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Analysis of the Impacts of Small-Scale LNG Projects for Energy Supply of the North Region of Brazil: The Case of Roraima

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Abstract: Natural gas is a fossil resource less polluting compared to oil and coal. Despite the large volumes of proven reserves in Brazil, exploration and production are low because of several factors like the lack of infrastructure along several regions of the country, the regulatory model in the consolidation phase, and legal impasses regarding tariffs. In the Brazilian north region, the expansion of the natural gas market is even more complex due to regional specificities both in relation to natural characteristics and the existence of conflicts of interest that impact regional development. However, natural gas has been gaining notoriety over the years, with the existence of large projects that foster the gas market in some states in the region. This article aimed to discuss the impacts of increasing the participation of natural gas in the regional energy matrix through small-scale LNG projects, analyzing the case of the state of Roraima and the impacts of the Azulão-Jaguatirica II Project on this state. As a result, this research presented an evaluation of the existent regulation in Brazilian's northern states, a bibliometric analysis of natural gas in the Brazilian Amazon which demonstrated how little the topic is covered, and a SWOT matrix about the impacts of natural gas in regional energy supply in order to help future decision-making on the subject.

Keywords: natural gas; Roraima; Azulao-Jaguatirica II; Amazon; energy supply

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1. Introduction

Population growth and the urban-industrial advance led to an exponential increase in energy demand to meet the needs of modern society worldwide, with a high dependence on fossil fuels for the most diverse uses. Electricity has become increasingly necessary for the population's routine and productive activities, however, accessibility to this resource has not been everyone's privilege [1,2]. Thus, countries have intensified the exploration of energy resources available in their territories with an emphasis on hydrocarbons, especially oil and natural gas (NG).

Initially, natural gas was used less when compared to oil and coal due to its greater complexity in logistics, transportation, and storage. This scenario began to change due to advances in science and technology, as several evolution and improvement processes occurred—and are still occurring—thus, contributing to revolutions in the gas industry, intensifying the exploration and production of this source and making its use more present in many countries. The growth in the use of this input can be observed in data presented by the International Energy Agency [3] through a comparison between the energy supply matrix showing that in 1973 oil represented 46.2%, coal 24.7%, and gas 16.1%, while in 2019 the numbers changed to, respectively, 30.9%, 26.8% and 23.2%.

Thus, there was an intensification of searches for new reserves of this energy resource around the world, which led several nations to invest heavily in increasing geological and geophysical studies throughout their territories in order to map areas that showed signs of potential gas reserves. Furthermore, countries interested in taking advantage of this energy input found that to enable the effective development of a solid natural gas market, technology alone would not be enough. In this way, they also began to establish specific

regulations for exploration and production (E&P) processes, limits for each gas component, that is, specifications of its composition and quality, in addition to regulatory limits for the separation of activities that form its value chain.

Brazil has the second largest natural gas reserve among the countries of Central and South America, with about 380 billion cubic meters (bcm) [4]. Potential reserves are distributed along sedimentary basins in different regions of the national territory and the regional gas markets are heterogeneous among themselves, with some being more developed and structured, such as those in the southeast region. In contrast, others are premature, such as those in the northern region. Such disparities in the levels of development between the Brazilian regional markets exist due to several factors, such as differences in demand between the regions, difficulties in implementing the necessary structure for the displacement of gas (transport and distribution pipelines), and impasses related to charging and the payment of taxes on exploration and production activities, among others.

Although there are several barriers, the participation of this source is gaining more and more space in the Brazilian energy matrix, especially through the increase in production resulting from the post-salt and pre-salt zones and gas from imports from countries such as Bolivia (Bolivia-Brazil Gas Pipeline, called Gasbol), Nigeria, Tobago, Trinidad, and the United States [4]. It is also important to highlight that Brazil is going through the energy transition process and natural gas is constantly pointed out as an energy source that can help in the decarbonization of the planet, due to its lower capacity to release Greenhouse Gases (GHG) compared to other fossil fuels.

Therefore, it is noted that, despite its vast energy reserves of this input, the Brazilian natural gas market, in relation to transport logistics and commercial transactions, is considered immature, being little developed in relation to international markets that are referenced at a level worldwide, such as the United States and the European Union. This happens for several reasons, including the strong influence and dominance of Petrobras over the oil and gas market in the country and the existence of gaps in the regulatory model relating to the gas chain, which in turn generate uncertainty regarding the limits between some of the stages in the chain and, therefore, negatively impact the effective establishment and expansion of the gas market in the national territory [5].

The present article analyzes the impacts of increasing natural gas in the regional energy matrix, especially through SSLNG projects, highlighting the necessity of finding solutions to problems that involve regions with characteristics more complex, but with a high exploratory and productive potential for natural gas, as the northern region of Brazil. The authors analyzed the Azulao-Jaguatirica Project II, located in the Amazonas and Roraima states, using available data about this project and the Brazilian NG market, referring to estimated and proven reserves of the input in the continental sedimentary basins of the region, the general aspects of the exploratory process in each of them, in addition to the difficulties involved and the obstacles that hinder its solutions.

This article was divided into five sections. Section two presents the methodologies used to construct the research. Section three demonstrates the results obtained through each methodology covered in section two. The results are discussed through an overview of the research in section four. Finally, section five highlights the main conclusions obtained through the data collected by the authors and suggests new paths to be explored in future studies related to the article's theme.

2. Materials and Methods

This article used five research methods: a survey of the national and international literature available on the subject, document analysis (including federal and state legislation), bibliometric analysis, and a case study via SWOT analysis.

The public data was available through the Brazilian Eneva Company, the National Agency of Petroleum, Natural Gas and Biofuels (ANP), and the Energy Research Company (EPE). The extraction and evaluation of the technical aspects related to the potential of

natural gas in the north of Brazil, in addition to the characteristics that make the area attractive for the implementation and development of new projects focused on the use of this energy input. Federal and state laws were also used to provide the regulatory basis for the arguments and analyses presented throughout this study.

Based on the data collected in the national and international literature survey, a brief bibliometric analysis was used. Ref. [6] defended that the bibliometric analysis method has been used over the last few years by researchers to assist, optimize, and enable the analysis of many documents and scientific data used in the construction of detailed research on a given topic. The creation of specific software for bibliometric analysis was fundamental for this methodology to become more popular and detailed. Therefore, this article was prepared using the Scopus platform and the VOSviewer software (Version 1.6.18). These tools enabled the generation of graphs and maps that illustrated the number of existing publications about natural gas in the Amazon which are the areas of study that analyze this topic, thus, demonstrating the need to develop more studies with an emphasis on the natural gas market in the Brazilian north region.

The choice of the Azulão-Jaguatirica II Project—by the company Eneva—as the case study to be analyzed was due to the fact that this project consists, in a simplified way, of seeking to develop and consolidate the natural gas market in the state of Roraima. Thus, the main purpose of analyzing the impact of its implementation and its operation in the north of Brazil, in order to highlight and analyze the issues discussed throughout this research, through a recent and concrete project that covers the various aspects elucidated throughout this research.

The analysis of the aforementioned case study was carried out using SWOT analysis, which consists of an acronym for the following words: S for Strengths, W for Weaknesses, O for Opportunities, and T for Threats [7]. This method is widely used in the preparation of strategic planning as it results in a practical qualitative view of the characteristics and variables that involve a given topic, which in turn facilitates the definition of objectives to be achieved and considerably reduces uncertainties in the evaluation of scenarios futures [6]. This methodology is used to provide a broader analysis of a topic, considering external and internal elements for its structuring, thus, enabling the identification of possible impacts in the short and medium term. The evaluation of internal elements aims to understand the strengths and weaknesses of the subject and can be considered easier to control, while the evaluation of external issues aims to analyze the opportunities and risks not being controllable because they are aspects that may be affected by unplanned events for the topic [6–8]. To this, internal factors (strengths and weaknesses) related to the increased use of LNG for power generation are evaluated. On the other hand, external factors (opportunities and threats) are mainly related to environmental, economic, and regulatory aspects of the sector, as well as the environmental licensing process, the organizational outline of the LNG terminals, and the legislation pertinent to the construction and operation of these and other structures necessary for the exploration and production of the input.

3. Results

3.1. Bibliometric Analysis

The Brazilian gas market has undergone a transformation process over the last 15 years, thus, intensifying discussions about the need to make it more consistent and the importance of minimizing differences between regional markets for its effective expansion and consolidation [5,9]. It should be noted that these processes were strongly influenced by the federal government's incentive programs for the expansion of the Brazilian gas market and the enactment of Law No. 14,134 in the country [10].

In the case of the north region of Brazil, the natural gas market is still little understood and discussed, and it is essential to deepen the debates on the possible uses of this input in the Amazon so that a greater understanding of the specificities of the region can be obtained. In addition, it is possible to draw up a development plan for its regional natural gas market since the population of some states (such as Amapá and Roraima) constantly suffer from

the impacts of insecurity in the local electricity supply. In addition, with the change of government that took place in 2023, the region gained greater visibility due to the increase in debates on deforestation, violence against indigenous peoples that occurred in the last 4 years, and the role of the Amazon in advancing the world energy transition [11–14].

