MINISTÉRIO DE MINAS E ENERGIA
SECRETARIA DE PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS

# PIPE

## Indicative Natural Gas Processing and Outflow Plan

Empresa de Pesquisa Energética

15 anos

MINISTÉRIO DE MINAS E ENERGIA

PÁTRIA AMADA BRASIL
GOVERNO FEDERAL

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## Indicative Natural Gas Processing and Outflow Plan

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# SUMMARY

# 1 INTRODUCTION

One of the great challenges pointed out for the monetization of natural gas reserves in Brazil, especially in the Pre-Salt areas, has been the lack of a broad infrastructure, as well as the difficulty of access to existing outflow and processing infrastructures. These infrastructures are necessary to provide the molecule to the market and to sell natural gas to consumers in different sectors. However, as their implementation costs are very high when compared to the use of existing facilities, in several countries around the world they are understood as essential facilities, being subject to specific regulations and with access being provided to third parties whenever possible.

In Brazil, the owners of these facilities are not yet obliged to provide access to third parties, although sharing can be provided through direct negotiation between the owner and the interested third party (MACHADO *et al.*, 2018). However, in the Cease and Desist Agreement ("TCC" for its acronym in Portuguese) between Petrobras and the Administrative Council for Economic Defense (CADE), Petrobras is committed, among other issues, to providing non-discriminatory negotiated access to the outflow gas pipelines and natural gas processing plants (NGPPs)[1] (PETROBRAS, 2019).

According to EPE estimates, the national net natural gas production is expected to increase from a volume of 59 million $m^3$/day in 2018 to 147 million $m^3$/day in 2030 (EPE, 2019), which represents an increase of about 6.6% p.a., as shown in Figure 1.1.

[1] According to the signed Cease and Desist Agreement (free translation),

"2.3. PETROBRAS undertakes to negotiate, in good faith and in a non-discriminatory manner, the third party access to the natural gas gathering systems, respected, in the cases where the systems have co-owners, the rules established for such systems.

2.4. PETROBRAS undertakes to negotiate, in good faith and in a non-discriminatory manner, the third-party access to the natural gas processing plants, observing the guidelines set out in Annex I - "Book of Good Practices for Natural Gas - Guidelines for Third Party Access to Natural Gas Processing Plant- NGPP", or even regulations to be edited by the ANP applicable to all agents in the sector. (…)

2.6. The SIGNATORY undertakes to publish a competitive process public notice for the lease of the Regasification Terminal of Todos os Santos Bay (...). The SIGNATORY further undertakes to publish the notice, to speed up the following stages of the process, known and monitored by the Monitoring Trustee".

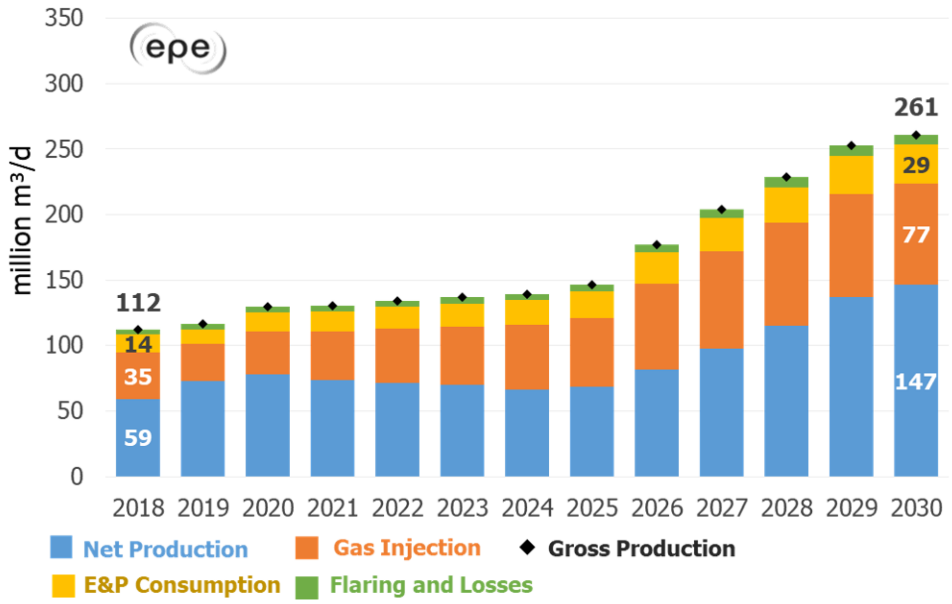



**Figure 1.1. Prospects for natural gas production in Brazil**

Source: EPE.

The main drivers for this growth forecast are the higher production in the Pre-Salt, in Santos and Campos Basins and in offshore fields on the coast of Espírito Santo and Sergipe, mainly in regions not yet served by gathering or outflow pipelines or NGPPs. Production may be even higher in other scenarios, depending on market conditions and portions of the volume of natural gas that can be sent to the coast after the injection to optimize oil recovery. Comparing the production prospects with the existing natural gas outflow capacity from the Pre-Salt (Routes 1, 2 and 3), it is observed that infrastructure expansion will be required from the year 2027, as shown in Figure 1.2.

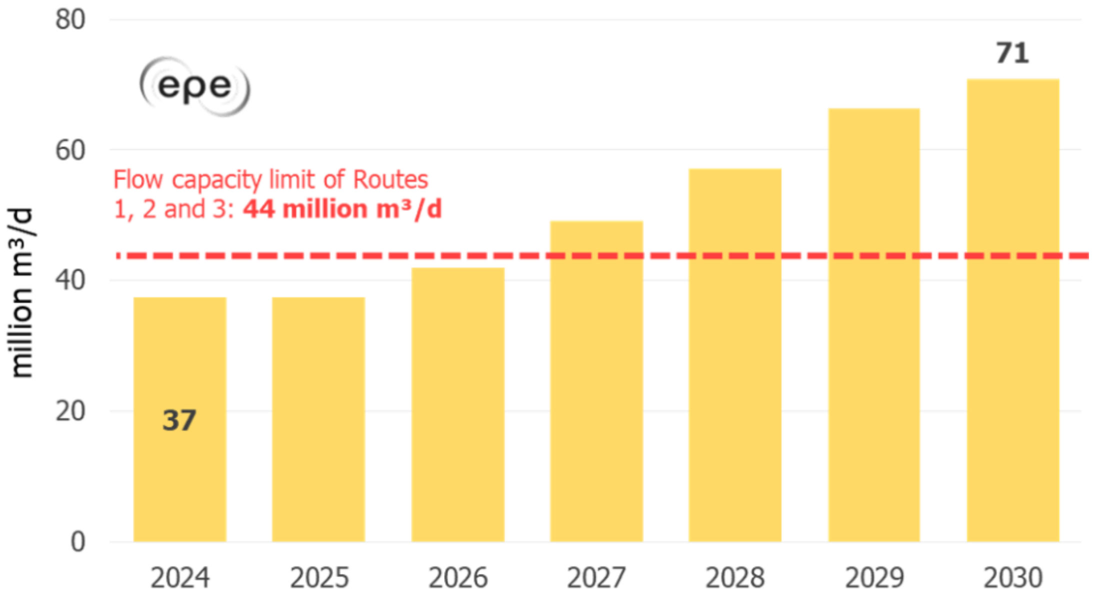



**Figure 1.2. Prospects for natural gas production in the Pre-Salt layer and existing outflow capacity**

Source: EPE.

Therefore, it may be necessary to install new natural gas processing and outflow infrastructures or to duplicate existing infrastructures for allowing the monetization of natural gas from these regions. Alternatively, the monetization of natural gas in these new fields may be carried out by means of offshore liquefaction projects (floating liquefied natural gas, FLNG) or Gas-to-Liquids (floating gas to liquids, FGTL). However, these solutions are more complex and depend a lot on the conditions of each specific field to become feasible, which makes the outflow and processing alternative the reference case in the monetization analyses at planning and projections level.

The Indicative Natural Gas Processing and Outflow Plan (PIPE) is a study carried out by EPE for society, as part of the duties described in Article 4 of Law No. 10,847/2004, item XII: “It is a task of EPE' (...) to prepare studies related to the master plan for the development of the natural gas industry in Brazil” (free translation). More specifically, PIPE seeks to present the analyses carried out by EPE regarding the processing plants and outflow gas pipelines that may be implemented in the coming years in Brazil, in an indicative way, based on supply and demand studies, in addition to technical-economic and socioenvironmental analyses.

Within the scope of the Gas to Grow Initiative and the discussions of the Technical Committee for the Development of the Natural Gas Industry in Brazil - CTGN, launched in December 2016 and whose work was carried out throughout 2017 and 2018, EPE participated in Subcommittee 1 giving important contributions regarding the provision of negotiated and non-discriminatory third-party access to processing plants, gas pipelines and LNG terminals, considered essential facilities in the natural gas sector.

Decree No. 9,616/2018 was published at the end of 2018, which changed the provisions of Decree 7,382/2010, among them the one that set forth that it would be up to EPE elaborating the expansion studies for the Brazilian transmission gas pipeline network, now considering the investment plans of the transmission companies, market information and the guidelines from the Ministry of Mines and Energy. In order to better carry out such studies, considering that new routes for the outflow of natural gas and NGPPs could provide gas supply for new transmission gas pipelines, EPE decided to elaborate the expansion studies for the network of gathering and outflow pipelines, as well as natural gas processing plants in Brazil, considering all these guidelines.

In 2019, the New Gas Market Program was created with the objective of evaluating the improvements needed to promote competition in the natural gas market (BRASIL, 2019). PIPE is fully aligned with this Program, with the objectives of improving the use of natural gas in Brazil, in addition to expanding investments in natural gas outflow and processing infrastructure, in LPG logistics and other products, among other facilities.

In this context, PIPE aims at presenting the planned and indicative outflow gas pipelines and NGPPs. It should be noted that, although outflow and processing projects are presented in this Plan, their feasibility must be analyzed and compared, by the market agents, with other monetization alternatives before the final investment decision.

Thus, this study is a planning tool for the natural gas sector, in addition to allowing a series of gains for market agents and society, namely:

- reduction in information asymmetry on net production potentials, processing capacity, socioenvironmental conditions and route proposals, contributing to the identification by the industry of opportunities for new gas pipelines and NGPPs that have not been detected in the current planning cycle;
- dissemination, in a transparent manner, of the evaluation criteria used for the preparation of this study;
- coordination of expectations and interests among agents of the natural gas industry aiming to promote investments in gathering or outflow pipelines and natural gas processing plants in the country.

This Plan is organized as follows: initially, it is presented a brief overview of the existing Brazilian natural gas outflow and processing infrastructure, planned and indicative. Then, the methodology used to choose the alternatives for expanding the outflow routes and further processing plants is discussed, as well as the technical, economic and socioenvironmental analyses which were carried out, and the description of the alternatives analyzed by EPE. The final chapters present the results of the study in a summarized form with general commentaries assessing the conditions that can influence its feasibility, as well as the prospects for implementing each project.

# 2 EXISTING, PLANNED AND INDICATIVE INFRASTRUCTURE

There are several planned and indicative natural gas outflow and processing projects in the country for the coming years, including the possible expansion of existing routes and also to new production frontiers. There may also be a need for new infrastructure when existing facilities do not attend the characteristics of the new streams that will be produced (for example, differences in composition or pressure), which entails new investments in outflow pipelines and NGPPs to allow access to the markets.

The outflow pipelines that are in operation and under construction related to the Santos Basin pre-salt fields comprise Routes 1, 2 and 3. Route 1, which connects the Santos Basin to Caraguatatuba (SP), has a capacity of 10 million m³/day and has recently undergone improvements in its outflow system, which allows it greater operational flexibility. Route 2 connects this Basin to Cabiúnas (RJ), with a capacity of 16 million m³/day. The expansion of this Route's capacity to up to 20 million m³/day was issued through ANP Authorization No. 468, dated June 28, 2019. Route 3, which is under construction, will connect the Santos Basin to Itaboraí (RJ), with a capacity of 18 million m³/day, scheduled for completion in 2020. Figure 2.1 shows the main outflow pipelines in operation and under construction in the Pre-Salt fields.

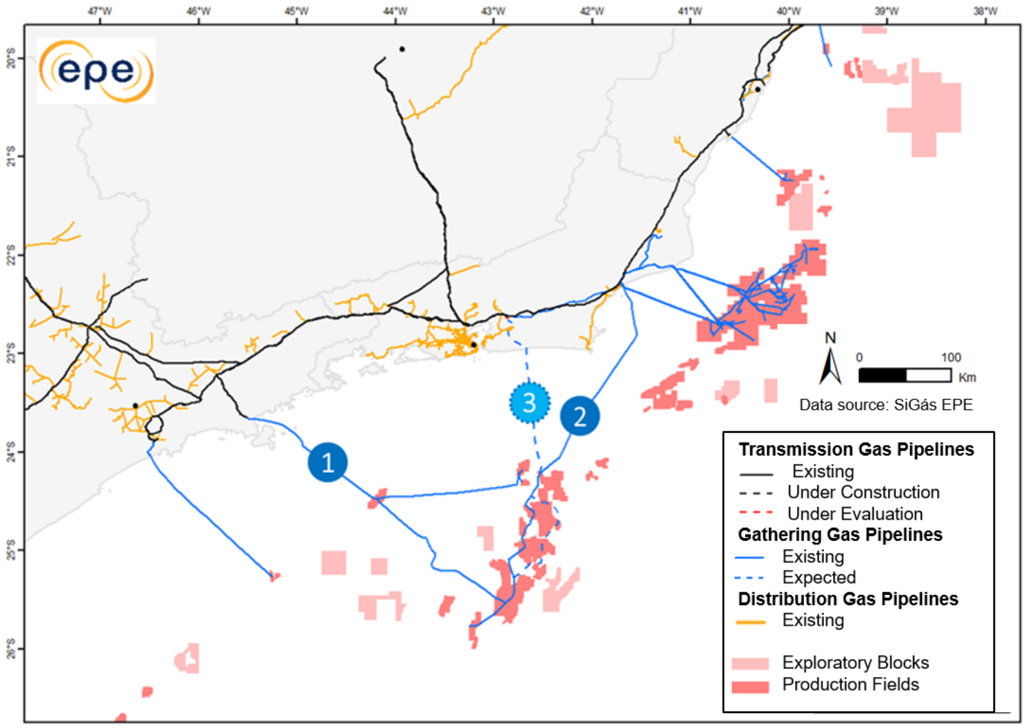



**Figure 2.1. Pre-salt outflow pipelines**

Source: EPE.

With regard to natural gas processing units, the NGPP in COMPERJ, in Itaboraí/RJ, is under construction, which will have a processing capacity of 21 million m³/day, scheduled for operation in 2021.

According to recent estimates, the net production of natural gas in the Pre-Salt is expected to increase from 37 to 71 million $m^3$/day between 2024 and 2030, respectively. Since the outflow capacity limit of Routes 1, 2 and 3 is 44 million $m^3$/day and that the net production forecast in 2027 exceeds this value, as shown in Figure 1.2, there is a need to expand the outflow infrastructure in the pre-salt. Regarding the net offshore production of natural gas in the Sergipe-Alagoas Basin, a significant increase is expected from 0.6 million $m^3$/ day in 2024 to 32 million $m^3$/day in 2030, which also indicates the need to expand the gathering and outflow infrastructure of this Basin (EPE, 2019).

This Plan involves the study of alternative outflow pipelines and NGPPs in the Pre-Salt area, in the Santos and Campos Basins and in the Post-Salt area, in the ES-Mucuri and SEAL Basins, which will be illustrated below. It is important to point out that, regarding oil and natural gas fields in which production has not yet started, the final investment decision (FID) for the construction of outflow and processing infrastructures depends on more detailed technical and economic feasibility analyses in addition to the occupation scheduled for Routes 1, 2 and 3 at the time of the beginning of production in these fields.

In the pre-salt area, there are blocks in the exploration phase and fields in production phase close to the existing infrastructure, in addition to some in regions farther from Routes 1, 2 and 3. In Figure 2.2, the indicative Pre-Salt Routes, selected for study in this Plan, are shown schematically: Route 4, subdivided into alternatives 4a and 4b; Route 5, with alternatives 5a, 5b and 5c and Route 6, with alternatives 6a and 6b.

In the post-salt environment, in turn, some blocks in the exploration phase can be highlighted with prospects for future production in the ES-Mucuri and Sergipe-Alagoas Basins, which indicate the need for outflow projects. In Figure 2.3 and Figure 2.4, these projects are presented schematically, and two alternatives were selected for the study of this Plan for each Basin: ES-Mucuri-A, ES-Mucuri-B, SEAL-A and SEAL-B. Each of these alternatives will be further detailed in the next sections of this document.

