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CRISTIANO MOURA BORGES

EVALUATION OF GAS-INTEGRATED TECHNOLOGIES AIMING AT LEVERAGING PROFITS OF SANTOS BASIN PRE-SALT CLUSTER FOR SOCIETY AND THE INDUSTRY

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Dissertation presented at the Energy Graduation Program from the Institute of Energy and Environment from the University of São Paulo

Supervisor: Prof. Dr. Edmilson Moutinho dos Santos

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Thesis Defence Members:

Prof. Dr.:______________________________ Institution:__________________________

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ABSTRACT

BORGES, C.M. **"Evaluation of gas-integrated technologies aiming at leveraging profits of Santos Basin Pre-salt Cluster for society and the industry"**. 2021. 175p. PhD Dissertation – Graduate Program on Energy, University of São Paulo, São Paulo. 2021.

The small-scale mobile Floating Liquefied Natural Gas (ssm-FLNG) process, which is an emerging technology, is an alternative to reduce logistics costs of natural gas (CH_4-rich stream) in offshore fields and consequently to better manage associated gas streams. In the background of a significant oil discovery in the Brazilian Santos Basin in the Pre-salt Cluster (SBPC), ssm-FLNG combined with miscible CO_2 Water-Alternating-Gas-enhanced oil recovery (CO_2-WAG) is proposed as an alternative to the conventional process based on reinjection of associated gas with rich-CH_4 component in it. The author supports that LNG has turned into competitive even at lower scales and highlights mobility of liquefaction plants as an important factor to achieve economic viability of projects. The CO_2-WAG-enhanced oil recovery becomes a fundamental element in the integrated business model as it accelerates oil production and at the same time allows permanent storage of CO_2 in existing pre-salt fields. This work is a first study to evaluate the deployment of ssm-FLNG combined with CO_2-WAG enhanced oil recovery in SBPC. It considers updated gas-oil-ratios (GOR) and CO_2 component in fluids registered in the Brazilian Pre-salt Cluster, providing a detailed techno-economic analysis. As a conclusion, it is suggested that ssm-FLNG and CO_2-WAG, associated to CO_2 storage, has the potential to monetize a material volume of natural gas (CH_4) produced in the Brazilian SBPC, enhancing fields' economics.

Key words: pre-salt, techno-economic assessment, liquefied natural gas, enhanced oil recovery, carbon capture and storage.

RESUMO

BORGES, C.M. **"Avaliação de tecnologias integradas do gás ambicionando alavancar lucros do Pré-sal da Bacia de Santos para a sociedade e para a indústria"**. 2021. 175f. Tese de Doutorado – Programa de Pós-Graduação em Energia. Universidade de São Paulo.

O processo de liquefação de gás natural em plataformas móveis em pequena escala (ssm-FLNG) é uma tecnologia emergente e representa uma alternativa para reduzir os custos logísticos do gás natural (corrente de gás rica em metano, CH_4) em campos offshore, bem como pode oferecer a oportunidade de melhor gerenciamentos dos fluxos de gases associados a produção de petróleo. No contexto da importante descoberta do Pré-sal no Brasil, mais especificamente o Cluster do Pré-sal da Bacia de Santos (SBPC), o processo de liquefação de gás natural em plataformas móveis em pequena escala (ssm-FLNG), combinado com o método de recuperação de petróleo denominado (CO_2-WAG) é a proposta alternativa ao processo convencional baseado na reinjeção de gás associado que inclui a corrente de gás rica em metano (CH_4). O autor defende que o gás natural liquefeito (GNL) se tornou competitivo mesmo em escalas mais baixas e destaca a mobilidade das plantas de liquefação como um fator importante para se atingir a viabilidade econômica dos projetos. A recuperação de petróleo aprimorada pela técnica de CO_2-WAG torna-se um elemento fundamental no modelo de negócios integrado, pois acelera a produção de petróleo e ao mesmo tempo permite o armazenamento permanente de CO_2 nos campos existentes do pré-sal. Este trabalho é um primeiro estudo para avaliar a implantação de ssm-FLNG combinado com recuperação avançada de óleo de CO_2-WAG em SBPC. O trabalho considera a relação gás-óleo (GOR) e a concentração de CO_2 no gás associado produzido. O trabalho apresenta uma análise técnico-econômica detalhada. Como conclusão, sugere-se que ssm-FLNG e CO_2-WAG, associados ao armazenamento de CO_2, têm o potencial de monetizar um volume material de gás natural (CH_4) produzido na SBPC brasileira, melhorando a viabilidade econômica dos campos de produção de petróleo no cluster do Pré-sal da Bacia de Santos.

Palavras-chave: pré-sal, avaliação técnico-econômica, gás natural liquefeito; recuperação melhorada de óleo, captura e armazenamento de carbono

FIGURE LIST

TABLE LIST

SUMMARY

1 INTRODUCTION

This work compiles the findings of two papers that were developed by the author during the research process. The first paper provides insights into how small-scale mobile-Floating Liquefied Natural Gas (ssm-FLNG) process, which is an emerging technology, is an alternative to reduce logistics costs of natural gas (CH_4-rich stream) in Búzios Pre-salt field. In the first instance the author limited the focus of the research into Búzios field, which is one of the largest fields in Santos Basin Pre-Salt Cluster (SBPC). Thus, the parameters and assumptions mined during this initial research, combined with the in-house Excel model developed to support this first analysis served as a starting point for the evaluation and, in some cases, deployment of integrated-gas related technologies in deep offshore pre-salt fields that have high volumes of associated gas, high CO_2 concentration in fluids and further complexities.

The second article is a natural evolution from the first paper. It evaluates the deployment of the same integrated-gas technologies in a cluster instead of in a single field which allows a holistic approach and consequently better utilization rates of assets and consequently improved economic results. In the second paper, the research object is ten selected fields of Santos Basin Pre-salt Cluster, which required further research in terms of updated data and analysis.

This introduction presents in detail the research background, literature gap, research problem and other crucial elements to explain the purpose of this work and the proposed solution. Chapter 2 will describe in detail the methodology and the in-house Excel developed model to perform the required techno-economic evaluation. The following chapters (3 and 4) follow a typical article structure, presenting paper one and paper two developed by the author. Therefore, those chapters will present an overview and relevant literature review for each article developed. The final conclusions of this work are in section 4.4 inside paper two section. The appendix presents further information of the techno-economic model and oil recovery curves of each analysed field.

1.1 Motivation and background

In the future energy scenarios NG and LNG are seen as an optimal vehicle to ensure an orderly transition from the fossil-fuel driven economy to one driven by renewable energy. Under this context, Santos Basin Pre-salt Cluster (SBPC), which is one of most significant recent oil discoveries Worldwide (Moczydlower, 2012) has the potential to produce more than

19.6 billion barrels of oil and 21.2 trillion standard cubic feet (scf) of natural gas. It is located in ultra-deep waters (1,900-2,400 m) approximately 300 km offshore from the coast of Brazil´s South-eastern states (Rio de Janeiro and São Paulo) [1]. This can generate up to 1.90 trillion dollars of income, assuming oil price at 76.00 USD/bbl and gas price at 4.0 USD/MM BTU (Gaffney, 2010).

Having such a large natural resource at its disposal would bring Brazilian society several economic and social benefits. It would provide affordable source of energy for the foreseeable future, as well as income in terms of taxes and royalties and would lead to jobs creation. Based on the recent analysis the exploitation of the SBPC could generate up to 432.00 USD billion in taxes, 190.00 USD billion in royalties and 19.00 USD billion in local Research & Development (R&D), as well create more than one million job (Gaffney, 2010; Almeida, 2016). The latter addressing currently a critical need in Brazil.

On the other hand, this prolific hydrocarbon reserve is accompanied by important issues, such as the need of better management of massive volumes of associated gas that require treatment and logistics. In the literature, there is a gap relating to an updated technical economic assessment of integrated-gas technologies in SBPC, considering actual GOR, CO_2 content, prices and its commercial aspects.

This research provides a starting point in our ability to optimally utilize natural produced in pre-salt sites in Brazil, as it will tackle the still unresolved challenges encountered in exploiting associated natural gas that require treatment and logistics to move the natural gas rich stream to final consumers. This work is a first study to evaluate the deployment of ssm-FLNG combined with CO_2-WAG enhanced oil recovery in Santos Basin pre- Salt Cluster (SBPC). It considers updated gas-oil-ratios (GOR) and CO_2 component in fluids registered in the Brazilian Pre-salt Cluster, delivering a revised detailed techno-economic analysis of this important hydrocarbon cluster.

The research hypothesis is that integrated-gas technologies, likewise small scale mobile Floating Liquefied Natural Gas (ssm-FLNG) combined with enhanced oil recovery method (CO_2-WAG) may have achieved, in specific cases, the necessary conditions to effectively contribute to the need of leveraging the social-economic benefits of the existing oil and gas activity in remote offshore locations, such as the Brazilian Pre-Salt.

1.2 Purpose of this work and proposed solutions

In the industry, for instance Petrobras, Cosan and other groups have been investigating the viability to build gas pipelines to move the gas to onshore consumptions areas. For example, Project Rota 4, which plans to build a gas pipeline to move natural gas to São Paulo, has not been executed yet, mainly due to its complexity and modest return to its prospective investors as a consequence of uncertainty of domestic consumption.

The purpose of this work is to explore a different logistics alternative and to evaluate the utilization of ssm-FLNG, combined with enhanced oil recovery (CO_2-WAG) and CO_2 storage. To reach that purpose, it is investigated how certain techno-economic aspects impact the viability of deploying integrated-gas technologies in the target oil reserve to monetize its natural gas. It is important to emphasise that one key characteristic of this reservoir is the presence of associated gas and its high CO_2 content. It means that to produce and commercialize the profitable oil stream it is necessary to find suitable outlets for the produced gas that cannot be released in the atmosphere for environmental reasons. One of the initial hypotheses is that modularity and mobility of the proposed floating liquefaction plants are key enablers of profitability due to its flexibility in terms of capacity expansion.

1.3 Deliverables and contributions

This work has two major deliverables: first, it proposed a feasible and better management of gas streams through the deployment of integrated-gas technologies. Second, it delivered a techno-economic model to support future feasibility studies relating to gas-integrated technologies.

In terms of research contribution this work provides three points: it demonstrates how integrated-gas technologies can leverage the benefits of existing oil production for the society and the industry. Second, it shares with the scientific community actual and updated information, such as gas-oil-ratio (GOR) and CO_2 content in fluids in SBPC, starting from a dedicated study of Búzios field. Third, it enlightens that there is a potential conflict of interest between the established and profitable liquid fuels business and the opportunity to unlock massive volumes of cheap natural gas to supply the electricity and transportation needs in the Brazilian domestic market.

1.4 Why this work is special?

This interdisciplinary research covered technical, economical, commercial, organisational, and political aspects of the natural gas and liquified natural gas industry in Brazil. The researcher had to perform this multidisciplinary approach to deliver a successful research. He worked with researchers from different fields in collaboration with University of São Paulo (USP), Imperial College London, Sustainable Gas Institute, Shell and Petrobras and other key institutions to develop an appropriate understanding of the multiple factors involved in the deployment of the technologies for NG production from Brazil's pre-salt fields.

1.5 How did this work succeed?

This work was an independent and collaborative research, "sandwich Ph.D." (36 months at USP and 12 months at Imperial College London), which trained and equipped a future, multidisciplinary professional in gas innovation with the ability to serve the Brazilian oil and gas industry, while building out RCGI and SGI's research activity in LNG.

It further strengthened Brazil-UK links in this area, as it is focussed on developing a commercial and sustainable natural production from pre-salt fields. This research involved University of São Paulo, Imperial College, Research Centre for Gas Innovation and Sustainable Gas Institute.

2 METHODOLOGY AND MODEL DEVELOPMENT

As indicated in the introduction section, this study aims to address the issue of unlocking stranded gas in SBPC, by providing a detailed techno-economic analysis of deploying integrated-gas technologies. To reach that goal, factors affecting the monetization of associated gas were investigated, leading into the conceptualization of a techno-economic model to support the required analysis.

The key building blocks of the research methodology are summarized as follows:

- Characterization of the research object
- Define the research problem-question and value drivers.
- Collect and process real system data.
- Formulate and develop the techno-economic model.
- Select appropriate design and experimental conditions.
- Validate the model.
- Perform simulation runs, analysis and synthesis.
- Results and recommendations

2.1 Characterization of the research object

The characterization of SBPC started by Búzios field, which is one of the largest fields in Santos Basin Pre-salt Cluster (SBPC) and then in a second moment evolved to ten selected fields in this cluster. The representation of Búzios field and SBPC was based on literature review and conversation with experts and are represented in Figures 1 and 2.

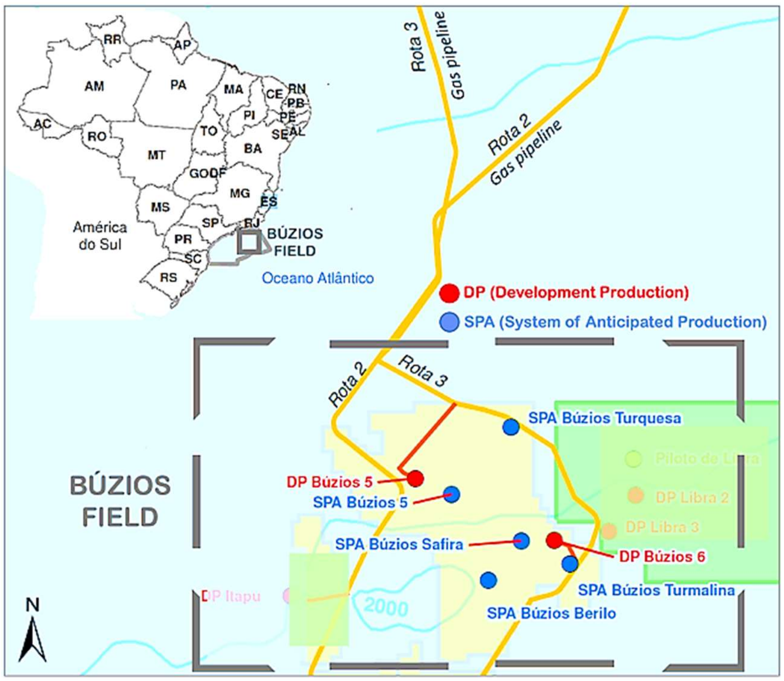

Figure 1 - Representation of Búzios Pre-salt field
Source: Petrobras 2017

In relation to the required logistics that would enable moving natural gas to onshore consumption centres, according to Petrobras' information to IBAMA (2017) Petrobras is considering to build two short pipelines (17.1 and 7.3 km) for DP Búzios 5 and 6. Those planned pipelines are going to connect to the existing gas pipeline network (Rota 2 and Rota 3). For the remaining five SPAs, no gas pipeline had been considered until September 2017.

On the other hand, a recent report from Cosan to IBAMA, indicates the plan to build an additional pipeline, named Rota 4 gas pipeline, with an estimated capacity of 21 million m^3/day and a total length of 288 km. It will expand the current natural gas flow system, composed of the Rota 1 gas pipeline, in operation since 2011 (gas treatment at the Monteiro

Lobato Gas Treatment Unit - UTGCA, in Caraguatatuba, SP), Rota 2 gas pipeline, in operation since 2016 (gas treatment at the Cabiúnas Gas Treatment Terminal - TECAB, in Macaé, RJ) and Rota 3 gas pipeline, in the process of installation (treatment will be at the Rio de Janeiro State Petrochemical Complex - COMPERJ, in Itaboraí, RJ).

UTGN will have the capacity to process all the gas drained by the Rota 4 gas pipeline, generating in addition to the natural gas specified for sale, also the liquefied petroleum gas (LPG), ethane and C5 + 1 by-products.

The characterization of SBPC allowed to develop an initial high-level understanding of the components of the research problem and corresponding research question.

2.2 Defining the research problem

The research problem was the need of producing more affordable energy with low CO_2 footprint in Santos Basin Pre-salt Cluster (SBPC), considering its production environment. In addition, there was the need of finding outlets for the growing volumes of associated gas produced in SBPC considering its logistics issues.

In relation to the specific issue of not finding outlets for the produced gas, it can generate direct limitation on oil production flow, which impacts revenues and cash flows. According to Petrobras (2017), the produced gas from Long-Term Duration Test (TLD), Anticipated Production System (SPA) and short-term Production Development (DP) is primarily utilized as fuel in the FPSO (Floating Production Storage and Offloading), and then the gas surplus may have two destinations: one destination, whenever possible, is the gas reinjection and the second destination is flaring/venting, which has important limitations to be considered.

In Petrobras report to IBAMA (2017), the document complements that the oil production from TLD, SPA and DP is limited by the amount of gas authorized to burn by the National Petroleum Agency (ANP) and IBAMA (Brazilian Institute of the Environment), which can vary according to gas-oil-ratio (GOR). In addition, in some cases, there may be other technical limitation in the amount of gas reinjected in the field.

Consequently, if there are not enough outlets to absorb the associated gas or if GOR is higher than planned, it may limit the oil production and its profitability. Alternatively, "unintended leakage" could happen, especially when there are lose control systems and this fact is happening miles away from public eyes and awareness.

In addition to the lack of infrastructure to move the natural gas to the onshore consumption centres, the high CO_2 content within the gas stream make it has been difficult to achieve the necessary financial thresholds. Consequently, most volume of the natural gas produced is planned to be reinjected and may not be properly monetized and the society may not capture the related benefits of having access to this cheap energy source.

As a consequence of this complex production environment, the conceived research question was: "How to utilize integrated-gas technologies to leverage the social and economic benefits of oil production in Santos Basin Pre-salt Cluster (SBPC) and to reduce its environmental side effects, based on the urgent need of promoting economic growth and create jobs in Brazil?"

Therefore, this research question drove the study to present a feasible proposal to deploy integrated-gas technologies, enabling a better management of gas streams produced in pre-salt, considering the need of profitability.

2.3 Collect and process real system data.

After an initial understanding of the research problem, it was mapped the key value drivers affecting it, and then it was searched the required information to populate the model. The model running with actual and updated information lead into the conceptualization of financial scenarios (expected, high and low) that were fundamental to deliver the ambitioned analysis.

The following picture has a representation of the production environment of oil, its associated gas and the logistics. Then, it drills down on its components being the first level composed by 3 categories: technical, economic and commercial. Then, in a deeper level, there are the selected assumptions that drive value in each category.

Assumptions 1 to 4 are quantitative assumptions and are part of the calculation of techno-economic model. Even though the 5th assumption is not a quantitative assumption and is not part of the calculation it is considered in the whole overall analysis and described in more details in section commercial aspects within the corresponding sections of papers 1 and 2.

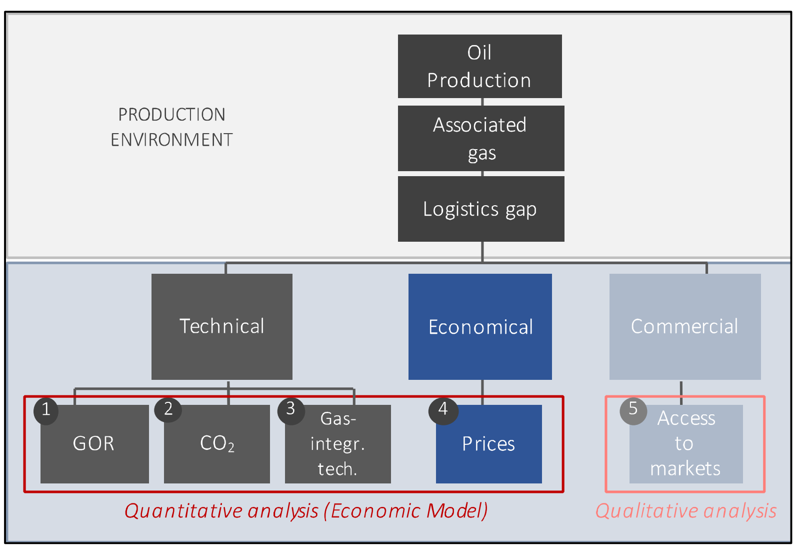

Figure 2 - Schematic representation of selected value drivers for the evaluation of a profitable monetization of stranded gas utilizing gas-integrated technologies

The initial building block of the model was Gaffney, Cline & Associates Inc. (GCA) study on ten selected fields of Santos Basin Pre-salt Cluster (SBPC). GCA was hired by ANP (Brazilian National Petroleum Agency) to review technical data, development plans, work obligations and associated investments related to the discoveries and independently estimate resources. For some fields, such as Búzios, ANP provided GCA sector simulation model results for a given reservoir volume with homogeneous average properties, number of production wells, water injection wells and gas injectors. These simulation models were used by ANP for estimating the reservoir performance under injection of gas with the CO_2 produced in each field at the top of the structure and injection of water at the bottom of the oil zone. GCA understood that the operator was planning to use water-alternating-gas (WAG) as the standard technique for improving recovery in these pre-salt fields.

2.4 Formulate and develop the model

The formulation and development of the model was based on the methodology indicated by Morse (1997) and Maria (2014), which are the same methodology that drove the overall research methodology. The software utilized to calculate and develop the required economic simulations was Microsoft Excel. Its development process is summarized by the following schematic representation:

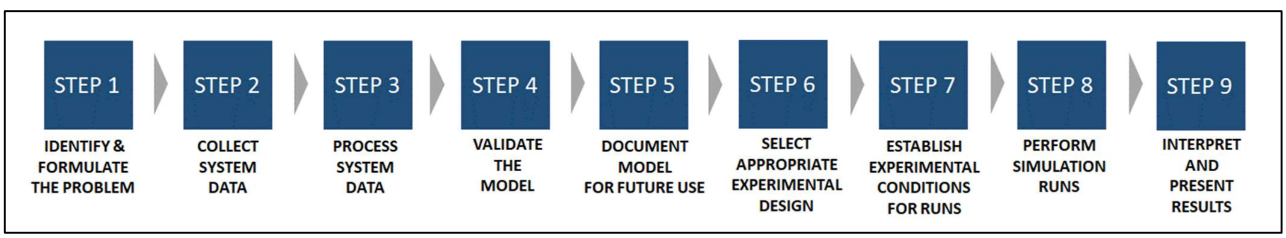

Figure 3 - Schematic representation of model development

One of the key challenges was to simulate the effect of changing the recovery method from water-alternating-gas (WAG) adopted in the base case scenario from GCA to water-alternating-gas with CO_2 (CO_2-WAG). Ahmadi (2015) made a laboratory displacement study of several enhanced-oil-recovery methods, including WAG and CO_2-WAG. This study was the basis to simulate the oil production impact relating adopting CO_2-WAG as the new recovery method. The equations of oil productions curves are detailed in papers one and two in the upcoming sections.

2.5 Select appropriate experimental design and corresponding experimental conditions

In this part, it was select key performance measures (KPIs) and few inputs variables that have the highest influence in the key outcomes of the system. The main elements to formulate and develop the model are listed, as following: oil and gas production, natural gas consumption to fuel FPSO (Floating Production Storage and Offloading), gas injection, expenses, taxes and net cash flow.

The key parameters considered to develop the model were oil and gas production, operational expenditure (Opex), capital expenditure (Capex), revenue and net present value (NPV), which are detailed in the following sections. In the case of key assumptions, it was considered gas-oil-ratio (GOR), CO_2 in fluid, utilization rate of liquefaction plants, unitary Capex and unitary Opex. The main sources of information were GCA, Petrobras-IBAMA and International Gas Union (IGU).

Drilling down on tax regime, Brazil has a mixed regulatory regime. Before 2010 the regime was a concession and then it changed to production sharing. Since the comparison of regimes and its financial implication are outside the scope of this work, it was considered the concession regime for all fields. In summary, 10% Royalty and 34% Corporate Tax, but it excludes a Signature Bonus, Special Participation Tax, PIS and COFINS and a Research Contribution. In the updated scenarios, it was included 1.0% of additional royalties, relating to the legal obligation of investing in research and development in the country.

To address the challenge of obtaining accurate information and the most useful information from each run, it was collected and organized the key outputs from the discounted cash flow (DCF) model. These organized outputs supported the analysis and lead to synthesis and conclusions.

It is important to note that the anticipation of oil and gas production based on the CO2-WAG enhanced oil recovery method is based on a laboratory study and there is a the extrapolation risk that was not considered in this study.

2.6 Validate the model

The validation process started by comparing the original information from Gaffney, Cline & Associates (GCA, 2010) with the information extracted from the developed model.

Table one indicates the comparison of GCA information and the developed model. It presents a high adherence to the preliminary data from GCA.

Table 1 - Model adherence

	Gaffney, Cline & Associates (GCA)	Techno-economic model	Adherence
Oil Production (MM bbl/year)	19,607	19,607	100,00%
Gas Production (MM scf/year)	21,223,000	21,224,085	100,01%
Oil Revenue (MM USD)	1,955,947	1,955,945	100,00%
Net Cash Flow (MM USD)	895,701	895,699	100,00%
NPV/bbl (USD/bbl)	9,40	9,35	99.54%

Source: author’s techno-economic model (folder Step 4a)

3 PAPER ONE – EVALUATION OF GAS-INTEGRATED TECHNOLOGIES IN BÚZIOS PRE-SALT FIELD

This Chapter presents the full text of the article submitted to Energy Conversion and Management under the title: "Evaluation of gas-integrated technologies in Búzios Pre-salt field aiming at leveraging profits for society and the industry". The structure here follows the same one used in the final paper, but the published version will eventually contain changes suggested by the journal's editor and reviewers. Some few alterations were also done to adapt the article to this thesis format.

Sub-chapter 3.1 will present study's motivations and objectives. Sub-chapter 3.2 presents methodology. Sub-chapter 3.3 will describe the key evaluated aspects relating to this research work. Sub-chapter 3.4 presents and discuss model's results. Finally, sub-chapter 3.5 will draft our conclusions and recommendations for the deployment of gas-integrated technologies in the Brazilian Pre-salt.

3.1 Introduction

The Santos Basin Pre-salt Cluster (SBPC) is located in ultra-deep waters (1,900-2,400 m) approximately 300 km offshore from the coast of Brazil's South-eastern states (Rio de Janeiro and Sao Paulo) [1]. According to the analysis carried out by Gaffney et al. [2] which was based on ten selected fields from this cluster, the SBPC has the potential to produce more than 19.6 billion barrels of oil and 21.2 trillion standard cubic feet (scf) of natural gas. This can generate up to 1.9 trillion dollars of income, assuming oil price at 76 USD/bbl and gas price at 4.0 USD/MM BTU [2]. Having such a large natural resource at its disposal would bring Brazilian society a number of economic and social benefits. It would provide affordable source of energy for the foreseeable future, as well as income in terms of taxes and royalties and would lead to jobs creation. Based on the recent analysis [2-3] the exploitation of the SBPC could generate up to 432 USD billion in taxes, 190 USD billion in royalties and 19 USD billion in local Research & Development (R&D), as well create more than one million job [3]. The latter addressing currently a critical need in Brazil.

The social and economic prosperity that could be achieved by exploitation of this natural resource requires overcoming significant exploration and environmental issues. The former is due to operating at challenging water depths far from the coast and dealing with high-pressure and high-temperature reservoirs that are spread over very large areas and that lay immediately bellow a thick salt layer. The latter arises from dealing with large amounts of associated gas, that has a high CO_2 content.

