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# Prospects and challenges of the liquefied natural gas market in Brazil

## Perspectivas e desafios do mercado de gás natural liquefeito no Brasil

## Perspectivas y desafíos del mercado de gas natural licuado en Brasil

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**Abstract**
The liquefied natural gas can overcome current barriers, mainly for natural gas transportation over long distances, enabling global trade and overcoming intercontinental distances. Following this trend, Brazil is entering this global market for liquefied natural gas. Therefore, this study aims to evaluate the prospects and challenges of liquefied natural gas for the Brazilian natural gas market through reports from the government and the national industry. It was possible to identify the strengths, weaknesses, opportunities, and threats (SWOT) of this natural gas supply option within the national matrix through the SWOT analysis. After this, the gravity, urgency, and tendency (GUT) matrix were applied and adapted to classify just one dimension, as the importance of each point of the SWOT. As a result, substantial material was gathered for analysis demonstrating positive and negative characteristics of liquefied natural gas for Brazil, besides the government's view on the subject, which can be useful mainly for the academic, commercial, and industrial.
**Keywords:** Liquefied Natural Gas; Natural Gas; Energy Mix; Brazil.

**Resumo**
O gás natural liquefeito vem superando as barreiras atuais, principalmente no transporte de gás natural por longas distâncias, viabilizando o comércio global e superando distâncias intercontinentais. Seguindo essa tendência, o Brasil vem adentrando nesse mercado global. Logo, este estudo tem como objetivo avaliar as perspectivas e desafios do gás natural liquefeito para o mercado brasileiro de gás natural por meio da análise de relatórios do governo e da indústria nacional. Identificou-se assim, os pontos fortes, oportunidades, pontos fracos e ameaças (FOFA) desta opção de fornecimento de gás natural dentro do mix nacional por meio da análise FOFA. Em seguida, a matriz de gravidade, urgência e tendência (GUT) foi aplicada e adaptada para classificar apenas uma dimensão de importância de cada ponto da FOFA. Como resultado, o material analisado demonstrou as características positivas e negativas do gás natural liquefeito para o Brasil, além da visão do governo sobre o assunto, sendo assim, útil tanto para o meio acadêmico como para os setores comercial e industrial.
**Palavras-chave:** Gás Natural Liquefeito; Gás Natural; Matriz Energética; Brasil.

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**Resumen**
El gas natural licuado viene superando las barreras actuales, especialmente en el transporte de gas natural a largas distancias, posibilitando el comercio global y superando las distancias intercontinentales. Siguiendo esta tendencia, Brasil ha estado entrando en este mercado global. Por lo tanto, este estudio tiene como objetivo evaluar las perspectivas y los desafíos del gas natural licuado para el mercado de gas natural brasileño a través de informes gubernamentales y de la industria nacional. A través del análisis FOFA se logró identificar las fortalezas, debilidades, oportunidades y amenazas (FODA) de esta opción de suministro de gas natural dentro de la matriz nacional. Luego, se aplicó y adaptó la matriz de severidad, urgencia y tendencia (GUT) para clasificar solo una dimensión de importancia de cada punto FODA. Como resultado, se recolectó material sustancial para análisis, demostrando las características positivas y negativas del gas natural licuado para Brasil, además de la visión del gobierno sobre el tema, que puede ser útil tanto para el ambiente académico como para los sectores comercial e industrial.
**Palabras clave:** Gas Natural Licuado; Gas Natural; Matriz Energética; Brasil.

## 1. Introduction

Natural gas (NG) in Brazil is gaining relevance in the Brazilian energy mix, being pointed out as responsible in 2019 for 6.9% of all energy consumption among all sources and with growth prospects for 9.2% in 2029 (EPE, 2021b). Currently, the participation of natural gas in the Brazilian energy mix consists of domestic production of pre-salt and post-salt, the Bolivia-Brazil gas pipeline (GASBOL), and imports of liquefied natural gas (LNG) from several countries, such as Nigeria, Trinidad and Tobago, The United States, among others. At the end of 2020, LNG represented 27.8% of the supply of NG in Brazil (MME, 2020). Besides, NG is currently considered a commodity for commercialization in the global market, but its consumption was limited to geographical issues, being consumed at or near the place of its production due to high logistical costs (Santos, 2019) and limited by geographical factors due to the lack of infrastructure, such as gas pipelines, thus having the majority of trading partners in neighboring countries. However, through greater flexibility in the mode of transportation, the LNG revolution made it possible to sell it over long distances and has contributed to the global liquidity of the NG market (Zhang et al., 2018).

LNG has the same chemical characteristics as NG transformed into a liquid state through the liquefaction process, when it is cooled down to a temperature of -162º Celsius (or -260º Fahrenheit, in the unit of measurement most used within the LNG market), reducing its volume up to 600 times (Pirrong, 2014; Thomas & Dawe, 2003). Therefore, it is possible to transport more LNG than NG, being attractive mainly for transportation over long distances such as intercontinental or interoceanic ones (Zhang et al., 2018). It also can be used for fueling the vehicles that are used for its own transportation, such as trucks and ships. Besides the transformation into a gaseous state for transporting, LNG can be used in the liquid form in various applications such as electricity generation or as raw material in the industry (Zhang et al., 2018).

Therefore, the NG and LNG trade has become an important aspect of the energy strategy for any country that wants to guarantee the security of the energy supply (Elliott et al., 2021; Lecarpentier, 2018). The Brazilian government research company (Empresa de Pesquisa Energética, EPE) predicts that the international LNG market will continue to grow at an accelerated rate (EPE, 2019b). The Brazilian history of LNG importation started in August 2008 with few deliveries but has been increasing its movement year by year, reaching almost a third of the national LNG supply by the end of 2020 (MME, 2020). The period from 2013 to 2015 should be highlighted, as there was a continuous importation of large volumes to produce electricity in order to compensate for the low hydraulic generation of electricity due to the water crisis of that period (ANP, 2019). However, for this acceleration to take place effectively, the national NG market must be a safe environment for companies to negotiate attractive prices. In the case of supply via LNG, projects for regasification terminals linked to a thermal power generation unit are in construction in Brazil (CNI & ABRACE, 2016). Beyond this type of project, the LNG is also seen as a source for industrial consumers of NG and the transportation sector (Fraga et al., 2020; P. A. Gomes, 2018).

In Brazil, it is emphasized that there are structures of regasification terminals necessary to receive the ships on the coast and transform the LNG from liquid to gas, allowing it to be injected into the national gas network. Currently, there are five terminals, three of which belong to Petrobras (Brazilian Oil Company), which is also responsible for their operation, in the states of Bahia, Ceará, and Rio de Janeiro. Of the two newest terminals, one is in the state of Sergipe, linked to the Porto Sergipe 1 Thermoelectric Power Plant (TPP), which started operating in 2020, and is the first private LNG terminal in Brazil. The other is in Rio de Janeiro, and in January 2021, it had the first delivery of LNG in the project called Porto do Açu. There is another project still in the implementation phase in the state of Rio de Janeiro, associated with the TPP Marlim Azul, scheduled to start operating in 2022 (EPE, 2019e). In March 2021, the Bahia terminal completed the bidding process to allow operational access to private companies in addition to Petrobras.

Based on the panorama above mentioned, this article aims to analyze the prospects and challenges of LNG for the Brazilian NG market through reports from government and national industry. Through the SWOT (acronym for Strengths, Weaknesses, Opportunities, and Threats) analysis, it was possible to identify the strengths, weaknesses, opportunities, and threats of this natural gas supply option within the national matrix. After this, the GUT was applied and adapted to classify the importance of each point of the SWOT. Through this analysis, the article proposes to answer the following questions: in what uses and applications will LNG play the role of an additional source of NG within the national matrix, being an interesting and financially attractive option? What are the advantages and disadvantages of LNG compared to other sources of NG? Having a clear view on these issues becomes mainly important for large consumers within a free market, choosing which source of NG is most appropriate, as well as being a driver for international agreements between nations to foment the LNG and NG market.

The first part of this article will present the criteria for selecting gray literature, the basis to be applied in the SWOT analysis and the elaboration of the adapted GUT (Gravity, Urgency, and Tendency) matrix. It will identify arguments associated with four distinct points: LNG's strengths, weaknesses, threats, and opportunities for Brazil. Then the second part of this article will discuss the points raised in the SWOT analysis, crossed with gray literature references and academic and scientific references, to create a detailed text with explanations of each topic. Finally, the article will end with the conclusions obtained.

## 2. Materials and Methods

This work followed the methodology starting with: i) the review of the gray literature, formed by reports issued by the Brazilian federal government with the help of reinforcing or even countering the view of private institutions of national studies and research, having selected those that are related to the theme of NG and Brazilian LNG. The material consulted can be understood as gray literature. It is not conventional articles and publications from the academic or commercial world, following bibliographic rules and controls, but reflections on the vision of public administration and the federal government. The material research considered materials published over the last four years, from January of 2016 to April of 2021, due to the news in the global LNG market as well as the accelerated development of the NG market from the American shale gas in recent years. In addition, current paths in the Brazilian NG market on the pre-salt exploratory influences on Argentine exploration in the *Vaca Muerta* field and the Bolivian NG importation contract renewal were other reasons for the delimitation of the period. ii) Four distinct points on these reports were selected: LNG's strengths, weaknesses, threats, and opportunities for Brazil. iii) The SWOT was applied to elaborate a GUT matrix that was adapted to just one dimension as importance, making possible to identify and detail the main advantages and disadvantages of LNG used in the national NG mix (Carmelita & Moreno, 2021; Ferrel & Hartline, 2013; Josiany et al., 2021). Both are tools dedicated to assistance in decision making, the definition of projects, as well as the choice of suppliers, or supply channels, such as the theme of this study (Ferrel & Hartline,

2013). They make it possible to identify the competitive advantages that define the differences in the options raised, making the best choice clear in light of that set of studied parameters (Carmelita & Moreno, 2021; Ferrel & Hartline, 2013; Josiany et al., 2021).

