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Indicative LNG Terminals Plan

PITER

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1. Introduction

The Indicative LNG Terminals Plan (PITER) is part of the EPE's publications with the objective to support the Brazilian government to plan the natural gas (NG) sector by presenting new investment opportunities in LNG terminals. The projects are studied in a conceptual level and, therefore, the interested companies may detail their own studies later. If one or more of the alternatives prove to be feasible and become connected to the national natural gas transmission pipeline network, then, it may allow an increase in the Brazilian NG supply capacity, more energy flexibility and security. These alternatives were studied to offer NG at different Brazilian regions that, today, are not totally supplied and to create flexible supply points in a given region, encouraging new gas demands to be stablished near them.

The EPE's Directorate of Oil, Gas and Biofuels Studies[1] published this first PITER as part of its natural gas infrastructure's indicative plans, together with three previous documents: Indicative Transmission Gas Pipeline Plans – PIG 2019 and PIG 2020 and, also, the Indicative Natural Gas Processing and Outflow Plan – PIPE 2019. Therefore, PITER considers integration with those indicative plans in order to ensure an integrated Brazilian energy planning and develop efficient solutions from the government's point of view. This plan is part of EPE's initiative to bring predictability to the Brazilian natural gas market for possible investment alternatives in new LNG regasification terminals, according to the main objectives of the New Gas Market Program, which helped the discussion of the New Gas Law (Law 14,134 of April 8th, 2021) and its regulatory decree (Decree 10,712 of June 2nd, 2021), aiming at the creation of an open, dynamic and competitive natural gas market, that is, contributing to the economic development of the country.

According to the article 4 in the Law 10,847 of March 15th, 2004, which created EPE: "EPE is responsible (...) for producing studies related to the master plan for the natural gas industry's development in Brazil". In order to fulfill its institutional role and promote the Brazilian NG market, EPE indicates possible LNG terminals locations. Thus, based on supply and demand NG studies associated with the other documents published by this company, PITER brings technical and economic analyzes for each studied alternative. Based on those results, EPE tries to raise knowledge about the main competitive advantages of these alternatives, establishing new flexible NG offer for potential NG demands.

This study is a government planning tool for the Brazilian NG sector, in addition to introducing a series of advances like the reduction of information asymmetry about potential LNG terminals in Brazil, the identification of investment opportunities, the alignment of expectations and interests among the NG's companies and the transparent disclosure of the methodology used by EPE in costs estimating for LNG projects.

Regarding this document outline, the second chapter presents a brief historical review of LNG terminals in Brazil. Chapter three presents the methodology used to define the LNG terminals alternatives' technical features and costs estimation. The fourth chapter describes the four alternatives' locations and costs, remembering those points were selected in the Brazilian territory, aiming at connect the terminals with other NG facilities that were previously studied by EPE like PIG (for transmission pipelines) or PIPE (for natural gas processing plants and gathering/outflow pipelines). Chapter five summarizes the main results and discuss some advantages and challenges of

[1] In Portuguese, *Diretoria de Estudos do Petróleo, Gás e Biocombustíveis (DPG).*

each alternative. The sixth chapter describes the case study chosen to evaluate the alternative located at the Southeast Region using different regasification capacities and studying the results with or without onshore tanks in order to study the regasification rates and tariffs. Chapter seven brings updates on the progress of the main Brazilian LNG terminal projects described at the EPE's Technical Note named "LNG Terminals in Brazil – Cycle 2019/2020" (EPE, 2020a) and presents news about them. The last chapter presents the final remarks.

2. Overview of LNG projects in Brazil

This chapter presents the context and a brief history of Brazilian LNG terminals. For more details on the history of LNG in Brazil, as well as additional information about the configurations of each terminal, it is suggested to read the special chapter of the Technical Note LNG Terminals in Brazil – Cycle 2019/2020 (EPE, 2020a).

Liquefied natural gas is an important source of natural gas supply to Brazil, making up, with domestic production and imports via pipelines, the total amount of natural gas available to meet Brazilian demands. LNG provides flexibility to the Brazilian gas market, helping to control demand variations that may occur over time.

In Brazil, there are currently five LNG regasification terminals in operation. The first two have similar configurations and belong to Petrobras: the Pecém/CE terminal, inaugurated in January 2009 and the Guanabara Bay/RJ terminal, inaugurated in April of the same year. The third terminal, also owned by Petrobras, was inaugurated in 2014 at Todos os Santos Bay/BA. The two remaining terminals were built more recently, both belonging to other market players: the Sergipe Port/SE terminal, by CELSE[2], inaugurated in 2019; and the terminal at Açu Port/RJ, by GNA, inaugurated in 2021. There are also three additional terminals with Final Investment Decisions (FIDs) announced by the company New Fortress Energy: Gás Sul/SC; Suape/PE and Barcarena/PA (EPBR, 2021a).

Figure 1 presents the evolution of regasification capacity installed on the Brazilian coast through LNG terminals over the years, as well as the projection for expansion in the horizon of the announced projects. Chronologically, the following facts are described:

• entry into operation of the Pecém/CE and Guanabara Bay/RJ terminals, in January and April 2009, respectively, totaling an installed capacity of 21 million m³/day;

• startup of the Todos os Santos Bay/BA terminal in January 2014, with 14 million m³/day;

• increase in the regasification capacity of the terminal at Guanabara Bay/RJ in 2014, going from the initial 14 million m³/day to 20 million m³/day;

• entry into operation of the CELSE terminal in Barra dos Coqueiros/SE in November 2019, with 21 million m³/day;

• authorization to operate the Açu Terminal in May 2021, with 21 million m³/day;

• planned expansion of the terminal at Guanabara Bay/RJ to 30 million m³/day as of 2021;

• expected start-up in 2022 of the Barcarena/PA Terminal, with 15 million m³/day and the Suape/PE Terminal with 14 million m³/day;

• Start-up of Gás Sul Terminal in São Francisco do Sul/SC, scheduled for 2023, with 15 million m³/day.

[2] In Portuguese, *Centrais Elétricas de Sergipe S.A.*

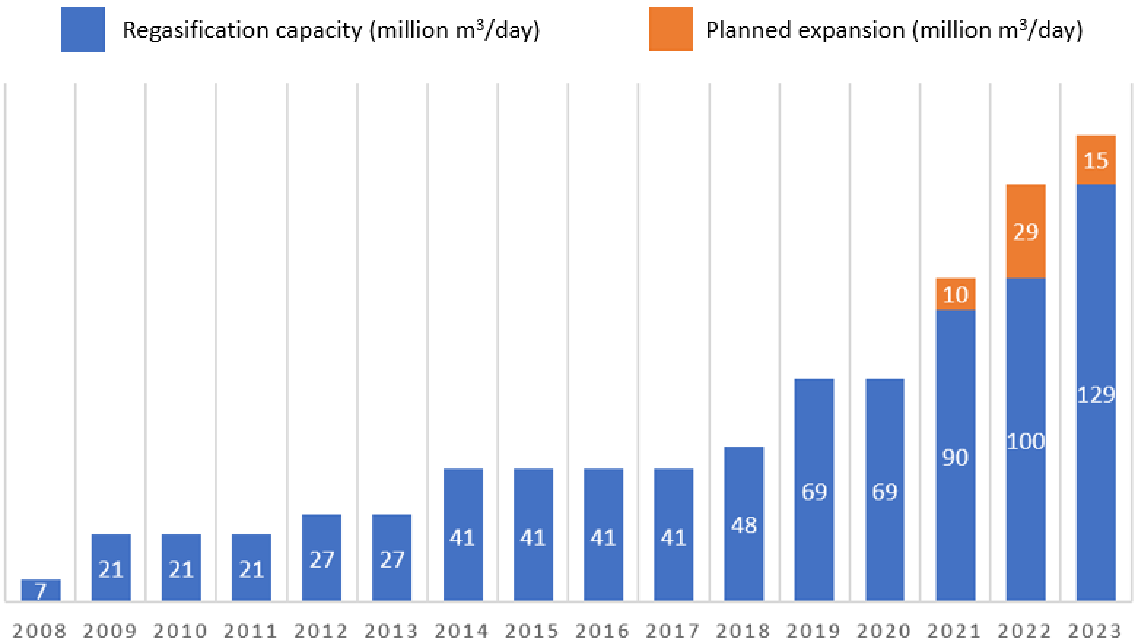

Figure 1. Brazilian LNG terminals' capacities evolution
Source: EPE considering EPE (2020a), MME (2021) and EPBR (2021a).

Historically, Brazilian LNG terminals connected to thermoelectric power plants have brought flexibility to the national interconnected electrical system. This advantage is important when there are variations in the need for thermoelectric dispatch due to renewable sources' (wind and solar) intermittence and seasonality. Since Brazilian natural gas production is mostly associated with oil, it is not always possible to reduce or stop its production without prejudice to oil extraction. Thus, LNG helps to balance the pipeline network and control variations in natural gas demand.

As a result of this flexibility need, the largest gas-fired power plant projects that have won energy auctions in recent years have their own integrated LNG terminals. It is noteworthy, however, that other factors such as: the inexistence (and the high cost) of underground gas storage facilities, the projections of low LNG prices in the international market, the limitations or inexistence of natural gas transport infrastructure in some Brazilian regions, may justify projects with this configuration.

It is noteworthy that, historically, the flexibility required by thermoelectric plants connected to the integrated gas pipeline network was guaranteed by Petrobras' LNG terminals. Thus, despite not being the only possible source of flexible natural gas supply, recently, the importance of LNG terminals for expanding thermoelectric demand in Brazil is noted, as can be observed in Figure 2 and Figure 3.

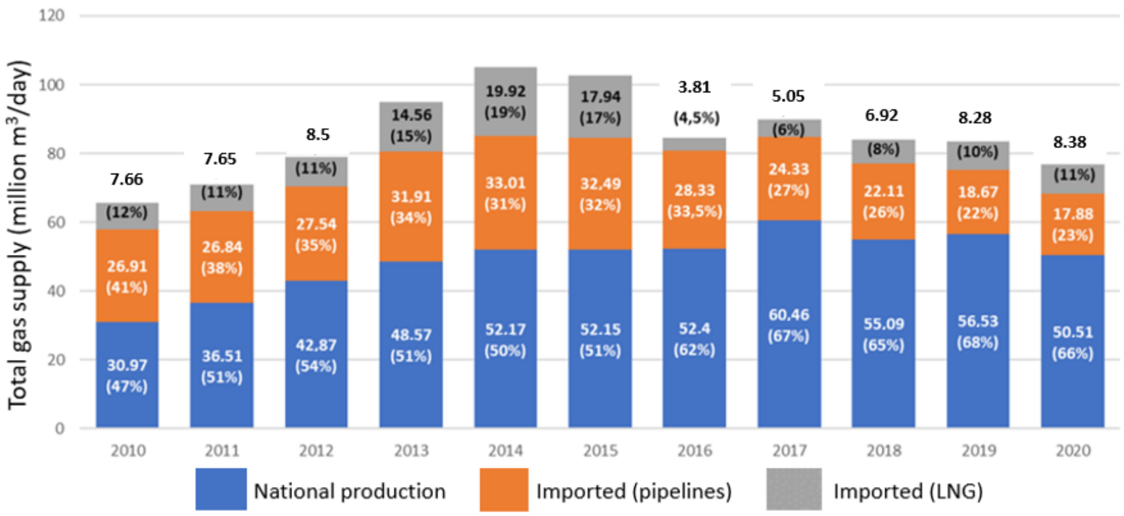

Figure 2. Total national natural gas supply by source in million m^3/day and percentage
Source: MME (2017) and MME (2021).

Figure 2 shows that the period with greatest LNG participation in national natural gas supply (2013-2015) corresponds to a period of high thermoelectric generation using natural gas, as can be seen in Figure 3, which demonstrates the role of LNG to ensure flexibility for this type of demand.