The difficult production environment of SPBC, including the need of managing associated gases, both CH_4 and CO_2 streams, the lack of gas pipelines and potential environmental hazards has already been discussed in literature by number of authors [4]-[13]. The consensus is that the main technological barrier to surpass is how to optimally extract oil with associated gas, at high gas-oil-ratio (GOR), and how to deal with high CO_2 content of the produced gas. In addition to the lack of sufficient infrastructure to move the natural gas to onshore consumption centres, the high CO_2 content within the gas stream makes it difficult to achieve the necessary financial thresholds to justify the monetization of associated gas. Consequently, the current view is that most of the produced associated gas is to be re-injected and may not be properly monetized. If this turns out to be the case, the Brazilian society will not capture the related benefits of having access to this readily available energy source, which otherwise could play a major role in the forthcoming country's energy transition strategy. In this work we explore alternative strategies to avoid re-injecting the whole gas stream by making use of the gas-integrated technologies that can offer viable alternatives.

A number of works have already looked at viable alternatives. Araujo [21], in his study, evaluated CO_2 separation alternatives, by considering early enhanced oil recovery (EOR) as the final destination of CO_2. Ahmadi et al. [22] provided a laboratory displacement study of several Water-Alternating-Gas (WAG) methods for enhancing oil recovery, by considering two options, namely associated gas/water and CO_2/water injections. Based on this work, it is possible to assume that CO_2-WAG anticipates oil production, even though it might reduce the total oil recovery when it achieves recoverable levels above 80%, which is not the case in this field. Emadi et al. [23] and Moradi et al. [24] indicate that CO_2 injection is an efficient EOR method, which improves the oil recovery factor, providing temperature and pressure are such that all the CO_2 is dissolved in oil. Van't Veld et al. [26] and Azzolina et al. [27] performed an economic evaluation of CO_2-EOR combined with CO_2 storage, showing that the deployment of this technology results in better cash flows from oil production, even in less favourable situations when economic incentives coming from lower CO_2 emissions is lacking. Bachu [25] stated that CO_2 disposal in sedimentary basins are the best option currently available for the long-term sequestration of CO_2.

The lack of current infrastructure in SBPC also raises serious issues of how to most efficiently transport natural gas to the coastal sites. Apart from pipelines, liquefying natural gas also offers a plausible alternative. Alkthatib [15] conducted a historic overview of the development of liquefied natural gas (LNG) industry, indicating that it represents the only economical alternative to natural gas transport by pipelines. It also provides greater flexibility in contrast to pipelines. Markou [16] performed a detailed and more recent review of LNG-related technologies, as well as in-depth analysis of the status of the market by 2015, indicating that one of the major trends in LNG technology is to extend it to offshore application by employing floating LNG technology (FLNG). Wang [17] proposed a development plan for the use FLNG in China and concluded that FLNG technology would be effective and feasible for developing difficult-to-produce offshore reservoirs. Bukowski [18] discussed the challenges related to liquefaction on a floating platform, including motion of the production vessel (particularly important in less favourable ocean conditions), weight and space limitations as well as discussing corrosion and flammability issues. They indicate that some of the issues can be addressed by taking advantage of new purpose-built heat exchangers and compressors that offer exceptional mechanical strength and performance. Rattanavich [19] stated that small-scale FLNG (ss-FLNG) projects usually face diseconomies of scale, in comparison to larger plants. Nevertheless, the advantages behind constructing ss-FLNG plants are faster construction time, simpler liquefaction processes, and lower maintenance and lower initial capital costs. Those are important positive aspects of ss-FLNG regardless of any other additional advantage associated to marketing strategies for produced gas. Tan [20] investigated the deployment of onshore mobile (and modular) ss-LNG plants (ssm-LNG) as an attractive alternative to offshore gas monetization. The author proposes a multi-period optimization framework which determines the optimal dynamic allocation and operating decisions, considering time-varying supply, price and demand. The work indicates that utilizing mobile plants offered a profitable and flexible method to monetize associated gas in Bakken shale play in Mississippi region. Although a number of techniques have been studied to address the noted production and environmental issues the previous work has neither systematically analysed the techno-economic performance nor examined the benefits of combining different technologies. Therefore, in this study we perform a techno-economic evaluation of a particular gas-integrated technology that consists of small-scale mobile FLNG plants (ssm-FLNG) operating in conjunction to CO_2-WAG-EOR and CO_2-storage.

The main objectives of this work are: i. to investigate the key factors of the techno-economic performance and competitiveness of ssm-FLNG combined with CO2-WAG and CO_2-storage; ii. to promote better management of CH_4 and CO_2 streams produced in SBPC field. It is envisaged that the results of this study will help policy makers and investors to optimally implement gas-integrated technologies in Brazil and abroad.

3.2 Methodology

3.2.1 Model development

In the first instance we have limited our study to Búzios field. It is one of the largest fields in Santos Basin Pre-salt Cluster, SPBC [2], and it has high gas-oil-ratio (GOR) and high CO_2 content [28]-[34]. The potential volume of natural gas to be produced in Búzios field is around 8.7 billion m^3/year, which is equivalent to 35% of the total natural gas volume consumed in Brazil [34]. It can thus serve as a proxy for the whole SPBC. It is a potential valuable energy source, available in large quantities, for the Brazilian society over the next decades.

This methodology section aims to explain how the techno-economic model was developed to support the research analysis. The following sub-sections provide further details on the evaluated technical, economic, and commercial aspects that impact on the deployment of integrated-gas technologies in Brazil.

The starting point of our methodology was to build a model that would represent the study of Gaffney, Cline & Associate (GCA) [2] who performed a review and economic evaluation of ten selected prospects in SBPC considering the available information at that time (2010). On that time Agência Nacional do Petróleo, Gas Natural e Biocombustíveis (ANP), in support of efforts by the Brazilian Government, hired GCA who reviewed and audited the technical data, development plans, work obligations and associated investments related to the discoveries and prospects and independently estimated hydrocarbon resources. GCA's base evaluation contemplated only oil volumes although it is acknowledged that development plans include gas exploitation for fuel, injection and eventual export and sale. That is the main reason why it has been considered as the benchmark for this work and has been nominated as the base case scenario. Gaffney [2] considered a recovery factor between 10% and 48%, with a most likely value of 26% for the 28o API oil.

In the second step we made use of Petrobras (Brazilian National Oil Company) reports to IBAMA (Brazilian Institute of the Environment) about Búzios Pre-salt field, to develop revised production profiles, considering updated gas-oil-ratio (GOR) and CO_2 content in fluids.

Based on the work performed by Ahmadi [22], it was simulated the impact of liquefying the rich-CH_4 stream in a ssm-FLNG unit after gas separation, and then proceed with CO_2-WAG enhanced oil recovery method. The rich-CO_2 stream would be reinjected during the field production lifetime and stored in the existing sedimentary basin similarly to the current gas injection method (WAG).

In relation to performing the analysis, we have developed three scenarios in addition to GCA base case scenario. Therefore, this work considers the following scenarios: base, expected, high and low. The expected scenario contains updated assumptions and corresponding results which the authors consider most likely. The high case scenario contains updated assumptions which deliver improved economic results, and consequently, the low case scenario has the assumptions that deliver inferior economic results. The assumptions that drive those scenarios are detailed in table 2, page 36.

Figure 5 has a simplified representation of the described methodology, which starts by developing a techno-economic model to represent GCA numbers, passing through populating the model, performing simulation and finally performing the required analysis.

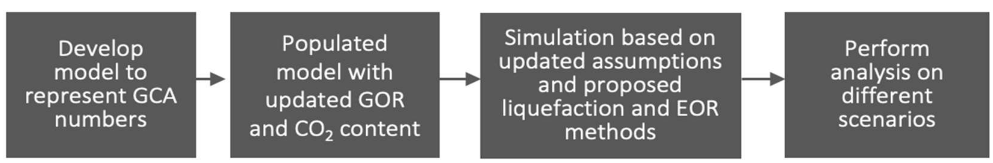

Figure 4 - Schematic representation of research methodology

The model allowed us to simulate the deployment of selected gas-integrated technologies (ssm-FLNG and CO_2-WAG combined with CO_2 storage) and evaluate corresponding production and economic impact, embedded by the mobility aspect. The key parameters considered in this study were oil and gas production, operational expenditure (Opex), capital expenditure (Capex), revenue and net present value (NPV), which are detailed in section results. In the case of key assumptions, it was considered gas-oil-ratio (GOR), CO_2 content in fluid, utilization rate of liquefaction plants, unitary Capex and unitary Opex.

For modelling purposes, LNG plant capacity was considered as 1.0 MTPA based on information from International Gas Union, IGU [35]. For ssm-FLNG, it was assumed a plant capacity of 0.5 MTPA. It was also assumed that plants should achieve at least 33.33% of nameplate capacity, otherwise they are not implemented due to excessive idle capacity. On the other side, it was assumed that liquefaction plants do not goes beyond 87.00% of nameplate capacity.

In the case of key assumptions, in GCA base case scenario, oil price was considered at 75.98USD/bbl and increased in an annual basis by inflation (2.0% per year). In the expected case, oil price was considered at USD 50.00/bbl and natural gas price at the wellhead at USD 5.50/bbl, both with a 50% plus and minus variation for high and low scenarios, increasing by inflation over the years (2.0% per year).

Drilling down the assumptions, IGU's average liquefaction cost from 2012 to 2015 ranged from 807 to 1,508 USD/tonne, being floating plants 1,373 USD/tonne [35]. Based on that information and unitary Capex correlation with oil prices, it was assumed a unitary floating LNG capital expenses (Capex) ranging from 800 to 1,200 USD/tonne, being the expected case at 1,000 USD/tonne. In the case of ssm-FLNG it was assumed an additional unitary Capex of 7.00% mainly due to diseconomy of scale and mobility requirements, delivering an equivalent value of USD 1,070 USD/tonne. This additional Capex for ssm-FLNG considers the net effect between diseconomy of scale partially compensated by savings relating to reduction of space utilization on FPSO deck. Then, a 20% plus and minus variation was considered for high and low scenarios. In table 1, there is a summary of Capex for base, expected, high and low cases.

Finally, in relation to operational expenses (Opex), it was assumed that the application of the evaluated gas-integrated technologies results in minor increase in Opex. Based on the fact that most of the Opex is linked to the existing oil and gas production system, including treating the associated gas, we assumed that annual operational expenses relating to the deployment of integrated-gas technologies will vary in line with corresponding annual capital expenses variance, based on the following metric: Δ Annual Opex = Δ Annual Capex X 5%. This rational applies to either FLNG or ssm-FLNG technologies. Next, on table 2, there is a summary of the key data input of Búzios field that is relevant to explain our methodology and analysis.

The idea is to establish ranges of maximum and minimum results and in between the expected results, therefore there is an intentional combination of the assumption to define these ranges.

Table 2: Input data (Búzios field)

	Base	Expected	High	Low
GOR (m^3/m^3)	197.38	359.89	426.47	197.38
CO_2 (%)	-	54.77%	43.81%	65.72%
Oil Prices (USD/bbl)	75.98	50.00	75.00	25.00
NG Prices (USD/MM BTU)	4.00	5.50	8.25	2.75
Unit Capex LNG (USD/MTPA)	-	1,000	800	1,200
Unit Capex SSLNG (USD/MTPA)	-	1,070	856	1,284
Δ Opex LNG and ssm-FLNG as a function of Δ Capex	-	5.00%	4.00%	6.00%

Sources: Gaffney, 2010, Petrobras, 2017, IGU, 2012-2015 and author's estimations

The method to calculate the new oil and gas production profile considers injection of rich-CO_2 stream (CO_2-WAG) instead of injection of a mixture of associated gases (WAG). The latter is the base case developed by by Gaffney et al. [2]. The new production profile was built based on curves presented in the work presented by Ahmadi [22], which was a laboratory displacement study. The equations of oil production curves are indicated in Table 3.

Table 3: Equation of oil production curves (Búzios field)

	Oil production curves per year (MM bbl./year, year 1 to 40)
Base Case (WAG)	$y = -5.0062x^2 + 396.48x – 2,257.5$
Expected Case (CO_2-WAG)	$y = -3.7941x^2 + 361.46x - 1,213.7$
High Case (CO_2-WAG)	$y = -4.5529x^2 + 433,75x - 1,456.4$
Low Case (CO_2-WAG)	$y = -3.1617x^2 + 301.21x – 1,011.4$

Source: author's techno-economic model

The outputs of the model are the revised profile of oil and gas production curves with corresponding Capex, Opex and economic indicators, such as revenue and net present value, which are detailed in results section. It is important to note that in Gaffney's model, natural gas is allocated as a by-product, being mainly applied to low value activities like gas lifting and enhancing oil recovery through water alternated gas (WAG) or flaring/venting.

This work proposes to develop an alternative and improved management of gas streams by promoting a better allocation of natural gas (CH_4-rich stream) and carbon dioxide streams (CO_2-rich stream). The hypothesis is that the appropriate allocation and monetization of CH_4 and the enhanced substitution of WAG by CO_2-WAG improves the profitability and intrinsic utility of these products. To achieve this goal, it is necessary to fill the logistics gap by the effective deployment of ssm-FLNG combined with enhanced oil recovery (CO_2-WAG) and permanent storage of CO_2.

In figure 6, there is a schematic description of the conventional gas management (base case) versus the proposed gas management, considering deploying ssm-FLNG in Búzios field. The process starts in the production manifold (1) where you have the separation of oil, gas and water. Then the gas, which is a by-product from oil production, is treated and separated into two major streams. One stream (2) is rich in natural gas (CH_4) and the other (3) is rich in carbon dioxide (CO_2).

In the conventional gas management, CH_4-rich stream is primarily used to fuel the FPSO (4) and the remaining volume is used for gas lifting and sold through pipelines, whenever possible (5 and 6). If at this point there is still CH_4 available, it will join the CO_2-rich stream and be reinjected (WAG) (7). Finally, if there is still residual CH_4 that cannot be reinjected for any technical reason, it will be sent to flaring or venting, which has environmental issues (highlighted in the red box). Therefore, the proposed strategy is to allocate as much as possible volumes of CH_4 into commercial activities that will allow its monetization, having, for example, as final users electricity production, transportation fuel and high-value chemicals. In the case of the CO_2-rich stream, the goal is to allocate as much as possible volumes of CO_2 to sweep oil from reservoirs based on the theory that pure CO_2-rich streams have better sweeping properties than a mixed gas stream [35].

In the proposed gas management, which aims to increase sale volume of CH_4 by offshore pipelines and ssm-FLNG units (5). Consequently, flaring and venting of CH_4 would not be necessary anymore such as in the conventional gas management. At the same time, the rich-CO_2 stream would be allocated to low-value activities such as gas lifting and CO_2-WAG enhanced oil recovery with permanent storage.

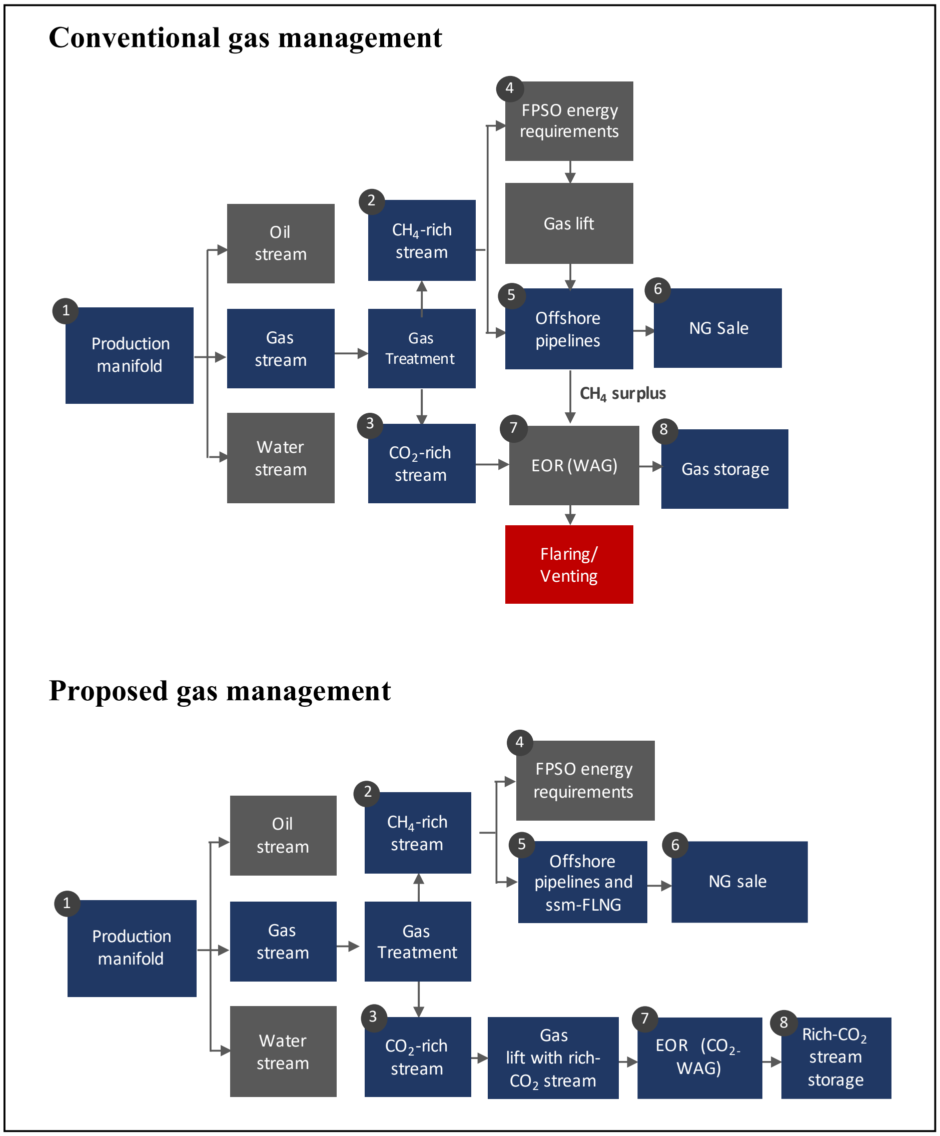

Figure 5 - Conventional and proposed gas managemnt

3.3 Key evaluated aspects

The previous section provided an overview of the developed model. In this current section, the goal is to provide more granular information about the technical aspects utilized in this work, starting from gas-oil-ratio (GOR).

3.3.1 Gas-oil-ratio (GOR)

The ratio of the volume of gas that comes out of solution to the volume of oil at standard conditions (GOR) was calculated and estimated based on information from Gaffney et. al [2] and Petrobras [27]-[33]. GOR represents one of the key value drivers related to the profitability of the hydrocarbon field and the corresponding availability of natural gas to be monetized. Thus, it impacts directly the viability of deploying any gas-integrated initiatives. For the analysis it was considered a GOR range from 197.38 to 426.47 m^3/m^3.

3.3.2 CO_2 content in gas stream

On one hand, CO_2 content in gas stream reduces the availability of other molecules, such as CH_4, which can be sold as fuel. Consequently, under normal conditions, higher CO_2 content reduces the potential revenue from the hydrocarbon reservoir, among other side effects, such as corrosion of pipes. On the other hand, in some reservoirs, CO_2 can be reinjected as one EOR method, anticipating oil production [28]. Consequently, under certain conditions it can anticipate cash flow generation and increase project's net present value (NPV). Therefore, high CO_2 content in gas stream has a material effect on production strategy and its economics that will be detailed in section results. Based on oil and gas production forecast from Petrobras [33], it was considered the volume of CO_2 in the produced gas inside the range of 24.30% to 48.50%.

3.3.3 Gas-integrated technologies

Gas-integrated technologies, mainly LNG, have been shaping the global natural markets in terms of supply, demand and trading flows and there is the opportunity to occur the same in Brazil. This work evaluates three gas-integrated technologies for Búzios pre-salt field: Liquified Natural Gas (LNG), small scale mobile Floating Liquefied Natura Gas (ssm-FLNG) and Enhanced Oil Recovery combined with CO_2 storage (CO_2-WAG).

Liquefied Natural Gas (LNG)

The first gas-integrated technology considered in this work, LNG (Liquefied Natural Gas), is a method of transporting natural gas. It involves liquefying natural gas by cryogenic cooling which is then loaded onto a LNG carrier that transports the LNG to a receiving terminal where it is offloaded and then vaporized to be transported to the final consumer [13].

According to Ruster [38], transportation of natural gas via LNG has been around 40 years and has turned from being an expensive and only regionally traded fuel to a global traded source of energy with rapidly diminishing cost.

In the case of Búzios field, LNG may be a steppingstone to promote natural gas monetization, enabling a better management of major gas streams (CH_4 and CO_2) in comparison to the current production process as previously described in Figures 5 and 6.

Small scale mobile Floating Liquefied Natural Gas (ssm-FLNG)

The oil industry has been used to deploy large-scale investments due to economies of scale. The issue, however, is that the capital investments required for large-scale LNG plants are very high [20]. On the other hand, more flexible and scalable solutions, likewise small scale mobile Liquefied Natural Gas (ssm-LNG) are emerging to fill the infrastructure gap and to meet the growing supply and demand of natural gas. Small scale mobile Floating Liquefied Natural Gas (ssm-FLNG) enables to ramp-up production quickly to the scale they need, while reducing investments and their risk on larger, more complex investments.

This work elaborated an illustration (Figure 4) to explain the potential opportunity relating to deploying ssm-FLNG in Búzios field. In the case of Búzios, the idea is to allocate ssm-FLNG plants, whenever the utilization rate is high enough to deliver the necessary financial thresholds (NPV, IRR and pay-back time).

As a hypothetical example, initially at period A, there would be the allocation of ssm-FLNG plants (e.g. three plants) coupled with selected FPSOs (figure 4). Those plants would attend only the FPSOs that would provide enough volume CH_4 to utilize a material part of ssm-FLNG nameplate capacity, delivering attractive financial numbers. Then, in a second moment (period B), when CH_4 volumes are not enough to deliver attractive financial numbers, ssm-FLNG plants would move to other production FPSOs with larger availability of profitable CH_4 volumes.

Finally, as indicated in period C, if there are not enough volumes of gas at the FPSOs located in Búzios field, ssm-FLNG plants could move to other FPSOs beyond Búzios field but still within Santos Basin Pre-salt Cluster, taking advantage of s-FLNG mobility. The hypothesis is that this mobility aspect combined with higher utilization rates and partially or totally depreciated assets would help economic viability for this emerging technology.

In the case of mobile offshore plants, s-FLNG plants constitutes an important technological milestone, as it has the potential to enable development of stranded and deep-water gas fields. In addition, ssm-FLNG provides flexibility in supply and is more cost-efficient over larger distances compared to pipelines [15].

As an emerging technology, ssm-FLNG has some important challenges such as the ability to start up and shut down quickly, capability of processing different gas compositions and safety of offloading under various environmental conditions [20]. Recent concepts for implementing LNG technology at a small-scale and modular level have the game-changing potential to shift the paradigm away from large capital expenditures and one fixed location. However, such technology is unproven in the marketplace and this work started exploring its viability in Búzios Pre-salt field, as an initial step to evaluate it in a broader scale within Santos Basin Pre-salt Cluster (SBPC). It was attributed to the developed model the utilization rate of FLNG and ssm-FLNG plants between 33.33% to 87.00%.

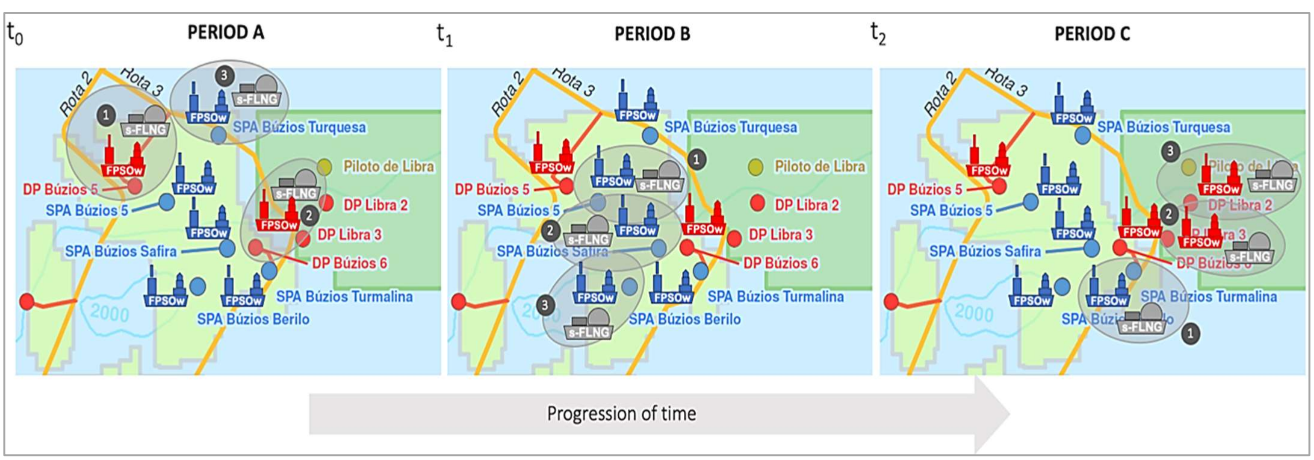

Figure 6 - Theoretical allocation example of s-FLNG plants over the time within Búzios field
Source: authors' elaboration based on Petrobras 2017

Enhanced Oil Recovery (CO2-WAG) with permanent CO_2 storage

The previous mentioned technologies (LNG and ssm-FLNG) described liquefaction of natural gas as one alternative to promote better management of the rich-CH_4 stream. In this section, the focus is to evaluate how to promote a better allocation of the rich-CO_2 stream using EOR CO_2-WAG technology.

As explained by Green and Willhite [37], CO_2 is able to displace the residual oil, which is immobilized by water flooding, and, therefore, it improves the microscopic displacement efficiency. CO_2 injection is one of the efficient enhanced oil recovery methods, which improves the oil recovery factor [23], mainly in the miscible condition through a multicontact process, i.e., CO_2 injection above minimum miscibility pressure (MMP). One of the benefits of CO_2 injection includes the expansion of oil volume and the reduction of oil viscosity [23], [38].

Therefore, water-alternating-gas (WAG) combined with carbon dioxide injection (CO_2) in Búzios field is expected to combine oil production increase with one additional benefit: reduction in carbon dioxide emissions through the permanent storage of CO_2 in the existing pre-salt caverns.

In the developed model, CO_2-WAG increases the speed of producing oil and gas, based on the work developed by Ahmadi [22]. One of the key challenges was to simulate the effect of CO_2-WAG instead of WAG (base case) in oil and gas production and corresponding effects on economics. Ahmadi described in his paper a laboratory displacement study of several Enhanced-Oil-Recovery (EOR) scenarios including WAG and CO_2-WAG, which was the base to develop the new oil production curves (expected, high and low cases).

3.3.4 Economic aspects

The previous sections provided an overview of the model and further details of its technical aspects. In the following sections it will be presented the key economic aspects utilized in the analysis, such as prices of oil and gas. Finally, it will be presented the commercial aspects of the business opportunity, which impacts the deployment of integrated-gas technologies in Brazil.