To elaborate the SWOT analysis, 41 reports were selected and evaluated as results of the research in publications of Brazilian governmental institutions such as the Brazilian Ministry of Mines and Energy (MME), the Ministry of Science, Technology, Innovations and Communications (MCTI), the Company of Energy Research (EPE), the National Petroleum and Biofuels Agency (ANP) and the National Bank for Economic and Social Development (BNDES) with the help of reinforcing, or even counter, the view of private institutions such as the Getúlio Vargas Foundation ( FGV) and the National Confederation of Industry (CNI) still within the national scope. After the SWOT analysis, the GUT was based on in the analysis of the common topics found in the reports.

## 3. Discussion and Results

The global LNG market has been going through a period of great development and expansion, with its liquefaction capacity showing strong investments worldwide. The generation of this availability has added an amount of LNG volume that leads to the development of markets and new consumer points. Brazil, in this chain, is seen as one of those important consuming countries for producers in Central America, North America, Africa and the countries of the Middle East. The trend for the future of the natural gas market is that low LNG prices be currently available on the international market, including Brazil (FGV, 2019a). This competitive opportunity changes the scenario of NG in Brazil, creating opportunities in several areas such as power generation, transportation, and industry. The recent changes in the legislation and regulation of the NG sector that have arisen from the government program "New Gas Market" (*Novo Mercado de Gás)* (2019) (FGV, 2019a; MME, 2019b) have caused an evolution in all links of the chain and aroused the interest of several national and international companies to invest in the sector of Brazilian NG, thus generating new opportunities (FGV, 2019a). This program represents another step in the evolution of the gas market, as it was built upon previous programs such as "More Gas Brazil" (*Mais Gás Brasil)* (2013) and "Gas to Grow" (*Gás para Crescer)* (2016), the latter generating forums at several critical points with contributions from various agents that generated knowledge to arrive at the most recent program (FGV, 2019a). However, some issues still need to be discussed and clarified, which has been a constant concern for the next steps by the federal Government.

An analysis of the national NG matrix, composed of domestic production in the pre-salt and post-salt basins, as well as the importation of NG from Bolivia, demonstrates a need for high investments in the domestic production that are not foreseen in the planning of oil exploration companies on the Brazilian coast for the coming years. While in the Bolivian importation option, there are concerns about political instability and uncertainty regarding the volume of the remaining reserves of the Bolivian NG, leaving doubts about this source in the long term (CNI, 2018).

About the LNG, the Brazilian government seeks to meet the necessary and fundamental energy security to guarantee the country's development in the coming decades. This includes flexibility in supply and the extent required for the accelerated addition of gas TPPs to the planned national energy park (Michelena, 2018). On the other hand, it is necessary to be aware of some weaknesses in this option of supplying NG via LNG, for example, the need for high investments and commercial conditions required by suppliers that limit consumer markets. Initially, commercialization depends on high take-or-pay or ship-or-pay contracts, adding to the requirement for credit guarantees and the requirement for bulk deliveries of indivisible cargo in a single terminal (FGV, 2019a).

### 3.1 SWOT Analysis

**Table 1.** SWOT matrix of LNG in Brazil.

| STRENGTHS | WEAKNESSES |
|---|---|
| a) Great LNG worldwide availability.<br>b) Competitive LNG prices in recent years.<br>c) Serves large volumes for a specific period, required in TPPs.<br>d) Serves regional supplies (remote delivery) located in markets not served by pipeline structures with large capacity.<br>e) Global trend with an increasingly dynamic global market, with greater liquidity and tending toward commoditization, generating contractual and market agents' maturity.<br>f) Diversification of sources and increased energy security.<br>g) New projects for regasification terminals and TPPs to LNG already awarded in auctions to sell energy.<br>h) Ability to serve different markets since NG is a generic energy source used in all sectors of the economy.<br>i) LNG is another facilitator for the use of NG, seen as a transition energy source for a sustainable matrix.<br>j) Independence of oil production in national production and, consequently, independent of environmental regulation of the national output.<br>k) Strengthening national energy security.<br>l) The end of the American LNG service in Japan (with the resumption of nuclear power plants) will create a surplus of LNG available for new markets.<br>m) Possible surplus of the national production of LNG could make the flow of Brazil a world exporter, causing moments of import and others of export, fomenting the market of national LNG.<br>o) Recent political instability in Bolivia may hinder the supply of NG to Brazil.<br>p) Political risk of Argentine supply may hinder a possible supply to Brazil.<br>q) High seasonal Argentine consumption during the winter may hinder a possible supply to Brazil.<br>h) The pre-salt NG has a high content of contaminating gases and carbon dioxide ($CO_2$), increasing costs.<br>i) LNG can be delivered close to the place of consumption, reducing costs and environmental licensing of gas pipelines.<br>j) The pre-salt layer still has many uncertainties regarding the necessary investments and monetization of the NG use.<br>k) National production is concentrated in the Southeast, requiring a lot of investment in gas pipelines for transportation to the other regions of Brazil.<br>l) LNG does not depend on gas pipelines or chain links to operate. | a) Contractual requirements and rigidity. With high take-or-pay or ship-or-pay.<br>b) Know-how of business and operation model concentrated in few companies (in the Brazilian case, Petrobras, Shell, Golar LNG, BP, among others)<br>c) Difficulty in licensing new terminals on the shore.<br>d) Requirement of terminals protected from rough seas, reflecting an increase in investment.<br>e) Because it is viable with large volumes, it generates dependence on large anchor projects.<br>f) The current Brazilian regulation does not encourage all parts in the NG chain, such as the distribution sector.<br>g) Tax and fiscal barriers related to the operation of LNG terminals.<br>h) Forecast for 2025, the global LNG supply capacity must reach its limit and not meet demand.<br>i) The investment of LNG processing can become useless at times of high LNG prices in the world market, even if it is not representative.<br>j) Legal and regulatory barriers: tax and fiscal risks, as mentioned above, in addition to sharing large volumes in terminals and logistical structures between various users.<br>k) Need for storage for handling large volumes of NG and LNG. However, there are still no rules for storage agents in Brazil. There are barriers in environmental licensing that prevent the use of underground reservoirs.<br>l) The installation of regasification terminals, as they operate with large volumes of NG in a single location, generate risks of accidents for the surroundings where they are installed. |

| OPPORTUNITIES | THREATS |
|---|---|
| a) To be an interconnecting agent for energy markets around the world.<br>b) Reduces the dependence on large investments in scattered pipeline networks or in the outflow pipelines of offshore reserves.<br>c) To be an NG supplier in the face of uncertainties in the Bolivian supply.<br>d) It attends very well to the large momentary volume required in TPPs.<br>e) The gas pipelines already installed in Brazil have fixed capacity and any increase requires expensive investments.<br>f) The entry of other consuming countries in South America interested in acquiring Bolivian NG.<br>g) The United States, intending to enter closer markets as in South America, is willing to relax contractual conditions.<br>h) To meet the future national need for electricity, a series of new TPPs is being provided for NG and LNG.<br>i) The Brazilian regulatory evolution of the NG in progress will generate new opportunities.<br>k) The Brazilian government's recent change in regulating access to regasification terminals and gas pipelines has worked well. It has been well accepted in the market.<br>l) NG is seen as a vector in the global energy transition, being adopted as energy for the next years or decades. LNG helps with this idea.<br>m) Recent regulatory adjustments have brought large companies to invest in the Brazilian NG and LNG sector.<br>n) The forecast of continuity of low LNG prices in the global market will create opportunities in the national market.<br>o) New LNG projects, such as regasification terminals and TPPs, are ongoing.<br>p) Other applications for LNG, such as in the transportation area (small-scale LNG projects).<br>q) Pre-salt flow projects still have many geological and structural risks that need to be overcome to be viable.<br>r) The Term of Commitment and Termination (TCC) with the Brazilian Administrative Council for Economic Defense (CADE) and Petrobras establishes the end of the monopoly of the state-owned company on NG. In LNG terminals, this allows third-party access.<br>s) Industries such as cellulose, fertilizers, petrochemicals, steel, glass, and ceramics are waiting for the most attractive NG to expand their production.<br>t) Development of remote regions since the LNG will serve the extremes of Brazil where the gas pipeline networks do not support or have limited capacity.<br>u) Argentina can be an alternative to supplying via LNG, compared to suppliers in the Northern Hemisphere.<br>v) LNG processing technologies are constantly evolving, reducing investment, and operating costs. | a) Foreign exchange risk because the price depends on the currency of the international supplier.<br>b) Price reference risk to Henry Hub (HH) or National Balancing Point (NBP) suffering external impacts due to events of various kinds from the origin country, such as geopolitical, economic, or technological.<br>c) International political risk.<br>d) Dependence on the seasonality (climate, winter/summer) of production and consumption in the supplier countries.<br>e) Arbitration of international prices suffering the impact of several reasons (transport, countries willing to pay more).<br>f) The Bolivian supply has served, operationally and strategically, very well until today, showing excellent reliability.<br>g) Given the high investments made worldwide in LNG terminals, financial institutions' availability for new investments begins to be increasingly limited.<br>h) The national NG is rich in energy, and its production associated with oil presents a large quantity of other chemical products, favoring the viability of its production.<br>i) Need to combine the investment in the terminal project, the long-term LNG supply contract, and the LNG or NG purchase contract by the consumer.<br>j) The lack of transparency in pricing can harm the market by generating a monopoly and harming buyers.<br>k) To fulfill the predicted global energy transition process, a high investment of financial resources may be warranted for the next years. Since the sector's investors have already made large investments in recent years, a new wave of contributions may suffer limitations from not having the same availability in the LNG chain.<br>l) When the limitation of flow pipelines to produce NG on the national offshore production is overcome, this NG will need to be consumed, causing an impact on the energy matrix.<br>m) There are several flow pipeline projects currently being planned and studied in Brazil.<br>n) The development of the exploration of *Vaca Muerta* Field (Argentina) and the possibility of investing in gas pipelines to take it to Brazil.<br>o) New discoveries of NG in the basins in Sergipe and Alagoas may threaten the LNG.<br>p) Resolving the obstacles with Bolivia, the solution may be responsible for long-term contracts, causing rigidity in the national NG matrix.<br>q) To supply Brazil, approximately 600 km of gas pipelines need to be built and may be adopted by any company or project.<br>r) The development of technology for compressed natural gas (CNG) has evolved a lot, making it more accessible and viable.<br>s) The appropriate technology for long-distance transportation, such as LNG, CNG and gas pipelines, shows viability for different distance ranges.<br>t) Development of the REATE program (Revitalization of the Exploration and Production of Oil and Natural gas in Terrestrial Areas) providing onshore NG production in Brazil. |