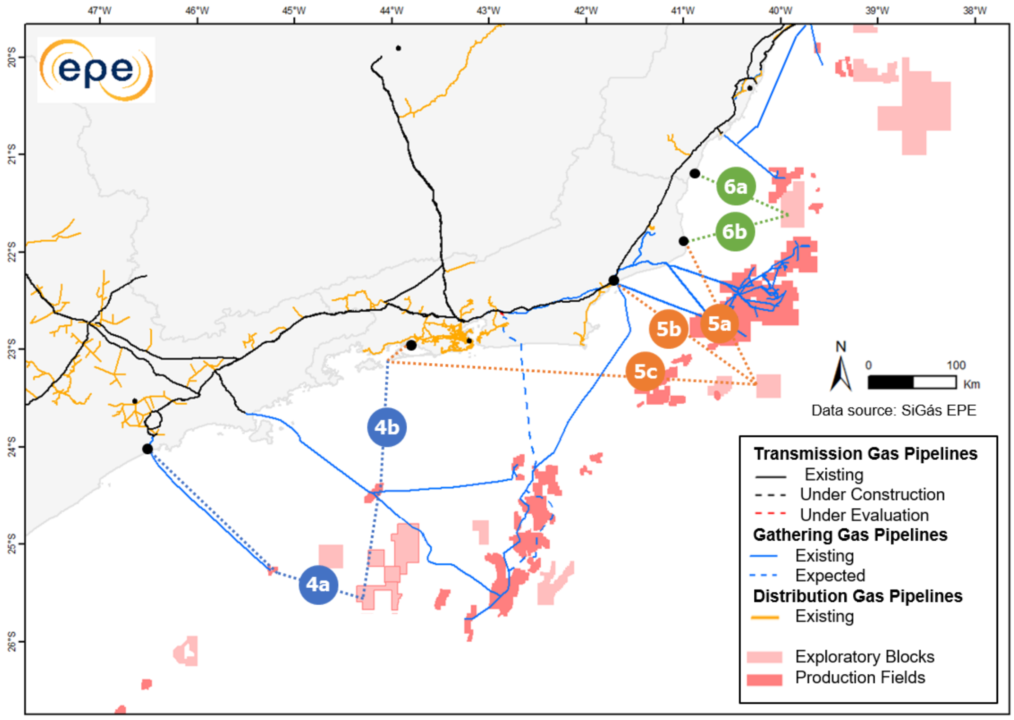



**Figure 2.2. Alternatives for outflow pipelines in the Santos and Campos Basins**
Source: EPE.

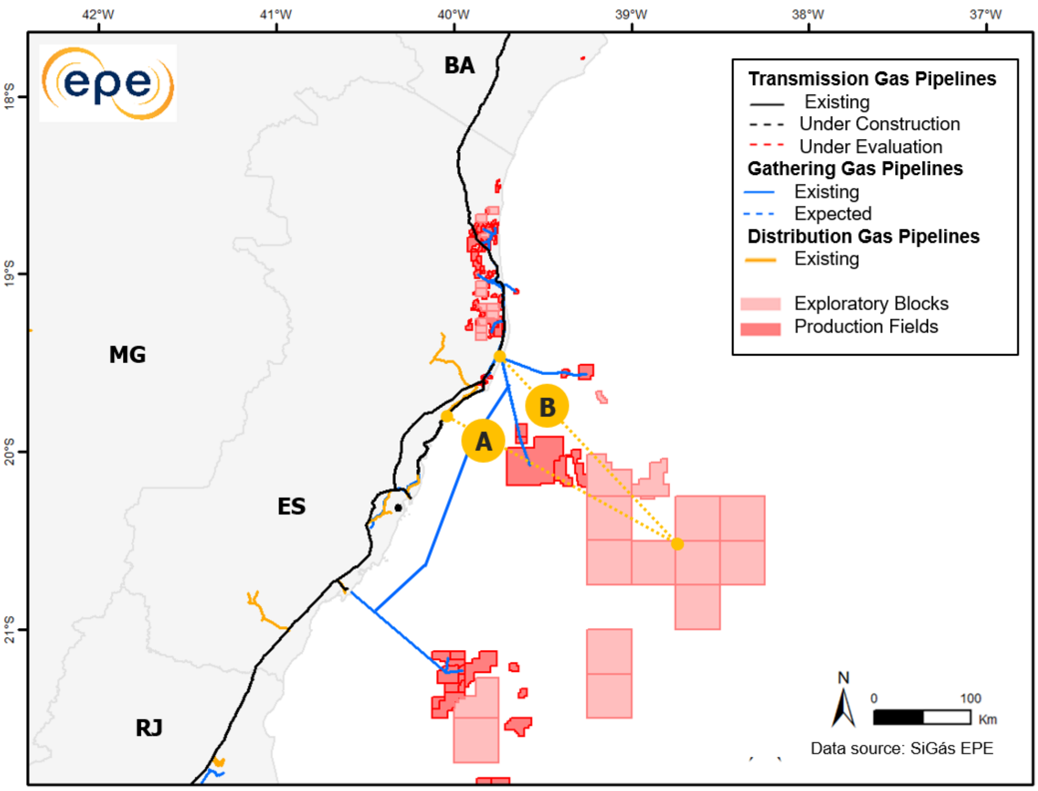



**Figure 2.3. Alternatives for outflow pipelines in the Espírito Santo-Mucuri Basin**
Source: EPE.

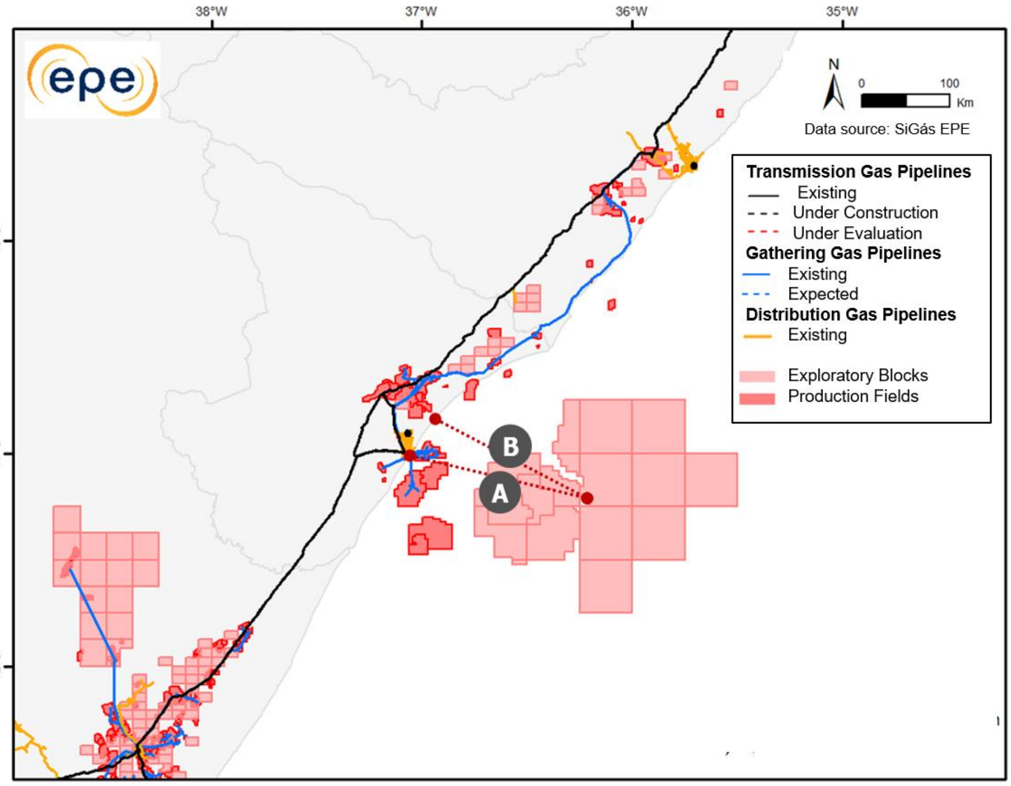



**Figure 2.4. Alternatives for outflow pipelines in the Sergipe-Alagoas Basin**
Source: EPE.

In the Espírito Santo-Mucuri and Sergipe-Alagoas Basins, there are several blocks in the exploration phase that constitute new frontiers, since the existing gathering and outflow infrastructure is located closer to the coast. Therefore, the will be a need for new gas pipelines with considerable extensions so that natural gas from future production fields can outflow to the coast. In the next sections, these 11 projects related to the pre-salt and post-salt geological horizons will be detailed, discussed and their respective investment estimates will also be presented.

Outside the pre-salt polygon, but still in deep waters, in the post-salt environment, there have been important discoveries since 2010 on the coast of the municipality of Barra dos Coqueiros/SE (PETRONOTÍCIAS, 2011). Block SEAL-M-426, operated by Petrobras, is located about 80 km from the coast, and has prospects for production in the Farfan, Barra and Muriú reservoirs, with the possibility of producing 100,000 barrels per day of oil and 8.5 $MMm^3/d$ of natural gas (EPBR, 2018).

The alternatives for indicative NGPPs considered in this Plan will be installed in the following locations: Cubatão/SP, Itaguaí Port/RJ, TEPOR/RJ, Açu Port/RJ and Central Port/RJ, in the Campos and Santos Basin; Imetame Port and NGPP Cacimbas, in the Espírito Santo-Mucuri Basin; and NGPP Atalaia and Sergipe Port in the Sergipe-Alagoas Basin. The NGPP in Itaboraí/RJ is expected to start operating in 2021. Figure 2.5 illustrates the alternatives for indicative and planned NGPPs.

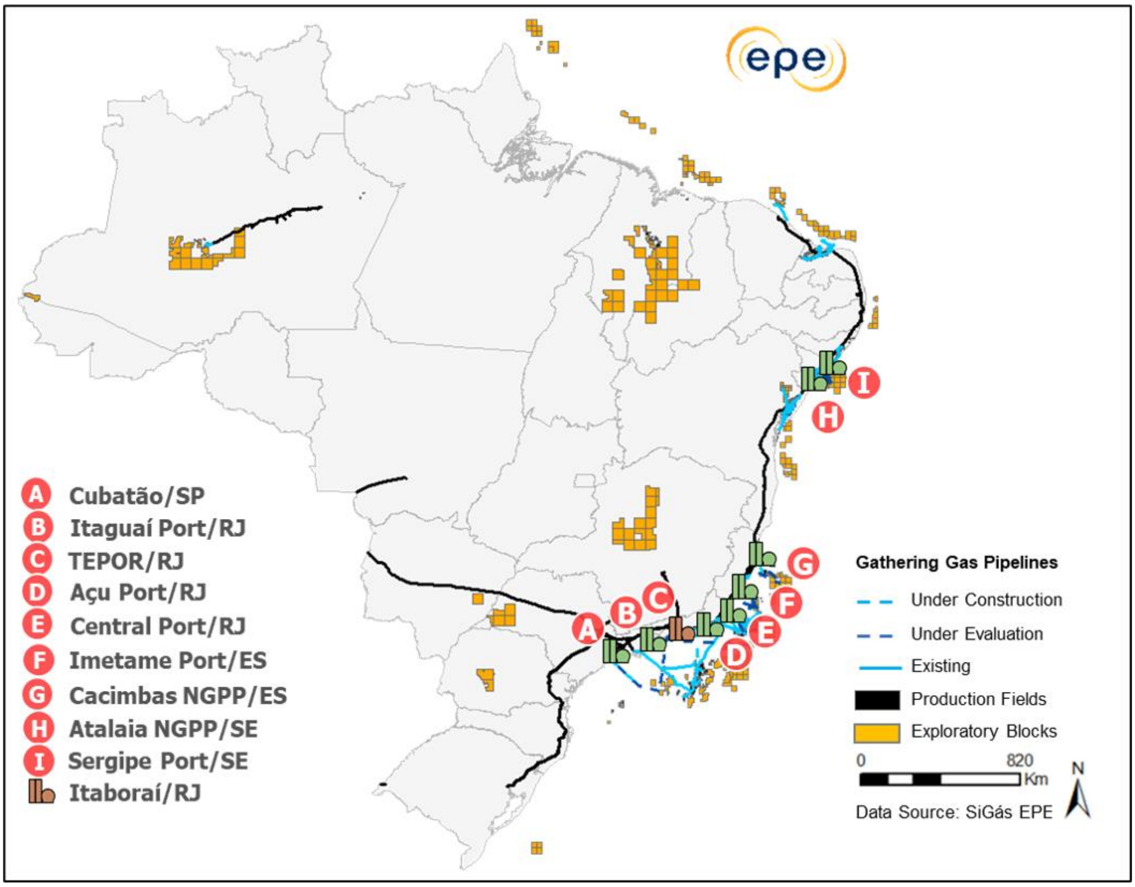



**Figure 2.5. Indicative and planned alternatives for NGPPs**

Source: EPE.

Some alternatives for adaptations and extensions to existing outflow pipelines were also observed in the present study, for cases in which the volumes of net natural gas production from the new fields did not, at first, allow the construction of new gathering and outflow infrastructures until the coastline. These alternatives were:

- interconnection between the Jubarte/ES and Roncador/RJ fields, promoting the connection of the existing gas pipelines in the Espírito Santo Basin and the Campos Basin, and allowing flow optimization between the two outflow pipeline networks;
- interconnection between the fields under development in SEAL Basin and the existing outflow infrastructure in Piranema/SE field, forming a connection that allows flow optimization in this location.

However, these alternatives were not detailed in terms of technical and economic aspects, since they would depend on several technical constraints of the existing facilities, in addition to the entrepreneurs' decision to carry them out, considering the technical, economic, and socioenvironmental criteria and the risk analyses.

# 3 ANALYSIS METHODOLOGY

In this section, the simplified analysis methodologies that were used to estimate the selected projects will be presented, considering the following themes: general characterization of the project, technical-economic feasibility analysis and socioenvironmental analysis. Figure 3.1 summarizes the steps of the methodology.

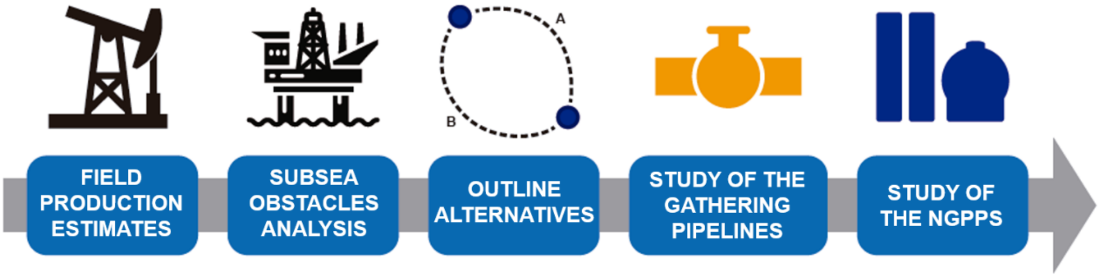



**Figure 3.1. Methodology for analyzing alternatives for expanding the natural gas outflow and processing infrastructure**

Source: EPE.

In the general characterization of the project, it will be addressed the definition of origin and destination, extension and capacity of the gas pipeline, as well as the availability of supply and potential demand and the analysis of the natural gas outflow and processing infrastructure. Regarding the analysis of the feasibility, the technical and economical characteristics of the project will be presented, as well as the capital costs estimated for the project. Finally, in the socioenvironmental analysis, the criteria used to define the outline will be presented in general, in addition to the indication of areas with submarine obstacles or environmental or social restrictions. The elements that must be observed in the subsequent environmental licensing process for each alternative by the entrepreneurs will also be indicated.

## 3.1 Technical Analysis Methodology

In this stage, there are defined the outlines of the gas pipelines to be studied, based on studies of net production, corresponding outflow capacity and information from the market and the investment plans of the companies. Then, the outflow pipeline is designed, which includes only the maritime stretch, being defining its diameter, wall thickness and other characteristics.

For the mechanical sizing of the outflow pipeline, an approximate altimetric profile was elaborated for the outflow pipeline guideline for each alternative. This profile can present high variations of elevation, which consequently causes pressure variations, internal and external, along the extension of the gas pipeline, which can also affect its flow rate. In order to minimize the cost of alternative outflow gas pipelines, the gas pipelines were divided into several segments that have different design pressures and minimum thicknesses required for these pressures. The division into segments was defined in order to minimize the number of different pipe thickness levels applied, since the use of pipelines with different thicknesses increases the cost of logistics to control the stock and increases the cost of the material, with lower economies of scale, on account of purchasing small quantities of each type of pipe. On the other hand, the use of just one thickness for the entire project would tend to increase the total cost, with over-sized thicknesses being used in some segments.

The calculation of the thickness of each segment of gas pipeline was based on the DNVGL-ST-F101 standard, October 2017 (DNV GL, 2017). It is important to note that the order of magnitude of the thickness of each segment of the subsea gas pipeline is only one part of a set of assessments that must be taken into account when designing the gas pipeline. In order to confirm the thickness of the gas pipeline, an analysis of the installation must be carried out using specific software, assuring that the gas pipeline can be installed with a minimum level of risk and with adequate schedule flexibility, considering the chosen installation methodology and the environmental conditions regarding the gas pipeline installation operation.

In all cases, a 1 km directional drilling was considered, carried out in the shore-approach segment, reaching a valve that would later be connected to the hypothetical NGPP. This methodology seeks to widely mitigate the social, environmental and economic impacts in the border region between the offshore and onshore stretches. In some cases, there were studied some alternatives for onshore segments to connect the shore approach segment to the NGPP. However, the costs of such onshore segments were not considered in the cost estimates, since this segment is short (considering the cases analyzed) and can be classified as a transmission, transfer or outflow pipeline, depending on the parameters adopted, the implementation of each project, and the location of the NGPP.

With regard to the composition of natural gas, a high richness in compounds heavier than methane was considered; notably, it was considered that the natural gas streams, after the separation of $CO_2$ carried out on the platforms, would have a content of about 10% ethane, 6% propane, 3% butane and 1% pentane and heavier, with 4% inerts (residual $CO_2$ and $N_2$). The sizing was also tested considering natural gas streams with less richness, however we arrived at the conclusion that the characteristics of the richest natural gas stream - compatible with the composition of the pre-salt natural gas - incurred in a project with greater robustness and that it also allows the outflow and processing of streams with less natural gas liquids, if necessary.

The indicative NGPPs of this plan are positioned at the final point of the outflow pipelines and are located both close to the coast and in the port areas, considering the specificities of each route. The indicative NGPPs located close to the coast can either be new NGPPs or the expansion of existing ones; however, for the purposes of cost estimation in this study, new NGPPs using turbo-expansion technology were considered, with standard layout according to EPE (2018a). The capacity estimate adopted for the indicative NGPPs was equivalent to the outflow pipelines flow rate.

## 3.2 Economic Analysis Methodology

In this stage, the investment costs of each alternative are estimated, both regarding the outflow pipelines and the indicative NGPPs.

With regard to the outflow pipelines, the studied projects were defined in a simplified way, considering the following premises: receipt of natural gas at the limit of the ring-fence[2], excluding costs with compressors and riser; the same diameter was used across the entire pipe; and there were included subsea features in terms of control equipment (2 PLEMs[3]) and derivation equipment (2 ILTs[4] and 1 Jumper[5]).

The costs for mobilization and demobilization, in addition to PLEMs, ILTs and Jumpers, were based on contracts already carried out in the country that are made public through the Petrobras transparency portal and the Electronic System of the Citizen Information Service (e-SIC). Piping costs were based on the Preston-Pipe data base. For the other items, cost data from the literature was used, as well as information from specialized consultants.