Prices of oil and gas

Prices represent a key value driver for any oil and gas project. The main challenge relating to this factor is volatility over the years, which impact investment decisions. In figure 5 there is a representation of historical oil prices in the long term. In real terms, it ranged from 10.00 to 123.00 USD/bbl.

Thus, based on historical data, it is considered in model's price assumption a material volatility of oil price over the future decades, which is represented by an expected oil price of USD 50.00/bbl with a plus and minus 50% variation for high and low cases (low case: USD 25.00/bbl and high case: USD 75.00/bbl).

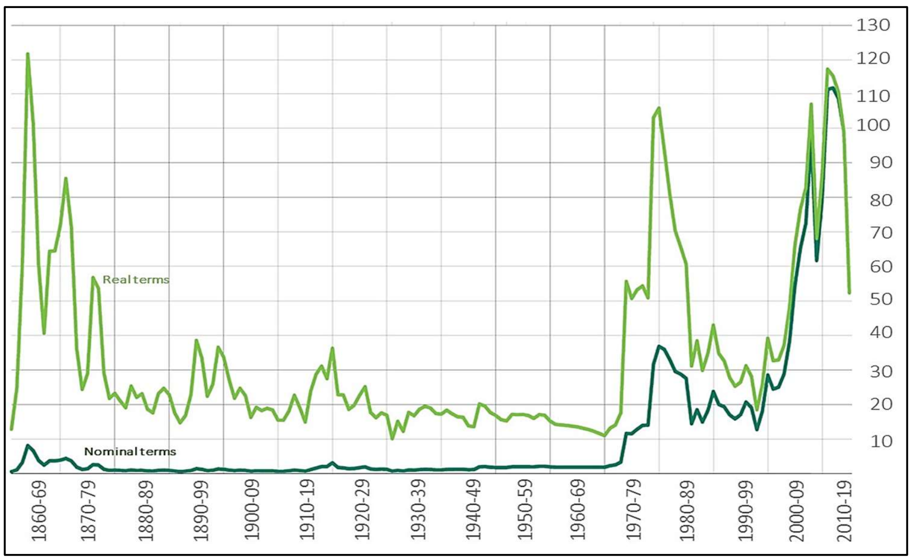

Figure 7 - Historical price of oil over decades (USD/bbl)
Source: BP, 2016

3.3.5 Commercial Aspects

Differently from the previous described four value drivers (GOR, CO_2, gas-integrated technologies and prices), market access is a qualitative value driver which was not included in the techno-economic model; however, it is key to be considered in the analysis of the research problem and then help on proposing a viable solution on how to deploy gas-integrated technologies in SBPC. Currently in Brazil, there are 88 exploration and production companies, being 49 natural gas producers. However, Petrobras (Brazilian National Oil Company) controls 95% of gas production. Therefore, Petrobras still has control of natural gas supply in the Brazilian market through large and strategic commercial contracts. The difficulties to access the market by independent companies with low volumes make the monetization of natural gas produced in pre-salt dependent almost exclusively in the efforts from Petrobras to invest in the required infrastructure to link production to consumptions centres [40].

Floating regasification vessels can provide the required flexibility to make viable new operations in places that suffer with poor long-term planning, therefore it offers the opportunity to start operating in a shorter timeframe and lower investment compared to land-based regasification plants. Consequently, it can enable the supply of affordable natural gas from stranded reserves to final consumers (e.g. southeast of Brazil).

3.4 Results

3.4.1 Production profile

In Figure 9, there is a representation of gas-oil-ratio (GOR) over the production cycle and four scenarios. There is the base case scenario, based on Gaffney et al. study [2], and there are the expected, high and low cases scenarios, based on updated information from Petrobras .

The base case [2] is represented by the grey line. The peak is on year 5 (GORmax 237.05 m^3/m^3) and slightly reduces over the time, reaching on year 26 (162.82 m^3/m^3) and then there is a reversal and GOR starts growing gradually until year 36, reaching 196.65 m^3/m^3. On year 36 onwards, GOR presents a sharp reduction, reaching 147.00 m^3/m^3 on year 39 just before ending its production lifetime by the 40th year. The expected case is represented by the darker line, the high case is represented by the dotted dark line and the low case is represented by the dotted light line.

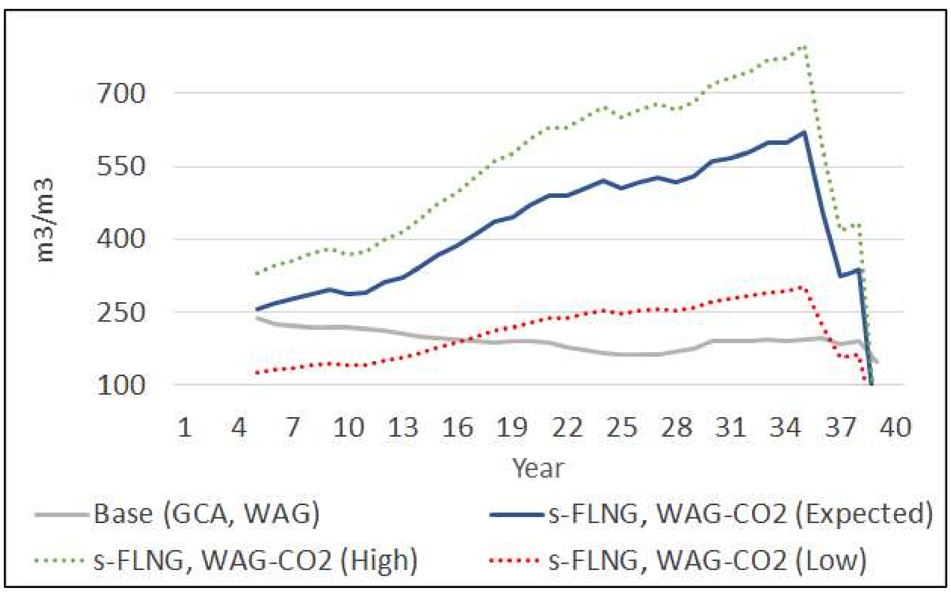

Figure 8: Gas-oil-ratio (GOR), Búzios Pre-salt field
Source: GCA (2010) and self-elaboration based on authors' model output

This work presents a material review in relation to the values and shape of the GOR curve over the project lifecycle and consequently on oil and gas production curves. In the specific case of GOR, the original curve decreased over the time and the updated curves (expected, high and low cases) increase over the time. The updated shape of the curves, indicated in blue colours, was calculated based on the forecasted oil and gas volumes that Petrobras informed to IBAMA [28]-[40]. This new shape, which has higher GOR over the time, is also consistent with enhanced oil recovery (EOR), considering gas reinjection. Differently from the base case, the expected, high and low cases, GOR consistently grows from year 5 up to the peak of production by year 37.

Using the same scheme of colours and line types, in Figure 10, the grey line indicates the base case forecasted oil production by Gaffney et al. [2]. The production ramp up starts on year 5 and goes up to year 11, when it reaches a plateau until year 18 and then it goes down. Simulating new oil production, considering updated GOR and CO_2-WAG application as the enhanced oil recovery method, there is an anticipation in oil production when compared to GCA base case. It was assumed that in all updated scenarios, CO_2-WAG method anticipates oil production keeping the same amount of total oil recovery by the end production lifetime, as indicated by Ahmadi´s study [22].

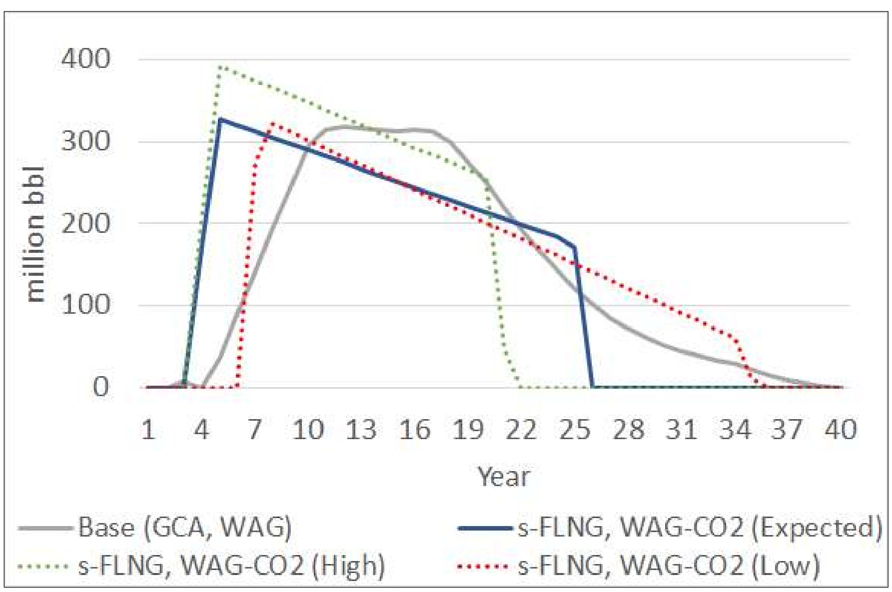

Figure 9 - Oil production based on different EOR methods (Búzios Pre-salt Field)
Source: GCA (2010) and self-elaboration based on authors' model output

The following figure indicates the impact of GOR variance and CO_2-WAG application in gas production. One of the issues associated to the deployment of gas-integrated technologies, such as LNG, relays on gas production profile over project lifetime. As indicated in Figure 11, the material variance of gas production over the years, can imply in a material idle capacity of assets or monetizing a tiny portion of the total produced gas. Thus, deploying mobile, modular plants, such as small scale mobile Floating Liquefied Natural Gas (ssm-FLNG) has been identified as a possible attractive route in these cases [19]. Therefore, assuming the possibility to allocate these plants with higher utilization rates, it improves project´s financials numbers.

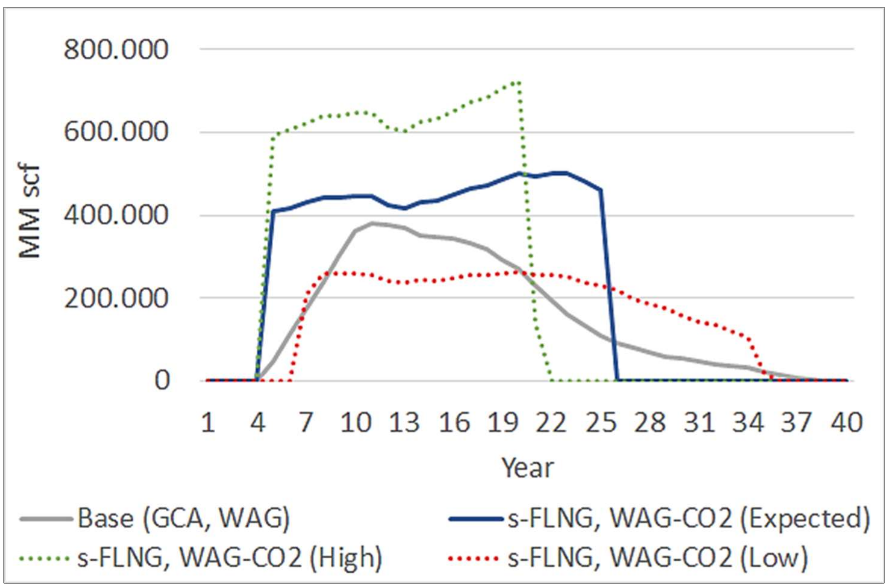

Figure 10 - Gas production based on different EOR methods (Búzios Pre-salt Field)
Source: GCA (2010) and self-elaboration based on authors' model output

3.4.2 Revenue breakdown and corresponding benefits for society and industry

Gaffney et al. [2] estimated revenue generation from Búzios field at 545.84 USD billion (oil price at 75.98 USD/bbl). This work revised the financial evaluation initially developed by Gaffney et al., considering updated and complementary techno-economic information over the last years.

The first point to highlight in the revenue analysis is related to oil and natural gas prices that represents a non-technical factor that is outside operational control. This factor has the largest impact on the base case revenue forecast. The revised prices reduced revenues by 186.67 USD billion (-34%). It is mainly driven by oil price update that in the expected scenario reduces from 75.98 to 50.00 USD/bbl (-34%). On the other hand, natural gas price is expected to increase from 4.00 to 5.50 USD/MMBTU (+38%), which had a minor financial impact.

In Figure 12, there is a step-by-step illustration on the initial revenue calculated by Gaffney, Cline and Associates (GCA) [2] and the revised revenue calculated by the model. In addition to the expected result, there are the high and low scenarios range for each value driver analysed.

Values are in USD MM

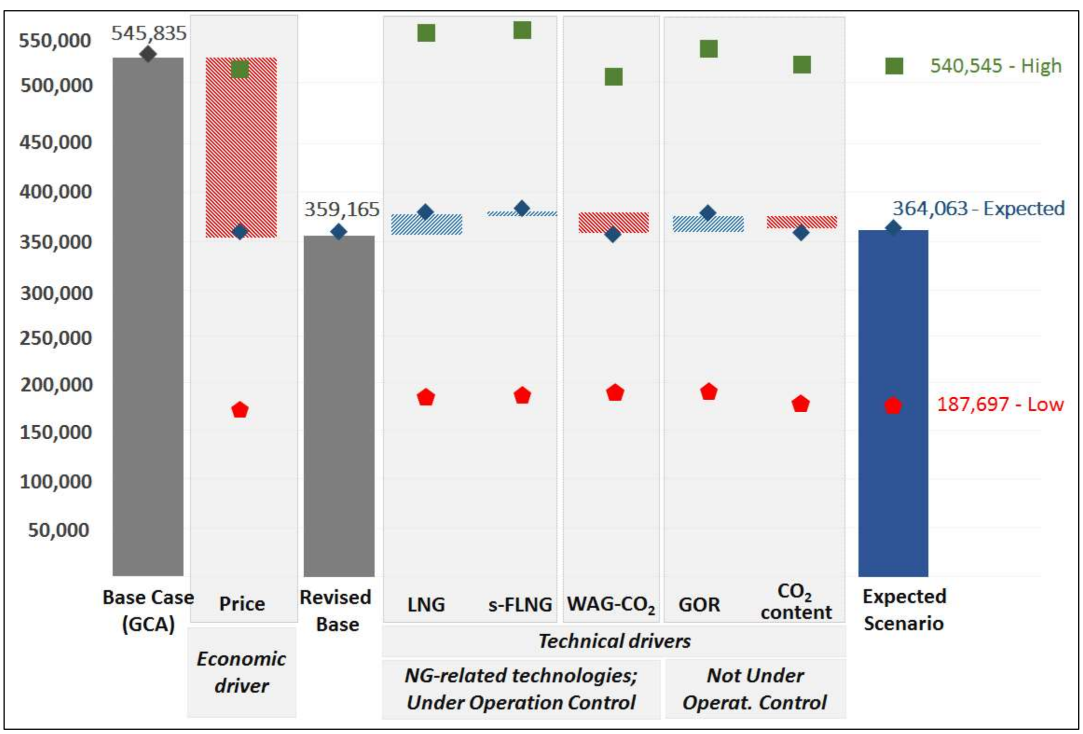

Figure 11 - Revenue analysis considering expected, high and low scenarios
Source: self-elaboration based on authors' model output

It is important to highlight that oil price variation has an important impact on revenue streams for social programs as described below. Law 12,858 establishes that royalties, which are 10% of the revenue, must be divided into the following public services: 25% health and 75% education. Thus, oil price volatility will drive the amount of cash that flows into those public services. On top of that, there is another revenue stream for local research & development (R&D) based on law 9,478, which establishes that 1% of gross revenue should be allocated to promote research and development in the country, being at least 50% through national universities and/or national research institutes.

In table 4 there is a summary of oil and gas prices variation and corresponding impact on revenue generation for social services, considering the different case scenarios.

Table 4 - Oil and natural gas prices variation, impacting revenue and corresponding cash into social services (nominal value and present value; values are in USD billion)

	Expected Case	PV	High Case	PV	Low Case	PV
Revenue impact	(186.7)	(64.9)	(7.1)	(2.5)	(366.3)	(127.3)
Social impact	(37.3)	(13.0)	(1.4)	(0.5)	(73.3)	(25.5)
Public health	(4.7)	(1.6)	(0.2)	(0.1)	(9.2)	(3.2)
Public education	(14.0)	(4.9)	(0.6)	(0.2)	(27.5)	(9.6)
Local R&D	(1.9)	(0.7)	(0.1)	(0.0)	(3.7)	(1.3)
Social contr.	(16.8)	(5.9)	(0.6)	(0.2)	(33.0)	(11.5)

Source: authors' techno-economic model

Expected price will reduce project's revenue and subsequently the corresponding revenue stream for social projects which is projected to be reduced by USD 37.33 billion (USD 12.98 billion at present value). In the high case scenario this reduction would shrink to USD 1.41 billion (USD 0.49 billion at present value) and in the low case scenario the reduction would achieve USD 73.25 billion (USD 25.46 billion at present value).

The fourth, fifth and sixth columns in Figure 9 indicate the evaluated gas-integrated technologies, which aim to promoting a better management of associated gas and corresponding gas streams (CH_4 and CO_2-rich streams). Taking a first look into the technology options to liquefy natural gas, it was identified that LNG increases revenue by USD 21.70 billion and ssm-FLNG supplements with a limited revenue of USD 0.05 million (chart 9, fourth and fifth bars).

On the other hand, in the case of CO_2-WAG, it reduces revenue by USD 21.30 billion, leading into a limited contribution in terms of combined result of gas-integrated technologies at USD 0.45 billion.

Drilling down the analysis, under the perspective of present value (PV), the expected revenue increases by USD 25.26 billion, growing from USD 124.90 billion to USD 150.16 billion, driven by the deployment of CO_2-WAG. Further details in the following table 5 and figure 10.

The reason behind the nominal reduction of revenue and at the same time an increase of revenue at present value is a consequence of the CO_2-WAG application. This recovery technology anticipates oil and gas production, therefore, there is anticipation of cash flow generation, which boosts present value. In addition, the model considers an annual increase of oil prices at 2.0% per year, which inflates the nominal revenue in the base case scenario (WAG) versus the expected scenario (CO_2-WAG).

Table 5 provides a summery in terms of revenue impact driven specifically by gas-integrated technologies for the different scenarios.

Table 5 - Gas-integrated technologies impact on project revenue and present value with corresponding cash into social services considering different scenarios - (values are in USD million)

	Expected Cases	Present Value	High Case	Present Value	Low Case	Present Value
Revenue impact	0.45	25.26	(18.96)	51.70	(6.32)	(4.22)
Social impact	0.09	5.05	(3.79)	10.34	(1.26)	(0.84)
Public health	0.01	0.63	(0.47)	1.29	(0.16)	(0.11)
Public education	0.03	1.89	(1.42)	3.88	(0.47)	(0.32)
Local R&D	0.01	0.25	(0.19)	0.52	(0.06)	(0.04)
Social contr.	0.04	2.27	(1.71)	4.65	(0.57)	(0.38)

Source: authors' techno-economic model

The assumption analysed in this work is gas-oil-ratio (GOR), which is indicated in Figures 11 and 12 as the seventh bar. Gaffney et al. [2] indicated that GOR for Búzios would range from 147.44 to 237.05 m^3/m^3. From the production volumes informed by Gaffney et al., it was calculated an average 197.38 m^3/m^3.

Additionally, Petrobras reported that GOR starts at 223.00 m^3/m^3 growing over the 35-year production period with an equivalent average GOR of 359,89 m^3/m^3. Based on the developed model and updated information from Petrobras the projected GOR average for Búzios field was revised to 359,89 m^3/m^3 (increase of 82.33% versus Gaffney et al. base case).

Considering the assumption of monetizing part of this gas volume through the liquefaction and commercialization of natural gas (CH_4-rich stream), the GOR growth represents an equivalent revenue increase of 17.22 USD billion (expected case), ranging from 0 to 38.00 USD billion (low and high cases).

The previous positive contribution in terms of potential revenue increase coming from GOR growth assumes that total oil production remains the same and consequently there is a corresponding increase of gas production. This assumption is aligned with latest Petrobras reports, which indicate that the expected recoverable oil from Búzios field is higher than forecasted in preliminary contracts.

The last value driver analysed is CO_2 content in associated gas and corresponding impact in revenues. Under the financial perspective, it was calculated that CO_2 content of 32.77% would reduce revenue by 12.8 billion, assuming that it would reduce the availability of natural gas (CH_4-rich stream) to be commercialized.

In summary, Figure 11 indicates that the initial revenue forecast from Gaffney was USD 545.84 billion and this study revised it down considering the considered lower price forecast for oil. On the other hand, the deployment of gas-integrated technologies combined with higher GOR could partially compensate this loss, delivering a final revenue of USD 364.1 billion, ranging from USD 187.7 billion to USD 540.5 billion (low and high cases).

3.4.3 NPV breakdown and corresponding benefits for society and industry

In relation to project's value, Gaffney et al. [2] estimated net present value (NPV) from Búzios field at 56.8 USD billion. Considering the revised expected price for oil and gas, NPV would drop to 31.8 USD billion, representing a reduction of 44%.

In line with the revenue analysis, pricing is the most important value driver for value creation. In the case of gas-integrated technologies (fourth, fifth and sixth columns), it has the potential to increase NPV by 6.5 USD billion (20% increase of NPV), being most of this result relating to CO_2-WAG, which accelerates oil extraction.

Gas-oil-ratio (GOR) has an expected NPV contribution of USD 739 million and CO_2 content in gas is expected to reduce NPV by USD 490 million as indicated in Figure 14.

Values are in USD MM

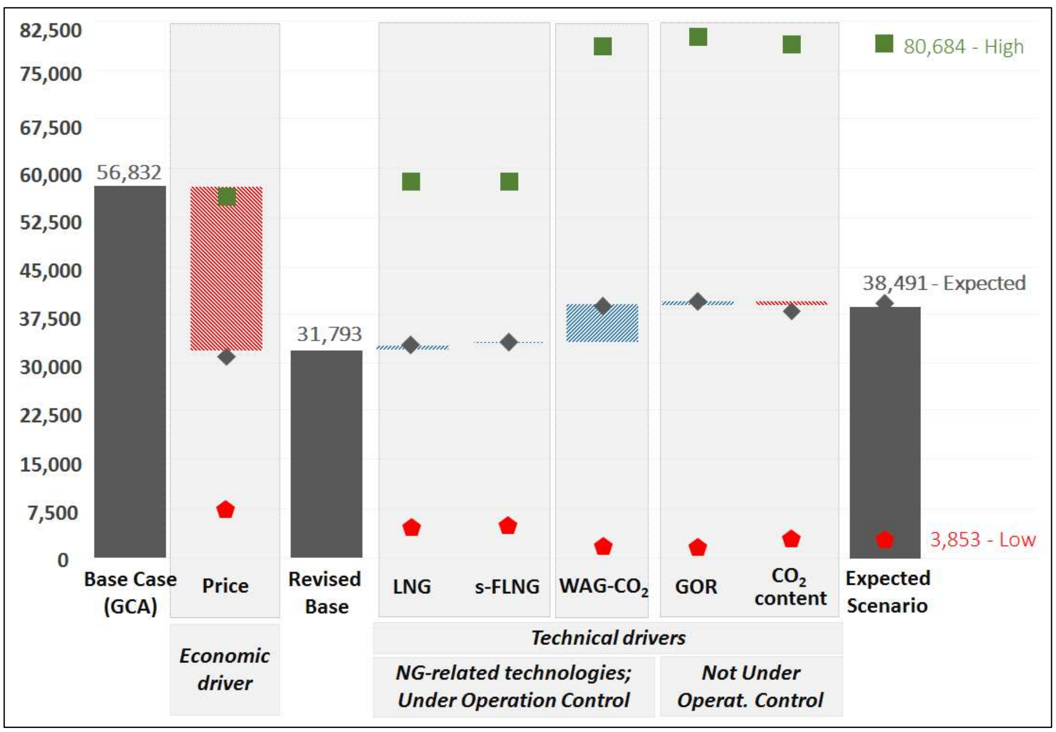

Figure 12 - NPV analysis considering expected, high and low scenarios.
Source: self-elaboration based on authors' model output

The model indicates that ssm-FLNG application has significant higher utilization rate (Table 6) than LNG plants.

Table 6 - Utilization rate per liquefaction technology (Búzios Pre-salt field)

	Base	Expected	High	Low
LNG	34.20%	48.43%	47.81%	39.03%
ssm-FLNG	70.95%	75.50%	77.95%	71.02%

In summary, NPV forecast from Gaffney et al. [2] was USD 56.8 billion over the production cycle and then it was revised down considering the revised price forecast for oil. On the other hand, the deployment of NG-related technologies could partially compensate this loss, delivering a final NPV of USD 38.5 billion, which could range from USD 3.8 billion to USD 80.7 billion (low and high cases).

3.5 Conclusions (Búzios field)

This work has developed a techno-economic model to evaluate the deployment of gas-integrated technologies, more specifically the application of small scale mobile Floating Liquefied Natural Gas (ssm-FLNG) and CO_2-enhanced oil recovery (CO_2-WAG) combined with CO_2 storage. The aim is monetizing associated gas produced in Búzios Pre-salt field and reducing its emissions by permanent storing of CO_2.

It has four major deliverables: i. to propose a better management of gas streams through the deployment of gas-integrated technologies; ii. to demonstrate the potential of gas-integrated technologies to leverage the benefits of existing oil exploration at SBPC; iii. to provide actual and updated information regarding GOR and CO_2 content in SBPC; and iv. to enlighten a potential conflict of interest between the established and profitable liquid fuels business versus the opportunity to unlock massive volumes of an affordable fuel to compete with liquid fuels.

The first discussion point is the higher availability of associated gas that will be produced in Búzios and in SBPC than initially planned by operators and the government. It is a key issue and at the same time a massive opportunity based on the need of supplying the Brazilian domestic market with more affordable fuels. At the same time, wherever possible, there is the need to promote better management of produced gas streams, mainly methane and carbon dioxide, instead of utilizing the conventional approach of reinjection most of the associated gas.

Second, there are discussions on how to develop the logistics of natural gas from offshore FPSOs to Brazil´s onshore, where there might be potential demand for natural gas. Therefore, modular small-scale liquefaction plants may arise as a realistic alternative to fill this logistic gap with the required economics.

Third, traditionally the oil and gas industry has been associated with large-scale infrastructure investments, based on the rational of economies of scale. The issue is that the capital investments required for conventional LNG plants are extremely high and can make some projects uneconomical. On the other hand, recent proposals for deploying mobile modular plants, such as those indicated in this work, have been identified as possible attractive routes for gas monetization. The mobility of liquefaction plants and corresponding higher utilization rates were identified as contributing factors to enhance its economic viability.

Fourth, CO_2-WAG in Búzios field is expected to combine oil production increase with one additional benefit: reduction in carbon dioxide emissions through permanent storage of CO_2, reducing its environmental side effects.

In summary those four discussion points converge to the point that utilizing ssm-FLNG (small scale mobile Floating Liquefied Natural Gas) combined with CO_2-enhanced oil recovery (CO_2-WAG) offers a profitable way to monetize associated gas in Búzios Pre-salt field and possibly within the broader Santos Basin Pre-salt Cluster (SBPC).