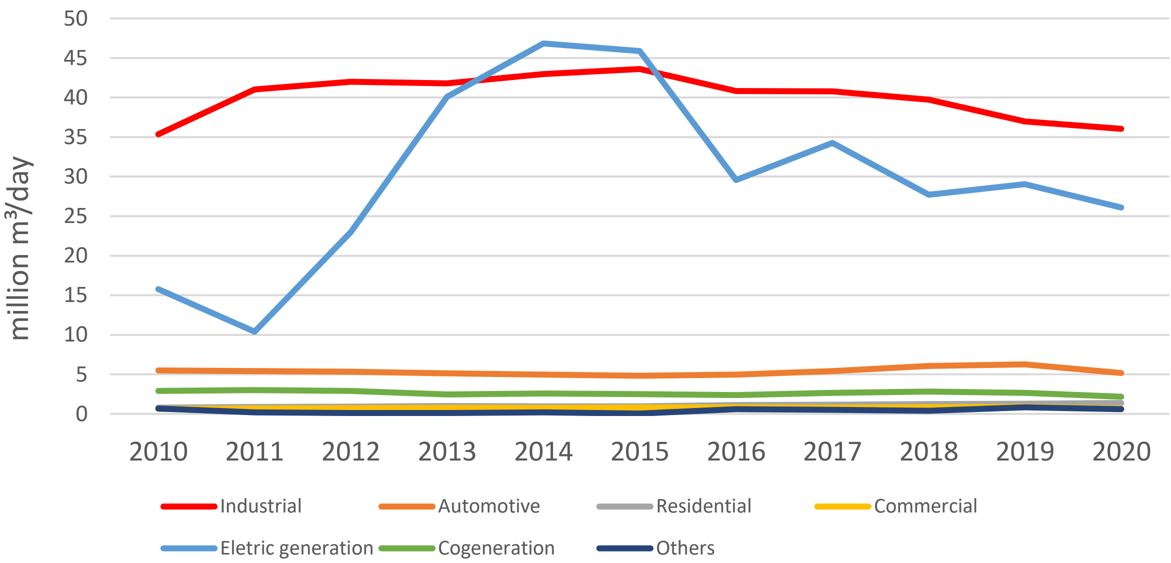

Figure 3. Natural gas consumption in Brazil between 2010 and 2020 by segment
Source: EPE (2020b).

Regarding future prospects, in the Ten Year Energy Expansion Plan up to 2030[3] publication it is expected that the thermoelectric demand will increase by more than 100% in the 10-year horizon, as can be seen in Figure 4. It is expected that at least part of this expansion can take advantage of the (existing or future) available regasification capacity of LNG terminals throughout the country. If these terminals connect to the integrated pipeline network, it will be possible to guarantee, in addition to the security of supply to the natural gas network, greater security in the electricity generation.

[3] In Portuguese, *Plano Decenal de Expansão de Energia (PDE 2030).*

Figure 4. Natural gas demand's projection in the horizon 2021-2030.
Source: EPE (2020c).

Additionally, the short-term perspectives present the possibility of meeting demands via small scale LNG, possibly starting in 2022. It is expected that natural gas will be internalized in locations not yet served by this energy source, using barges and cabotage shipping, via road transportation modal with mounted iso-container tanks and through the creation of new infrastructure for the supply of heavy vehicles along known cargo transport routes – also known as Blue Corridors. In this way, municipalities and even states not yet connected to the existing gas pipeline network or without a local natural gas supply could start receiving this fuel, which would help to create new demands that, in the future, may justify and enable the natural gas infrastructure expansion in a feasible fashion (EPE, 2020a).

3. Methodology

In this chapter, the main considerations and assumptions that guided the Capital Expenditure (CAPEX) estimation studies for the indicative terminals will be addressed. In the special chapter of the "Technical Note LNG Terminals in Brazil – Overview of Main Projects (2019-2020 Cycle)", typical terminal configurations had been studied along with their general cost estimates. In the current indicative plan, the aim is to analyze specific terminal projects, estimating the costs for each case. The gain and refinement of information collected over the last year for this document's publication is noteworthy, due to the collaboration provided by companies operating in the LNG sector through technical meetings held throughout 2021.

Initially, it is important to highlight that the infrastructure's location is a crucial factor in determining its costs. Through detailed studies of bathymetry, tidal movement, wind speed and direction, wave profile, depth, soil conditions at the bottom of the sea, distance from the coast, environmental analysis, among others, the entrepreneur evaluates the best configuration applicable to the LNG terminal, allowing for cost estimates to be made.

The search aims to find places where the cost associated with that terminal is the lowest possible, avoiding places where it is necessary to build a breakwater dyke or large volumes of dredging and rock removal, in addition to seeking existing facilities close to the site that can be used, such as canals and existing navigation or auxiliary port structure, with tugboats, for example. These detailed studies are not carried out by EPE and are not part of the objectives of this study, it being up to the interested entrepreneur to go deeper into these assessments.

In view of the diversity of possible configurations for an LNG terminal, an evaluation of the existing configurations in Brazil was carried out in order to allow the definition of the type of LNG terminal to be adopted in this study as the standard terminal, in relation to the type of berthing, LNG unloading method, equipment on the pier, among other features with a strong impact on project costs.

In Brazil, we have different configurations in the existing terminals, although they all use FSRU (Floating Storage and Regasification Unit) vessels for LNG regasification. Petrobras' pioneer terminals, in Guanabara Bay/RJ and Pecém/CE, have similar configurations: two berths, with a pier between them, cryogenic piping and cryogenic unloading arms on the pier. The Todos os Santos/BA terminal, in turn, has a single berth and a ship-to-ship unloading system (LNG transfer directly between the ships), through cryogenic hoses. While the first two use more equipment on the pier for the LNG unloading process, the second, as it does not need a pier between the ships, presents advances in relation to the need for equipment throughout the process.

The more recently built terminals, in Barra dos Coqueiros/SE and Açu Port/RJ, also use an FSRU and carry out the unloading of LNG through the ship-to-ship system. The difference is due to the form of mooring. While the first uses a previously innovative technology for LNG terminals in Brazil, with Submerged Soft-Yoke berthing buoys, in which the ships tied together manage to rotate around the axis of the buoy, the terminal at Açu Port follows the traditional pier line built under a jetty at the port, with unloading arms only for regasified gas, connecting the FSRU to a pipeline dedicated to supply the associated thermoelectric power plant.

There has been an evolution in Brazilian LNG terminals construction, being observed that the current trend is the ship-to-ship configuration. Also, new projects such as those in Barcarena/PA, São

Francisco do Sul/SC and Santos/SP also denote the tendency to reduce the amount of equipment on the pier.

This equipment's optimization results in a reduction in the workforce dedicated to operating the terminal, allowing the remote operation of the facility, in addition to other gains in scope. The trend observed through these projects, however, does not totally eliminate the importance of projects that make use of traditional equipment such as unloading arms, which can still be applicable in some specific conditions.

Thus, when seeking to define the configurations to be used in each indicative terminal in this plan, the trends discussed about the LNG terminal market in Brazil were taken into account. The projects described in this indicative plan would be offshore terminals, with an FSRU, in addition to making use of LNG unloading through the ship-to-ship system, seeking to optimize the amount of equipment on the pier.

As a premise, the regasification capacity of the FSRUs in this study was defined as 14 million m^3/day. However, it should be noted that the terminal's regasification capacity is not as restrictive when trying to estimate its CAPEX costs. The capacity of a terminal is associated with the FSRU that will be chartered, and this ship can be replaced by another in a new contract when needed. Thus, to convert a terminal with a regasification capacity of 7 million m^3/day to a terminal of 21 million m^3/day, for example, the new charter of an FSRU with this capacity would be enough. It is remarkable that, for this replacement of the FSRU, seeking to increase the terminal's capacity, the infrastructure for the flow of regasified gas by the FSRU (such as pipelines and other structures) must support the increase in flow, which requires simulations and performance tests for its confirmation. Although some adjustments are still being made in these cases, most terminal projects already dimension their associated pipelines and other infrastructure foreseeing a possible expansion in the future (EPE, 2020a). In this sense, although the terminals considered in this indicative plan present a capacity of 14 million m^3/day, the infrastructures for the flow of regasified gas were dimensioned to allow the flow of up to 21 million m^3/day without the need for future expansion of these structures.

For this indicative plan, at least one LNG project per Brazilian geographic region was established, except for the Midwest, as it does not have direct access to the sea. We sought to define the locations of the projects based on existing studies of terminal projects in those regions, choosing, when possible, not to be too close to existing LNG terminals, in order to avoid project redundancy, concentration of supply and injection in a single point of the existing pipeline network. Thus, the terminals indicated in this publication would probably be terminals with preliminary studies already initiated, tending to have their location previously known and optimized according to the results of advanced analyzes (bathymetry, tidal movement, among others) carried out by the interested companies.

As previously stated, we seek to increase the accuracy of the costs presented in this plan. Although terminals generally have a direct relationship with thermoelectric demand, as noted in Chapter 2, the projects analyzed in this study were not limited to information on the best location of the terminals due to thermoelectric plants for the National Interconnected System[4]. Although most LNG terminal projects may be associated with consumers of this type, the analysis of the terminals

[4] In Portuguese, *Sistema Interligado Nacional (SIN).*

considered the possibility of developing the local natural gas industry in the non-thermoelectric segments, and not exclusively in the thermoelectric market.

To calculate the costs associated with the construction of each terminal, the EPE's Regasification Terminal Assessment System[5] was used, which is a tool associated with a database with cost information for existing projects and terminals under planning, international references and cost references prepared by a specialized technical consultancy contracted by EPE. In order to align the costs used here, as well as gather the main information from each project, EPE has also held meetings with agents who have LNG terminal projects in more advanced stages of development.

The capital costs estimates considered the reference date as December 2020. For imported equipment and international specialized labor, when necessary, the exchange rates were BRL 5.14/USD and BRL 6.26/EUR. The FSRU's acquisition costs were not considered, as it is a market practice to charter the ship, instead of buying it. In any case, the costs associated with the purchase of the FSRU are around USD 250 to 350 million, depending on the model and regasification capacity, if a given entrepreneur prefers this type of purchase. The operational costs for chartering the vessel would be around USD 100,000/day not including the costs related to the specialized crew.

Also, as a premise for the terminal construction's costs, the contingencies (indirect cost) were considered as 30% due to the conceptual level analysis. In addition, it was necessary to estimate an average Budget Difference Income (BDI), an indirect cost. According to the Federal Court of Auditors[6] agreement number 2,622/2013, BDI includes costs with central administration, risks, insurance and guarantees, financial expenses, profit, taxes (PIS, COFINS, ISS)[7] and social security contribution on gross revenue[8]. For each previous item, a percentage that makes up the final BDI is estimated. For projects similar to the configuration defined, the authors adopted a recommended reference percentage of 27.48% of the project's direct costs.

Finally, it should be noted that the costs presented here have a high degree of uncertainty, due to the level of detail in the conceptual design, as well as the peculiarities of LNG terminal projects. Under these conditions, it is reasonable to adopt a precision percentage of -20% to -50% and +30% to +100%, according to AACEI (2011).

CAPEX costs were divided into seven items:

- **General Services**: costs not directly associated with the construction, but include costs related to the construction neighboring site, local administration and equipment, executive project, management and local inspection of the work and licensing.
- **Civil Structure (Pier)**: costs associated with the construction of the terminal's pier; includes, mainly, dolphins, operating platform and metallic structures. They may also include, depending on the project, support blocks for the pipeline and the walkway, in addition to the walkway itself and complementary mooring systems with quick release technology[9].

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[5] In Portuguese, *Sistema de Avaliação de Terminais de Regaseificação (SATIR).*

[6] In Portuguese, *Tribunal de Contas da União (TCU).*

[7] Social Integration Program or *Programa de Integração Social (PIS)*; Contribution to Social Security Financing or *Contribuição para o Financiamento da Seguridade Social (COFINS)* and Tax over services or *Imposto Sobre Serviços (ISS)*.

[8] In Portuguese, *Contribuição Previdenciária sobre a Receita Bruta (CPRB).*

[9] Used to speed up the unberthing process when the vessel is at risk.

- **Gas Pipeline Implementation**: includes the costs of onshore and/or offshore gas pipelines under the pier and other complementary facilities, such as scrapper (pig) launcher and receiver, valves, anti-corrosion system, etc.
- **Transfer of custody station**: this is the equipment installed at the end of the pipeline that is part of the terminal, necessary for carrying out the transfer of custody of the regasified natural gas. Includes costs related to equipment and costs of construction and assembly services.
- **Tanking**: includes tank and discharge system costs.
- **Contingencies**: percentage of the cost of the aforementioned items.
- **BDI**: percentage on direct costs.

The costs of opening a navigation channel and the costs of other special works, such as dredging (removal of sand), rock removal (removal of stones) and breakwater were not considered since the projects analyzed here were either close to or located in Organized Ports (public ports) or Private Use Terminals[10]. In addition, there is high uncertainty when trying to estimate an average cost for these projects, depending on specific engineering projects for greater accuracy.