*Source: Elaborated by the authors.*

**3.1.1 Strengths**

The global LNG market has undergone substantial changes in the last 15 years, not only due to the volume that has increased exponentially but also the contractual pattern and global flows that have changed significantly (Jr & Martin, 2019). Since 2016, this expansion has been accentuated due to the combination of the liquefaction capacity of NG with the sharp drop in world prices of oil and NG (Elliott et al., 2021; Hureau & Serbutoviez, 2020). Since 2018, new countries have joined the group of LNG exporting countries, like Cameroon and Argentina, and this is a lasting trend, a fact that makes this energy source a competitive option to be adopted by countries that import and consume NG (CNI & ABRACE, 2016; EPE, 2016, 2017, 2019b, 2020c, 2020h, 2021b, 2021a; Lecarpentier, 2018). In Brazil, the LNG market has been in full development since 2006, having several strengths, including those related to the importation of NG from neighboring Bolivia, through GASBOL. However, issues of political instability and uncertainty regarding the volume of the remaining reserves of the Bolivian NG lead the Brazilian government to look to LNG as a source of energy security, given the flexibility of its supply (EPE, 2010, 2017, 2020c, 2020h; Michelena, 2018; MME, 2020). It is worth emphasizing that energy security is fundamental in order to understand the importance of the development of LNG in Brazil, given the overdependence on the supply of Bolivian NG, which can generate numerous vulnerabilities to national consumers. The pipeline GASBOL, for example, under normal conditions can operate with 15 million normal cubic meter per day ($Nm^3$/day) of NG, for an average daily consumption in Brazil in 2015 of 30 million $Nm^3$/day, that is, in the event of an abrupt discontinuation of the supply of Bolivian NG, Brazilian consumers, from TPPs to urban centers, would only have 12 hours of electrical power operation (Dassunção & Moutinho dos Santos, 2015).

Currently, it is estimated that Brazil has about 370 billion cubic meter ($m^3$) of proven NG reserves, of which 82% are offshore (Kerdan et al., 2019). However, Brazil has not found alternatives for competitive exploitation of NG in domestic production as having more mature countries in the segment. So, there is currently a dependency on LNG imports. In addition, the real impact on the matrix of how the exploration of pre-salt NG and shale gas will behave is unknown, nor is the impact on the price of the input for TPP generation (BNDES, 2017, 2021; EPE, 2010; FGV, 2019c, 2021). National NG reserves, concentrated especially in the pre-salt, are a strength to LNG due to their high Gas/Oil Ratio (GOR), where NG production is dependent on the oil market. Currently, about 80% of NG production in Brazil is gas associated with oil, leading these hydrocarbons to simultaneous production, characterizing the need for NG to be produced and used on a regular basis, and in the same proportions, during the production of oil. If this does not occur, NG is reinjected or burned (EPE, 2018a). On the other hand, the lack of flexibility is a strength of the LNG modal, which can be contracted and supplied without depending on other productions. To the national NG is added another disadvantage, the considerable content of contaminants present in offshore gas, in particular carbon dioxide ($CO_2$), where the process of separating these gases from the NG increases production costs (ANP, 2020). The high levels of $CO_2$ are also a considerable technical barrier for the transportation of NG via pipelines, in view of their corrosive effects when in the presence of water, generating costs associated with the protection and maintenance of the pipelines (EPE, 2020a). In this sense, LNG presents itself as a competitive alternative to national NG, while its prices may be lower than those practiced in the pre-salt.

Another point is the deficient flow infrastructure and the concentration of gas pipelines in southeastern Brazil, making LNG regasification terminals strategic points for the supply of NG to other regions of the country. The terminals also make it possible to supply remote markets, meet seasonal demands, diversify LNG supply sources, and guarantee the country's energy security (EPE, 2016, 2018c, 2019b, 2019e, 2021b, 2021a; FGV, 2021). Furthermore, LNG contemplates a transportation cost-benefit ratio superior to other NG modes, if we consider volumes of 2 to 8 million cubic meter per day ($MMm^3$/day) transported by road over distances from 750 to 2000 km in national territory, the LNG thus being able to expand

its reach farther into the country through the average consumers of NG, which is economically unfeasible for gas pipelines or other modes of NG (G. F. da Costa & Alfradique, 2020; EPE, 2020f).

In addition, the accelerated addition of NG TPPs to the national energy park, as observed with the 23 new TPP projects registered in 2017 in the A-6 auction, together totaled 21.5 gigawatt (GW) or 40% of all new energy recorded. Among these projects, TPPs with the supply of NG originated from LNG obtained the best competitive results (EPE, 2018c). In Brazil, LNG is mainly intended for TPPs. However, there are already small-scale LNG projects and trucks powered by LNG, which will further reinforce the demand for energy in the country (Fraga et al., 2020; P. A. Gomes, 2018). Small-scale projects can also reduce the idleness of LNG regasification terminals built by Petrobras. These projects consider the distribution of small volumes of LNG, transported from regasification terminals through trucks, trains, small ships, coastal vessels, and other means, expanding the reach of NG in the country (Fraga et al., 2020; P. A. Gomes, 2018).

From a governmental point of view, the scenario is positive for all NG modes, with several programs and legal adjustments aimed at expanding this market in the country, such as the Regulatory Framework for the Electric Sector of 2018, the New Gas Market program of 2019 and Resolution nº16 of 2019 (FGV, 2019a). Concerning resolution nº16, guidelines for the improvement of energy policies aimed at the unbundling of the NG chain were established, creating conditions for third-party access to all essential infrastructures in the sector, for example, gas pipelines, gas processing units and LNG terminals, thus opening the market and promoting competition (EPE, 2019e; FGV, 2019a).

### 3.1.2 Weaknesses

LNG has some weaknesses, which make new investments more expensive and limit consumer markets. Initially, commercialization depends on high take-or-pay or ship-or-pay contracts, which both establish the obligation of the buyer to pay for the minimum contracted volume, regardless of actual consumption (Petrobras, 2012). This adds to the requirement for credit guarantees and the requirement for bulk deliveries of indivisible cargo in a single terminal, a fact that favors large consumers, for example, TPPs, to the detriment of small consumers of NG (CNI & ABRACE, 2016). Take-or-pay contracts can be especially costly in cases where buyers depend on markets that experience volatility in their NG consumption (Tavares & Mitro, 2018). This is the Brazilian scenario, where the LNG has flow mainly in periods of reduction in electricity production of the hydroelectric plants. Importing countries, such as Brazil, must take into account that LNG prices are established in dollars, and linked to the dynamic prices of oil and NG nodal points (gas hubs), being subject to great volatilities, both internal exchange rates in each nation and pricing, as a result of the dynamics of supply and demand, in addition to seasonal and geopolitical factors (CNI & ABRACE, 2016; EPE, 2017, 2020e). In international markets, prices must be compared in the same currency, and, therefore, exchange rate movements may also exist (Richardson, 1977).

The supply of LNG is transported in tanker ships of high volume. For this reason, the most interesting option is to have one large anchor client that will consume most of the available LNG in the ship, and other, smaller clients in conjunction with this anchor. When there is no single large anchor client, it is essential to have several other smaller clients that can substitute it and together, consume the entire cargo of the ship. However, it is operationally difficult to satisfy a large number of smaller clients because they each have their own supply curve demands, seasonalities, and other conditions. These factors make it complex for the LNG supplier to administer a large number of distinct contracts (EPE, 2018c). In view of this difficulty, the use of a large anchor consumer is necessary for these projects' economic and contractual viability.

