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Review History

Rev.	Date	Description
0	12/16/2021	Original Publication in Portuguese
1	12/21/2021	Update on the Coastal Sea Associated Gas project (Camamu-Almada Basin)
2	03/08/2023	Publication in English

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1. Introduction

EPE presents the second edition of the Indicative Natural Gas Processing and Outflow Plan (PIPE), which is part of the set of indicative plans that the Oil, Gas and Biofuels Studies Division (DPG) periodically publishes, together with the Indicative Transmission Gas Pipeline Plan (PIG) and the Indicative LNG Terminals Plan (PITER). These studies result on integrated energy planning for the Brazilian natural gas sector (EPE, 2019a; 2019b; 2020a; 2021a). PIPE follows the New Gas Market Program´s objectives (Novo Mercado de Gás in Portuguese), which supported the New Gas Law´s elaboration (Law Number 14,134 of April 8th, 2021) and its regulatory decree (Decree Number 10,712, of June 2nd, 2021), aiming at the formation of an open, dynamic, and competitive natural gas market, contributing to the Brazilian economic development.

By presenting natural gas outflow pipeline´s alternatives both in onshore and offshore environments in an indicative manner, PIPE seeks to encourage investments, also collaborating with the guidelines of the Program for the Revitalization of Onshore Oil and Gas Exploration and Production Activities (REATE in Portuguese) and the Program for the Revitalization and Incentive to the Production of offshore fields (Promar), both from the Federal Government.

One of REATE's objectives is to revitalize E&P activities onshore. In this sense, PIPE presents: two alternatives for the onshore outflow of possible accumulations in the Solimões Basin, and an alternative in the Parnaíba Basin.

In the offshore environment, the Promar program aims to make better use of domestic oil resources, increase the payment of government participations, create jobs and expand the goods and services industry focused on oil and natural gas E&P in offshore areas. In this sense, PIPE presents twelve offshore projects: three in the Campos Basin, two in the Santos Basin, three in the Espírito Santo Basin, two in the Camamu-Almada Basin and two in the Sergipe-Alagoas Basin.

PIPE's main objective is to present the projects of outflow gas pipelines and natural gas processing plants (NGPP in English or UPGN in Portuguese) at a conceptual level, whose technical-economic and Socioenvironmental analyzes must be detailed and compared with other alternatives for monetization by market players to assess the FID (Final Investment Decision). If the market is interested in these alternatives, the projects can increase the supply of gas and, therefore, bring greater flexibility and security of supply.

Among the other objectives of PIPE, the following stand out:

• the decrease in the asymmetry of information evidenced on potential areas of net production, processing capacity, socioenvironmental conditions and preliminary proposals for pipeline tracings, contributing to the identification of opportunities for new gas pipelines and hubs that have not been identified in previous studies;

• dissemination of the evaluation criteria used to elaborate this study;

• coordination of expectations and interests among players in the Brazilian natural gas industry, promoting investments in outflow pipelines and natural gas processing plants.

When analyzing the supply prospects according to the 2030 Ten Year Energy Expansion Plan (PDE 2030), prepared by EPE, it is noted that the share of natural gas production sustained only by resources in the reserve category reaches the highest volumes in 2028, when a production peak close to 183 million m^3/day is reached. In the decade, the largest contributions are associated with the Santos, Campos, Solimões and Parnaíba Basins. The largest proportion of natural gas produced in the decade is associated gas, with 85% of the total 2030 forecast in the Campos and Santos Basins. In the case of non-associated natural gas, the predominant influence of the production units in the Barreirinhas, Campos, Parnaíba, Santos, Sergipe-Alagoas and Solimões Basins remains. The same document says net natural gas production is expected to increase from 2025 onwards with the entry of new projects, with emphasis on the Sergipe-Alagoas and Solimões Basins and the start of production of the surplus from the Onerous Assignment Regime (EPE, 2020b).

In addition, given the success of the second Cycle of the Permanent Offer by the end of 2020, with the offering of 17 exploratory blocks in addition to an area of marginal accumulation, there is a need to expand the natural gas outflow infrastructure to meet such projects and support the prospects of increased domestic production. Considering the forecasts for an increase in the supply of natural gas, published in PDE 2031, the possibilities of new projects contemplating expansions in the natural gas outflow infrastructure are also pictured.

In this sense, it is worth mentioning that there are different ways of monetizing natural gas, and the decision on which one should be used will depend on several factors, among which the following stand out: oil, natural gas and LNG prices; supply and demand conditions and necessary investments in infrastructure for the outflowing, processing and movement of natural gas (EPE, 2020c; 2020d).

From demand perspective, the recovery of the world and Brazilian economy stands out with the reduction of the Covid-19 pandemic. During this period, a significant increase in global demand for energy is noticeable, which has caused a shortage of oil and natural gas supply in the world. It is expected that the relationship between supply and demand for these fuels will remain unaligned for some time, being reflected in current prices and in the price projections of these commodities for the coming years. This reinforces the need to expand the gas outflow infrastructure so that a greater supply of energy is available in the domestic market.

In terms of the document structure, it initially presents the methodology used for the selection of typical projects, their assumptions, CAPEX (Capital Expenditure) estimates and the conditions of the Socioenvironmental analysis. The project alternatives are analyzed in the following order: onshore, offshore pre-salt[1], offshore post-salt and offshore hubs. Subsequently, the results are presented and discussed focusing on the conditions that may influence its viability, as well as on the prospects for implementing each project. Finally, the document presents the progress of project alternatives for PIPE 2019 or similar projects in Brazil.

[1] The geological pre-salt, classification considered in this document, is a sequence of sedimentary rocks formed more than 100 million years ago, from the separation of the current American and African continents. The salt layer, which currently can be up to 2 km thick, settled on the accumulated organic matter, retaining it for millions of years, until thermochemical processes transformed the organic layer into oil and natural gas (PETROBRAS, 2021a).

2. Methodology

This section will present the simplified analysis methodologies used to estimate the selected projects, considering the following steps: selection of typical projects, definition of assumptions, CAPEX estimates and Socioenvironmental analysis. Figure 1 summarizes the methodology.

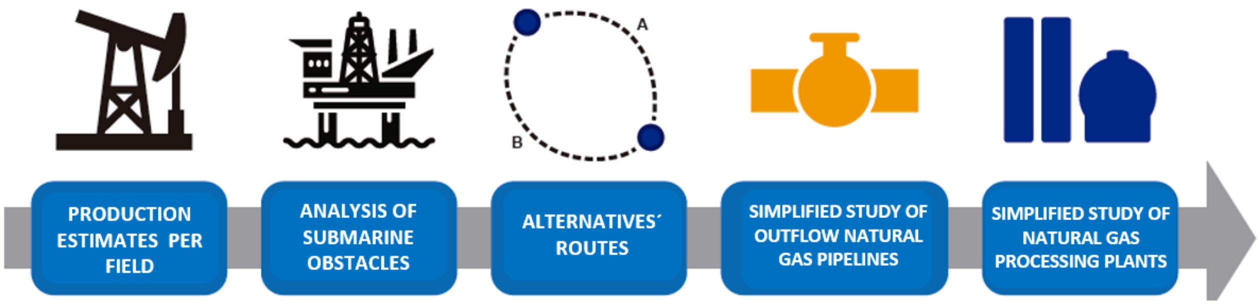

Figure 1. Alternatives´ analysis methodology
Source: EPE.

The general project characterization addresses the following items: the definition of the origin, destination, length, and capacity of the outflow gas pipeline; the estimation of the potential production defining the capacity of the analyzed projects, and finally the analysis of the natural gas outflow and processing infrastructure.

The analysis of the technical-economic feasibility presents the technical and budgetary project assumptions, as well as the project CAPEX estimate. Finally, the Socioenvironmental analysis provides the criteria used to define the tracing in addition to indicating areas with Socioenvironmental restrictions. The elements that must be observed in the subsequent process of environmental permission of each alternative by the project´s owners are also indicated.

2.1. Selection of Typical Projects

Typical projects were selected according to the following classification, depending on the environment and water depth: onshore, offshore coastal sea, offshore deep water, offshore ultra-deep water. These projects were chosen based on the type of natural gas: associated and non-associated. In offshore cases, projects were also selected based on the characteristics of the reservoir: post-salt or pre-salt (according to geological classification).

The projects to be simulated were built from E&P data from existing exploratory blocks and producing fields. For the analysis of pipeline alternatives, the modeling considered E&P characteristics like those of a typical project in the same sedimentary basin, with the same water depth classification in the case of offshore projects, which already had the natural gas outflow infrastructure. All the chosen projects for analysis are in domestic territory and are not served yet by other pipelines.

Figure 2 presents the production fields and exploratory blocks under concession in addition to the blocks in permanent offer regime, whose information is available, free of charge, in the GeoAnp database (ANP, 2021a).

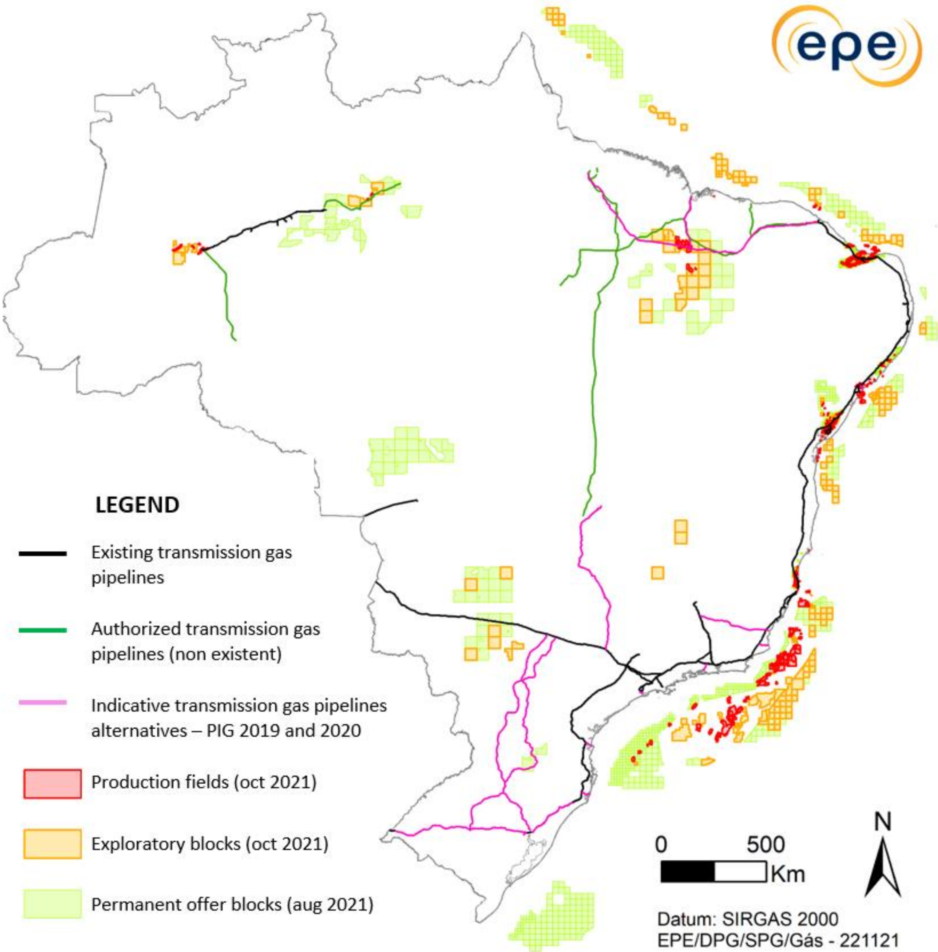

Figure 2. Map of production fields, exploratory blocks and transmission gas pipelines
Source: EPE based on ANP (2021a).

Based mainly on the exploratory blocks presented, in addition to projects in an onshore environment (with associated and non-associated gas), projects in an offshore environment in the post-salt (with associated and non-associated gas) in coastal seas (less than 500 m of water depth), deep water and ultra-deep water (more than 1,500 m water depth) were analyzed. Regarding the offshore environment in the geological pre-salt, projects were analyzed considering two distinct production development scenarios. The first scenario consisted of a system called stand-alone, which corresponds to a floating infrastructure dedicated to the project, independent of infrastructure related to other fields. The second scenario was based on a tie-back system, considering connection to an existing floating infrastructure in another producing field. In both scenarios, the treated natural gas streams would be moved to the coast through outflow pipelines.

Offshore natural gas hubs were also analyzed. They are formed by Floating Production, Storage and Offloading Units (FPSOs) with the capacity to receive natural gas streams from different producing fields, perform primary processing, compression and distribution of these treated streams by outflow gas pipeline to selected natural gas processing plants.

In total, 15 cases were analyzed, 3 in onshore environment and 12 in offshore environment, including 3 projects in offshore environment in pre-salt, 6 projects in offshore environment in post-salt and 3 offshore hubs.

2.2. Definition of Premises

After the selection of typical projects, E&P data were searched in exploratory blocks and Brazilian producing fields corresponding to these projects and then used to compose the relevant characteristics of each alternative.

Input data for project simulation was researched on specific platforms, plans, newsletters, and presentations, such as the Vantage platform, Oil or Natural Gas Discovery Assessment Plans (PAD in Portuguese)[2], Development Plans (PD in Portuguese), Executive Summaries, and publicly available information by the operating companies. Among those data, we can mention:

- volumes of recoverable reserves;
- reservoir characteristics (such as depth, pressure, temperature and dimensions);
- fluid characteristics and the respective ratios between produced fluids;
- amounts of wells;
- production curve;
- surface equipment design;
- among others.

In the case of offshore hubs, the typical assumptions for projects located in the sedimentary basin where each hub would be located were also considered. Much of this information was obtained through access to cost databases[3].

The choice of typical projects for the alternatives analyzed, considering the use of E&P data from existing exploratory blocks or producing fields in the simulations of new alternatives for outflow gas pipelines, considered the following similarity criteria:

- water depth;
- distance between the origin and destination of gas pipelines;
- natural gas flow to be drained by the project;
- pipe diameter and thickness (defined based on outflow and distance) and
- technology chosen for the NGPP (Turboexpansion was adopted as standard).

The analyzes considered a hypothetical case in which the exploratory block or the producing field selected as the origin of the outflow pipeline will produce associated or non-associated natural gas volumes like those indicated. For project detailing, if the type of natural gas, the outflow gas pipeline length, the volume produced, reservoir characteristics and/or the water depth are different from those indicated in this indicative plan, the values must be reassessed by the interested companies. It should be noted that the blocks chosen for each alternative may not necessarily produce associated or non-associated natural gas, and that the indicated volumes may be higher or lower than those that can potentially be produced in the future, given the inherent uncertainties of E&P activities.

[2] Document elaborated by the contractor, at any time during the exploration phase, which describes the discovery made and presents a work program with the activities, deadlines, and investments necessary for its evaluation (ANP, 2021b).

[3] The IHS Markit's Vantage platform was used in this study and it has a robust database on technical-economic attributes of onshore and offshore E&P projects´ assets updated and fed by sources recognized in the market.

2.3. CAPEX estimates

CAPEX estimates for each of the alternatives were calculated using a cost software [4]. Total costs were estimated for each project to compose a production development scenario considering all equipment, materials and services related to E&P activities. Subsequently, only the drainage system costs were considered including the following items:

- Materials and Equipment;
- Construction and Assembly;
- Engineering Project;
- Insurance and Certification
- Contingencies.

For the three offshore hubs, the complete natural gas movement system costs were considered, including, in addition to the highlighted items referring to the FPSO platform itself, its topside equipment related to the steps of redirection and compression of natural gas.

The costs of NGPPs were estimated considering the formula elaborated by EPE in its studies on the monetization of natural gas (EPE, 2020d), corrected for June 2021 using the CEPCI index. There was a 15.14% increase in the costs of facilities related to the chemical industry between 2019 and 2021 (EC, 2020; 2021); therefore, for the same capacity, the costs presented in this PIPE 2021 are about 15% higher than those considered in the Technical Note (EPE, 2020d).

Considering that equipment costs are generally estimated in dollar according to the oil and gas sector practices, CAPEX was estimated in dollar and later converted into real, considering the exchange rate of BRL 5.20 /USD in all cases.

However, it was not necessarily considered that the equipment, materials and services will be imported or will use foreign labor, so that domestic contracts and purchases can be carried out whenever exists capacity for service by the domestic industry and that the costs are equal to or less than the estimates presented. Therefore, although the cost estimates were constructed based on dollar values, in practice they could be domestic prices considering the international opportunity cost.

[4] The software Que$tor, from the company IHS Markit, was used, which allows the determination of CAPEX, OPEX and ABEX project costs from a regional cost base and technical information.

2.4. Routes and Socioenvironmental Analysis

The development of reference routes for the indicated gas pipelines is the result of the simultaneous application of the Ambientrans tool[5], together with the convergence analysis methodology developed by EPE, to enable feasible alternatives.

In the convergence analysis, preliminary outlines are drawn up by the analysts to envision the various options for interconnecting the gas pipeline, considering propositions based on criteria defined by the team . Insertion of notable points must guide the layouts to justify the main vertices related to the respective layout propositions, such as:

- diversions from mining areas and rugged relief;
- crossings (water bodies, wetlands)
- diversions from buildings and rural improvements;
- distancing from caves;
- and others.

Convergence analysis considers that two or more analysts must participate in the activity, preparing the routes individually (double-blind), without knowledge or interference from third parties. To use Ambientrans, the most relevant Socioenvironmental aspects of the study region must be previously selected and surface friction and weight values assigned. By the end of the process, the tool creates a corridor and a route guide. In both methodologies, public georeferenced data are used, coming from the Brazilian Institute of Geography and Statistics (IBGE) databases, the Geological Survey of Brazil (CPRM), the National Indian Foundation (FUNAI), the National Institute of Colonization and Agrarian Reform (INCRA) and the Ministry of Environment (MMA), among others. In addition, public satellite images available in Google's Google Earth® software were consulted.

Based on the set of preliminary outlines and the Ambientrans guidelines, these proposals are superimposed for analysis, comparisonand adjustments. Considering the maximum convergence of the routes, the reference line is defined.

It should be noted that, within the scope of PIPE, field work, geotechnical and geological investigations to characterize the material to be excavated, aerial surveys, bathymetric surveys, risk analysis studies and technical visits to the places crossed by the proposed layouts were not carried out, since the present work is a study at the indicative long-term planning level. Therefore, it is necessary to carry out the constructive and Socioenvironmental details of each alternative in later stages related to environmental permission.

Most alternative pipeline extensions did not consider topographic variations and ocean floor morphology. Therefore, we recommend that the interested player verify the actual lengths and diameters of each project based on the results of the detailed studies.

The proposals for the reference routes are based on the following set of premises:

- Take the shortest path (length in km);

[5] Tool developed by the Electric Energy Research Center – Cepel (Eletrobrás Group) in Python programming language and implemented in Toolbox format in ArcGIS for the elaboration of corridors or layouts for linear infrastructures.

• Seek proximity to roads and accesses, as it facilitates the construction and maintenance of pipelines, at the same time that vectors of urban expansion associated with roads must be observed and avoided (onshore alternatives);

• Divert or minimize crossings with linear infrastructures, such as roads, railways, transmission lines (LTs), pipes (onshore alternatives);

• Distance at least 1 km from LTs, when possible, due to electrical interference or electromagnetic influences (onshore alternatives);

• Avoid environments that may imply constructive complexity and additional costs, such as wet areas or areas subject to flooding, reservoirs or expressive water bodies, uneven relief and areas susceptible to landslides on slopes or accentuated erosion processes (onshore alternatives);

• Avoid interference in areas that require more time for environmental permission, specific studies, authorizations or blocks, such as conservation units, indigenous lands, quilombola territories (communities with African slaves' descendants), forest formations, and mining processes.

For cases in which the outflow gas pipelines originate and end in an offshore environment, socioenvironmental analyzes were not executed due to the need to carry out specific field research in the affected areas, in addition to the need for detailed oceanographic databases.

3. Onshore Project Analysis

In this Section, the three onshore projects analyzed will be described, two of them in the Solimões Basin (one of associated gas close to the existing NGPP, and one of non-associated gas distant from the current infrastructure), and one of them in the Parnaíba Basin (non-associated gas away from existing facilities).