With regard to tanking, a variation of the proposed terminal in the Southeast Region was considered, taking into account the possibility of building an onshore tank to store an additional quantity of LNG, together with the storage capacity of the FSRU itself[11]. Thus, based on onshore terminal projects in international references, the premise was defined for the construction of a 180,000 m³ tank on the coast. Finally, we have estimated the costs associated with an additional tank in case the developer decide it may be necessary.

[10] In Portuguese, *Terminais de Uso Privado (TUPs).*

[11] Depending on the FSRU, the LNG storage capacity is generally between 150,000 m³ and 180,000 m³.

4. Detailing of indicative LNG Terminals alternatives

In this chapter, the LNG terminal projects evaluated by EPE, chosen to assemble the project portfolio of this indicative plan, will be addressed. It is important to highlight that other existing terminal projects, with different degrees of maturity, located close to those presented in PITER 2021, could also be able to meet the conditions defined in the plan that justify the choice of a certain geographic location. However, it should be noted that variations in design and location, different from those presented in this study, may imply changes in the costs involved. Figure 5 presents the location of the studied projects, having been evaluated one project in each Brazilian region (with the exception of the Midwest), in the following States: Amazonas; Maranhão, Espírito Santo and Paraná.

As mentioned in the methodology section, there were selected locations in those states where there is at least one terminal project announced or under analysis by entrepreneurs. This was done as a way to select a location in which there have already been initial studies that attest to the technical feasibility of building an LNG terminal. Other assumptions taken into account when choosing the location of the terminal were the parameters that guide PITER: guaranteeing the supply of gas in places of high demand, allowing economic development and the local natural gas industry, security of supply (especially in isolated systems) and reinforce the national gas pipeline network, especially in the southern region of the country.

Thus, the terminals that will be described in this plan are located at:

- Itacoatiara/AM, an important commercial city near Manaus and with a still deep draft on the Amazon River;
- São Luís/MA, state capital not yet supplied by natural gas and with relevant demand potential;
- Presidente Kennedy/ES, a city close to the integrated grid with some projects for the arrival of gas from the pre-salt and the interiorization of gas in the country;
- Pontal do Paraná/PA, enabling new supply of natural gas into the integrated grid in the South Region.

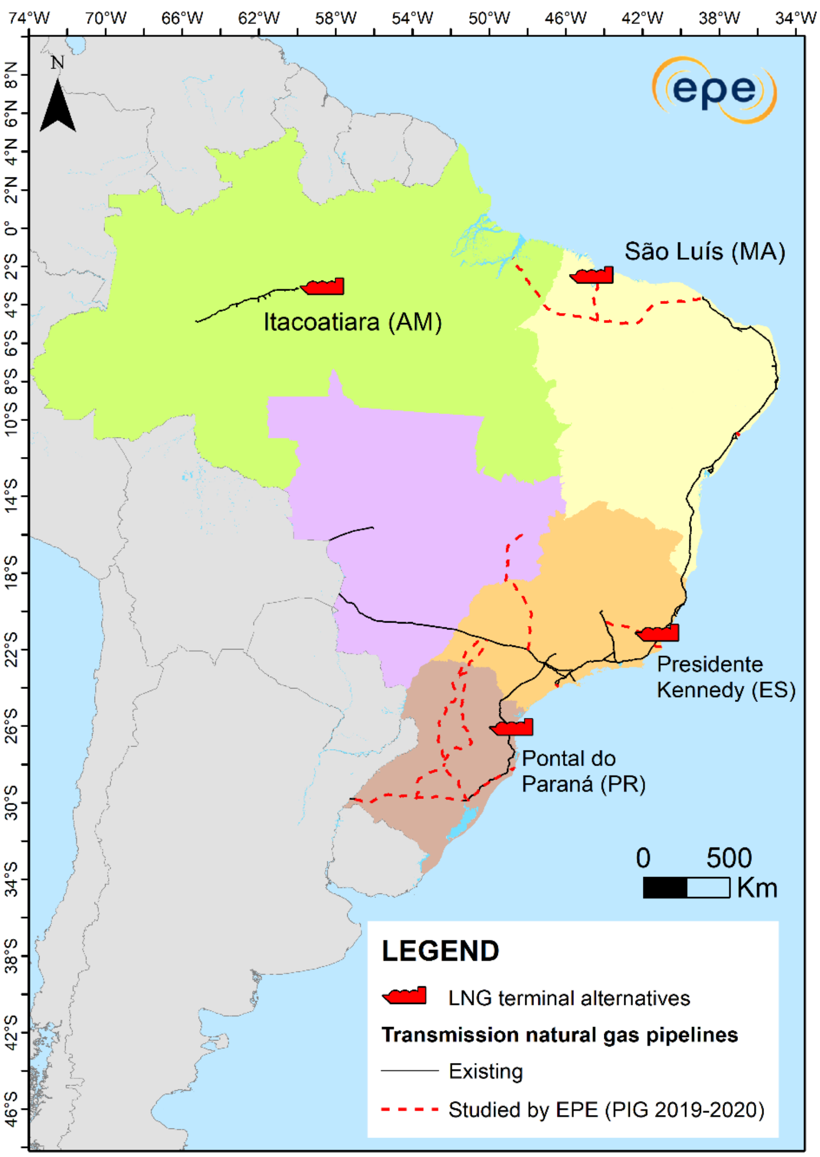

Figure 5. Location map of the studied LNG terminal alternatives
Source: EPE.

4.1. North Region

The project selected in the North Region is located at Itacoatiara, in Amazonas State, on the banks of the Amazon River, 265 kilometers from Manaus via the AM-010 highway. This region is characterized by a more dispersed potential natural gas demand, in addition to having the potential to substitute fuel oil or diesel in small thermoelectric plants. This has helped to stimulate small-scale LNG distribution project initiatives. The possibility of building an LNG regasification terminal could serve as a small-scale LNG distribution center while stimulating the design of larger projects such as a thermoelectric plant in the vicinity of the terminal. There is also the possibility of developing an industrial hub in the region, motivated by a supply of gas in the municipality, or even the expansion of the distribution network of the local natural gas distribution company.

4.1.1. Project features

The project would be installed in the vicinity of the area used by the company Terminais Fluviais do Brasil (TFB), built by DISLUB Equador (Figure 6). In addition to being a terminal anchored to an existing pier, it would have a 500-meter pipeline installed over the pier, which would move the regasified gas to land to a transfer of custody point, where other projects could be connected.

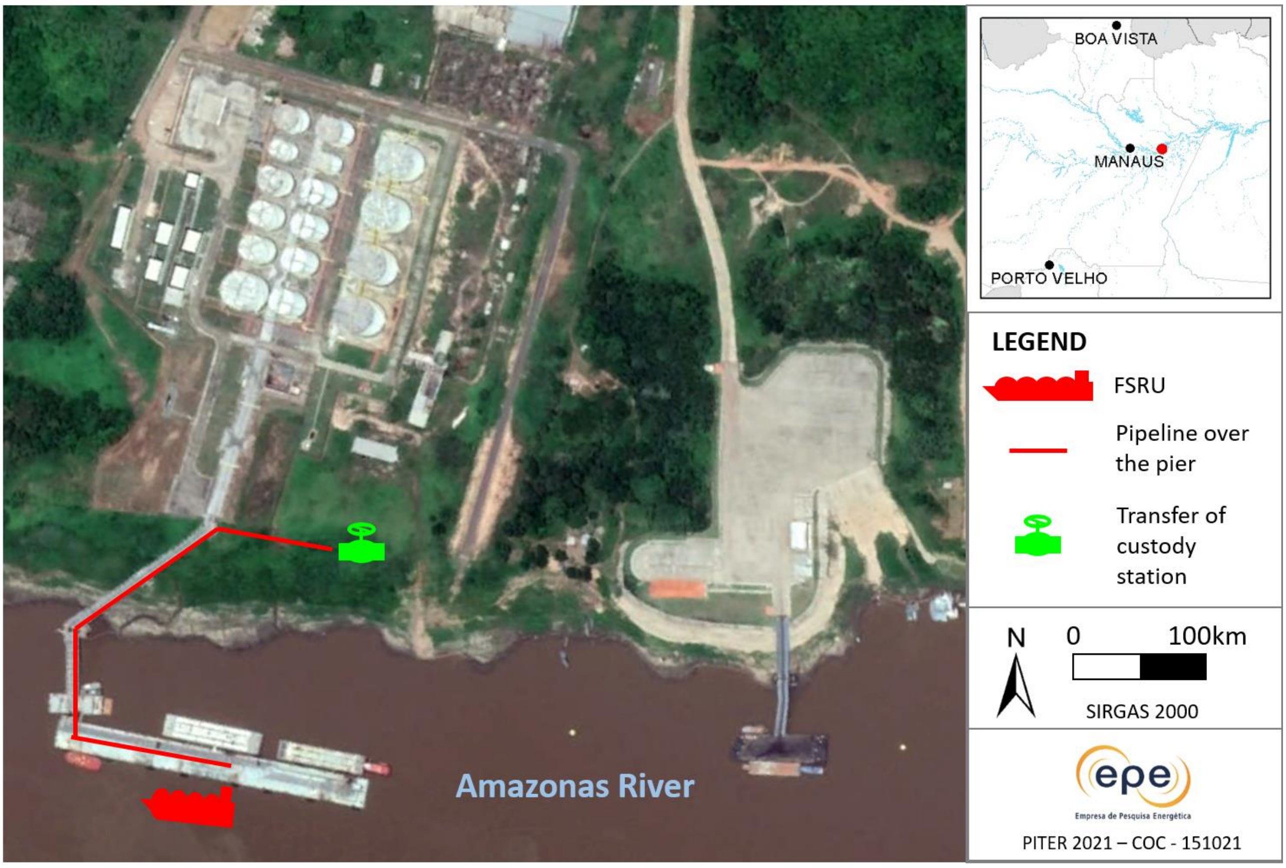

Figure 6. Representation of the LNG terminal project at Itacoatiara/AM
Source: EPE based on Google Earth Pro satellite image.

The choice of TFB to implement the Itacoatiara project regards the logistics infrastructure already installed for the movement of liquids by the company DISLUB Equador, so that the company's experience could benefit the terminal's operating costs. This terminal, inaugurated in March 2013, consists of a project with 107,000 m^2 and 18 tanks with a total capacity of 103,000 m^3 of fuels. The maximum draft is 20 m during the Amazon River flood period (TFB S.A., 2018). Additionally, the TFB has a storage area for packages which could allow, in the future, the installation of a storage tank for LNG. This LNG storage facility can develop the local natural gas industry through small-scale LNG distribution.

The location chosen for the installation of this project also considers the Itacoatiara’s public port nearby, with breakwater dykes approximately 350 meters away from those of the TFB. However, the Itacoatiara Port was not selected as the exact location for this project due to the aforementioned expertise of TFB in the handling and operation of fuels, in addition to the existence of infrastructure already built in the TFB Port and its availability of access to third parties.

It is noteworthy that if the entrepreneur chooses to settle in the Itacoatiara's public port, it is not expected that there will be significant variations in the project, given the proximity between the ports and the space needs to implement specific infrastructure for LNG. However, for this location to be used it would be necessary for the entrepreneur to negotiate with the TFB company. As a premise in this study it was considered that TFB, at first, might be interested in leasing an area of its port structure for the mooring of FSRU and passage of pipelines over the pier to the Transfer of Custody Station in an adjacent area to TFB.

4.1.2. Cost estimate

The costs for the terminal were estimated according to the methodology presented in Chapter 3, resulting in a total investment amount of around BRL 175 million. Table 1 presents the main cost items and their values.

Table 1. Cost estimate for the LNG terminal at Itacoatiara/AM

Description	
Direct Costs	**BRL million**
General Services	24.4
Civil Structure (pier)	34.5
Pipeline implementation on pier	42.5
Transfer of custody station	9.9
Total	**111.3**
Indirect Costs	**BRL million**
BDI – Budget Difference Income	30.6
Contingencies	33.4
Total	**64.0**
TOTAL INVESTMENT (base date Dec/2020)	**175.3**

Note: estimates based on the analysis of conceptual designs, with -20% to -50% and +30% of +100% accuracy.
Source: EPE.

Regarding the distribution of direct costs, it can be seen in Figure 7 that the item referring to the implementation of the gas pipeline over the pier is presented as the most significant, corresponding to 38% of the project's direct costs. Then, with a share similar to the previous one, the costs related to the civil structure of the pier stand out, with a percentage of 31% of the direct costs for this terminal. Figure 7 presents the presents the direct costs' percentage distribution.