Another point is that the terminals, in their onshore model, depend on extensive port structuring works to ensure their operational safety, requiring ports protected by breakwaters with a draft of at least 14 meters and, depending on the region of their insertion, dredging and constant overturning. Meanwhile, in the offshore or FSRU model, there is the influence of the

type of mooring of the ships and the need or not of protection, depending on the offer of tug ships to stabilize the terminals in case of rough seas, among other factors (EPE, 2018c). There are fixed maintenance and personnel costs in both terminal models, varying by region, making it more expensive and impossible to install terminals in some of them (ANP, 2018b; EPE, 2017, 2018c). The onshore or offshore regasification terminals also offer the risk of causing accidents or serious spills in the regions of their implantation, according to (Martins et al., 2016). This can put the local population, the environment, and neighboring facilities in danger, as did one of the major accidents that occurred in 1994 in Cleveland in the United States, when an accident resulted in a gas leak, explosion, and fires, killing 130 people. According to the author, although these occurrences are rare, between 1964 and 2005, the United States Department of Energy recorded about 180 accidents in the LNG industry (Martins et al., 2016).

Along with the terminals, for the handling and processing of large volumes of NG and LNG present in a methane tank, there is a need to work with storage, a type of incipient agent in Brazil. To meet the large volume of NG, it is also necessary to explore the forms of underground storage (EPE, 2016), which will also serve as stock for times when TPPs or another anchor consumer tied to the terminal are not operating. In their research, (P. V. M. Costa et al., 2017) report that the next stage of the LNG sector in Brazil will be developing the underground storage of natural gas (UGS). The report states that at the level of international experience, in the Brazilian regulatory field or in its technical and geological features, the UGSs are an excellent alternative for expanding the LNG market in line with the increase in national energy security and with the international development standards of the sector.

In the national market, LNG suffers from a lack of large anchor customers. The NG imported from Bolivia is sufficient for and dedicated to the constant use of industry, while the LNG, via regasification terminals, is restricted to thermoelectric production. The TPPs are, however, subject to seasonality and put into use only during periods of drought when the hydroelectric plants are unable to meet demands. This seasonality of consumption reduces the economic competitiveness of the infrastructures, as they sit inoperative for long periods (ANP, 2018b; Chávez-Rodríguez et al., 2017; CNI & ABRACE, 2016; EPE, 2018c, 2019b, 2021b, 2021a). The entities (CNI & ABRACE, 2016) elaborated a study that presents modelling of the dynamics of NG in the Southern Cone of South America, which infers that if there were not a seasonality in Brazil's hydroelectric production, there would not have been the need to import LNG from 2017 to 2021, nor would the regasification capacity have needed to be expanded. LNG is therefore used as an additional source to complete national energy security.

In the long run, the national NG will meet the outflow needs of NG production from the pre-salt offshore to the coast. In addition, the vast fields of the pre-salt will be viable in the decade 2019-2029, and their production will only become feasible with the increase in the consumption of national NG in a structural way. Added to this are the prospects for the decline of other producing regions such as Bolivia and the state of Amazonas and the low expectation of new projects in different locations in the period mentioned. In this sense, in the short term, LNG will be of vital importance for opening up gas markets in the country. However, in the long term, the pre-salt NG will replace imported gas (EPE, 2020d).

### 3.1.3 Opportunities

The current scenario of reduction of investments by Petrobras in the NG sector, the delay in the construction of infrastructures for the flow of NG production from the pre-salt, as well as uncertainties of the Bolivian supply, may cause the national supply of LNG to contribute to reducing the risk of lack of NG for Brazilian consumers (CNI & ABRACE, 2016; MME, 2020). In addition, the regulatory opening developed by the Government in recent years will allow new players to enter the NG and LNG market. Recently, new LNG terminals and TPPs supplied by these terminals are entering into operation, providing new opportunities and indirect businesses that use this structure as an anchor (ANP, 2018b; CNI, 2018; EPE, 2010,

2018a, 2019b, 2019a, 2021b; FGV, 2019a, 2019b; I. Gomes, 2016). According to (Louro et al., 2020), in 2018, the consumption of NG fueling TPPs was at levels of 27 million $Nm^3$/day, about 35% of the total consumption of NG in the country in 2018, reaching consumption levels of 30 to 60 million $Nm^3$/day in 2027.

In the last auctions for the sale of electrical power, thermal generation from NG has played a strong role, providing a greater volume of contracted NG, increasing competitiveness and the prospect of lower costs for the entire chain (Carlos et al., 2022; Carlos & Costa, 2021; FGV, 2019a). In the 2019 A-6 Auction, 52 TPP projects were registered, 26 of which were enabled, and 19 with LNG supply terminals, representing 18.1 GW of the 21.6 GW enabled in the entire auction (EPE, 2019b). The TPPs have been frequently dispatched by the National Electric System Operator (ONS) due to the prolonged dry period that has occurred since 2016. The Ten Year Energy Plan 2026 indicates the forecast of six new LNG terminals for seasonal service of TPPs, as a way to meet the electricity demand of the next decade (BNDES, 2020; EPE, 2016, 2018c, 2019b, 2019a, 2019c, 2021b). Currently, LNG is not only present in the supply of TPPs. Several projects are being implemented for the distribution of LNG in bulk by trucks and vessels along the coast and vessels inland throughout the country, utilizing cabotage, serving regions far from the coast (EPE, 2019b; FGV, 2019a; MME, 2019a), in addition to being used in the transportation of vehicles hitherto done by diesel (EPE, 2019b, 2019e; FGV, 2019a). (Carolina et al., 2021) connotes that in 2018, with the national strike of truck drivers and transporters, the use of diesel was put in check concerning cheaper fuel alternatives, with the question of diesel pricing not yet fully resolved, thus opening a range of LNG opportunities. However, still in accordance with (Carolina et al., 2021), there are several barriers to this small-scale modality of LNG. Among the barriers are the supply infrastructure, the lack of knowledge on the part of truck drivers of the energy advantages in LNG, competition with other fuels, and a prejudiced view of the use of NG on the part of users of the transportation sector. The energy source has been credited with a false notion of lower efficiency compared to traditional fuels, for example, that the trucks were losing power when fueled with NG.

We can mention projects that use the anchor of a TPP connected to an LNG terminal, using cabotage to take NG to regions where the pipeline network does not yet reach, as in the case of Golar Power in Sergipe and Barcarena in Pará, and Amazônica Energy in Amazonas (FGV, 2019a). Another solution that has been adopted is the use of trucks to carry the LNG, as in the Petrobras and White Martins GEMINI project, which already compresses or liquefies NG in the State of São Paulo and sells it to other regions of the country (FGV, 2019a). There are other companies, such as ENEVA and Amazônica Energy, with projects using this modal. In the case of ENEVA, the project consists of liquefying natural gas from the Azulão field in Amazonas and transporting it by truck to supply the Jaguatirica II TPP in Boa Vista, state of Roraima (FGV, 2019a). Amazon Energy uses container trucks to complement its fleet of barges for transporting LNG across the Amazon region (EPE, 2019b). Both projects are reported by (H. K. de M. Costa et al., 2021). They contextualize that this LNG consumer market cannot concentrate on a few supply companies to avoid monopolies or cartelization in the NG distribution chain. However, the authors point out that the LNG infrastructure depends on high initial investments. Therefore, LNG is only feasible with long-term contracts, like GASBOL's Take-Or-Pay contract due to the amounts involved.

The existing structure of gas pipelines, both for importing Bolivian NG and domestic transportation through Brazil, has a limited capacity (EPE, 2010). To have an increase in capacity, it would have to undergo new high-value investments. In contrast, the structures for LNG can more easily have their size and capacity increased or moved from one location to another (EPE, 2017). The terminal being installed in areas far from the network expands the reach of NG, providing development in remote regions hitherto served by a large volume of energy (ANP, 2018a, 2020; EPE, 2019e, 2020a, 2020f).

The geological uncertainties still unknown for the construction of a network of complementary flow pipelines for the pre-salt warn of the risk of making the use of the pre-salt gas unfeasible for any use other than the reinjection or generation

of energy on offshore platforms (BNDES, 2020; EPE, 2019c), as well as the costs of reducing the $CO_2$ content of the NG from the pre-salt, another concern for the feasibility of using NG (EPE, 2020a, 2020d, 2020g).

In GASBOL, the structure set up to exclusively serve this purpose generates long-term costs, political risk, and the dependence on a good relationship with other countries (EPE, 2017). According to the Bolivian NG renegotiation evaluation model prepared by (Kerdan et al., 2019), with the observation that GASBOL, in its current structural and contractual format, will not meet the growth of the Brazilian NG market by 2050, the authors developed three different renegotiation scenarios with Bolivia, where other options for the supply of NG, such as supply via pre-salt, via LNG or via a new Argentine gas pipeline, were considered. The three scenarios reach the same conclusion: regardless of whether the Bolivian NG will be maintained to a greater or lesser extent in the national energy mix, Brazil will diversify its sources of NG, expanding both imports of LNG and Argentine NG, as well as production in the pre-salt. This third scenario of (Kerdan et al., 2019) is the most interesting for LNG. In this scenario, Brazil would choose to interrupt the supply of Bolivian NG, increasing the weight of the national matrix LNG to more than one third.