In this sense, the following subsubsections present the results of the bibliometric analysis methodology used to substantiate the relevance of the topics covered throughout this research.

3.1.1. Data Analysis: Scopus

Based on the review of existing literature, an analysis was carried out using data from the scientific research platform Scopus and the bibliometric analysis software VOSviewer, with the aim of understanding how natural gas in the Amazon has been approached from a scientific point of view and how relevant it is in terms of publications. Figure 1, generated through Scopus, shows the evolution of the number of scientific articles published over the period 1975–2023 on the platform, with a total of 108 using the keywords "natural gas" and "Amazon" as search parameters. It is remarkable that there was strong growth between 2003 and 2007, which can be related to the period when Law 11,909/2009 (the old Gas Law) was being constructed. Subsequently, there was a fluctuation in the number of works published, followed by a fall, which demonstrated the scarcity of content on the subject and the importance of carrying out more research focusing on the northern region.

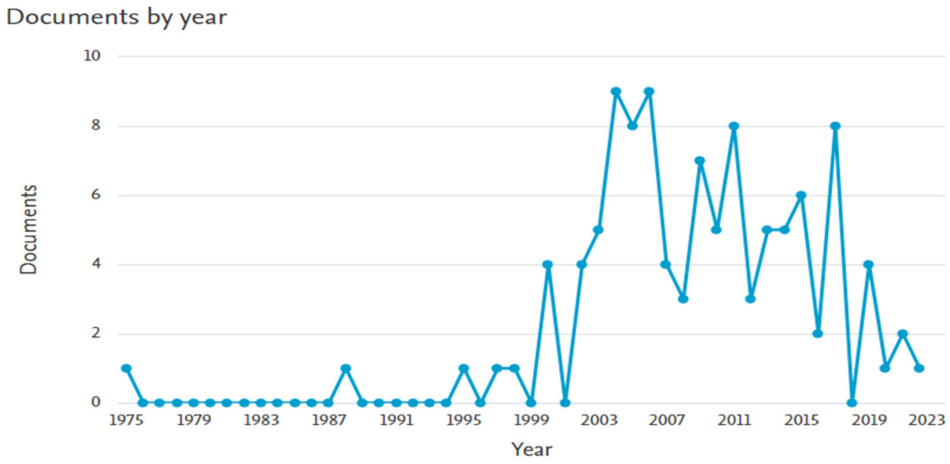

Figure 1. Evolution of scientific publications between 1975 and 2023.

With regard to the origin of the publications, it can be seen that the authors were mostly from Brazil or linked to Brazilian institutions, followed by the United States (USA) and Peru, as shown in Figure 2.

In addition, the data from the platform also made it possible to illustrate the separation of the 108 articles by areas of research that were published based on these keywords, as shown in Figure 3. This result showed that most (30.2%) of the publications on the subject belonged to the energy area, thus, proving the relevance of the subject addressed in this paper.

3.1.2. Data Analysis: VOSviewer

After exporting the data acquired through the search on the Scopus platform, the 108 articles obtained were entered into the VOSviewer software. Figure 4 shows the results of the analysis of the keywords "natural gas" and "Amazon" from 32 scientific materials that dealt with both subjects simultaneously, with each occurring at least four times.

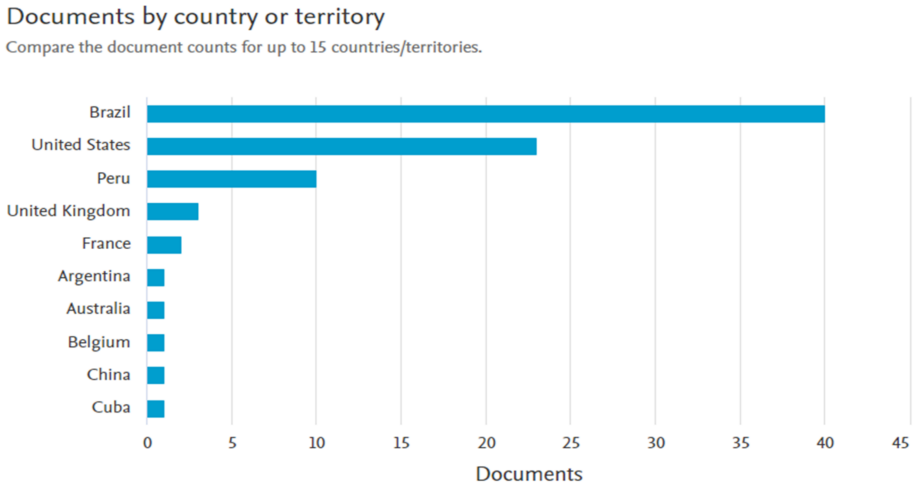

Figure 2. Survey of the main countries generating scientific production on the subject.

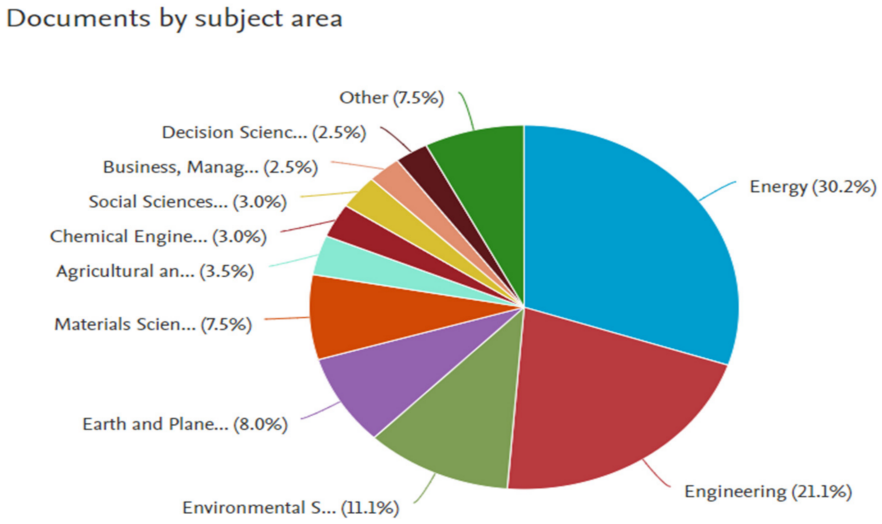

Figure 3. Results using the keyword clusters "natural gas" and "amazon", in terms of study areas.

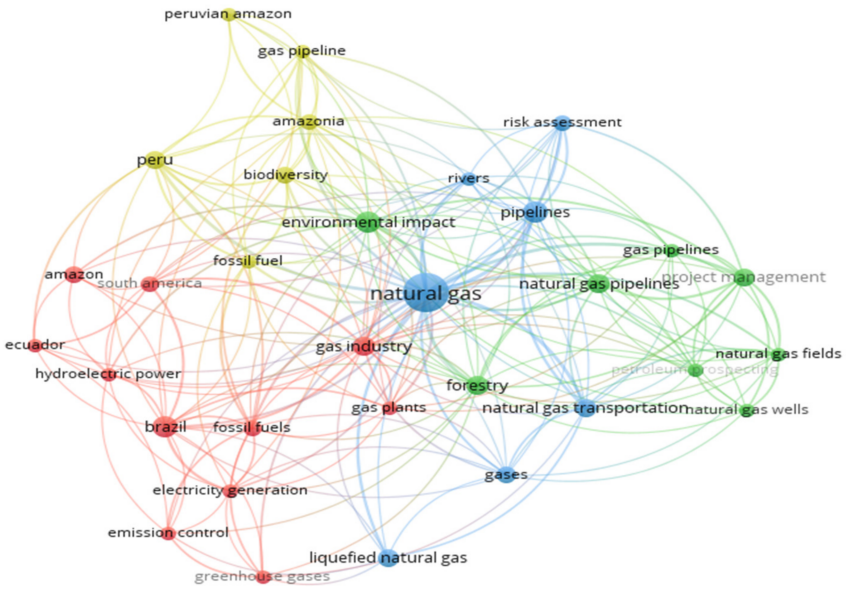

Figure 4. Result using the keyword clusters "natural gas" and "amazon" in the VOSviewer software.

Of the 32 articles mapped by the software, the four most cited, which deal with the part of the Legal Amazon located in Brazilian territory and discuss energy, were published between 2005 and 2017.