Costs related to land segments after shore approach were not included in the estimates, since in the cases studied, where these segments are small, they generally do not represent a large percentage of the total value of the projects; in addition, depending on the option for the specific location of the NGPP, the extensions of onshore segments may vary, as well as their costs. The date reference used for costs was June 2019.

Regarding the indicative NGPPs, the investment costs were also estimated in a simplified way, considering the inflow of natural gas with high richness in each NGPP (characteristic composition of offshore associated gas fields), and dimensioning of equipment for the maximum liquid content from this gas. The methodology for estimating NGPPs costs follows that described in EPE (2018a).

## 3.3 Socioenvironmental Analysis Methodology

The socioenvironmental analysis methodology considered maps and databases of several agents, such as the Navy and the Ministry of the Environment, to analyze and point out elements that should be considered in the future during the environmental licensing stage of each project, as well as demographic issues that could guide the choice of the best routes. In this sense, we sought to identify areas with potential presence of coral reefs close to the shore approach region, demographic aspects of the

[2] Ring Fence is the area around a field created with the objective of increasing the probability of discovering new producing fields in the asset.

[3] Pipeline End Manifold (PLEM) is a piece of equipment installed at the end of a pipeline stretch that allows controlling the flow of natural gas and stablishes the interconnection with other pipeline sections or other equipment.

[4] In-line tee (ILT) is a derivation installed in subsea pipelines for future connections with other facilities.

[5] The Jumper is used to connect equipment to rigid lines.

arrival at the coast, as well as subsea obstacles that could cause changes in the gas pipeline routes, in cases where there was potential interference.

However, as mentioned, these analyses of a socioenvironmental nature did not bring enough detailing that would allow observing all the aspects involved in the construction of the outflow pipelines and the NGPPs; therefore, they must be detailed at the moment of preparing the engineering projects and during the environmental licensing of each alternative that comes to fruition in the future.

# 4 DETAILING OF PRE-SALT PROJECTS

As already mentioned, the alternatives studied in the pre-salt environment include Routes 4a and 4b, in the Santos Basin, and Routes 5a, 5b, 5c, 6a and 6b, in the Campos Basin. It is observed that the feasibility of these Routes will depend mainly on the prospects for the production of natural gas and on the discoveries that may be made in the exploration blocks of both Basins, including the confirmation of the volumes and their declaration of commerciality. The cashflow of the project can benefit from the gains in scale that may occur in the sharing of infrastructure between future producing fields, including the possibility of concomitant construction of the two alternatives, if the two distinct regions shown on the map present considerable volumes of gas.

## 4.1 Santos Basin Pre-salt - Cubatão/SP: Route 4a

The Santos Basin - Cubatão/SP (Route 4a) alternative aims to outflow the raw natural gas produced in a Santos Basin cluster to an indicative NGPP, located in Cubatão/SP near Presidente Bernardes Refinery. The natural gas coming from this processing unit would have several possibilities for monetization, including interconnection to the transmission pipeline network through a future gas pipeline or meeting the demand of future thermoelectric power plants.

There are different alternatives for tracing the route 4a gas pipeline alternative. Regarding the offshore stretch of the gas pipeline on this route, the alternative that considers the direct connection to the coast has 10 km less in extension than the alternative that considers sharing part of the route with the Merluza gas pipeline. However, such an alternative that does not share the layout would require the passage through a marked depression in the sea floor in its intermediate portion, in addition to mooring areas (anchoring of ships) and crossing submerged optical fibers, which could present greater design complexity.

Figure 4.1 shows a sea chart of the region, where some of the offshore obstacles related to the lesser extension alternative can be observed: mooring areas, submerged optical fibers and a marine state park. These obstacles can possibly make the route shared with Merluza gas pipeline more advantageous.

Three alternatives were assessed for approaching the coast, which may also result in slight modifications at the end of the offshore segment for connection with the onshore segment. Regarding the onshore segment, the choice for the Route 4a outflow pipeline will depend on the technical, economic and socioenvironmental conditions of each alternative. In Figure 4.2, the alternatives identified for the onshore segment of the outflow pipeline are presented.

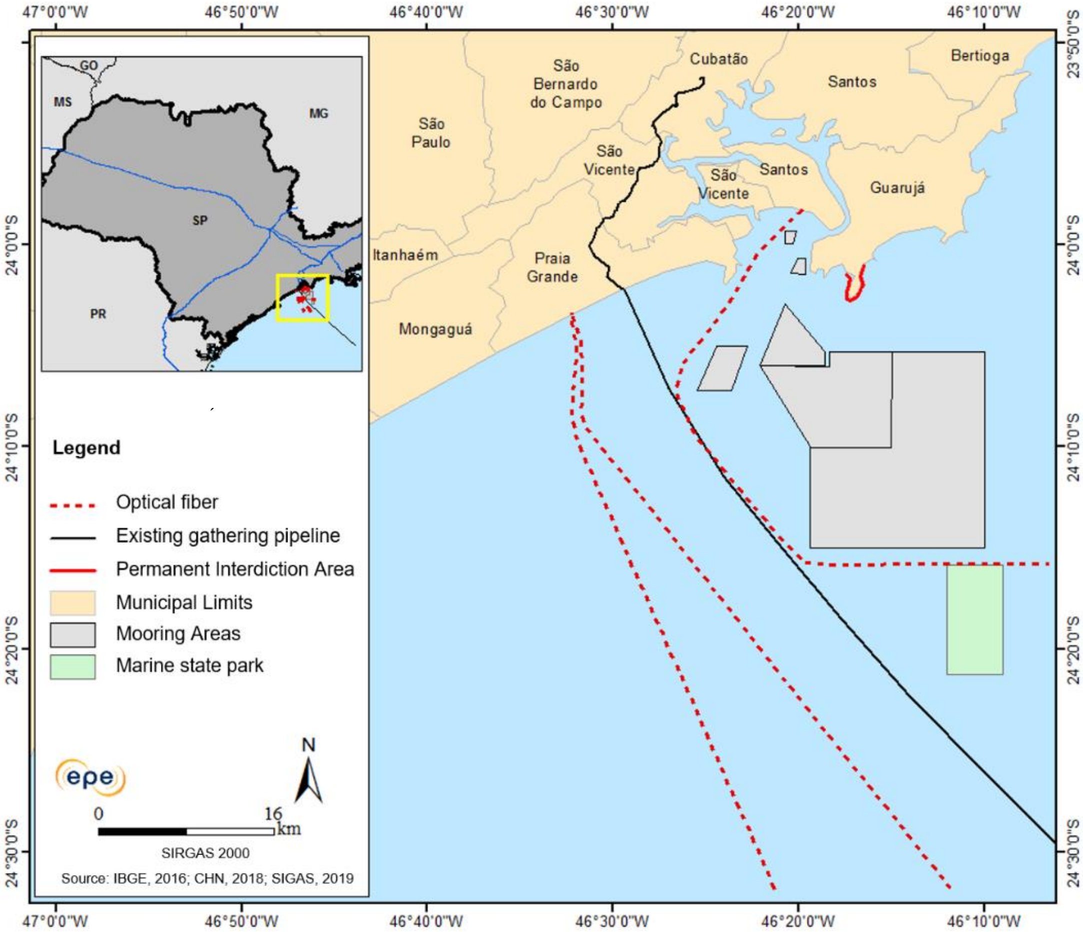



**Figure 4.1. Sea Chart for the Vicinities of the Santos Port**
Source: adapted from the Navy Hydrography Center (CHN, 2018).


**Figure 4.2. Alternatives for the onshore segment of Route 4a outflow pipeline**
Source: EPE.

The analysis of the proposed routes for the onshore stretch shows that there are opportunities to share the right-of-way with Merluza outflow gas pipeline. Although in this case there is an increase in the extension of the gas pipeline by about 5 km, the alternative can reduce the total cost associated with the purchase of the land, in addition to reducing the socioenvironmental impacts that could occur with the opening of a new right-of-way (and the risks associated with passing through areas with heavy traffic flow). However, as mentioned, the costs related to the onshore segment were not included in the cost estimate for this alternative, since this stretch can be considered a transfer, gathering or outflow gas pipeline, depending on the parameters adopted in the implementation. When comparing the two alternatives that do not share terrain with the Merluza gas pipeline, it is emphasized that there may be greater complexity in Environmental Licensing for the alternative that passes through the São Vicente Bay and São Vicente Lake and through mangrove regions.

Figure 4.3 illustrates the outflow and processing alternative for Route 4a, in which the exploration blocks, the producing fields and the existing infrastructure are shown. Some of the exploratory blocks, such as BM-S-9 and BM-S-8 (areas of Carcará and Norte de Carcará), may decide to connect to a NGPP in Cubatão if their volumes of natural gas make it feasible to build a new outflow Route and if the opportunity to share the right-of-way with Merluza gas pipeline is confirmed.

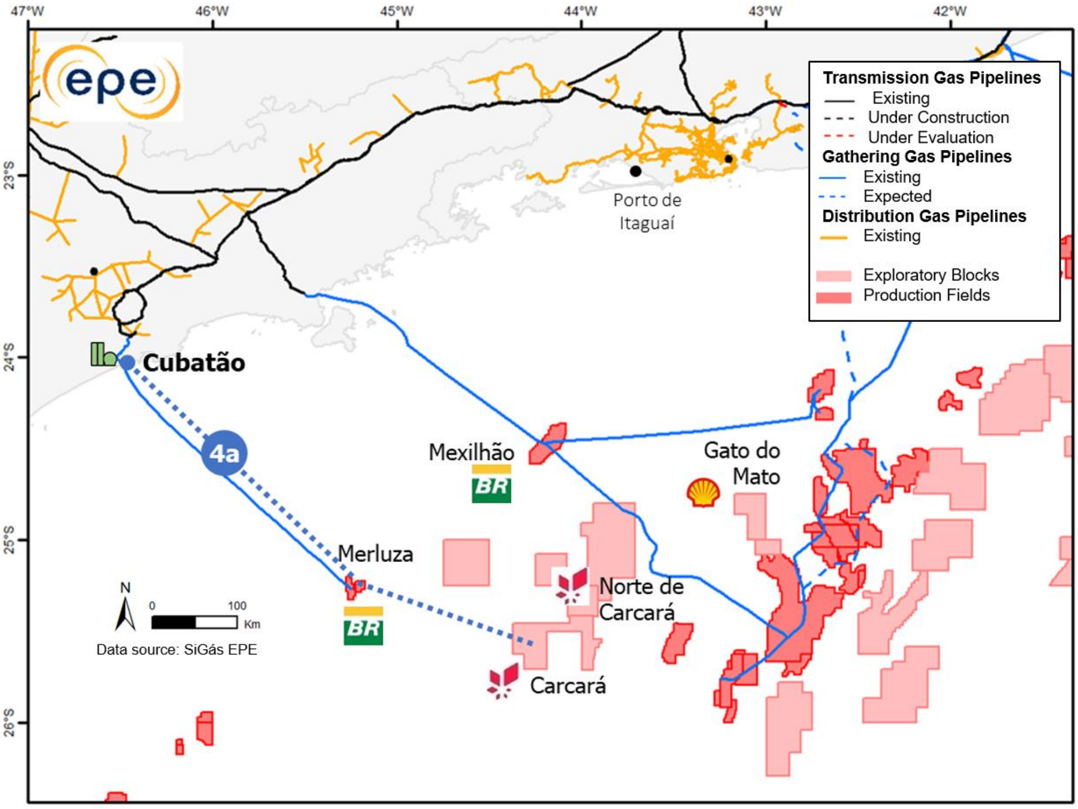



**Figure 4.3. Outflow and processing alternative for Route 4a**

Source: EPE.

Figure 4.4 presents the altimetric profile of guideline for the outflow pipeline of Route 4a, which indicated a total extension of 291 km for this alternative, including the onshore and offshore segments. The constructive data for the cost estimate of this gas pipeline is shown in Table 4.1.

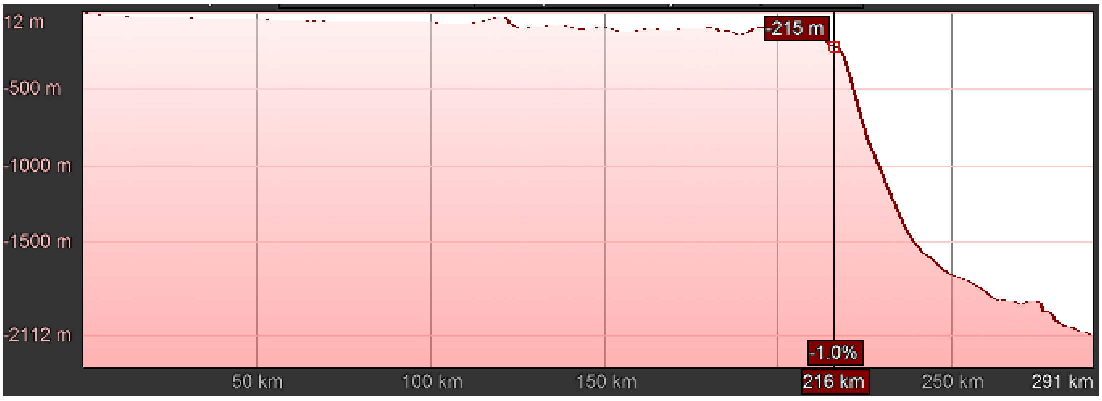



**Figure 4.4. Altimetric profile of guideline for the Route 4a outflow gas pipeline**
Source: EPE.

**Table 4.1. Construction data for the Route 4a outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 226 | 225 | 16.2 |
| Depth 300-1500m | Small S-Lay | 226 | 245 | 19 | 19.9 |
| Depth > 1500m | Small S-Lay | 245 | 291 | 46 | 23.8 |

Source: EPE.

Route 4a indicated in this Plan is similar to the route of Project Alpha, led by COSAN, which has stakes, among other companies, in COMGÁS, the largest local distribution company in the State of São Paulo. It aims to outflow the raw natural gas produced in the Santos Basin to Baixada Santista, with processing and delivery of specified natural gas for COMGÁS and the possibility of connecting to the integrated network through a future transmission pipeline (COSAN, 2015). The project also has an intermediate compression platform, where natural gas from several fields could be received, mixed and sent to shore, in this case with economies of scale regarding the segment in shallow water depth, that would be shared between several E&P projects. This outflow gas pipeline project is more generally known as “Route 4”.

It should be noted that Route 4a may have complementary natural gas supply in relation to the LNG terminal announced at the Santos Port (GASNET, 2018), which would allow the supply of natural gas during maintenance shutdowns on the gas pipeline, in addition to providing operational safety for the project.

Considering an optimistic scenario of expansion of the net production of natural gas in the pre-salt environment, the outflow gas pipeline was designed for a flow rate of 20 million $m^3$/d (EPE, 2019). The other premises used in the route 4a gas pipeline project were a 291 km extension and a 24-inch diameter. With the extension data, flow rate, and information about construction in Table 4.1, the investment cost of the gas pipeline was calculated. Table 4.2 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 4.2. Calculation of CAPEX for the Route 4a outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 739.71 | 16 % |
| Components | 477.85 | 11 % |
| Construction, assembly and launch | 1,026.83 | 23 % |
| Commissioning | 43.65 | 1 % |
| Indirect costs | | |
| Engineering Project | 228.80 | 5 % |
| Indirect Costs and Profits | 490.78 | 11 % |
| Taxes | 490.05 | 11 % |
| Contingencies | 1,049.30 | 23 % |
| TOTAL INVESTMENT<br>(reference value, with contingencies, reference date Jun/19) | **4,546.97** | 100% |

Source: EPE.

Note: estimates based on the analysis of conceptual projects, with an accuracy of -30% to -50% and + 50% to + 100%.

As shown in Table 4.2, the investment cost for the outflow gas pipeline of route 4a, which is 291 km long and 24 inches in diameter, under the defined conditions, would be R$ 4,547 million. The indicative NGPP in Cubatão for Route 4a, with a processing capacity of 20 million $m^3$/d of raw gas from the Santos Basin pre-salt, would have an investment cost of R$ 3,500 million.

## 4.2 Santos Basin Pre-salt - Itaguaí Port/RJ: Route 4b

The Santos Basin - Itaguaí Port alternative (Route 4b) aims to outflow the raw natural gas produced in a Santos Basin cluster to a NGPP located near the Itaguaí Port. For this alternative, it will not be necessary to build a considerable segment of onshore gas pipeline, since the Itaguaí Port touches the coast. The natural gas from this processing plant would have several monetization alternatives, including the possibility of interconnection to the integrated network through a future transmission gas pipeline, or a liquefaction facility to meet the national or international demand for LNG in addition to meeting the demand for thermoelectric power plants.

Figure 4.5 illustrates the outflow and processing alternative for Route 4b, in which the exploration blocks, the producing fields and the existing infrastructure are shown. In this case, some of the exploratory blocks, such as Carcará and Norte de Carcará, may decide to connect their gas pipelines to a NGPP in Cubatão if their volumes of natural gas make it possible to build a new outflow system, instead of using existing infrastructure.