In relation to deployment strategy, it was identified three critical aspects. The first aspect involves the application of small-scale mobile FLNG plants into oil and gas wells with high gas outputs and then in a second moment, when gas production falls under 33.33% of plants' nameplate capacity, to move them to higher output fields. This allocation is key to increase asset utilization of mobile liquefaction plants from 34.2% to 70.95% (LNG case vs ssm-FLNG case). It would be worth developing complementary studies detailing how higher asset utilization of liquefaction plants can take advantage of the potential synergies within SBPC´s fields.

The second critical point relates to anticipating oil and gas production and corresponding cash flow, which boosts NPV and IRR. It is obtained by the application of CO_2-WAG recovery method versus WAG recovery method. In this sense CO_2-WAG reduced the production life cycle from 40 years to 25 years, increasing NPV by 5.76 USD billion (expected case versus base case). The third and last critical point consists on trapping the CO_2-rich stream into the existing pre-salt reservoirs, reducing its environmental side effects.

Under the economic perspective, the combined application of ssm-FLNG and CO_2-WAG for Búzios Pre-salt field, indicated a tremendous opportunity of generating thousands of jobs and income for social programs. It resulted over a twenty-five-year period an NPV of 6.5 USD billion

In addition, it is worthwhile noting that the deployment of gas-integrated technologies depends on its commercialization aspects, such as contracting, marketing, and partnering. In this sense, one commercialization strategy could be exploring the formation of a stand-alone Joint Venture (JV) that would make the required investments to deploy and operate this solution in synchronisation with the needs of the different production cycles, relating to various fields and operators, who are mainly focused on the operational aspects of exploring oil with safety and low costs. This topic could be explored in further details in complementary studies related to non-technical drivers for a successful monetization of natural gas in SBPC.

In conclusion, the intent of this work is providing a starting point to demonstrate how market participants could consider ssm-FLNG and CO_2-WAG combined with CO_2 storage to monetize the vast amount of associated gas in SBPC, generating benefits for the Brazilian society and the industry. Although SBPC is currently the most promising oil and gas field in Brazil, other opportunities may arise in the future to apply this proposal, as more oil and gas fields at Pre-salt can be discovered in a worldwide basis.

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4 PAPER TWO – ASSESSMENT OF GAS-INTEGRATED TECHNOLOGIES IN TEN SELECTED FIELDS IN SANTOS BASIN PRE-SALT CLUSTER (SBPC)

This Chapter presents the full text of the article to be submitted to a journal under the title: "Assessment of gas-integrated technologies in Ten Selected Fields in Santos Basin Pre-salt Cluster (SBPC) aiming at leveraging profits for society and the industry".

The structure here follows the same one used in the final paper, but the published version will eventually contain changes suggested by the journal's editor and reviewers. Some few alterations were also done to adapt the article to this thesis format.

Sub-chapter 4.1 will present study's motivations and objectives. Sub-chapter 4.2 presents methodology. Sub-chapter 4.3 will describe the key evaluated aspects relating to this research work. Sub-chapter 4.4 presents and discuss model's results. Finally, sub-chapter 4.5 will draft our conclusions and recommendations for the deployment of gas-integrated technologies in the Brazilian Pre-salt.

4.1. Introduction

The Santos Basin Pre-salt Cluster (SBPC) is located in ultra-deep waters (1,900-2,400 m) approximately 300 km offshore from the coast of Brazil's South-eastern states (Rio de Janeiro and Sao Paulo) [1]. According to the analysis carried out by Gaffney et al. [2] which was based on ten selected fields from this cluster, the SBPC has the potential to produce more than 19.7 billion barrels of oil and 21.2 trillion standard cubic feet (scf) of natural gas. This can generate up to 1.97 trillion dollars of income, assuming oil price at 75.98 USD/bbl and gas price at 4.0 USD/MM BTU [2]. Having such a large natural resource at its disposal would bring Brazilian society a number of economic and social benefits. It would provide affordable source of energy for the foreseeable future, as well as income in terms of taxes and royalties and would lead to jobs creation. Based on the recent analysis [2-3] the exploitation of the SBPC could generate up to 450 USD billion in taxes, 197 USD billion in royalties and 20 USD billion in local Research & Development (R&D), as well create more than one million job [3]. The latter addressing currently a critical need in Brazil.

The social and economic prosperity that could be achieved by exploitation of this natural resource requires overcoming significant exploration and environmental issues. The former is due to operating at challenging water depths far from the coast and dealing with high-pressure and high-temperature reservoirs that are spread over very large areas and that lay immediately bellow a thick salt layer. The latter arises from dealing with large amounts of associated gas, that has a high CO_2 content.

The difficult production environment of SPBC, including the need of managing associated gases, both CH_4 and CO_2 streams, the lack of gas pipelines and potential environmental hazards has already been discussed in literature by number of authors [4],[5],[6],[7],[8],[9],[10],[11],[12],[13]. The consensus is that the main technological barrier to surpass is how to optimally extract oil with associated gas, at high gas-oil-ratio (GOR), and how to deal with high CO_2 content of the produced gas. In addition to the lack of sufficient infrastructure to move the natural gas to onshore consumption centres, the high CO_2 content within the gas stream makes it difficult to achieve the necessary financial thresholds to justify the monetization of associated gas. Consequently, the current view is that most of the produced associated gas is to be re-injected and may not be properly monetized. If this turns out to be the case, the Brazilian society will not capture the related benefits of having access to this readily available energy source, which otherwise could play a major role in the forthcoming country's energy transition strategy. In this work we explore alternative strategies to avoid re-injecting the whole gas stream by making use of the gas-integrated technologies that can offer viable alternatives.

A number of works has already looked at viable alternatives. Araujo [14], in his study, evaluated CO_2 separation alternatives, by considering early enhanced oil recovery (EOR) as the final destination of CO_2. Ahmadi et al. [15] provided a laboratory displacement study of several Water-Alternating-Gas (WAG) methods for enhancing oil recovery, by considering two options, namely associated gas/water and CO_2/water injections. Based on this work, it is possible to assume that CO_2-WAG anticipates oil production, even though it might reduce the total oil recovery when it achieves recoverable levels above 80%, which is not the case in this field when in operational scale. Emadi et al. [16] and Moradi et al. [17] indicate that CO_2 injection is an efficient EOR method, which improves the oil recovery factor, providing temperature and pressure are such that all the CO_2 is dissolved in oil. Van't Veld et al. [18] and Azzolina et al. [19] performed an economic evaluation of CO_2-EOR combined with CO_2 storage, showing that the deployment of this technology results in better cash flows from oil production. Bachu [20] stated that CO_2 disposal in sedimentary basins are the best option currently available for the long-term sequestration of CO_2.

The lack of current infrastructure in SBPC also raises serious issues of how to most efficiently transport natural gas to the coastal sites. Apart from pipelines, liquefying natural gas also offers a plausible alternative. Alkthatib [21] conducted a historic overview of the development of liquefied natural gas (LNG) industry, indicating that it represents the only economical alternative to natural gas transport by pipelines. It also provides greater flexibility in contrast to pipelines. Markou [22] performed a detailed and more recent review of LNG-related technologies, as well as in-depth analysis of the status of the market by 2015, indicating that one of the major trends in LNG technology is to extend it to offshore application by employing floating LNG technology (FLNG). Wang [23] proposed a development plan for the use FLNG in China and concluded that FLNG technology would be effective and feasible for developing difficult-to-produce offshore reservoirs. Bukowski [24] discussed the challenges related to liquefaction on a floating platform, including motion of the production vessel (particularly important in less favourable ocean conditions), weight and space limitations as well as discussing corrosion and flammability issues. They indicate that some of the issues can be addressed by taking advantage of new purpose-built heat exchangers and compressors that offer exceptional mechanical strength and performance. Rattanavich [25] stated that small-scale FLNG (ss-FLNG) projects usually face diseconomies of scale, in comparison to larger plants. Nevertheless, the advantages behind constructing ss-FLNG plants are faster construction time, simpler liquefaction processes, and lower maintenance and lower initial capital costs. Those are important positive aspects of ss-FLNG regardless of any other additional advantage associated to marketing strategies for produced gas. Tan [26] investigated the deployment of onshore mobile (and modular) ss-LNG plants (ssm-LNG) as an attractive alternative to offshore gas monetization. The author proposes a multi-period optimization framework which determines the optimal dynamic allocation and operating decisions, considering time-varying supply, price and demand. The work indicates that utilizing mobile plants offered a profitable and flexible method to monetize associated gas in Bakken shale play in Mississippi region. As indicated by Wang [27], the objectives of economic optimization in LNG is to minimize cost including OPEX and CAPEX and each expense has individual factors to influence the plant cost.

Although a number of techniques have been studied to address the noted production and environmental issues the previous works have neither systematically analysed the techno-economic performance nor examined the benefits of combining different technologies.

Therefore, in this study we perform a techno-economic evaluation of a particular gas-integrated technology that consists of small-scale mobile FLNG plants (ssm-FLNG) operating in conjunction to CO_2-WAG-EOR and CO_2-storage.

The main objectives of this work are i. to investigate the key factors of the techno-economic performance and competitiveness of ssm-FLNG combined with CO_2-WAG and CO_2-storage; ii. to promote better management of CH_4 and CO_2 streams produced in SBPC field. It is envisaged that the results of this study may help policy makers and investors to optimally implement gas-integrated technologies in Brazil and abroad.

4.2.Methodology

4.2.1 Model development

In the first instance we have limited our study to Búzios field. It is one of the largest fields in Santos Basin Pre-salt Cluster, SPBC [2], and it has high gas-oil-ratio (GOR) and high CO_2 content [28]-[34]. The model calculates that the potential volume of natural gas to be produced in the ten selected fields in SBPC, which is 32.08 billion m3/year, which is equivalent to 89.35% of the total NG volume consumed in Brazil [34]. It was as a steppingstone for developing the model for the ten selected fields of this study, which could serve as a proxy for the whole SBPC. It is a potential valuable energy source, available in large quantities, for the Brazilian society over the next decades.

This methodology section aims to explain how the techno-economic model was developed to support the research analysis. The following sub-sections provide further details on the evaluated technical, economic and commercial aspects that impact on the deployment of integrated-gas technologies in Brazil.

The starting point of our methodology was to build a model that would represent the study of Gaffney, Cline & Associate (GCA) [2] who performed a review and economic evaluation of ten selected prospects in SBPC considering the available information at that time (2010). On that time Agência Nacional do Petróleo, Gas Natural e Biocombustíveis (ANP), in support of efforts by the Brazilian Government, hired GCA who reviewed and audited the technical data, development plans, work obligations and associated investments related to the discoveries and prospects and independently estimated hydrocarbon resources. GCA's base evaluation contemplated only oil volumes although it is acknowledged that development plans include gas exploitation for fuel, injection and eventual export and sale. That is the main reason why it has been considered as the benchmark for this work and has been nominated as the base case scenario. Gaffney [2] considered a recovery factor between 10% and 48%, with a most likely value of 26% for the 28o API oil.

In the second step we made use of Petrobras (Brazilian National Oil Company) reports to IBAMA (Brazilian Institute of the Environment) to develop revised production profiles, considering updated gas-oil-ratio (GOR) and CO_2 content in fluids.

Based on the work performed by Ahmadi [15], it was simulated the impact of liquefying the rich-CH_4 stream in a ssm-FLNG unit after gas separation, and then proceed with CO_2-WAG enhanced oil recovery method. The rich-CO_2 stream would be reinjected during the field production lifetime and stored in the existing sedimentary basin similarly to the current gas injection and storage method using gas (WAG).

In relation to performing the analysis, we have developed three scenarios in addition to GCA base case scenario. Thus, this work considers the following scenarios: base, expected, high and low. The expected scenario contains updated assumptions and corresponding results which the authors consider most likely. The high case scenario contains updated assumptions which deliver improved economic results, and consequently, the low case scenario has the assumptions that deliver inferior economic results. The assumptions that drive those scenarios are detailed in tables7 to 70, on page 65 to 67.

Figure 13 has a simplified representation of the described methodology, which starts by developing a techno-economic model to represent GCA numbers, passing through populating the model, performing simulation, and finally performing the required analysis.

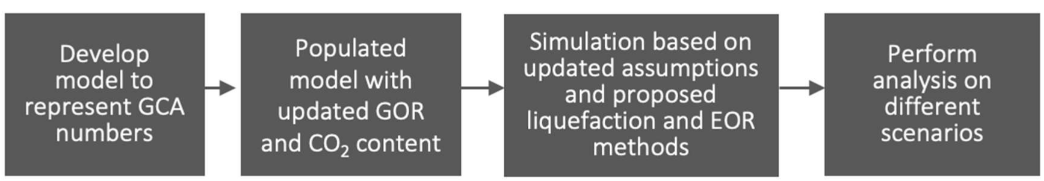

Figure 13 - Schematic representation of research methodology

The model allowed us to simulate the deployment of selected gas-integrated technologies (ssm-FLNG and CO_2-WAG combined with CO_2 storage) and evaluate corresponding production and economic impact, embedded by the mobility aspect. The key parameters considered in this study were oil and gas production, operational expenditure (Opex), capital expenditure (Capex), revenue and net present value (NPV), which are detailed in section results. In the case of key assumptions, it was considered gas-oil-ratio (GOR), CO_2 content in fluid, utilization rate of liquefaction plants, unitary Capex and unitary Opex.

For modelling purposes, LNG plant capacity was considered as 1.0 MTPA based on information from International Gas Union, IGU [35]. For ssm-FLNG, it was assumed a plant capacity of 0.5 MTPA. It was also assumed that plants should achieve at least 33.33% of nameplate capacity, otherwise they are not implemented due to excessive idle capacity. On the other side, it was assumed that liquefaction plants do not goes beyond 87.00% of nameplate capacity.

In the case of key assumptions, in GCA base case scenario, oil price was considered at 75.98USD/bbl and increased in an annual basis by inflation (2.0% per year). In the expected case, oil price was considered at USD 50.00/bbl and natural gas price at the wellhead at USD 5.50/bbl, both with a 50% plus and minus variation for high and low scenarios, increasing by inflation over the years (2.0% per year).

According to IGU, plant costs vary widely and depend on oil and gas prices, location, capacity, liquefaction process among other cost drivers. The average liquefaction estimated by IGU, period 2017-2022, is around 500 to 1,541 USD/tonne [35]. Based on that information and capex correlation with oil prices, it was assumed a unitary floating capital expense (Capex) ranging from 800 to 1,200 USD/tonne, being the expected case at 1,000 USD/tonne.

In the case of ssm-FLNG it was assumed an additional unitary Capex of 7.00% mainly due to diseconomy of scale and mobility requirements, delivering an equivalent value of USD 1,070 USD/tonne. This additional Capex for ssm-FLNG considers the net effect between diseconomy of scale partially compensated by savings relating to reduction of space utilization on FPSO deck. Then, a 20% plus and minus variation was considered for high and low scenarios. In table 7, there is a summary of Capex for base, expected, high and low cases.

Finally, in relation to operational expenses (Opex), it was assumed that the application of the evaluated gas-integrated technologies results in minor increase in Opex. Based on the fact that most of the Opex is linked to the existing oil and gas production system, including treating the associated gas, we assumed that annual operational expenses relating to the deployment of integrated-gas technologies will vary in line with corresponding annual capital expenses variance, based on the following metric: Δ Annual Opex = Δ Annual Capex X 5%. This rational applies to either FLNG or ssm-FLNG technologies.

In the following pages, tables 7 to 10 provide the key data input that is relevant to explain our methodology and analysis.

Table 7 – Input data of ten selected fields in Santos Basin Pre-salt Cluster

	Base	Expected	High	Low
GOR (m^3/m^3)	192,80	563,36	811,88	279,49
CO_2 and other contaminants (%)	-o-	55.84%	45.01%	66.15%
Oil Prices (USD/bbl)	75.98	50.00	75.00	25.00
NG Prices (USD/MM BTU)	4.00	5.50	8.25	2.75
Unit Capex LNG (USD/MTPA)	-	1,000	800	1,200
Unit Capex SSLNG (USD/MTPA)	-	1,070	856	1,284
Δ Opex LNG and ssm-FLNG as a function of Δ Capex	-	5.00%	4.00%	6.00%

Sources: Gaffney, 2010, Petrobras, 2017, IGU, 2012-2015 and author's estimation

The idea is to establish ranges of maximum and minimum results and in between the expected results, therefore there is an intentional combination of the assumption to define these ranges.

Table 8 – Input data of gas-oil-ratio (GOR) related to ten selected fields in SBPC (m^3/m^3)

	Base	Expected	High	Low
1. Búzios (former Franco)	197.38	359.89	426.47	197.38
2. Libra	197.22	919.29	1,464.68	410.00
3. Lula South (former Tupi Extension)	211.45	401.28	431.85	224.97
4. Sépia (former Tupi Nordeste)	207.76	248.30	262.17	207.76
5. Peroba	170.10	208.80	273.37	170.13
6. Sururu North, Sururu South, Berbigão North, Berbigão South e Atapu (former Iara Extension)	196.22	306.11	340.81	194.32
7. Florim	202.98	249.19	279.17	184.34
8. Jupiter Extension	118.02	144.87	179.89	118.04
9. Pau Brasil	116.61	143.15	179.89	116.63
10. Sapinhoa South, Sapinhoa, Sapinhoa Extension, Cernambi, Caracara, Carcara Norte, Lapa, Gato do Mato, Gato do Mato Sul, Uruguá, Caramba e Sagitario (former South Guara)	170.20	232.45	262.17	170.20
Ten selected fields in Santos Basin Pre-salt (calculated)	192.80	563.36	811.88	279.49

Sources: Gaffney, 2010, Petrobras, 2017, IGU, 2012-2015 and author's estimation

Table 9 - Input data of CO_2 content and other contaminants related to ten selected fields in SBPC (v/v)

	Expected	High	Low
1. Búzios (former Franco)	54,77%	43,81%	65,72%
2. Libra	57,30%	45,84%	68,76%
3. Lula South (former Tupi Extension)	46,37%	37,10%	55,64%
4. Sépia (former Tupi Nordeste)	50,98%	40,78%	61,18%
5. Peroba*	40,00%	32,00%	48,00%
6. Sururu North, Sururu South, Berbigão North, Berbigão South e Atapu (former Iara Extension)	50,91%	40,73%	61,09%
7. Florim*	40,00%	32,00%	48,00%
8. Jupiter Extension	82.94%	66,35%	94,52%
9. Pau Brasil*	40,00%	32,00%	48,00%
10. Sapinhoa South, Sapinhoa, Sapinhoa Extension, Cernambi, Caracara, Carcara Norte, Lapa, Gato do Mato, Gato do Mato Sul, Uruguá, Caramba e Sagitario (former South Guara)*	40,00%	32,00%	48,00%
Ten selected fields in Santos Basin Pre-salt Cluster (calculated)	55,48%	45,01%	66,15%

Sources: Gaffney, 2010, Petrobras, 2017, IGU, 2012-2015 and author's estimation. Indicated numbers with (*) are synthetic data.

Table 10 – Input data of CH_4 content in produced gas related to ten selected fields in SBPC (v/v)

	Expected	High	Low
1. Búzios (former Franco)	45,24%	56,19%	34,28%
2. Libra	42,70%	54,16%	31,24%
3. Lula South (former Tupi Extension)	53,63%	62,90%	44,36%
4. Sépia (former Tupi Nordeste)	49,02%	59,22%	38,82%
5. Peroba*	60,00%	68,00%	52,00%
6. Sururu North, Sururu South, Berbigão North, Berbigão South e Atapu (former Iara Extension)	49,09%	59,27%	38,91%
7. Florim*	60,00%	68,00%	52,00%
8. Jupiter Extension	17,06%	33,65%	0,47%
9. Pau Brasil*	60,00%	68,00%	52,00%
10. Sapinhoa South, Sapinhoa, Sapinhoa Extension, Cernambi, Caracara, Carcara Norte, Lapa, Gato do Mato, Gato do Mato Sul, Uruguá, Caramba e Sagitario (former South Guara)*	60,00%	68,00%	52,00%
Ten selected fields in Santos Basin Pre-salt Cluster (calculated)	44,16%	54,99%	33,85%

Sources: Gaffney, 2010, Petrobras, 2017, IGU, 2012-2015 and author's estimation. Indicated numbers (*) are synthetic data.

The method to calculate the revised oil and gas production profile considers injection of rich-CO_2 stream (CO_2-WAG) instead of conventional injection of a mixture of associated gases (WAG). The latter is the base case developed by Gaffney et al. [2]. New production profile was built based on curves presented Ahmadi's work [15], which was a laboratory displacement study. Further details and corresponding equations of calculated oil production curves are indicated in results' section.

This work proposes to develop an alternative and improved management of gas streams by promoting a better allocation of natural gas (CH_4-rich stream) and carbon dioxide streams (CO_2-rich stream). The hypothesis is that the appropriate allocation and monetization of CH_4 and the enhanced substitution of WAG by CO_2-WAG improves the profitability and intrinsic utility of these products. To achieve this goal, it is necessary to fill the logistics gap by the effective deployment of ssm-FLNG combined with enhanced oil recovery (CO_2-WAG) and permanent storage of CO_2.

In figures 14 there is a schematic description of the conventional gas management (base case) versus the proposed gas management (figure 15) , considering deploying ssm-FLNG in SBPC. The process starts in the production manifold (1) where you have the separation of oil, gas and water. Then the gas, which is a by-product from oil production, is treated and separated into two major streams. One stream (2) is rich in natural gas (CH_4) and the other (3) is rich in carbon dioxide (CO_2).

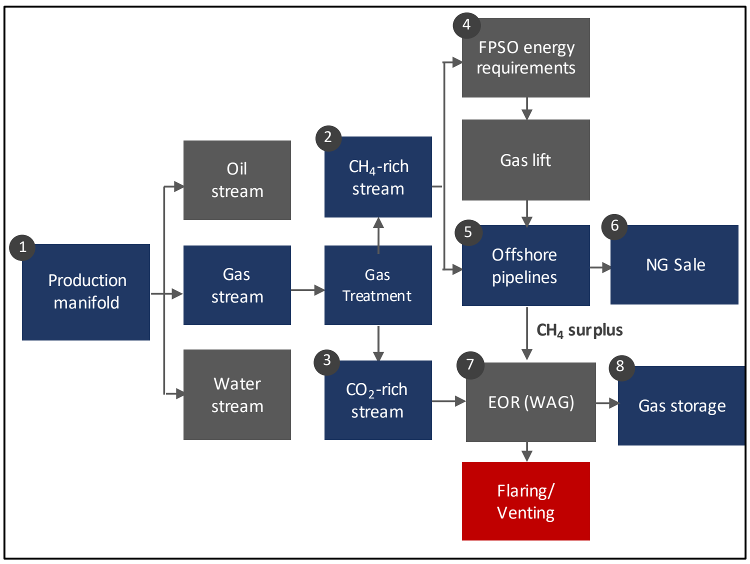

Figure 14 - Conventional gas management (Ten Selected Fields in Santos Basin Pre-salt Cluster - SBPC)

In the conventional gas management, CH_4-rich stream is primarily used to fuel the FPSO (4) and the remaining volume is used for gas lifting and sold through pipelines, whenever possible (5 and 6). If at this point there is still CH_4 available, it will join the CO_2-rich stream and be reinjected (WAG) (7). Finally, if there is still residual CH_4 that cannot be reinjected for any technical reason, it will be sent to flaring or venting, which has environmental issues (highlighted in the red box). Therefore, the proposed strategy is to allocate as much as possible volumes of CH_4 into commercial activities that will allow its monetization, having, for example, as final consumers of produced electricity, transportation fuel and high-value chemicals. In the case of the CO_2-rich stream, the goal is to allocate as much as possible volumes of CO_2 to sweep oil from reservoirs based on the theory that pure CO_2-rich streams have better sweeping properties than a mixed gas stream [35].

In figure 15 there is a representation of the proposed gas management, which aims to increase sales volume of CH_4 by offshore pipelines and ssm-FLNG units (5). Consequently, flaring and venting of CH_4 would be reduced in comparison to the conventional process described in figure 2. At the same time, most of the rich-CO_2 stream would be allocated to low-value activities such as gas lifting and CO_2-WAG enhanced oil recovery (7) with CO_2 permanent storage (8).

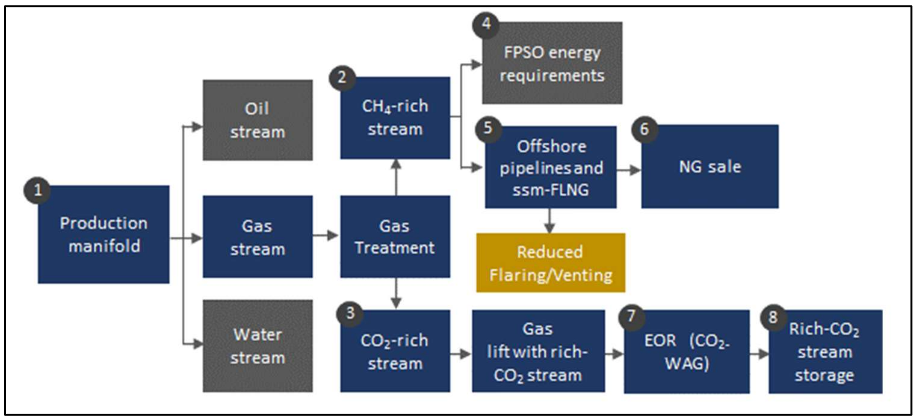

Figure 15 - Proposed gas management (Ten Selected Fields in Santos Basin Pre-salt Cluster - SBPC)

4.3 Key evaluated aspects

The previous section provided an overview of the developed model. In this current section, the goal is to provide more granular information about the technical, economical and commercial aspects utilized in this work, starting from gas-oil-ratio (GOR).

4.3.1 Gas-oil-ratio (GOR)

The ratio of the volume of gas that comes out of solution to the volume of oil at standard conditions (GOR) was calculated and estimated based on information from Gaffney et. al [2] and Petrobras [28]-[33]. GOR represents one of the key value drivers related to the profitability of the hydrocarbon field and the corresponding availability of natural gas to be monetized. Thus, it directly impacts the viability of deploying any gas-integrated initiatives. For the analysis it was considered a GOR range from 192.80 to 811.88 m^3/m^3, representing SBPC.

4.3.2 CO2 content and other contaminants in gas stream

On one hand, CO_2 content in gas stream reduces the availability of other molecules, such as CH_4, which can be sold as fuel. Consequently, under normal conditions, higher CO_2 content reduces the potential revenue from the hydrocarbon reservoir, among other side effects, such as corrosion of pipes. On the other hand, in some reservoirs, CO_2 can be reinjected as one EOR method, anticipating oil production [15]. Consequently, under certain conditions it can anticipate cash flow generation and increase project's net present value (NPV). Therefore, high CO_2 content in gas stream has a material effect on production strategy and its economics that will be detailed in section results. Based on oil and gas production forecast from Petrobras [33], it was considered the volume of CO_2 and other contaminants in the produced gas inside the range of 45.01% to 66.15%, representing the ten selected fields in Sanos Basin Pre-salt Cluster.

4.3.3 Gas-integrated technologies

Gas-integrated technologies, mainly LNG, have been shaping the global natural markets in terms of supply, demand and trading flows and there is the opportunity to occur the same in Brazil. This work evaluates three gas-integrated technologies for SBPC pre-salt field: Liquified Natural Gas (LNG), small scale mobile Floating Liquefied Natura Gas (ssm-FLNG) and Enhanced Oil Recovery combined with CO_2 storage (CO_2-WAG).