3.1. Onshore Associated Gas (Solimões Basin)

The onshore associated gas project analysis considered existing projects in the Solimões Basin that are close to Block SOL-T-170 and Urucu/AM NGPP, which processes the natural gas collected from the surrounding fields and then sends thespecified gas for the Cigás distribution network, through the Urucu-Coari-Manaus transmission gas pipeline. Figure 3 presents the project schematically.

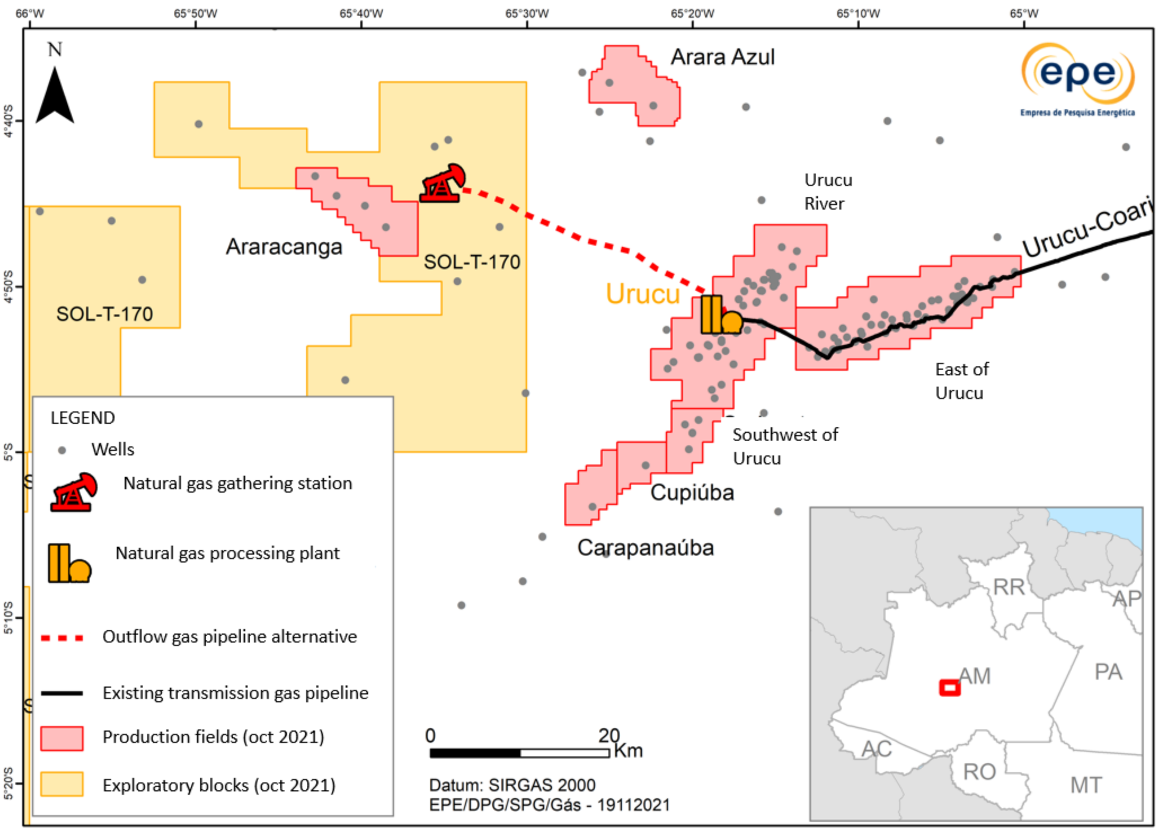

Figure 3. Onshore Associated Gas (Solimões Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 2.7 million m³/day. The considered distance between the gas gathering station and the point where the connection with the existing transmission gas pipeline network would occur was 34 km, resulting in an outflow gas pipeline with 34 km in length and 12 inches in diameter.

In the case of the NGPP, the additional capacity of 2.7 million m³/d could be established as a new processing plant close to the existing one in Urucu/AM, or as payment for third-party access to this facility, by signing an agreement under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021).

Cost estimation considered installation of a new NGPP, but the market players may choose the option of third-party access, if it has a cost equal to or less than this alternative, and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others). Table 1 shows a summary of the alternative's costs.

Table 1. Outflow gas pipeline CAPEX for Onshore Associated Gas (Solimões Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	32.7	44%
Construction and Assembly	23.1	31%
Indirect Costs		
Engineering Project	7.7	10%
Insurance and Certification	0.6	1%
Contingencies	9.6	13%
TOTAL INVESTMENT (reference date Jun/21)	**73.7**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.6 billion for the installation of a new processing unit close to the existing facilities in Urucu/AM.

Socioenvironmental Analysis - Solimões Basin

The reference route defined for the gas pipeline measures 34 km and crosses two municipalities in the center of Amazonas, starting from a hypothetical point in Block SOL-T-170, in Tefé, heading to the NGPP, at the Urucu Complex, in Coari.

The development of reference routes for the indicated gas pipelines is the result of the simultaneous application of the Ambientrans tool together with the convergence analysis methodology developed by EPE, to enable feasible alternatives. The guideline was established seeking the least interference on watercourses and flood surfaces.

The defined route crosses an extremely preserved Amazon Forest region, with no road access or other infrastructure. Therefore, the gas pipeline construction will represent a great logistical challenge, being necessary to use air and river transport for the arrival of equipment in the region. Due to the high degree of preservation in the region, it is recommended that the implementation of the enterprise be carried out avoiding the opening of accesses that could become deforestation fronts.

The database consulted includes relief of alluvial plains and plateaus with flat (0 to 3%) and smooth wavy (3 to 8%) slope rates, according to data from the CPRM (2004). From the topographic point of view, these units do not represent greater complexities for the gas pipeline implementation.

The tableland relief is associated with unconsolidated deposits (Q1i) of the Içá Formation, such as sand, gravel, clay, silt and peat. The alluvial plains represent alluvial deposits (Q2a), which correspond to materials of different particle size and composition, indicating the geotechnical complexity of the terrain. The route was designed trying to minimize crossings with water courses and their respective flooding surfaces. It is important to emphasize that the limits of the mentioned geological units probably have cartographic inaccuracies, since the base consulted was developed for the Brazilian territory, therefore, of a referential nature. Both units present strong indications of geotechnical complexity in relation to the composition of the materials, as well as the presence of soils saturated in water.

The suggested route crosses three watercourses, the Urucu River being the most relevant. The Amazon Biome context in which the study area is located, considering the crossing of watercourses and the mentioned geotechnical conditions, indicates additional costs for the construction phase along the entire length of gas pipeline.

The study area is close to a mining process in the availability phase (sand), not indicating the possibility of future interference.

The route crosses the Rio Urucu natural gas production field. Therefore, when defining the final gas pipeline tracing, it is necessary to pay attention to the production and outflow equipment from the natural gas fields existing in the region.

According to the database consulted, the reference route defined for the gas pipeline does not intersect with indigenous lands, conservation units, quilombola territories or Priority Areas for Conservation, Sustainable Use and Sharing of the Benefits of Biodiversity (APCBs).

It is noteworthy that within the exploratory block SOL-T-170, from which the reference route starts, there are sections of APCBs and the buffer zone (ZA) of the National Forest (FLONA) of Tefé, which should be avoided during the definition of the final route of gas pipeline.

In 2020, the Environmental Study of a Sedimentary Area in the Solimões Onshore Basin (PIATAM/COPPETEC and EPE, 2020) was published, which, among other results, classified the basin into suitable or unsuitable regions (that is, adequate or inadequate) for oil and natural gas exploration. The proposed route for the gas pipeline is fully inserted in an area classified as suitable, whose Socioenvironmental conditions and characteristics identified from the Studyare compatible with activities and ventures for the exploration and production of oil and natural gas, using the industry best practices.

The document provides recommendations for environmental permission, such as: i) prioritize technological alternatives that minimize the right of way width for the outflow pipes; and ii) establish a program to control erosion processes generated by the implementation of wells, outflow pipes and processing plants. Therefore, to build the gas pipeline, it is necessary to take these recommendations into account within the permission process scope.

Figure 4 Shows the Socioenvironmental characterization of this alternative.

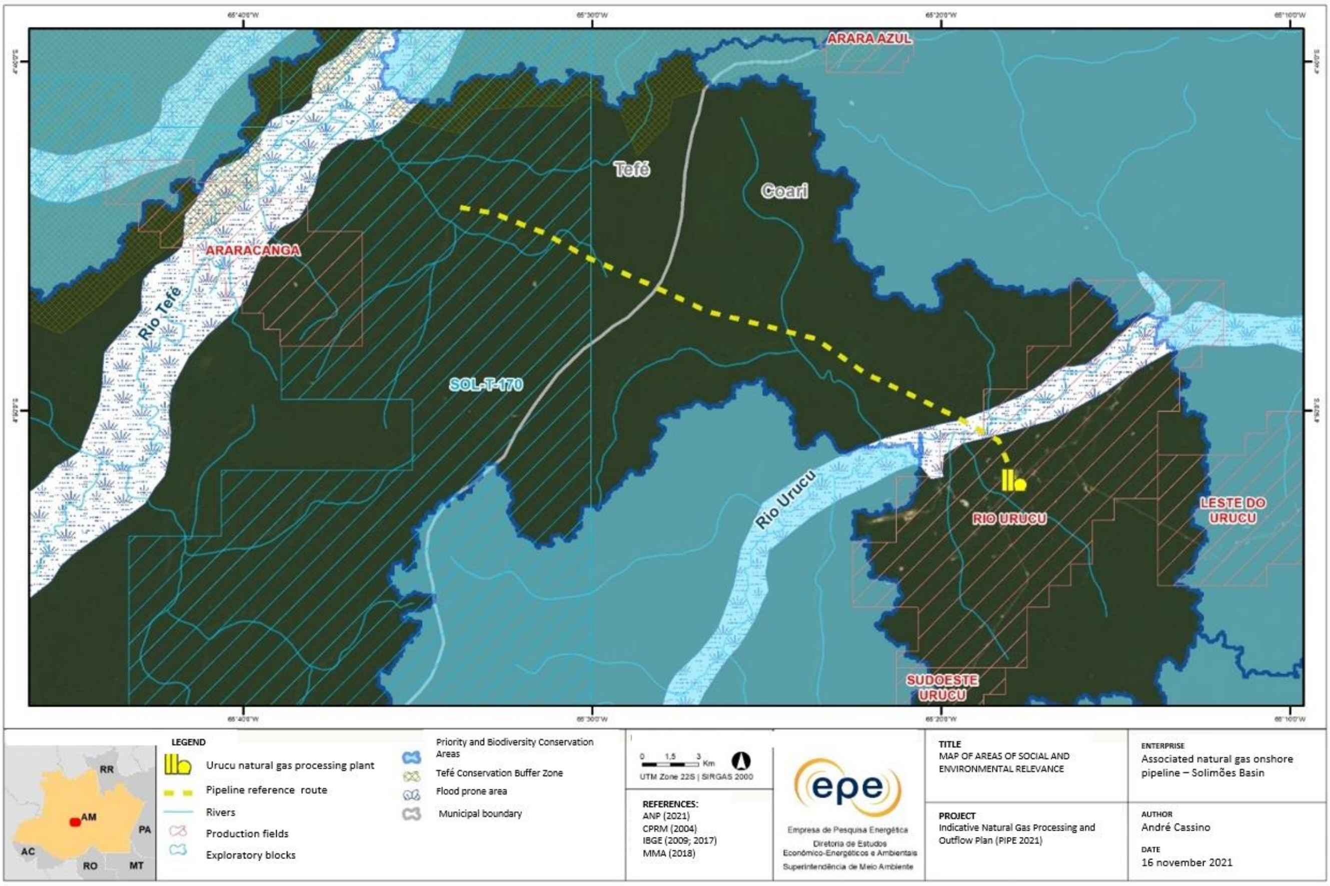

Figure 4. Socioenvironmental relevance areas in the region where the gas pipeline will be implemented in the Solimões Basin
Source: EPE.

3.2. Onshore Non-Associated Gas (Solimões Basin)

The second onshore non-associated gas project analysis considered existing projects in the Solimões Basin that are distant from the Urucu/AM NGPP, which have been the subject of several studies over the years. Figure 5 shows the project schematically.

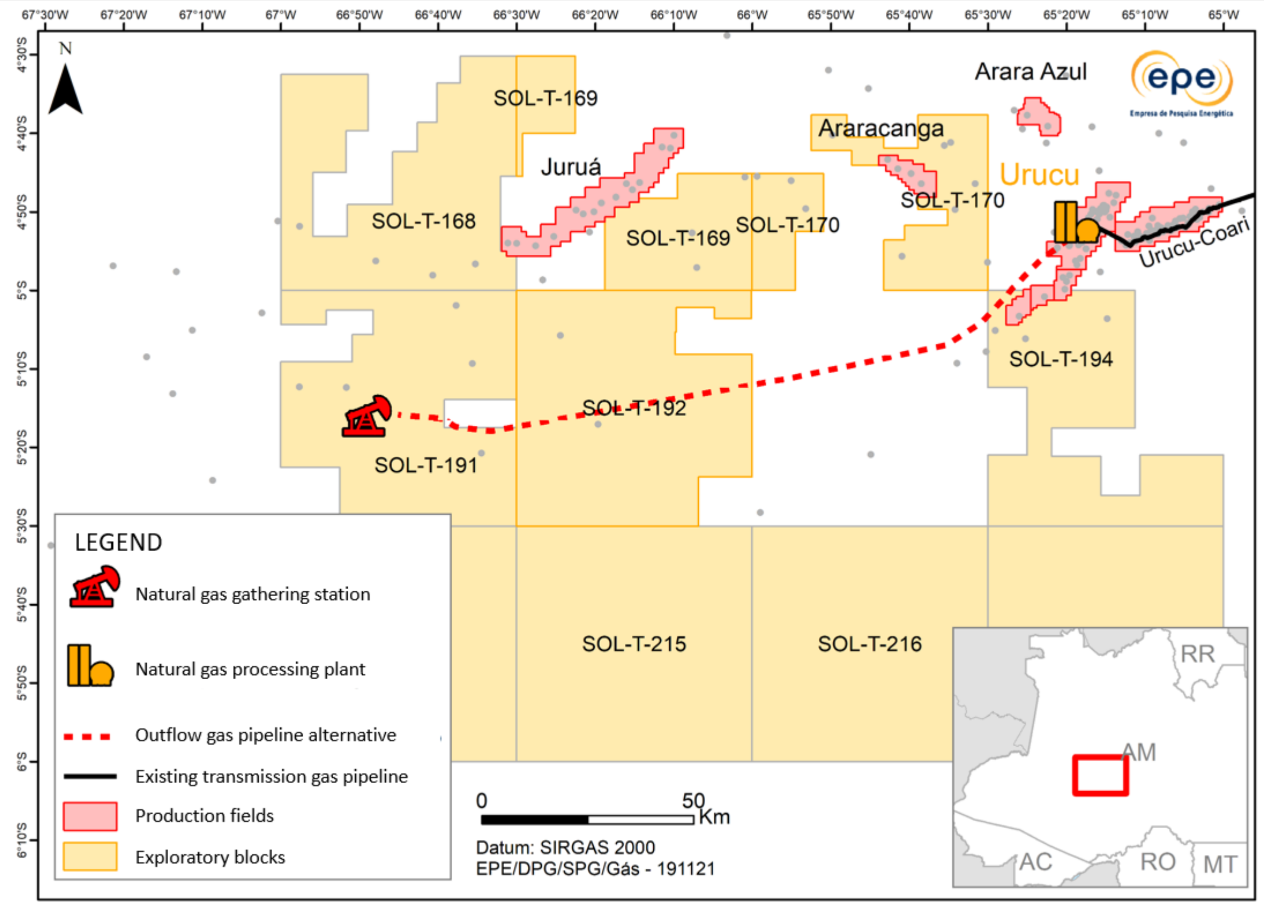

Figure 5. Onshore Non-Associated Gas (Solimões Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 1.57 million m³/day. The considered distance between the gas gathering station and the point where the connection with the existing transmission gas pipeline network would occur was 174 km, resulting in an outflow gas pipeline with 174 km in length and 10 inches in diameter.

In the NGPP case, the additional capacity of 1.57 million m³/d could be established as a new NGPP close to the existing one in Urucu/AM, or as payment for third-party access to this facility, by signing an agreement under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021).

Cost estimation considered installation of a new NGPP, but the market players may choose the option of third-party access, if it has a cost equal to or less than this alternative, and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others). Table 2 shows a summary of the costs for this alternative.

Table 2. Outflow gas pipeline CAPEX for Onshore Non-Associated Gas (Solimões Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	150.4	46%
Construction and Assembly	98.6	30%
Indirect Costs		
Engineering Project	33.2	10%
Insurance and Certification	2.8	1%
Contingencies	42.8	13%
TOTAL INVESTMENT (reference date Jun/21)	**327.8**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.3 billion for the installation of a new processing unit close to the existing facilities in Urucu/AM.

Socioenvironmental Analysis - Solimões Basin

The reference route established for the gas pipeline is 174 km long and crosses two municipalities in the center of Amazonas, starting from a hypothetical point in Tefé county, heading to the processing plant, at the Urucu Complex, in Coari.

When defining the route, interference possibilities were minimized regarding Tefé and Urucu river flood plain and their tributaries. The route was designed using Ambientrans tool, together with a convergence analysis methodology developed by EPE, to provide feasible alternatives for routes seeking maximum convergence between them.

The defined route crosses an extremely preserved Amazon Forest region, with no road access or other infrastructure. Therefore, the gas pipeline construction will represent a great logistical challenge, being necessary to use air and river transport for the arrival of equipment in the region. Due to the high degree of preservation in the region, it is recommended that the implementation of the enterprise be carried out avoiding the opening of accesses that could become deforestation fronts. Along the route, there are alluvial plains and plateaus with flat (0 to 3%) and smooth wavy (3 to 8%) slope rates, according to data from the CPRM (2004). From the topographic point of view, these units do not represent greater complexities for the gas pipeline construction.

The tableland relief is associated with unconsolidated deposits (Q1i) of the Içá Formation, such as sand, gravel, clay, silt and peat. The alluvial plains represent alluvial deposits (Q2a), which correspond to materials of different particle size and composition, indicating the geotechnical complexity of the terrain. The route was designed trying to minimize crossings with water courses and their respective flooding surfaces. It is important to emphasize that the limits of the mentioned geological units probably have cartographic inaccuracies, since the base consulted was developed for the Brazilian territory, therefore, of a referential nature. Both units present strong indications of geotechnical complexity in relation to the composition of the materials, as well as the presence of soils saturated in water.

The suggested route crosses three main rivers: Tefé, Igarapé Ingá and Urucu. Considering the Amazon Biome context in which the study area is located and that is necessary to cross a dense network of small watercourses, additional costs for the construction phase along the entire length of gas pipeline can be expected. The study area is not close to mining processes, with no possibility of interference.

The route crosses the Rio Urucu natural gas production field and touches three others: Carapanaúba, Cupiúba and Sudoeste Urucu. Therefore, when defining the gas pipeline final route, it is necessary to pay attention to the production and outflow equipment from the natural gas fields existing in the region. According to the database consulted, the reference route defined for the gas pipeline does not intersect with indigenous lands, conservation units or quilombola territories.

In 2020, the Environmental Study of a Sedimentary Area in the Solimões Onshore Basin (PIATAM/COPPETEC and EPE, 2020) was published, which, among other results, classified the basin into suitable or unsuitable regions (that is, adequate or inadequate) for oil and natural gas exploration. The proposed route for the gas pipeline is fully inserted in an area classified as suitable, whose Socioenvironmental conditions and characteristics, identified from the Study, are compatible with activities and ventures for the exploration and production of oil and natural gas, using the industry best practices.

The document provides recommendations for environmental permission, such as: i) prioritize technological alternatives that minimize the right of way width for the outflow pipes; and ii) establish in a program to control erosion processes generated by the implementation of wells, outflow pipes and processing plants. Therefore, to implement a gas pipeline, it is necessary to take such recommendations into account within the permission process.