Ref. [14] analyzed two projects to increase national electricity generation that were driven by the energy shortage faced by Brazil in 2001, which led to 9 months of rationing: the Urucu-Coari-Manaus gas pipeline and the Belo Monte hydroelectric plant. The author pointed out that the projects faced a lot of resistance from environmental Non-Governmental Organizations (NGOs) and social movements, due to their complexity and high financial costs, as well as the environmental and social impacts that their implementation could have on the Amazon region. With this in mind, the research pointed out that given the country's need for energy development—much debated at the time and still today—and in order to guarantee the population's energy supply, it would be important to align the speeches and objectives of the coalitions opposed to the implementation of large-scale energy projects, so that their struggles become broader instead of dealing with each case they oppose, and not neglecting the local needs and political contexts of each region involved in the projects. Thus, creating more constant and consistent discussions about energy development.

The article by [15] addressed the difficulty of predicting energy generation through hydroelectric plants due to the lack of storage in the plants of this model present in northern Brazil, which sometimes ends up jeopardizing the planning of electricity supply when there are more extensive or even unexpected periods of drought, as occurred in the years 2001, 2014, and 2021. The authors therefore proposed the "Energy Crop Storage" model, which is based on the principle of growing and storing biomass in eucalyptus plantations and then using it to generate energy during periods of dry rainfall. This model was proposed to promote the replacement of natural gas thermoelectric plants with a view to reducing generation costs. Finally, the study concluded that, in addition to savings, the implementation of the proposed model could expand the national potential for electricity storage by around 49.5%.

The research by [9] presented the environmental impacts caused by a thermoelectric plant in an Isolated System (called IS, i.e., those that are not connected to the National Interconnected Energy Supply System—Called SIN) located in the Amazon region, comparing two situations: if the plant were powered only by fuel oil (mono-fuel) or if it were powered by natural gas and fuel oil simultaneously (bi-fuel)—the second possibility currently being called a Hybrid Generating Station (UGH), in accordance with the Normative Resolution (REN) of the National Electric Energy Agency (ANEEL) No. 954/2021. The comparative analysis found that the hybrid model would generate fewer local and regional impacts in terms of GHG emissions than the oil-only model. However, the authors pointed out that their results could have been more robust if more data had been available on the production and use of natural gas in the region.

Ref. [16] discussed the importance of looking for less polluting energy sources that have a positive impact on energy security in the state of Amazonas, arguing that natural gas would be an excellent short-term option to replace oil and diesel in local thermoelectric plants. The result of the study was that this substitution would reduce CO_2 emissions in the state by 30% and boost the development of the local economy. Therefore, the bibliometric analysis carried out showed that there are few studies on the natural gas market in the northern region of Brazil, which made it difficult to construct more robust critical analyses on the subject. However, the most cited articles showed that there is a growing interest in how this input could be used to reconfigure regional energy planning in the short and medium term. In view of the potential—proven and estimated—for the exploration, production, and use of natural gas in the sedimentary basins of the northern region of Brazil, plus the imminent energy transition that the region must undergo, this research aimed to raise the profile of the energy needs of the inhabitants of this place.

Thus, the bibliometric analysis allowed us to understand that, despite being a topic that is increasingly being discussed in Brazil, the use of natural gas as an alternative energy

supply for regions further away from the country's coastal region is still little debated. It is therefore necessary to broaden discussions on this subject so that there is a better basis for building more efficient energy planning. In the case of the northern region, which is marked by the presence of energy insecurity and isolated systems, discussing the issue becomes even more complex, since the location requires more specific aspects to be observed, such as logistics that minimally affect the region's natural resources, as well as analysis of how the insertion of natural gas and the structures that enable its exploration and production could affect the socio-economic reality of the population.

That said, the following subsection will discuss the main regulatory aspects in Brazil in relation to the natural gas value chain, from federal regulations to the main state regulations in the northern region of the country that are focused on this energy resource.

3.2. Regulatory Analysis

According to the Federal Constitution (FC) [17], there are divisions between the activities that compete only with the Union, activities divided by Union, State and Federal Districts, in addition to the division of issues of local interest between the state and municipal spheres. In the case of the natural gas value chain and all aspects related to it, the competences are divided between the federal (Union) and state spheres [18].

Pursuant to Art. 177 of the CF, the Union may contract state or private companies in accordance with the conditions defined by law for research and exploitation of deposits (oil, natural gas, and other fluid hydrocarbons), refining oil (whether domestic or imported), import and export the products and derivatives of the aforementioned hydrocarbons, in addition to transporting them via pipelines or in the maritime environment [17].

In this sense, on 6 August 1997, Law No. 9478/1997, known as the Petroleum Law, was sanctioned. Through it, important aspects of Brazilian energy policy were established, such as its principles and objectives, definitions of the need to end Petrobras' monopoly on the exploration and production of oil and natural gas, and definitions of the foundation of two institutions of great relevance for the energy market in Brazil: the National Energy Policy Council (CNPE) and the ANP. As a result, this law also brought about the end of Petrobras' monopoly on oil research, exploration, production, and refining. As a consequence, the country underwent and continues to undergo an expansion of the energy sector, becoming a producer and exporter of oil, ethanol, and other energy inputs [4,6,18,19].

In addition to these institutions, the institutional framework of the natural gas sector is made up of other agents, the main ones being the Ministry of Mines and Energy (MME), the CNPE, the ANP, and the EPE, which are responsible for the delimitation, inspection, and planning of most activities in the natural gas value chain. In addition to these, there are regulatory agencies and the government secretariat, which consist of monitoring natural gas at the state level.

The MME was founded on 22 July 1960, through Law No. 3782, thus, becoming the primary agent of the Brazilian energy sector. Its main objective is to conduct and promote decisions regarding energy and mining policy, through the CNPE, the Electricity Sector Monitoring Committee (CMSE), and 4 secretariats with specific activities. In the case of the CNPE, its main responsibility is to assist the President of the Republic in national policy decisions, focused on the energy sector. Matters related to fuels are dealt with by the Secretariat of Petroleum and Natural Gas and Biofuels (SPG) and, depending on the issue in focus, by the Secretariat of Energy Planning and Development (SPE). In addition to its general attributions, the SPG is composed of 4 departments and each of them has specific responsibilities. The departments are the Department of Natural Gas (DGN), Policy for Exploration and Production of Oil and Natural Gas (DEPG), the Department of Fuels Derived from Petroleum (DCDP), and the Department of Biofuels (DB) [17].

With the growth of the energy sector and the exploration of oil and natural gas, the Petroleum Law was created, which determined the creation of the ANP. In this context, the ANP was constituted in 1998, being fundamental for the development and consolidation of the regulatory framework for both fossil fuels and biofuels. The agency has numerous

responsibilities, some of which were established in the Petroleum Law itself, while others were assigned to them over the years, through new laws in the energy sector, with the most recent modifications arising from Law No 0705/2002. In short, all its attributions have the main purpose of promoting regulatory aspects, the contracting and inspection of the entire natural gas value chain, and activities related to the oil and biofuel sectors [6,17,18].

Another fundamental institution for the natural gas sector is EPE. Its creation was authorized on 15 March 2004 through Law No. 10,847/2004, but only from Decree No. 5184/2004 on 16 August 2004, the EPE was effectively created. Its main attribution is to assist the MME with studies and research that support the preparation of energy planning for the electricity, oil, natural gas and its derivatives, and biofuels sectors. Thus, in relation to natural gas, the company carries out medium to long-term projections and analyses of demand, supply, consumption, and possibilities for expanding exploration and production of this energy source in Brazil. Among the main materials resulting from their studies, the following can be highlighted: the National Zoning of Oil and Gas Resources, the Expansion Studies of the Pipeline Transport Network (such as the Indicative Plan for Transport Gas Pipelines—PIG), the Economic Bulletin of the Petroleum Industry, the National Energy Balance, and the Ten-Year Energy Expansion Plan [4,18]. Such materials were fundamental for the elaboration of this research since they contained information of great relevance on all Brazilian sedimentary basins, including those in which there was no exploration of natural gas, but which harbor proven and estimated reserves of this input, as is the case of most basins located in the northern region of Brazil.

On 8 April 2021, Law No. 14,134/2021 was sanctioned, which became known as the New Gas Law, whose purpose was to improve the regulation aimed at natural gas in order to encourage the expansion of the market Brazilian gas industry, making it safer, more open and competitive. The approval of the New Natural Gas Law was an essential step toward making the Brazilian gas market more dynamic, competitive, and open. As some of the main consequences, the expansion and strengthening of the role of the ANP in decision-making related to activities in the natural gas value chain, it is expected that there will be a reduction in the cost of domestic gas in the medium term, incentives for free competition and expansion of use of the input in carrying out activities in various industrial segments [4,20]. Added to this, this Law may provide for growth in the number of investments related to the production and exploitation of this energy input, so that there is the generation of new jobs and local development. In States that already have a state regulation for this input, the Law can promote the improvement of their legislation. In the case of States that still do not have a regulation focused on the natural gas chain, the Law will serve as a strong incentive to expand debates so that the majority can benefit from the development of this market [9,10,18].