Liquefied natural gas (LNG)

The first gas-integrated technology considered in this work, LNG (Liquefied Natural Gas), is a method of transporting natural gas. It involves liquefying natural gas by cryogenic cooling which is then loaded onto a LNG carrier that transports the LNG to a receiving terminal where it is offloaded and then vaporized to be transported to the final consumer [13].

According to Ruster [38], transportation of natural gas via LNG has been around 40 years and has turned from being an expensive and only regionally traded fuel to a global traded source of energy with rapidly diminishing cost.

In the case of SBPC field, LNG may be a steppingstone to promote natural gas monetization, enabling a better management of major gas streams (CH_4 and CO_2) in comparison to the current production process as previously described in Figures 14 and 15.

Small scale mobile Floating Liquefied Natural Gas (ssm-FLNG)

The oil industry has been used to deploy large-scale investments due to economies of scale. The issue, however, is that the capital investments required for large-scale LNG plants are very high [26]. On the other hand, more flexible and scalable solutions, likewise small scale mobile Liquefied Natural Gas (ssm-LNG) are emerging to fill the infrastructure gap and to meet the growing supply and demand of natural gas. Small scale mobile Floating Liquefied Natural Gas (ssm-FLNG) enables to ramp-up production quickly to the scale they need, while reducing investments and their risk on larger, more complex investments.

This work elaborated an illustration (Figure 16) to explain the potential opportunity relating to deploying ssm-FLNG in SBPC. In the case of SBPC, the idea is to allocate ssm-FLNG plants, whenever the utilization rate is high enough to deliver the necessary financial thresholds such as NPV, IRR and pay-back time.

As a hypothetical example, initially at period A, there would be the allocation of ssm-FLNG plants (e.g. three plants) coupled with selected FPSOs (figure 4). Those plants would attend only the FPSOs that would provide enough volume CH_4 to utilize a material part of ssm-FLNG nameplate capacity, delivering attractive financial numbers. Then, in a second moment (period B), when CH_4 volumes are not enough to deliver attractive financial numbers, ssm-FLNG plants would move to other production FPSOs with larger availability of profitable CH_4 volumes.

Finally, as indicated in period C, if there are not enough volumes of gas at the FPSOs located in SBPC field, ssm-FLNG plants could move to other FPSOs inside SBPC cluster, taking advantage of mobility. The hypothesis is that this mobility aspect combined with higher utilization rates and partially or totally depreciated assets would help economic viability for this emerging technology.

In the case of mobile offshore plants, FLNG plants constitutes an important technological milestone, as it has the potential to enable development of stranded and deep-water gas fields. In addition, ssm-FLNG provides flexibility in supply and is more cost-efficient over larger distances compared to pipelines [21].

As an emerging technology, ssm-FLNG has some important challenges such as the ability to start up and shut down quickly, capability of processing different gas compositions and safety of offloading under various environmental conditions [26]. Recent concepts for implementing LNG technology at a small-scale and modular level have the game-changing potential to shift the paradigm away from large capital expenditures and one fixed location.

However, such technology is unproven in the marketplace and this work started exploring its viability in SBPC. It was attributed to the developed model the utilization rate of FLNG and ssm-FLNG plants between 33.33% to 87.00%.

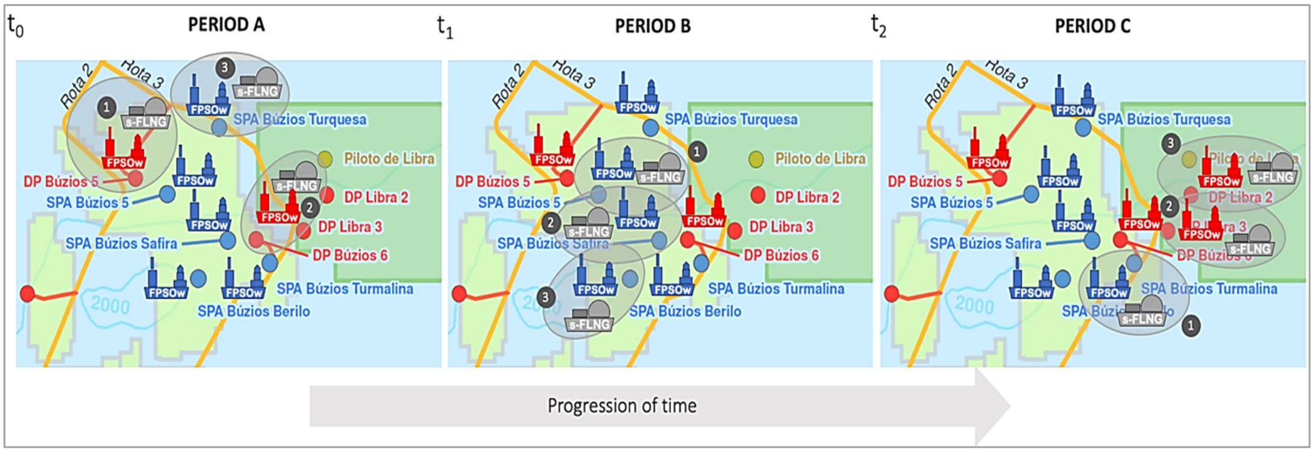

Figure 16 - Theoretical allocation example of ssm-FLNG plants over the time in SBPC

Source: authors' elaboration based on Petrobras 2017

Enhanced Oil Recovery (CO_2-WAG)

The previous mentioned technologies (LNG and ssm-FLNG) described liquefaction of natural gas as one alternative to promote better management of the rich-CH4 stream. In this section, the focus is to evaluate how to promote a better allocation of the rich-CO_2 stream using EOR CO_2-WAG technology.

As explained by Green and Willhite [37], CO_2 is able to displace the residual oil, which is immobilized by water flooding, and, therefore, it improves the microscopic displacement efficiency. CO_2 injection is one of the efficient enhanced oil recovery methods, which improves the oil recovery factor [16], mainly in the miscible condition through a multicontact process, i.e., CO_2 injection above minimum miscibility pressure (MMP). One of the benefits of CO_2 injection includes the expansion of oil volume and the reduction of oil viscosity [16], [38].

Therefore, large volumes of CO_2 produced with the associated gas is valuable and must be recovered and recycled to the reservoir [39]. Consequently water-alternating-gas (WAG) combined with carbon dioxide injection (CO_2) in SBPC is expected to combine oil production increase with one additional benefit: reduction in carbon dioxide emissions through the permanent storage of CO_2 in the existing pre-salt caverns.

In the developed model, CO_2-WAG increases the speed of producing oil and gas, based on the work developed by Ahmadi [15]. One of the key challenges was to simulate the effect of CO_2-WAG instead of WAG (base case) in oil and gas production and corresponding effects on economics. Ahmadi described in his paper a laboratory displacement study of several Enhanced-Oil-Recovery (EOR) scenarios including WAG and CO_2-WAG, which was the base to develop the new oil production curves (expected, high and low cases).

4.3.4 Economic aspects

The previous sections provided an overview of the model and further details of its technical aspects. In the following sections it will be presented the key economic aspects utilized in the analysis, such as prices of oil and gas. Finally, it will be presented the commercial aspects of the business opportunity, which impacts the deployment of integrated-gas technologies in Brazil.

Prices of oil and gas

Prices represent a key value driver for any oil and gas project. The main challenge relating to this factor is volatility over the years, which impact investment decisions. In figure 5 there is a representation of historical oil prices in the long term. In real terms, it ranged from 10.00 to 123.00 USD/bbl.

Figure 17 - Historical price of oil (USD/bbl, WTI or Nymex adjusted by inflation)
Source: Macrotrends

Thus, based on historical data, it is considered in model's price assumption a material volatility of oil price over the future decades, which is represented by an expected oil price of USD 50.00/bbl with a plus and minus 50% variation for high and low cases (low case: USD 25.00/bbl and high case: USD75.00/bbl).

4.3.5 Commercial Aspects

Differently from the previous described four value drivers (GOR, CO_2 content in fluid, gas-integrated technologies and prices), market access is a qualitative value driver which was not included in the techno-economic model; however, it is key to be considered in the analysis of the research problem and then help on proposing a viable solution on how to deploy gas-integrated technologies in SBPC. Currently in Brazil, there are 88 exploration and production companies, being 49 natural gas producers. However, Petrobras (Brazilian National Oil Company) controls 95% of gas production.

Therefore, Petrobras still has control of natural gas supply in the Brazilian market through large and strategic commercial contracts. The difficulties to access the market by independent companies with low volumes make the monetization of natural gas produced in pre-salt dependent almost exclusively in the efforts from Petrobras to invest in the required infrastructure to link production to consumptions centres [27]

Floating regasification vessels can provide the required flexibility to make viable new operations in places that suffer with poor long-term planning, therefore it offers the opportunity to start operating in a shorter timeframe and lower investment compared to land-based regasification plants. Consequently, it can enable the supply of affordable natural gas from stranded reserves to final consumers (e.g. southeast of Brazil).

4.4 Results

The outputs of the model are the revised profile of oil and gas production curves with corresponding Capex, Opex and economic indicators, such as revenue and net present value, which are detailed over this section. The equations of oil productions curves are indicated in Table 11.

Table 11 - Equations of oil production curves

	Oil production curves per year (MM bbl./year, year 1 to 40)
Base Case (WAG)	$y = -17.447x^2 + 1,399.8x – 7,939.4$
Expected Case (CO_2-WAG)	$y = -13.66x^2 + 1,301.3x – 4,369.6$
High Case (CO_2-WAG)	$y = -16.392x^2 + 1,561.6x - 5,243.5$
Low Case (CO_2-WAG)	$y = -11.383x^2 + 1,084.5x – 3,641.3$

Source: author’s techno-economic model

4.4.1 Production profile

In Figure 18, there is a representation of gas-oil-ratio (GOR) over the production cycle and four scenarios. There is the base case scenario, based on Gaffney et al. study [2], and there are the expected, high and low cases scenarios, based on updated information from Petrobras .

The base case [2] is represented by the grey line. The peak is in the first year (GOR_{max} 233.38 m^3/m^3) and slightly reduces over the time, reaching on year 40 (180.06 m^3/m^3. The revised expected case is represented by the blue line, the high case is represented by the dotted green line and the low case is represented by the dotted red line.

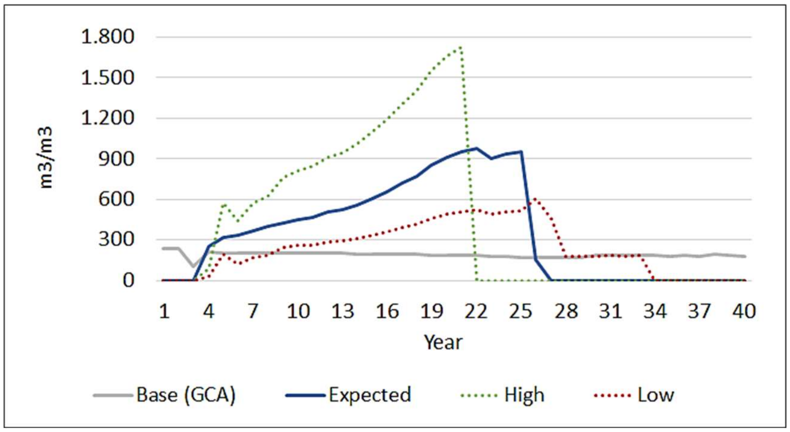

Figure 18 - Gas-oil-ratio in ten selected fields in Santos Basin Pre-salt Cluster (SBPC)
Source: author's techno-economic model

This work presents a material review in relation to the values and shape of the GOR curve over the project lifecycle and consequently on oil and gas production curves. In the specific case of GOR, the original curve gradually decreased over the time and the updated curves (expected, high and low cases) increase over the time. The updated shape of the curves was calculated based on the forecasted oil and gas volumes that Petrobras informed to IBAMA [28]-[40]. This new shape, which has higher GOR over the time, is also consistent with enhanced oil recovery (EOR), considering gas reinjection. Differently from the base case, the expected, high and low cases, GOR consistently grows from year 5 up to year 20.

Using the same scheme of colours and line types, in Figure 19, the grey line indicates the base case forecasted oil production by Gaffney et al. [2]. Simulating new oil production, considering updated GOR and CO_2-WAG application as the enhanced oil recovery method, there is an anticipation in oil production when compared to GCA base case. It was assumed that in all updated scenarios, CO_2-WAG method anticipates oil production keeping the same amount of total oil recovery by the end production lifetime, as indicated by Ahmadi´s study [15].

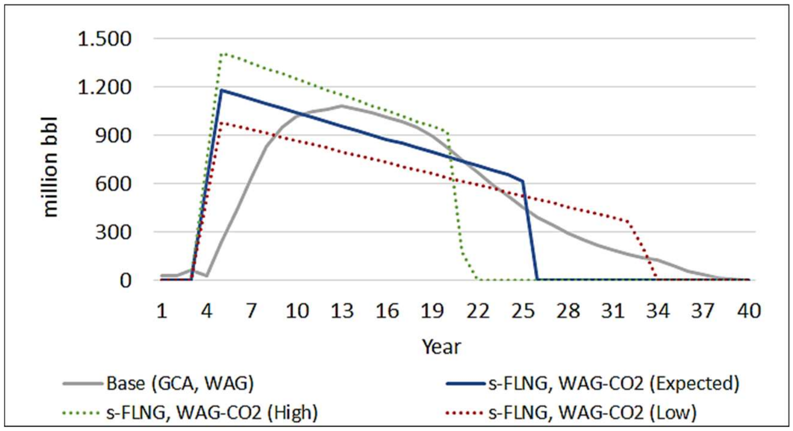

Figure 19 - Oil production based on different GOR assumptions and EOR methods, Ten Selected Fields in Santos Basin Pre-salt Cluster (SBPC)

Source: author's techno-economic model

The following figure 20 utilizes the same scheme of colours and lines of previous figures. Thus, the grey line indicates the base case forecasted gas production by Gaffney et al. [2] and the other lines indicate the impact of GOR variance and CO_2-WAG application in gas production. As indicated in Figure 20, the material variance of gas production over the years, can imply in a material idle capacity of assets or monetizing a tiny portion of the total produced gas, resulting in poor economic results. Thus, deploying mobile, modular plants, such as small scale mobile Floating Liquefied Natural Gas (ssm-FLNG) has been identified as a possible attractive solution to overcome that type of issue [25]. Thus, assuming the possibility to allocate these plants with higher utilization rates, it improves project´s financials numbers.

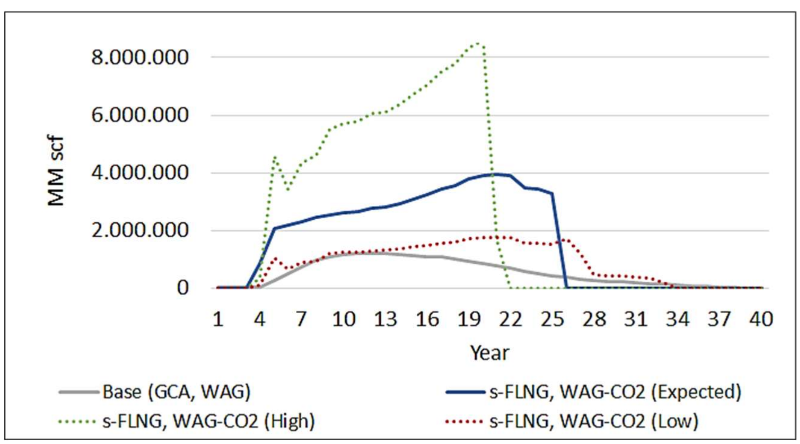

Figure 20 - Gas production based on different GOR assumptions and EOR methods, Ten Selected Fields in Santos Basin Pre-salt Cluster (SBPC).

Source: author's techno-economic model

4.4.2 Revenue breakdown and corresponding benefits for society and industry

Gaffney et al. [2] estimated revenue generation from Santos Basin Pre-salt Cluster (SBPC) at 1,955,947 million USD (oil price at 75.98 USD/bbl). This work revised the financial evaluation initially developed by Gaffney et al., considering updated and complementary techno-economic information over the last years.

The first point to highlight in the revenue analysis is related to oil and natural gas prices that represents a non-technical factor that is outside operational control. This factor has the largest impact on the base case revenue forecast. The revised prices reduced revenues by 668,911 million USD (-34%). It is mainly driven by oil price update that in the expected scenario reduces from 75.98 to 50.00 USD/bbl.

In Figure 21, there is a step-by-step illustration on the initial revenue calculated by Gaffney, Cline and Associates (GCA) [2] and the revised revenue calculated by the model. In addition to the expected result, there are the high and low scenarios range for each value driver analysed, which can be verified in the table 12 on the following page.

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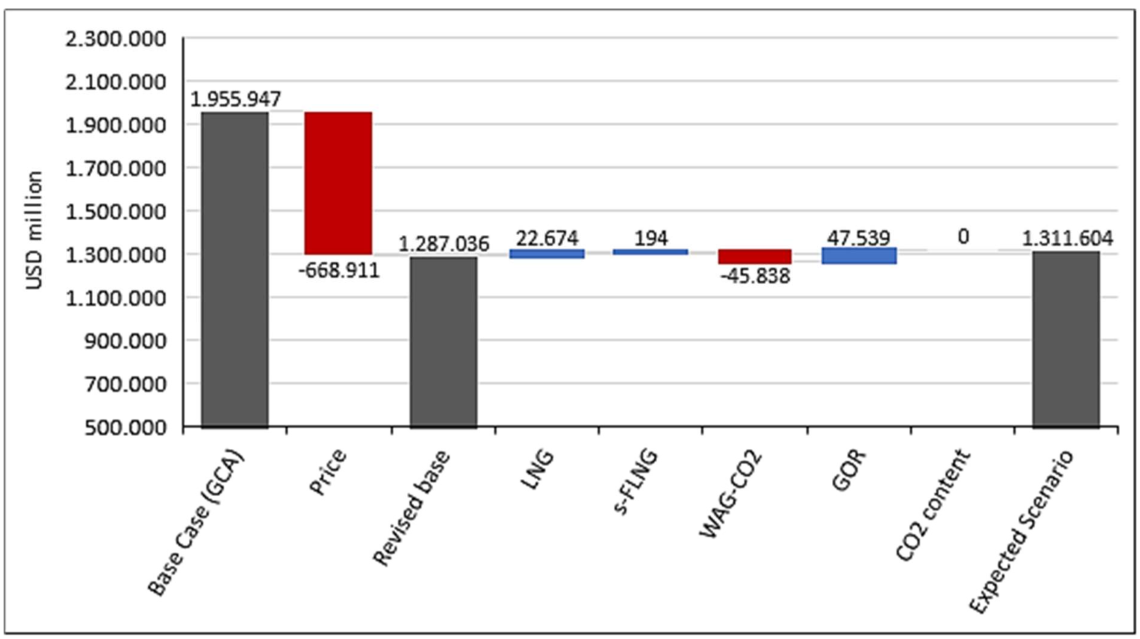

Figure 21 - Revenue analysis considering expected scenario. Ten selected fields in Santos Basin Pre-salt Cluster (SBPC)
Source: author's techno-economic model

It is important to highlight that oil price variation has an important impact on revenue streams for social programs as described below. Law 12,858 establishes that royalties, which are 10% of the revenue, must be divided into the following public services: 25% health and 75% education. Thus, oil price volatility will drive the amount of cash that flows into those public services. On top of that, there is another revenue stream for local research & development (R&D) based on law 9,478, which establishes that 1% of gross revenue should be allocated to promote research and development in the country, being at least 50% through national universities and/or national research institutes.

In Table 3 there is a summary of oil and gas prices variation and corresponding impact on revenue generation for social services, considering the different case scenarios.

Table 12 - Oil and natural gas prices variation, impacting revenue and corresponding cash into social services (nominal value and present value; USD million).

	Expected Case Scenario	**High Case Scenario**	**Low Case Scenario**
Revenue impact	**(668,911)**	**(25,339)**	**(1,312,483)**
Revenue impact on social services	**(133,782)**	**(5,068)**	**(262,497)**
Public health	(16,723)	(633)	(32,812)
Public education	(50,169)	(1,900)	(98,436)
Local R&D	(6,689)	(253)	(13,125)
Social contribution	(60,202)	(2,281)	(118,124)

Source: authors' economic model

Expected price will reduce project's revenue and subsequently the corresponding revenue stream for social projects which is projected to be reduced by USD 133,782 million. In the high case scenario this reduction would reduce to USD 5,068 million and in the low case scenario the reduction would achieve USD 262,497 million.

The fourth, fifth and sixth columns in Figure 21, on previous page, indicate the evaluated gas-integrated technologies, which aim to promoting a better management of associated gas and corresponding gas streams (CH_4 and CO_2-rich streams). Taking a first look into the technology options to liquefy natural gas, it was identified that LNG increases revenue by USD 22,674 million and ssm-FLNG supplements with a limited revenue of USD 194 million (chart 21, fourth and fifth bars). On the other hand, in the case of CO_2-WAG, it reduces revenue by USD 45,838 million.

Table 13 provides a summary in terms of nominal revenue impact driven specifically by gas-integrated technologies for the different scenarios. According to table 13, gas-integrated technologies combined with GOR increase nominal revenue by USD 24,569 million, consequently increasing social services' revenue by USD 4,914 million (expected scenario).

Table 13 - Gas-integrated technologies and corresponding impact on revenue considering different scenarios - (values are in USD million).

	Expected Case Scenario	High Case Scenario	Low Case Scenario
Revenue impact	24,569	83,293	11,125
Revenue impact on social services	4,914	16,659	2,225
Public health	614	2,083	278
Public education	1,843	6,247	834
Local R&D	246	833	111
Social contribution	2,211	7,496	1,001

Source: authors' techno-economic model

One of the key assumptions analysed in this work is gas-oil-ratio (GOR), which is indicated in 21 and 22 as the seventh bar. Gaffney et al. [2] indicated that GOR in SBPC fields would range from 116.61 to 211.45 m^3/m^3. From the production volumes informed by Gaffney et al., it was calculated an average of 192.80 m^3/m^3.

Based on the developed model and updated information from Petrobras the projected GOR average for SBPC field was revised to 563,36 m^3/m^3 (increase of 192% versus Gaffney's base case). Considering the assumption of monetizing part of this gas volume through the liquefaction and commercialization of natural gas (CH_4-rich stream), the GOR growth represents an equivalent revenue increase of 47,539 USD million (expected case).

The positive contribution in terms of potential revenue increase coming from GOR growth assumes that total oil production remains the same and consequently there is a corresponding increase of gas production. This assumption is aligned with latest Petrobras reports, which indicate that the expected recoverable oil from SBPC field is higher than forecasted in preliminary contracts.

The last value driver analysed is CO_2 content in associated gas and its corresponding impact on revenues. GCA report does not make clear the gas composition and its CO_2 content. Based on that fact, we inferred for GCA the same CO2 content as in the expected scenario, therefore there is no financial impact for this variable.

In summary, Figure 21 indicates that the initial revenue forecast from Gaffney was USD 1,955,947 billion and this study revised it down considering the revised lower price forecast of oil. On the other hand, the deployment of gas-integrated technologies combined with higher GOR could partially compensate this loss, delivering a final revenue of USD 1,311,604 million.

4.4.3 Net Present Value (NPV) breakdown and corresponding benefits for society and industry

In relation to project's value, Gaffney et al. [2] estimated net present value (NPV) from Santos Basin Pre-salt Cluster at 183,945 USD million. Considering the revised expected price for oil and gas, NPV would drop to 92,469 USD million, representing a reduction of 49.73%.

In line with the revenue analysis, pricing is the most important value driver for value creation. In the case of gas-integrated technologies combined with the expected increase of gas-oil-ratio (GOR), it has the potential to increase NPV by 11,523 USD million. Most of this increase relates to the proposed enhanced oil recovery method (CO_2-WAG), which has an expected NPV contribution of USD 9,352 million.

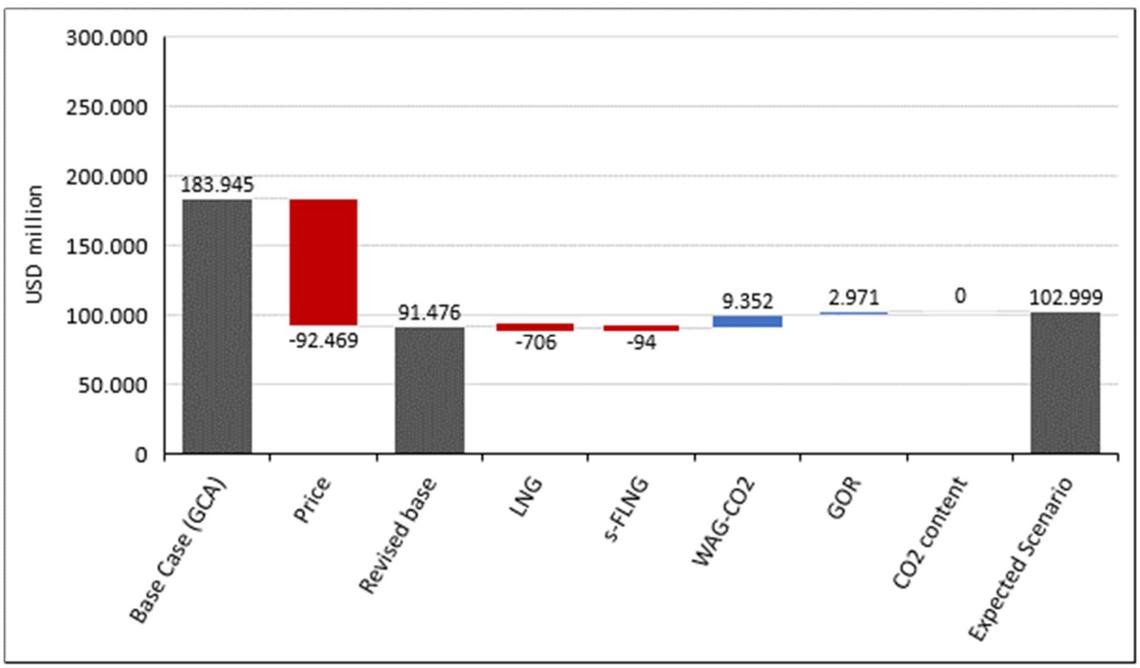

Figure 22 - NPV analysis considering expected scenario. Ten selected fields in Santos Basin Pre-salt Cluster (SBPC)
Source: author's techno-economic model

The model indicates that ssm-FLNG application has significant higher utilization rate (Table 14) than LNG plants.

Table 14 - Utilization rate per liquefaction technology (SBPC)

	Base	Expected	High	Low
LNG	34.25%	43.40%	43.09%	34.42%
ssm-FLNG	69.87%	78.82%	81.94%	74.31%

Source: authors' economic model

In summary, NPV forecast from Gaffney et al. [2] was USD 183,945 million over the production cycle and then it was revised down considering the revised price forecast for oil. On the other hand, the deployment of gas-integrated technologies combined with higher GOR could partially compensate this loss, delivering a final NPV of USD 102,999 billion.

4.5 FINAL CONCLUSIONS

This work has developed an economic model to evaluate the deployment of gas-integrated technologies, more specifically the application of small scale mobile Floating Liquefied Natural Gas (ssm-FLNG) and CO_2-enhanced oil recovery (CO_2-WAG) combined with CO_2 storage. The aim is monetizing associated gas produced in Santos Basin Pre-salt Cluster and reducing its emissions by permanent storage of CO_2.