As noted in Figure 6, the reference route crosses five extensive Priority Areas for the Conservation, Sustainable Use and Benefit Sharing of Biodiversity (APCBs in Portuguese). So, it will be necessary to look for ways to make the implementation while taking the priority actions defined for these APCBs into account.

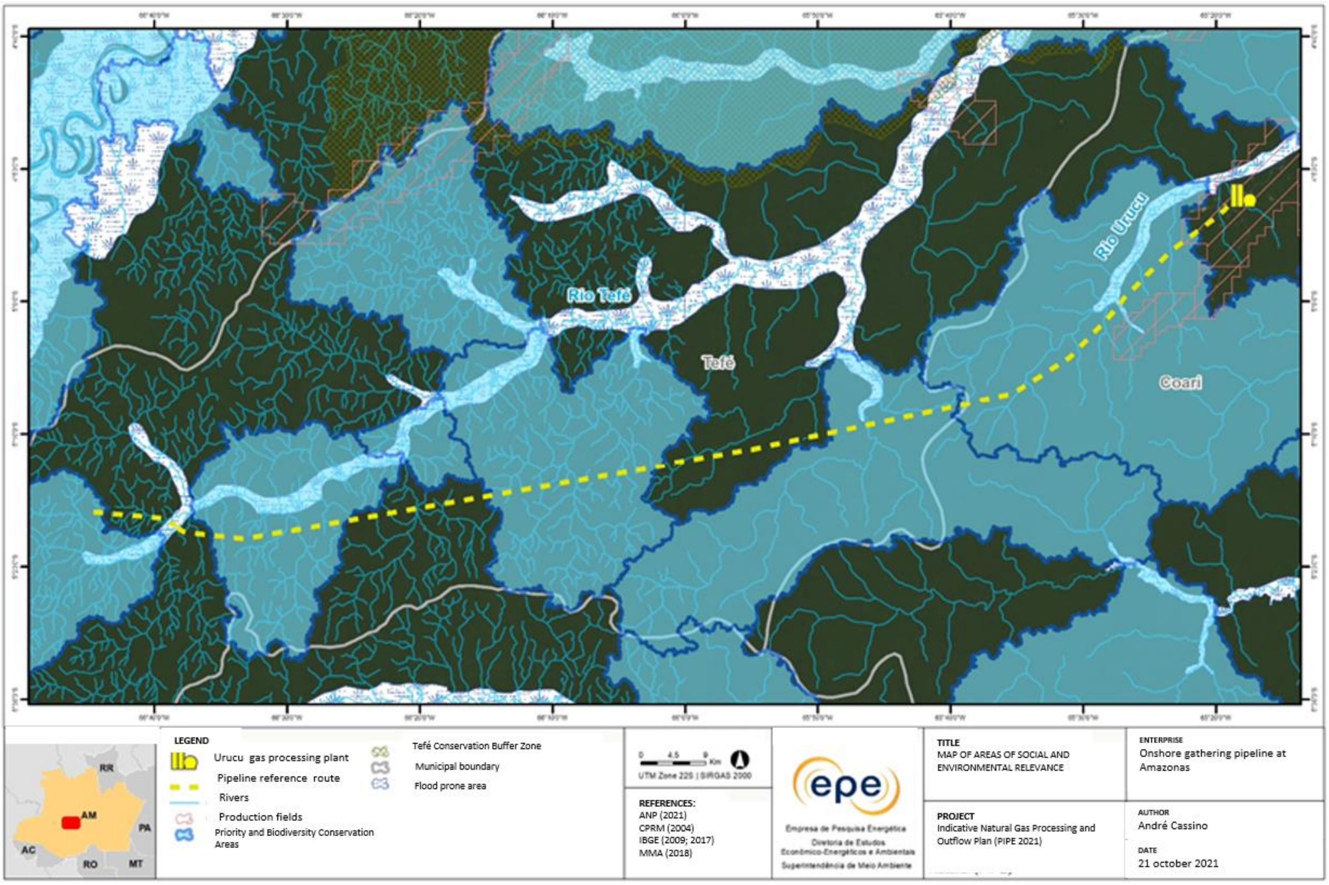

Figure 6. Socioenvironmental relevance areas in the region where the gas pipeline will be implemented in the Solimões Basin
Source: EPE.

3.3. Onshore Non-Associated Gas (Parnaíba Basin)

The first onshore non-associated gas project analysis considered existing projects in the Parnaíba Basin that are close to the NGPP in Santo Antônio dos Lopes/MA, which processes the natural gas collected from the surrounding fields and subsequently sends the specified natural gas to the nearby thermoelectric complex. However, unlike the existing projects, the new project would be about 100 km far from the NGPP, requiring the installation of a new outflow gas pipeline. Figure 7 shows the project schematically.

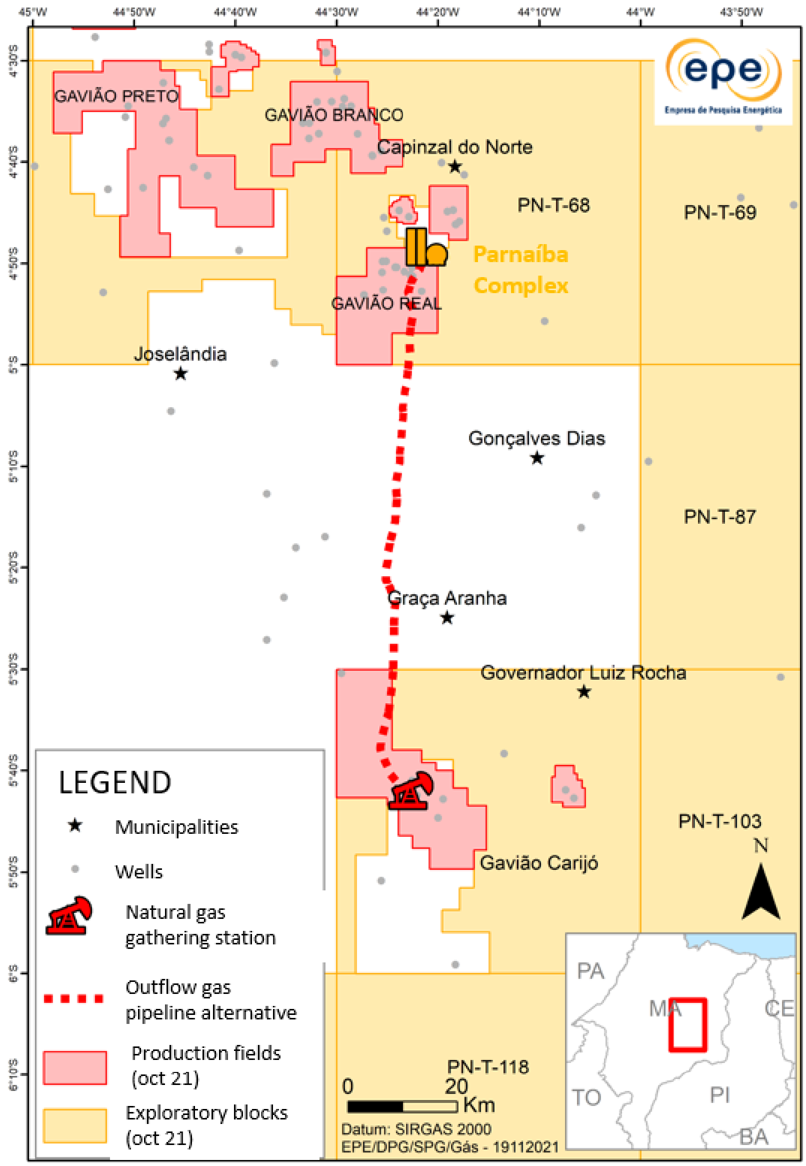

Figure 7. Onshore Non-Associated Gas (Parnaíba Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 1.95 million m³/day. The considered distance between the gas gathering station and the point where the connection with the existing processing plant would occur was 98 km, resulting in an outflow gas pipeline with 98 km in length and 12 inches in diameter. In the case of the processing plant, as in the previous case, the additional capacity could be established as a new processing plant close to the existing one in Santo Antônio dos Lopes/MA or as payment for third-party access to this facility, by signing an agreement under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021). Cost estimation considered installation of a new processing plant, but market players may choose the option of third-party access if it has a cost equal to or less than this alternative and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others).

Table 3 shows a summary of the costs for this alternative.

Table 3. Outflow gas pipeline CAPEX for Onshore Non-Associated Gas (Parnaíba Basin)

Description	**BRL million**	
Direct Costs		
Materials and Equipment	103.1	61%
Construction and Assembly	30.9	18%
Indirect Costs		
Engineering Project	12.6	7%
Insurance and Certification	1.5	1%
Contingencies	22.3	13%
TOTAL INVESTMENT (reference date Jun/21)	**170.7**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.4 billion for the installation of a new NGPP close to the existing facilities in Santo Antônio dos Lopes/AM.

Socioenvironmental Analysis - Parnaíba Basin

The reference route established for the gas pipeline measures 98 km and crosses five municipalities in the central region of Maranhão – São Domingos do Maranhão, Graça Aranha, Presidente Dutra, Dom Pedro and Santo Antônio dos Lopes. The route starts from a hypothetical point in Gavião Carijó field, in the municipality of São Domingos do Maranhão, heading to the Gas Treatment Unit (GTU in Portuguese), in the Parnaíba Complex, in Santo Antônio dos Lopes.

The route was defined with efforts to divert it from urban areas, rural settlement projects, areas with mining processes and more extensive forest fragments. The route was designed using Ambientrans tool, together with the convergence analysis methodology developed by EPE, to enable feasible alternatives for routes, seeking maximum convergence between them.

The route crosses regions with good road infrastructure, with the presence of federal and state highways (BR-135, BR-226, MA-141, MA-360, MA-256), in addition to unpaved roads that serve small towns and properties in rural areas in the region.

The route defined for the gas pipeline crosses six high voltage transmission lines (LTs in Portuguese), one with a voltage of 230 kV and five of 500 kV. According to the data consulted, there is no crossing with pipelines or railways.

The reference route is in a transition region of biomes where there are elements of the Amazon Forest, Cerrado and Caatinga. This mosaic gives rise to the Mata dos Cocais, characterized by the presence of plant species such as Carnaúba and Babaçu. The pattern of land use remains constant throughout the entire gas pipeline, with the presence of agricultural areas, important fragments of native vegetation, in addition to small villages. In the route northern section, the presence of equipment from the producing wells and the outflow gas pipeline network of Campo de Gavião Real stands out.

The route is bordered by hills and low slopes, dissected plateaus and levelled surfaces with flat (0 to 3%) and gently wavy (3 to 8%) angles, together with lowly undulating stretches (8 to

20%), according to CPRM data (2013). There are no significant crossings over water courses, wetlands (swamps, bogs), lakes or reservoirs along the suggested route. Primarily, this physical environment configuration does not pose constructive complexity for implementation of the gas pipeline.

The route does not interfere in areas with mining processes. On the other hand, it is important to mention that the route is close to a limestone prospecting process, in the research phase. Environments where carbonate rocks occur, such as limestone, may be subject to processes such as subsidence or karst sinking, which suggests attention and geotechnical investigation in the basic design phase to remove any risks to the project in question.

The route passes along two natural gas production field areas (Gavião Carijó and Gavião Real) and two exploratory blocks (PN-T-102A and PN-T-68). Therefore, when defining the gas pipeline final route, it is necessary to pay attention to the production and outflow equipment from the natural gas fields existing in the region.

According to the database consulted, the reference route does not cross indigenous lands or conservation units. There is a quilombola community called Cruzeiro, certified by the Palmares Cultural Foundation - FCP (2021), in the municipality of Dom Pedro. However, we have no georeferenced polygon of that Community, and it is not currently possible to say whether the proposed route crosses it or not.

It is noteworthy that, close to the reference point of exit of the gas pipeline in Campo do Gavião Carijó, the route goes around the Varandado rural settlement project, in the municipality of São Domingos do Maranhão. According to the information consulted, there are no archaeological sites or caves near the gas pipeline reference route.

Figure 8 shows the areas of Socioenvironmental relevance in the region where the gas pipeline in the Parnaíba Basin will be implemented.

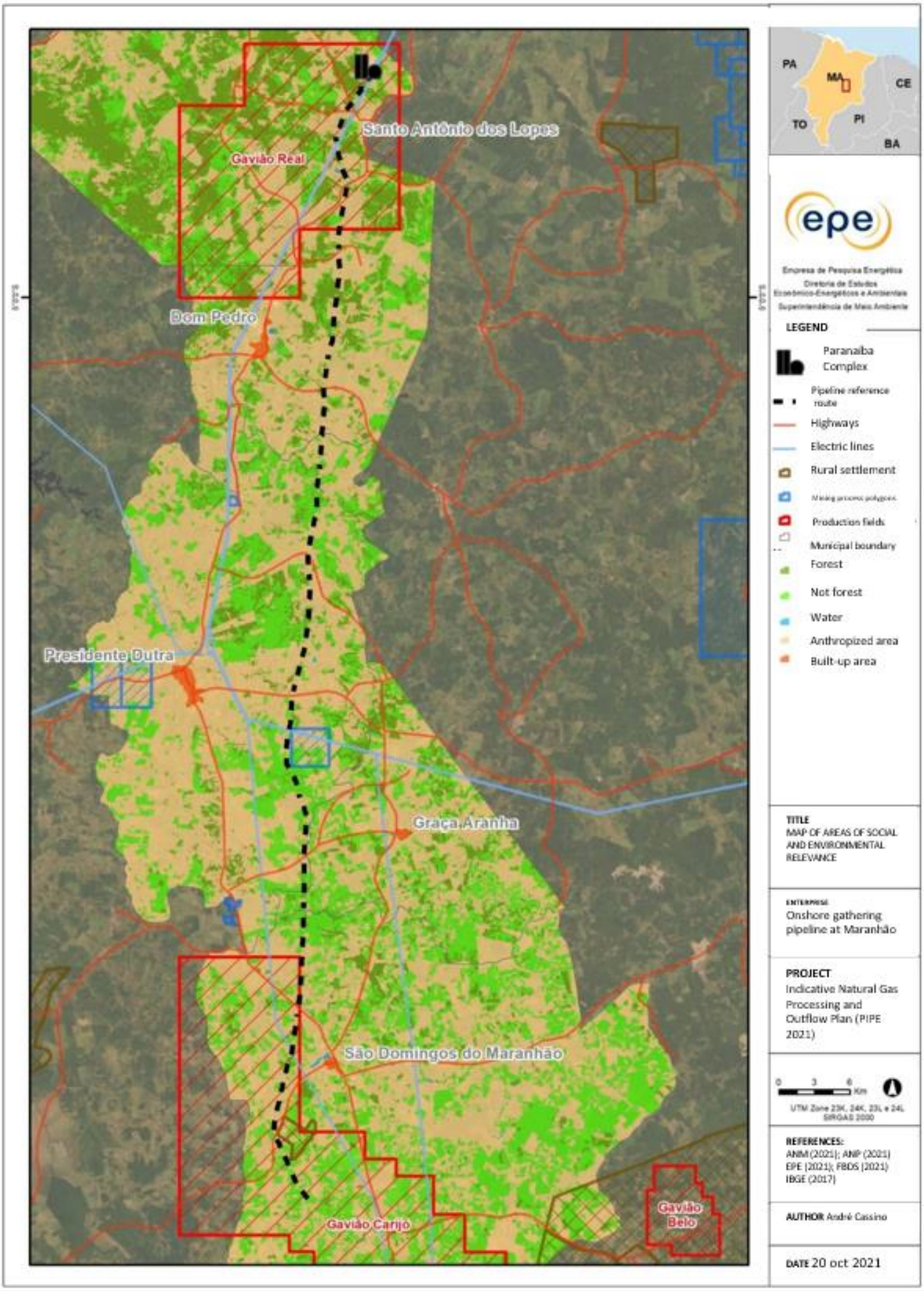

Figure 8. Socioenvironmental relevance areas in the region where the gas pipeline will be implemented in the Parnaíba Basin
Source: EPE.

4. Analysis of Offshore Projects in the Pre-Salt

This Section described 3 pre-salt associated gas projects analyzed, considering the typical characteristics of producing fields in the Campos and Santos Basins.

4.1. Associated Gas in the Pre-Salt (Campos Basin)

The first pre-salt associated gas project analysis considered existing projects in the Campos Basin that are close to BM-C-33, with geological characteristics and natural gas composition like those of Pão de Açúcar, Gávea and Seat prospects. This case assumed that the natural gas will be treated on the offshore platform so that its specification is already adequate for injection into the transmission gas pipeline network, and the NGPP onshore would only do a simplified processing to adjust the gas stream conditions as necessary after arrival at the coast. Figure 9 shows the project schematically.

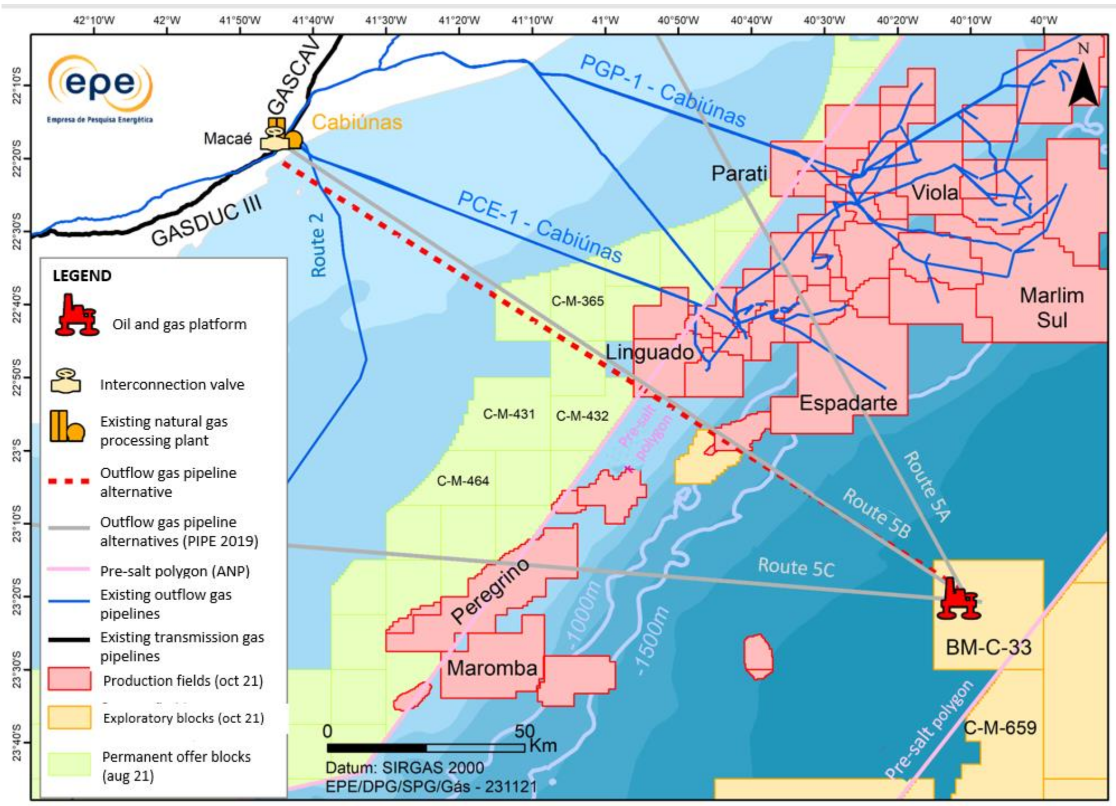

Figure 9. Associated Gas in the Pre-Salt (Campos Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 16 million m³/day. The considered distance between the production platform and the point where the connection with the transmission gas pipeline network would occur through a valve was 205 km, resulting in an outflow gas pipeline with 205 km in length and 16 inches in diameter.

Table 4 shows a summary of the costs for this alternative.

Table 4. Outflow gas pipeline CAPEX for Associated Gas in Pre-Salt (Campos Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	635.8	40%
Construction and Assembly	642.1	40%
Indirect Costs		
Engineering Project	62.3	4%
Insurance and Certification	53.6	3%
Contingencies	209.1	13%
TOTAL INVESTMENT (reference date Jun/21)	**1602.8**	**100%**

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

As mentioned, in this case the natural gas processing could take place directly on the production platform, with the installation of only one valve and/or condensate collection system at the point of connection with the transmission gas pipeline network.