The demand for LNG around the world has been increasing year after year, and with this there is an increase in the commercialization of LNG (Lecarpentier, 2018). This provides developments and investments in the sector in technology and equipment, which end up reducing costs, proliferating the use globally, with South America and Brazil being important markets for multinational companies in the sector (ANP, 2018a; EPE, 2016, 2019b). Brazil has attracted attention in the sector from companies such as ExxonMobil, Repsol, Total, and Chevron, as well as strengthening the position of other international companies in Brazil, such as Equinor, Shell and BP Energy (MME, 2019a). According to (H. K. de M. Costa et al., 2021; Da Silva et al., 2017), among the several new LNG projects in Brazil, one of the most promising is that of the Port of Sergipe I of the company Centrais Elétricas de Sergipe S.A. (CELSE) with offshore regasification floating terminal connected to the largest TPP fueled by LNG in Latin America, with 1.5GW of power, the LNG being supplied by ExxonMobil. According to the authors (EPE, 2019e, 2021a), this project will be supplied by LNG and will generate electricity for 25 years from 2020. In addition, Argentina can be one more option of LNG supplier, through its terminals for export to other countries in the world, providing opportunities for investment in this structure, proximity to Brazil, and geopolitical behavior different from other suppliers in the northern hemisphere (EPE, 2021b, 2019b).

With the development and investments in the gas chain, the importance of portfolio management and the concern of underground storage of NG increase in order to guarantee backup supply in times of crisis, to combat price volatility, and to equalize the consumers' energy balance or that of the NG transportation system (EPE, 2019b). Through guaranteeing national energy security, it is possible to overcome possible deficits, allowing companies and several sectors of the economy to have their operation without risks of energy shortages halting their production (CNI & ABRACE, 2016).

The increase in global NG consumption is motivated by increased industrialization and energy demand, especially in emerging countries of Asia and Africa, along with the transition from coal to gas, especially in China (Lecarpentier, 2018; Luo et al., 2021), and the growing low-cost exploratory reserves in North America and the Middle East (ANP, 2018b; EPE, 2016; Hureau & Serbutoviez, 2020). Natural gas has been playing an important role in the "green transition", with the combustion of a natural gas unit generating about half of the $CO_2$ emissions of an equivalent amount of coal (53,07 kilograms (kg) of $CO_2$ per millions of British thermal unit (MMBtu) versus 95,35 kg of $CO_2$ per MMBtu) (MCTI & ONU, 2017; Shaton et al., 2020). The international scene has been dedicating efforts to an energy transition through low emission sources and less participation of fossil fuels (Awais & Wang, 2019). In this scenario, NG is seen as a transitional element managing to meet the world demand for energy for the next decade (Luo et al., 2021). This will generate new opportunities associated with NG and LNG worldwide (BNDES, 2020; EPE, 2018b).

This increase has led to the development of the sector and companies related to the NG sector, providing opportunities throughout the whole chain (EPE, 2016, 2019b). LNG contracts are increasingly being marketed as short-term contracts, with fewer than seven years of supply, as well as with greater flexibility in the destination, either by changing the contract portfolio between global traders or by pooled purchases formed by several consumers (EPE, 2019b).

Brazil itself can start to be an exporter of NG via LNG as a way of monetizing offshore pre-salt NG (EPE, 2020d, 2020g; EPE et al., 2020). In addition, the national industry depends on optimizing energy costs to develop and expand its production, main sectors such as cellulose, fertilizers, petrochemicals, steel, glass, and ceramics, which have an intense consumption of NG (FGV, 2019b). LNG contributes to global energy integration, following the similar scenario that occurred with NG in Europe, which carried out energy integration within the continent (Asche et al., 2001; Bartelet & Mulder, 2019). Industrial development has acted as a growth engine for several countries over the past decades around the world (Szirmai, 2012; Szirmai & Verspagen, 2015). Being connected to a global energy market with innovation and industrial technology is fundamental to a country's growth, and LNG is an important ally in this regard (Coad et al., 2019; Goedhuys & Veugelers, 2012).

**3.1.4 Threats**

Threats are all those factors that may jeopardize the choice of LNG in the national matrix, starting with dependence on international pricing in foreign currency, leading to exchange rate risk and international price arbitrage defined in the global market (Ritz, 2014). Being linked to the price of gas or oil, which are priced at nodal points of systems in other countries, the price of LNG is subject to great volatility in each market due to the dynamics of supply, regional demand, and seasonal and geopolitical factors of this specific region (CNI & ABRACE, 2016). In this way, these regional issues from other places in the world end up interfering in the price of LNG to be acquired in Brazil, making the national energy sector have dynamics that are tied more and more to world dynamics (CNI & ABRACE, 2016).

LNG has been fulfilling the function of integrating prices in different local markets worldwide, a fact reported by (Neumann, 2008). The entry to Europe of LNG from the United States has caused the approximation of the prices of Henry Hub (HH), which represents America's pricing, and the National Balancing Point (NBP), which in turn represents pricing in Europe (Brent). This pricing format has been emerging in the international market (Bartelet & Mulder, 2019; EPE, 2018c). This globalized LNG market makes the price of HH play a fundamental role in determining future prices (Cornot-ganDolphe, 2016; EPE, 2021a).

The regional NG market in South America has vital geopolitical importance for Brazil due to the capacity of the country to serve as an articulator of connections between the different NG producing and consuming regions of the continent. According to (Jaeger, 2016), if we sum up the South American gas reserves, we realize that the current reserves make the region self-sufficient in NG, with the Venezuelan reserves alone proven capable of sustaining the continent for about 50 years (Jaeger, 2016). Therefore, in regional aspects, the energy integration factor can diminish the relevance of LNG in the Brazilian scenario, even considering that the energy integration conjunctures in South America have not had great advances since the opening of GASBOL in 1999.

In the global market, there are price relationships caused by periods of high seasonal demand in Asian countries, causing large volumes of LNG to be transported from the Atlantic Basin to Asia, when transportation costs are diluted in the large volume transported, reflecting in prices lower than the difference between these two basins (Chrisopoulou, 2018). Therefore, Brazil suffers impacts from behaviors and events from other markets around the world, and may, at times, have a cut in supply because it is not considered a priority or because it is not willing to pay higher prices. This is maximized when it

is considered that the Brazilian currency does not match the currency value of other developed countries and large consumers of NG (EPE, 2019b, 2019a, 2020c; I. Gomes, 2016).

National regulatory issues related to NG and LNG have been evolving in recent years, leading to the opening of the market. However, this evolution still needs to be broader, and the regulations need to be more transparent in order to provide fully effective conditions for market agents, for example, on fiscal and tax issues when it comes to sharing importation terminals. These are still seen as barriers for companies to accept investment and dedicate themselves to LNG projects (EPE, 2019b). These issues need to be overcome in order to expand opportunities, increase consumption, and secure gas supplies, in addition to reducing prices (ANP, 2018b; CNI & ABRACE, 2016; EPE, 2010, 2020a; MME, 2019a). The Brazilian natural gas market has a regulatory configuration without incentives for efficiency in all segments of the chain, especially in the distribution segment. As a result, this leads to stagnation and uncompetitive prices (MME, 2019a). It is also noteworthy that the largest Brazilian consumption is concentrated in the southeastern region, where the network is connected to the pipeline GASBOL, where NG from Bolivia is injected. Therefore, this region is more conducive to the entry of LNG, with greater competition still occurring (ANP, 2018a; EPE, 2017).

On the other hand, the Brazilian investment scenario in recent years in LNG terminals and connected TPPs may cause difficulties in financing new projects. In addition, the search for short-term contracts does not contribute to the approval of bank financing for this type of project (EPE, 2018c, 2019b). Most LNG projects in operation and under development in Brazil are based on TPPs used as anchors to consume a large volume and thus provide viability for other marginal consumption to these plants (EPE, 2019e; FGV, 2019b). However, the dependence generated by these anchor projects also causes the interruption of the availability of NG for the other uses adjacent to the project when, for whatever reason, their operation is interrupted (EPE, 2019e, 2020f). This dependence could be more critical if the anchor projects are an industry without a long-term forecast for their production, unlike the current case of most LNG contracts, from 80 to 90%, which are traded in the global market on the long term, greater than 20 years (Hartley, 2015; Neumann et al., 2015), maintaining the relationship with the anchor projects that are linked to the contracting of electricity production, such as a UTE with a 20-year energy sale contract, according to the rule of the last Brazilian auctions.

Thus, like the concerns about competing LNG terminals, even though each has its own anchor project, secondary markets that may arise in the area can suffer competition with the LNG terminal that is geographically close (EPE, 2018c). When high-investment projects are implemented, such as the pre-salt NG flow pipelines, they become a priority in the face of future projects yet to be implemented. When a project's barriers are overcome, it ends up killing its competition for decades (EPE, 2018a, 2019d). In addition, the pre-salt gas has a very energy-rich NG and the presence of other chemical and energetic products useful for industry (Ethane, LPG, and Gasoline). On the other hand, high productivity can lead in the long run to a low relative cost in the exploration (EPE, 2020f). Currently, the investment forecast for the pre-salt exploration chain is high for the coming years, as well as in the Sergipe and Alagoas basins and other discoveries of national NG reserves (BNDES, 2020; EPE, 2019c, 2020d, 2020h; FGV, 2019b; MME, 2019c).

These risks, associated with competition between projects, occur both in the development of new pre-salt gas pipelines and in the possible structure to import gas from the *Vaca Muerta* projects in Argentina, from where large quantities of NG can be injected and arrive in Brazil (EPE, 2020c; MME, 2019a). These investments would generate a source to be monetized for decades in long-term contracts with Brazil (Delgado & Lamassa, 2019; EPE, 2020b). Thus, like the possibility of Argentine imports, Bolivian supply to Brazil has been renegotiated, having a mutual interest between the two countries in the context of broader regional integration (EPE, 2020c; MME, 2020).