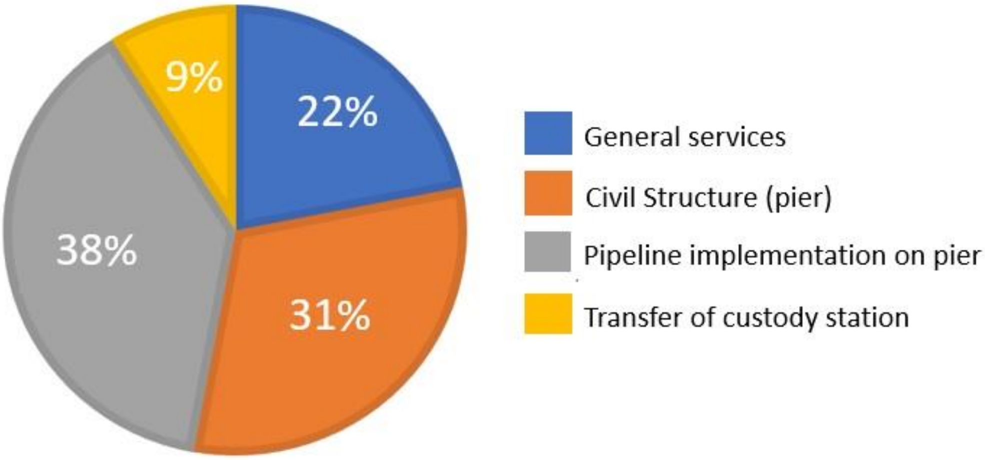

Figure 7. Direct costs' percentage distribution for the LNG terminal at Itacoatiara/AM
Source: EPE.

4.2. Northeast Region

The selected project is located at São Luís, in Maranhão State, in the São Marcos Bay, 11 kilometers away from the center of the capital. The Northeast Region is currently served by three LNG terminals, totaling a regasification capacity of 48 million m³/day (EPE, 2020c). In addition, there are three terminals in different stages of development, being one at Suape/PE and two at São Luís/MA, of which the first project is more advanced (EPE, 2020a). Specifically, about Maranhão, there is still a potential demand for natural gas to be explored that could justify the presence of a new terminal in this location. In addition to having some large thermoelectric projects in São Luís, natural gas could be used in Vale's pelletizing plant. There are other potential segments with facilities throughout the state that present gas demand that could be met by local natural gas distribution companies using this new gas supply in the region, relating to both thermoelectric and non-thermoelectric demand.

4.2.1. Project features

The proposed terminal would be built in the area of the Itaqui Organized Port, managed by EMAP[12] in the planned berth 94 that will be designed to moor a FSRU vessel. The terminal's construction is already planned and was included in the 2019 Plan of Zoning and Development[13] (EMAP, 2019). Figure 8 illustrates the design of the proposed LNG terminal.

Currently, the main port's operations are the export of soy and corn and the import of diesel and gasoline (EMAP, 2021). The port has 2,156 meters of mooring strip divided into eight operational berths and three exclusive berths for bulk liquid. The maximum draft varies from 11.5 to 18.5 meters depending on the cradle. Among the companies operating in the port are: Vale (copper); Suzano (cellulose) and Moinhos Cruzeiro do Sul (wheat bran). In addition, there is a tank area operated by several companies (EMAP, 2019).

[12] In Portuguese, *Empresa Maranhense de Administração Portuária*.

[13] In Portuguese, *Plano de Desenvolvimento e Zoneamento (PDZ).*

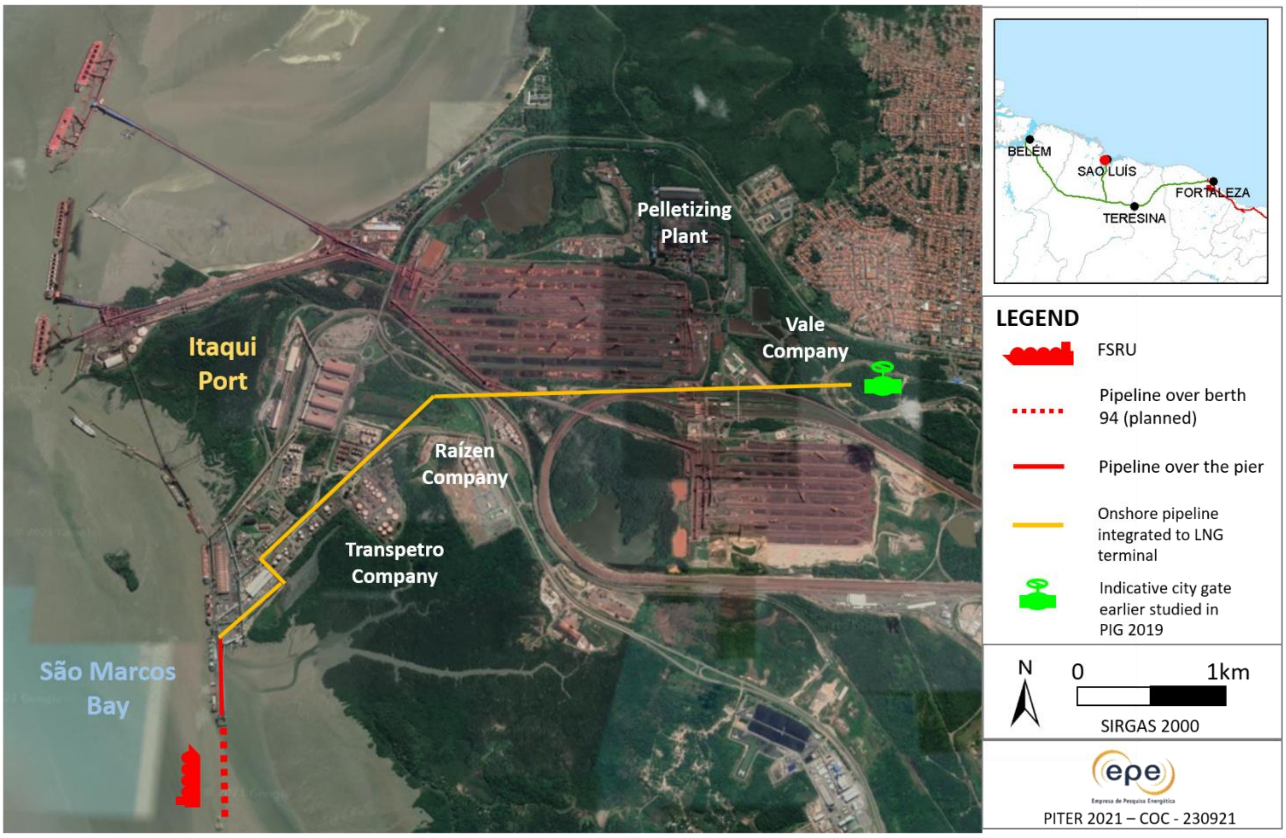

Figure 8. Representation of the LNG terminal project at São Luís/MA
Source: EPE based on Google Earth Pro satellite image.

For the LNG terminal analyzed, a new 1,900-meter pier connecting the FSRU to land was proposed. The natural gas would arrive on land through a pipeline that is part of the terminal, 6,400 meters long and 20 inches in diameter. The gas pipeline would have 1,900 meters over the pier and 4,500 meters underground, mostly crossing the port's polygonal. The layout was defined in order to take advantage of parallelism with internal streets and roads in order to minimize construction costs and impacts related to the opening of ditches and special services.

The interconnection of the gas pipeline that is part of the terminal was assumed to occur by means of the Santo Antônio dos Lopes/MA - São Luís/MA indicative gas pipeline, described in PIG 2020 (EPE, 2020d). The gas pipeline, 282 kilometers long and 20 inches in diameter, once built and connected to the terminal, could guarantee supply to the thermoelectric park in Santo Antônio dos Lopes, if there is expansion or maintenance stoppage of the producing fields that supply these plants, in addition to allowing the fulfillment of demands along this pipeline. Furthermore, after the construction of the other gas pipelines that would make up the Maranhão system, and which were proposed in PIG 2020, it would become possible for the gas from the Itaqui/MA terminal to be also sent to the integrated pipeline network.

4.2.2 Cost estimate

The costs for the terminal were estimated according to the methodology presented in Chapter 3, disclosed in a total investment amount of around BRL 352 million. Table 2 presents the main cost items and their values.

Table 2. Cost estimate for the LNG terminal at at São Luís/MA

Description	
Direct Costs	**BRL million**
General Services	24.4
Civil Structure (pier)	42.6
Gas pipeline implementation on pier	32.3
Implementation of onshore gas pipeline	114.8
Transfer of custody station	9.6
Total	**223.7**
Indirect Costs	**BRL million**
BDI – Budget Difference Income	61.5
Contingencies	67.1
Total	**128.6**
TOTAL INVESTMENT (base date Dec/2020)	**352.3**

Note: estimates based on the analysis of conceptual designs, with -20% to -50% and +30% of +100% accuracy.
Source: EPE.

Regarding the distribution of direct costs, it can be observed in Figure 9 that the item referring to the implementation of the onshore gas pipeline is the most significant cost, corresponding to 51% of the project's direct costs. Regarding the item referring to the civil structure of the pier, which represents 19% of direct costs, the most significant costs are due to mooring strip and dolphins.

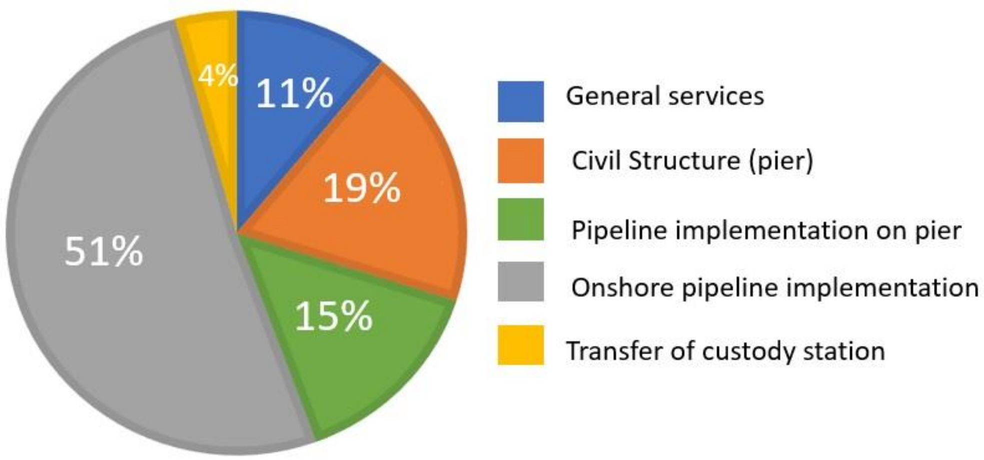

Figure 9. Direct costs percentage distribution for the LNG terminal at São Luís/MA
Source: EPE.

4.3. Southeast Region

The assessed project is located at Presidente Kennedy, in Espírito Santo State, in the extreme south of this state, 150 kilometers away from the capital Vitória. This state emerges as one of the central areas in the Brazilian natural gas market, connecting the Northeast and Southeast markets. The Southeast Region, in turn, is currently supplied by two LNG terminals, namely: the Guanabara Bayt/RJ terminal, with a regasification capacity of 30 million m³/day and connected to the integrated gas pipeline network and the Açu Port/RJ terminal, owned by Gás Natural Açu (GNA), which will supply gas to thermoelectric projects. In addition, several investors have turned their attention to the region, with at least six additional terminals being studied, at different stages of development (EPE, 2020a).

The region's demand profile should be highlighted: large volumes of gas due to the proximity to the consumption center and a seasonality in thermoelectric demand due to the high concentration of large thermoelectric plants in the region. There are at least two medium or large-scale thermoelectric projects at Presidente Kennedy, in addition to the construction of an industrial port area, with the forecast for implementation of facilities by large gas consumers. The region is a candidate to receive a new pre-salt gas flow route, as presented in PIPE 2019 (EPE, 2019a) and there are already plans to establish a natural gas hub in Espírito Santo (ENP, 2021).

4.3.1. Project features

The proposed terminal would be located in the area of Central Port/ES, a private multipurpose port, as can be seen in Figure 10. This port, although not yet built, already has an Installation License as per consultation with the environmental agency (IBAMA, 2021). This is a deep water port project up to 25 meters deep and with an approximate area of 2,000 hectares. The purpose of this port will be to serve large companies in the oil and gas, mining, agricultural and offshore industry support sectors, with a shipyard and a container terminal and various cargoes terminals also being planned (PORTO CENTRAL, 2021).