It has four major deliverables: i. to propose a better management of gas streams through the deployment of gas-integrated technologies; ii. to demonstrate the potential of gas-integrated technologies to leverage the benefits of existing oil exploration in Santos Basin Pre-salt Cluster (SBPC); iii. to provide actual and updated information regarding GOR and CO_2 content in SBPC; and iv. to enlighten a potential conflict of interest between the established and profitable liquid fuels business versus the opportunity to unlock massive volumes of an affordable natural gas fuel to compete with conventional liquid fuels.

The first discussion point is the higher than planned availability of associated gas than initially planned by operators and the government for SBPC and its corresponding cluster. It is a key issue and at the same time a massive opportunity based on the need of supplying the Brazilian domestic market with more affordable fuels. At the same time, wherever possible, there is the need to promote better management of produced gas streams, mainly methane (CH_4) and carbon dioxide (CO_2) , instead of utilizing the conventional approach of reinjection most of the associated gas (CH_4, CO_2 and other contaminants).

Second, there are discussions on how to develop the logistics of natural gas from offshore FPSOs to Brazil´s onshore, where there might be potential demand for natural gas. Therefore, modular small-scale liquefaction plants may arise as a realistic alternative to fill this logistic gap with the required economics.

Third, traditionally the oil and gas industry has been associated with large-scale infrastructure investments, based on the rational of economies of scale. The issue is that the capital investments required for conventional LNG plants are extremely high and can make some projects uneconomical. On the other hand, recent proposals for deploying mobile modular plants, such as those indicated in this work, have been identified as possible attractive routes for gas monetization. In addition, the mobility aspect of modular plants and its corresponding higher utilization rates were identified as important contributing factors to enhance economic viability.

Fourth, CO2-WAG in SBPC is expected to accelerate oil production and enable permanent storage of CO2, reducing oil and gas production environmental side effects in the Brazilian Pre-salt.

In summary, those four discussion points converge to the point that utilizing gas-integrated technologies, such as ssm-FLNG (small scale mobile Floating Liquefied Natural Gas) combined with CO_2-enhanced oil recovery (CO_2-WAG) offers a profitable way to monetize a material volume of associated gas in Santos Basin Pre-salt Cluster (SBPC).

In relation to deployment strategy, it was identified three critical aspects. The first aspect involves the application of small-scale mobile FLNG plants into oil and gas wells with high gas outputs and then in a second moment, when gas production falls under 33.33% of plants' nameplate capacity, to move them to fields with higher production volumes. This allocation is key to increase asset utilization of mobile liquefaction plants from 43.40% to 78.82% (expected cases of LNG and ssm-FLNG). It would be worth developing complementary studies detailing how higher asset utilization of liquefaction plants can take advantage of the potential synergies within SBPC´s fields.

The second critical point relates to anticipating oil and gas production and corresponding cash flow, which boosts NPV. It is obtained by the application of CO_2-WAG recovery method versus the conventional WAG recovery method. In this sense CO_2-WAG reduced the production life cycle from 40 years to 25 years, increasing NPV by 9,352 USD million (expected case versus base case). Under the social perspective, the combined application of ssm-FLNG and CO2-WAG for SBPC, indicated a tremendous opportunity of generating thousands of jobs and income for social programs.

In addition, it is worthwhile noting that the deployment of gas-integrated technologies depends on its commercialization aspects, such as contracting, marketing and partnering. In this sense, one commercialization strategy could be exploring the formation of a stand-alone Joint Venture (JV) that would make the required investments to deploy and operate this solution in synchronisation with the needs of the different production cycles, relating to various fields and operators, who are mainly focused on the operational aspects of exploring oil with safety and low costs. This topic could be explored in further details in complementary studies related to non-technical drivers for a successful monetization of natural gas in Santos Basin Pre-salt Cluster (SBPC).

In conclusion, the intent of this work is providing a starting point to demonstrate how market participants could consider ssm-FLNG and CO_2-WAG combined with CO_2 storage to monetize the vast amount of associated gas in SBPC, generating benefits for the Brazilian society and the industry. Although SBPC is currently one of the most promising oil and gas field in Brazil, other opportunities may arise in the future to apply this proposal, as more oil and gas fields at Pre-salt can be discovered in a worldwide basis.

4.6 Acknowledgments

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The present publication reflects only the authors' views and the scholarship's sponsors are not liable for any use that may be made of the information contained here.

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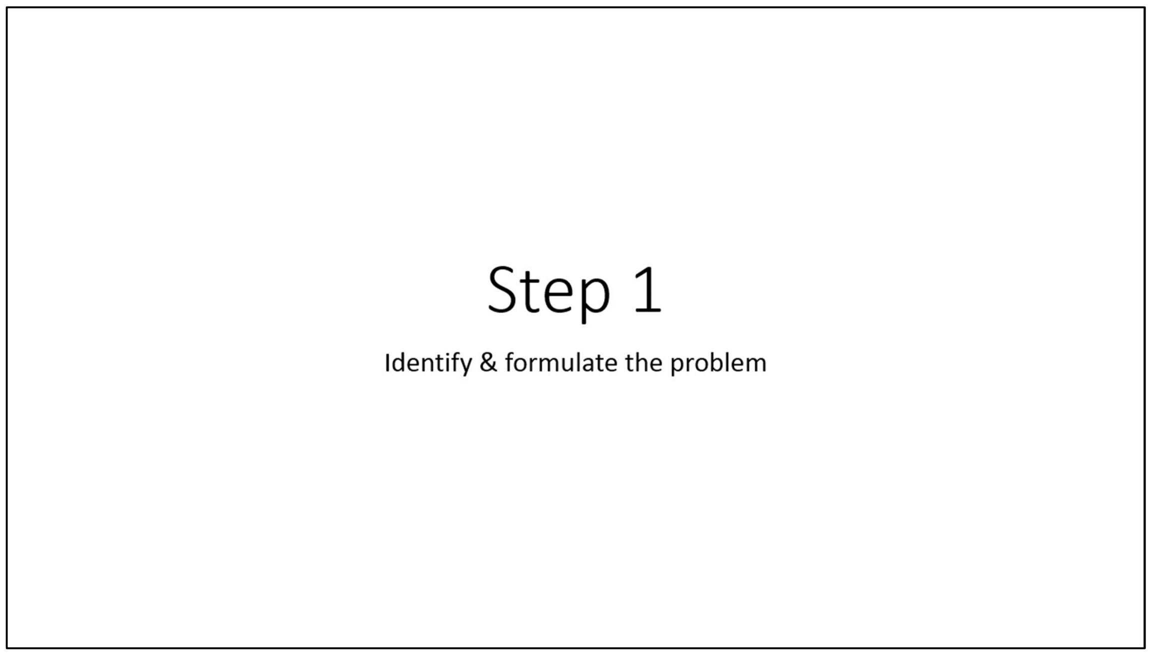
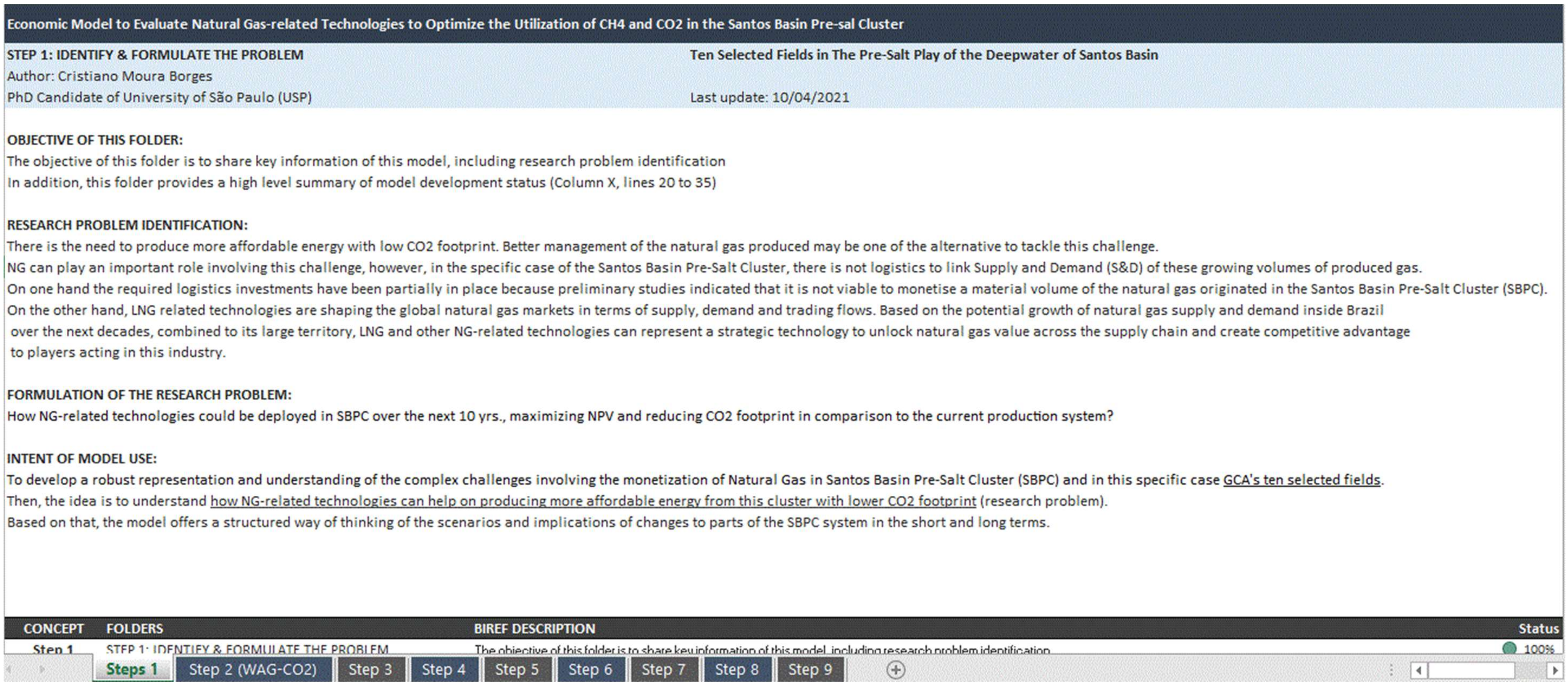
5 APPENDIX A – TECHNO-ECONOMIC MODEL



This part of the document contains selected information of the in-house Excel developed model.



Economic Model to Evaluate Natural Gas-related Technologies to Optimize the Utilization of CH4 and CO2 in the Santos Basin Pre-sal Cluster

STEP 1: IDENTIFY & FORMULATE THE PROBLEM | **Ten Selected Fields in The Pre-Salt Play of the Deepwater of Santos Basin**

Author: Cristiano Moura Borges

PhD Candidate of University of São Paulo (USP) | Last update: 10/04/2021

OBJECTIVE OF THIS FOLDER:

The objective of this folder is to share key information of this model, including research problem identification

In addition, this folder provides a high level summary of model development status (Column X, lines 20 to 35)

RESEARCH PROBLEM IDENTIFICATION:

There is the need to produce more affordable energy with low CO2 footprint. Better management of the natural gas produced may be one of the alternative to tackle this challenge.

NG can play an important role involving this challenge, however, in the specific case of the Santos Basin Pre-Salt Cluster, there is not logistics to link Supply and Demand (S&D) of these growing volumes of produced gas.

On one hand the required logistics investments have been partially in place because preliminary studies indicated that it is not viable to monetise a material volume of the natural gas originated in the Santos Basin Pre-Salt Cluster (SBPC).

On the other hand, LNG related technologies are shaping the global natural gas markets in terms of supply, demand and trading flows. Based on the potential growth of natural gas supply and demand inside Brazil over the next decades, combined to its large territory, LNG and other NG-related technologies can represent a strategic technology to unlock natural gas value across the supply chain and create competitive advantage to players acting in this industry.

FORMULATION OF THE RESEARCH PROBLEM:

How NG-related technologies could be deployed in SBPC over the next 10 yrs., maximizing NPV and reducing CO2 footprint in comparison to the current production system?

INTENT OF MODEL USE:

To develop a robust representation and understanding of the complex challenges involving the monetization of Natural Gas in Santos Basin Pre-Salt Cluster (SBPC) and in this specific case GCA's ten selected fields.

Then, the idea is to understand how NG-related technologies can help on producing more affordable energy from this cluster with lower CO2 footprint (research problem).

Based on that, the model offers a structured way of thinking of the scenarios and implications of changes to parts of the SBPC system in the short and long terms.

CONCEPT	FOLDERS	BIREF DESCRIPTION	Status
Step 1	STEP 1: IDENTIFY & FORMULATE THE PROBLEM	The objective of this folder is to share key information of this model, including research problem identification	100%

Figure 23 - Screen shot of folder Step 1 that is the starting point of the model and provides an overview of the research problem.

Economic Model to Evaluate Natural Gas-related Technologies to Optimize the Utilization of CH4 and CO2 in the Santos Basin Pre-sal Cluster			
STEP 1: IDENTIFY & FORMULATE THE PROBLEM		Ten Selected Fields in The Pre-Salt Play of the Deepwater of Santos Basin	
CONCEPT	**FOLDERS**	**BIREF DESCRIPTION**	**Status**
Step 1	STEP 1: IDENTIFY & FORMULATE THE PROBLEM	The objective of this folder is to share key information of this model, including research problem identification	100%
Step 2	STEP 2: COLLECT SYSTEM DATA	The objetive is to define the starting point of this research. This folder COLLECTS non-technical information to develop a DCF analysis of Ten Selected Fields in the Pre-Salt Play of the Deepwa	100%
	STEP 2b: COLLECT SYSTEM DATA	The objetive of this folder is to COLLECT non-technical information to develop the unit and modular cost, considering OPEX and CAPEX of each NG-related technology	100%
	STEP 3a: COLLECT SYSTEM DATA	The objetive of this folder is to PROCESS and SIMULATE based on the value drivers and value levers.	100%
	STEP 2e: COLLECT SYSTEM DATA	The objetive of this folder is to COLLECT expected O&G production of SBPC and to design a thorough production scenario for the next 20 years	100%
Step 3	STEP 3: PROCESS SYSTEM DATA	The objetive of this folder is to PROCESS and SIMULATE based on the value drivers and value levers.	100%
	STEP 3a1: PROCESS SYSTEM DATA	The objetive of this folder is to PROCESS the non-technical information of Step 3aX, which was selected from GCA Report 2010 and GEM's output	100%
	STEP 3c: PROCESS SYSTEM DATA	The objetive of this folder is to PROCESS the non-technical information of Step 3b, which was selected during the research process and then carry on with analysis and synthesis.	100%
	STEP 3d: PROCESS SYSTEM DATA	The objetive of this folder is to PROCESS the technical information from Step 3c and then perform the analysis and syntesis.	100%
	STEP 3e: PROCESS SYSTEM DATA	The objetive of this folder is to PROCESS the overall information (tech. and non-tech.) to perform the ANALYSIS of the collected information.	100%
	STEP 3f: PROCESS SYSTEM DATA	The objetive of this folder is to PROCESS the overall information (tech. and non-tech.) to perform the SYNTHESIS of the collected information.	100%
Step 4	STEP 4: VALIDATE THE MODEL	The objetive of this folder is to summarize the process of VALIDATION of the model	100%
Step 5	STEP 5: DOCUMENT MODEL FOR FUTURE USE	The objetive of this folder is to DOCUMENT the model for future use	100%
Step 6	STEP 6: SELECT APPROPRIATE EXPERIMENTAL DESIGN	Select performance measures (KPIs), a few inputs variables that have the highest influence in the key outcomes of of the system.	100%
Step 7	STEP 7: ESTABLISH EXPERIMENTAL CONDITIONS FOR RUNS	To address the challenge of obtaining accurate information and the most useful information from each run, considering it is a stationay system (to be understood)	100%
Step 8	STEP 8: PERFORM SIMULATION RUNS	To perform simulations and runs	100%
Step 9	STEP 9a1: INTERPRET AND PRESENT RESULTS	Collect the emerging insights from Santos Basin Pre-Salt Cluster	100%
	STEP 9b: INTERPRET AND PRESENT RESULTS	Design the initial CHARTS to support analysis and synthesis	100%
	STEP 9c: INTERPRET AND PRESENT RESULTS	The objetive of this folder is to organize and streamline the outputs of the model in order to facilitate the analysis and synthesis of economic assessment of SBPC.	100%
	STEP 9d: INTERPRET AND PRESENT RESULTS	The objetive of this folder is to consolidate the information to perform a thorough analysis and reccomendation	100%
	BACK UP FOLDERS		

Steps 1 | Step 2 (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 24 - Additional picture of folder Step 1 that provides a summary of model development methodology that was mainly based on nine steps.

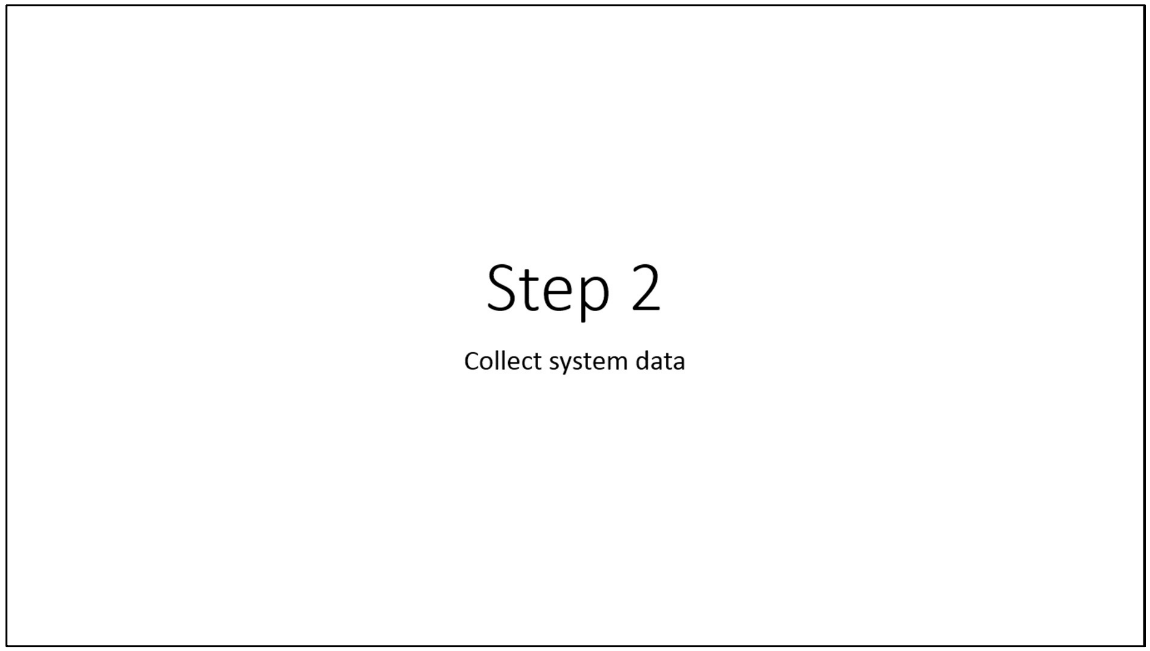


Figure 25 - Section related to Step 2, collection of system data

Economic Model to Evaluate Natural Gas-related Technologies to Optimize the Utilization of CH4 and CO2 in the Santos Basin Pre-sal Cluster

STEP 2: COLLECT SYSTEM DATA **Ten Selected Fields in The Pre-Salt Play of the Ten Selected Fields in The Pre-Salt Play of the Deepwater of Santos Basin**

Author: Cristiano Moura Borges
PhD Candidate of University of São Paulo (USP) Last update: 10/04/2021

OBJECTIVE OF THIS FOLDER:

The objetive is to define the starting point of this research. This folder COLLECTS non-technical information to develop a DCF analysis of Ten Selected Fields in the Pre-Salt Play of the Deepwater of Santos Basin.
The starting point is Gaffney, Cline & Associates Report (GCA 2010). This folder calculates the results for different GOR assumptions (Base, Expected, High, Low)

METHODOLOGY:

The methodology has the starting point of the Base Case Scenario, which is based on GCA's production projections, considering 100% reinjection and forecasted prices at that time (2010).
The first step is to design hypothetical CASES based on the selected NG-related technologies (Cases 1-7) to allow, in a second moment,
measuring the economic impact of each technology. The measurment of the economic impact of each technology is performed in folder "Step 3a".
After initial processing and analysis of these CASES at Step 3a, more structured SCENARIOS will be proposed to focus and drill down the analysis leading to the extraction of high quality insights, synthesis and conclusions.

1 Case 1: Base case (100% injection) [redacted]se case (100

Year		Oil production	Gas production	Natural Gas production	CO2 production	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMbbl	year MMscf
2019	1	32	41.610	0	0	0	0	0	32	0
2020	2	31	40.880	0	0	0	0	0	31	0
2021	3	69	39.055	0	0	0	0	0	69	0
2022	4	33	39.420	0	0	0	0	0	33	0
2023	5	238	274.845	0	0	0	0	0	238	0
2024	6	439	509.175	0	0	0	0	0	439	0
2025	7	647	746.425	0	0	0	0	0	647	0

Year		Oil price	Natural Gas Price	Oil revenue	Natural Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	Net income before tax	NIAT	NET CASH FLOW	Discounted Cash Flow
		USD/bb 75,98	USD/MMBT 4,00	MM USD 7,90%	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD 10,00%
2019	1	77,50	4,08	2.267	0	227	135	1.836	0	1.864	1.230	-565	-514
2020	2	81,04	4,16	2.343	0	234	110	2.691	0	1.808	1.193	-1.307	-1.081
2021	3	84,24	4,24	5.299	0	530	523	1.109	0	3.516	2.320	1.941	1.458
2022	4	85,84	4,33	2.626	0	263	286	391	0	1.932	1.275	1.029	703
2023	5	86,94	4,42	18.911	0	1.891	990	17.278	0	13.656	9.012	-5.892	-3.659
2024	6	88,24	4,50	35.485	0	3.549	1.901	25.107	0	26.004	17.163	-3.913	-2.209
2025	7	89,54	4,59	53.047	0	5.305	2.809	26.640	0	38.612	25.484	5.165	2.651

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 26 - Picture of folder Step 2, indicating the collection of the information and then linking to processing data, which is the following step 3.

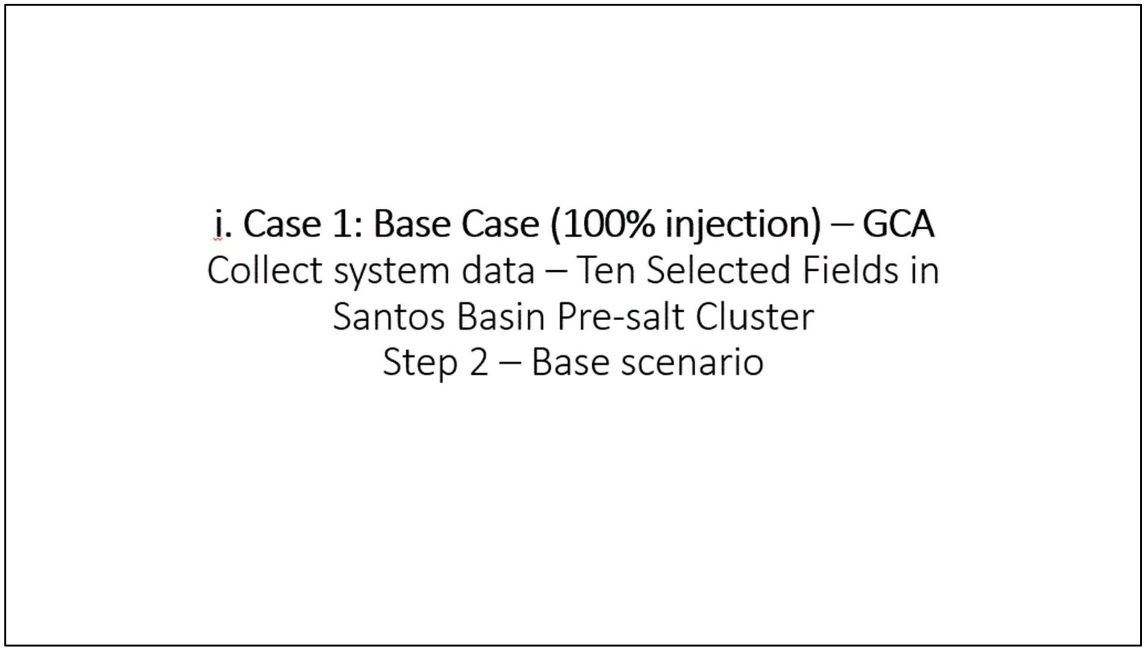


Figure 27 - Section related to data collection of Ten Selected Fields in Santos Basin Pre-salt Cluster

Economic Model to Evaluate Natural Gas-related Technologies to Optimize the Utilization of CH4 and CO2 in the Santos Basin Pre-sal Cluster

STEP 2: COLLECT SYSTEM DATA **Ten Selected Fields in The Pre-Salt Play of the Ten Selected Fields in The Pre-Salt Play of the Deepwater of Santos Basin**

Author: Cristiano Moura Borges

PhD Candidate of University of São Paulo (USP) Last update: 10/04/2021

OBJECTIVE OF THIS FOLDER:

The objetive is to define the starting point of this research. This folder COLLECTS non-technical information to develop a DCF analysis of Ten Selected Fields in the Pre-Salt Play of the Deepwater of Santos Basin.
The starting point is Gaffney, Cline & Associates Report (GCA 2010). This folder calculates the results for different GOR assumptions (Base, Expected, High, Low)

METHODOLOGY:

The methodology has the starting point of the Base Case Scenario, which is based on GCA's production projections, considering 100% reinjection and forecasted prices at that time (2010).
The first step is to design hypothetical CASES based on the selected NG-related technologies (Cases 1-7) to allow, in a second moment,
measuring the economic impact of each technology. The measurment of the economic impact of each technology is performed in folder "Step 3a".
After initial processing and analysis of these CASES at Step 3a, more structured SCENARIOS will be proposed to focus and drill down the analysis leading to the extraction of high quality insights, synthesis and conclusions.

1 Case 1: Base case (100% injection) [redacted]se case (100

Year		Oil production	Gas production	Natural Gas production	CO2 production	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMbbl	year MMscf	USD/bb 75,98
2019	1	32	41.610	0	0	0	0	0	32	0	77,50
2020	2	31	40.880	0	0	0	0	0	31	0	81,04
2021	3	69	39.055	0	0	0	0	0	69	0	84,24
2022	4	33	39.420	0	0	0	0	0	33	0	85,84
2023	5	238	274.845	0	0	0	0	0	238	0	86,94
2024	6	439	509.175	0	0	0	0	0	439	0	88,24
2025	7	647	746.425	0	0	0	0	0	647	0	89,54

Year	Natural Gas Price	Oil revenue	Natural Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	Net income before tax	NIAT	NET CASH FLOW	Discounted Cash Flow
	USD/MMBT 4,00	MM USD 7,90%	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD 10,00%
2019	4,08	2.267	0	227	135	1.836	0	1.864	1.230	-565	-514
2020	4,16	2.343	0	234	110	2.691	0	1.808	1.193	-1.307	-1.081
2021	4,24	5.299	0	530	523	1.109	0	3.516	2.320	1.941	1.458
2022	4,33	2.626	0	263	286	391	0	1.932	1.275	1.029	703
2023	4,42	18.911	0	1.891	990	17.278	0	13.656	9.012	-5.892	-3.659
2024	4,50	35.485	0	3.549	1.901	25.107	0	26.004	17.163	-3.913	-2.209
2025	4,59	53.047	0	5.305	2.809	26.640	0	38.612	25.484	5.165	2.651

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 28 - First scenario section, Case 1, Base Case, which considers 100% gas injection and base case assumptions from GCA study.