As already mentioned, it is up to the States to regulate the gas distribution activity, which is a public service whose regulation considers the specific needs of each state and is therefore not unanimous. State governments can opt for regulatory entities that follow the regulatory agency or state government secretariat (or portfolio) model. Currently, of the 22 states that have regulatory models for natural gas, only 1 has a secretariat (Minas Gerais), while the others adopt regulatory agencies [11,21,22]. Ref. [21] defended that state regulations aimed at providing piped gas services encompass some basic aspects, such as aiming to adjust the economic-financial balance of the concession, outlining the rights and duties of users, and delimiting the rules that the concessionaire must follow when provide the service. In addition, the contracts must ensure a trade-off between the distributor's commitments to captive users and guaranteed supply to free consumers.

It should be noted that it is also the responsibility of the state regulatory entity to pay attention to definitions of concepts, defaults, and the closing of contracts related to the free market so that the criteria for framing an agent as a free consumer and the rules for self-production and self-import are well defined [10,11]. The concept of free consumer must be very specific, as it involves issues such as the minimum consumption (including by segment), the minimum period for the migration process from the captive market to

the free market to be carried out, the definition of whether or not there is the possibility of consumption partially free, the definition of the Contract for the Use of the Gas Distribution System (CUSD), and the methodology for calculating the Tariff for the Use of the Gas Distribution System (TUSD) in addition to which period must be considered for the agent to remain in the market free and whether it is possible to return to the captive market in that state [20].

Considering all the states of the northern region (Figure 5), those that have regulations regarding natural gas regulations and the free gas market regulations, are Amapá, Amazonas, Pará, Rondônia and Tocantins.

Figure 5. Map of the northern region of Brazil.

The lack of regulatory models in the other states that make up the region is due to some factors, among which we can highlight the fact that not all states have an active gas market, as mentioned in previous sections, and divergences of interests between government officials, which can make it difficult or even unfeasible to define specific norms. Based on the documentary survey, a comparative table was built between the main legislation specifically aimed at natural gas existing in the region, as shown below in Table 1:

Table 1. Summary of regulations related to natural gas existing in the northern region.

State	Regulation	Main Objectives	Free NG Market
Amapá	(a) Law No. 0705/2002 (b) Law No. 0750/2003 (c) Law No. 2656/2022	(a) Create the Gas Company of Amazonas (CIGÁS) (b) Create Transportadora de Gas do Amazonas S.A (TGA) (c) Authorize the privatization of CIGÁS (d) Establish the general rules for the provision of piped gas services to free consumers, self-producers, and self-importers	(a) No specific minimum volume (b) CUSD and TUSD not yet disclosed
Amazonas	(a) Law No. 2325/1995 (b) Law No. 2567/1999 (c) Law No. 3690/2011 (d) Law No. 5420/2021	(a) Create the Gas Company of Amazonas (CIGÁS) (b) Create Transportadora de Gas do Amazonas S.A (TGA) (c) Authorize the privatization of CIGÁS (d) Establish the general rules for the provision of piped gas services to free consumers, self-producers and self-importers	(a) Consumption equal to or greater than 300,000 m^3/month (b) CUSD and TUSD not yet disclosed

Table 1. *Cont.*

State	Regulation	Main Objectives	Free NG Market
Pará	(a) Law No. 7719/2013 (b) Decree No. 1771/2017	(a) Establish the general rules for the provision of piped gas services to free consumers, self-producers and self-importers (b) Regulate Law No. 7719/2013	(a) Consumption equal to or greater than 500,000 m^3/month (b) CUSD and TUSD not yet disclosed
Rondônia	(a) Law No. 728/1997 (b) Law No. 5288/2021	(a) Establish the Rondoniense Gas Company (RONGÁS) (b) Encourage competition by opening the state natural gas market to attract investment to the state	-
Tocantins	Law No. 2275/2009	Establish the Tocantins Gas Company (TOCANTINSGÁS)	-

Source: Elaborated by authors.

3.2.1. Amapá

On 5 July 2002, the Legislative Assembly of Amapá sanctioned Law No. 0705/2002, through which the Executive Power was authorized to constitute the Companhia de Gás do Amapá (GASAP), to link the distributor to the State Secretariat for Infrastructure, and define some of the obligations to be followed by said company. Subsequently, the wording of articles 1 and 5 underwent changes through State Law No. 0750/2003 [23,24].

GASAP is a mixed capital company governed by private law. Its main purpose, according to state regulation, is "Exploration, with exclusivity, of the public service of distribution and commercialization of piped gas. It may also explore other forms of distribution of natural or manufactured gas produced in the State of Amapá, by Union, national third parties or resulting from importation, for industrial, commercial, residential purposes and any other lawful purpose of direct consumption or as a production component, consistent with today's technology available, observing the laws and norms of protection to the environment throughout the territory of the State of Amapá". The exclusive exploration grant has a term of 30 years [24].

Added to this, it was also established that the company can carry out the exploration and/or prospection of natural gas deposits to produce and distribute the input throughout the State. From this, it would also be up to GASAP to implement and operate distribution networks and all other infrastructure that could enable the activities of treatment, storage, and regasification of natural gas in Amapá [24]. Despite its existence, GASAP is currently not operating as the beginning of its activities depends on the construction of a transport gas pipeline or the implementation of logistics that enables the transport of the input via virtual gas pipelines, which may carry Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG) to the state. According to the company, the virtual gas pipeline model could be used in Amapá as there is already an LNG Regasification Terminal in the city of Barcarena-PA, which would facilitate its adoption.

Recently, Law No. 2656 of 2 February 2022 was sanctioned, and this became part of the current legislation in Amapá focused on natural gas, adding greater robustness to state regulations. Its main objective is to establish the norms for the provision of local piped gas services, and, for that, its text contains some definitions of fundamental concepts of the natural gas chain, and the requirements to classify the agents (free consumer, self-producer, and self-importer), among other aspects [24]. By Law No. 2656/2022, it is up to the Regulatory Agency for Delegated Services of the State of Amapá (ARSAP) to ratify the tariff referring to the assignment of contractual volume to GASAP, in order to avoid tariff reasonableness for other users. In addition, the agency acts in the classification of gas pipelines present in the territory of the state of Amapá as distribution gas pipelines.

The government of Amapá has already expressed its favorable position for the development of a regional natural gas market, especially after the recent blackouts that occurred

in the state. Between 3 and 20 November 2020, there were two blackouts, which affected 13 municipalities in Amapá, thus, being considered one of the longest in the history of Brazil and immensely harming the population of Amapá, making evident the energy vulnerability to which the state is subject. The normalization of the energy supply occurred only after 21 days, causing serious damage to the population, which even had the supply of drinking water and food compromised. However, the increase in the share of natural gas in the state's energy matrix is strongly related to the increase in the use of inflexible thermal power plants in the northern region and is therefore a subject that requires careful analysis and energy planning that respects regional characteristics, so that such thermal plants can operate using natural gas as fuel, but without compromising the quality of life of the population and the balance of the environment [24–26].

3.2.2. Amazonas

The legislation of the state of Amazonas is the most robust, compared to other states in the north of Brazil, as it has been built over the decades, starting with State Law No. 2.325 of the Mixed Economy Society called Companhia de Gás do Amazonas—CIGÁS, whose purpose would be "to promote the exploitation of piped gas services, either as raw material for energy generation or other purposes and uses, being able to implement and operate a network distribution, as well as performing all services that may be necessary to make gas available to consumers, including with regard to the acquisition of natural gas or any other fuel gas" [27].

A few years later, on November 25, 1999, the creation of the Joint Stock Company called Transportadora de Gás do Amazonas S.A—TGA was decreed, through Law No. 2567, "the construction and operation of gas pipelines, as well as terminals for the receipt, storage, and delivery of natural gas or gas from any other source, in any form or physical state, in the Amazonian territory" [28].

After more than a decade, on 21 December 2011, State Law No. 3690 authorized the privatization of CIGÁS. Finally, on 17 March 2021, Law No. 5420/2021 was enacted. Similar to the Pará legislation, this one is also focused on detailing the provision of services, punctuating on the concepts of self-producer, self-importer and free consumer, delimiting the rights and duties of distributors and consumers. The regulatory body for activities related to natural gas in the state is ARSEPAM and the distribution company is CIGÁS [29,30].

Thus, it is important to note that the legislation in force in Amazonas can serve as a model for the construction and/or improvement of regulations in other states in the northern region of Brazil. As discussed in Chapter 2, this state has the most active gas market in the region, and, given the potential of its gas reserves, the production of its fields can serve other states, as is currently the case in Roraima.

3.2.3. Pará

On 24 June 2013, the Legislative Assembly of the State of Pará sanctioned Law No. 7719/2013, whose main objective was to establish the "general rules for the provision of piped gas services to free consumers, self-producers and self-importers" [31]. Such services should be provided by Companhia de Gás do Pará, which is the concessionaire, with exclusivity, to provide services for the distribution and sale of piped gas in the State.