Another possibility of producing national NG, competing with imported LNG, could be developed through the REATE program providing production of shale gas onshore in Brazil (EPE et al., 2020). This program was developed by MME in 2017 with the intention of promoting the exploration and production of oil and natural gas in terrestrial areas in Brazil, gathering information from agents to provide synergies, facilitate the obtainment of financing, and promote competitiveness in the sector.

### 3.2. Adapted GUT Analysis

With the assessment of the SWOT analysis completed and discussed, the relevance of each argument was identified within the group of reports studied in the gray literature. To define the level of size of the matter, we considered the number of reports that defended each of the points in the four divisions of the SWOT analysis. That is, among all the points classified as forces, how many reports defended each argument, and then this method was repeated with the other points classified as weaknesses, opportunities, and threats. That done, the points that were most defended were selected, and with that the GUT matrix was generated (Table 2). With this numbering, it was possible to cross the Strengths and Weaknesses with the Opportunities and Threats, having an index calculated by multiplying each of the numbers of the importance of each point, which in turn, represents the number of reports that defended that score. Although the GUT is applied to three indicators, we adopted its application to just one dimension, as the important parameter of each point concerning the main theme of this work.

**Table 2.** GUT matrix of LNG of Brasil.

| | | | **Opportunities** | | | | **Threats** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Be Inserted in The Global Market | Accelerate Regulatory Developments | Reduce Dependence on Gas Pipelines | Development of Surrounding Projects | Domestic Supply | Global Price Risk | International Political Risk | Bolivian Supply |
| | | Import. | 10 | 11 | 12 | 18 | 23 | 19 | 14 | 13 |
| **Strengths** | Remote Delivery | 13 | 130 | 143 | 156 | 234 | 299 | 247 | 182 | 169 |
| | Attractive and Competitive Prices | 16 | 160 | 176 | 192 | 288 | 368 | 304 | 224 | 208 |
| | Global Availability | 22 | 220 | 242 | 264 | 396 | 506 | 418 | 308 | 286 |
| | Energy Security | 28 | 280 | 308 | 336 | 504 | 644 | 532 | 392 | 364 |
| **Weaknesses** | Unclear Regulatory and Tax Rules | 14 | 140 | 154 | 168 | 252 | 322 | 266 | 196 | 182 |
| | Dependence on Large Projects | 12 | 120 | 132 | 144 | 216 | 276 | 228 | 168 | 156 |
| | Contractual Requirements and Rigidity | 10 | 100 | 110 | 120 | 180 | 230 | 190 | 140 | 130 |
| | Terminal Construction Requirements | 8 | 80 | 88 | 96 | 144 | 184 | 152 | 112 | 104 |

Source: Elaborated by the authors.

As a result of this multiplication, we have the numbers at each crossing from one point to the other, as seen in the GUT matrix. Colors were assigned to promote understanding and scaling, with the greenest being the most important, yellow for the intermediate and red for the smallest. Based on these criteria, the items with the highest score, being marked in green, are concentrated in the junction between forces and threats, mainly in energy security and global availability due to arguments of strength, and in the threat by domestic supply and global price risk. There are opportunities and weaknesses in the items with the lowest score, marked in the darkest red color. Thus, it can be concluded with the GUT matrix that LNG is seen as presenting more strength to Brazil but is linked to threats to its existence.

Among the points of strength, there is the energy security provided by LNG, being added to the national NG matrix as the most relevant factor, followed by the global availability of the energy source. Among the points of weakness, there are the regulatory and tax barriers, as well as unclear rules, as the point that most impedes the use and development of the Brazilian LNG market. Following this, the dependence on large anchor projects to make the necessary base consumption of the large volume of LNG cargoes present in the methane tankers makes one of the most important arguments of weaknesses. Overcoming this point is exactly the greatest opportunity for the entry of LNG in greater quantity in Brazil, in addition to reducing the dependence on the gas pipelines, which in turn has a very restricted and limited network, practically spread over the large capitals. On the LNG threats side, the possibility of expanding domestic production due to the exploration of the pre-salt layer is the main one and cannot be omitted. Lastly, global price and currency risks can make LNG very expensive at national levels. As opportunities, the most relevant points identified in the government reports were the development around LNG terminals, with the secondary markets that they can provide. And finally, as already mentioned, reducing dependence on expensive and limited gas pipelines is one of the most relevant opportunities that the LNG modal can improve.

## 4. Conclusions

LNG, as an option of an abundant source of NG with the ability to meet large seasonal demands, is well regarded by the Brazilian Government and its institutions, in accordance with the analysis of this article. With the opening of the market and the possibility for a consumer agent to have the option of several sources of NG, it is necessary to develop portfolio analyses within the reach of large consumers, who may be an industry, a TPP, or even an NG distributor, at the moment of the supply contract, which will be distributed to its customers. These, who could only purchase from a single supplier such as the local distributor, and with this opening in the market, will need to evaluate the best options available to sign a long-term contract in view of the best conditions also discussed in this article

The importance of studying the LNG market in Brazil is also justified by the recent water crisis that the country experienced in 2021. This scenario of scarcity culminated in the activation of UTEs supplied with NG to contribute to the generation of electricity in the national territory. This fact led to an increase in the consumption of NG, as well as the import of LNG to record levels. Although the scenario is favorable, it is important to note that the increase in the supply of NG by one of the sources of the national matrix must be directly related to the increase in consumption, in order to preserve the balance between Supply and Demand. The possible entry of a new LNG terminal connected to a distributor could result in an oversupply and, consequently, a drop in energy prices in this region.

It is important to consider that in order to have a strong and robust market, it is necessary to reinforce energy security with the complementarity of characteristics and attributes that each source can contribute, that is, the national production of NG has characteristics of high continuity in supply and therefore being linked to and depending on oil production, when it demands its production in large volume, it makes the production of NG mandatory and consequently that its consumption is a priority over other sources. On the other hand, the supply of NG to a thermoelectric plant is sporadic, since

the generation of energy is made at specific times within the national electricity matrix when there are difficulties in the supply of hydroelectric plants. When, then, the supply via LNG meets the characteristic of large volumes in a short and fast space of time, being, therefore, seen as a source complementarity with the national production. Thus, it is seen as a complement to national production and consequently bringing energy security.

The evaluations carried out in several reports from government institutions show that LNG is an important option within the national NG matrix. It brings energy security in times of crisis from other sources and supplies large volumes of NG in a short period, a necessary condition for the generation of electrical energy in a TPP, or the production of large industrial plants. Another outstanding advantage is the fact that LNG can be delivered to locations not served by the gas pipeline network, enabling large volumes of gas in locations with capacity limitations or not even served by gas pipelines, thus developing a secondary gas market near these LNG projects, such as a TPP or petrochemical industry, for example. Although Brazil is experiencing an exceptional moment of oil exploration on the high seas in the pre-salt reserves, for NG, this opportunity still depends on high investments and becoming part of the planning of companies responsible for national exploration. It also faces uncertainties regarding political risks in relationships with other countries, such as the Bolivian supply or a possible Argentine supply. Together with the advantages of LNG, these uncertainties increase the possibilities of its importation in large quantities to Brazil.

From this, it is concluded that the studied reports raise more strengths and opportunities, with some very clear threats, however, few weaknesses have been identified. The view of the federal government institutions, authors of these reports argue the insertion of LNG in the national NG matrix in a positive, attractive, and interesting way for Brazil. It is highlighted that the importation of LNG in Brazil presents itself as a promising energy source, with low costs, legal and regulatory favors and governmental support, being a good option for supplying companies. of the NG sector. The results become extremely important to support the industry in understanding the factors that affect each of the sources of NG in its supply matrix, taking a more detailed view of the dynamics of NG. Furthermore, to the points discussed in this article, it is considered relevant to explore other factors such as environmental, tax and technological issues, which are suggested by the authors for future work.

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## References

ANP. (2018a). *Desverticalização na Indústria do Gás Natural*. http://www.anp.gov.br/images/central-de-conteudo/notas-estudos-tecnicos/notas-tecnicas/nota-tecnica-04-2018-sim.pdf

ANP. (2018b). *Regulamentação da Transparência da Formação de Preços: Mercado de Gás Natural*. http://www.anp.gov.br/arquivos/cap/2019/cap18/nt-9_cap18-2019.pdf

ANP. (2019). *Anuário Estatístico Brasileiro do Petróleo, Gás Natural e Biocombustíveis 2019*. www.anp.gov.br

ANP. (2020). *Anuário Estatístico Brasileiro do Petróleo, Gás Natural e Biocombustíveis 2020*. http://www.anp.gov.br/arquivos/central-conteudos/anuario-

estatistico/2019/2019-anuario-versao-impressao.pdf

Asche, F., Osmundsen, P., & Tveterås, R. (2001). Market integration for natural gas in Europe. *International Journal of Global Energy Issues*, *16*(4), 300–312. https://doi.org/10.1504/IJGEI.2001.000925

Awais, M., & Wang, B. (2019). Analyzing the role of governance in CO 2 emissions mitigation : The BRICS experience. *Structural Change and Economic Dynamics*, *51*, 119–125. https://doi.org/10.1016/j.strueco.2019.08.007

Bartelet, H., & Mulder, M. (2019). *Natural Gas Markets in the European Union: Testing Resilience*. https://doi.org/10.5547/2160-5890.8.2.hbar

BNDES. (2017). *Panoramas setoriais 2030: desafios e oportunidades para o Brasil*.