1 Case 1: Base case (100% injection) [redacted]se case (100

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas production year MMscf	CO2 production year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bb 75,98	Natural Gas Price USD/MMBT 4,00	Oil revenue MM USD 7,90%	Natural Gas revenue MM USD	Royalties MM USD	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	Net income before tax MM USD	NIAT MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2019	1	32	41.610	0	0	0	0	0	32	0	77,50	4,08	2.267	0	227	135	1.836	0	1.864	1.230	-565	-514
2020	2	31	40.880	0	0	0	0	0	31	0	81,04	4,16	2.343	0	234	110	2.691	0	1.808	1.193	-1.307	-1.081
2021	3	69	39.055	0	0	0	0	0	69	0	84,24	4,24	5.299	0	530	523	1.109	0	3.516	2.320	1.941	1.458
2022	4	33	39.420	0	0	0	0	0	33	0	85,84	4,33	2.626	0	263	286	391	0	1.932	1.275	1.029	703
2023	5	238	274.845	0	0	0	0	0	238	0	86,94	4,42	18.911	0	1.891	990	17.278	0	13.656	9.012	-5.892	-3.659
2024	6	439	509.175	0	0	0	0	0	439	0	88,24	4,50	35.485	0	3.549	1.901	25.107	0	26.004	17.163	-3.913	-2.209
2025	7	647	746.425	0	0	0	0	0	647	0	89,54	4,59	53.047	0	5.305	2.809	26.640	0	38.612	25.484	5.165	2.651
2026	8	833	958.125	0	0	0	0	0	833	0	91,04	4,69	69.490	0	6.949	3.699	26.365	0	50.032	33.022	15.467	7.215
2027	9	948	1.087.335	0	0	0	0	0	948	0	92,64	4,78	80.539	0	8.054	4.385	20.276	0	57.228	37.772	28.369	12.031
2028	10	1.020	1.170.190	0	0	0	0	0	1.020	0	94,44	4,88	88.362	0	8.836	4.945	15.399	0	62.132	41.008	38.058	14.673
2029	11	1.052	1.207.055	0	0	0	0	0	1.052	0	96,34	4,97	93.020	0	9.302	5.380	11.051	0	64.712	42.709	45.284	15.872
2030	12	1.066	1.211.800	0	0	0	0	0	1.066	0	98,24	5,07	96.168	0	9.617	5.737	8.033	0	66.632	43.977	50.126	15.972
2031	13	1.082	1.219.465	0	0	0	0	0	1.082	0	100,24	5,17	99.595	0	9.960	6.104	7.965	0	68.400	45.144	52.311	15.153
2032	14	1.065	1.171.285	0	0	0	0	0	1.065	0	102,24	5,28	100.055	0	10.005	6.342	3.632	0	67.944	44.843	56.974	15.003
2033	15	1.039	1.134.785	0	0	0	0	0	1.039	0	104,34	5,38	99.567	0	9.957	6.559	2.964	0	67.560	44.590	57.117	13.673
2034	16	1.013	1.106.680	0	0	0	0	0	1.013	0	106,34	5,49	98.986	0	9.899	6.791	3.276	0	68.356	45.115	55.779	12.139
2035	17	988	1.077.480	0	0	0	0	0	988	0	108,54	5,60	98.529	0	9.853	7.014	2.827	0	69.488	45.863	55.210	10.923
2036	18	952	1.023.095	0	0	0	0	0	952	0	110,64	5,71	96.729	0	9.673	7.235	2.621	0	69.636	45.959	53.523	9.627
2037	19	893	947.540	0	0	0	0	0	893	0	112,90	5,83	92.606	0	9.261	7.440	1.871	0	66.508	43.823	51.349	8.396
2038	20	824	872.350	0	0	0	0	0	824	0	115,10	5,94	87.109	0	8.711	7.631	818	0	63.508	41.916	48.357	7.188
2039	21	751	787.670	0	0	0	0	0	751	0	117,40	6,06	81.008	0	8.101	7.800	556	103	58.756	38.779	44.471	6.009
2040	22	675	695.325	0	0	0	0	0	675	0	119,80	6,18	74.259	0	7.426	7.937	0	105	53.166	35.090	40.715	5.002
2041	23	596	598.600	0	0	0	0	0	596	0	122,20	6,31	66.844	0	6.684	8.044	0	470	46.850	30.921	35.717	3.989
2042	24	523	512.825	0	0	0	0	0	523	0	124,60	6,43	59.834	0	5.983	8.073	0	452	40.732	26.882	31.476	3.196

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 29 - First scenario section, Case 1, Base Case, which considers 100% gas injection and base case assumptions from GCA study.

1 Case 1: Base case (100% injection) — Case 1: Base case (100

Year		Oil production	Gas production	Natural Gas production	CO2 production	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Natural Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	Net income before tax	NIAT	NET CASH FLOW	Discounted Cash Flow
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMbbl	year MMscf	USD/bb 75,98	USD/MMBT 4,00	MM USD 7,90%	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD 10,00%
2036	18	952	1.023.095	0	0	0	0	0	952	0	110,64	5,71	96.729	0	9.673	7.235	2.621	0	69.636	45.959	53.523	9.627
2037	19	893	947.540	0	0	0	0	0	893	0	112,90	5,83	92.606	0	9.261	7.440	1.871	0	66.508	43.823	51.349	8.396
2038	20	824	872.350	0	0	0	0	0	824	0	115,10	5,94	87.109	0	8.711	7.631	818	0	63.508	41.916	48.357	7.188
2039	21	751	787.670	0	0	0	0	0	751	0	117,40	6,06	81.008	0	8.101	7.800	556	103	58.756	38.779	44.471	6.009
2040	22	675	695.325	0	0	0	0	0	675	0	119,80	6,18	74.259	0	7.426	7.937	0	105	53.166	35.090	40.715	5.002
2041	23	596	598.600	0	0	0	0	0	596	0	122,20	6,31	66.844	0	6.684	8.044	0	470	46.850	30.921	35.717	3.989
2042	24	523	512.825	0	0	0	0	0	523	0	124,60	6,43	59.834	0	5.983	8.073	0	452	40.732	26.882	31.476	3.196
2043	25	456	438.000	0	0	0	0	0	456	0	127,10	6,56	53.228	0	5.323	8.080	0	1.031	35.204	23.235	26.825	2.476
2044	26	396	374.855	0	0	0	0	0	396	0	129,60	6,69	47.102	0	4.710	8.014	0	1.619	30.088	19.858	22.529	1.890
2045	27	343	321.565	0	0	0	0	0	343	0	132,20	6,83	41.572	0	4.157	7.870	0	2.113	25.628	16.914	18.717	1.428
2046	28	296	277.765	0	0	0	0	0	296	0	134,90	6,96	36.627	0	3.663	7.618	0	2.606	21.596	14.255	15.399	1.068
2047	29	253	242.360	0	0	0	0	0	253	0	137,60	7,10	31.867	0	3.187	6.849	0	2.758	18.208	12.018	12.884	812
2048	30	219	226.665	0	0	0	0	0	219	0	140,30	7,25	28.212	0	2.821	6.479	0	3.057	15.282	10.087	10.659	611
2049	31	188	194.910	0	0	0	0	0	188	0	143,10	7,39	24.648	0	2.465	5.980	0	3.490	12.426	8.201	8.488	442
2050	32	164	171.550	0	0	0	0	0	164	0	146,00	7,54	21.867	0	2.187	5.476	0	3.561	10.476	6.914	7.080	335
2051	33	142	149.650	0	0	0	0	0	142	0	148,90	7,69	19.405	0	1.941	5.026	0	3.761	8.868	5.853	5.663	244
2052	34	126	132.130	0	0	0	0	0	126	0	151,90	7,84	17.455	0	1.745	4.406	0	3.971	7.296	4.814	4.851	190
2053	35	90	91.980	0	0	0	0	0	90	0	154,90	8,00	12.796	0	1.280	3.116	0	3.235	5.300	3.498	3.363	120
2054	36	58	59.860	0	0	0	0	0	58	0	158,00	8,16	8.405	0	840	2.218	0	2.333	3.324	2.195	1.884	61
2055	37	35	35.770	0	0	0	0	0	35	0	161,20	8,32	5.205	0	520	1.503	0	1.540	1.752	1.156	1.045	31
2056	38	17	18.615	0	0	0	0	0	17	0	164,40	8,49	2.545	0	254	956	0	1.142	332	219	79	2
2057	39	10	9.855	0	0	0	0	0	10	0	167,70	8,66	1.468	0	147	623	0	875	28	18	-187	-5
2058	40	5	5.540	0	0	0	0	0	5	0	171,00	8,83	865	0	86	325	0	597	788	589	-343	-8
Total		19.607	21.224.085	0	0	0	0	0	19.607	0	99,76	6,16	1.955.945	0	195.594	192.409	182.706	38.820	1.325.628	874.912	895.699	183.108

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 30 - Continuation of figure 29, highlighting in black cells total oil production, gas production, revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

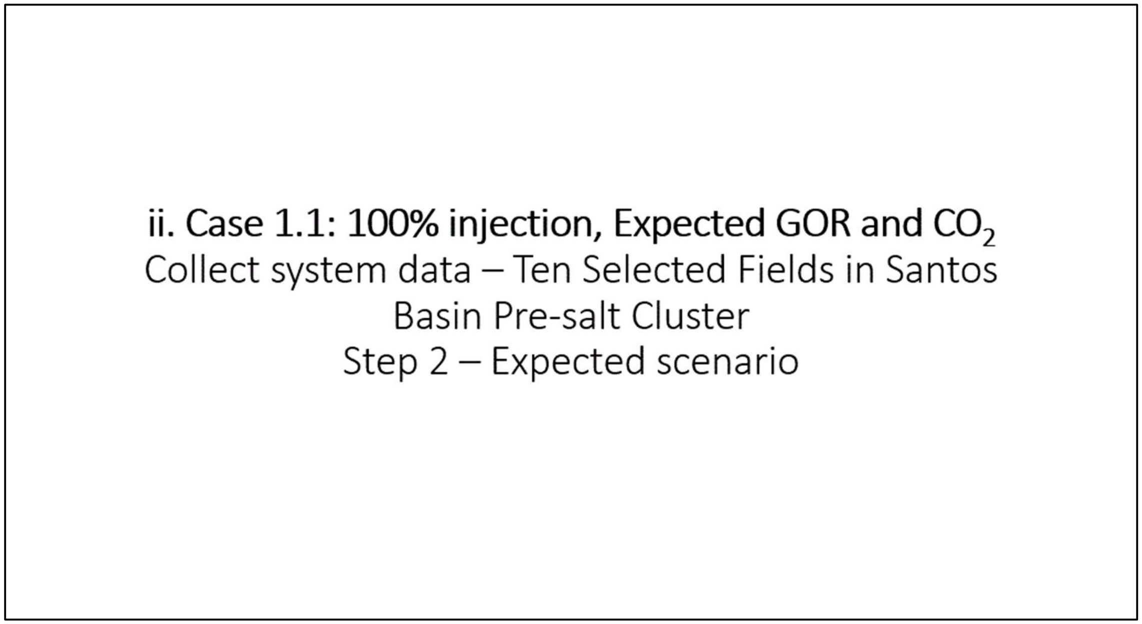


Figure 31 - Second scenario section, Case 1.1, which considers 100% gas injection and expected GOR and CO will be presented over the next couple slides..

Case 1.1: 100% injection with expected GOR and CO2																					
Year		Oil production	Gas Production	Natural Gas production	CO2 production	CO2 production	Natural Gas Demand (fuel)	Gas injection	Natural Gas injection	CO2 injection	Oil price	Natural Gas price	Oil revenue	Royalties	OPEX	CAPEX	Aband. costs	Net income before tax	NET CASH FLOW	Discounted Cash Flow
		year	year	year	day	year	year	year	year	year	USD/bbl	USD/M	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD
		MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	50,00	5,50	7,90%							10,00%
2020	1	32	0	0	0	0	0	0	0	0	51,00	5,61	1.492	149	135	1.836	0	1.166	-1.025	-932
2020	2	31	0	0	0	0	0	0	0	0	53,33	5,72	1.542	154	110	2.691	0	1.087	-1.783	-1.474
2021	3	69	73.492	38.233	97	35.258	12.617	60.875	25.616	35.258	55,44	5,84	3.487	349	523	1.109	0	1.885	865	650
2022	4	33	48.589	26.058	62	22.531	8.599	39.989	17.459	22.531	56,49	5,95	1.728	173	286	391	0	1.124	496	339
2023	5	238	327.012	156.083	468	170.928	51.508	275.504	104.576	170.928	57,21	6,07	12.445	1.245	990	17.278	0	7.836	-9.732	-6.043
2024	6	439	646.815	299.327	952	347.488	98.778	548.037	200.549	347.488	58,07	6,19	23.352	2.335	1.901	25.107	0	15.084	-11.121	-6.277
2025	7	647	1.033.061	474.722	1.530	558.339	156.658	876.403	318.063	558.339	58,92	6,32	34.909	3.491	2.809	26.640	0	22.287	-5.609	-2.878
2026	8	833	1.456.701	669.313	2.157	787.388	220.873	1.235.827	448.440	787.388	59,91	6,44	45.729	4.573	3.699	26.365	0	28.647	1.352	631
2027	9	948	1.816.284	834.222	2.691	982.062	275.293	1.540.990	558.929	982.062	60,96	6,57	53.000	5.300	4.385	20.276	0	32.443	12.009	5.093
2028	10	1.020	2.067.007	944.648	3.075	1.122.359	311.734	1.755.273	632.914	1.122.359	62,15	6,70	58.148	5.815	4.945	15.399	0	34.940	20.110	7.753
2029	11	1.052	2.278.507	1.031.637	3.416	1.246.870	340.440	1.938.067	691.197	1.246.870	63,40	6,84	61.213	6.121	5.380	11.051	0	36.086	26.390	9.250
2030	12	1.066	2.527.015	1.134.297	3.816	1.392.718	374.318	2.152.697	759.979	1.392.718	64,65	6,98	63.285	6.328	5.737	8.033	0	37.038	30.594	9.748
2031	13	1.082	2.801.174	1.248.249	4.255	1.552.925	411.922	2.389.252	836.327	1.552.925	65,96	7,11	65.540	6.554	6.104	7.965	0	37.751	32.083	9.293
2032	14	1.065	2.923.306	1.298.269	4.452	1.625.036	428.429	2.494.877	869.841	1.625.036	67,28	7,26	65.843	6.584	6.342	3.632	0	37.153	36.649	9.651
2033	15	1.039	3.084.969	1.365.945	4.710	1.719.024	450.762	2.634.207	915.183	1.719.024	68,66	7,40	65.522	6.552	6.559	2.964	0	36.919	36.894	8.832
2034	16	1.013	3.271.228	1.444.039	5.006	1.827.189	476.533	2.794.695	967.506	1.827.189	69,98	7,55	65.139	6.514	6.791	3.276	0	37.894	35.675	7.764
2035	17	988	3.495.710	1.538.972	5.361	1.956.739	507.861	2.987.850	1.031.111	1.956.739	71,43	7,70	64.839	6.484	7.014	2.827	0	39.167	35.197	6.964
2036	18	952	3.740.176	1.641.970	5.749	2.098.206	541.850	3.198.326	1.100.120	2.098.206	72,81	7,86	63.654	6.365	7.235	2.621	0	39.869	33.878	6.093
2037	19	893	3.784.708	1.658.618	5.825	2.126.089	547.344	3.237.364	1.111.274	2.126.089	74,30	8,01	60.941	6.094	7.440	1.871	0	38.010	32.613	5.332
2038	20	824	3.923.581	1.716.166	6.048	2.207.415	566.335	3.357.246	1.149.831	2.207.415	75,74	8,17	57.324	5.732	7.631	818	0	36.701	30.663	4.558
2039	21	751	3.843.465	1.679.590	5.928	2.163.875	554.265	3.289.200	1.125.325	2.163.875	77,26	8,34	53.309	5.331	7.800	556	103	33.827	28.016	3.786
2040	22	675	3.579.080	1.563.716	5.522	2.015.364	516.026	3.063.054	1.047.690	2.015.364	78,84	8,50	48.867	4.887	7.937	0	105	30.314	25.611	3.146
2041	23	596	3.059.988	1.319.003	4.770	1.740.985	435.271	2.624.717	883.732	1.740.985	80,42	8,67	43.988	4.399	8.044	0	470	26.279	22.066	2.464
2042	24	523	2.777.515	1.197.018	4.330	1.580.497	395.016	2.382.499	802.002	1.580.497	82,00	8,85	39.375	3.937	8.073	0	452	22.319	19.250	1.954

Figure 32 - Figures are related to second scenario, Case 1.1, which considers 100% gas injection and expected GOR and CO_2.

Case 1.1: 100% injection with expected GOR and CO2

Year	Oil production year MMbbl	Gas Production year MMscf	Natural Gas production year MMscf	CO2 production day MMscf	CO2 production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 50,00	Natural Gas price USD/M 5,50	Oil revenue MM USD 7,90%	Royalties MM USD	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	Net income before tax MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2036 18	952	3.740.176	1.641.970	5.749	2.098.206	541.850	3.198.326	1.100.120	2.098.206	952	0	72,81	7,86	63.654	6.365	7.235	2.621	0	39.869	33.878	6.093
2037 19	893	3.784.708	1.658.618	5.825	2.126.089	547.344	3.237.364	1.111.274	2.126.089	893	0	74,30	8,01	60.941	6.094	7.440	1.871	0	38.010	32.613	5.332
2038 20	824	3.923.581	1.716.166	6.048	2.207.415	566.335	3.357.246	1.149.831	2.207.415	824	0	75,74	8,17	57.324	5.732	7.631	818	0	36.701	30.663	4.558
2039 21	751	3.843.465	1.679.590	5.928	2.163.875	554.265	3.289.200	1.125.325	2.163.875	751	0	77,26	8,34	53.309	5.331	7.800	556	103	33.827	28.016	3.786
2040 22	675	3.579.080	1.563.716	5.522	2.015.364	516.026	3.063.054	1.047.690	2.015.364	675	0	78,84	8,50	48.867	4.887	7.937	0	105	30.314	25.611	3.146
2041 23	596	3.059.988	1.319.003	4.770	1.740.985	435.271	2.624.717	883.732	1.740.985	596	0	80,42	8,67	43.988	4.399	8.044	0	470	26.279	22.066	2.464
2042 24	523	2.777.515	1.197.018	4.330	1.580.497	395.016	2.382.499	802.002	1.580.497	523	0	82,00	8,85	39.375	3.937	8.073	0	452	22.319	19.250	1.954
2043 25	456	2.463.010	1.060.941	3.841	1.402.069	350.111	2.112.899	710.831	1.402.069	456	0	83,64	9,02	35.028	3.503	8.080	0	1.031	18.824	15.946	1.472
2044 26	396	2.162.679	931.683	3.373	1.230.996	307.455	1.855.223	624.227	1.230.996	396	0	85,29	9,20	30.996	3.100	8.014	0	1.619	15.593	12.898	1.082
2045 27	343	2.214.277	952.702	3.456	1.261.574	314.392	1.899.885	638.310	1.261.574	343	0	87,00	9,39	27.357	2.736	7.870	0	2.113	12.835	10.214	779
2046 28	296	1.303.384	562.674	2.029	740.710	185.682	1.117.701	376.991	740.710	296	0	88,77	9,58	24.103	2.410	7.618	0	2.606	10.324	7.857	545
2047 29	253	252.493	113.031	382	139.462	37.300	215.193	75.731	139.462	253	0	90,55	9,77	20.971	2.097	6.849	0	2.758	8.401	6.363	401
2048 30	219	229.784	102.932	348	126.852	33.968	195.816	68.964	126.852	219	0	92,33	9,96	18.566	1.857	6.479	0	3.057	6.600	4.879	280
2049 31	188	206.191	92.348	312	113.844	30.475	175.717	61.873	113.844	188	0	94,17	10,16	16.220	1.622	5.980	0	3.490	4.841	3.429	179
2050 32	164	170.846	79.404	251	91.441	26.203	144.642	53.201	91.441	164	0	96,08	10,36	14.390	1.439	5.476	0	3.561	3.747	2.596	123
2051 33	142	149.271	69.279	219	79.992	22.862	126.409	46.417	79.992	142	0	97,99	10,57	12.770	1.277	5.026	0	3.761	2.896	1.678	72
2052 34	126	134.106	62.293	197	71.814	20.557	113.550	41.736	71.814	126	0	99,96	10,78	11.486	1.149	4.406	0	3.971	1.924	1.270	50
2053 35	90	93.549	43.330	138	50.219	14.299	79.250	29.031	50.219	90	0	101,93	11,00	8.421	842	3.116	0	3.235	1.362	764	27
2054 36	58	48.761	22.685	71	26.076	7.486	41.275	15.199	26.076	58	0	103,97	11,22	5.531	553	2.218	0	2.333	738	176	6
2055 37	35	21.877	10.154	32	11.723	3.351	18.526	6.803	11.723	35	0	106,08	11,44	3.425	343	1.503	0	1.540	150	-35	-1
2056 38	17	8.816	3.988	13	4.828	1.316	7.500	2.672	4.828	17	0	108,19	11,67	1.674	167	956	0	1.142	-451	-591	-16
2057 39	10	0	0	0	0	0	0	0	0	10	0	110,36	11,91	966	97	623	0	875	-424	-629	-15
2058 40	5	0	0	0	0	0	0	0	0	5	0	112,53	12,14	569	57	325	0	597	522	-678	-15
Total	**19.607**	**62.018.423**	**27.387.538**	**94.879**	**34.630.884**	**9.037.888**	**52.980.535**	**18.349.651**	**34.630.884**	**19.607**	**0**	**65,65**	**8,47**	**1.287.144**	**128.714**	**192.409**	**182.706**	**38.820**	**723.708**	**497.279**	**90.665**

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 33 - Continuation of Figure 32, continuation of Figure 33, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

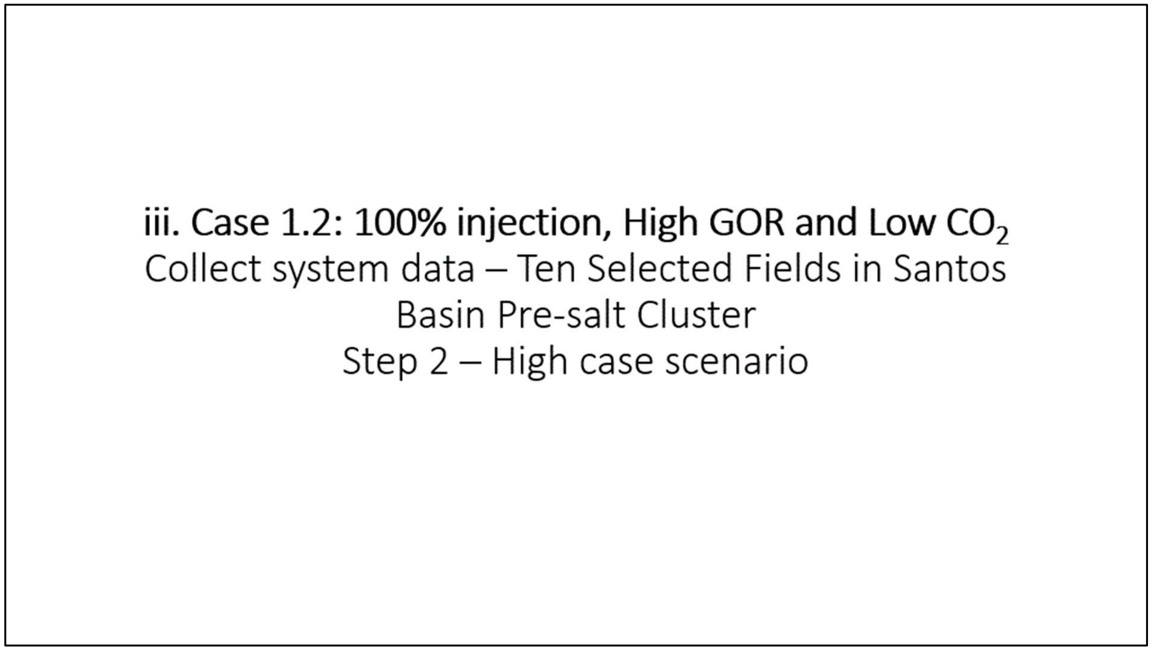


Figure 34 - Third scenario section, Case 1.2, which considers 100% gas injection and High GOR and low CO2 will be presented over the next couple slides