The company is classified as a mixed company, governed by private law and its own equity. It is currently in the pre-operational phase and has sought to make its operations viable through a regasification terminal to be implemented in the municipality of Barcarena.

Subsequently, on 16 June 2017, the governor of the state of Pará sanctioned Decree No. 1771/2017. The main purpose of this decree was to regulate Law No. 7719/2013, so that contractual aspects referring to the obligations and rights of Gás do Pará were more detailed, as well as the criteria for classifying the agent (captive user) as a free consumer, self-producer, or self-importer. Another key point established in this decree was the attribution of specific regulatory powers regarding the piped gas distribution service

to the State Agency for Regulation and Control of Public Services in the State of Pará (ARCON) [31].

Thus, it is noted that Pará has the potential to develop a natural gas market since the fuel in its liquefied standard (LNG) could be used by industries to carry out their activities and meet the demand for automotive vehicles in the state through its gaseous form (CNG), which, in turn, could contribute to the reduction of greenhouse gas emissions, thus, improving air quality.

3.2.4. Rondônia

On 14 July 1997, the then governor of the state of Rondônia sanctioned Law No. 728, the main purpose of which was to create Companhia Rondoniense de Gás (RONGÁS). This legislation attributed the Company, in Art. 2, as a social objective "[. . .] the exploitation with exclusivity of local gas services, local services being understood as the distribution and commercialization of natural gas and other sources, using overland routes to provide these services and fluvial, in addition to other similar related activities, necessary for the distribution of gas to the entire consumer segment, whether as fuel, raw material, petrochemicals, fertilizer or as an oxy-reducer in the steel industry, whether for thermoelectric power generation or other purposes and uses made possible by technological advances". Also, Art. 6 established that RONGÁS would have the concession for 50 years to carry out, with exclusivity, local gas services in the state territory. In addition, the aforementioned Law also defined issues related to the Company's Bylaws [32].

Years later, on 23 December 2021, the state government sanctioned Law No. 5288, promoting some changes to Law No. 728/1997. These alterations had the main objective of encouraging competition by opening the state's natural gas market and thus attracting investments that would generate its expansion. To define the most appropriate changes to achieve these objectives, the state government claimed that it carried out analyses of the gas sector and thus, had the help of the MME and some private sector agents [32].

Due to this more modern Law, the company Eneva showed interest in taking its investments to the state and thus entered into a partnership with the government of Rondônia to carry out feasibility studies for the start of the use of natural gas in the capital, Porto Velho. At first, the Company's idea was to use gas from Azulão (AM), similar to what was happening in the state of Roraima, with the difference that, instead of transporting the input by road, as is the case for Boa Vista, in Rondônia, the possibility of taking the gas through the Madeira River waterway was being studied.

3.2.5. Tocantins

The government of the state of Tocantins sanctioned Law No. 2275 on December 29, 2009, in order to create Companhia de Gás do Tocantins—TOCANTINSGÁS. It was established in this regulation that the Company's social objective, in accordance with its Art. 1, paragraph 1 "[. . .] the exploration, with exclusivity, of the public service of distribution and commercialization of piped gas, being able also to explore other forms of distribution of natural or manufactured gas, including compressed or liquefied, of own production or of third parties, national or imported, for commercial, industrial, residential, automotive, thermoelectric generation purposes or any other purposes and uses made possible by technological advances, throughout the area comprised in the territory of the State". In addition, the Law defined in its Art. 3 the concession to exploit piped gas services for up to 30 years, with the possibility of renewal [33].

3.3. Study of Case: Impacts of Azulao-Jaguatitica Project in Roraima State

Firstly, it should be noted that the current state of Roraima was considered a Federal Territory (TF) until the 1980s and was then called the Federal Territory of Rio Branco. Since the establishment of the Federal Constitution in 1988, it has been defined as the State of Roraima, making it one of the most recently constituted Brazilian states [34,35]. It has a total area of approximately 224,300.506 km^2, is located in the northernmost region of

Brazilian territory, and borders the states of Amazonas and Pará, and the countries of Guyana and Venezuela, as illustrated in Figure 6 [24]. As a result of the crisis in Venezuela, and because it borders that country, the state is facing a population bulge, with around 659,950 inhabitants today [24,25]. It concentrates the main economic activities so there is strong occupational centralization, and it is also the only capital city in the country not connected to the SIN.

Figure 6. Location of the state of Roraima.

With regard to electricity, its matrix is made up of 87% diesel oil, but its composition has been changing as the state goes through a time of transition in the energy sector. Roraima was dependent for around 20 years on energy imports from Venezuela, which were carried out via the Guri/Macágua Transmission Line, with energy coming from the Guri Hydroelectric Plant (Puerto Ordaz—Venezuela) and the supply was interrupted in 2018 due to the political instabilities faced by the supplier country [33,36]. The municipalities furthest from the capital, located in the interior of the state, are supplied by small machines from the energy distributor Roraima Energia, which is responsible for supplying 86 isolated systems in the state [34,36,37].

With the strong economic and social crisis in Venezuela, several sectors collapsed in the country, including the energy sector, which led to the total interruption of Venezuela's energy supply to the state of Roraima. As a result, the state had to look for alternatives to prevent the power supply from being interrupted. Thus, the state ended up opting to reactivate the Jatapu Small Hydroelectric Power Plant (SHPP), which led to an increase in the energy tariff paid by the population [2,15,22].

Therefore, it is clear that Roraima suffers from issues related to energy vulnerability, both because Boa Vista is the only Brazilian capital that is not yet interconnected to the SIN and because of the low energy security offered by the current supply system, which has led to a long history of blackouts in the state. In this sense, the federal government is trying to find solutions that will make it possible to change this scenario, through studies carried out by the EPE to plan for the integration of Boa Vista into the SIN. However, connection to the SIN involves complex issues involving environmental, logistical, technical, economic, social, cultural, and political aspects [2,15,22].

In order to solve or at least mitigate the issue of energy vulnerability in the state of Roraima due to the aspects discussed in the previous section, the MME published Ordinance No. 512/2018, Article 1 of which determined that the "Auction for Supply to Boa Vista and Connected Localities" would take place, the aim of which was to enable the acquisition of energy and power from the selling agent [8,11]. In May 2019, the National

Electricity Agency (ANEEL) held Generation Auction No. 1/2019, which resulted in the negotiation and contracting of nine projects involving the use of various energy sources (natural gas, biofuels, wood chips/residues, diesel oil, and hybrid systems).

Through this Auction, the company Eneva (which in the Auction acted as Azulão Geração de Energia S.A.) acquired the right to build the Jaguatirica II Thermoelectric Power Plant (TPP) in Boa Vista, which receives and uses the natural gas produced in the Azulão field, located in the state of Amazonas. According to the company, the project aims to contribute to improving Roraima's energy supply, making it possible for the capital Boa Vista to be independent of diesel generation, thus, supplying the capital and the towns adjacent to it via thermoelectric generation, benefiting most of the population (approximately 70% of the state's demand). In addition, the project also aims to generate electricity at more attractive costs with the Reservoir to Wire (R2W) model, which consists of using natural gas produced in the northern region to generate electricity, as well as reducing greenhouse gas emissions in Roraima and promoting the expansion of the gas market in the northern region [8,11].

In addition, according to EPE, it will also contribute to the integration of the region's gas markets and could stimulate improvements in the relationship between state governments, a fundamental factor for regional development. According to a study carried out by EPE [4,19], this is a Small-Scale LNG (SSLNG) distribution project, which uses the gas produced in the Azulão Field to supply the Jaguatirica II thermoelectric plant. Figure 7 shows how this type of project works, both from onshore and offshore production.

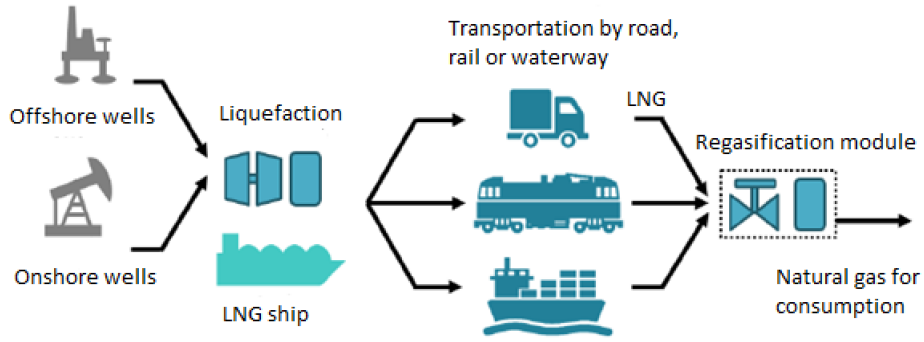

Figure 7. SSLNG operating model.