For the proposed terminal, a 2,200-meter pier would be developed connecting the FRSU to land. The natural gas would reach the connection point through a pipeline 5,600 meters long and 20 inches in diameter. The gas pipeline is made up of two segments, the first being an aerial pipeline with 2,200 meters above the pier and the second a buried gas pipeline with 3,400 meters.

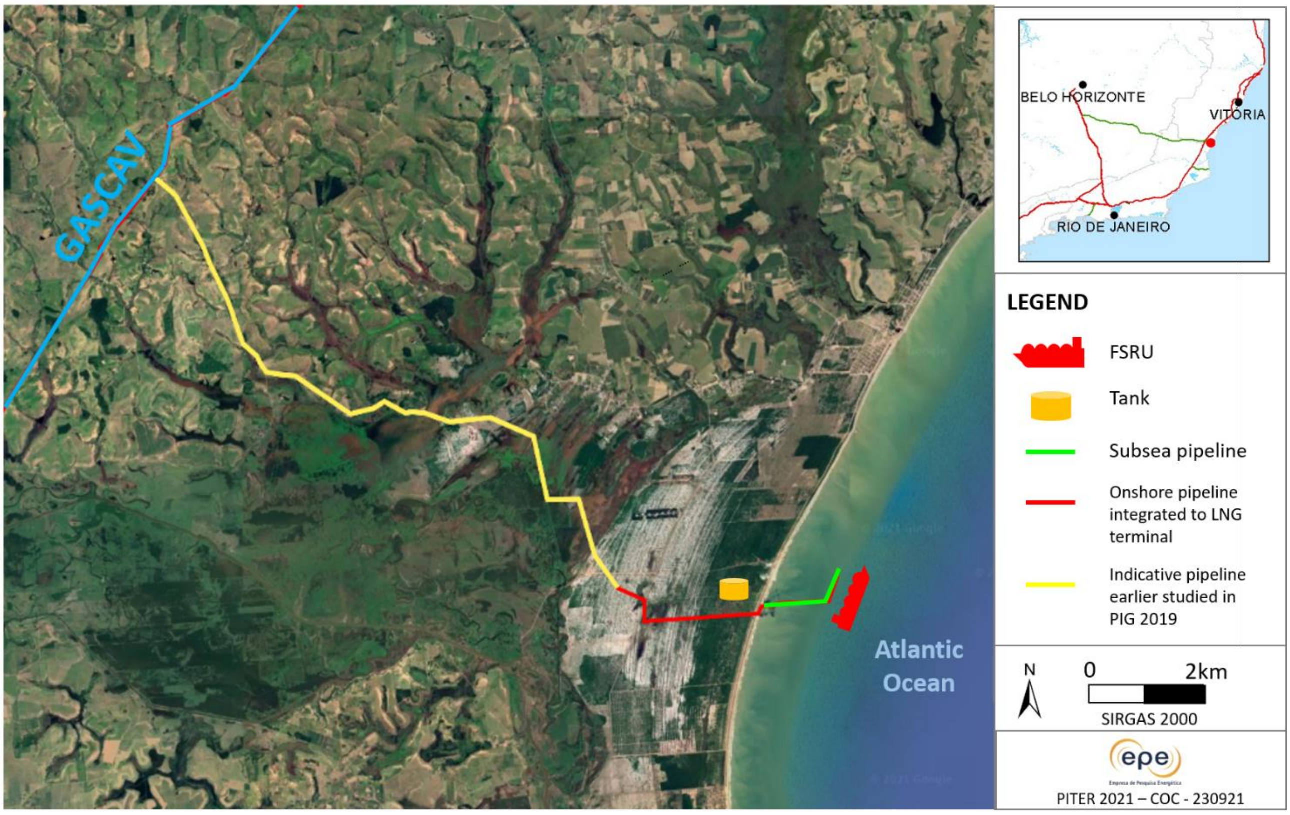

Figure 10. Representation of the LNG terminal project at Presidente Kennedy/ES
Source: EPE based on Google Earth Pro satellite image.

The interconnection of the terminal to an interconnection point in Central Port/ES - GASCAV/ES gas pipeline was assumed, which would require a 15-kilometer and 20-inch pipeline, studied in PIG 2019 (EPE, 2019b). Additionally, it is noteworthy that this pipeline would connect to the integrated network through the GASCAV pipeline, thus providing more opportunities for the flow of regasified gas through the terminal – comprising of North and/or South gas flows. In addition, in PIG 2020 (EPE, 2020d) another gas pipeline for the region was also indicated, the Presidente Kennedy/ES – São Brás do Suaçuí/MG gas pipeline, with 332-kilometer, 20-inch and 12 million m^3/day of capacity, interconnected to the Central Port/ES - GASCAV/ES gas pipeline, which would allow the shipment of this gas directly to Minas Gerais, serving various segments in the Minas Gerais market.

Given the high demand potential and the possibility of considerable variations in gas consumption due to thermoelectric plants in the region, an additional design hypothesis for this terminal was studied. The possibility of inserting an additional onshore tank was analyzed, building a tank on the coast with a capacity of 180,000 m^3 of LNG, equivalent to about 105 million m^3 of regasified gas, in an area already reserved in the Central Port project. Thus, in this indicative plan, both the costs of a terminal without tanks and one with this infrastructure were analyzed.

The use of a tank system was proposed in this case as it may be easily interconnected to the existing gas pipeline network. For comparison purposes, it is estimated that the volume of gas stored in the tank would be sufficient to meet the demands of the GASENE pipeline system for 11 days[14].

[14] Calculated from the average of volumes delivered in December 2020 at citygates as declared by the shipper (TAG, 2020).

With the New Gas Law (Law nº 14,134 of 2021) publication and the forecast of the multiplicity of agents in the entire Brazilian gas chain, flexibility has become a widely discussed topic.

As mentioned, it is worth remembering that, especially in the Southeast region, there are several other terminal projects, so that, although the proposed terminal in Presidente Kennedy/ES has been the object of study in this document, other terminals in the region could also provide the system with a new point of gas supply and a new flexibility instrument to the grid, in a similar fashion.

4.3.2. Cost estimate

Initially, the costs of the terminal without tanking were estimated according to the methodology presented in Chapter 3, resulting in a total investment amount of around BRL 291 million. Table 3 presents the main cost items in addition to their respective values.

Table 3. Cost estimate for the LNG terminal at Presidente Kennedy/ES without an onshore tank

Description	
Direct Costs	**BRL million**
General Services	24.4
Civil Structure (pier)	38.9
Gas pipeline implementation on pier	33.6
Implementation of onshore gas pipeline	78.2
Transfer of custody station	9.6
Total	**184.7**
Indirect Costs	**BRL million**
BDI – Budget Difference Income	50.8
Contingencies	55.4
Total	**106.2**
TOTAL INVESTMENT (base date Dec/2020)	**290.9**

Note: estimates based on the analysis of conceptual designs, with -20% to -50% and +30% of +100% accuracy.
Source: EPE.

Regarding the distribution of direct costs for the project without a storage tank, it can be observed, in Figure 11, that the item referring to the implementation of the onshore gas pipeline is the most significant cost, corresponding to 43% of the project's direct costs. Regarding the item referring to the civil structure of the pier, which represents 21% of direct costs, the most significant costs are due to mooring dolphins.

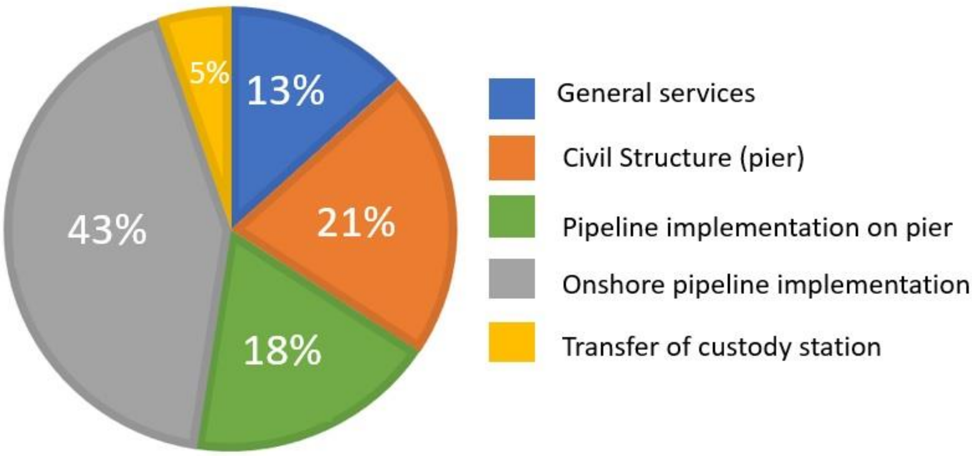

Figure 11. Direct costs' percentage distribution for the LNG terminal at Presidente Kennedy/ES without a tank.
Source: EPE.

Additionally, the tank's cost according to the methodology presented in Chapter 3 is equal to BRL 2.7 billion, an increase of BRL 2.4 billion in relation to the project without storage tanks. This increase is exclusively due to the direct and indirect costs related to the installation of the tank itself. Table 4 presents the main items and their values.

Table 4. Cost estimate for the LNG terminal at Presidente Kennedy/ES with an onshore tank

Description	
Direct Costs	**BRL million**
General Services	24.4
Civil Structure (pier)	38.9
Gas pipeline implementation on pier	33.5
Implementation of onshore gas pipeline	78.2
Transfer of custody station	9.6
Tanking	1,523.0
Total	**1,707.7**
Indirect Costs	**BRL million**
BDI – Budget Difference Income	469.3
Contingencies	512.3
Total	**981.6**
TOTAL INVESTMENT (base date Dec/2020)	**2,689.3**

Note: estimates based on the analysis of conceptual designs, with -20% to -50% and +30% of +100% accuracy.
Source: EPE.

Regarding the distribution of direct costs in Figure 12, the storage tank represents 89% of all direct costs. Consisting of cryogenic tanks and gas pipelines, in addition to other infrastructure, the configuration of the tank for onshore LNG storage has high costs both in terms of material costs and the value of construction and assembly, around BRL 1.5 billion. Due to these high costs, it is difficult to find agents willing to make these investments, however this decision can be taken if it is part of an entrepreneur's strategy, if there may be customers willing to pay the cost differential for the supply's security or if it is possible to earn additional revenue from the possibility of storing LNG in periods of low global price.

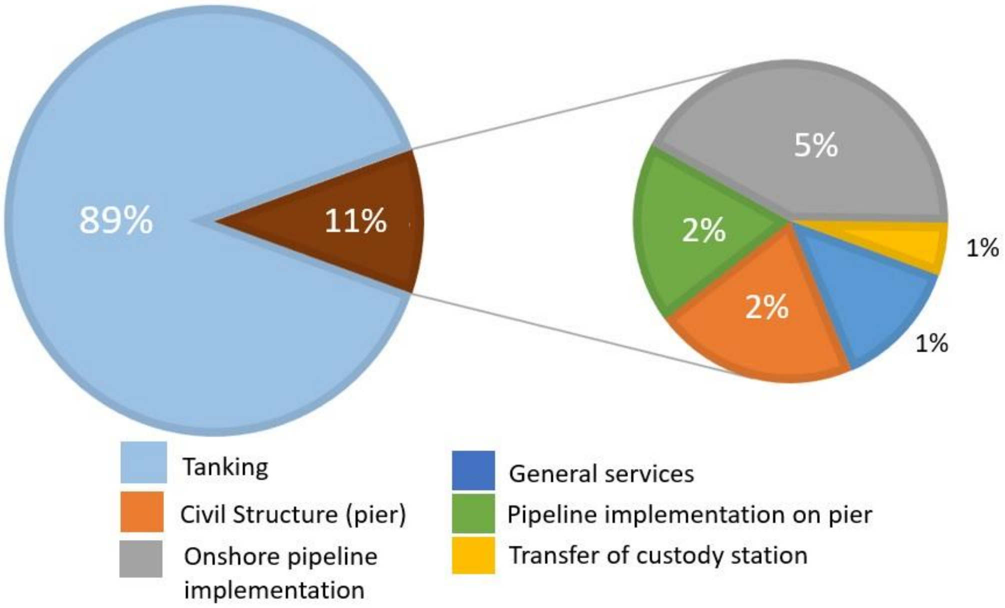

Figure 12. Direct costs' percentage distribution for the LNG terminal at Presidente Kennedy/ES with tank
Source: EPE.