Socioenvironmental Analysis - Pre-Salt (Campos Basin)

This analysis consists of a characterization of the arrival reference region, in the onshore section of the outflow gas pipeline, considering physical environment aspects and the most relevant Socioenvironmental elements. This characterization established a radius of 25 km around the Cabiúnas/RJ Center. The reference region of the gas pipeline arrival onshore covers seven municipalities in the north of Rio de Janeiro, comprising urban areas and industrial and port areas of Macaé and Rio das Ostras.

There are 14 conservation units in the region interior, five of which are for full protection and nine for sustainable use. Among these units, the Restinga de Jurubatiba National Park (PARNA in Portuguese) and its buffer zone, and the Santana Archipelago Environmental Protection Area (APA in Portuguese) stand out, located in potential areas for the indicated gas pipeline passage. The region displays large pasture areas in the rural regions of the municipalities. It also shows fragments of native vegetation, often associated with areas of greater declivity. Also noteworthy is the presence of sandbanks and sandy ridges in the PARNA of Restinga de Jurubatiba.

The reference region encompasses eight rural settlement projects, three in Macaé, two in Carapebus, two in Conceição de Macabu and one in Rio das Ostras. According to the georeference database provided by Institute of National Historical and Artistic Heritage (IPHAN in Portuguese), there are 23 archaeological sites within the region, which should be avoided when defining the gas pipeline route if the project becomes feasible. According to the database consulted, there are no indigenous lands or quilombola territories in the reference region.

According to the database consulted, plains, hills and mountainous domains predominate. There are also other units, such as high hills and boards, on a smaller scale. The study area plains have flat slopes (0 to 3%) and consist of marine, lake or alluvial sedimentary deposits that correspond to materials of different particle size and composition, indicating geotechnical terrain complexity. They are expressive in the coastal strip of the municipality of Carapebus and along the Macaé and São Pedro rivers. According to the Rio de Janeiro State Geodiversity Map (CPRM, 2017), these plains, in addition to unfavorable geotechnical conditions, are also susceptible to flooding associated with water courses, as well as in other reference area points, such as in the city of Macaé's Lagomar, Cabiúva and São José do Barreto districts.

The hills are also expressive, with slopes varying from gentle undulating (3 to 8%) to undulating (8 to 20%) and usually delimiting the plains. High hills, on the other hand, occur as enclaves in areas dominated by hills and have high rates of declivity, ranging from strongly undulating (20 to 45%) to mountainous (45 to 75%). The mountainous domains are in the northwest reference area portion and have the highest rates of declivity and relief amplitude in the study region. Both the high hill reliefs and the mountainous domains represent surfaces of high constructive complexity for the passage of gas pipelines due to the inherent topographical aspects, as well as the presence of rock outcrops, shallow soils or deposits of unconsolidated materials (talus or colluvium), in addition to the susceptibility to gravitational mass movements (sliding, creeping).

Despite the dense network of watercourses and existing channels, there are no water masses in the region that represent significant crossings for the passage of gas pipelines.

The study area overlaps with 129 mining processes registered with the National Mining Agency. Research authorization processes, licensing, and various requirements for the exploration of sand, gravel, gneiss and granite predominate. There are five processes in the mining concession phase for granite, gneiss and mineral water exploration. There are four offshore mining processes for sand and ilmenite exploration.

A significant pipeline network installed towards the Cabiúnas Terminal crosses the area (Figure 10), in addition to two planned ones, requiring greater attention when defining the gas pipeline final route.

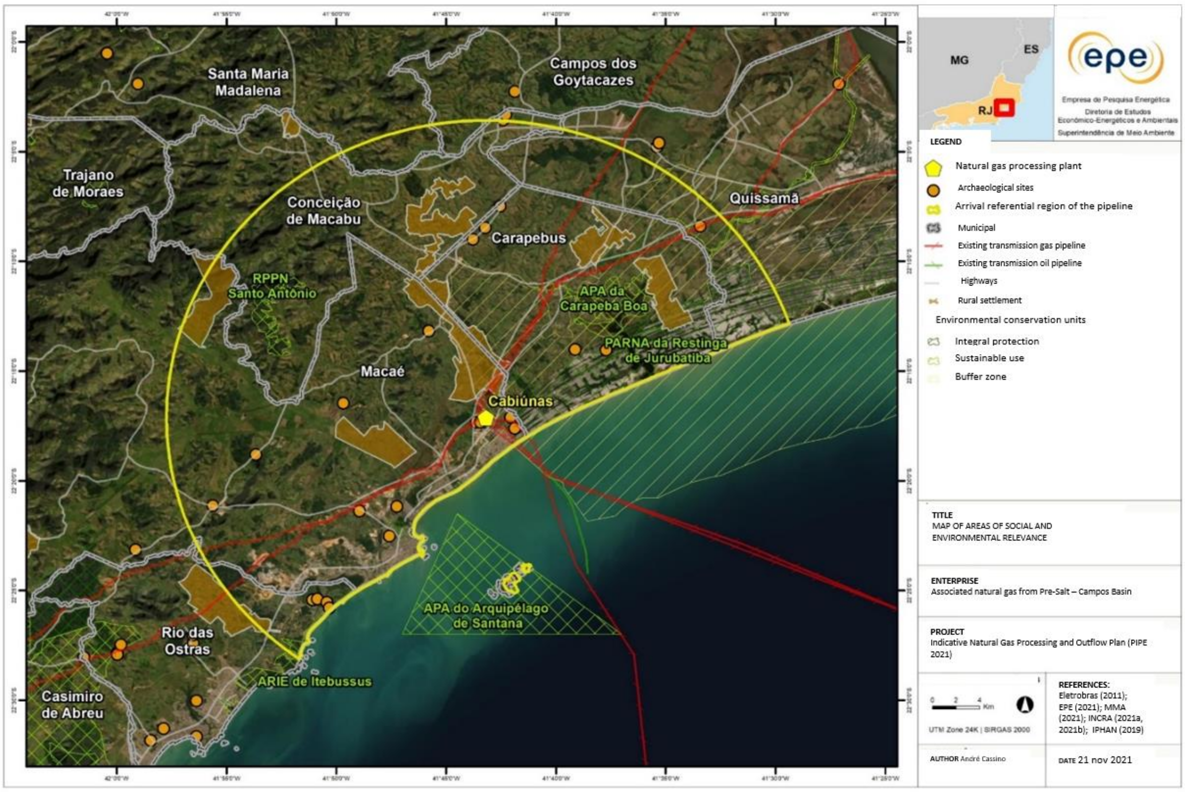

Figure 10. Areas of Socioenvironmental relevance in the arrival reference region of gas pipeline
Source:EPE.

4.2. Associated Gas in the Pre-Salt (Campos Basin) tie-back 1

The second pre-salt associated gas project analysis considered existing projects in the Santos Basin that are close to the Sépia field, with similar geological characteristics and natural gas composition. This case assumed that the natural gas will be connected by means of a tie-back to a nearby platform that would proceed to send the gas onshore, where it will then be processed. Figure 11 presents the project schematically.

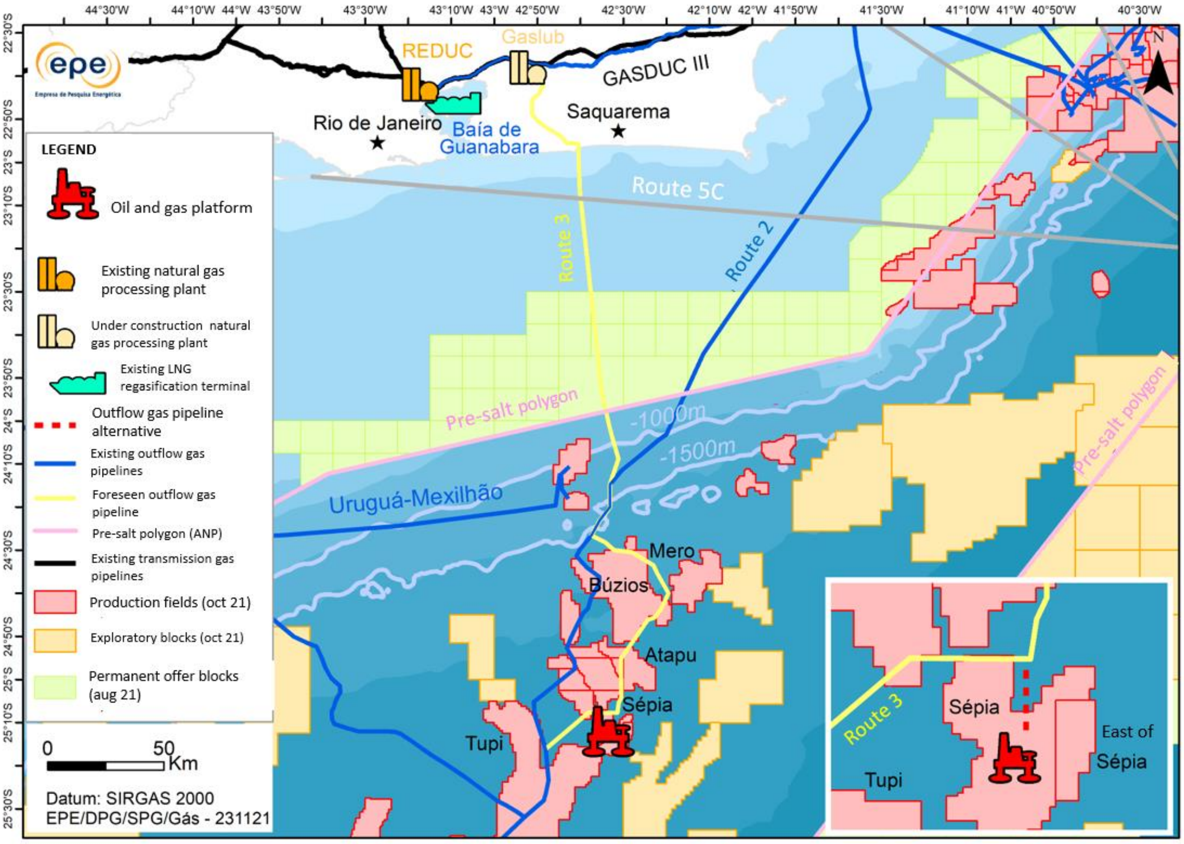

Figure 11. Associated Gas in the Pre-Salt (Campos Basin)- 1
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 3.87 million m³/day. The considered distance between the production platform and the point where the connection with the existing outflow gas pipeline network would occur was 12 km, resulting in an outflow gas pipeline with 12 km in length and 14 inches in diameter.

In the case of the NGPP, the additional capacity of 3.87 million m³/d could be established as a new NGPP close to the existing one in Itaboraí/RJ, or as payment for third-party access to this facility, by signing an agreement under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021). Cost estimation considered installation of a new NGPP, but the market players might choose the option of third-party access, if it has a cost equal to or less than this alternative, and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others).

Table 5 shows a summary of the costs for this alternative.

Table 5. Outflow gas pipeline CAPEX for Associated Gas in tie-back 1 Pre-Salt (Santos Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	113.4	46%
Construction and Assembly	74.8	30%
Indirect Costs		
Engineering Project	17.3	7%
Insurance and Certification	8.2	3%
Contingencies	32.1	13%
TOTAL INVESTMENT (reference date Jun/21)	**245.8**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.8 billion for the installation of a new NGPP close to the existing facilities in Itaboraí/RJ. Another option is processing natural gas in the existing NGPP by execution of an agreement for third-party access if it is compatible with the natural gas and the cost is feasible.

Socioenvironmental Analysis - Pre-Salt (Santos Basin)

This project included no socioenvironmental analysis, because the gas pipeline in question was not connected to the coast. As assessed, the Associated Gas in the Pre-Salt (Santos Basin) tie-back 1 alternative connects to the Route 3 Gas Pipeline, which is in the final stage of construction, with its Socioenvironmental analysis, regarding the arrival route at the coast, already carried out and approved.

4.3. Associated Gas in the tie-back 2 Pre-Salt (Santos Basin)

The third pre-salt associated gas project analysis considered existing projects in the Santos Basin that are close to the Atapu field, with similar geological characteristics and natural gas composition. This case assumed connecting the natural gas by means of a tie-back to a nearby platform that would proceed to send the gas onshore, where it will then be processed. Figure 12 presents the project schematically.

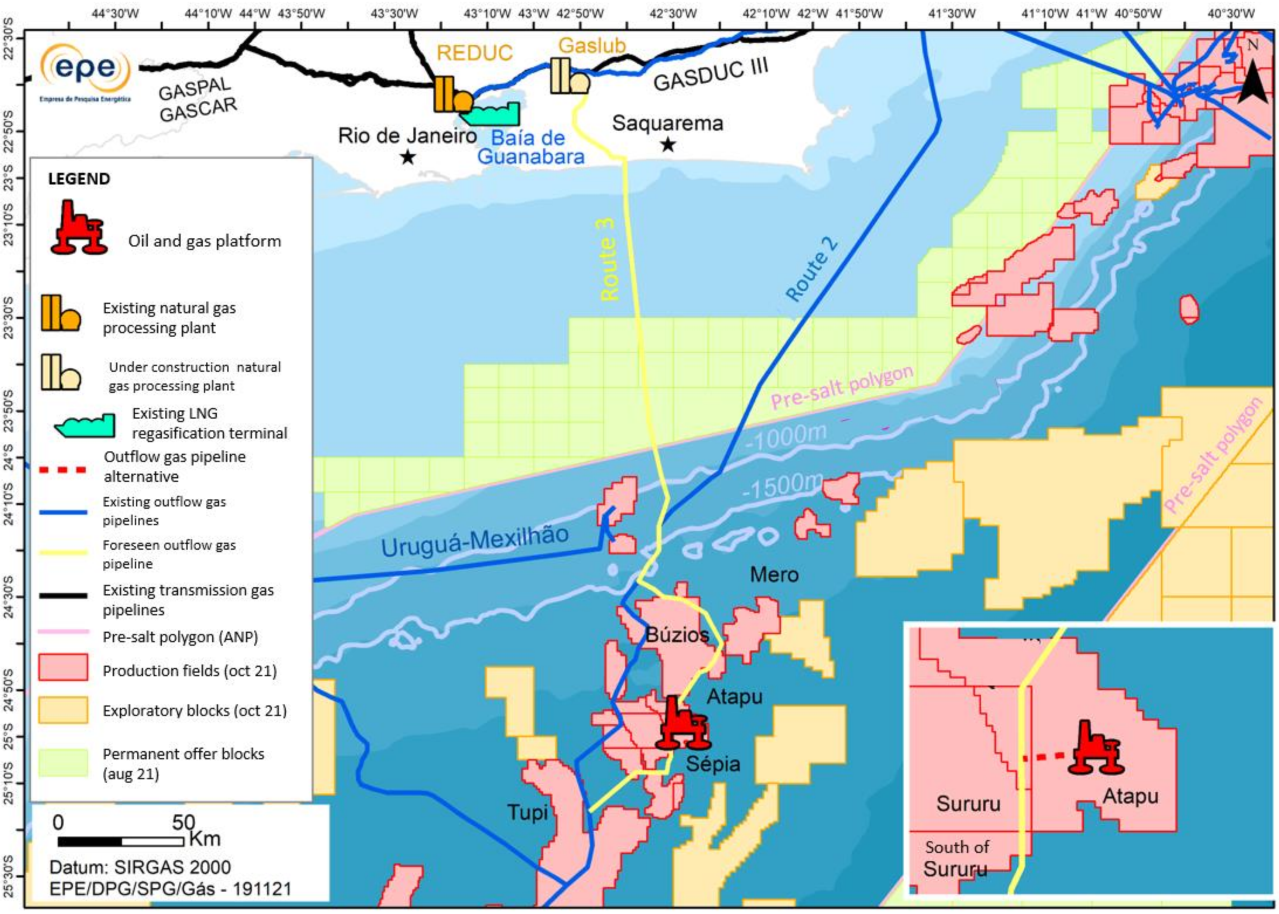

Figure 12. Associated Gas in the tie-back 2 Pre-Salt (Santos Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 3.26 million m³/day. The considered distance between the production platform and the point where the connection with the existing outflow gas pipeline network would occur was 8 km, resulting in an outflow gas pipeline with 8 km in length and 12 inches in diameter. In the case of the NGPP, the additional capacity of 3.26 million m³/d could be established as a new NGPP close to the existing one in Itaboraí/RJ, or as payment for third-party access to this facility, by signing an agreement under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021). Cost estimation considered installation of a new NGPP, but the option of third-party access might be chosen by the market players if it has a cost equal to or less than this alternative and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others).

Table 6 shows a summary of the costs for this alternative.

Table 6. Outflow gas pipeline CAPEX for Associated Gas in tie-back 2 Pre-Salt (Santos Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	87.4	42%
Construction and Assembly	69.8	34%
Indirect Costs		
Engineering Project	16.6	8%
Insurance and Certification	7.0	3%
Contingencies	27.1	13%
TOTAL INVESTMENT (reference date Jun/21)	**207.9**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.7 billion for the installation of a new NGPP close to the existing facilities in Itaboraí/RJ. Optionally, the existing NGPP could process natural gas by execution of an agreement for third-party access if it is compatible with natural gas and the cost is feasible.

Socioenvironmental Analysis - Pre-Salt (Santos Basin)

This project included no socioenvironmental analysis, because the gas pipeline in question was not connected to the coast. As assessed, the Associated Gas in the Pre-Salt (Santos Basin) tie-back 2 alternative connects to the Route 3 Gas Pipeline, which is in the final stage of construction, with its Socioenvironmental analysis, regarding the arrival route at the coast, already carried out and approved.

5. Analysis of Offshore Projects in the Post-Salt

This Section analyzes the 6 offshore projects in the Campos, Camamu-Almada, Espírito Santo and Sergipe-Alagoas Basins. Project analyses consider associated or non-associated natural gas in coastal seas, deep water and ultra-deep water.

5.1. Coastal Sea Gas (Camamu-Almada Basin)

Associated Gas Coastal Sea (Camu-Almada Basin)

The offshore associated gas project analysis considered projects in the Camamu-Almada Basin close to Manati field, having similar geological characteristics and natural gas composition. This case assumed connecting the natural gas by a pipeline to the existing Manati-Vandemir Ferreira gas pipeline, where it will be processed. Figure 13 presents the project schematically.