The Azulão-Jaguatirica II Project will work as follows:

1. The Azulão field will be used for the exploration and production of onshore natural gas wells. The product will go through the liquefaction process and thus be prepared for transportation in the LNG tanking process.
2. With the LNG in cryogenic tanks, it will be transported via virtual gas pipelines from Azulão to the Jaguatirica II TPP, along 1100 km of paved road.
3. Upon arriving in Boa Vista, the LNG will go through the tanking process in the vicinity of the TPP followed by regasification in the LNG Regasification Unit.
4. Finally, the fuel will be used in the Jaguatirica II TPP and will generate thermoelectric power for Boa Vista and adjacent municipalities.

It is expected that the Azulão-Jaguatirica II project benefits the states involved, as well as the northern region, in a number of ways. Both will have some benefits in common, such as the creation of new jobs, the attraction of new investments to the region, the expansion of the possibilities for local suppliers to develop their businesses, greater incentives to qualify, use, and value local labor, structural, financial and social improvements for local communities, and the expansion of regional development, both in terms of the gas market and attracting new investments of various kinds.

Therefore, it is remarkable that the project is promising, despite the existing complexities, and has the potential to generate positive impacts on the energy market in the northern region, as well as providing improvements to the regional economy and the social and

structural development of the states of Amazonas and Roraima. In view of this, Section 3.4 presents the SWOT matrix constructed based on the bibliographical survey carried out and the case analyzed in Section 3.3.

3.4. SWOT Matrix

As briefly discussed in Section 1, SWOT is an acronym for the words Strengths, Weaknesses, Opportunities, and Threats. The elements analyzed were separated into 4 quadrants that generated a matrix so that it is clear whether a given factor will be analyzed as a Strength, Weakness, Opportunity, or Threat within the context of the study under construction. In this way, the visual organization of the elements under analysis through the matrix is intended to facilitate the definition of objectives and conclusions on the central theme of the research, in addition to generating discussions about the possibilities of moving a certain aspect between the quadrants, which broadens the researcher's horizons and enables the deepening of the analysis to be carried out [8,21,38].

In 2019, EPE published a study on the main LNG regasification terminal projects in Brazil for the years 2018 and 2019, with the aim of promoting debates on important points for decision-making regarding the construction of these infrastructures. To this end, the Company prepared two SWOT matrices.

Therefore, it is noted that this methodology can be applied in various assessments, both at the business and academic levels. In this sense, from the contents found in the bibliographic survey carried out for the construction of the analyses that make up the present research, the SWOT matrix presented and discussed in the following topics was also constructed. In this sense, the SWOT methodology was chosen to complete the analysis of all the information gathered in this research in order to interconnect them analytically and, thus, generate a more consistent result and help to understand how the expansion of the use of natural gas could impact the regional economy and the lives of the population. In addition, the SWOT methodology also facilitates the identification of obstacles and makes it possible to construct actions because, in order to reach conclusions that can actually contribute to future analysis, it is essential that this construction includes outlining possible strategies to deal with the weaknesses and threats detected around the theme, as shown in the SWOT matrix below (Table 2):

Table 2. SWOT matrix.

Strengths	Weaknesses
- NG can be used as an auxiliary fuel in the energy transition process. - Intensification of the global LNG market. - It is already used in countries with vast territorial extensions to supply remote areas. - Competitive prices in relation to diesel oil and gasoline. - Feasibility of meeting different demands in each region through LNG on a small scale. - Optimization of the use of existing gas in the region, encouraging its use in the form of LNG. - Reduction of excess gas from regional production. - Greater energy security for local populations. - Diversification of the regional and national energy matrix. - Less polluting power, if compared to diesel oil and fuel oil. - Encouraging the development of the regional gas market. - LNG installation and operation processes are less invasive and costly compared to traditional NG. - The northern region is far from the major centers of national natural gas production, but LNG could make the use of this energy resource feasible even in regions far from the Urucu-Manaus gas pipeline. - Incentive to regional economic development, attracting new investments. - Possibility of distribution to regasification terminals via highways or waterways. - REATE program.	- Although less polluting compared to other fuels, it is still a source of fossil origin. - Resistance of regional actors to the increased use of non-renewable sources. - Resistance of regional actors to the exploration and production of new oil and natural gas reserves. - State regulations aimed at the gas distribution service are underdeveloped or even non-existent. - Region marked by inefficient public policies aimed at regional development, which often prioritize political interests rather than the quality of life of the population. - Complexity for the acquisition of authorizations and licenses for new LNG terminals. - Knowledge about operations and logistics (know-how) concentrated in a few companies. - Stricter contracts, especially in take-or-pay and ship-or-pay clauses.

Table 2. *Cont.*

Opportunities	Threats
- Reduction of national dependence on pre-salt production. - Contribute to increasing the capillarity of gas transport in Brazil. - Expansion of the national gas market. - Contribute to the maturation and/or creation of state legislation in the region specific to NG. - Boost the interconnection of the regional energy market. - Reduction of dependence of SISOLs on diesel oil for their operation. - Assist in increasing the generation of employment and income at the local level, due to the installation, operation, and maintenance of regasification terminals. - Possibility of building regasification terminals in Barcarena-PA and Itacoatiara-AM. - Contribute to increasing industrial production in various sectors in the region and, consequently, in Brazil. - Possibility that Brazil becomes a major exporter of LNG - Benefit from the development of Arco Norte, for the distribution of national production.	- Worldwide intensification of movements in favor of increasing the use of renewable energies. - Initiatives in favor of decarbonization can impact the competitiveness of gas prices in relation to renewable sources. - Relationship between LNG and UTEs. - National regulation in the consolidation phase. - Need for contractual alignment so that the installation of the regasification terminal does not compromise the supply of long-term projects. - Risk of negative impacts on the integrity of the Amazon rainforest.

Source: Elaborated by authors.

3.4.1. Strengths

In recent years, due to the growing quest to make the expansion of gas use feasible, use in the form of LNG has been intensified in many countries, especially those with vast territorial extension, as is the case of Brazil and China, due to the facilities that the liquefied form has to be transported to more remote areas by trucks and ships, without depending on the existence of a network of transport and distribution pipelines. This fact is also a consequence of the increase in the available supply of LNG globally, which was driven by technological advances, as well as the flexibility in contractual clauses and the increase in purchase and sale flows of the input between different nationalities [8,10,39].

As mentioned in previous chapters, natural gas is a fuel that can help in the energy transition process due to its energy efficiency, added to the fact that it allows for a variety of applications for end uses, in all its forms (gaseous NG, CNG, and LNG), and for emitting smaller amounts of GHG into the atmosphere. In addition, the input can be used in conjunction with renewable sources for the generation of electricity, thus, providing greater energy security in the generation of electricity [40,41].

In the case of the northern region, it is important to highlight the existence of problems around energy security that influence the quality of life of the population, which on several occasions was at the mercy of long blackouts that compromised the carrying out of daily activities, also affecting the economy of the states in the region. According to analyses carried out by the Federal Court of Auditors [42], the quality of the performance of the electrical system is considered bad by the criteria of the ONS itself, especially in relation to the interruption time of the supply. Thus, the diversification of the regional energy matrix through the use of new fuels can help to improve the stability of the energy supply, through the increase in the share of natural gas associated with other sources such as photovoltaics and biomass, among others.

Thus, as the northern region is far from the large centers of national natural gas production located in the coastal region of Brazil, LNG could be an alternative to make the use of this energy resource viable even in regions far from the Urucu-Manaus gas pipeline, mainly through its small-scale model (SSLNG). This model requires a smaller infrastructure than conventional LNG terminals and focuses on the distribution of small volumes of energy through trucks with cryogenic tanks or even barges [11,20]. However, studies such as [43] point out that the cost of the elements that make up the small-scale LNG chain varies according to the specificities of each project, mainly with regard to the composition and volume of the gas to be transported, as well as to which it will be taken before it reaches consumers. It is essential to evaluate each case to also analyze what the estimated maintenance costs of the projects will be and how much will be allocated for the

remuneration of the workforce needed for operations, even if the prospects are optimistic. The Azulão-Jaguatirica II Project uses this SSLNG model so that the LNG is taken from Azulão to Boa Vista via cryogenic trucks, thus, enabling the input to be used in the future in addition to the UTE Jaguatirica II supply, thus being extended to meet different demands in the region.

In addition, analyses such as those performed by [39,41] highlighted other advantages of using this model, such as the fact that financial returns occur faster for the investor since the necessary infrastructure and the technology used for its operation have lower CAPEX compared to conventional processes of the exploration and production of gas, also allowing for further expansion if there is an increase in demand. Furthermore, the SSLNG can drive advances towards optimizing the use of existing gas in the region, thus, contributing to the reduction of surplus gas from regional production and enabling the use of local production, as has been happening in the Azulão-Jaguatirica II, thus, demonstrating that this model can be adapted to regional specificities and that it has the potential to be replicated in other states in the region.