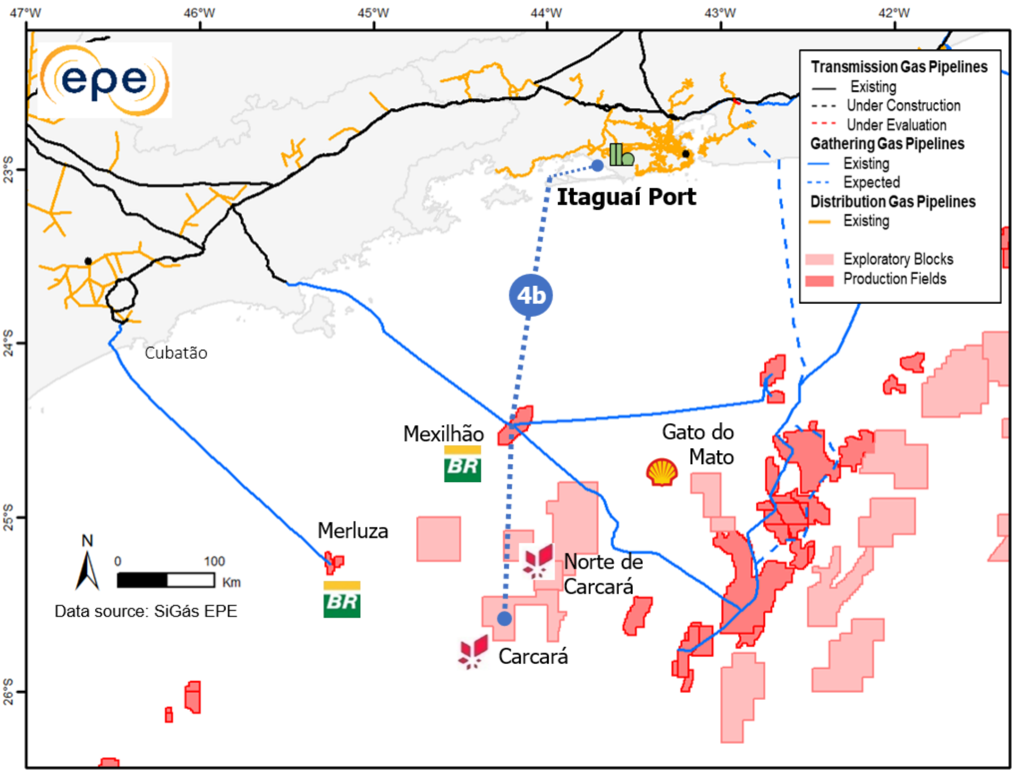



**Figure 4.5. Outflow and processing alternative for Route 4b**

Source: EPE.

Altimetric profile of guideline for the outflow pipeline Route 4b is illustrated in Figure 4.6, which indicated a total extension of 299 km for this alternative, including the onshore and offshore segments. The constructive data for the cost estimate of this gas pipeline is shown in Table 4.3.

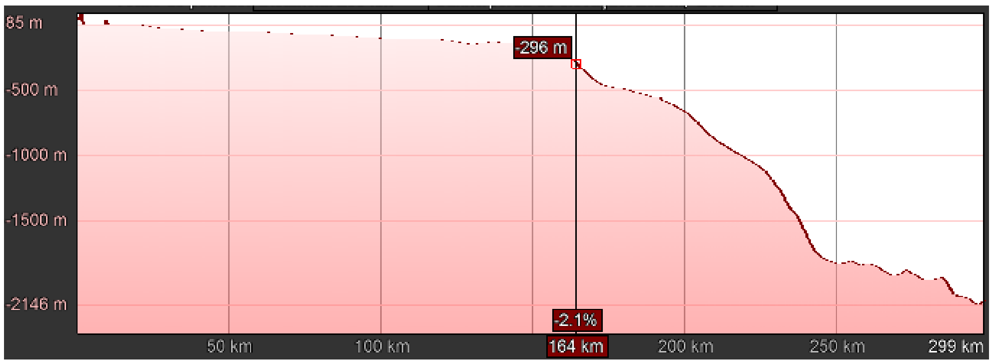



**Figure 4.6. Altimetric profile of guideline for Route 4b outflow gas pipeline**

Source: EPE.

**Table 4.3. Construction data for the Route 4b outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 164 | 163 | 16.2 |
| Depth 300-1500m | Small S-Lay | 164 | 240 | 76 | 19.9 |
| Depth > 1500m | Small S-Lay | 240 | 299 | 59 | 23.8 |

Source: EPE.

This route has as an indicative end point a NGPP in the retro area of the Itaguaí Port. Currently, the Port has docking facilities (container, coal, solid bulk and ore terminals) and storage facilities, in addition to port equipment and leased areas and facilities. The expansion and optimization of the infrastructure and operations of this Port in the next few years are currently being planned, considering new facilities, in addition to interventions for the recovery, adaptation and modernization of terminals (MI, 2019). The Port has a retro-area of 10,000,000 m², in which the infrastructure provided for in the integration plan with the oil and gas industry can be built (SEPETIBA TECON, 2019). Figure 4.7 illustrates the current layout of the Itaguaí Port (CDRJ, 2019).

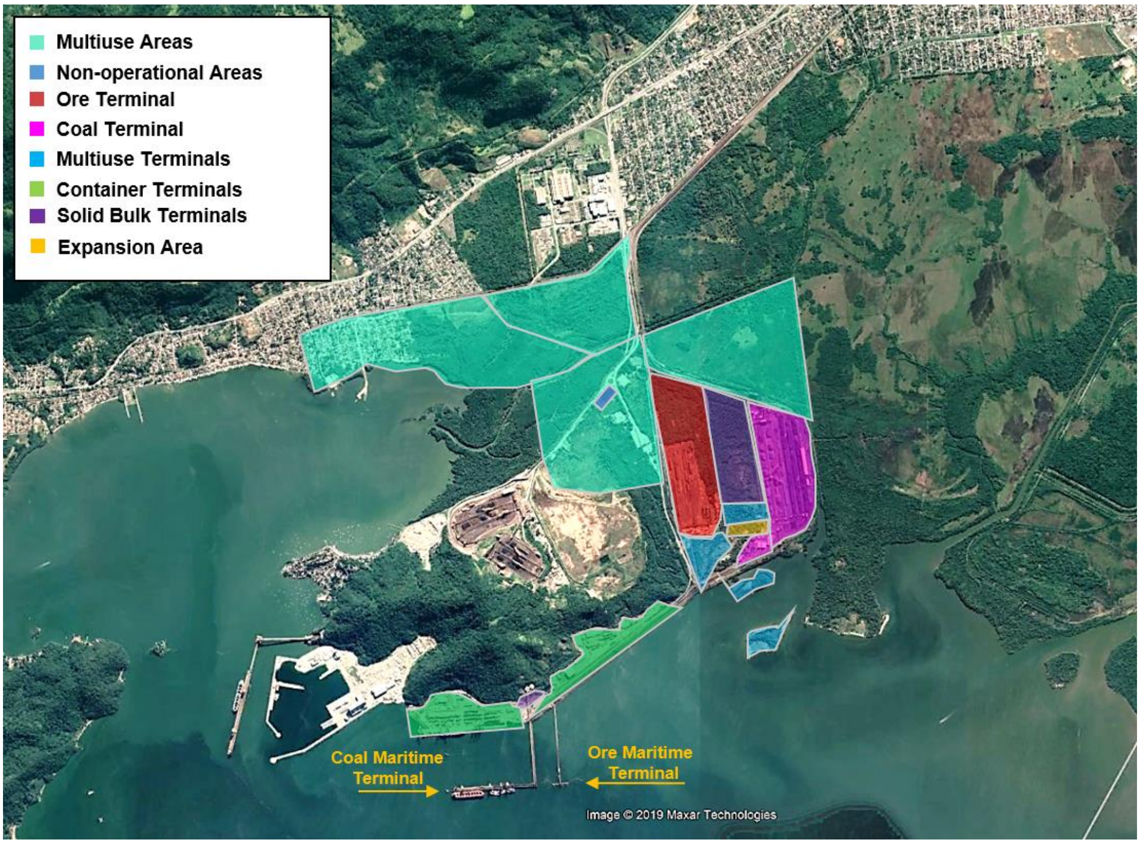



**Figure 4.7. Layout of Itaguaí Port**
Source: adapted from Companhia Docas do Rio de Janeiro (CDRJ, 2019).

Considering a scenario of expansion of the net production of natural gas in the pre-salt environment, the outflow gas pipeline was designed for a flow rate of 20 million m³/d (EPE, 2019). The other premises used in the project of the gas pipeline of Route 4b were a 299 km extension and a 24-inch diameter. With the extension data, flow rate, and construction data presented in Table 4.3, the investment cost of the pipeline was calculated. Table 4.4 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 4.4. Calculation of CAPEX for the Route 4b outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 788.61 | 16 % |
| Components | 477.99 | 10 % |
| Construction, assembly and launch | 1,135.96 | 23 % |
| Commissioning | 44.85 | 1 % |
| Indirect costs | | |
| Engineering Project | 244.74 | 5 % |
| Indirect Costs and Profits | 519.96 | 11 % |
| Taxes | 519.53 | 11 % |
| Contingencies | 1,119.50 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **4,851.15** | 100% |

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

As shown in Table 4.4, the investment cost for the outflow gas pipeline of Route 4b, which is 299 km long and 24 inches in diameter, under the defined conditions, would be R$ 4,851 million. The indicative NGPP in the retro area of the Itaguaí Port for Route 4b, with a processing capacity of 20 million $m^3/d$ of raw gas from the Santos Basin pre-salt, would have an investment cost of R$ 3,500 million.

## 4.3 Campos Basin pre-salt - Açu Port/RJ: Route 5a

The Campos Basin - Açu Port alternative (Route 5a) aims to outflow the raw natural gas produced in a Campos Basin cluster to a NGPP located near Açu Port. For this alternative, it will not be necessary to build a considerable stretch of onshore gas pipeline, since the Açu Port touches the coast. The natural gas from this NGPP would have several monetization alternatives, including the possibility of future interconnection to the transmission gas pipeline network, or liquefaction to meet the national or international demand for LNG in addition to meeting the demand for thermoelectric power plants.

It was considered that the use of post-salt outflow gas pipelines that already exist in this area of the Campos Basin would be unfeasible, due to the need for greater design pressures necessary for the outflow of pre-salt natural gas, with a high content of natural gas liquids.

Figure 4.8 illustrates the outflow and processing alternative for Route 5a, in which the exploration blocks, the productive fields and the existing infrastructure are shown. Some of the exploratory blocks to the south of Açu Port, such as CM-539 (Pão de Açúcar prospect) and CM-535 may decide to connect to Açu Port if their volumes of natural gas enable the construction of a new outflow system, instead of using existing infrastructure. On the other hand, some nearby blocks such as CM-473, CM-401 and CM-333 have been returned to ANP in recent years.

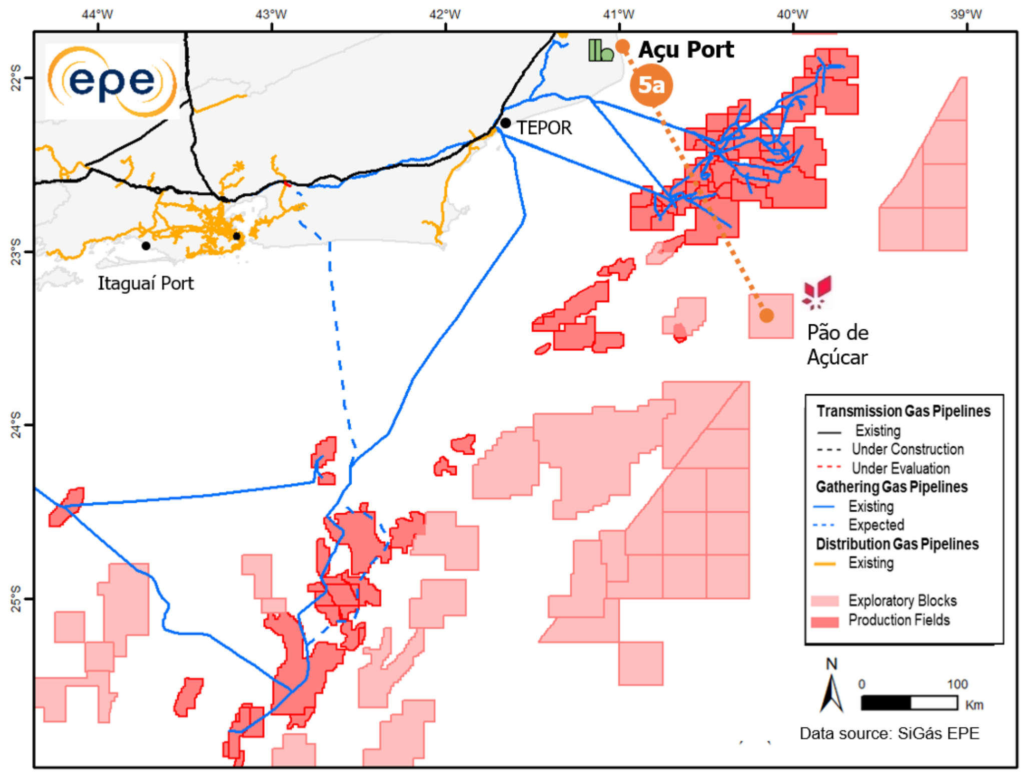



**Figure 4.8. Outflow and processing alternative for Route 5a**
Source: EPE.

The total extension of the gas pipeline for this route, including the onshore and offshore segments, is 199 km, according to the altimetric profile of its guideline, as shown in Figure 4.9. The constructive data for the cost estimate of the gas pipeline of Route 5a is shown in Table 4.5.

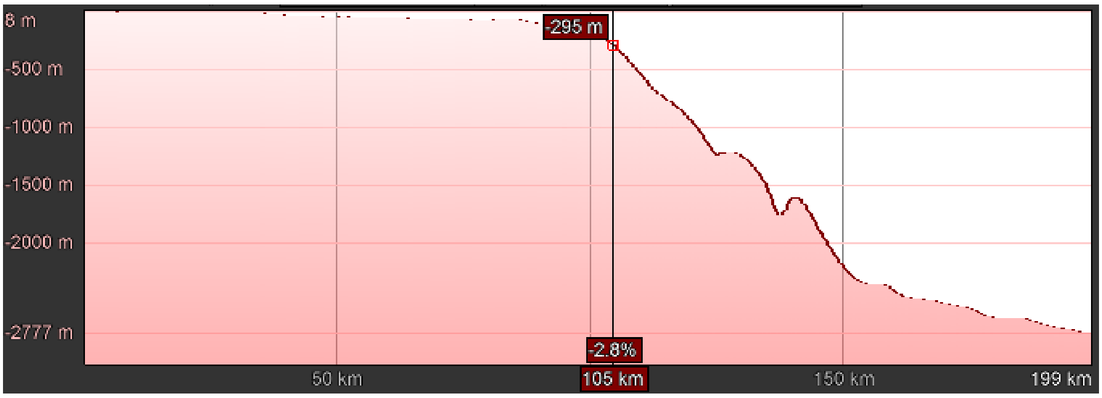



**Figure 4.9. Altimetric profile of guideline for the Route 5a outflow gas pipeline**
Source: EPE.

**Table 4.5. Construction data for the Route 5a outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 105 | 104 | 16.2 |
| Depth 300-1500m | Small S-Lay | 105 | 140 | 35 | 19.9 |
| Depth > 1500m | Small S-Lay | 140 | 199 | 59 | 23.8 |

Source: EPE.

This route has as an indicative end point a NGPP in the retro area of Açu Port/RJ. In this port, one LNG terminal (with a regasification capacity of 21 $MMm^3/d$) and two natural gas TPPs - TPPs Novo Tempo GNA I and TPP GNA II (with a maximum demand of approximately 6 $MMm^3/d$ each) - are already planned, and should start operating in 2021 and 2023, respectively.

The natural gas infrastructure under study in this Port provides for the formation of a gas hub with the possibility of accommodating other TPPs, in addition to NGPPs for processing the natural gas received from the Campos, Santos and Espírito Santo Basins, and a gas pipeline for connection to the integrated network of transmission pipelines (EPE, 2018b; AÇU PORT, 2019). Figure 4.10 shows the layout of Açu Port, including the 90,000,000 $m^2$ retro area, available for new enterprises.


In Operation | Under Construction | Project

**1.** Wärtsilä – 22,193 m²
**2.** TechnipFMC – 289,800 m²
**3.** NOV – 121,905 m²
**4.** Intermoor – 52,302 m²
**5.** Edison Chouest – 597,400 m²
**6.** Açu Port | Multicargo Terminal (T-MULTI)
**7.** Gerdau
**8.** Dome
**9.** Anglo American
**10.** BP Prumo – 215,079 m²
**11.** Ferroport – Iron ore terminal
**12.** Açu Petróleo
**13.** Oiltanking – Oil terminal
**14.** Shell
**15.** RPPN Caruara – Environmental preservation area – 40 km²
**16.** Vallourec – 15,000 m²
**17.** InterRio Hotel
**18.** Açu Condlog | Logistic Condominium
**19.** Estação Açu – Convenience Store
**20.** GNA – Thermoelectric Power Plant
**21.** LNG terminal
**22.** Liquids terminal
**23.** Repairs terminal
**24.** Available area – 1,090,746 m²
**25.** Naval industry – 3,200,000 m²
**26.** Liquefaction plant
**27.** Logistic Area
**28.** Natural Gas Processing Plant
**29.** Integrated distribution and storage centers
**30.** Truck Center
**31.** Oil treatment plant
**32.** Metal-mechanic industries
**33.** Helideck
**34.** Export Processing Zone

**Figure 4.10. Layout of Açu Port/RJ**
Source: adapted from Açu Port (2019).

The Route 5a gas pipeline was designed for a flow rate of 12 million m³/d, which is the typical size of the project considered to make a outflow gas pipeline feasible. The other premises used in the project of the gas pipeline of Route 5a were a 299 km extension and a 16-inch diameter. With the extension data, flow rate and information about construction presented in Table 4.5, the investment cost of the pipeline was calculated. Table 4.6 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 4.6. Calculation of CAPEX for the Route 5a outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 481.89 | 14 % |
| Components | 316.63 | 9 % |
| Construction, assembly and launch | 930.95 | 27 % |
| Commissioning | 29.85 | 1 % |
| Indirect costs | | |
| Engineering Project | 175.93 | 5 % |
| Indirect Costs and Profits | 358.10 | 10 % |
| Taxes | 358.91 | 10 % |
| Contingencies | 795.68 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **3,447.93** | 100% |

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

As shown in Table 4.6, the investment cost for the outflow gas pipeline of route 5a, with 199 km of extension and 16 inches in diameter, under the defined conditions, would be R$ 3,448 million. The indicative NGPP at Açu Port of route 5a, with a processing capacity of 12 million $m^3$/d of raw gas from the Campos Basin pre-salt, would have an investment cost of R$ 2,600 million.