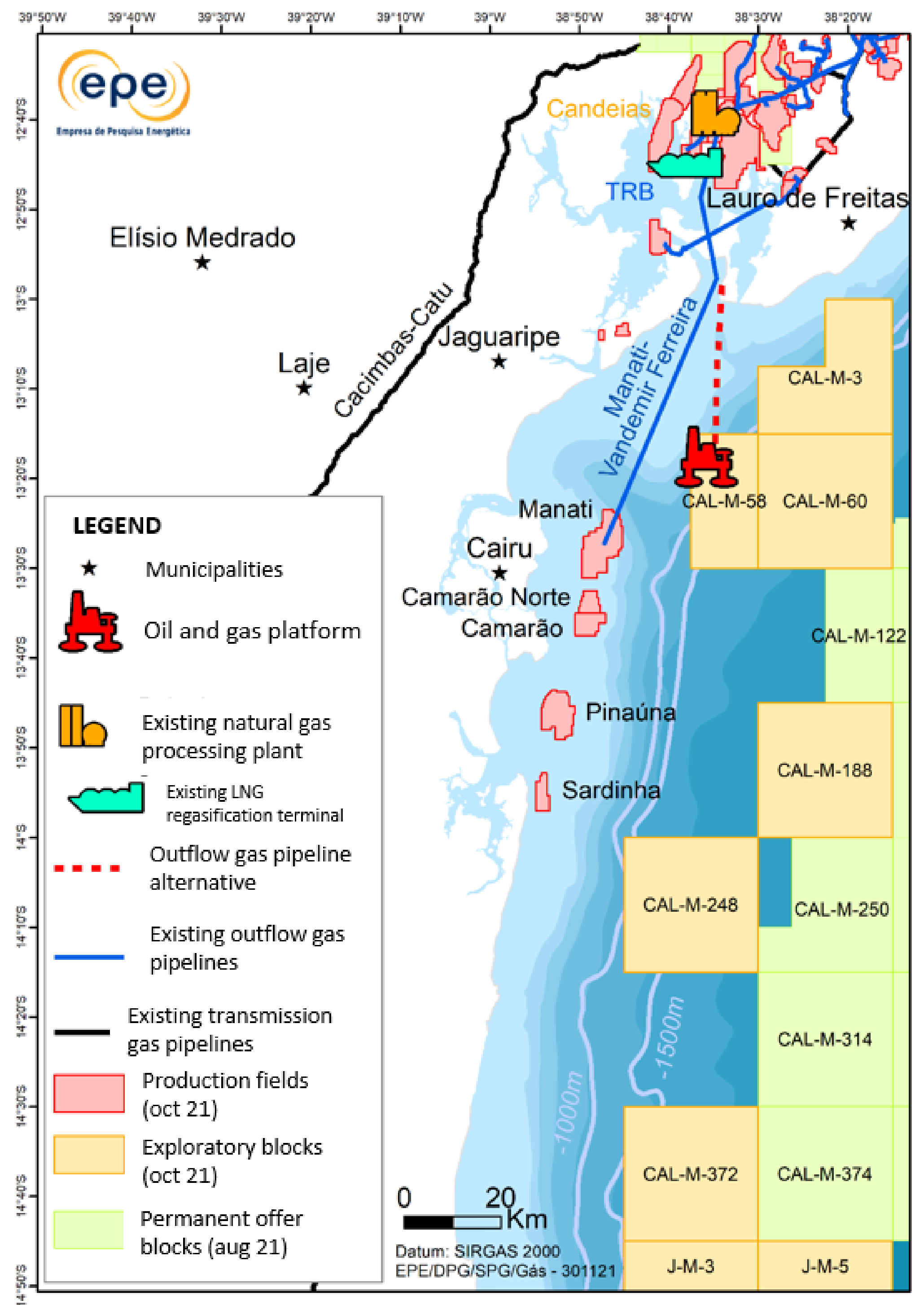

Figure 13. Associated Gas Coastal Sea (Camamu-Almada Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 172 thousand m^3/day. The considered distance between the production platform and the NGPP was 35 Km. In this case, there could also be a connection with the existing outflow gas pipeline network in the Manati field, with the same length considered. This assumption resulted in a 35 km long and 3-inch diameter pipeline.

In the case of the NGPP, the additional capacity of 172 thousand m³/d could be established as a new NGPP close to the existing one in São Francisco do Conde/BA, or as payment for third-party access to the NGPP in Candeias/BA, by connecting it to the Manati field and signing an agreement under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021). Cost estimation considered installation of a new NGPP, but the option of third-party access might be chosen by the market players if it has a cost equal to or less than this alternative and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others).

Table 7 shows a summary of the costs for this alternative.

Table 7. Outflow gas pipeline CAPEX for Coastal Sea Associated Gas (Camamu-Almada Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	13.4	12%
Construction and Assembly	61.5	56%
Indirect Costs		
Engineering Project	17.4	16%
Insurance and Certification	3.7	3%
Contingencies	14.4	13%
TOTAL INVESTMENT (reference date Jun/21)	**110.3**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.0 billion for the installation of a new NGPP close to the existing facilities in Itaboraí/RJ. Optionally, the existing NGPP could process natural gas by execution of an agreement for third-party access if it is compatible with natural gas and the cost is feasible.

Non-Associated Gas Coastal Sea (Camu-Almada Basin)

The offshore non-associated gas project analysis considered existing projects in the Camamu-Almada Basin that are close to the Manati field with approximate geological characteristics and natural gas composition. This case assumed connecting the natural gas by an outflow gas pipeline to the coastline, where its processing would take place. In Figure 14 presents the project schematically.

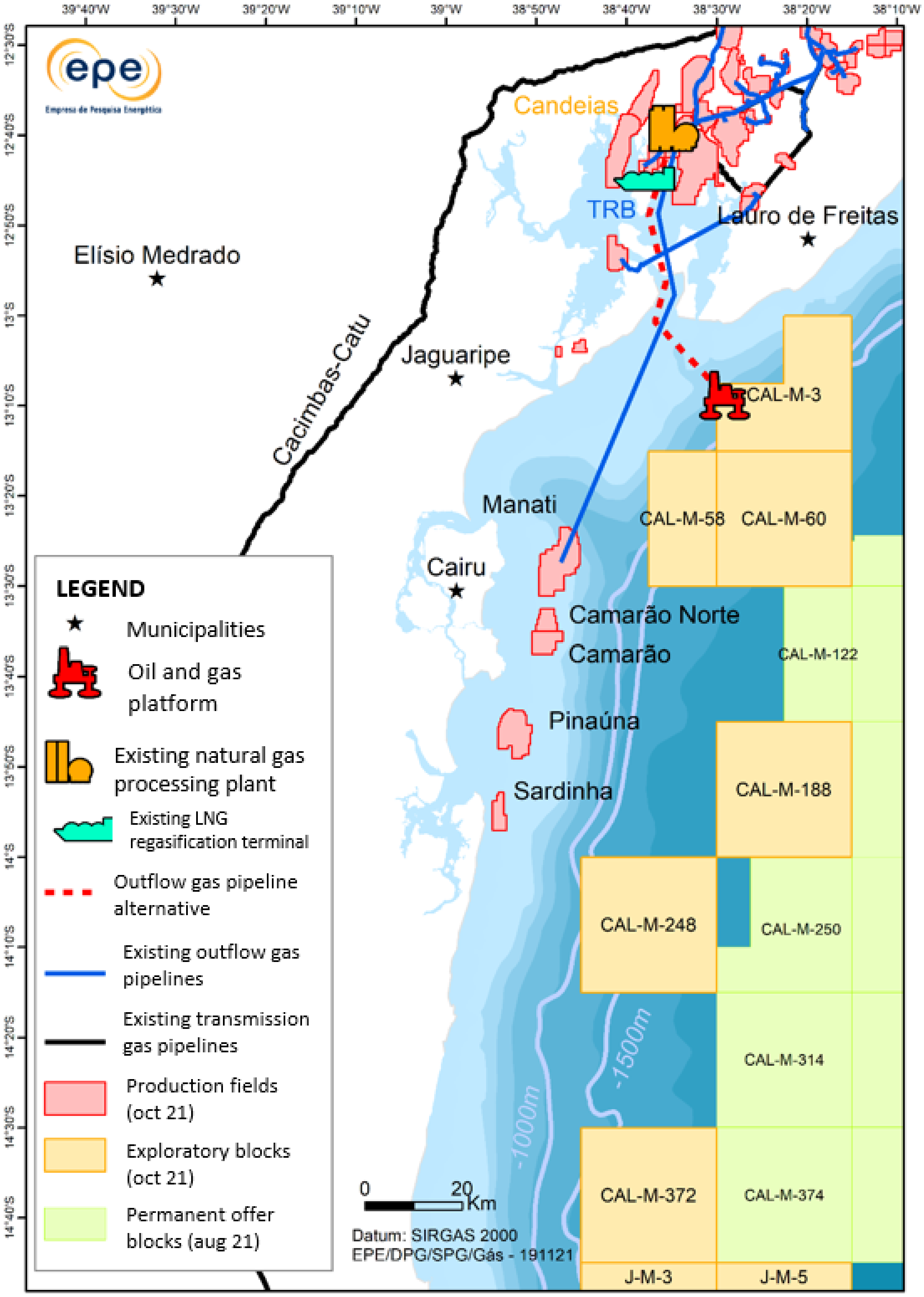

Figure 14. Non-Associated Gas Coastal Sea (Camamu-Almada Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 7.0 million m³/day. The considered distance between the production platform and the NGPP was 70 km. This assumption resulted in a 70 km long and 20-inch diameter pipeline.

In the case of the NGPP, the additional capacity of 7.0 million m³/d could be established as a new NGPP or as payment for third-party access to the NGPP from Candeias/BA, by connecting it to the Manati field and signing an agreement under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021). Cost estimation considered installation of a new NGPP, but the option of third-party access might be chosen by the market players, if it has a cost equal to or less than this alternative, and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others).

Table 8 shows a summary of the costs for this alternative.

Table 8. Outflow gas pipeline CAPEX for Coastal Sea Non-Associated Gas (Camamu-Almada Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	178.7	40%
Construction and Assembly	164.7	37%
Indirect Costs		
Engineering Project	29.2	7%
Insurance and Certification	14.9	3%
Contingencies	58.1	13%
TOTAL INVESTMENT (reference date Jun/21)	**445.5**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 2.4 billion for the installation of a new NGPP. Optionally, the existing NGPP could process natural gas by execution of an agreement for third-party access if it is compatible with natural gas and the cost is feasible.

Socioenvironmental Analysis - Camamu-Almada Basin (Associated and Non-Associated Gas)

Since both projects related to this basin are for the Candeias Processing Center, with the same point of arrival onshore, one socioenvironmental analysis was carried out for both pipelines. This analysis consists of a characterization of the arrival reference region, in the onshore section of these outflow gas pipelines, considering the physical environment aspects and the most relevant Socioenvironmental elements. For such characterization, a radius of 25 km was established around Candeias/BA Center.

The reference region for the arrival of the onshore gas pipelines covers 13 municipalities in the Metropolitan Region of Salvador, in intensely urbanized areas. Therefore, to implement the projects, it is necessary to avoid or minimize interference with those areas at the time of the route definition.

There are nine conservation units in the region interior, three of which are Environmental Protection Areas (APAs) and six Private Natural Heritage Reserves (RPPNs). Although they consist of sustainable use conservation units and, as a rule, the implementation of projects within their boundaries is not prohibited, it is important to consider the units' management plans to verify any existing restrictions and conditions.

Due to the presence of areas of mangroves, estuaries and native vegetation, it is recommended, when possible, that the routes follow the Manati - Estação Vandemir Ferreira gas pipeline right of way, to minimize the environmental impacts during the eventual implementation of gas pipeline.

In the region interior, there are nine rural settlement projects, five in Santo Amaro, two in São Sebastião do Passé, one in Candeias and one in Dias d'Ávila. There are also six quilombola territories, one in Salvador and the others in Simões Filho. According to the georeferenced database provided by IPHAN, there are 11 archaeological sites within the region's limits, which should be avoided when defining the gas pipeline routes, if the projects are to be implemented.

According to the database consulted, plateaus, hills and low hills and plains predominate, in addition to other units, on a smaller scale of occurrence (CPRM, 2017). The plains in the study area have flat slopes (0 to 3%) and correspond to marine, alluvial or lake sedimentary deposits with materials of different particle size and composition, suggesting geotechnical terrain complexity. The fluvial-lacustrine plains present unconsolidated material of variable thickness, formed from the base to the top by gravel, sand and clay. On the other hand, the fluvial-marine plains present irregular intercalations of sandy and clayey sediments, rich in organic matter in general (mangroves).

The boards are expressive and occupy most of the study area. They are flattened surfaces developed over sedimentary rocks, sometimes showing the relief dissection degrees depending on the drainage. The hills and low hills have slopes that vary from gentle wavy (3 to 8%) to wavy (8 to 20%), but with slopes that reach greater slopes. The hills and low mountains occupy the western portion of the studied area, have a slightly busier relief and higher slope rates for this context, although they are less representative.

The study area is in the Todos os Santos Bay, and the underwater crossing for the passage of the gas pipelines is the biggest point of attention and constructive complexity. Despite the dense network of existing watercourses, there are no water masses in the region that represent significant crossings for the passage of gas pipelines.

The area overlaps with 154 mining processes registered with ANM. Research authorization processes, research requests, mining concessions and mining requests predominate for the exploration of sand, clays, gravel, mineral water, shell-bearing or coral-limestones, among other substances, in addition to several blocks in availability. There are 26 processes in the mining concession phase for various substances. It is worth noting that the concentration of marine mining processes (in the aforementioned Bay) for the exploration of rock salt, limestones and clays.

As shown in **Figure 15**, there are 26 oil and gas production fields in the study area, most of which are in operation. Therefore, when defining the final route of the gas pipelines, it is necessary to pay attention to the production and outflow equipment of the existing natural gas fields.

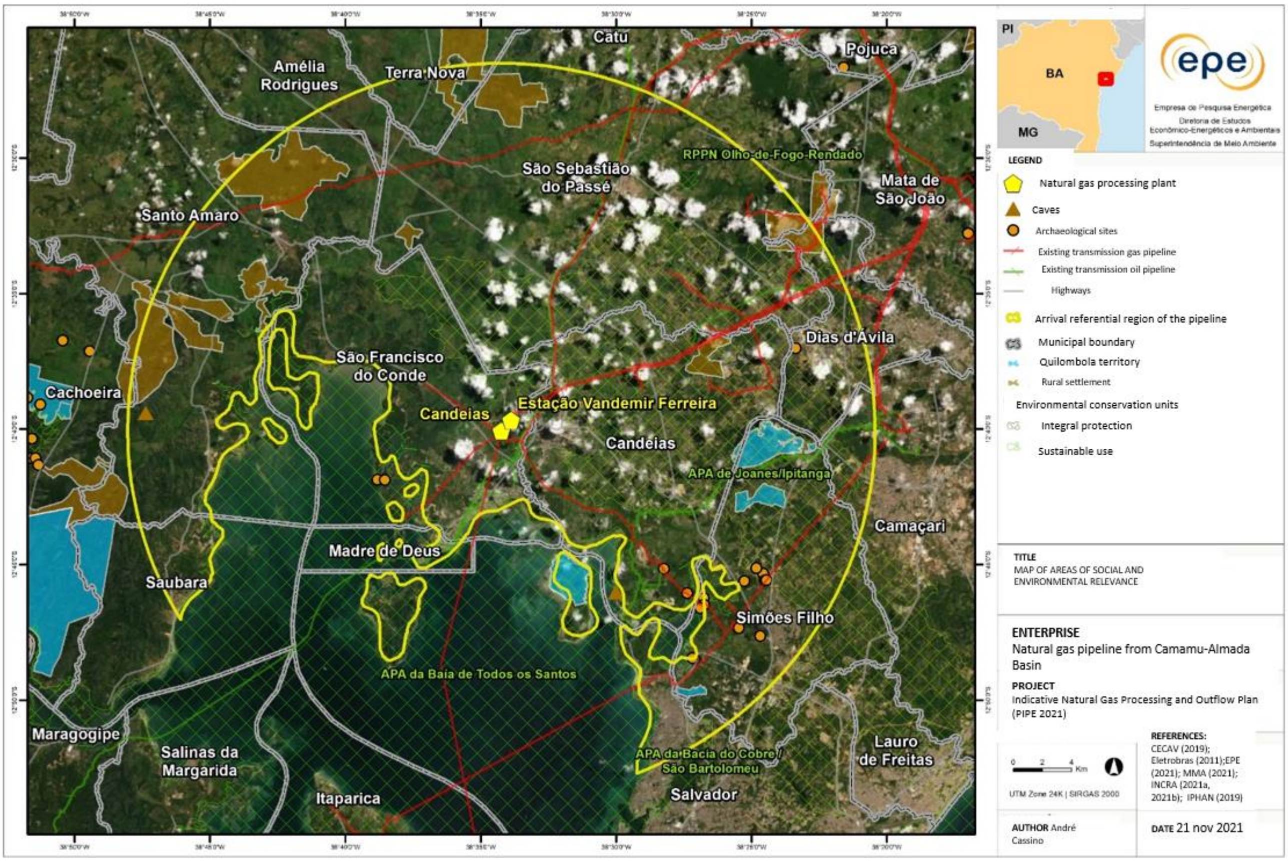

Figure 15. Areas of Socioenvironmental relevance in the arrival reference region of gas pipeline
Source: EPE.

5.2. Deep Water Associated Gas (Espírito Santo Basin)

The deep water offshore associated gas project analysis considered existing projects in the Espírito Santo Basin that are at a bathymetry like that of Gofinho field, with approximate geological characteristics and natural gas composition. This case assumed connecting the natural gas by an outflow gas pipeline to the coastline, where it will be processed. Figure 16 presents the project schematically.

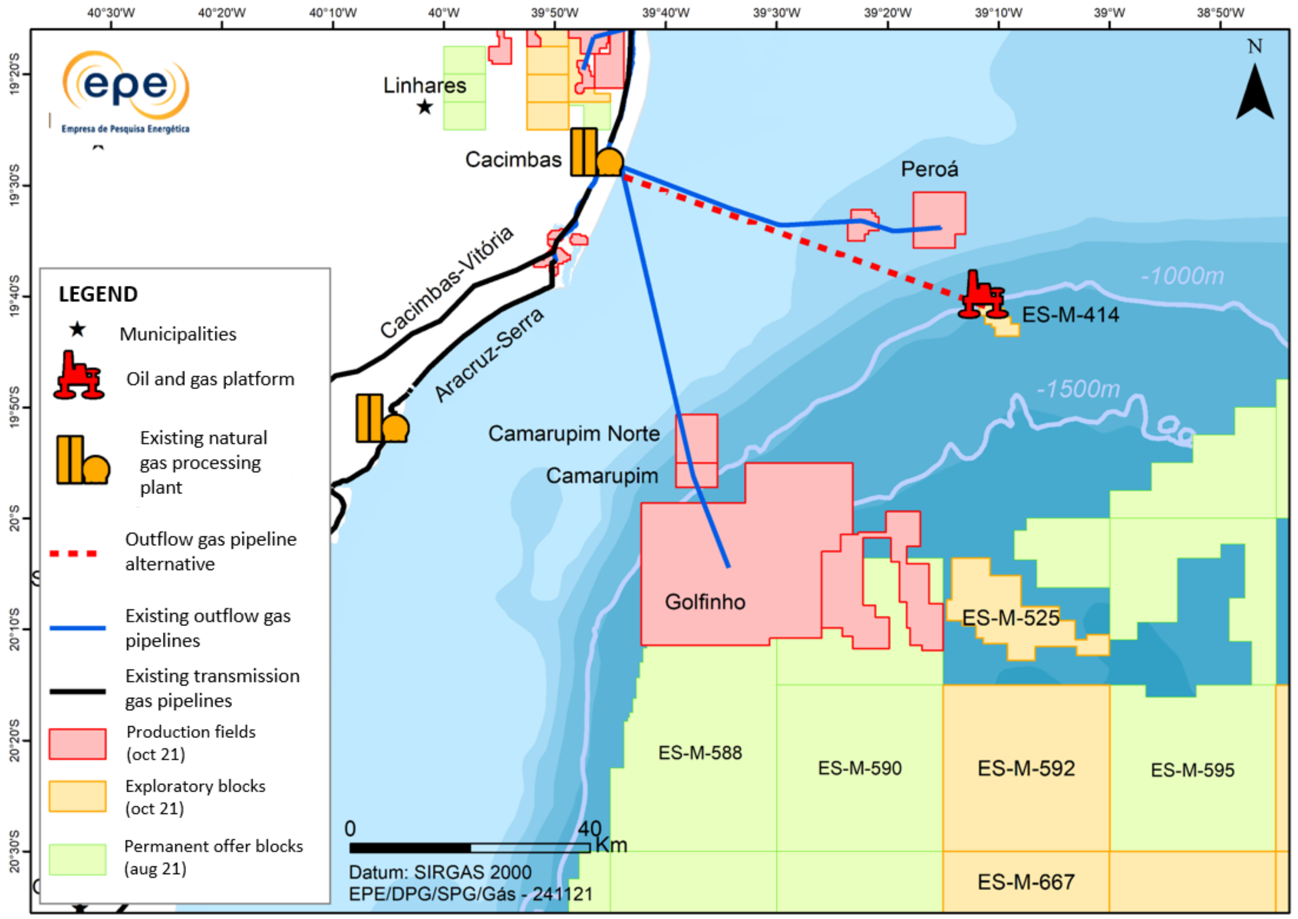

Figure 16. Deep Water Associated Gas (Espírito Santo Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 1.26 million m³/day of associated gas. However, it should be noted that not necessarily the selected blocks for each alternative will be able to produce associated or non-associated natural gas in the indicated volumes.