Although it brings benefits to the Brazilian gas system, the decision to use tanks may have higher costs and longer construction time. It is estimated that a terminal with the implementation of a tank needs 5 to 7 years (ERIA, 2018). In this process, the time for licensing stands out, which can last up to 2 years, while the labor for the construction of a cryogenic tank is scarce and highly specialized, possibly having to be contracted internationally (NEW FORTRESS ENERGY, 2021).

4.4. South Region

The project is located at Pontal do Paraná, in Paraná State, at the entrance of the Paranaguá Bay, 120 kilometers away from the capital Curitiba. The Southern Region still does not have a natural gas offer different from that coming through GASBOL pipeline. The difficulty in increasing the amount of gas sent to the region, given the infrastructure limitations in this pipeline and highlighted in the latest EPE's Ten-Year Plans, result in repressed demand in the Brazilian Southern Region. A new infrastructure that brings an additional option to supply gas is seen as essential to continue the market development.

In this sense, the proposed terminal adds to the existing projects to serve this area. The demand to be met by this LNG terminal is mostly non-thermoelectric, however the completion of such infrastructure may motivate new thermoelectric projects in its surroundings. It is noteworthy the existence of some thermoelectric projects in the coastal region of Paraná, as well as a project with final investment decision at Santa Catarina.

4.4.1. Project features

The proposed terminal would be located offshore, using an island-type configuration, to be built about 2 kilometers from the coast, close to the Pontal do Sul district and Techint's engineering complex, as can be seen in Figure 13. At first, it was considered that the Pontal do Paraná/PR Terminal would be dedicated to a demand located on the coast, in land adjacent to the terminal. In the present study, this demand, although it may be related to a large industrial free consumer, was considered to be more likely to belong to a large thermoelectric plant, which could justify and enable the construction of the LNG terminal.

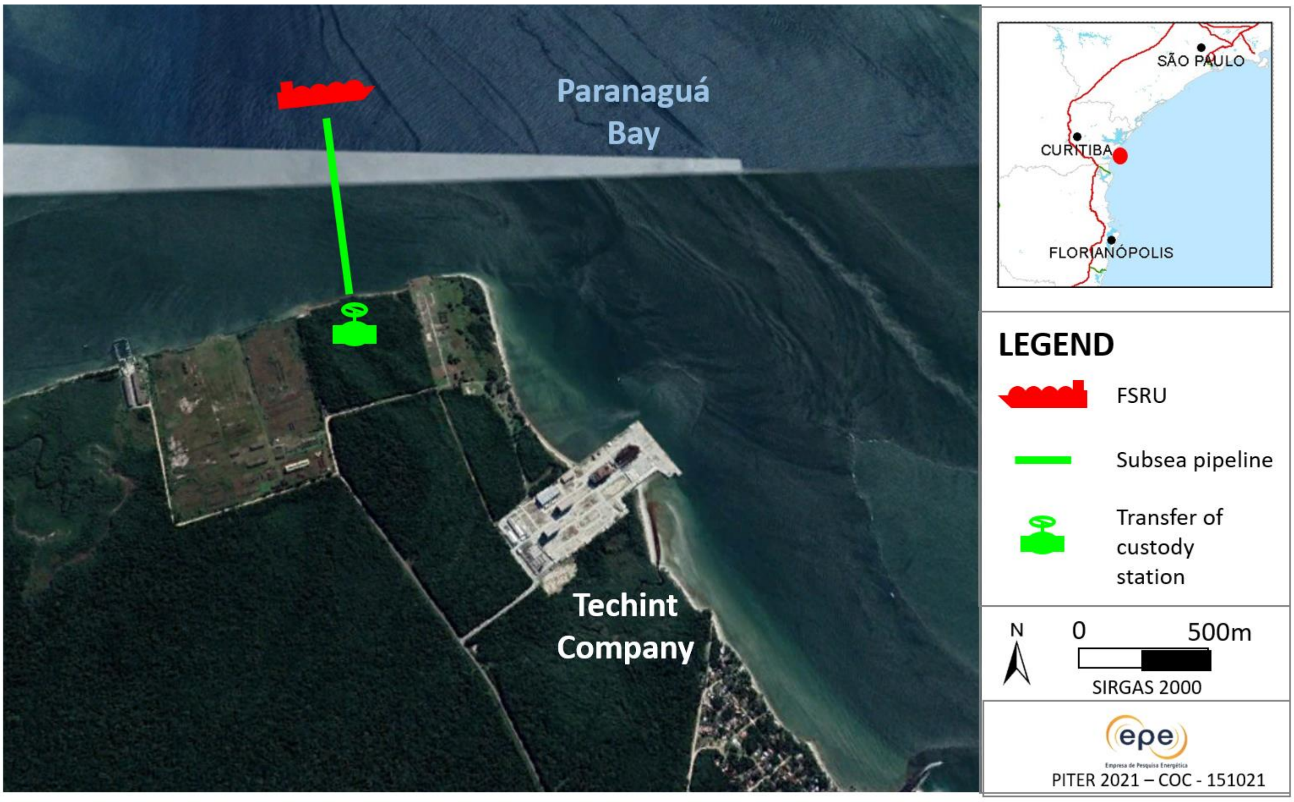

Figure 13. Representation of the LNG terminal project at Pontal do Paraná/PR
Source: EPE based on Google Earth Pro satellite image.

This proposal was designed to take into account ongoing projects that use this island-type configuration: South Gas Terminal[15], in São Francisco do Sul/SC, and the Regasification Terminal of São Paulo[16], in Santos/SP. Although these projects do not have their feasibility linked to thermoelectric demand, since both seek to connect directly to the gas pipeline network, their terminals would have the same constructive format as the one proposed in PITER for the South Region.

For this proposed terminal, a standard piled offshore pier would be developed 2,000 meters offshore. The LNG, once regasified, would reach land through a subsea pipeline, which, when

[15] In Portuguese, *Terminal Gás Sul (TGS).*

[16] In Portuguese, *Terminal de Regaseificação de São Paulo (TRSP).*

outcropping on the coast, would already end up in a Transfer of Custody Station, where it could be connected to a new project. In this project, as well as in the examples of similar ones mentioned above, the premise was to build the undersea section of the gas pipeline through a directional hole in order to reduce the environmental impacts in the region that is already more environmentally sensitive, as well as to protect the pipeline, since that its route ends up crossing waterways that connect Paranaguá to Ilha do Mel.

In the future, the terminal could be connected to the integrated network of gas pipelines in the metropolitan region of Curitiba, through connection to GASBOL. The pipeline for connection between the LNG terminal and GASBOL, for which there is already a third-party project under study, would be approximately 130 kilometers long and would go up Serra do Mar, sharing the right of way with the OLAPA pipeline, which already exists in the region (EPE, 2019b).

4.4.2. Cost estimate

The costs for the terminal were estimated according to the methodology presented in Chapter 3, resulting in a total investment amount of around BRL 275 million. Table 5 presents the main cost items of this project, in addition to their respective values.

Table 5. Cost estimate for the LNG terminal at Pontal do Paraná/PR

Description	
Direct Costs	**BRL million**
General Services	30.2
Civil Structure (pier)	35.1
Implementation of subsea pipeline	99.3
Transfer of custody station	9.9
Total	**174.6**
Indirect Costs	**BRL million**
BDI – Budget Difference Income	48.0
Contingencies	52.4
Total	**100.4**
TOTAL INVESTMENT (base date Dec/2020)	**275.0**

Note: estimates based on the analysis of conceptual designs, with -20% to -50% and +30% of +100% accuracy.
Source: EPE.

Regarding the distribution of direct costs in Figure 14, the implementation of the subsea gas pipeline is the most significant cost, corresponding to 57% of the project's direct costs. Piping-related costs frequently represent the majority of expenses for the implementation of offshore terminals that use the configuration used in this indicative plan (standard piling). Furthermore, in this project, it was decided to use horizontal directional drilling (HDD) due to characteristics of the terrain, increasing even more the costs related to the pipeline construction. Regarding the item referring to the civil structure of the pier, which represents 20% of direct costs, the most significant amounts are due to the mooring strip and dolphins staked on the seabed.

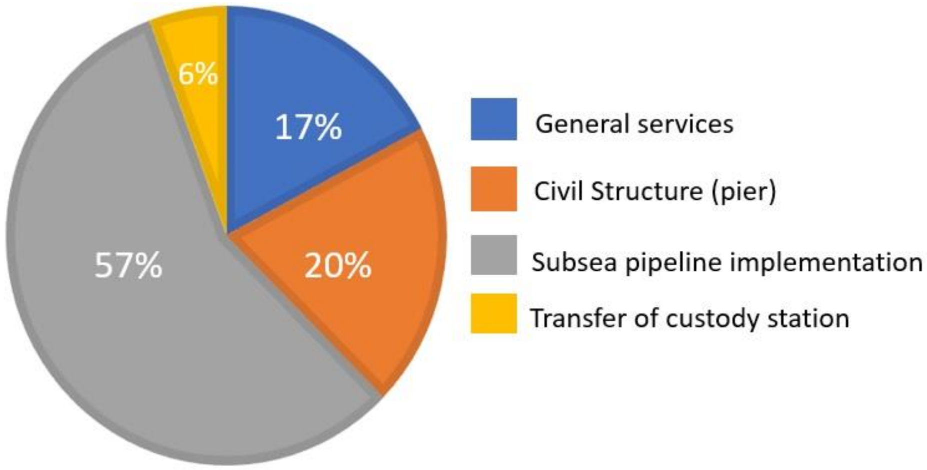

Figure 14. Direct costs' percentage distribution for the LNG terminal at Pontal do Paraná/PR
Source: EPE.

5. Results and discussion

The next table presents a summary of the main technical features and cost estimates for the four LNG terminals projects.

Table 6. Summary of studied alternatives for new LNG terminal projects

LNG Terminal	Regasification capacity (million m^3/day)	Pipeline associated (km)	Direct costs (BRL million)	Indirect costs (BRL million)	Total costs (BRL million)
Itacoatiara/AM	14	0.5	111.3	64.0	175.3
São Luís/MA	14	6.4	223.7	128.6	352.3
Presidente Kennedy/ES (without tank)	14	7.8	184.7	106.2	290.9
Presidente Kennedy/ES (with tank)	14	7.8	1,707.7	981.6	2,689.3
Pontal do Paraná/PR	14	2.0	174.6	100.4	275.0
Total*	**56**	**16.7**	**694.3**	**399.2**	**1,093.5**

* For the Total costs column, the Presidente Kennedy's costs with tanks were not considered since the terminal with tanks is only a case study for this alternative.

Note: estimates based on conceptual designs analysis with accuracy varying from -20% to -50% and +30% to +100%.

Source: EPE.

According to the previous table, there is a significant variation in costs depending on the characteristics of the terminals and other constraints related to the installation site. The biggest impact on the terminals budget is justified by the costs related to tankage. According to the calculated values, the CAPEX of a terminal with an onshore tank can reach almost 10 times its value without a tank depending on the characteristics of both the terminal (not including the FSRU, which would be paid as a charter contract) and the tank system.

Another important factor is the size of the pipeline associated with each terminal project. As one of the most significant direct costs in the design of a terminal, the size of the pipeline and its construction complexity are the main factors that generate the variation in total costs between projects. Last but not least, the configuration chosen for berthing (single or double berth, berthing buoy) and the location of the pier (whether on an existing pier or island-shaped pier) also significantly influence costs [17].

From the point of view of each project, the Itacoatiara/AM terminal has the lowest cost among those analyzed, which is mainly justified by the fact that it is located on an existing pier and has only 500 meters of pipeline included. This terminal is strategically located, close to the border between the states of Amazonas and Pará, and could be an alternative to increase the use of natural gas to replace other more expensive and polluting fuels such as fuel oil and diesel.

[17] When taking into account the premises of this study, that is, disregarding the costs of FSRU and special services as dredging and breakwater dyke or navigation channels' opening.

In the case of replacing existing demand, however, the feasibility of the strategy will depend on the relative prices of natural gas compared to other fuels so that the project is evaluated as feasible during its entire useful life. Despite this, as the volumes are still small, spread throughout the region, at first this project would probably be linked to a medium or large thermoelectric demand to ensure its economic viability and thus to reach FID for its construction. There are already projects of this type in the region that, once successful in the next energy auctions, could be sufficient for guaranteeing the feasibility and construction of this terminal.