Bearing in mind the challenges that the geography of the northern region presents for the implementation of large projects, such as gas pipelines, it should be noted that the region can still benefit from the use of the liquefied form of the input. As already discussed, the LNG installation and operation processes—especially in the SSLNG model—are less invasive and costly when compared to the input in the gaseous (GAS) and compressed (CNG) state, in addition to the fact that LNG has a high energy density—about 600 times greater than natural gas under normal temperature and pressure conditions (CNTP)—, being more advantageous for transporting larger volumes of natural gas over long distances [8,10,40].

Thus, in view of the great potential that the north region has for onshore gas production, federal government initiatives for E&P of this type of reservoir and better use of energy resources in remote areas are fundamental to the evolution of Brazilian energy policy and contribute to the expansion of the regional market for the input. The Onshore Oil and Natural Gas Exploration and Production Activity Revitalization Program—REATE was launched in 2017 and its main purpose is to boost onshore E&P activities so that gas production in this environment reaches a volume of 50 million cubic meters per day by the year 2030 [4,20,44,45].

However, as already discussed in previous subsections, the expansion of the natural gas market in the Amazon still faces some issues. The following subsubsection will deal with the weaknesses observed during the analysis of the data used in the elaboration of this research.

3.4.2. Weaknesses

Despite having many strong points, as discussed in Section 3.4.1, the increase in the use of natural gas in the Amazon also encompasses obstacles and/or disadvantages, called weaknesses in the SWOT analysis. Bearing in mind that the region is well known for its natural riches, it is important to highlight that even though it is less polluting in relation to other fuels—such as petroleum and diesel oil—it is still a source of fossil origin and, therefore, still emits GHG that can be harmful in the medium and long term to the environment [1,16,34].

For this reason, it is important to highlight that the resistance of regional actors to the growth in the use of natural gas in the region increases the complexity of acquiring authorizations and licenses for the construction of the necessary infrastructures for the exploration, production, and use of the input [2,16]. In view of the natural characteristics, the construction of a logistical plan that enables the implementation of the necessary infrastructure for the development of gas projects, as well as the flow of its production, must take into account the possible difficulty of accessing certain areas, both due to the rich vegetation local and by the presence of native indigenous peoples who mostly inhabit areas of environmental preservation.

Such issues are hampered by the low efficiency of existing public policies in relation to regional development since the needs of the population end up being less considered to the detriment of prioritizing political interests. Studies such as [12,46,47] showed that the game of interests is a striking feature of the northern region of Brazil, which impacts the paradox that even with vast wealth, strategic geographic location, and high development potential, it is the region with the worst social and economic indicators of the country.

Added to this, in the case of natural gas there is precariousness and/or absence of state regulations that define all the necessary conditions for the provision of the distribution service, due to the low synergy between investors and the federal and state regulatory models in force, even with the advances promoted by the regulatory changes that have occurred in recent years. Thus, of the 7 states that make up the region, only 3 of them have regulations aimed at gas activities, which creates a scenario of insecurity and political instability, making the attraction and implementation of new energy projects that encourage the expansion of the regional gas market difficult.

Another point that ends up compromising the expansion of the gas market is the contractual aspects, especially due to issues related to consumption variation. When consumption varies greatly in relation to the Contracted Daily Quantity (QDC) established in the contract, the consumer tends to pay penalties due to take-or-pay (TOP) or ship-or-pay (SOP) clauses. The first defines a minimum and/or maximum volume to be paid, regardless of consumption, while the second consists of the payment of a minimum and/or maximum volume that must be paid, regardless of the quantity transported [8,11].

Finally, it should also be noted that an aspect that weakens the development of gas projects both at the regional and national levels is the fact that existing projects involve few companies, so knowledge about operation and logistics (know-how) of both gaseous gas and LNG are highly concentrated. Thus, the construction of new projects is restricted to a few investors and, as a result, the market tends to expand more slowly [11].

After analyzing the weaknesses, the next topic aims to elucidate the opportunities that the topic offers for the northern region.

3.4.3. Opportunities

The national gas E&P comes from offshore reservoirs, mainly after the pre-salt discovery. According to available data [20], in June 2023 domestic onshore production was around 22 MMm^3/day, while production from the pre-salt layer was 109 MMm^3/day, thus, representing approximately 75% of the entire volume raw produced. For this reason, there is a concentration of production in the coastal regions of the country, which negatively impacts the expansion of consumption and, in turn, hinders the effective development of the gas market in Brazil. Thus, the need to reduce E&P's dependence on the pre-salt is evident, seeking economically viable ways to expand the exploration of onshore reserves. The north region has the potential to play an important role in this scenario, given the gas reserves present in its territory. However, it is essential that the E&P of such reserves occur in a way that respects the environment and local people. In this sense, SSLNG projects can be allies of this process, since they can promote increased capillarity in gas transport and distribution without requiring the presence of gas pipelines and the construction of new roads for their operation to take place [36,39,40,46].

NG and LNG can also boost the interconnection of energy markets in the northern region, as the model used in the Azulão-Jaguatirica II Project can be replicated by involving other states in the distribution of inputs. As disclosed by the government of Rondônia [32], a memorandum of understanding was signed between the State Government and Eneva to initiate feasibility studies for using the Madeira River waterway to transport gas to the state, followed by market analysis, aiming to map possible final uses for the input in Rondônia. In addition, according to information from the government of Amapá [24], some companies such as Evolution Power Partners S.A have already expressed interest in deploying gas-powered TTPs in the state, due to its strategic location that would also enable the arrival of the input to Amapá through the Madeira River.

According to [16], there is a forecast for the installation of new LNG terminals in various parts of Brazil. In the case of the North Region, the study highlighted that three terminals were under analysis to be built: one in Barcarena (PA), one in Ponta de Pedras (PA), and one in Itacoatiara (AM). In December 2020, the ANP authorized the construction of the Barcarena terminal, located in the Port of Vila do Conde (PA), which will have the Novo Tempo UTE as an anchor consumer, located in the same municipality, and will be an SSLNG project, with the transport of LNG through barges and/or trucks [4,44]. The Ponta de Pedras and Itacoatiara projects are still under evaluation, but the transport of inputs would be carried out by the Madeira River and the main anchor consumers would be mining industries and electric energy self-producers located in the first stretch of the source of the river (called headwaters).

It is also important to highlight that the northern region is marked by the presence of Isolated Systems. Therefore, the expansion of the use of NG and LNG could contribute significantly to the reduction of Isolated Systems dependent on diesel oil for their operation. Added to this, there would also be diversification of the regional energy matrix, which could also make Brazil independent of the importation of diesel from Venezuela and other countries, and make the matrix less polluting compared to the present, due to the lower GHG emission power of NG in compared to diesel, oil and coal.

It should also be noted that feeding Isolated Systems through NG or LNG would increase the region's energy security and this could contribute to the growth of industrial production in various sectors in the region, which tends to generate positive impacts on the regional and, consequently, national economy. Studies such as those carried out by [22,34,35] found that the region has the potential to host a chemical complex using NG or LNG to carry out its industrial processes The idea is based on the fact that the region has the presence of factories of various products and, bearing in mind that a large volume of gas is produced that is not fully used, it would be an option for better use of the input to serve both the regional market and other industrial markets.

Furthermore, it is possible that the northern region will also benefit from the development of Arco Norte. According to a study released by the Legislative Consultancy (2016), Arco Norte consists of an intermodal transport logistics corridor to be used to transport loads of various inputs produced nationally, especially of agricultural origin such as grains and cereals. The main objective of this project is to encourage the decentralization of the main ports in Brazil through the implementation of strategic corridors for export.

Thus, it is noted that the region is attractive for new projects of different natures, even with the existing obstacles. The increased visibility of the region in recent years reinforces the need to mature and/or create state legislation in the region that is specific to NG, which can boost movements in favor of consolidating more robust and safer regulatory models for both investors and consumers alike.

To conclude the analysis of the SWOT matrix presented in this section, the next section will address the threats identified in relation to NG and LNG in the Amazon.

3.4.4. Threats

Since the 1990s, movements in favor of the energy transition have been gaining more notoriety and, consequently, the incentive to replace fossil fuels with renewable energy sources, which has a negative impact on the expansion of the gas market, especially in the northern region of Brazil. Thus, there is great resistance from regional actors to the increased use of non-renewable sources and the E&P processes of oil and natural gas reserves existing in the Amazon, as discussed by [12,16]. It is important to promote debates on these topics, so that there is the possibility of boosting the improvement in the synergy of interests between the interested actors, thus, demystifying the idea that natural gas cannot be an ally of the energy transition.

According [11], decarbonization policies involve issues such as carbon pricing and subsidies for renewable energies, in order to make the choice of using fossil fuels more costly and less attractive. As a result, the prices of gaseous natural gas and LNG may

become less competitive in relation to energy inputs from renewable sources. In addition, these policies aim to minimize or even replace fossil-based resources with alternative energy sources, which tends to reduce dependence on these resources to carry out essential activities, thus leading to an ever-decreasing demand for fossil fuels.