## 4.4 Campos Basin pre-salt - TEPOR/RJ: Route 5b

The Campos Basin - Macaé Port Terminal (TEPOR) alternative (Route 5b) aims to outflow the raw natural gas produced in a Campos Basin cluster to a NGPP located in the TEPOR retro area. In this case, it will also not be necessary to build a considerable segment of onshore gas pipeline, since TEPOR would be tangent to the coast. The natural gas from this NGPP may have several monetization alternatives, including the possibility of future interconnection to the transmission gas pipeline network, or liquefaction to meet the national or international demand for LNG in addition to meeting the demand for thermoelectric power plants. Figure 4.11 illustrates the outflow and processing alternative for Route 5b, in which the exploration blocks, the producing fields and the existing infrastructure are shown.

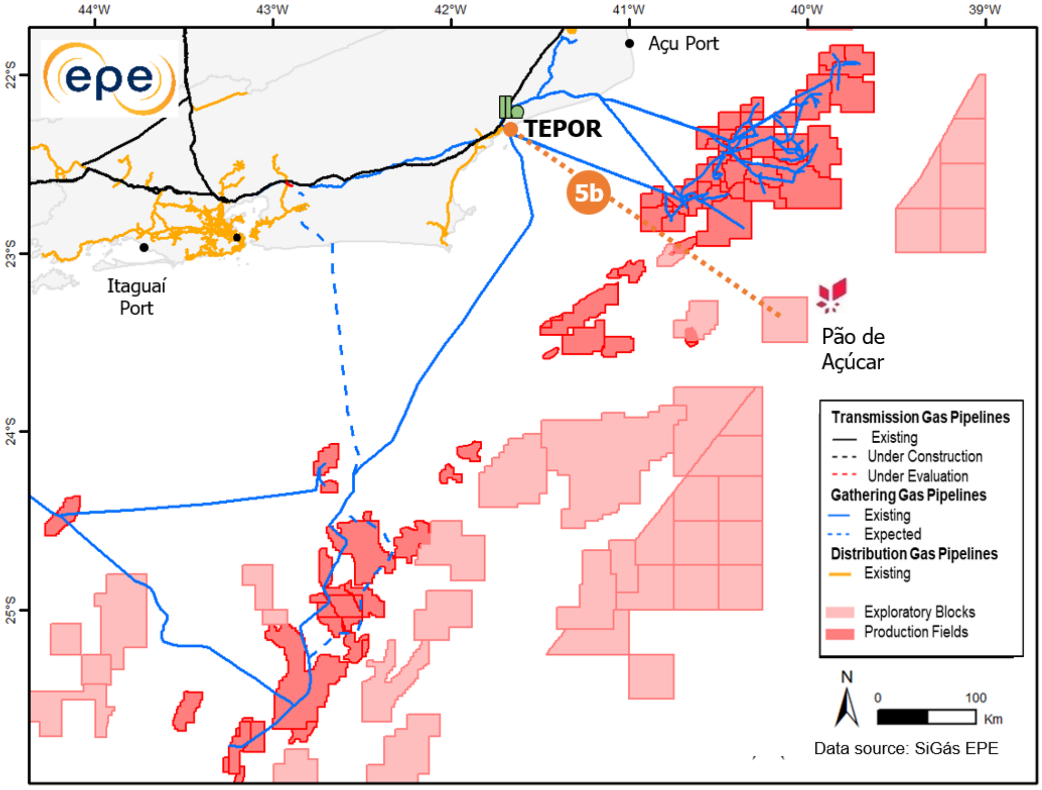



**Figure 4.11. Outflow and processing alternative for Route 5b**
Source: EPE.

The total extension of the outflow gas pipeline of Route 5b, including the onshore and offshore segments, is 200 km, according to the altimetric profile of its guideline, as shown in Figure 4.12. The constructive data for the cost estimate of this gas pipeline is shown in Table 4.7.

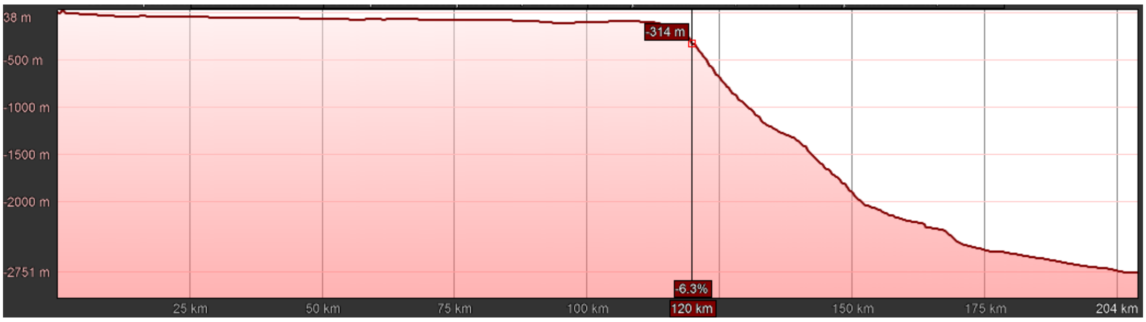



**Figure 4.12. Altimetric profile of guideline for the Route 5b outflow gas pipeline**
Source: EPE.

**Table 4.7. Construction data for the Route 5b outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 121 | 120 | 16.2 |
| Depth 300-1500m | Small S-Lay | 121 | 143 | 22 | 19,9 |
| Depth > 1500m | Small S-Lay | 143 | 200 | 57 | 23.8 |

Source: EPE.

This route has as an indicative end point a NGPP in the retro area of TEPOR/RJ. In this Port, two offshore terminals and an onshore retro area are planned. One of the terminals (terminal A) will be used for handling liquids, connected by pipeline to an onshore terminal for the storage of fuels, chemicals and other products, while the second terminal (terminal B) is intended for handling oil. Terminal A will also have an FSRU and an area reserved for LNG storage tanks. In the onshore area of 6,000,000 $m^2$, the construction of a NGPP for the processing of natural gas received from the Campos and Santos Basins is planned. Figure 4.13 shows the layout of TEPOR with the planned offshore and onshore infrastructures (TEPOR, 2019).


**Figure 4.13. TEPOR layout containing Terminals A and B and the onshore area**
Source: adapted from Oiti Consultoria Ambiental (OITI, 2018)

The gas pipeline of Route 5b was designed for a flow rate of 12 million $m^3/d$, which is the typical size of the project considered to make an outflow gas pipeline feasible.

The other premises used in the project of the gas pipeline of Route 5b were a 200 km extension and a 16-inch diameter. With the extension data, flow rate, and construction information presented in Table 4.7, the investment cost of the pipeline was calculated. Table 4.8 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 4.8. Calculation of CAPEX for the Route 5b outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 477.97 | 14 % |
| Components | 316.63 | 9 % |
| Construction, assembly and launch | 911.83 | 27 % |
| Commissioning | 30.00 | 1 % |
| Indirect costs | | |
| Engineering Project | 173.64 | 5 % |
| Indirect Costs and Profits | 354.34 | 10 % |
| Taxes | 355.08 | 10 % |
| Contingencies | 785.85 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **3,405.34** | 100% |

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

As shown in Table 4.8, the investment cost for the Route 5b outflow gas pipeline, with 200 km long and 16 inches in diameter, under the defined conditions, would be R$ 4,851 million. The indicative NGPP at TEPOR for Route 5b, with a processing capacity of 12 million $m^3/d$ of raw gas from the Campos Basin pre-salt, would have an investment cost of R$ 2,600 million.

## 4.5 Campos Basin Pre-salt - Itaguaí Port/RJ: Route 5c

Campos Basin - Itaguaí Port alternative (Route 5c) aims to outflow the raw natural gas produced in a Campos Basin cluster to a NGPP located near the Itaguaí Port, as mentioned in Route 4b alternative. For the Route 5c alternative, it will not be necessary to build a considerable extension of onshore gas pipeline, since the Itaguaí Port touches the coast. The natural gas from this processing plant would have several monetization alternatives, already mentioned in Route 4b. Figure 4.14 illustrates the outflow and processing alternative for Route 5c, in which the exploration blocks, the producing fields and the existing infrastructure are shown.

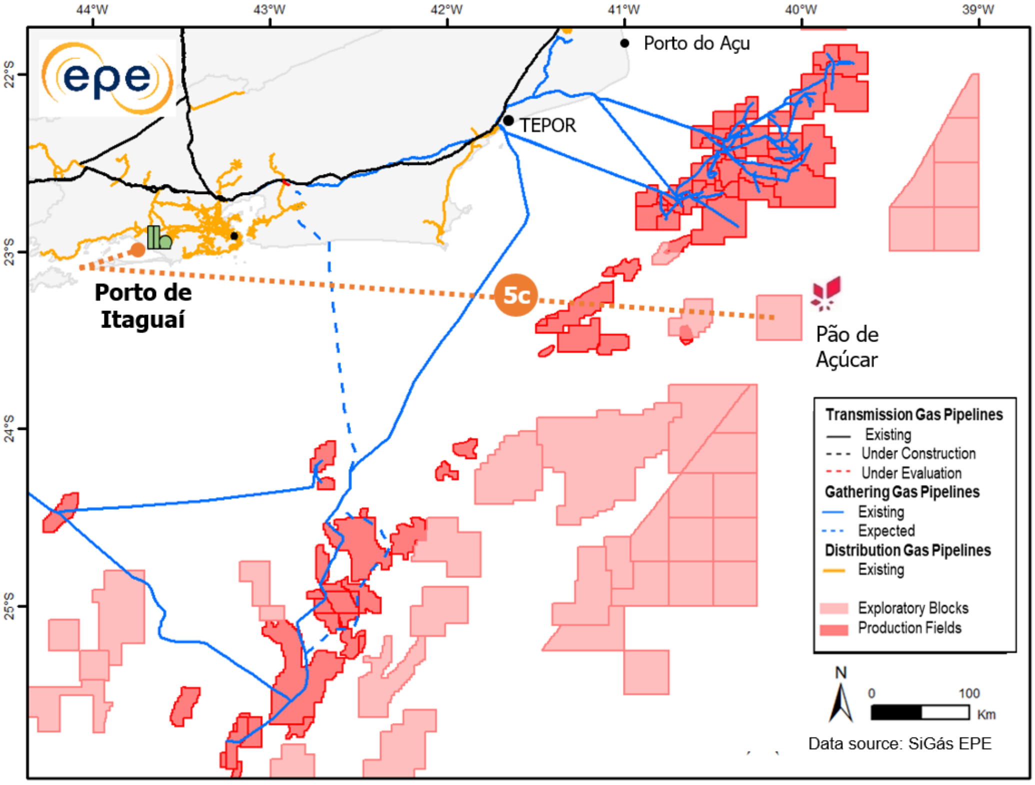



**Figure 4.14. Outflow and processing alternative for Route 4a**
Source: EPE.

Figure 4.15 presents the altimetric profile of the outflow pipeline guideline of Route 5c, which indicated a total extension of 421 km for this alternative, including the onshore and offshore stretches. The constructive data for the cost estimate of this gas pipeline is shown in Table 4.9.

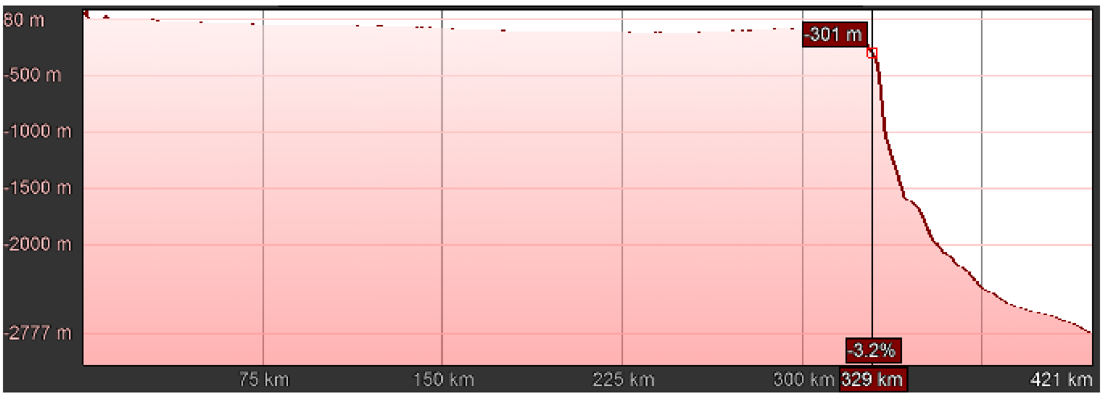



**Figure 4.15. Altimetric profile of guideline for the Route 5c outflow gas pipeline**
Source: EPE.

**Table 4.9. Construction data for the Rote 5c outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 329 | 328 | 16.2 |
| Depth 300-1500m | Small S-Lay | 329 | 340 | 11 | 19.9 |
| Depth > 1500m | Small S-Lay | 340 | 421 | 81 | 23.8 |

Source: EPE.

The outflow pipeline of Route 5c ends at a NGPP near the Itaguaí Port, whose characteristics have already been mentioned in item 4.2, referring to Route 4b.

The gas pipeline of Route 5c was designed for a flow rate of 12 million $m^3/d$, which is the typical size of the project considered so that a outflow gas pipeline can be feasible. The other premises used in the gas pipeline project of Route 5c were a 421 km extension and an 18-inch diameter. With this extension and flow rate, and the construction data presented in Table 4.9, the investment cost of the pipeline was calculated. Table 4.10 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 4.10. Calculation of CAPEX for the Route 5c outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 992.52 | 19 % |
| Components | 358.73 | 7 % |
| Construction, assembly and launch | 1,217.42 | 23 % |
| Commissioning | 63.15 | 1 % |
| Indirect costs | | |
| Engineering Project | 263,18 | 5 % |
| Indirect Costs and Profits | 557.63 | 11 % |
| Taxes | 557.28 | 11 % |
| Contingencies | 1,202.97 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **5,212.87** | 100% |

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

As shown in Table 4.10, the investment cost for the outflow gas pipeline of Route 5c, which is 421 km long and has 10 inches in diameter, under the defined conditions, would be R$ 5,213 million. The indicative NGPP at Itaguaí Port related to Route 5c, with a processing capacity of 12 million $m^3/d$ of raw gas from the Campos Basin pre-salt, would have an investment cost of R$ 2,600 million.

## 4.6 Campos Basin Pre-salt - Central Port/ES: Route 6a

The Campos Basin - Central Port alternative (Route 6a) aims to outflow the raw natural gas produced in a Campos Basin cluster to a NGPP located near Central Port. In this case, it will also not be necessary to build a considerable stretch of onshore gas pipeline since the Central Port is projected to be tangent to the coast. The natural gas from this NGPP may have several monetization alternatives, including the possibility of future interconnection to the transmission gas pipeline network, or liquefaction to meet the national or international demand for LNG in addition to meeting the demand for thermoelectric power plants. The NGPP can be placed in the retro-area of this port, requiring only a stretch of gas pipeline that will pass through the port and will depend on the position of the plant in relation to the layout of the project.

Figure 4.16 illustrates the outflow and processing alternative for Route 6a, in which the exploration blocks, the producing fields and the existing infrastructure are shown. Regarding the outflow of natural gas, Central Port is located about 120 km from blocks CM-101 (Wahoo prospect) and CM-61 (Itaipu prospect). In 2010, there were significant discoveries in the Wahoo prospect, when the company Anadarko carried out a formation test that indicated the production potential of 15 thousand barrels of oil equivalent per day (EPBR, 2019).

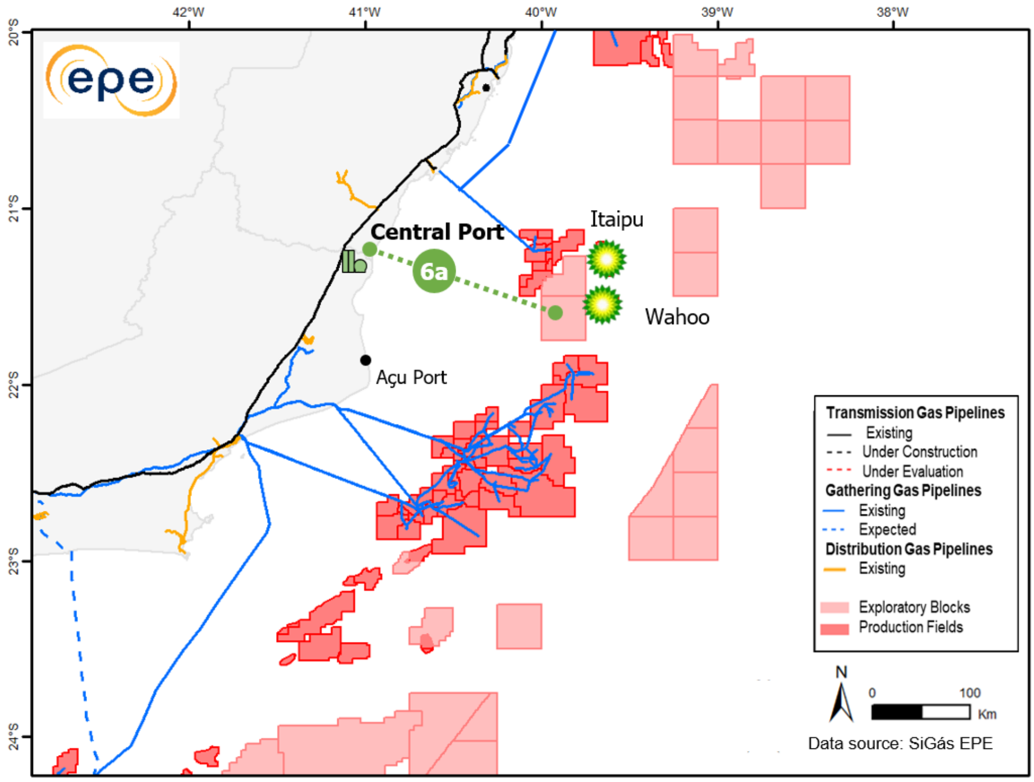



**Figure 4.16. Outflow and processing alternative for Route 6a**
Source: EPE.

Figure 4.17 presents the altimetric profile of guideline for the outflow pipeline of this route, which indicated a total extension of 119 km for this alternative, including the onshore and offshore stretches. The constructive data used for the cost estimate of this gas pipeline is shown in Table 4.11.