The São Luís/MA project, on the other hand, among the options without onshore storage, is the terminal with the highest cost among the options analyzed. Part of this is due to a larger stretch of its integral pipeline being onshore and underground, crossing a well-built port region, requiring the need for HDD. The project for an LNG terminal in São Luís is being studied by more than one company. This terminal would be part of the thermoelectric power plant project in the capital and could also play an important role in making natural gas available to industry in Maranhão State. Its geographic position favors the import of LNG from important players in the international market, such as the United States and Trinidad & Tobago, with the possibility of obtaining LNG at better prices, given the smaller portion of freight to this terminal.

The Presidente Kennedy/ES project, chosen to contemplate a similar terminal, although with onshore storage, would also be part of a strategic plan for natural gas in the Southeast Region. Since the region is already being considered for receiving a new pre-salt gas flow route and the construction of a natural gas processing plant, the implementation of this LNG terminal and its associated tank could transform this area into a gas hub in the future years - possibility also studied by other private agents (ENP, 2021). The Central Port, where all infrastructure would be located, still benefits from the proximity to the integrated natural gas network, the ease of road access, with the BR-101 and BR-262 highways and, in the future, with the EF-118 and EF-354 railways, which favors the possibility of internalization of natural gas, either through pipelines or through small-scale LNG.

Although the option of connecting the terminal to the grid could already make the project feasible, the existence of a large or medium-sized thermoelectric plant would help to further leverage the project. This is because, in this region, there are already other terminals or terminal projects that can also connect to the integrated network and come to fulfill the same function that the Presidente Kennedy/ES terminal would have in the network. The focus of this project is that Central Port gas hub has not yet started its works, even though it already has an installation license, resulting in a delay that could lead to the postponement of all projects that make up the hub.

Finally, there is the Pontal do Paraná/PR project, which has intermediate costs between the alternatives, which are similar to the costs of the Espírito Santo terminal. Aiming to replicate the model of some terminal projects to be implemented in Brazil, such as the CELSE terminal model in Sergipe, this project was defined as an offshore terminal and, at first, dedicated to a thermoelectric plant on the coast of Paraná. The project follows the line of some projects in the region and would have the possibility of connecting, in the future, to GASBOL, bringing one more gas supply point to the Southern Region to the network, as it is an extensive gas pipeline, with approximately 130 kilometers, which would considerably increase this terminal's costs.

This pipeline may be studied in a later edition of EPE's Indicative Transmission Gas Pipeline Plan (PIG). The Pontal do Paraná/PR terminal project also has the facility of being close to the navigation channel of the Paranaguá Port, in addition to having easy access to nearby highways and railways. Its feasibility would probably be associated with a large or medium-sized thermoelectric demand in its surroundings, as well as most of the projects described here, but if the connection to GASBOL is already considered from the first moment, the project could obtain FID independent of having or not an associated thermoelectric power plant.

It is worth emphasizing that all the projects listed in this work were studied indicatively, as potential alternatives for the expansion of LNG terminals in the country, and their future implementation will depend on the consideration of various factors by the agents interested in each project, such as: a signing of LNG supply contracts; the signing of natural gas demand contracts; the establishment of agreements for interconnection with existing gas pipelines; carrying out a public call for capacity allocation; the detailing of socio-environmental and engineering studies; among others.

In general, while half of the studied alternatives aim to bring gas to a region not yet served by the integrated network of gas pipelines, the other half can bring new natural gas supply points to the Natural Gas Transport System in Brazil, benefiting connected actors to the network throughout the country, which could have different options for buying and selling natural gas. Within a more open, dynamic and competitive market, as provided for with the Brazilian New Gas Market Program and with entry and exit transmission tariffs, it is expected that these new supply points can reduce the costs for all shippers in its area of influence, therefore reducing the price of natural gas for end customers in these states, as they will increase the gas flow through the grid, optimizing its use.

6. Case Study – Regasification Rates Estimates

In this chapter, a case study will be discussed with the objective of calculating the regasification rates for the terminal sized in the Southeast Region, in its two configurations (with and without storage tank). Based on CAPEX information calculated from the methodology presented in Chapter 3 and the Operational Expenditure (OPEX) assumptions used in this case study, a tariff study was carried out for an LNG regasification service with varying levels of terminal usage, using the discounted cash flow methodology. The study was carried out considering two cases developed from President Kennedy's LNG terminal:

- **Case 1:** terminal with 21 million m³/day of capacity on which three levels of regasification use/contracting were evaluated (7, 14 and 21 million m³/day).
- **Case 2:** terminal with 21 million m³/day with an onshore tank (180,000 m³) on which three levels regasification use/contracting were evaluated (7, 14 and 21 million m³/day).

In both cases, regasification tariffs were calculated using an internal rate of return[18] (IRR) of 10% and the assumption that the terminal would be built with 100% own capital. It was also considered that the Weighted Average Cost of Capital[19] (WACC) would be fixed and equal to 10% per year, while the Income Tax[20] and Social Contribution on Net Income[21] would be, respectively, 25% and 9%. The results obtained do not include Tax on Circulation of Goods and Services[22], Social Integration Programs[23]/Contribution for Social Security Financing[24] and Tax on Services[25].

In case 1 CAPEX totals BRL 290.9 million as can be seen in detail in Table 3. OPEX considered a fixed value of USD 120,000/day, as a premise, responsible for encompassing the charter of FRSU, hiring the crew, regasification costs and other costs necessary to operate the terminal, which would last for 30 years with 1 year of construction and commissioning and 29 years of operation.

In case 2 the owner or even another interested agent would implement a strategy to build an additional LNG tank system with a capacity of 180,000 m³ at the Presidente Kennedy/ES terminal. In this way, an offshore terminal consisting of an FRSU and an onshore tank would be implemented. CAPEX totaled BRL 2.7 billion as presented in Table 4. OPEX considered two categories: one relating to the FRSU and the gas handling activities, in the amount of USD 120,000/day, according to the assumption also adopted in case 1, and the other relating exclusively to the value of the tank, corresponding to 4% per year of the CAPEX. Finally, it was adopted that the lifetime of the system would be 30 years with 3 years of construction and commissioning and 27 years of operation.

[18] In Portuguese, *Taxa Interna de Retorno (TIR).*

[19] In Portuguese, *Custo Médio Ponderado de Capital*.

[20] In Portuguese, *Imposto de Renda (IR).*

[21] In Portuguese, *Contribuição Social sobre o Lucro Líquido (CSLL).*

[22] In Portuguese, *Imposto sobre Circulação de Mercadorias e Serviços (ICMS).*

[23] In Portuguese, *Programa de Integração Social (PIS).*

[24] In Portuguese, *Contribuição para o Financiamento da Seguridade Social (COFINS).*

[25] In Portuguese, *Imposto Sobre Serviços (ISS).*

Figure 15 shows the regasification rates calculated for both cases and the three levels of regasification use/contracting.

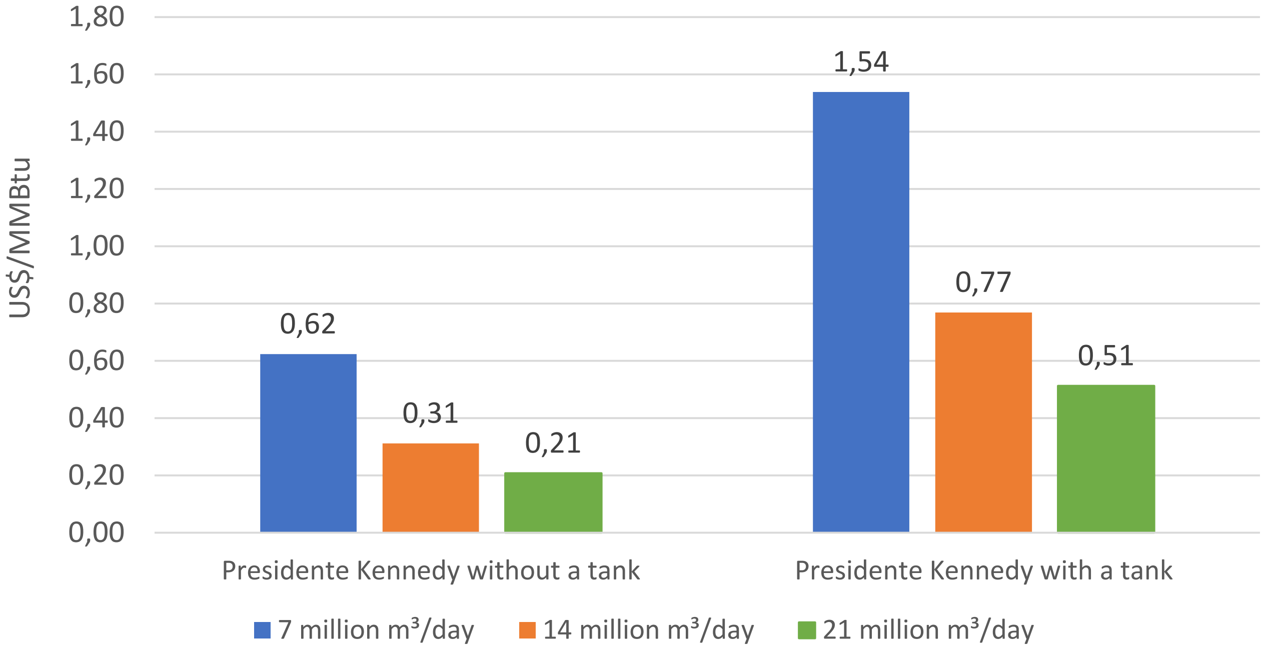

Figure 15. Regasification fees for Presidente Kennedy without and with a tank.
Source: EPE.

It can be observed that the regasification tariff values vary between USD 0.21/MMBtu for the terminal with a regasification usage of 21 million m³/day and USD 1.54/MMBtu for the combination of FSRU plus onshore tank with regasification usage of 7 million m³/day. Analyzing within the same case, it is possible to see that a greater use of the regasification capacity results in a lower tariff value, that is, there is an economic optimization when the terminal is operated at maximum capacity throughout its useful life. Thus, in order to maximize the use of the terminals seeking to reduce the regasification tariff, different strategies can be adopted, such as sharing the infrastructure by more than one agent or adding other additional demands to the original terminal project.

It is noteworthy that, when comparing the results of both cases at the same level of usage, an increase in the regasification tariff costs of around 150% can be seen when the storage tank was considered. Thus, the adoption of this configuration by a given entrepreneur should be assessed regarding the strategy to be adopted, the entrepreneur's business model, the possibility of arbitrage of LNG acquisition prices, the need to guarantee supply to consumers, among other possibilities that may promote the payment of the price differential between situations with or without tanking.

It should be noted that the presented analysis has some limitations, especially regarding CAPEX and OPEX estimates using historical database projects and not considering services such as dredging and rock removal, which can bring considerable variations to total investment. The monetization strategies for regasification projects may also be different from those mentioned here, as well as the WACC adopted in the feasibility analyses, which is influenced by the entrepreneur's risk analysis and its financing strategy.

7. Updates on ongoing LNG projects in Brazil

This chapter presents the latest updates on LNG terminal projects under development in Brazil. Figure 16 shows the locations of projects divided into 3 categories: existing LNG regasification terminals (Pecém/CE, Barra dos Coqueiros/SE, Todos os Santos Bay/BA, Açu Port/RJ and Guanabara Bay/RJ); planned terminals (Barcarena/PA, Suape/PE, Santos/SP and São Francisco do Sul/SC) and the projects studied by EPE in previous publications and studied by other companies. These last category of projects need more technical studies, such as an outlook for NG demand before taking the investment decision.