The distance between the production platform and the NGPP was considered equal to 65 km. This assumption resulted in a 65 km long and 8-inch diameter pipeline.

In the case of the NGPP, the additional capacity of 1.26 million m³/d could be established as a new NGPP or as payment for third-party access to the NGPP of Cacimbas/ES, by signing of a contract under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021). Cost estimation considered installation of a new NGPP, but the option of third-party access might be chosen by the market players if it has a cost equal to or less than this alternative and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others).

Table 9 shows a summary of the costs for this alternative.

Table 9. Outflow gas pipeline CAPEX for Deep Water Associated Gas (Espírito Santo Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	78.8	25%
Construction and Assembly	150.5	48%
Indirect Costs		
Engineering Project	33.1	11%
Insurance and Certification	10.5	3%
Contingencies	40.9	13%
TOTAL INVESTMENT (reference date Jun/21)	**313.8**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.3 billion for the installation of a new NGPP. Optionally, the existing NGPP could process natural gas by execution of an agreement for third-party access if it is compatible with natural gas and the cost is feasible.

Socioenvironmental Analysis - Espírito Santo Basin (Deep Water)

This analysis consists of a characterization of the arrival reference region, in the onshore section of this outflow gas pipeline, considering physical environment aspects and the most relevant Socioenvironmental elements. For such characterization, a radius of 25 km was established around the gas processing hub of Cacimbas /ES. The reference region for the gas pipeline arrival is in Linhares, a municipality in the north of Espírito Santo, covering the Doce River’s mouth.

There are two conservation units in the region interior, one for full protection (Comboios Biological Reserve) and one for sustainable use (Area of Relevant Ecological Interest in Degredo), both with the possibility of detouring along the gas pipeline route.

The presence of priority areas for turtle spawning throughout the coastline stands out, with TAMAR Project structures within the Biological Reserve of Comboios and in the Regência district. Therefore, it is necessary to pay attention to measures that avoid or mitigate impacts on fauna during the gas pipeline construction if the project becomes feasible.

In the region, there are areas of pasture, agricultural crops, especially sugarcane, forestry and native vegetation, mainly on the banks of Doce river. Spits and areas of resting a show up in the coastal strip and adjacencies. According to the database consulted, there are no indigenous lands, quilombola territories or rural settlement projects in the region interior.

According to the database consulted, alluvial, lake and marine plains with flat slopes (0 to 3%) predominate. These units consist of marine, lake or alluvial sedimentary deposits that correspond to materials of different particle size and composition, indicating the geotechnical terrain complexity. The marine plains presuppose the prevalence of sandy materials, while the others present greater intercalation of sand, silt, clay and, occasionally, peat. According to the Espírito Santo State Geodiversity Map (CPRM, 2017), the alluvial and lake plains, in addition to unfavorable geotechnical conditions, are also susceptible to flooding. The main eventual crossing over water courses refers to the Doce River, with stretches that exceed 1 km in length. It is important to note that three gas pipelines and one oil pipeline already cross the Doce River.

The study area overlaps with 189 mining processes registered with ANM. Processes of authorization and research request, mining request and permission for the exploration of sand, potassium salts, among other substances, predominate, in addition to several blocks in availability. There is only one process in the mining concession phase for the exploration of clay. It is worth noting the concentration of marine mining processes for the exploration of potassium salts in the study area.

The study area includes some exploration blocks and natural gas production fields, according to Figure 17. Therefore, when defining the gas pipeline final route, it is necessary to pay attention to the production and outflow equipment from the existing natural gas fields in the region.

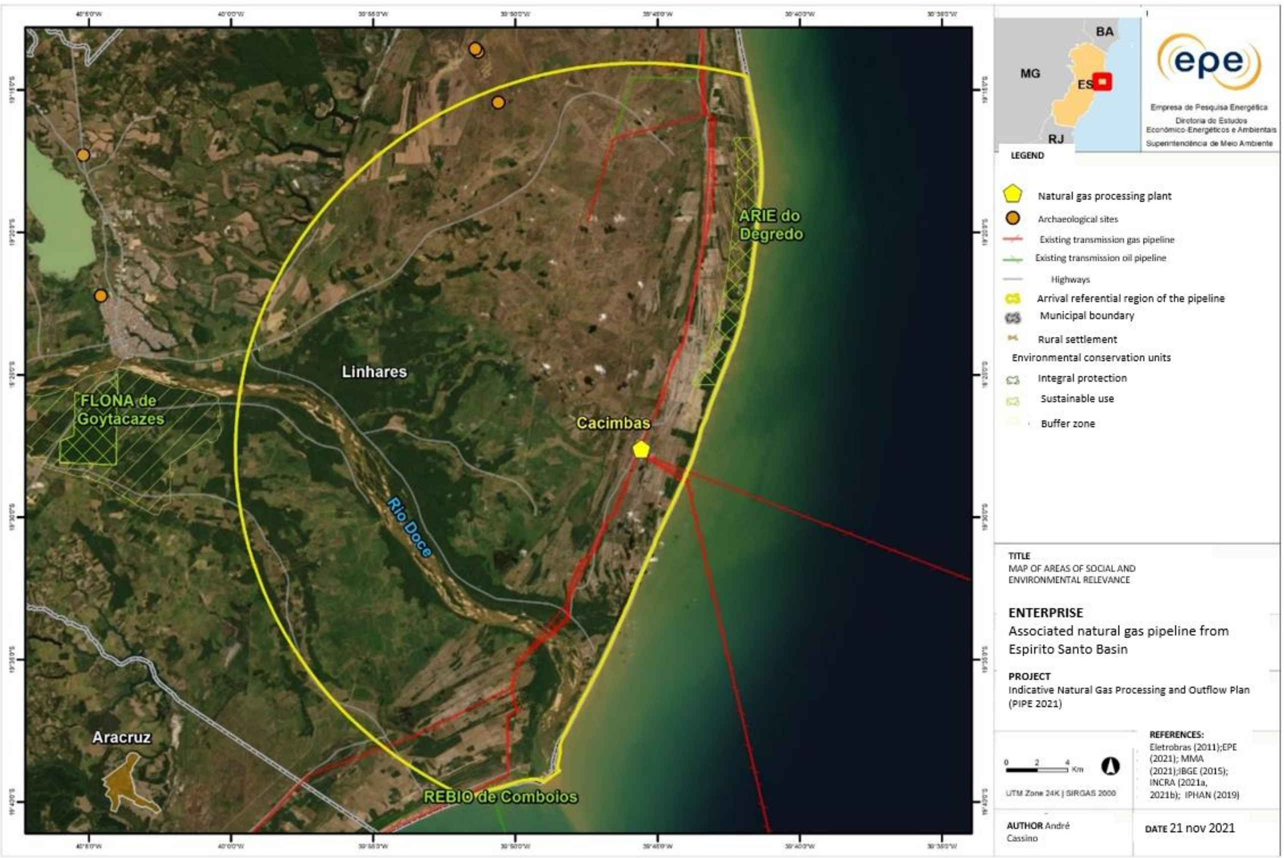

Figure 17. Areas of Socioenvironmental relevance in the arrival reference region of gas pipeline
Source: EPE.

5.3. Deep Water Non-Associated Gas (Sergipe-Alagoas Basin)

The deep water non-associated gas project analysis considered existing projects in the Sergipe-Alagoas Basin that are close to the BM-SEAL-4A block, with approximate geological characteristics and natural gas composition. This case assumed connecting the natural gas by an outflow gas pipeline to the coastline, where its processing would take place. In Figure 18 presents the project schematically.

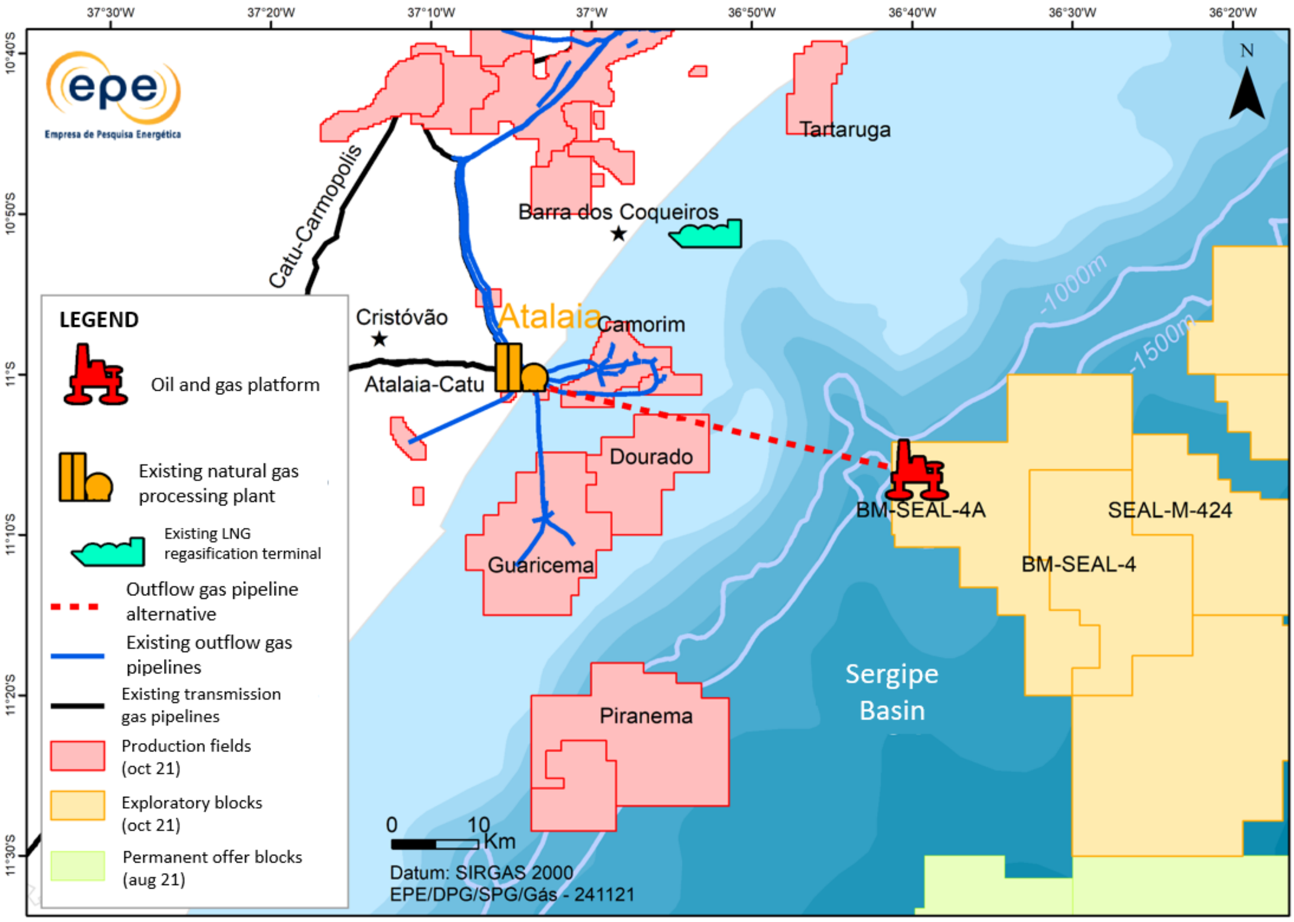

Figure 18. Deep Water Non-Associated Gas (Sergipe-Alagoas Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 2.83 million m³/day. The considered distance between the production platform and the NGPP was 50 km. This assumption resulted in a 50 km long and 12-inch diameter pipeline.

In the case of the NGPP, the additional capacity of 2.83 million m³/d could be established as a new NGPP, or as payment for third-party access to the NGPP of Atalaia/SE, by signing of a contract under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021). Cost estimation considered installation of a new NGPP, but the option of third-party access might be chosen by the market players, if it has a cost equal to or less than this alternative, and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flowrate, among others).

Table 10 shows a summary of the costs for this alternative.

Table 10. Outflow gas pipeline CAPEX for Deep Water Non-Associated Gas (Sergipe-Alagoas Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	113.7	34%
Construction and Assembly	137.4	41%
Indirect Costs		
Engineering Project	28.6	9%
Insurance and Certification	11.2	3%
Contingencies	43.6	13%
TOTAL INVESTMENT (reference date Jun/21)	**334.6**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.6 billion for the installation of a new NGPP. Optionally, the existing NGPP could process natural gas by execution of an agreement for third-party access if it is compatible with natural gas and the cost is feasible.

Socioenvironmental Analysis - Sergipe-Alagoas Basin (Deep Water)

This analysis consists of a characterization of the arrival reference region, in the onshore section of this outflow gas pipeline, considering physical environment aspects and the most relevant Socioenvironmental elements. For such characterization, a radius of 25 km was established around the gas processing hub of Atalaia/SE. The reference region for the gas pipeline arrival onshore covers eight municipalities in the Metropolitan Region of Aracajú and its surroundings, in areas with intense urbanization. Therefore, to build the gas pipeline, interference with those areas must be avoided or minimized at the time the route is defined.

There are 11 conservation units in the region interior, two of which are for full protection and nine for sustainable use, all with the possibility of detouring along the gas pipeline route. It is worth noting the presence of priority areas for spawning turtles along the entire coastline, with a base for the TAMAR Project at the Oceanário de Aracaju, on Atalaia beach. Therefore, adopting measures to avoid or mitigate impacts on fauna during the gas pipeline construction is necessary, if the project becomes feasible.

In addition to urban areas, pasture areas, agricultural crops and fragments of native Atlantic Forest vegetation show up in the reference region. The presence of the Sergipe and Vaza-Barris rivers’ mouths stands out.

The reference region covers eight rural settlement projects, three in São Cristóvão, three in Iporanga D’Ajuda, one in Santo Amaro das Brotas and one in Nossa Senhora do Socorro. There are also two quilombola territoriesin Aracajú and Laranjeiras. According to the georeference database provided by Iphan, there are 22 archaeological sites within the region. Also noteworthy are the presence of 22 caves in the municipalities of Laranjeiras (14), Nossa Senhora do Socorro (7) and São Cristóvão (1). It is necessary to avoid interference with archaeological sites and caves in order to build the gas pipeline,.

According to the database consulted, plateaus, plains and hills predominate (CPRM, 2010). The plains in the study area are very significant, they have flat slopes (0 to 3%) and correspond to marine, alluvial or lake sedimentary deposits with materials of different particle size and composition, suggesting geotechnical terrain complexity. The marine plains presuppose the prevalence of sandy materials, while the others present greater intercalation of sand, silt, clay and, occasionally, peat.

The tablelands have slopes that vary from smooth wavy (3 to 8%) to wavy (8 to 20%) and correspond to flattened surfaces developed on sedimentary rocks, sometimes presenting degrees of relief dissection depending on the drainage. The study area presents a complex of channels, lakes and rivers, indicating greater constructive complexity for the implementation of gas pipelines.

The area overlaps with 208 mining processes registered with ANM. Research authorization processes, research requests and mining requests predominate for the exploration of sand, clays, mineral water, limestone and potassium salts, among other substances, in addition to several blocks in availability. There are 36 processes in the mining concession phase, mainly for the exploration of mineral water, clay and limestone.

There are 13 oil production fields in the study area, seven in operation and six in return. Therefore, when defining the gas pipeline final route, it is necessary to pay attention to the production and outflow equipment of the natural gas fields existing in the region, according to Figure 19.

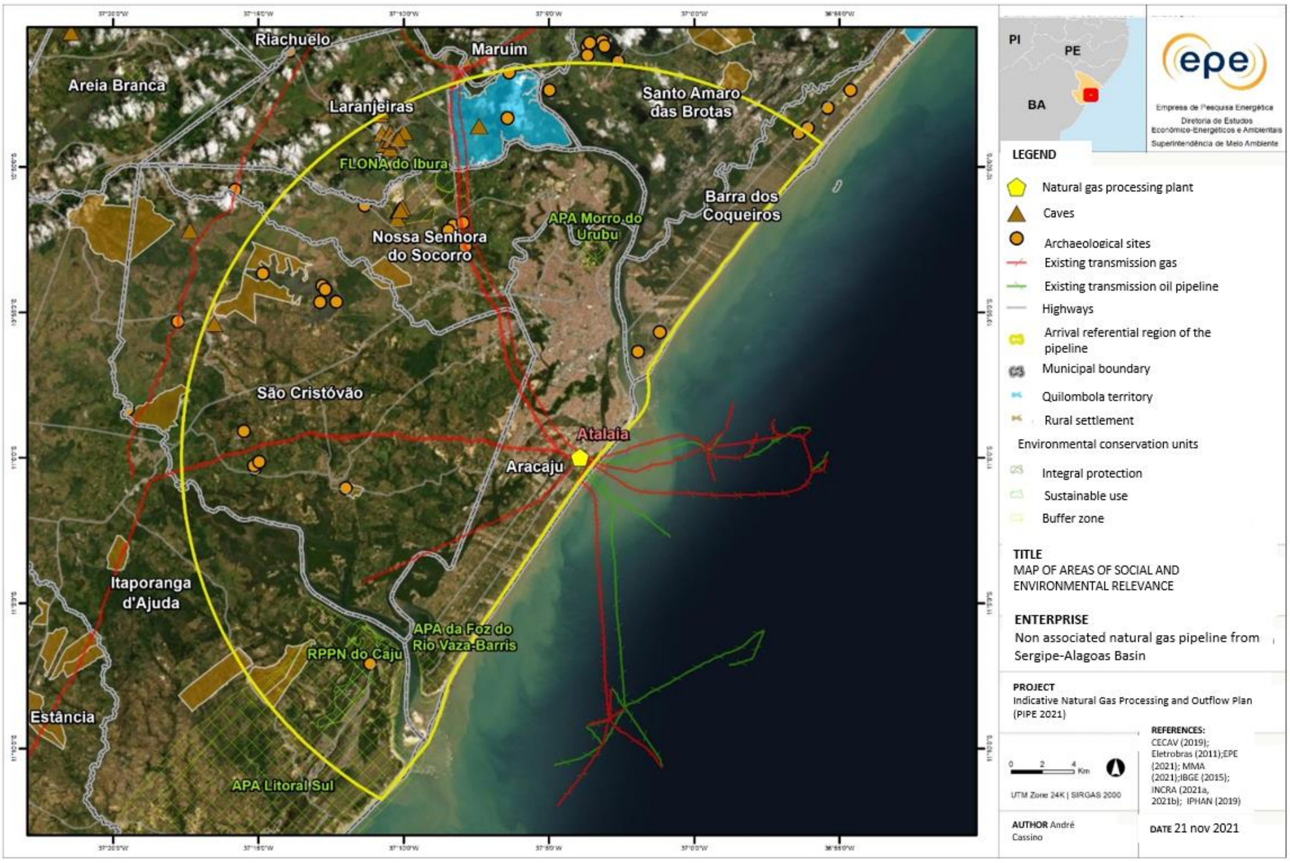

Figure 19. Areas of Socioenvironmental relevance in the arrival reference region of gas pipeline
Source: EPE.

5.4. Associated Gas Ultra-Deep Water (Campos Basin)

The basis for the ultra-deep water associated gas project analysis considered existing projects in the Campos Basin that are close to the Frade field, with approximate geological characteristics and natural gas composition. This case assumed connecting the natural gas by an outflow pipeline to the existing outflow gas pipeline network to the coast, where its processing would take place. In Figure 20 presents the project schematically.