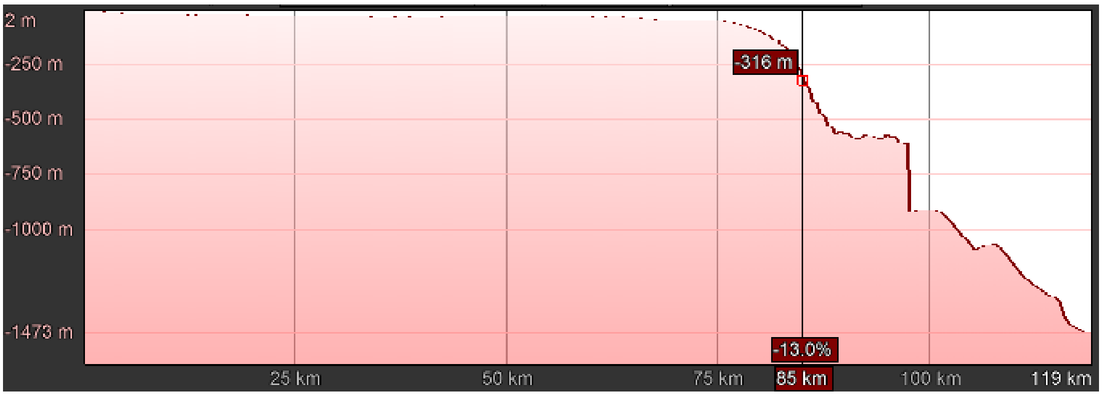


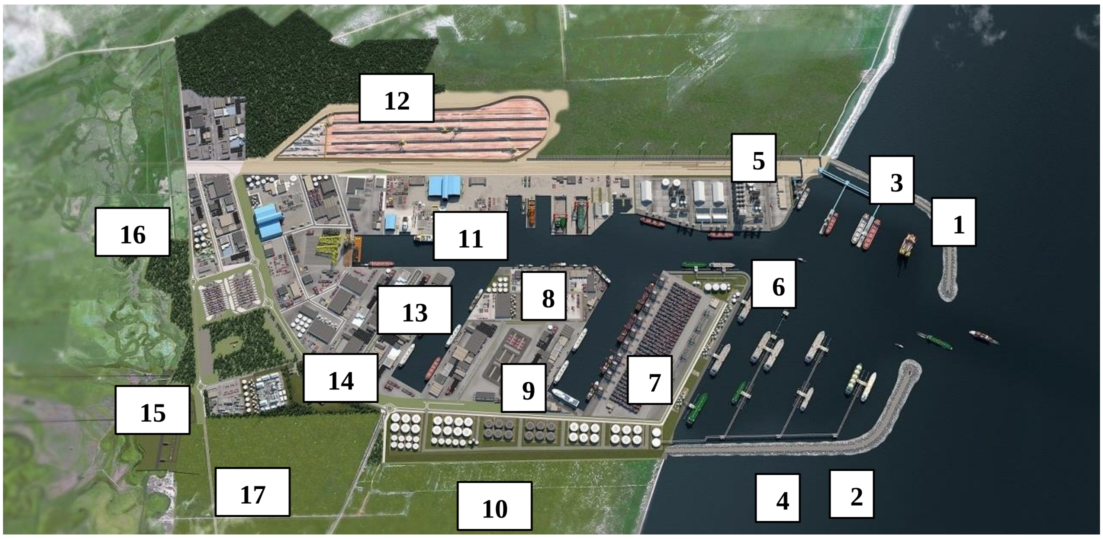

**Figure 4.17. Altimetric profile guideline for the Route 6a outflow gas pipeline**
Source: EPE.

**Table 4.11. Construction data for the Route 6a outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 85 | 84 | 16.2 |
| Depth 300-1500m | Small S-Lay | 85 | 119 | 34 | 19.9 |
| Depth > 1500m | Small S-Lay | 119 | 119 | 0 | 23.8 |

Source: EPE.

The Central Port is an enterprise developed by Port of Rotterdam and TPK Logística in the municipality of Presidente Kennedy/ES, currently undergoing negotiations and planning. This project will be built in phases, according to the demands of customers and the implementation schedules of the projects that will be installed on site, and the project includes future natural gas and LNG facilities (CENTRAL PORT, 2019). Figure 4.18 shows the layout of Central Port, including the 20,000,000 m² retro-area, available for new enterprises.




1. Offshore Cradle
2. LNG Terminal
3. Ore and Coal
4. Crude Oil
5. Grains and Fertilizers
6. Oil Transfer
7. Containers
8. Offshore Support
9. General Loads
10. Tanking of Liquids
11. Shipyard
12. Iron ore
13. Industrial area
14. Energy Complex
15. Offices
16. Warehouses and Industry
17. Helideck

**Figure 4.18. Layout of Central Port/ES**

Source: adapted from Central Port (2019).

The gas pipeline of Route 6a was designed for a flow rate of 12 million $m^3/d$, which is the typical size of the project considered so that an outflow gas pipeline can be feasible. The other premises used in this gas pipeline project were a 119 km extension and 14-inch diameter. With the extension data, flow rate, and construction data in Table 4.11, the investment cost of the pipeline was calculated. Table 4.12 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 4.12. Calculation of CAPEX for the Route 6a outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 259.56 | 10 % |
| Components | 276.37 | 11 % |
| Construction, assembly and launch | 744.97 | 29 % |
| Commissioning | 17.85 | 1 % |
| Indirect costs | | |
| Engineering Project | 129.88 | 5 % |
| Indirect Costs and Profits | 256.86 | 10 % |
| Taxes | 257.99 | 10 % |
| Contingencies | 583.04 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **2,526.51** | 100% |

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

As shown in Table 4.12, the investment cost for the outflow gas pipeline of Route 6a, which is 119 km long and has 14 inches in diameter, under the defined conditions, would be R$ 2,527 million. The indicative NGPP at Central Port of Route 6a, with a processing capacity of 12 million $m^3/d$ of raw gas from the Campos Basin pre-salt, would have an investment cost of R$ 2,600 million.

## 4.7 Campos Basin Pre-salt - Açu Port/RJ: Route 6b

The Campos Basin - Açu Port alternative (Route 6b) aims to outflow the raw natural gas produced in a Campos Basin cluster to a NGPP located near Açu Port, with several monetization alternatives, including the possibility of interconnection to the integrated network through a future transmission gas pipeline, or liquefaction to meet the national or international demand for LNG, in addition to meeting the demand for thermoelectric power plants. Although, as in Route 5a, the project also originates in the Campos Basin and as a destination the Açu Port/RJ, the location of this cluster is further North within this Sedimentary Basin, in areas that could not be so easily attended by Route 5a. The origin of the alternative Route 6b would have greater proximity to the Wahoo and Itaipu prospects, while the origin of the alternative Route 5a would have greater proximity to the Pão de Açúcar prospect, further South.

Figure 4.19 illustrates the outflow and processing alternative for Route 6b, in which the exploration blocks, the producing fields and the existing infrastructure are shown.

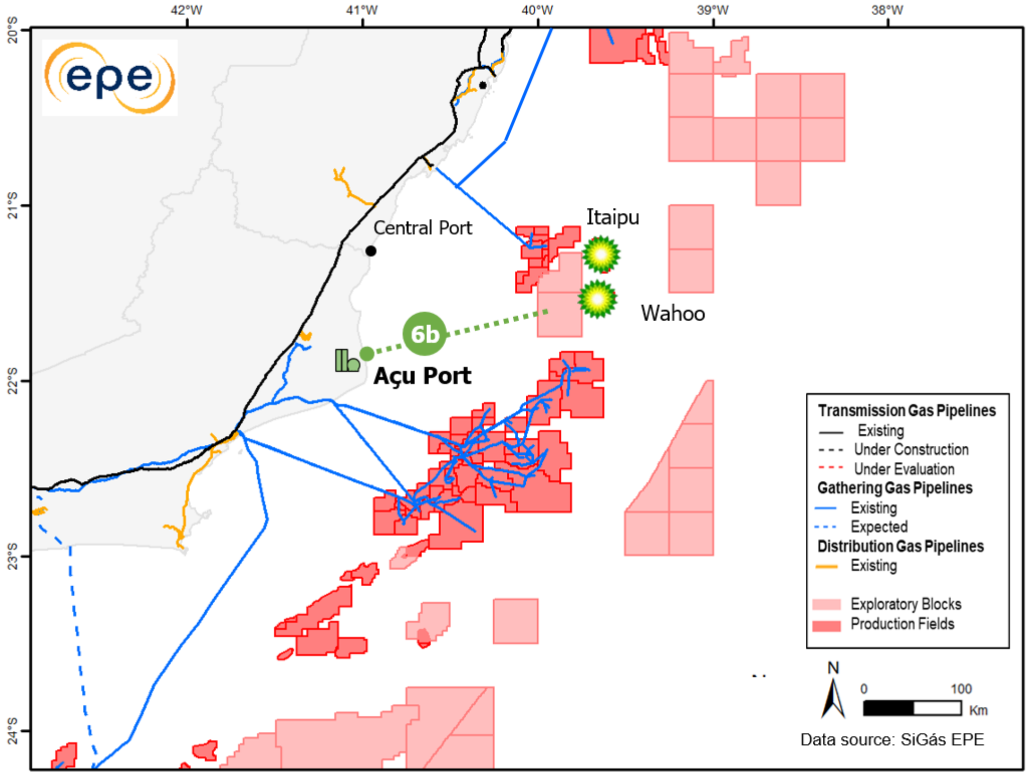



**Figure 4.19. Outflow and processing alternative for Route 6b**
Source: EPE.

The total extension of the gas pipeline for this route, including the onshore and offshore stretches, is 118 km, according to the altimetric profile of its guideline, as shown in Figure 4.20. The constructive data for the cost estimate of this gas pipeline is shown in Table 4.13.

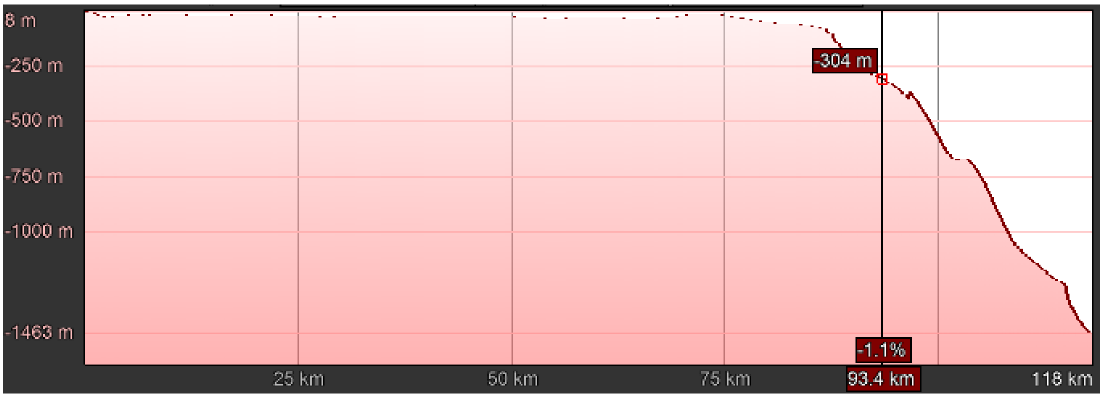



**Figure 4.20. Altimetric profile of guideline for the Route 6b outflow gas pipeline**
Source: EPE.

**Table 4.13. Construction data for the Route 6b outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 93 | 92 | 16.2 |
| Depth 300-1500m | Small S-Lay | 93 | 118 | 25 | 19.9 |
| Depth > 1500m | Small S-Lay | 118 | 118 | 0 | 23.8 |

Source: EPE.

The gas pipeline of Route 6b was designed for a flow rate of 12 million $m^3/d$, which is the typical minimal size considered to make an outflow gas pipeline feasible. The other premises used in the gas pipeline project of Route 6b were a 118 km extension and a 14-inch diameter. With the extension data, flow rate, and construction data presented in Table 4.13, the investment cost of the pipeline was calculated. Table 4.14 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 4.14. Calculation of CAPEX for the outflow gas pipeline of Route 6b**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 254.29 | 10 % |
| Components | 276.36 | 11 % |
| Construction, assembly and launch | 731.45 | 29 % |
| Commissioning | 17.70 | 1 % |
| Indirect costs | | |
| Engineering Project | 127.98 | 5 % |
| Indirect Costs and Profits | 253.46 | 10 % |
| Taxes | 254.56 | 10 % |
| Contingencies | 574.74 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **2,490.54** | 100% |

Source: EPE.

Note: estimates based on the analysis of conceptual projects, with an accuracy of -30% to -50% and + 50% of + 100%.

As shown in Table 4.14, the investment cost for the outflow gas pipeline of route 6b, 118 km long and 14 inches in diameter, under the defined conditions, would be R$ 2,491 million. The indicative NGPP at Açu Port of Route 6b, with a processing capacity of 12 million $m^3/d$ of raw gas from the Campos Basin pre-salt, would have an investment cost of R$ 2,600 million.

# 5 DETAILING OF POST-SALT PROJECTS

The alternatives studied in the post-salt environment include ES-Mucuri-A and ES-Mucuri-B projects, in the Espírito Santo-Mucuri Basin, and SEAL-A and SEAL-B projects, in the Sergipe-Alagoas Basin.

## 5.1 Espírito Santo-Mucuri Basin - Imetame Port/ES: ES-Mucuri-A

The Espírito Santo-Mucuri Basin - Imetame Port alternative (ES-Mucuri-A) aims to outflow the raw natural gas produced in ES-Mucuri basin to a NGPP located near Imetame Port, with several monetization alternatives, including the possibility of interconnection to the integrated network through a future transmission gas pipeline, or liquefaction to meet the demand for LNG, in addition to meeting the demand for thermoelectric power plants.

Figure 5.1 illustrates the outflow and processing alternative for ES-Mucuri alternative, in which the exploration blocks, the producing fields and the existing infrastructure are shown.

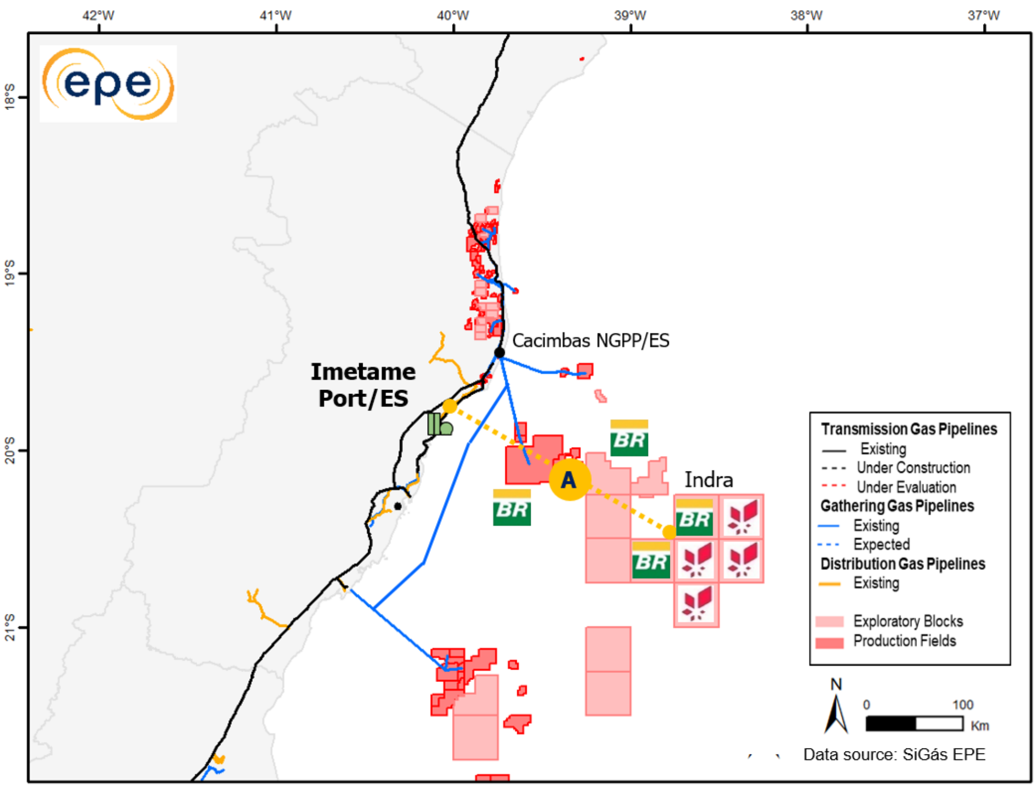



**Figure 5.1. Outflow and processing alternative for ES-Mucuri-A**
Source: EPE.

The total extension of the gas pipeline for this alternative, including the onshore and offshore stretches, is 155 km, according to the altimetric profile of its guideline, as shown in Figure 5.2. The constructive data for the cost estimate of this gas pipeline is shown in Table 5.1.

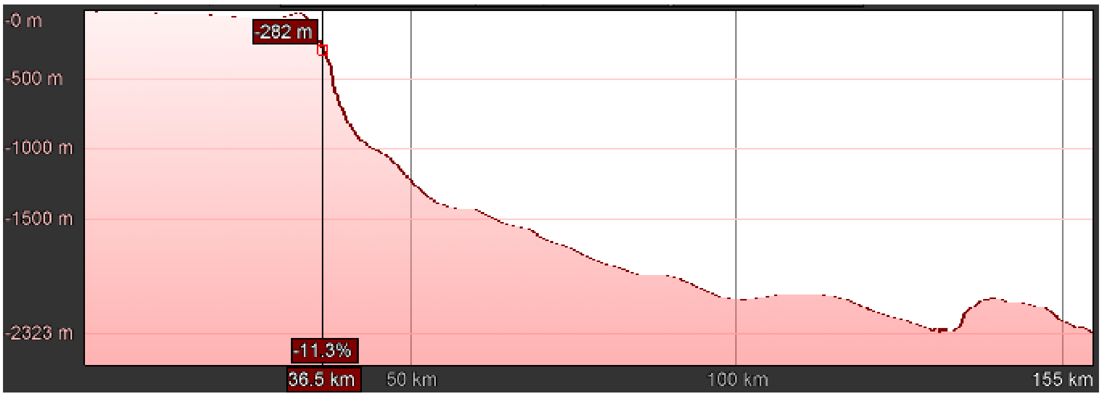



**Figure 5.2. Altimetric profile of guideline for the ES-Mucuri-A outflow gas pipeline**
Source: EPE.

**Table 5.1. Construction data for the ES-Mucuri-A outflow gas pipeline**

| Type | Constructive Method | Initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 35 | 34 | 16.2 |
| Depth 300-1500m | Small S-Lay | 35 | 60 | 25 | 19.9 |
| Depth > 1500m | Small S-Lay | 60 | 155 | 95 | 23.8 |

Source: EPE.