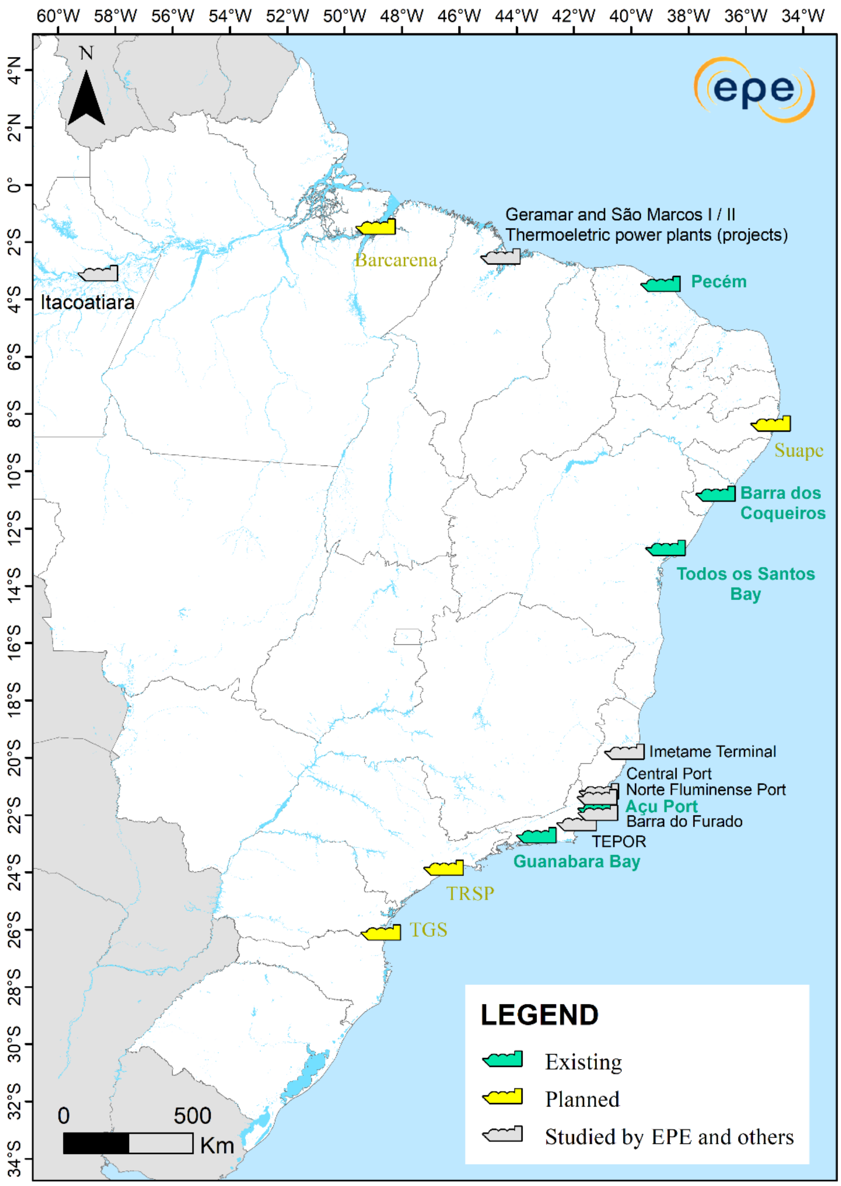

Figure 16. Location map of LNG regasification projects in Brazil
Source: EPE.

Table 7 presents the status of LNG regasification terminal projects listed from North to South Regions which was not under commissioning and/or operating until this document's publication.

Table 7. Summary of Brazilian LNG regasification terminal projects

Project	State	Capacity (million m^3/day)	Initial studies	Environmental Licensing	Final Investiment Decision*	Under Construction
CELBA Terminal	PA	15				
Uirapuru Amazonica Energy	AM/ PA	-				
Geramar III thermoeletric power plant (associated terminal)	MA	N.A.				
São Marcos I/II Thermoeletric power plants (associated terminal)	MA	21				
Suape	PE	21				
Central Port	ES	20				
Imetame Port	ES	N.A.				
Norte Fluminense Terminal	RJ	21				
TEPOR	RJ	21				
TRSP	SP	14				
TGS	SC	15				

Notes: N.A. - not available; terminals already built (commissioning or in operation) were not cited.
Source: EPE.

Compared to a similar table that was published in the previous EPE's Technical Note LNG Terminals in Brazil - Overview of Main Projects, Cycle 2019-2020 (EPE, 2020a), the column of terminal projects "in operation" was omitted, since they have reached the maximum level of development. Thus, Table 7 shows only projects that still need some degree of technical development. It was decided not to describe the progress of projects for which no recent publications were found in the specialized media or for which EPE was not officially informed about significant changes in the meetings held with companies.

Regarding the LNG terminal project in Barcarena/PA, on December 28, 2020, the National Agency of Petroleum, Natural Gas and Biofuels[26] published the authorization number 933 for the FSRU mooring and mooring facilities' construction with a regasification capacity of up to 15 million m^3/day and an operating platform with 2 flexible 16-inch diameter risers and 20-inch pipeline. This pipeline will connect the port facilities to the Transfer of Custody Station in the area of the 650 MW Novo Tempo Barcarena Power Plant (DOU, 2020). This unit is expected to operate at 2025 in order to respect the A-6 energy auction contract and can already operate at 2022 for other demands.

Regarding the LNG terminal in São Luís/MA, in March 2021, the Brazilian Antitrust Authority[27] approved the acquisition by New Fortress Energy (formerly Golar) of the 50% share belonging to its partner ENEVA in Centrais Elétricas São Marcos. Thus, the company controlled by Hygo Energy Transition now holds 100% of the plants (PETRÓLEO HOJE, 2021). The São Marcos Thermoelectric Complex foresees the installation of a FSRU with a regasification capacity of up to 21 million m^3/day

[26] In Portuguese, *Agência Nacional do Petróleo, Gás e Biocombustíveis (ANP).*

[27] In Portuguese, *Conselho Administrativo de Defesa Econômica (CADE).*

and is still in the initial licensing phase (Brazilian Federal Environmental Agency[28] process number 02001.018300/2018-06). There is the possibility of interiorization of LNG by cabotage, coming from a LNG regasification terminal to be installed in Suape/PE.

About the project in Suape/PE, CH4 Energia and New Fortress Energy are in charge of it, which is in the licensing phase. With operation scheduled for the end of 2022, it will be an LNG terminal integrated with a 1.4 GW power plant, which will supply 288 MW power purchase agreement (PPA). The estimated investment would be BRL 3 billion including the LNG terminal's installation, an 8-km pipeline and a thermoeletric power plant. In December 2020, the state government and CH4 Energia signed the Memorandum of Intent to make the project viable. The energy purchase and sale agreement signed with Petrobras foresees the operation of two thermal plants of 144 MW each, supplied by an FSRU vessel with a regasification capacity equal to 21 million m³/day. The LNG surplus may serve the Copergás network (EPBR, 2021b; PORTOS E NAVIOS, 2021) and/or be distributed by trucks and other vessels.

The Central Port project has a ship-to-ship configuration and is located in Presidente Kennedy/ES. It has a capacity of 20 million m³/day and seeks to meet thermoelectric projects, in addition to considering a possible connection to the transport gas pipeline network in the Cabiúnas-Vitória gas pipeline (PORTO CENTRAL, 2021). According to the entrepreneurs, the basic engineering project for the LNG terminal was contracted and the results of the electricity auctions to be held in 2021 are awaited. At the same time, EnP Oil Group and Central Port signed, in November 2020, the Memorandum of Understanding for the entry into operation by 2026 of RefinES (Espirito Santo Refinery), which will have the capacity to process up to 50,000 barrels/day. The estimated investment would be USD 640 million for the production of gasoline, diesel oil, LPG and marine diesel (PORTOS E NAVIOS, 2020). In March 2018, the Brazilian Federal Environmental Agency issued an installation license number 1203/2018 concerning the port (IBAMA, 2021).

The Norte Fluminense Port project is part of a port complex that will have a gas hub and power generation park, to be installed in the municipality of São Francisco do Itabapoana/RJ. The project as a whole includes a LNG regasification terminal with a capacity of 21 million m³/day or a terminal for receiving compressed natural gas, a natural gas processing plant and tank system (PORTO NORTE FLUMINENSE, 2021a). The estimated consumption of the thermoelectric power plants PNF I and PNF II would be 6 million m³/day each in order to supply 3.4 GW. There is also the possibility of connection with GASCAV pipeline. According to the entrepreneurs, the project may participate in new electricity auctions to be held in 2021 and, if successful, the terminal is expected to start operating by 2027 (PORTO NORTE FLUMINENSE, 2021b).

TEPOR project will have the ship-to-ship configuration and an FSRU vessel with a regasification capacity of up to 21 million m³/day which will be connected to the NTS[29] and TAG[30] pipeline networks. It is also expected the construction of a natural gas processing plant with up to 60 million m³/day capacity. This project is associated with the Macaé Logistics & Industrial Complex[31] which already has the Marlim Azul thermoelectric complex, in addition to other possible consumers. In November 2019, INEA-RJ issued a preliminary license number IN050584/2019. According to the entrepreneurs, the

[28] In Portuguese, *Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA).*

[29] In Portuguese, *Nova Transportadora do Sudeste.*

[30] In Portuguese, *Transportadora Associada de Gás.*

[31] In Portuguese, *Complexo Logístico & Industrial de Macaé (CLIMA).*

project is in the engineering detailing phase, after which the installation environmental license will be requested and the expected start-up is by the end of 2024 (TEPOR, 2021).

The project to be installed near the Port of Santos/SP will have a regasification capacity of 14 million m³/day and features a ship-to-ship configuration with offshore mooring. This project includes the LNG terminal, a gas pipeline to interconnect the distribution grid and a delivery point in Cubatão/SP with start-up scheduled for the end of 2021. However, in May 2021, the environmental licenses were suspended by the Environmental Company of São Paulo[32] to Compass Gás e Energia, of the Cosan group (MPSP, 2021). In June 2021, Minister Humberto Martins decided to allow construction to continue (ABEGÁS, 2021).

The TGS project, in turn, is located in Babitonga Bay, in the municipality of São Francisco do Sul/SC, and provides for the construction of a ship-to-ship terminal with a regasification capacity of 15 million of m³ / day with possibility of connection to GASBOL. About BRL 380 million may be invested and it is expected to start operating in early 2022. In May 2021, the Santa Catarina Environmental Institute[33] issued installation license number 2870/2021 (IMA SC, 2021).

[32] In Portuguese, *Companhia Ambiental do Estado de São Paulo (CETESB).*

[33] In Portuguese, *Instituto de Meio Ambiente de Santa Catarina (IMA SC).*

8. Final remarks

PITER 2021 studied four LNG regasification terminals projects totaling a regasification capacity of 56 million m³/day, which together represent investments of around BRL 1.1 billion[34]. In this document's cycle, terminals with the sole purpose of carrying out cabotage or liquefaction terminals have not yet been studied, but these may be subjects covered in the next editions.

However, before any investment decision, it is necessary to check the existence of natural gas demand. The quantification of potential natural gas demand for PITER 2021 indicates that large thermoelectric projects are frequently responsible for the largest portion of the identified demand. For the viability of these projects, it is necessary that there is a demand for electric energy and that they are victorious in the next electric energy auctions according to Brazilian models. Apart from thermoelectric demand, taking advantage of regional vocations must be combined with greater competitiveness of natural gas and long-term supply security, especially in relation to other fuels that could be displaced by natural gas.

It was observed that the use of the terminal in its entirety of its regasification capacity could reduce the price of the terminal's regasification tariffs. In the case study, which estimated the regasification rate to be charged according to the flow of use of the terminal, significant discounts were verified in this rate as a regasification module of 7 million m³/day was added in operation in the analysis of the project cash flow. This result shows that terminal projects that seek to add other demands to that project's anchor consumer tend to have the most competitive regasified gas, given that the costs of obtaining LNG were the same for all agents.

In this sense, the New Gas Market Program may encourage the feasibility of these projects, as it will promote competitiveness and diversity of agents, especially with regard to the new supply points. The establishment of an integrated Natural Gas Transport System will also promote new investments as the benefits can be shared by users of the integrated pipeline network allowing natural gas delivery to consumers near or far from the area of influence of each alternative.

It should be noted that the implementation of each project will depend on the detailing of various socio-environmental and engineering aspects, as well as confirmations about the demand, and agreements for interconnection with other projects, pipelines and/or consumers. Only after such details are completely defined by the interested companies, will it be possible to confirm how many and which of the projects studied are economically viable, and what will be the real increase in the Brazilian natural gas supply.

Finally, it should be noted that, together with the LNG regasification terminals, the use of small-scale LNG distribution from these terminals may help supply regions not yet connected to existing pipeline network. For this type of service, each of the terminal alternatives has a greater or lesser relative competitiveness among themselves, depending not only on the distance to the end customers, but also on the volumes to be transported. Also, new LNG projects may contribute to create demand points especially for long distances. Future studies may consider the complementary role of modals over time and even the feasibility of long pipelines after the creation of smaller-scale demand and its evolution towards higher volumes.

[34] The Presidente Kennedy's LNG terminal costs were considered only in the alternative with a tank.

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