In addition, it is important to highlight that, in the case of LNG, most of the existing projects and those under construction in Brazil so far are linked to the existence of UTEs, with the intention that most of the energy consumption is carried out by these power generation plants, such as the Barcarena Terminal [20]. Thus, if there are complications in the installation of UTEs, there may be a compromise or even abandonment of LNG projects, because without the presence of their "anchor consumer", profits would be reduced, which would be harmful to investors.

In this sense, another threat to gaseous natural gas and LNG projects is that, in the case of supply for long-term investments, it is essential that there is contractual alignment in order to minimize risks related to the abandonment and/or stoppage of these investments, as well as guarantees that the installation of the regasification terminal does not compromise the supply of the project, which will depend on the use of these inputs to operate throughout the period provided for in the contract [8]. It should also be noted that, despite the strengths and opportunities presented in this SWOT matrix, researchers such as [22] state that despite the existence of analyses such as the Sedimentary Area Environmental Study (EAAS), released by EPE, they show that the increase of oil and gas activities in the Amazon region does not depend on the creation of new roads in the region; it is not guaranteed that this will not occur. Thus, there is a risk that the pressures for the expansion of projects related to these energy sources have a negative impact on the preservation of the forest, with the need to deforest large areas for the construction of roads, which would affect both the environment and the native peoples.

Finally, despite the significant advances obtained with the approval of Law No. 14,134/2021, the national regulatory model focused on the natural gas chain is still in the consolidation phase and is, therefore, subject to changes given that there are still issues that need to be better defined to ensure the effective expansion of the Brazilian gas market, which reinforces insecurity for investments in new projects. Among such issues, one can highlight the tax aspects and harmonization between state regulations, so that the risks of projects involving more than one state are minimized, as is the case of Azulão-Jaguatirica II and which, possibly, would be the case of new projects of this nature that may be implemented in the future in the northern region of the country.

4. Discussion

Despite the strong presence of hydroelectric plants in the northern region, it should be noted that most of the energy generated by them is sent to other Brazilian regions, which ends up generating a great paradox; a region rich in energy resources does not enjoy energy security. This paradox is due to some factors that range from political issues to demographic aspects. Studies such as [12,15,34,47] state that due to its vast natural riches, the Amazon is constantly the scene of disputes and conflicts of interest regarding the use of these riches. According to [47], Latin American societies continue in the historical moment in which population expansion and urban and technological development are strongly related to social and political relations, and, therefore, the Amazon region ends up having its development compromised.

According to [15], the incorporation of the abundant Amazonian rivers into Brazilian energy planning took place with greater intensity during the period of the military dictatorship and, from then on, the country's energy security was linked to the movement to expand the implantation and the use of electricity generated in hydroelectric plants. With the end of the dictatorship, investments in these projects continued, linked to the idea of which projects could boost regional economic and social development, disregarding the fact that they could also bring various environmental and social problems to the population. Ref. [2] defend the view that the negative impacts generated by hydroelectric plants should

be more highlighted and debated since the idea that a renewable source is used to generate electricity in these plants is widespread, but little is known about the deterritorializations and the damage caused in the social and cultural spheres that its constructions cause to the local populations. Ref. [48] states that the expansion of hydroelectric plants has been suffering more and more limitations imposed by climate change and that, in view of the growing global concern in achieving the goals related to the energy transition process, it is necessary for Brazil to seek ways to make feasible the reduction of dependence of the national energy matrix in relation to the generation of energy from hydroelectric plants. However, the decrease in the participation of this energy source must occur in a way that does not compromise the security of the electric energy supply for the Brazilian population, in all regions, thus, seeking greater use of alternative sources to meet the country's energy demand.

Although it is still a non-renewable source, natural gas can contribute to the energy transition by replacing diesel oil, which is widely used in the region, and also contribute to increasing local energy security, since the hydroelectric source is intermittent and is strongly affected by climate change. In this sense, SSLNG projects can be an alternative to improve the supply of energy demand in the northern region, being able to configure the regional matrix both as the main source and as a complementary or backup source. The use of natural gas can be expanded to other purposes beyond thermoelectric generation, such as the transport sector, the grain drying industry, air conditioning, and refrigeration, among others. For this, it is necessary to evaluate the possible demands, analyzing the risks, advantages, and disadvantages for both investors and consumers. However, if the development of more SSLNG projects proves to be good alternatives to be implemented in more locations of the north region, the states that make up the region will have to go through several changes.

For example, in the case of Roraima, the institutional sphere will have to define which regulatory entity model will be adopted for the regulation of gas distribution services (government department or regulatory agency). Regarding the option of a government secretariat, analyzing the current administrative structure of the state, it is observed that there are currently several government secretariats, but none of them is directly related to the energy and mining sectors, so the secretariats that are closest to of these sectors among those existing so far are the Secretariat for Planning and Development (SEPLAN) and the Secretariat for Infrastructure (SEINF). As for the adoption of the regulatory agency model, the state will need to adapt its state legislation and take a series of initiatives to build the institutional and regulatory structure of an agency dedicated to gas services. In addition, regardless of the chosen model, the state will have to develop its own regulatory model for the provision of piped gas services. In this sense, the case of the regulatory survey existing in Brazilian's northern states focused on gas activities aimed to elucidate the situation of the current regulation of natural gas the at national level, since it has undergone several changes over the last decade in order to reach a more robust model that conveyed clarity in its definitions. Thus creating a safer, more attractive, and conducive scenario for the development of the Brazilian gas market.

5. Conclusions

Through the chosen theme, this article aimed to contribute to the construction of the scientific framework related to the existing energy issues in Brazil's northern region, increasing visibility to a region that is undervalued and suffers from the consequences of the negligence of the rulers, having its development economically and socially compromised. By highlighting the main aspects that constitute the region, from the geographic point of view to issues related to the energy supply of its states, it was verified that the region lives a paradox between wealth and poverty since it has countless natural and cultural riches, but it houses some of the municipalities with the worst social indicators in the country. Thus, it is evident that there is a need to seek solutions that make regional development possible, through the best use of its resources, aiming to achieve a balance between economic

development, environmental preservation, and respect for native peoples. The population that lives in the more affluent areas of the Amazon are, many times, made invisible by the rulers and even by the society that inhabits the other regions of Brazil, so their living conditions are often precarious, and their culture is often devalued or even questioned, as there is still enormous prejudice against the figure of indigenous peoples. Thus, it is worth highlighting again the importance of public policies becoming more efficient and designed to benefit the people, thus ceasing to be a tool used to serve political interests.

Through the analysis of the case study of Azulão-Jaguatirica II, it was possible to understand the functioning of the project, analyzing its objectives and possible consequences, mainly for the state of Roraima, which was also analyzed through an overview of its activities features, emphasizing the energy issues to be improved both in the state and in the region itself. Besides the main advantages and disadvantages of the project, the study aimed to show what changes need to happen to Roraima to expand the use of NG and LNG to meet its needs, as well as what are the expected impacts of the Project in the development of the state and the quality of life of the population.

Finally, the SWOT matrix resulting from all the data collected and analyzed throughout the construction of this research was constructed and presented, broadly evaluating the various aspects that involve the relationship between the expansion of the use of NG and/or LNG in the matrix regional energy, with the aim of contributing to assessments for decision-making to improve regional and national energy planning. Thus, the aspects raised were classified into 16 Strengths, 8 Weaknesses, 11 Opportunities, and 6 Threats. In this way, energy sources are good options to meet the needs of the region and can be allies in the energy transition process towards the gradual decarbonization of the Amazon, guaranteeing greater security and stability in the supply of electricity and not requiring the construction of infrastructures that compromise environmental preservation and the safety of local populations. Added to this, the resources showed favorable opportunities for regional and national development, which could boost the optimization of the use of energy resources available in Brazil, with the possibility of making the country less and less dependent on other countries to meet its energy demand. However, the identified weaknesses and threats must be taken into account in decision-making, so that there is detailed planning to mitigate these obstacles, respecting regional specificities.

To further enrich the debate on the topic, future studies may seek to add new points to the SWOT matrix presented in this article in order to return the discussion on this topic to an increasingly robust and complete one. For example, a fundamental aspect of decision-making in the energy sector is the price of a certain resource, thus, allowing the analysis of its economic forecast and, in this sense, a comparative analysis could be made between the price of natural gas and other energy resources, both renewable and non-renewable. That said, the research concluded that although it is still a non-renewable source, natural gas can contribute to the energy supply and replace diesel oil, thus contributing to energy stability and the reduction of GHG emissions, and being able to configure the regional matrix both as a main source and as a source complementary or reserve. In this sense, SSLNG projects can be used in other locations in the Brazilian north region as long as the projects are very well planned, and consider and respect local needs so that neither the environment nor the local population are harmed.

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