicator/qatar/natural-gas-exports#:~:text=Os%20dados%20de%20G%C3%A1s%20Natural,Cub%20m%20mn%20em%202020

Cruz, P. P. C. & Guerra, L. D. (2022). Estudo de caso da extensão de gasodutos no Brasil: ênfase nas alternativas para expansão de novas malhas. *XIII Fateclog*, Mauá, 13(1), 1-11.

EIA. *Annual Energy Outlook* (2022)**.** Washington: U.S. Department of Energy, 127 p.

EIA. *International Energy Outlook* (2019). Washington: U.S. Department of Energy, 85 p.

EIA**.** *International Energy Outlook* (2021). Washington: U.S. Department of Energy, 42 p.

ENERDATA. *World Energy & Climate Statistics – Yearbook 2022.* Available in https://yearbook.enerdata.net/natural-gas/balance-trade-world-data.html

EPE, Empresa de Pesquisa Energética (EPE, 2020). *Demanda de Gás Natural Nos Mercados Nacional Internacional***.** Brasil: Epe.

EPE, (2021). Empresa de Pesquisa Energética, Rio de Janeiro. *Estudos do Plano Decenal de Expansão de Energia 2031.* Rio de Janeiro: EPE. Available https://www.gov.br/mme/pt-br/assuntos/noticias/CadernodeGsNaturalPDE203130nov211.pdf

FGV (2019). *Transporte de Gás Natural no Brasil*. Rio de Janeiro: Ceri, 50 p.

Fuhrmann, G, L. (2016). *Análise dos novos condicionantes da oferta nacional de gás natural e a demanda termelétrica no próximo decênio*. (Dissertação de Mestrado), Departamento de Engenharia Química, COPPE UFRJ, Rio de Janeiro.

Galvão, J. & Bermann, C. (2015). Crise hídrica e energia: conflitos no uso múltiplo das águas. *Estudos Avançados*, São Paulo, 29(84), 43-68.

Gillingham, K. & Huang, P. (2019). Is Abundant Natural Gas a Bridge to a Low-carbon Future or a Dead-end? *The Energy Journal***,** Yale, 40(2), 1-26.

IBP, Instituto Brasileiro de Petróleo e Gás (IBP, 2019). Rio de Janeiro. *Relatório de atividades 2019. [internet] [cited 2022 jul 02].* Rio de Janeiro: IBP. 29 p. Available https://www.ibp.org.br/personalizado/uploads/2020/03/relatorio-atividades-2019-ibp-compactado.pdf.

IEA, International Energy Agency - IEA (2015). *Key World Energy Statistics 2015.* Available in**:** http://www.iea.org/publications/freepublications/publication/key-world-energy-statistics-2015. Html.

IEA, International Energy Agency – IEA (2020). *Global Energy Review 2020.* [internet]: Iea, 2020. 55 p. [cited 2022 out 15]. Available in https://iea.blob.core.windows.net/assets/7e802f6a-0b30-4714-abb1-46f21a7a9530/Global_Energy_Review_2020.pdf.

Kan, S. Y., Chen, B., Wu, X. F., Chen, Z. M., & Chen, G. Q. (2019). Natural gas overview for world economy: from primary supply to final demand via global supply chains. *Energy Policy*, Beijing, 124, 215-225.

Kerdan, I. G., Jalil-Vega, F., Toole, J., Gulati, S., Giarola, S., & Hawkes, A. (2019). Modelling cost-effective pathways for natural gas infrastructure: a southern Brazil case study. *Applied Energy*, Londres, 255, p. 11.

Lima, M. T. da S. L. & Souza, M. C. de. (2015). Discorrendo Sobre O Uso Das Termelétricas No Brasil. *Ciência e Natura*, Brasilia, 37, 17, 18 jun.

Pedroso, L., Silva, F., Melo, A., Junior, M., & Shimoya, A. (2018). Demandas atuais e futuras da biomassa e da energia renovável no Brasil e no mundo. *Brazilian Journal of Development*, 4 (5), 1980-1996.

Pereira, D. S. & Silva Neto, R. (2021). Diversificação de fontes geradoras da matriz elétrica brasileira: uma revisão sistemática. *Meio Ambiente (Brasil),* 3(1), 02-21.

Santos, E. M. dos & Peyerl, D.; Netto, A. L. A. (2020). *Oportunidades e Desafios do Gás Natural e do Gás Natural Liquefeito no Brasil***.** Rio de Janeiro: Letracapital, 186 p.

Santos, M. G. R. S., Correia, L. M. S., Medeiros, J. L. de, & Araújo, O. de Q. F. (2017). Natural gas dehydration by molecular sieve in offshore plants: impact of increasing carbon dioxide content. *Energy Conversion And Management***,** Rio de Janeiro, 149, 760-773.

Taets, L. A. R. (2021). *Análise da utilização conjunta do gás natural e das energias renováveis para a geração de eletricidade.* (Tese de doutorado). Instituto de Engenharia Mecânica, Universidade Federal de Itajubá. Itajubá.

Thomson Reuters Practical. (2022). *Practical Law***.** [internet], [cited 2022 dez 10], Manuscript available https://www.thomsonreuters.com.br/pt/juridico/practical-law.html.