BNDES. (2020). Mercado de embarcações de apoio a plataformas de produção de petróleo e gás natural. *BNDES Setorial 51*, 77–124. https://web.bndes.gov.br/bib/jspui/handle/1408/19820

BNDES. (2021). *Gás para o Desenvolvimento: Perspectiva de Oferta e Demanda no Mercado de Gás Natural no Brasil*. https://web.bndes.gov.br/bib/jspui/bitstream/1408/20581/1/Relatorio_Gas_Desenvolvimento Final.pdf

Carlos, D., & Costa, L. (2021). *Interdisciplinarity Applied to the Optimized Dispatch of Integrated Electricity and Natural Gas Networks using the Genetic Algorithm A interdisciplinaridade Aplicada ao Despacho Otimizado das Redes Integradas de Energia Elétrica Interdisciplinariedad Apli*. *2021*, 1–21. https://rsdjournal.org/index.php/rsd/article/view/12641/11430

Carlos, D., Costa, L., Cristina, A., Reis, F., Cristina, A., Reis, F., & Raiol, F. M. (2022). *Thermoelectric generation with reduced pollutants made possible by bio-inspired computing Geração termelétrica com redução de poluentes viabilizada pela computação bioinspirada Generación termoeléctrica con contaminantes reducidos posible gracias a la inf*. *2022*, 1–13. https://rsdjournal.org/index.php/rsd/article/view/24568/21645

Carmelita, R., & Moreno, P. (2021). *A Matriz SWOT e suas Subdimensões : Uma Proposta de Inovação Conceitual The SWOT Matrix and its Subdimensions : A Conceptual Innovation Proposal La Matriz SWOT y sus Subdimensiones : Una propuesta de innovación conceptual*. *2021*, 1–14. https://rsdjournal.org/index.php/rsd/article/view/12580/11239

Carolina, A., Teixeira, R., Gerber, P., Rocha, R., Luis, T., Brito, F., Moutinho, E., & Mouette, D. (2021). The use of liquefied natural g gas as an alternative fuel in freight transport – Evidence from a driver ' s point of view. *Energy Policy*, *149*(December 2020), 112106. https://doi.org/10.1016/j.enpol.2020.112106

Chávez-Rodríguez, M. F., Dias, L., Simoes, S., Seixas, J., Hawkes, A., Szklo, A., & Lucena, A. F. P. (2017). Modelling the natural gas dynamics in the Southern Cone of Latin America. *Applied Energy*, *201*, 219–239. https://doi.org/10.1016/j.apenergy.2017.05.061

Chrisopoulou, A. (2018). *Commercial, Financing and Climate Change challenges facing LNG Export Projects* [International Hellenic University]. https://repository.ihu.edu.gr/xmlui/bitstream/handle/11544/29074/IHU Dissertation template Anastasia Chrisopoulou 1108150004.pdf?sequence=1

CNI. (2018). *Gás Natural: Mercado e Competitividade*. https://static.poder360.com.br/2018/06/28-GAS-NATURAL-ELEICOES-2018.pdf

CNI, & ABRACE. (2016). Gás natural liquefeito: Cenários Globais e Oportunidades para a Indústria Brasileira. *Confederação Nacional de Indústria*, 169. http://bibliotecadigital.fgv.br/dspace/bitstream/handle/10438/18196/gas_natural_liquefeito_-_cenarios_globais_e_oportunidades.pdf?sequence=1&isAllowed=y

Coad, A., Grassano, N., Hall, B. H., Moncada-paternò-castello, P., & Vezzani, A. (2019). *Innovation and industrial dynamics & 50*, 126–131. https://doi.org/10.1016/j.strueco.2019.06.008

Cornot-ganDolphe, S. (2016). *The US natural gas exports* (Issue June). https://www.eia.gov/dnav/ng/hist/n9130us2a.htm

Costa, G. F. da, & Alfradique, M. (2020). *Estimativa de Custos para a Interiorização do Gás Natural no Brasil via GNC e GNL*. *2020* (December), 1–12.

Costa, H. K. de M., Ramos, K. N., & Petry, P. M. (2021). LNG Regulation: Analysis of the Gemini Project under the Brazilian Federal Supreme Court. In *Opportunities and Challenges of Natural Gas and Liquefied Natural Gas in Brazil*.

Costa, P. V. M., Costa, A. M., Szklo, A., Branco, D. C., Freitas, M., & Rosa, L. P. (2017). UGS in giant offshore salt caverns to substitute the actual Brazilian NG storage in LNG vessels. *Journal of Natural Gas Science and Engineering*, *46*, 451–476. https://doi.org/10.1016/j.jngse.2017.06.035

Da Silva, R. I., Liaw, C., Fraga, D. M., Borges, C. M., & Dos Santos, E. M. (2017). Overview of Brazil liquefied natural gas industry. *International Gas Research Conference Proceedings*, *1*, 670–679.

Dassunção, M., & Moutinho dos Santos, E. (2015). *Gás Natural no Cenário Brasileiro* (1st ed.). https://www.livrariasynergia.com.br/livros/000307/9788568483053/gas-natural-no-cenario-brasileiro.html

Delgado, F., & Lamassa, D. (2019). Vaca Muerta, Bolívia e Pré-Sal: como organizar todo esse gás? *Caderno Especial - Caderno Opinião - O Novo Mercado de Gás Natural: Opiniões de Especialistas, Perspectivas e Desafios Para o Brasil*.

Elliott, S., Bowles, A., Power, E., Gas, N., & Transition, E. (2021). *France ' s Total to focus on LNG , renewables in major clean energy drive*. 1–4. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/040221-us-and-iran-to-initiate-indirect-treaty-talks-on-april-6

EPE. (2010). *Brazilian Oil & Gas Report 2019/2020 - Trends and Recent Developments*. https://www.epe.gov.br/sites-en/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-197/topico-183/EPE_Brazilian Oil and Gas Report 2019-2020.pdf

EPE. (2016). *Energia Termelétrica: Gás Natural, Biomassa, Carvão, Nuclear*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-173/Energia Termelétrica - Online 13maio2016.pdf

EPE. (2017). *Panorama da Indústria de Gás Natural na Bolívia*. http://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-250/topico-307/EPE 2017 - Panorama da Indústria de Gás Natural na Bolívia 22jun17.pdf

EPE. (2018a). *Considerações sobre a Participação do Gás Natural na Matriz Energética no Longo Prazo*. 20. http://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-227/topico-457/Considerações sobre a Participação do Gás Natural na Matriz Energética no Longo Prazo.pdf

EPE. (2018b). *Plano Decenal de Expansão de Energia 2027*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/Documents/PDE 2027_aprovado_OFICIAL.pdf

EPE. (2018c). *Terminais de Regaseificação de GNL nos Portos Brasileiros Panorama dos Principais Projetos e Estudos*. https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/informe-tecnico-terminais-de-regaseificacao-de-gnl-nos-portos-brasileiros-panorama-dos-principais-projetos-e-estudos

EPE. (2019a). *Informe: Custos de Gás Natural no Pré-Sal Brasileiro*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-368/INFORME - Custos de Gás Natural no Pré-Sal Brasileiro.pdf

EPE. (2019b). *Informe: Mercado Internacional de GNL - 2018/2019*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-318/INFORME Mercado Internacional de GNL 2018-2027_rev1.pdf

EPE. (2019c). *Plano Decenal de Expansão de Energia 2029*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-422/PDE 2029.pdf

EPE. (2019d). *Plano Indicativo de Processamento e Escoamento de Gás Natural - PIPE*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-434/PIPE - Plano Indicativo de Processamento e Escoamento de Gás Natural.pdf

EPE. (2019e). *Terminais de Regaseificação de GNL no Brasil - Panorama dos Principais Projetos - Ciclo 2018-2019*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-412/Nota Técnica - Terminais de Regaseificação de GNL no Brasil (Ciclo 2018-2019).pdf

EPE. (2020a). *Acesso de Terceiros a Infraestruturas Essenciais: Doutrina de Infraestruturas Essenciais Aplicada a Gasodutos de Escoamento, Unidades de Processamento de Gás Natural e Terminais de GNL*. http://www.epe.gov.br

EPE. (2020b). *Nota Técnica: A Indústria de Gás Natural na Argentina: Panorama, Perspectivas e Oportunidades para o Brasil*.

EPE. (2020c). *Nota Técnica: Demanda de Gás Natural nos Mercados Nacional e Internacional - Horizonte 2020-2030*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-490/topico-531/EPE, 2020 - Nota Técnica Demanda de Gás Natural vFinal.pdf

EPE. (2020d). *Nota Técnica: Monetização de Gàs Natural Offshore no Brasil*.

EPE. (2020e). Nota Técnica: Projeção de Preços Internacionais de Petróleo e Derivados: 2020 - 2030. In *Site EPE* (Vol. 4).

EPE. (2020f). *Nota Técnica: Terminais de GNL no Brasil - Panorama dos Principais Projetos - Ciclo 2019-2020*.

EPE. (2020g). *Nota Técnica - Monetização de Gás Natural Onshore no Brasil*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-487/EPE, 2020 - NT Monetização de GN onshore - Rev1.pdf

EPE. (2020h). *PNE 2050 - Plano Nacional de Energia*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-227/topico-563/Relatorio Final do PNE 2050.pdf

EPE. (2021a). *Nota Técnica: Experiências Iinternacionais na Regulação da Indústria de Óleo & Gás*.