Imetame Port, located in Barra do Riacho - Aracruz/ES, is a project that considers the installation of several structures for cargo handling close to the existing facilities of Fibria Celulose (Aracruz Unit) and the existing port in Barra do Riacho/ES, with an area of at least 560,000 m² (ESBRASIL, 2018). Among the activities planned for the site, there is a exportation processing area, grain warehouse, tanking of liquid fuels and a possibility of a LNG terminal, as shown in Figure 5.3. The project already has an environmental license issued in 2018 by the State Institute of Environment and Water Resources of Espírito Santo - IEMA (GAZETA ONLINE, 2018).

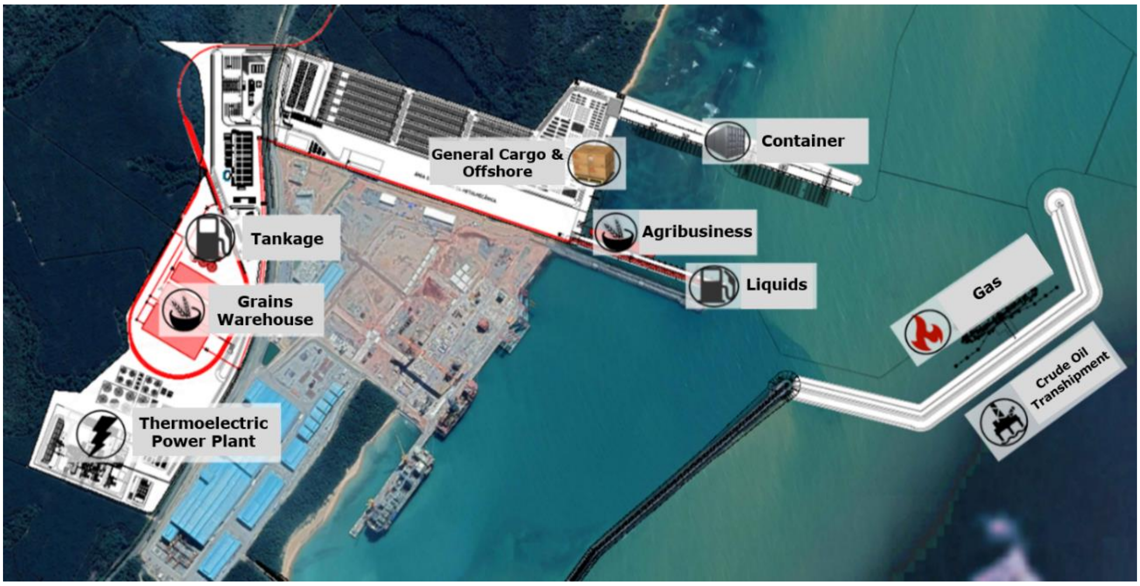



**Figure 5.3. Imetame Port Project**
Source: Imetame (2019).

The offshore stretch that would be necessary for the direct connection of the fields under development in the Post-Salt of the Espírito Santo-Mucuri Basin to the Imetame Port is 155 km long, while the segment that would be necessary for connection to the existing NGPP in Cacimbas/ES has the same approximate extension of 157 km. In this case, the two alternatives must be analyzed in relation to the presence of rhodoliths[6] in the shallow water region of the coast of Espírito Santo, since this issue has already been observed during the Environmental Licensing of the gathering and outflow gas pipelines implemented in this area, mainly South-North of Espirito do Santo gas pipeline, built in 2012 (GASNET, 2012). The presence of rhodoliths in the path of the alternative that is directly linked to the port (DIAS, 2015) may make it more feasible to build a project arriving on the coast at NGPP Cacimbas/ES and build an onshore stretch bordering the coast up to Imetame Port/ES.

The gas pipeline of the ES-Mucuri-A alternative was designed for a flow rate of 12 million $m^3$/d, which is the typical minimal size considered to make an outflow gas pipeline feasible. The other premises used in the ES-Mucuri-A gas pipeline project were a 155 km extension and a 14-inch diameter. With the extension data, flow rate, and construction data presented in Table 5.1, the investment cost of the pipeline was calculated. Table 5.2 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

[6] Calcareous algae that are deposited at the bottom of the oceans.

**Table 5.2. Calculation of CAPEX for the ES-Mucuri-A outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 400.05 | 13 % |
| Components | 276.59 | 9 % |
| Construction, assembly and launch | 905.26 | 29 % |
| Commissioning | 23.25 | 1 % |
| Indirect costs | | |
| Engineering Project | 160.51 | 5 % |
| Indirect Costs and Profits | 319.45 | 10 % |
| Taxes | 320.71 | 10 % |
| Contingencies | 721.75 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **3,127.57** | 100% |

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

As shown in Table 5.2, the investment cost for the ES-Mucuri-A outflow gas pipeline, 155 km long and 14 inches in diameter, under the defined conditions, would be R$ 3,128 million. An indicative NGPP in the Imetame Port in Aracruz, with a processing capacity of 12 million $m^3/d$ of raw gas from the ES-Mucuri Basin Post-salt, would have an investment cost of R$ 2,600 million.

## 5.2 Espírito Santo-Mucuri Basin – NGPP Cacimbas/ES: ES-Mucuri-B

The Espírito Santo-Mucuri basin – NGPP Cacimbas/ES alternative (ES-Mucuri-B) aims to outflow the raw natural gas produced in ES-Mucuri basin to a NGPP located in Cacimbas, with several monetization alternatives, including the possibility of interconnection to the integrated network through a future transmission gas pipeline, or liquefaction to meet the national or international demand for LNG, in addition to meeting the demand for thermoelectric power plants. Figure 5.4 illustrates the outflow and processing alternative for ES-Mucuri-B alternative in which the exploration blocks, the producing fields and the existing infrastructure are shown.

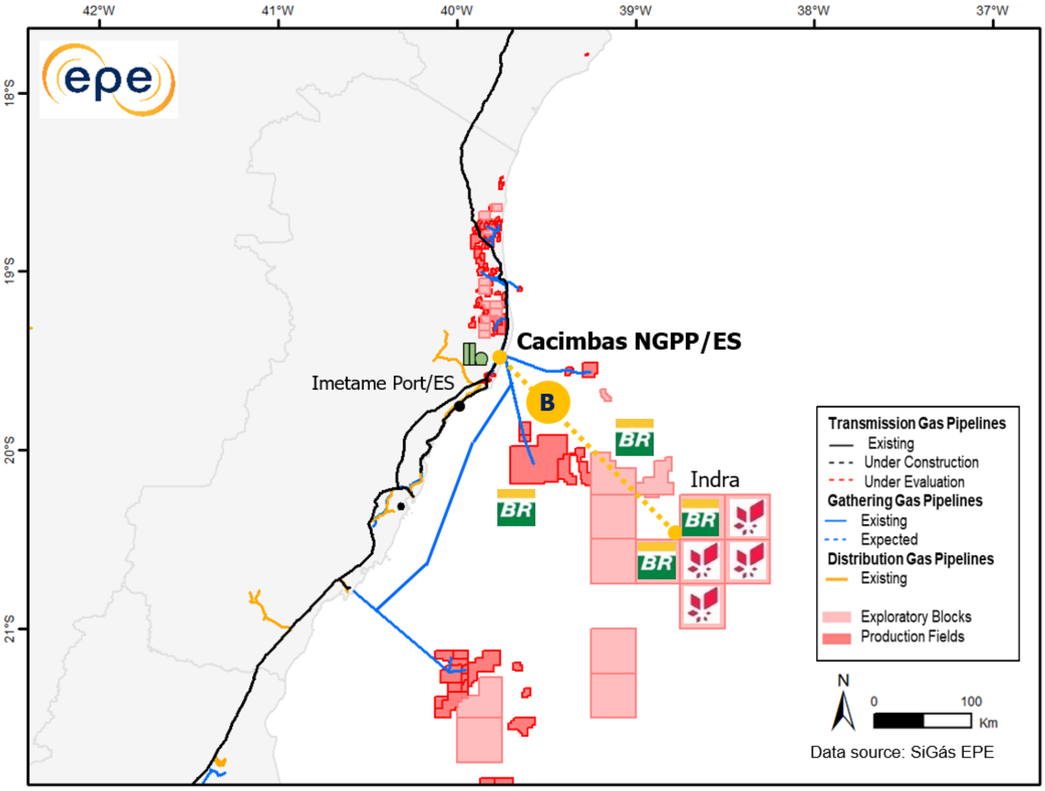



**Figure 5.4. Outflow and processing alternative for ES-Mucuri-B**
Source: EPE.

The total extension of the gas pipeline for this alternative, including the onshore and offshore stretches, is 157 km, according to the altimetric profile of its guideline, as shown in Figure 5.5. The constructive data for the cost estimate of this gas pipeline is shown in Table 5.3.

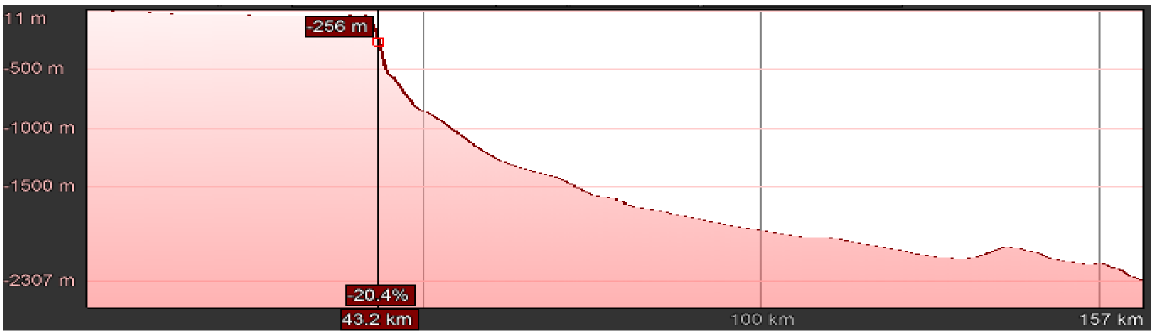



**Figure 5.5. Altimetric profile of guideline for ES-Mucuri-B outflow gas pipeline**
Source: EPE.

**Table 5.3. Construction data for the ES-Mucuri-B outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 43 | 42 | 16.2 |
| Depth 300-1500m | Small S-Lay | 43 | 75 | 32 | 19.9 |
| Depth > 1500m | Small S-Lay | 75 | 157 | 82 | 23.8 |

Source: EPE.

The gas pipeline related to ES-Mucuri-B alternative was designed for a flow rate of 12 million $m^3$/d, which is the typical minimal size considered to make an outflow gas pipeline feasible. The other premises used in the ES-Mucuri-B gas pipeline project were a 157 km extension and a 14-inch diameter. With the extension data, flow rate, and construction data presented in Table 5.3, the investment cost of the pipeline was calculated. Table 5.4 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 5.4. Calculation of CAPEX for the ES-Mucuri-B outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct costs | | |
| Piping | 397.27 | 13 % |
| Components | 276.61 | 9 % |
| Construction, assembly and launch | 899.98 | 29 % |
| Commissioning | 23.55 | 1 % |
| Indirect costs | | |
| Engineering Project | 159.74 | 5 % |
| Indirect Costs and Profits | 317.98 | 10 % |
| Taxes | 319.23 | 10 % |
| Contingencies | 718.30 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **3,112.65** | 100% |

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

As shown in Table 5.4, the investment cost for the outflow gas pipeline ES-Mucuri-B, 157 km long and 14 inches in diameter, under the defined conditions, would be R$ 3,113 million. Indicative NGPP of Cacimbas related to ES-Mucuri-B, with a processing capacity of 12 million $m^3$/d of raw gas from the ES-Mucuri Basin Post-salt, would have an investment cost of R$ 2,600 million. In this case, the NGPP can be built as a new project close to the existing NGPP in Cacimbas/ES, or it can be constituted as an extension of the existing NGPP.

## 5.3 Sergipe-Alagoas Basin - NGPP Atalaia/SE: SEAL-A

The Sergipe-Alagoas basin - NGPP Atalaia alternative (SEAL-A) aims to outflow the raw natural gas produced in Sergipe-Alagoas basin to NGPP Atalaia, with several monetization alternatives, including the possibility of interconnection to the integrated network through a future transport or liquefaction gas pipeline to meet the national or international demand for LNG, in addition to meeting the demand for thermoelectric power plants.

The choice of the path in this case will depends on the volumes expected for production. As NGPP Atalaia/SE has a processing capacity of about 3.0 MMm³/d, it may be necessary to expand it if net production exceeds this value and companies choose to process their natural gas in this NGPP. In addition, it could be necessary to expand the nearby transmission gas pipelines to allow the supply of these volumes of natural gas to the integrated network. In this alternative, there may be greater complexity in the environmental licensing of the offshore segment of the outflow gas pipeline due to the presence of nearby coral reefs (UFS, 2015).

Figure 5.6 illustrates the outflow and processing alternative for SEAL-A alternative, in which the exploration blocks, the producing fields and the existing infrastructure are shown.

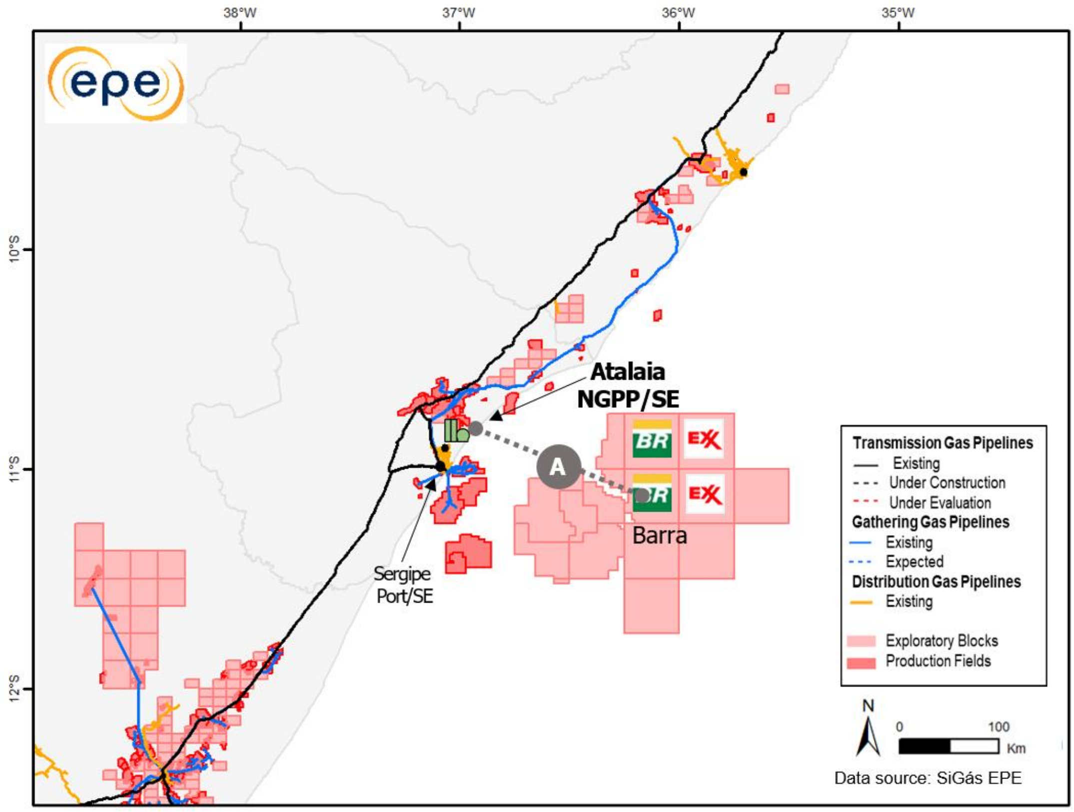



**Figure 5.6. Outflow and processing alternative for SEAL-A**

Source: EPE.

The total extension of the outflow gas pipeline for this alternative, including the onshore and offshore segments, is 106 km, according to the altimetric profile of its guideline, as shown in Figure 5.7. The constructive data for the cost estimate of this gas pipeline are shown in Table 5.5.

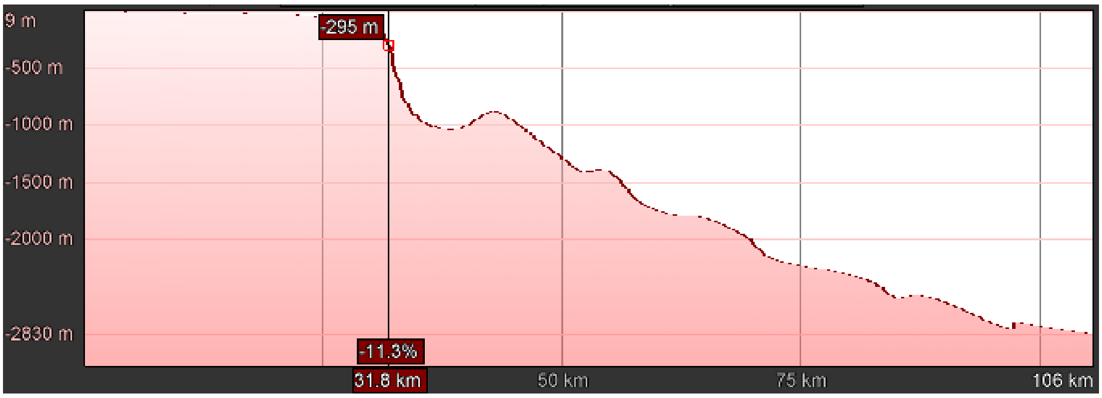



**Figure 5.7. Altimetric profile guideline for the SEAL-A outflow gas pipeline**
Source: EPE.

**Table 5.5. Construction data for the SEAL-A outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 32 | 31 | 16.2 |
| Depth 300-1500m | Small S-Lay | 32 | 55 | 23 | 19.9 |
| Depth > 1500m | Small S-Lay | 55 | 106 | 51 | 23.8 |

Source: EPE.