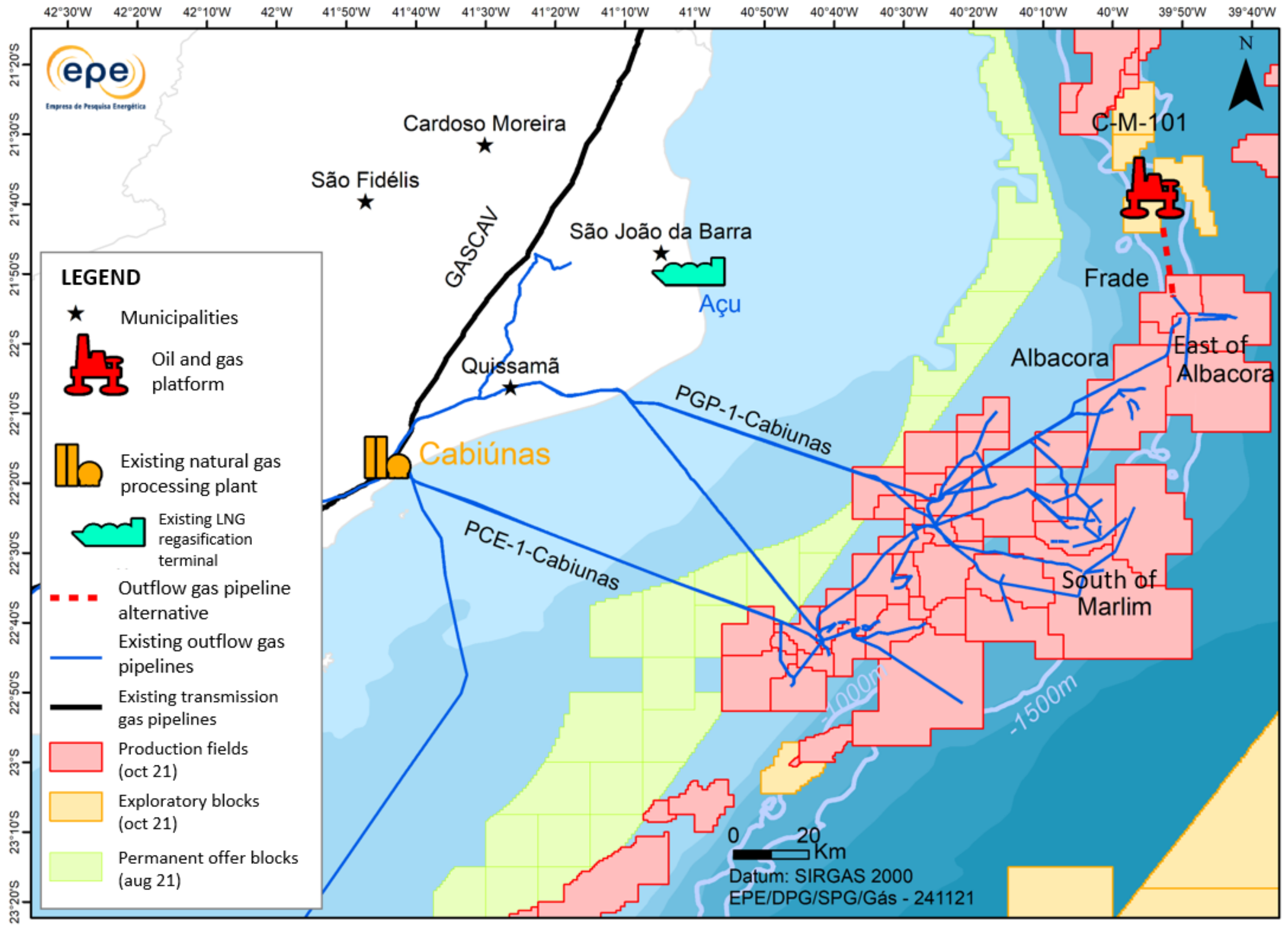

Figure 20. Associated Gas Ultra-Deep Water (Campos Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 235 thousand m³/day. The considered distance between the production platform and the existing outflow gas pipelines network was 14 km. This assumption resulted in a 14 km long and 3-inch diameter pipeline.

In the case of the NGPP, it is possible to establish an additional 235 thousand m³/d capacity as payment for third-party access to the NGPP of Cabiúnas/RJ, by signing of a contract under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021). Cost estimation considered installation of a new NGPP, but the option of third-party access might be chosen by the market players, if it has a cost equal to or less than this alternative, and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others). Table 11 shows a summary of the costs for this alternative.

Table 11. Outflow gas pipeline CAPEX for Ultra-Deep Water Associated Gas (Campos Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	30.8	24%
Construction and Assembly	58.9	46%
Indirect Costs		
Engineering Project	16.8	13%
Insurance and Certification	4.3	3%
Contingencies	16.6	13%
TOTAL INVESTMENT (reference date Jun/21)	**127.4**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.1 billion for the installation of a new NGPP. Optionally, the existing NGPP could process natural gas by execution of an agreement for third-party access if it is compatible with natural gas and the cost is feasible.

Socioenvironmental Analysis - Campos Basin (Ultra Deep Water)

This project included no socioenvironmental analysis, because the gas pipeline in question was not connected to the coast. As assessed, the Ultra-Deep Water Associated Gas alternative (Campos Basin) connects to the existing production collection and outflow system, in the vicinity of Frade and Albacora. Subsequently, the collected volumes go to the coast through existing outflow gas pipelines, whose socioenvironmental analyses, regarding their arrival route at the coast, were already carried out and approved.

5.5. Non-Associated Gas Ultra-Deep Water (Espirito Santo Basin)

The ultra-deep water non-associated gas project analysis considered existing projects in the Espírito Santo Basin that are close to the Canapu field, with approximate geological characteristics and natural gas composition. This case assumed connecting the natural gas by an outflow pipeline to the existing outflow gas pipeline network to the coast, where its processing would take place. Figure 21 presents the project schematically.

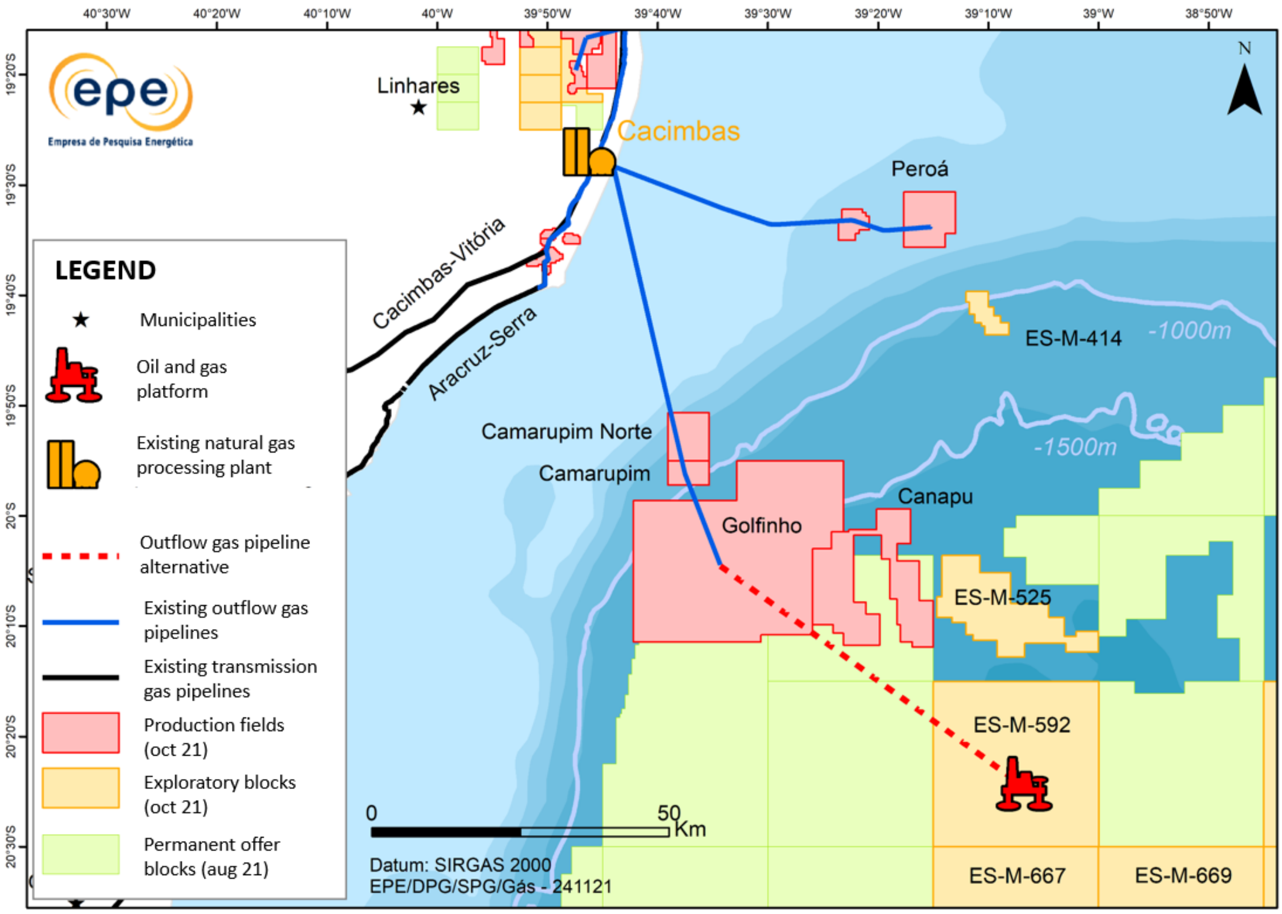

Figure 21. Non-Associated Gas Ultra-Deep Water (Espirito Santo Basin)
Source: EPE.

Due to the similarity with existing fields, the chosen natural gas flow rate was an average of 1.82 million m³/day. The considered distance between the production platform and the existing outflow gas pipeline network was 65 km. This assumption resulted in a 65 km long and 10-inch diameter pipeline.

In the case of the NGPP, it is possible to establish an additional 2.83 million m³/d capacity as payment for third-party access to the NGPP of Cacimbas/ES, by signing of a contract under the auspices of the New Gas Law (Article 28 of Law Number 14,134/2021, and Article 16 of Decree Number 10,712/2021). Cost estimation considered installation of a new NGPP, but the option of third-party access might be chosen by the market players, if it has a cost equal to or less than this alternative, and if the access conditions are satisfactorily met (composition of natural gas, pressure, variations in flow rate, among others).

Table 12 shows a summary of the costs for this alternative.

Table 12. Outflow gas pipeline CAPEX for Ultra-Deep Water Non-Associated Gas (Espírito Santo Basin)

Description	BRL million	
Direct Costs		
Materials and Equipment	112.0	31%
Construction and Assembly	155.6	43%
Indirect Costs		
Engineering Project	33.1	9%
Insurance and Certification	12.0	3%
Contingencies	46.9	13%
TOTAL INVESTMENT (reference date Jun/21)	**359.7**	**100%**

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

Considering the NGPP with Turboexpansion technology, the CAPEX estimate was around BRL 1.4 billion for the installation of a new NGPP. Optionally, the existing NGPP could process natural gas by execution of an agreement for third-party access if it is compatible with natural gas and the cost is feasible.

Socioenvironmental Analysis - Espírito Santo Basin (Ultra-Deep Water)

This project included no socioenvironmental analysis, because the gas pipeline in question was not connected to the coast. As assessed, the Ultra-Deep Water Non-Associated Gas alternative (Espírito Santo Basin) connects to the existing Camarupim/NGPP Cacimbas outflow gas pipeline, whose socioenvironmental analyses, regarding their arrival route at the coast, were already carried out and approved.

6. Offshore Hub Analysis

The offshore hub analysis was carried out with the assumption that they would be composed of platforms with a compression capacity for 20 million m³/day of natural gas, connected to outflow gas pipelines equipped with waiting valves along their length, allowing for future connection of various projects. At their ends, it is possible to connect the outflow gas pipelines initially to existing outflow gas pipeline network or to projects further away from the defined compression plants.

6.1. Campos Basin Hub

The hub in Campos Basin analysis considered existing projects in this Basin, with approximate geological characteristics and composition of natural gas. In this case, it was considered that the natural gas is collected from several nearby projects through an outflow gas pipeline, brought to the platform, processed in a primary way, compressed, and redirected to the existing outflow gas pipeline network. Figure 22 presents the project schematically.

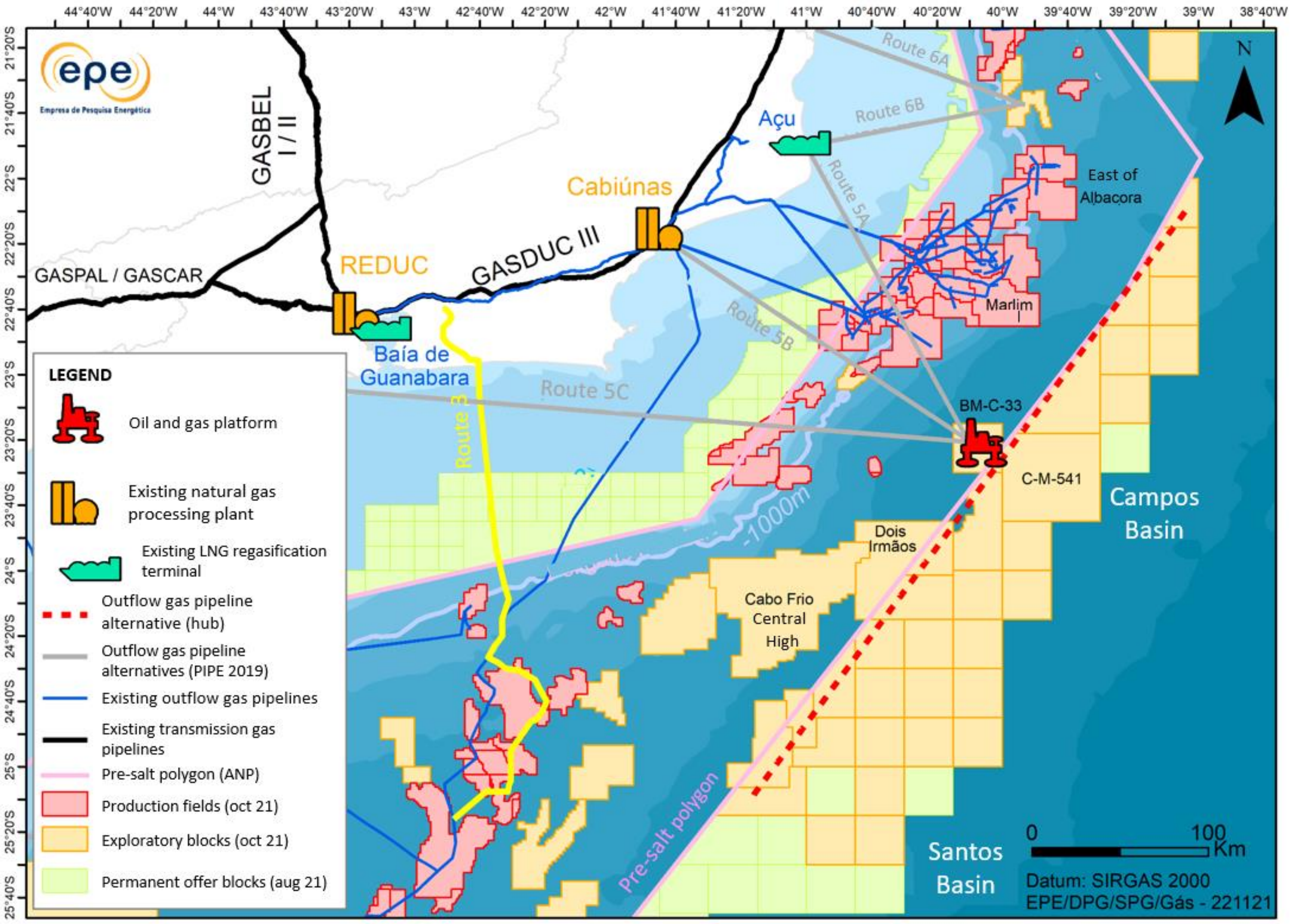

Figure 22. Map of the Campos Basin Hub
Source: EPE.

The considered length for the outflow gas pipelines connected to the platform was 415 km, resulting in a 415 km long and 28-inch diameter pipeline. Table shows a summary of the costs for this alternative.

Table 13. Outflow gas pipeline CAPEX to the Campos Basin Hub

Description	BRL million	
Direct Costs		
Materials and Equipment	1934.4	48%
Construction and Assembly	1297.4	32%
Indirect Costs		
Engineering Project	116.8	3%
Insurance and Certification	133.9	3%
Contingencies	522.4	13%
TOTAL INVESTMENT (reference date Jun/21)	**4005.0**	**100%**

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

The estimated additional CAPEX related to the installation of a new platform for the compression and redirection of 20 million m³/day of natural gas was BRL 4.9 billion. Processing of natural gas in existing NGPPs with available processing capacity was considered, with this hub responsible only for the outflow and natural gas flow management between the pipelines connected to it.

Socioenvironmental Analysis – Campos Basin Hub

This project included no socioenvironmental analysis, because the gas pipeline in question was not connected to the coast. The hub is a system of production collection from several producing areas with the objective of subsequent outflow through a route to be defined by the interested parties (Routes 5A, 5B or 5C, already presented in PIPE 2019 or defined by the players).

6.2. Espírito Santo Basin Hub

The hub in Espírito Santo Basin considered existing projects in this Basin, with approximate geological characteristics and composition of natural gas. In this case, it was considered that the natural gas is collected from several nearby projects through an outflow gas pipeline, brought to the platform, processed in a primary way, compressed, and redirected between the existing outflow gas network in the Campos Basin and in the Espírito Santo Basin. Figure 23 presents the project schematically.

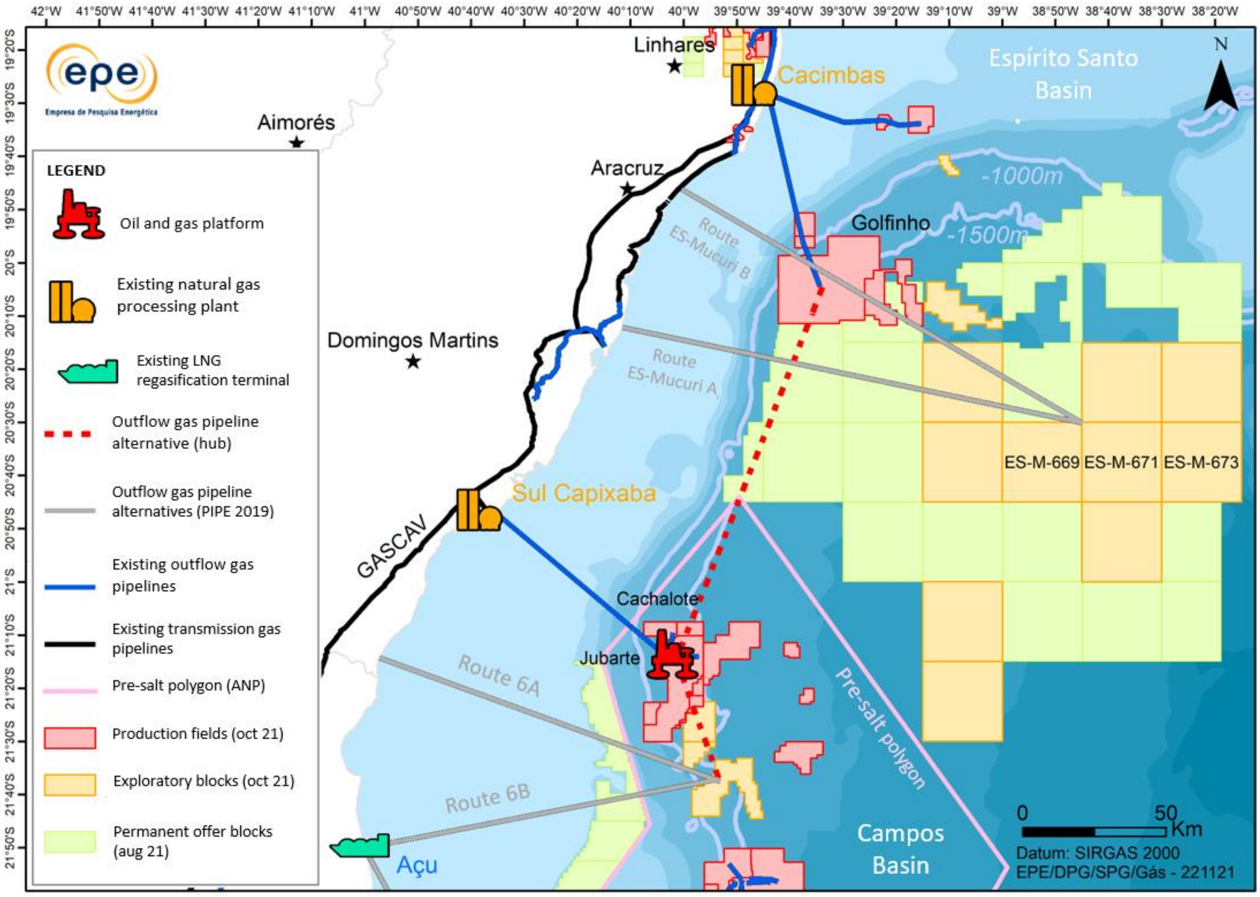

Figure 23. Map of the Espírito Santo Basin Hub
Source: EPE.