EPE. (2021b). Plano Decenal de Expansão de Energia 2030. *Ministério de Minas e Energia. Empresa de Pesquisa Energética*. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-490/PDE 2030_RevisaoPosCP_rv2.pdf

EPE, ANP, BNDES, & Pré-Sal Petróleo. (2020). *Estudo Sobre o Aproveitamento do Gás Natural do Pré-Sal*. http://www.anp.gov.br/arquivos/estudos/aproveitamento-gn-pre-sal.pdf

Ferrel, & Hartline. (2013). *Marketing Strategy - Text and Cases* (Vol. 4, Issue 3). http://marefateadyan.nashriyat.ir/node/150

FGV. (2019a). *Edição Especial - Caderno Opinião - O Novo Mercado de Gás Natural: Opinões de Especialistas, Perspectivas e Desafios para o Brasil*. 128. https://fgvenergia.fgv.br/sites/fgvenergia.fgv.br/files/caderno_opiniao_-_agosto_-_web_versao_final.pdf

FGV. (2019b). *Novo Mercado de Gás Natural*. https://static.poder360.com.br/2019/04/FGV-SeminarioGasEnergy-29.abr_.pdf

FGV. (2019c). O Shale Gas à espreita no Brasil: desmistificando a exploração de recursos de baixa permeabilidade. *Journal of Chemical Information and Modeling*, *8*(9), 1–58.

FGV. (2021). *O Desenvolvimento da Exploração de Recursos Não-Convencionais no Brasil: Novas Óticas de Desenvolvimento Regional*. https://fgvenergia.fgv.br/sites/fgvenergia.fgv.br/files/caderno_desenvolvimento_da_exploracao_de_recursos_nao-convencionais_no_brasil.pdf

Fraga, D. M., Peyerl, D., Moutinho dos Santos, E., Luisa, A., Netto, A., Augusto, C., & Pereira, A. (2020). *Oportunidades e desafios do Gás Natural e do Gás Natural Liquefeito no Brasil*.

Goedhuys, M., & Veugelers, R. (2012). Innovation strategies , process and product innovations and growth : Firm-level evidence from Brazil. *Structural Change and Economic Dynamics*, *23*(4), 516–529. https://doi.org/10.1016/j.strueco.2011.01.004

Gomes, I. (2016). *O GNL no Brasil e no Cenário Internacional*.

Gomes, P. A. (2018). *Avaliação das Oportunidades do Gás Natural Liquefeito em Pequena Escala no Brasil sob as Perpectivas do Proutor, Transportados e do Consumidor Final* [Universidade Federal do Rio de Janeiro - UFRH]. https://pantheon.ufrj.br/handle/11422/12276

Hartley, P. R. (2015). The future of long-term LNG contracts. *Energy Journal*, *36*(3), 209–233. https://doi.org/10.5547/01956574.36.3.phar

Hureau, G., & Serbutoviez, S. (2020). E&P Investments. Drilling Activities and Markets, Geophysics and Offshore Construction (2019). *Economic Climate Outlook IFPEN*. https://www.ifpenergiesnouvelles.com/article/ep-investments-drilling-activities-and-markets-geophysics-and-offshore-construction-2019

Jaeger, B. C. (2016). *O Grande Gasoduto do Sul: Impactos Sobre a Integração Regional e o Desenvolvimento Sul-Americano*. *5*, 271–292.

Josiany, M., Medeiros, V., Souza, F., Filho, R., Pryscilla, Y., Costa, D., Ângela, P., & Freitas, B. (2021). *Diagnóstico organizacional através da matriz SWOT : a aplicação da ferramenta em um curso de Administração Organizational diagnosis through the SWOT matrix : the application of the tool in a Administration Diagnóstico organizacional mediante la matriz DAF*. *2021*, 1–11. https://rsdjournal.org/index.php/rsd/article/view/11532/10255

Jr, R. G. F., & Martin, F. T. (2019). *Trade and Commercial Interactions in the Atlantic Basin: Present and Future Issues*. https://www.orkestra.deusto.es/images/investigacion/publicaciones/libros/libros-capitulos-libro/lng-trade-atlantic-basin.pdf#page=16

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*, *255*, 113799. https://doi.org/10.1016/j.apenergy.2019.113799

Lecarpentier, A. (2018). Recent Developments and Outlook for The Gas Market. *IFP Energies Nouvelles (IFPEN)*. https://www.ifpenergiesnouvelles.com/article/recent-developments-and-outlook-gas-market

Louro, P. M. M., Castiñeiras Filho, S. L. P., Souza, R. C., Almeida, E. F. de, & Fernandez, E. F. y. (2020). *Análise de sensibilidade do despacho termelétrico de gás natural no planejamento nacional : efeitos e oportunidades*. *2020*(December).

Luo, G., Liu, S., Yan, X., & Guo, Y. (2021). Institutional constraints to China ' s low carbon transition : A case study of China ' s coal-to-gas program. *Structural Change and Economic Dynamics*, *57*, 121–135. https://doi.org/10.1016/j.strueco.2021.01.005

Martins, M. R., Pestana, M. A., Souza, G. F. M., & Schleder, A. M. (2016). Quantitative risk analysis of loading and offloading liquefied natural gas (LNG) on a floating storage and regasification unit (FSRU). *Journal of Loss Prevention in the Process Industries*, *43*, 629–653. https://doi.org/10.1016/j.jlp.2016.08.001

MCTI, & ONU. (2017). *Modelagem setorial de opções de baixo carbono para o setor de óleo e gás natural*. https://www.researchgate.net/publication/333652180_MODELAGEM_SETORIAL_DE_OPCOES_DE_BAIXO_CARBONO_PARA_O_SETOR_DE_OLEO_E_GAS_NATURAL

Michelena, B. D. (2018). *Modelo Temporal da Oferta e Demanda do Gás Natural Liquefeito no Brasil* [Universidade Federal da Bahia - UFBA]. https://repositorio.ufba.br/ri/handle/ri/30844

MME. (2019a). *Nota Conjunta: Comitê De Promoção Da Concorrência No Mercado De Gás Natural Do Brasil*. http://epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-369/INFORME -

MME. (2019b). *Novo Mercado de Gás*. https://www.gov.br/mme/pt-br/assuntos/secretarias/petroleo-gas-natural-e-biocombustiveis/novo-mercado-de-gas

MME. (2019c). *O Novo Mercado de Gás*. http://www.mme.gov.br/web/guest/conselhos-e-comites/cmgn/novo-mercado-de-gas

MME. (2020). *Boletim Mensal de Acompanhamento da Indústria de Gás Natural*. https://www.gov.br/mme/pt-br/assuntos/secretarias/petroleo-gas-natural-e-biocombustiveis/publicacoes-1/boletim-mensal-de-acompanhamento-da-industria-de-gas-natural/2020/11-boletim-mensal-de-acompanhamento-da-industria-de-gas-natural-novembro-2020.pdf/view

Neumann, A. (2008). Linking Natural Gas Markets - Is LNG Doing its Job? *SSRN Electronic Journal*, *September*. https://doi.org/10.2139/ssrn.1425519

Neumann, A., Rüster, S., & Von Hirschhausen, C. (2015). *Data Documentation: Long-Term Contracts in the Natural Gas Industry-Literature Survey and Data on 426 Contracts (1965-2014)*. www.diw.de

Petrobras. (2012). *Novas Modalidades de Contratação de Gás Natural*. http://www.zonaeletrica.com.br/downloads/NOVAS_MODALIDADES_PETROBRAS-04-01.pdf

Pirrong, C. (2014). *Fifty years of global LNG*. 1–15. https://www.trafigura.com/media/1284/2014_trafigura_fifty_years_of_global_lng_en.pdf

Richardson, J. D. (1977). *Some Empirical Evidence on Commodity Arbitrage and The Law of One Price*. *1975*, 341–351. https://www.sciencedirect.com/science/article/pii/0022199678900272

Ritz, R. A. (2014). Price discrimination and limits to arbitrage : An analysis of global LNG markets. *Energy Economics*, *45*, 324–332. https://doi.org/10.1016/j.eneco.2014.07.013

Santos, D. S. dos. (2019). *Elementos para a Discussão Sobre a Renovação do Contrato de Fornecimento de Gás Natural Boliviano para o Brasil no Contexto do Aumento da Produção Brasileira de Gás*.

Shaton, K., Hervik, A., & Hjelle, H. M. (2020). The environmental footprint of natural gas transportation: LNG vs. Pipeline. *Economics of Energy and Environmental Policy*, *9*(1). https://doi.org/10.5547/2160-5890.8.2.ksha

Szirmai, A. (2012). Industrialisation as an engine of growth in developing countries , 1950 – 2005. *Structural Change and Economic Dynamics*, *23*(4), 406–

420. https://doi.org/10.1016/j.strueco.2011.01.005

Szirmai, A., & Verspagen, B. (2015). Manufacturing and economic growth in developing countries , 1950 – 2005. *Structural Change and Economic Dynamics*, *34*, 46–59. https://doi.org/10.1016/j.strueco.2015.06.002

Tavares, F. B., & Mitro, T. (2018). *Manual for the Open LNG Regasification Model*. *October*, 1–29.

Thomas, S., & Dawe, R. A. (2003). Review of ways to transport natural gas energy from countries which do not need the gas for domestic use. *Energy*, *28*(14), 1461–1477. https://doi.org/10.1016/S0360-5442(03)00124-5

Zhang, H. Y., Xi, W. W., Ji, Q., & Zhang, Q. (2018). Exploring the driving factors of global LNG trade flows using gravity modelling. *Journal of Cleaner Production*, *172*, 508–515. https://doi.org/10.1016/j.jclepro.2017.10.244