Considering an optimistic scenario of expansion of the net production of natural gas in the post-salt environment, the outflow gas pipeline was designed for a flow rate of 20 million $m^3/d$ (EPE, 2019). The other premises used in the gas pipeline project SEAL-A were a 106 km extension and a 24-inch diameter. With the extension data, flow rate, and construction data presented in Table 5.5, the investment cost of the pipeline was calculated. Table 5.6 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 5.6. Calculation of CAPEX for the SEAL-A outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 300.09 | 10 % |
| Components | 474.45 | 15 % |
| Construction, assembly and launch | 798.17 | 25 % |
| Commissioning | 15.90 | 1 % |
| Indirect costs | | |
| Engineering Project | 158.86 | 5 % |
| Indirect Costs and Profits | 330.84 | 11 % |
| Taxes | 331.04 | 11 % |
| Contingencies | 722.80 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **3,132.15** | 100% |

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

As shown in Table 5.6, the investment cost for the SEAL-A´s outflow gas pipeline, 106 km long and 24 inches in diameter, under the defined conditions, would be R$ 3,132 million. The indicative NGPP Atalaia of SEAL-A, with a processing capacity of 20 million m³/d of raw gas from the SEAL Basin post-salt, would have an investment cost of R$ 3,500 million. In this case, the NGPP can be built as a new project close to the existing NGPP in Atalaia/SE, or it can be constituted as an extension of the existing NGPP.

## 5.4 Sergipe-Alagoas Basin - Sergipe Port/SE: SEAL-B

The Sergipe-Alagoas basin - Sergipe Port alternative (SEAL-B) aims to outflow the raw natural gas produced in Sergipe-Alagoas basin to a NGPP located in the vicinities of the Sergipe Port, with several monetization alternatives, including the possibility of interconnection to the integrated network through a future transmission gas pipeline, or liquefaction to meet the national or international demand for LNG, in addition to meeting the demand for thermoelectric power plants.

Figure 5.18 illustrates the outflow and processing alternative for SEAL-B, showing the exploration blocks, the productive fields and the existing infrastructure.

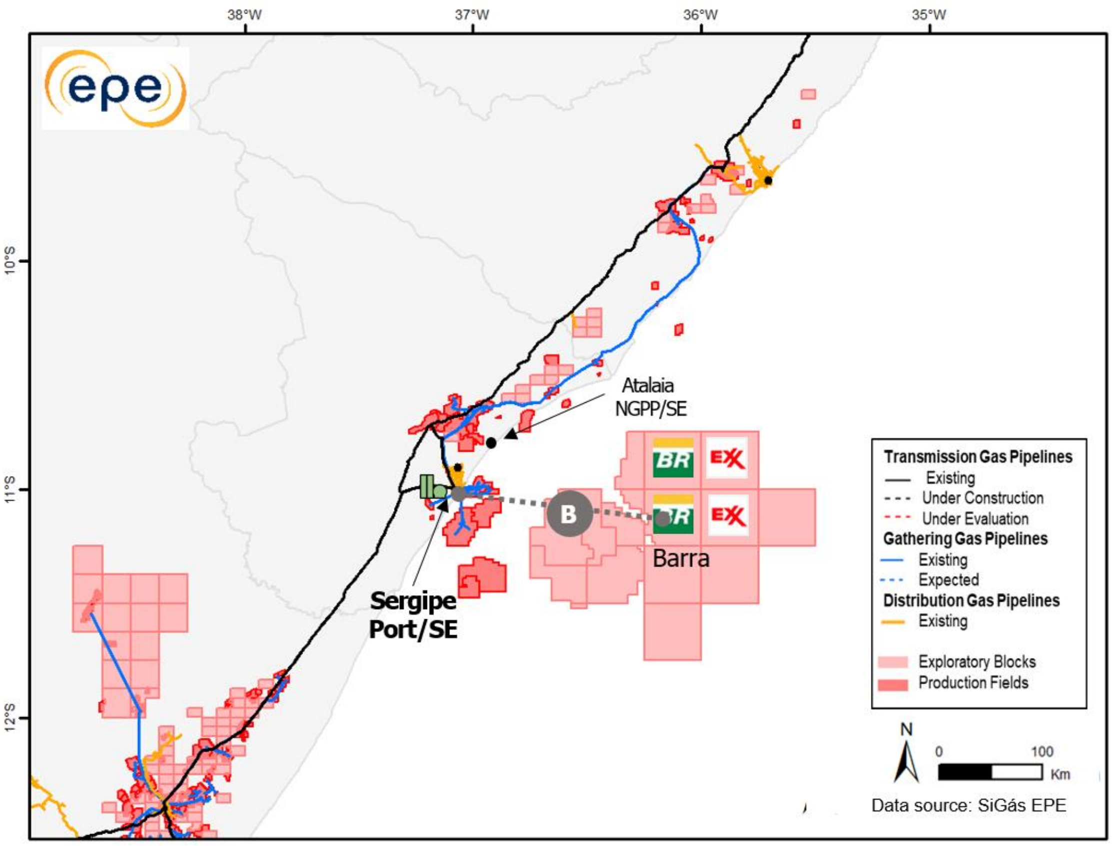



**Figure 5.8. Outflow and processing alternative for SEAL-B**

Source: EPE.

It was considered that the onshore segment of this alternative would require about 25 km to connect to the integrated transport gas pipeline network, which would be classified as an outflow pipeline if the new NGPP is located close to the network, or as a transport gas pipeline if a new NGPP is located on the coast near Sergipe Port/SE (which will have a LNG terminal in the future). It should be noted that the possibility of installing a NGPP in Japaratuba/SE, close to the existing transport network, has already been broadcast in the media (EPBR, 2018); in this case, the onshore segment would be classified as an outflow gas pipeline. The alternatives for the onshore segment and for the location of the NGPP are shown in Figure 5.9.

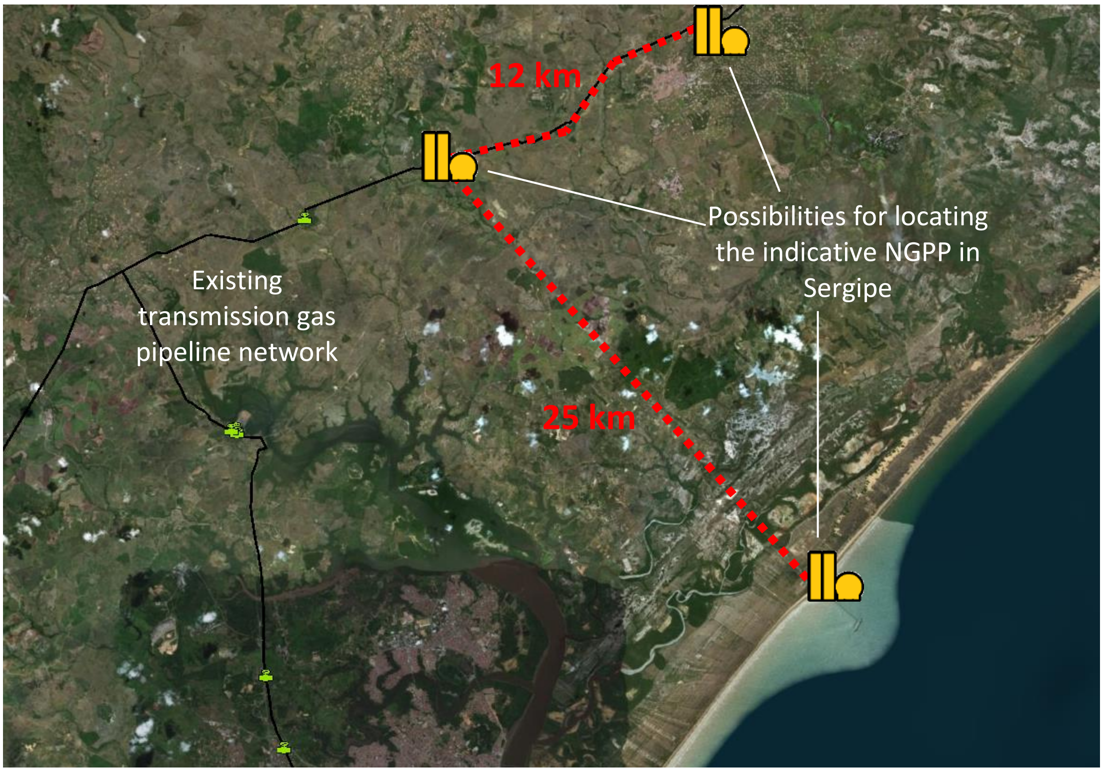



**Figure 5.9. Alternatives for the onshore segment of SEAL-Sergipe Port/SE pipeline**
Source: EPE.

The total extension of the offshore segment of outflow gas pipeline of this alternative is 96 km, according to the altimetric profile of its guideline, as shown in Figure 5.10. The constructive data for the cost estimate of this gas pipeline is shown in Table 5.7.

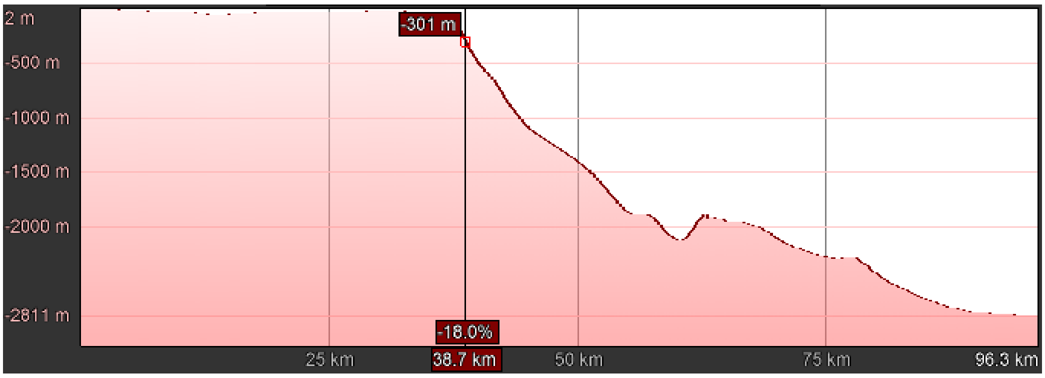



**Figure 5.10. Altimetric profile of the guideline for SEAL-B outflow gas pipeline**
Source: EPE.

**Table 5.7. Construction data for the SEAL-B outflow gas pipeline**

| Type | Constructive Method | initial km | final km | Extension (km) | Thickness (mm) |
|---|---|---|---|---|---|
| Shore Approach | Directional Drilling | 0 | 1 | 1 | 18.0 |
| Depth <300m | Large S-Lay | 1 | 39 | 38 | 16.2 |
| Depth 300-1500m | Small S-Lay | 39 | 50 | 11 | 19.9 |
| Depth > 1500m | Small S-Lay | 50 | 96 | 46 | 23.8 |

Source: EPE.

Considering an optimistic scenario of expansion of the net production of natural gas in the post-salt environment, the outflow gas pipeline was designed for a flow rate of 20 million $m^3/d$ (EPE, 2019). The other premises used in the gas pipeline project SEAL-B were a 96 km extension and a 24-inch diameter. With the extension data, flow rate, and construction data presented in Table 5.7, the investment cost of the pipeline was calculated. Table 5.8 below summarizes the calculated costs of the gas pipeline, separated by type of costs.

**Table 5.8. Calculation of CAPEX for the SEAL-B outflow gas pipeline**

| Description | R$ mi | |
|---|---|---|
| Direct Costs | | |
| Piping | 268.17 | 9 % |
| Components | 474.26 | 16 % |
| Construction, assembly and launch | 761.44 | 24 % |
| Commissioning | 14.40 | 1 % |
| Indirect costs | | |
| Engineering Project | 151.83 | 5 % |
| Indirect Costs and Profits | 316.50 | 11 % |
| Taxes | 316.67 | 11 % |
| Contingencies | 690.98 | 23 % |
| TOTAL INVESTMENT (reference value, with contingencies, reference date Jun/19) | **2,994.24** | 100% |

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

As shown in Table 5.8, the investment cost for outflow gas pipeline SEAL-B, 96 km long and 24 inches in diameter, under the defined conditions, would be R$ 2,994 million. The indicative NGPP at the Sergipe Port related to SEAL-B alternative, with a processing capacity of 20 million $m^3/d$ of raw gas from the SEAL Basin post-salt, would have an investment cost of R$ 3,500 million.

# 6 RESULTS AND DISCUSSION

As presented throughout the study, 11 indicative projects of outflow gas pipelines connected to NGPPs were mapped, 7 of them based on volumes of natural gas from the pre-salt and 4 based on volumes of natural gas from the post-salt. These projects are shown in Table 6.1, along with their extensions, diameters, flow rates and estimated CAPEX values.

**Table 6.1. Summary of the characteristics of the studied projects**

| Project | Extension (km) | Diameter (inch) | Flow Rate ($MMm^3/d$) | CAPEX of the outflow gas pipeline (R$ million) | NGPP CAPEX (R$ million) |
|---|---|---|---|---|---|
| **Pre-salt projects** | | | | | |
| Route 4a | 291 | 24 | 20 | 4,547 | 3,500 |
| Route 4b | 299 | 24 | 20 | 4,851 | 3,500 |
| Route 5a | 199 | 16 | 12 | 3,448 | 2,600 |
| Route 5b | 200 | 16 | 12 | 3,405 | 2,600 |
| Route 5c | 421 | 18 | 12 | 5,213 | 2,600 |
| Route 6a | 119 | 14 | 12 | 2,526 | 2,600 |
| Route 6b | 118 | 14 | 12 | 2,490 | 2,600 |
| **Post-salt projects** | | | | | |
| ES-Mucuri-B | 155 | 14 | 12 | 3,128 | 2,600 |
| ES-Mucuri-B | 157 | 14 | 12 | 3,113 | 2,600 |
| SEAL-A | 106 | 24 | 20 | 3,132 | 3,500 |
| SEAL-B | 96 | 24 | 20 | 2,994 | 3,500 |

Source: EPE.

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

All of the projects listed in the study were studied in an indicative manner, as potential alternatives for increasing the offshore natural gas outflow capacity in the country, and their future implementation will depend on the consideration of several factors by the agents interested in each enterprise , such as: the declaration of commerciality of the projects mentioned in the study; the signing of outflow and processing contracts with entrepreneurs with projects nearby or in the area of influence of the studied gas pipelines; detailing the projects in view of the applicable standards; conducting simulations with a greater level of detail (mainly with regard to flow rates, pressures and diameters) and for various sets of conditions, including risk analysis; the details of socio-environmental and engineering studies; among others.

With regard to the amortization of investments, this can take the form of a value added to natural gas to be made available on the coast after outflow and processing, or in the form of a tariff for the outflow and processing service, to be paid by entrepreneurs who use each infrastructure. The company or consortium responsible for building and operating each project may become agents that also operate in the upstream segment, as well as special purpose companies constituted by these agents. Alternatively, the projects can be implemented and operated by companies operating exclusively in the midstream sector, which will provide agents with a schedule of spare capacity and a manual of conditions for access, reserve these capacities according to the needs of each agent, and charge for outflow and processing services.

Finally, it is observed that the alternatives studied can become feasible individually or jointly, and the feasibility of each one will require a new study in relation to the next alternatives to be implemented, since some of them may be exclusive. In addition, new gas pipelines can be made feasible taking advantage of the proximity to projects already built, which may represent a reduction in the socio-environmental impacts of the project, as well as cost reductions due to economies of scale and scope at the natural gas arrival points, where the NGPP will be located.

# 7 CONCLUSIONS

The existence of available natural gas outflow capacity from offshore fields in several basins to the coast of Brazil, as well as processing capacity, has been identified as a primary factor to allow monetization of the additional volumes of natural gas that will be produced in the next decades. This available capacity may be related to the access of third-parties to existing installations that are not being used to their full capacity, but also (and in some cases necessarily) to the implementation of new outflow and processing projects, both in the pre-salt and post-salt.

In this sense, 11 outflow gas pipeline projects connected to NGPPs were mapped at the level of indicative studies, totaling approximately 2,100 km in extension. These projects may add more than 70 MMm$^3$/day of outflow capacity in offshore environment in the country, in addition to NGPPs with a total natural gas processing capacity of more than 70 million m$^3$/d, corresponding to about 70 % of currently installed capacity (MME, 2019).

Investments in the projects that were studied sum up to approximately R$ 40 billion, in 4 Brazilian states: RJ, SP, ES and SE. However, the investments to be effectively made will depend on the choice of the layout to be built among the options mapped for each project. In terms of direct jobs, these projects have the potential to generate around 8 thousand jobs in the construction phase and 6 thousand steady jobs in the operation phase; with regard to the additional collection of royalties referring to natural gas, this was estimated at around R$ 2 billion per year in total (FGV, 2019). It should be noted that these estimates are simplified, refer to projects with an outflow and processing capacity of 12 to 20 MMm$^3$/d, and should be better detailed once the conditions and parameters of the projects to be executed are defined.

Finally, as noted above, it should be emphasized that the implementation of new outflow pipelines and new NGPPs will depend on the strategic decisions of natural gas producers regarding the monetization of the volumes produced. Alternatively or in a complementary way to outflow and processing, these volumes can be injected to improve oil recovery (up to acceptable injection limits due to the stability of the reservoirs and the optimal liquid recovery regime), liquefied in the sea and monetized via LNG (FLNG technology), converted into liquid products for monetization via GTL (FGTL technology), among other options. In addition, several producers can negotiate the construction of joint infrastructures to take advantage of economies of scale, or independent companies can build such infrastructures and sell outflow and/or processing services to producers.

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