The considered length for the outflow gas pipelines connected to the compression platform and used to collect the natural gas was 182 km, resulting in a 182 km long and 28-inch diameter pipeline. Table 14 shows a summary of the costs for this alternative.

Table 14. Outflow gas pipeline CAPEX to the Espírito Santo Basin Hub

Description	BRL million	
Direct Costs		
Materials and Equipment	968.2	46%
Construction and Assembly	728.3	34%
Indirect Costs		
Engineering Project	68.9	3%
Insurance and Certification	70.6	3%
Contingencies	275.4	13%
TOTAL INVESTMENT (reference date Jun/21)	**2111.4**	**100%**

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

The estimated additional CAPEX related to the installation of a new platform for the compression and redirection of 20 million m³/day of natural gas was BRL 4.7 billion. Processing of natural gas in existing NGPPs with available processing capacity was considered, with this hub responsible only for the outflow and natural gas flow management between the pipelines connected to it.

Socioenvironmental Analysis – Espírito Santo Basin Hub

This project included no Socioenvironmental analysis, because the gas pipeline in question was not connected to the coast. The hub is a system for collecting productions from producing areas with the objective of allowing the movement of gas between basins as well as allowing for different points of arrival onshore. It was considered that the subsequent outflow could be carried out through a route to be defined by the interested parties (Route 6A or 6Balready presented in PIPE 2019 or defined by the players) or along the Camarupim/NGPP Cacimbas outflow gas pipeline, whose Socioenvironmental analysis regarding their arrival route at the coast were already carried out and approved.

6.3. Sergipe-Alagoas Basin Hub

The hub in Sergipe-Alagoas Basin considered existing projects in this Basin, with approximate geological characteristics and composition of natural gas. In this case, it was considered that the natural gas is collected from several nearby projects through an outflow gas pipeline, brought to the platform, processed in a primary way, compressed, and redirected to the existing outflow gas pipeline network. Figure 24 presents the project schematically.

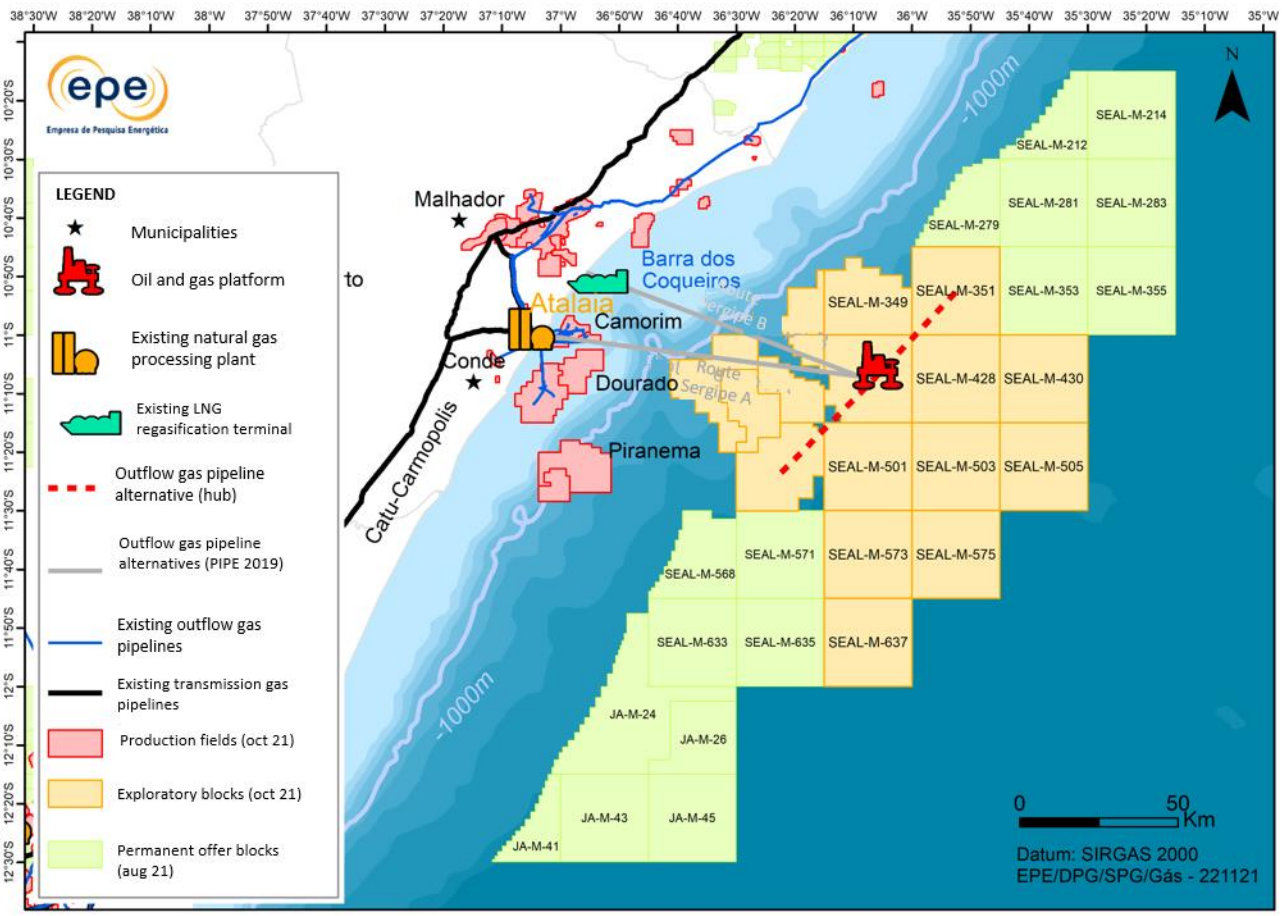

Figure 24. Sergipe-Alagoas Basin Hub
Source: EPE.

The considered length for the outflow gas pipelines connected to the compression platform and used to collect natural gas was 80 km, resulting in a 80 km long and 28 inch diameter pipeline. Table 15 shows a summary of the costs for this alternative.

Table 15. Outflow gas pipeline CAPEX to the Sergipe-Alagoas Basin Hub

Description	BRL million	
Direct Costs		
Materials and Equipment	408.8	46%
Construction and Assembly	292.0	33%
Indirect Costs		
Engineering Project	46.7	5%
Insurance and Certification	29.9	3%
Contingencies	116.6	13%
TOTAL INVESTMENT (reference date Jun/21)	**893.9**	**100%**

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

The estimated additional CAPEX related to the installation of a new platform for the compression and redirection of 20 million m³/day of natural gas was BRL 5.5 billion. Processing of natural gas in existing NGPPs with available processing capacity was considered, with the analyzed hub responsible only for the outflow and natural gas flow management between the gas pipelines connected to it.

Socioenvironmental Analysis – Sergipe-Alagoas Basin Hub

This project included no socioenvironmental analysis, because the gas pipeline in question was not connected to the coast. The hub is a system of collection of production from several producing areas with the objective of subsequent outflow through a route to be defined by the interested parties (Sergipe A and Sergipe B route, already presented in PIPE 2019 or defined by the players).

7. Results and discussion

As discussed in the document, this PIPE cycle studied a total of 1,562 km of outflow gas pipelines, accounting for 100 million m³/day of natural gas outflow capacity. The analyzed outflow gas pipeline projects add up to a total of BRL 11 billion in investments, while the NGPPs add up to about BRL 17 billion and the hubs add up to about BRL 15 billion that can be invested in the coming years in Brazil.

Table 16 briefly presents the projects studied, as well as their main technical characteristics and estimated costs.

Table 16. Summary of Projects analyzed in PIPE 2021

	Project	Length (km)	Diameter (pol)	Flow rate (MMm³/d)	Outflow gas pipeline CAPEX (BRL million)	NGPP or hub CAPEX (BRL million)
	Projects in Onshore Environment					
A	Onshore NG (Solimões Basin)	34	12	2.7	73.7	1561.8
B	Onshore GNA (Solimões Basin)	174	10	1.6	327.8	1331.3
C	Onshore GNA (Parnaíba Basin)	98	12	2.0	170.7	1,408.8
	Offshort Environment Projects (Pre-salt)					
D	NG in Pre-Salt (Campos Basin)	205	16	16.0	1,602.8	-
E	NG in tie-back 1 Pre-Salt (Santos Basin)	12	14	3.9	245.8	1,800.5
F	NG in tie-back 2 Pre-Salt (Santos Basin)	8	12	3.3	207.9	1,676.0
	Offshort Environment Projects (Post-salt)					
G	Coastal Sea GA (Camamu-Almada Basin)	35	3	0.2	110.3	1,046.1
H	Coastal Sea GNA (Camamu-Almada Basin)	70	20	7.0	445.5	2,439.0
I	Deep Water NG (Espírito Santo Basin)	65	8	1.3	313.8	1,268.1
J	Deep Water LNG (Sergipe-Alagoas Basin)	50	12	2.8	334.6	1,588.3
K	Ultra-Deep-Water NG (Campos Basin)	14	3	0.2	127.4	1,059.0
L	Ultra-Deep Water LNG (Espírito Santo Basin)	65	10	1.8	359.7	1,382.3
	Natural Gas Offshorte Hub Projects					
M	Hub in Campos Basin	415	28	20.0	4,005.0	4,879.2
N	Hub in the Espírito Santo Basin	182	28	20.0	2,111.4	4,673.8
O	Hub in the Sergipe-Alagoas Basin	80	28	20.0	893.9	5,464.2
	TOTAL	**1,562**	**N.A.**	**100.4**	**11,448.3**	**31,578.2**

Source: EPE.

Note: The letters in the first column refer to the approximate location of the alternatives on the map of Brazil.

The projects were analyzed to cover typical assumptions and characteristics for a specific exploratory environment, type of natural gas (associated or not with oil) and sedimentary basin, based on technical data from nearby producing fields, mainly those with the Development Executive Summary provided by the ANP website.

Therefore, it is important to emphasize that the characteristics of specific projects, once detailed by the players, can vary considerably. Also, as they used a methodology compatible with studies at the conceptual level, a variation of -50% to +100% in costs is expected after detailing phase, a range indicated by AACEI (2011) for this type of analysis.

Figure 25 shows the location of the projects studied in this document.

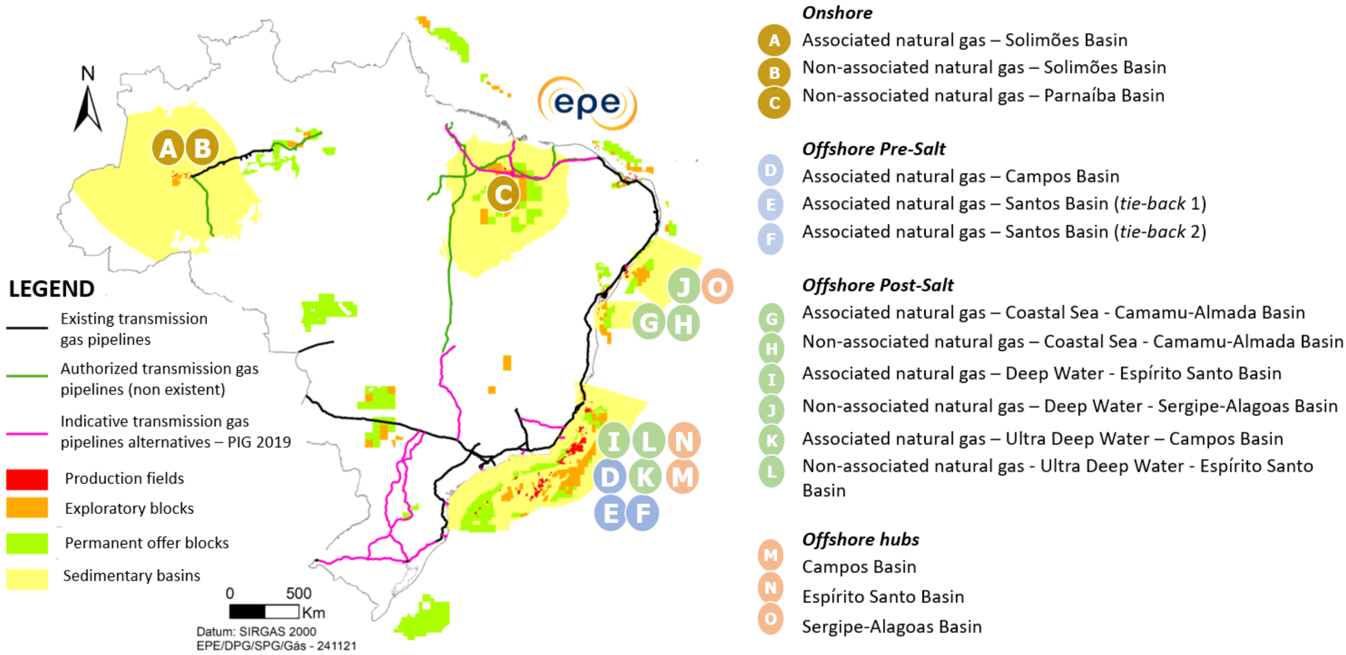

Figure 25. Map of the studied outflow gas pipeline alternatives
Source: EPE.

8. Projects updates

This section presents the main information published in the specialized media and on the companies' websites related to the projects analyzed in previous PIPE cycles.

It is necessary to consider that some of the alternatives assessed by EPE at a conceptual level, and indicated as opportunities in the Indicative Plans, may be detailed by the companies in different business models from those initially considered by EPE. These changes may be due to new information obtained during the projects detailing phase, due to change in market conditions that arise at the time of the basic project elaboration or construction of the alternatives, or due to new technologies or business models that prove to be more technically, economically and/or socioenvironmental advantageous.

Table 17 presents the projects analyzed in the previous PIPE cycle, as well as their main updates or similar projects described by the companies since then. In 2014, Cosan, through Rota 4 Participações S.A., filed a license application for Rota 4a with IBAMA. In 2019, the License/Authorization - ABio 1183/2019 was issued. The same company also filed the Route 4b permission process (proceeding nº 02001.037018/2019-09). This project has a 313 km long gas pipeline, 294 km of which are offshore and 19 km onshore, connecting the pre-salt production Santos Basin hub to Ilha da Madeira, in the Port of Itaguaí, in Rio de Janeiro. In addition to the gas pipeline, the project also considers the installation of a NGPP at the Port of Itaguaí facilities (EPBR, 2020).

Regarding the outflow gas pipeline from the Sergipe Basin, Petrobras, in its strategic plan, indicated the implementation of a new gas outflow system with a capacity of 18 million m³/day. However, this project is still in the planning phase and the expected start of operation will be after the year 2026 (PETROBRAS, 2021b).

Regarding the other NGPPs, the NGPP at the Macaé Port Terminal (TEPOR) already has a Preliminary License Number IN050584 with a processing capacity of up to 60 million m³/day.

As for the other projects, no progress was verified in the period. There was an advancement in the project related to the non-associated gas outflow system BM-C-33, object of study of PIPE 2021, with an outflow capacity of 16 million m³/day of gas and average flow estimated at 14 million m³/day (EQUINOR, 2021).

Table 17. Summary of Projects analyzed in PIPE 2019

Project		Initial Studies	Under Permitting Process*	FID	Under Construction
4a	Santos – Cubatão Basin/SP: Tracing 4a				
4b	Santos Basin – Itaguaí Port/RJ: Tracing 4b				
5a	Campos Basin – Do Açu Port/RJ: Tracing 5a				
5b	Campos Basin – TEPOR/RJ: Tracing 5b				
5c	Campos Basin - Itaguaí Port/RJ: Tracing 5c				
6a	Campos Basin- Central Port/ES: Tracing 6a				
6b	Campos Basin - Do Açu Port/RJ: Tracing 6b				
ESa	Espírito Santo-Mucuri Basin – Imetame Port/ES: ES-Mucuri-A Tracing				
ESb	Espírito Santo-Mucuri Basin – NGPP Cacimbas/ES: ES-Mucuri-B Tracing				
SEa	Sergipe-Alagoas Basin – NGPP Atalaia/SE: SEAL-A Tracing				
SEb	Sergipe-Alagoas Basin – Sergipe Port/SE: SEAL-B Tracing				

Source: EPE.

Notes:

*: Includes environmental permission processes for similar projects, for projects that share stretches or the entire right of way and expired environmental permission processes.

**: Final Investment Decision (FID) occurs when the developers confirm that the project has the technical, operational, commercial and financial conditions to advance to the development and construction phase.

9. Final remarks

When analyzing the projections for the expansion of natural gas production in the timeframe from 2021 to 2030, a new infrastructure for the outflow and processing of natural gas is needed to support the prospects of increasing domestic production in this period, especially those from the Santos, Campos, Solimões and Parnaíba basins. It is noteworthy that the outflow and processing capacity necessary for these expansions can be obtained by building gas pipelines or NGPPs or granting access to third parties, by means of a contract, if there is compatibility between the gases to be flowed/processed.

Another point worth mentioning is the recovery of economy after the Covid-19 pandemic, resulting in a possible mismatch between supply and demand for fuels in the short term. Thus, it is expected that this will reflect in the current prices and in the price projections of these commodities in the coming years, which reinforces the need to expand the gas outflow and processing infrastructure in domestic market.

Considering these factors, PIPE 2021 sought to map alternatives to present options to market players. In this edition of PIPE, production fields and exploratory blocks not yet served by outflow gas pipelines but with investment opportunities, as well as natural gas processing plants, were analyzed with the objective of contributing to the Brazilian natural gas infrastructure planning.

In this document, alternatives were analyzed in an onshore (both associated and non-associated) and in an offshore environment. Regarding offshore projects, they present a greater diversity of alternatives, as direct connections to the coast, connection to existing outflow infrastructures and, finally, offshore gas hubs capable of receiving, compressing, and redirecting natural gas flows between outflow systems or NGPPs connected to them. It is noteworthy that the projects evaluated considered typical assumptions and characteristics for a given exploratory environment, type of natural gas (associated or not) and sedimentary basin, based on technical data from nearby producing fields, especially the ones the ANP website provided the Executive Summary of Development Plans.

The projects assessed in PIPE 2021 cycle represent a total of 1,562 km of outflow gas pipelines, accounting for 100 million m³/day of natural gas outflow capacity and a total of BRL 11 billion in investments. The NGPPs, on the other hand, add up to around BRL 17 billion, while the hubs add up to around BRL 15 billion that can be invested in Brazil in the coming years. The projects analyzed in this edition of PIPE locate in six states of Brazil, namely: Amazonas and Maranhão for the onshore projects and Rio de Janeiro, Bahia, Espírito Santo and Sergipe for the offshore projects.

It is noteworthy that the investments from the market players will depend on the choice of route to be effectively built among the options mapped by EPE, with the alternatives presented in this edition of PIPE being subject to changes in favor of projects or business models that best adapt to the strategic decisions of natural gas producers regarding the monetization of produced volumes. Additionally, options such as injection to improve oil recovery, liquefaction, or offshore processing as well as gas-to-liquids (GTL) conversion technologies can also be part of the alternative scope for market players. It is also important to highlight that these infrastructures, as presented in this PIPE, in addition to the other options mentioned, can be built jointly or by independent companies with the objective of selling outflow and/or processing services to producers.

Finally, it is important to mention that small volumes characterize some of the analyzed projects, so that the costs related to their outflow and processing can be significant, due to the fixed portion of these costs. Such characteristic can impact the viability of these projects individually. However, this edition of PIPE shows that projects in this situation can use other mechanisms to monetize the gas. In this sense, it is possible to use the offshore gas monetization alternatives presented in EPE (2020c), through integrated projects to build the infrastructures in a shared way or, as already mentioned, there is the possibility of these smaller volumes access third-party infrastructure.

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