Case 1.2: 100% injection, HIgh GOR and Low CO2, WAG

Case 1.2: 100% injection, HIgh GOR and Low CO2, WAG

Year		Oil producti on year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Oil price USD/bbl	Natural Gas Price USD/M	Oil revenue MM USD	Nautral Gas revenue MM USD	Royalties MM USD	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	EBITDA MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD
											75,00	8,25	0,079	0	0,1	0	0	0	0	0,00	10,00%
2020	1	32	41.610	26.174	15.436	1.536	32.972	17.537	15.436	32	76,50	8,42	2.237	0	224	135	1.836	0	1.879	-582	-529
2020	2	31	40.880	25.715	15.165	2.380	32.394	17.229	15.165	31	79,99	8,58	2.313	0	231	110	2.691	0	1.971	-1.325	-1.095
2021	3	69	39.055	24.567	14.488	5.173	30.948	16.460	14.488	69	83,15	8,75	5.230	0	523	523	1.109	0	4.184	1.901	1.428
2022	4	33	39.420	24.797	14.623	7.003	31.237	16.614	14.623	33	84,73	8,93	2.592	0	259	286	391	0	2.047	1.009	689
2023	5	238	732.042	412.300	319.742	12.976	595.983	276.241	319.742	238	85,82	9,11	18.668	0	1.867	990	17.278	0	15.811	-6.036	-3.748
2024	6	439	1.490.876	833.409	657.467	13.260	1.215.851	558.384	657.467	439	87,10	9,29	35.027	0	3.503	1.901	25.107	0	29.624	-4.185	-2.362
2025	7	647	2.268.164	1.267.118	1.001.046	13.827	1.850.015	848.969	1.001.046	647	88,39	9,48	52.363	0	5.236	2.809	26.640	0	44.318	4.759	2.442
2026	8	833	2.999.666	1.673.424	1.326.242	14.231	2.447.436	1.121.194	1.326.242	833	89,87	9,67	68.594	0	6.859	3.699	26.365	0	58.036	14.934	6.967
2027	9	948	3.573.221	1.989.220	1.584.001	14.909	2.916.778	1.332.777	1.584.001	948	91,45	9,86	79.500	0	7.950	4.385	20.276	0	67.165	27.750	11.769
2028	10	1.020	4.031.008	2.233.278	1.797.730	15.389	3.294.026	1.496.296	1.797.730	1.020	93,22	10,06	87.222	0	8.722	4.945	15.399	0	73.555	37.380	14.412
2029	11	1.052	4.449.908	2.455.259	1.994.649	15.779	3.639.673	1.645.024	1.994.649	1.052	95,10	10,26	91.820	0	9.182	5.380	11.051	0	77.258	44.572	15.622
2030	12	1.066	4.797.250	2.639.325	2.157.925	16.557	3.926.273	1.768.347	2.157.925	1.066	96,97	10,46	94.927	0	9.493	5.737	8.033	0	79.697	49.390	15.737
2031	13	1.082	5.133.702	2.818.467	2.315.235	17.080	4.203.608	1.888.373	2.315.235	1.082	98,95	10,67	98.311	0	9.831	6.104	7.965	0	82.375	51.548	14.932
2032	14	1.065	5.118.320	2.807.595	2.310.725	17.549	4.191.814	1.881.089	2.310.725	1.065	100,92	10,89	98.764	0	9.876	6.342	3.632	0	82.546	56.208	14.801
2033	15	1.039	5.072.035	2.781.094	2.290.941	18.411	4.154.274	1.863.333	2.290.941	1.039	102,99	11,10	98.283	0	9.828	6.559	2.964	0	81.896	56.354	13.491
2034	16	1.013	5.055.925	2.770.778	2.285.147	19.216	4.141.568	1.856.421	2.285.147	1.013	104,97	11,33	97.709	0	9.771	6.791	3.276	0	81.147	55.021	11.974
2035	17	988	5.051.337	2.767.276	2.284.062	20.243	4.138.136	1.854.075	2.284.062	988	107,14	11,55	97.258	0	9.726	7.014	2.827	0	80.518	54.454	10.774
2036	18	952	4.875.103	2.670.522	2.204.581	20.913	3.993.831	1.789.250	2.204.581	952	109,21	11,78	95.482	0	9.548	7.235	2.621	0	78.698	52.783	9.493
2037	19	893	4.532.832	2.482.642	2.050.190	21.211	3.713.560	1.663.370	2.050.190	893	111,44	12,02	91.411	0	9.141	7.440	1.871	0	74.830	50.712	8.292
2038	20	824	4.197.333	2.299.163	1.898.170	23.394	3.438.610	1.540.439	1.898.170	824	113,62	12,26	85.986	0	8.599	7.631	818	0	69.756	47.689	7.089
2039	21	751	3.854.334	2.111.007	1.743.327	24.031	3.157.701	1.414.375	1.743.327	751	115,89	12,50	79.963	0	7.996	7.800	556	103	64.167	43.850	5.926
2040	22	675	3.437.078	1.882.289	1.554.790	23.829	2.815.923	1.261.133	1.554.790	675	118,25	12,75	73.301	0	7.330	7.937	0	105	58.034	40.146	4.932
2041	23	596	2.978.207	1.631.405	1.346.801	20.613	2.439.843	1.093.042	1.346.801	596	120,62	13,01	65.982	0	6.598	8.044	0	470	51.340	35.205	3.932
2042	24	523	2.552.257	1.398.401	1.153.856	19.653	2.090.784	936.929	1.153.856	523	122,99	13,27	59.062	0	5.906	8.073	0	452	45.083	31.016	3.149

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 35 - Third scenario, Case 1.2, which considers 100% gas injection High GOR and Low CO_2

Case 1.2: 100% injection, HIgh GOR and Low CO2, WAG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl
2036	18	952	4.875.103	2.670.522	2.204.581	20.913	3.993.831	1.789.250	2.204.581	952
2037	19	893	4.532.832	2.482.642	2.050.190	21.211	3.713.560	1.663.370	2.050.190	893
2038	20	824	4.197.333	2.299.163	1.898.170	23.394	3.438.610	1.540.439	1.898.170	824
2039	21	751	3.854.334	2.111.007	1.743.327	24.031	3.157.701	1.414.375	1.743.327	751
2040	22	675	3.437.078	1.882.289	1.554.790	23.829	2.815.923	1.261.133	1.554.790	675
2041	23	596	2.978.207	1.631.405	1.346.801	20.613	2.439.843	1.093.042	1.346.801	596
2042	24	523	2.552.257	1.398.401	1.153.856	19.653	2.090.784	936.929	1.153.856	523
2043	25	456	2.148.121	1.177.022	971.099	19.506	1.759.704	788.605	971.099	456
2044	26	396	1.820.874	998.148	822.726	19.897	1.491.485	668.759	822.726	396
2045	27	343	1.536.999	842.773	694.225	22.830	1.258.883	564.658	694.225	343
2046	28	296	1.293.832	709.738	584.094	18.504	1.059.618	475.524	584.094	296
2047	29	253	1.109.321	607.991	501.329	9.338	908.684	407.354	501.329	253
2048	30	219	1.051.901	576.094	475.808	9.506	861.790	385.983	475.808	219
2049	31	188	893.105	488.816	404.289	9.708	731.796	327.507	404.289	188
2050	32	164	775.159	424.152	351.007	7.014	635.189	284.182	351.007	164
2051	33	142	672.262	367.719	304.543	6.930	550.915	246.372	304.543	142
2052	34	126	585.981	320.492	265.490	7.008	480.219	214.730	265.490	126
2053	35	90	436.011	238.343	197.668	5.176	357.357	159.690	197.668	90
2054	36	58	293.600	159.350	134.250	4.367	241.015	106.764	134.250	58
2055	37	35	192.413	104.900	87.513	3.698	157.796	70.283	87.513	35
2056	38	17	108.040	58.726	49.313	2.874	88.660	39.347	49.313	17
2057	39	10	59.636	32.299	27.337	1.163	48.977	21.640	27.337	10
2058	40	5	38.493	20.764	17.728	0	31.641	13.912	17.728	5
Total		**19.607**	**89.377.312**	**49.152.553**	**40.224.759**	**526.681**	**73.156.970**	**32.932.211**	**40.224.759**	**19.607**

Year		Oil price USD/bbl 75,00	Natural Gas Price USD/M 8,25	Oil revenue MM USD 0,079	Nautral Gas revenue MM USD 0	Royalties MM USD 0,1	OPEX MM USD 0	CAPEX MM USD 0	Aband. costs MM USD 0	EBITDA MM USD 0	NET CASH FLOW MM USD 0,00	Discounted Cash Flow MM USD 10,00%
2036	18	109,21	11,78	95.482	0	9.548	7.235	2.621	0	78.698	52.783	9.493
2037	19	111,44	12,02	91.411	0	9.141	7.440	1.871	0	74.830	50.712	8.292
2038	20	113,62	12,26	85.986	0	8.599	7.631	818	0	69.756	47.689	7.089
2039	21	115,89	12,50	79.963	0	7.996	7.800	556	103	64.167	43.850	5.926
2040	22	118,25	12,75	73.301	0	7.330	7.937	0	105	58.034	40.146	4.932
2041	23	120,62	13,01	65.982	0	6.598	8.044	0	470	51.340	35.205	3.932
2042	24	122,99	13,27	59.062	0	5.906	8.073	0	452	45.083	31.016	3.149
2043	25	125,46	13,53	52.542	0	5.254	8.080	0	1.031	39.208	26.414	2.438
2044	26	127,93	13,81	46.494	0	4.649	8.014	0	1.619	33.831	22.165	1.860
2045	27	130,49	14,08	41.035	0	4.104	7.870	0	2.113	29.062	18.397	1.403
2046	28	133,16	14,36	36.155	0	3.615	7.618	0	2.606	24.921	15.114	1.048
2047	29	135,83	14,65	31.456	0	3.146	6.849	0	2.758	21.462	12.639	797
2048	30	138,49	14,94	27.849	0	2.785	6.479	0	3.057	18.584	10.443	598
2049	31	141,25	15,24	24.330	0	2.433	5.980	0	3.490	15.918	8.300	432
2050	32	144,12	15,55	21.584	0	2.158	5.476	0	3.561	13.950	6.913	327
2051	33	146,98	15,86	19.155	0	1.915	5.026	0	3.761	12.214	5.514	237
2052	34	149,94	16,18	17.230	0	1.723	4.406	0	3.971	11.101	4.719	185
2053	35	152,90	16,50	12.631	0	1.263	3.116	0	3.235	8.251	3.265	116
2054	36	155,96	16,83	8.296	0	830	2.218	0	2.333	5.249	1.819	59
2055	37	159,12	17,17	5.138	0	514	1.503	0	1.540	3.121	1.006	30
2056	38	162,28	17,51	2.512	0	251	956	0	1.142	1.305	60	2
2057	39	165,54	17,86	1.449	0	145	623	0	875	681	-202	-5
2058	40	168,79	18,22	854	0	85	325	0	597	443	-425	-9
Total		**98,47**	**12,71**	**1.930.717**	**0**	**193.072**	**192.409**	**182.706**	**38.820**	**1.545.236**	**880.692**	**179.633**

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 36 - Continuation of Figure 35, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

iv. Case 1.3: 100% injection, Low GOR and High CO2
Collect system data – Ten Selected Fields in Santos Basin Pre-salt Cluster
Step 2 – Low case scenario

Figure 37 - Fourth scenario section, Case 1.3, which considers 100% gas injection and low GOR and high CO_2

Case 1.3: 100% injection, Low GOR and High CO2, WAG

Year		Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand	Gas injection	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale
		year	year	year	year	year	day	year	year	year	year	year
		MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMbb	MMscf
2020	1	32	41.610	18.457	23.153	6.091	97	35.519	12.366	23.153	32	0
2020	2	31	40.880	18.133	22.747	5.984	96	34.896	12.149	22.747	31	0
2021	3	69	39.055	17.323	21.732	5.717	91	33.338	11.607	21.732	69	0
2022	4	33	39.420	17.485	21.935	5.770	92	33.650	11.715	21.935	33	0
2023	5	238	311.005	128.575	182.430	42.430	736	268.576	86.145	182.430	238	0
2024	6	439	593.922	227.721	366.202	75.148	1.421	518.775	152.573	366.202	439	0
2025	7	647	882.097	322.672	559.425	106.482	2.125	775.615	216.190	559.425	647	0
2026	8	833	1.148.018	413.652	734.365	136.505	2.771	1.011.512	277.147	734.365	833	0
2027	9	948	1.328.235	471.201	857.034	155.496	3.213	1.172.739	315.705	857.034	948	0
2028	10	1.020	1.449.725	508.071	941.654	167.663	3.512	1.282.062	340.408	941.654	1.020	0
2029	11	1.052	1.552.167	534.513	1.017.654	176.389	3.769	1.375.778	358.124	1.017.654	1.052	0
2030	12	1.066	1.635.510	555.025	1.080.485	183.158	3.979	1.452.352	371.867	1.080.485	1.066	0
2031	13	1.082	1.715.887	575.918	1.139.969	190.053	4.180	1.525.834	385.865	1.139.969	1.082	0
2032	14	1.065	1.700.897	567.860	1.133.037	187.394	4.147	1.513.503	380.466	1.133.037	1.065	0
2033	15	1.039	1.682.862	560.010	1.122.853	184.803	4.104	1.498.059	375.207	1.122.853	1.039	0
2034	16	1.013	1.673.838	555.061	1.118.777	183.170	4.084	1.490.668	371.891	1.118.777	1.013	0
2035	17	988	1.670.457	552.376	1.118.080	182.284	4.077	1.488.173	370.092	1.118.080	988	0
2036	18	952	1.615.641	533.433	1.082.208	176.033	3.944	1.439.608	357.400	1.082.208	952	0
2037	19	893	1.503.235	495.947	1.007.288	163.662	3.670	1.339.572	332.284	1.007.288	893	0
2038	20	824	1.397.284	461.032	936.251	152.141	3.411	1.245.143	308.892	936.251	824	0
2039	21	751	1.283.220	422.895	860.325	139.555	3.133	1.143.665	283.340	860.325	751	0
2040	22	675	1.144.802	377.192	767.610	124.473	2.795	1.020.328	252.719	767.610	675	0
2041	23	596	998.491	329.017	669.475	108.576	2.438	889.916	220.441	669.475	596	0
2042	24	523	862.218	284.530	577.688	93.895	2.105	768.323	190.635	577.688	523	0

Year		Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		USD/bbl	USD/MM	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD
		25,00	2,75	0,079	0	0,1	0	0	0	0	0	10,00%
2020	1	25,50	2,81	746	0	75	135	1.836	0	536	-1.468	-1.335
2020	2	26,66	2,86	771	0	77	110	2.691	0	584	-2.241	-1.852
2021	3	27,72	2,92	1.743	0	174	523	1.109	0	1.046	-226	-170
2022	4	28,24	2,98	864	0	86	286	391	0	492	-17	-12
2023	5	28,61	3,04	6.223	0	622	990	17.278	0	4.610	-13.447	-8.350
2024	6	29,03	3,10	11.676	0	1.168	1.901	25.107	0	8.607	-18.075	-10.203
2025	7	29,46	3,16	17.454	0	1.745	2.809	26.640	0	12.900	-16.016	-8.219
2026	8	29,96	3,22	22.865	0	2.286	3.699	26.365	0	16.879	-12.331	-5.753
2027	9	30,48	3,29	26.500	0	2.650	4.385	20.276	0	19.465	-3.972	-1.684
2028	10	31,07	3,35	29.074	0	2.907	4.945	15.399	0	21.222	2.484	958
2029	11	31,70	3,42	30.607	0	3.061	5.380	11.051	0	22.166	7.678	2.691
2030	12	32,32	3,49	31.642	0	3.164	5.737	8.033	0	22.741	11.024	3.512
2031	13	32,98	3,56	32.770	0	3.277	6.104	7.965	0	23.389	11.504	3.332
2032	14	33,64	3,63	32.921	0	3.292	6.342	3.632	0	23.287	15.663	4.125
2033	15	34,33	3,70	32.761	0	3.276	6.559	2.964	0	22.926	15.987	3.827
2034	16	34,99	3,78	32.570	0	3.257	6.791	3.276	0	22.522	15.140	3.295
2035	17	35,71	3,85	32.419	0	3.242	7.014	2.827	0	22.163	15.093	2.986
2036	18	36,40	3,93	31.827	0	3.183	7.235	2.621	0	21.409	14.508	2.609
2037	19	37,15	4,01	30.470	0	3.047	7.440	1.871	0	19.983	13.982	2.286
2038	20	37,87	4,09	28.662	0	2.866	7.631	818	0	18.165	13.472	2.003
2039	21	38,63	4,17	26.654	0	2.665	7.800	556	103	16.189	11.957	1.616
2040	22	39,42	4,25	24.434	0	2.443	7.937	0	105	14.053	10.815	1.329
2041	23	40,21	4,34	21.994	0	2.199	8.044	0	470	11.751	8.642	965
2042	24	41,00	4,42	19.687	0	1.969	8.073	0	452	9.646	7.113	722

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 38 - Fourth scenario, Case 1.3, which considers 100% gas injection Low GOR and High CO_2.

Case 1.3: 100% injection, Low GOR and High CO2, WAG

Year		Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand	Gas injection	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		year	year	year	year	year	day	year	year	year	year	year	USD/bbl	USD/MM	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD
		MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMbb	MMscf	25,00	2,75	0,079	0	0,1	0	0	0	0	0	10,00%
2036	18	952	1.615.641	533.433	1.082.208	176.033	3.944	1.439.608	357.400	1.082.208	952	0	36,40	3,93	31.827	0	3.183	7.235	2.621	0	21.409	14.508	2.609
2037	19	893	1.503.235	495.947	1.007.288	163.662	3.670	1.339.572	332.284	1.007.288	893	0	37,15	4,01	30.470	0	3.047	7.440	1.871	0	19.983	13.982	2.286
2038	20	824	1.397.284	461.032	936.251	152.141	3.411	1.245.143	308.892	936.251	824	0	37,87	4,09	28.662	0	2.866	7.631	818	0	18.165	13.472	2.003
2039	21	751	1.283.220	422.895	860.325	139.555	3.133	1.143.665	283.340	860.325	751	0	38,63	4,17	26.654	0	2.665	7.800	556	103	16.189	11.957	1.616
2040	22	675	1.144.802	377.192	767.610	124.473	2.795	1.020.328	252.719	767.610	675	0	39,42	4,25	24.434	0	2.443	7.937	0	105	14.053	10.815	1.329
2041	23	596	998.491	329.017	669.475	108.576	2.438	889.916	220.441	669.475	596	0	40,21	4,34	21.994	0	2.199	8.044	0	470	11.751	8.642	965
2042	24	523	862.218	284.530	577.688	93.895	2.105	768.323	190.635	577.688	523	0	41,00	4,42	19.687	0	1.969	8.073	0	452	9.646	7.113	722
2043	25	456	728.527	240.481	488.045	79.359	1.779	649.168	161.123	488.045	456	0	41,82	4,51	17.514	0	1.751	8.080	0	1.031	7.683	5.070	468
2044	26	396	622.259	205.649	416.610	67.864	1.519	554.395	137.785	416.610	396	0	42,64	4,60	15.498	0	1.550	8.014	0	1.619	5.934	3.153	265
2045	27	343	529.210	175.183	354.027	57.810	1.292	471.400	117.373	354.027	343	0	43,50	4,69	13.678	0	1.368	7.870	0	2.113	4.441	1.541	118
2046	28	296	447.717	148.334	299.383	48.950	1.093	398.767	99.384	299.383	296	0	44,39	4,79	12.052	0	1.205	7.618	0	2.606	3.228	136	9
2047	29	253	384.140	126.796	257.344	41.843	938	342.298	84.954	257.344	253	0	45,28	4,88	10.485	0	1.049	6.849	0	2.758	2.588	-388	-24
2048	30	219	360.674	118.669	242.005	39.161	881	321.513	79.508	242.005	219	0	46,16	4,98	9.283	0	928	6.479	0	3.057	1.875	-1.235	-71
2049	31	188	308.335	101.407	206.928	33.464	753	274.871	67.943	206.928	188	0	47,08	5,08	8.110	0	811	5.980	0	3.490	1.320	-2.170	-113
2050	32	164	269.532	88.430	181.102	29.182	658	240.350	59.248	181.102	164	0	48,04	5,18	7.195	0	719	5.476	0	3.561	999	-2.562	-121
2051	33	142	235.327	77.242	158.085	25.490	575	209.837	51.752	158.085	142	0	48,99	5,29	6.385	0	638	5.026	0	3.761	721	-3.040	-131
2052	34	126	206.526	67.641	138.885	22.322	505	184.205	45.320	138.885	126	0	49,98	5,39	5.743	0	574	4.406	0	3.971	763	-3.208	-126
2053	35	90	150.314	48.238	102.075	15.919	368	134.395	32.320	102.075	90	0	50,97	5,50	4.210	0	421	3.116	0	3.235	673	-2.562	-91
2054	36	58	96.132	30.031	66.101	9.910	236	86.222	20.121	66.101	58	0	51,99	5,61	2.765	0	277	2.218	0	2.333	271	-2.067	-67
2055	37	35	58.995	18.961	40.034	6.257	144	52.738	12.704	40.034	35	0	53,04	5,72	1.713	0	171	1.503	0	1.540	39	-1.502	-44
2056	38	17	32.155	10.192	21.963	3.363	79	28.791	6.829	21.963	17	0	54,09	5,84	837	0	84	956	0	1.142	-202	-1.344	-36
2057	39	10	16.694	5.215	11.479	1.721	41	14.973	3.494	11.479	10	0	55,18	5,95	483	0	48	623	0	875	-188	-1.063	-26
2058	40	5	11.053	3.686	7.367	1.217	27	9.837	2.470	7.367	5	0	56,26	6,07	285	0	28	325	0	597	-69	-930	-21
Total		19.607	30.768.066	10.414.256	20.353.809	3.436.705	74.880	27.331.361	6.977.552	20.353.809	19.607	0	32,82	4,24	643.572	0	64.357	192.409	182.706	38.820	386.806	95.098	-1.332

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 39 - Continuation of Figure 38, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

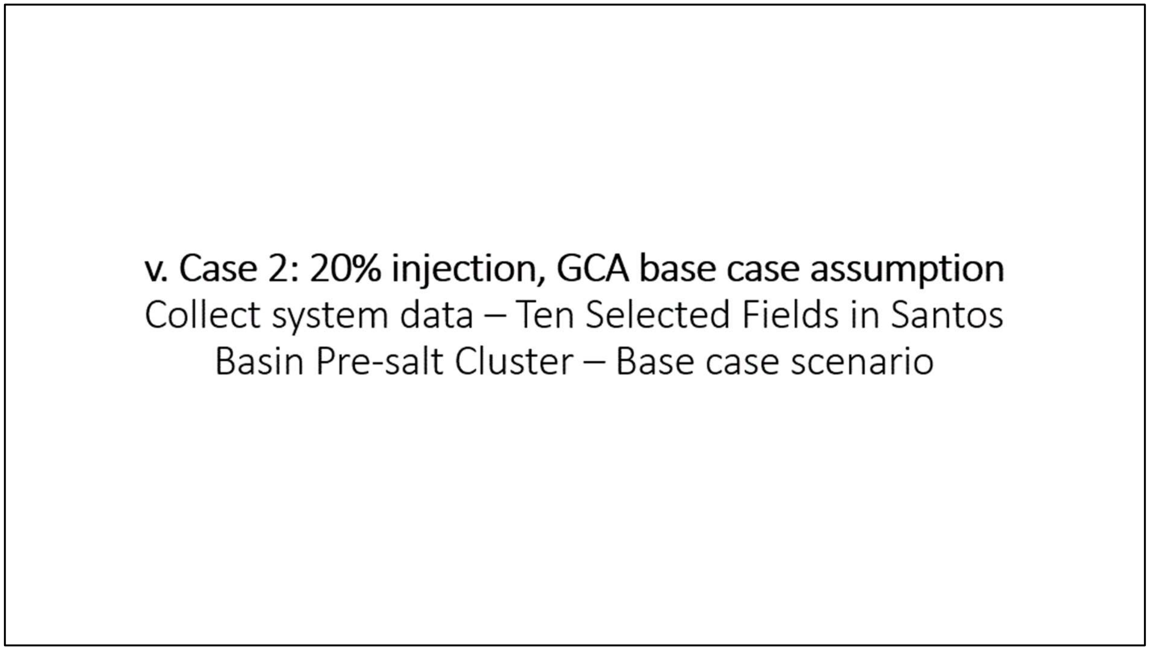


Figure 40 - Fifth scenario section, Case 2, which considers 100% gas injection and base case assumptions

2 Case 2: 20% injection and sale of NG at whellhead

Year		Oil production	Gas production	Natural Gas production	CO2 production	Gas injection	NG injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Natural Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	Net income before tax	NIAT	NET CASH FLOW	Discounted Cash Flow
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMbbl	year MMscf	USD/bb 75,98	USD/MMBT 4,00	MM USD 7,90%	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD 10,00%
2019	1	32	41.610	22.315	19.295	23.758	4.463	19.295	32	9.964	77,50	4,08	2.267	39	231	140	1.910	0	1.894	1.250	-620	-563
2020	2	31	40.880	21.924	18.956	23.341	4.385	18.956	31	9.789	81,04	4,16	2.343	39	238	115	2.789	0	1.839	1.214	-1.385	-1.145
2021	3	69	39.055	20.945	18.110	22.299	4.189	18.110	69	9.352	84,24	4,24	5.299	38	534	540	1.150	0	3.534	2.332	1.912	1.436
2022	4	33	39.420	21.141	18.279	22.507	4.228	18.279	33	9.439	85,84	4,33	2.626	39	267	296	408	0	1.957	1.290	1.028	702
2023	5	238	274.845	133.153	141.692	168.323	26.631	141.692	238	59.453	86,94	4,42	18.913	253	1.917	1.023	17.831	0	13.852	9.142	-6.315	-3.921
2024	6	439	509.175	240.355	268.820	316.891	48.071	268.820	439	107.318	88,24	4,50	35.487	466	3.595	1.964	25.965	0	26.362	17.399	-4.535	-2.560
2025	7	647	746.425	347.990	398.435	468.033	69.598	398.435	647	155.378	89,54	4,59	53.050	688	5.374	2.904	27.566	0	39.140	25.832	4.588	2.354
2026	8	833	958.125	444.643	513.482	602.411	88.929	513.482	833	198.533	91,04	4,69	69.494	897	7.039	3.828	27.354	0	50.714	33.471	14.927	6.964
2027	9	948	1.087.335	503.003	584.332	684.932	100.601	584.332	948	224.591	92,64	4,78	80.544	1.035	8.158	4.543	21.123	0	58.006	38.284	28.033	11.889
2028	10	1.020	1.170.190	537.406	632.784	740.266	107.481	632.784	1.020	239.952	94,44	4,88	88.367	1.128	8.950	5.130	16.133	0	62.967	41.558	37.874	14.602
2029	11	1.052	1.207.055	549.754	657.301	767.252	109.951	657.301	1.052	245.465	96,34	4,97	93.025	1.177	9.420	5.585	11.578	0	65.571	43.277	45.325	15.886
2030	12	1.066	1.211.800	548.028	663.772	773.378	109.606	663.772	1.066	244.695	98,24	5,07	96.173	1.197	9.737	5.958	8.400	0	67.494	44.546	50.328	16.036
2031	13	1.082	1.219.465	548.433	671.032	780.719	109.687	671.032	1.082	244.875	100,24	5,17	99.601	1.222	10.082	6.341	8.333	0	69.268	45.717	52.515	15.212
2032	14	1.065	1.171.285	525.028	646.257	751.263	105.006	646.257	1.065	234.425	102,24	5,28	100.061	1.193	10.125	6.589	3.811	0	68.776	45.392	57.345	15.101
2033	15	1.039	1.134.785	507.592	627.193	728.711	101.518	627.193	1.039	226.640	104,34	5,38	99.573	1.177	10.075	6.816	3.123	0	68.367	45.122	57.491	13.763
2034	16	1.013	1.106.680	493.761	612.919	711.671	98.752	612.919	1.013	220.464	106,34	5,49	98.992	1.167	10.016	7.059	3.455	0	69.144	45.635	56.120	12.213

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 41 - Fifth scenario, Case 2, which considers 20% gas injection, natural gas selling at well head and base case assumptions.

Case 2: 20% injection and sale of NG at whellhead

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas production year MMscf	CO2 production year MMscf	Gas injection year MMscf	NG injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bb 75,98	Natural Gas Price USD/MMBT 4,00	Oil revenue MM USD 7,90%	Natural Gas revenue MM USD	Royalties MM USD	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	Net income before tax MM USD	NIAT MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2042	24	523	512.825	227.226	285.599	331.044	45.445	285.599	523	101.456	124,60	6,43	59.838	629	6.047	8.396	0	462	40.979	27.046	31.629	3.211
2043	25	456	438.000	194.058	243.942	282.753	38.812	243.942	456	86.647	127,10	6,56	53.231	548	5.378	8.404	0	1.057	35.376	23.347	26.912	2.484
2044	26	396	374.855	166.186	208.669	241.906	33.237	208.669	396	74.202	129,60	6,69	47.105	479	4.758	8.337	0	1.665	30.199	19.930	22.554	1.892
2045	27	343	321.565	142.633	178.932	207.459	28.527	178.932	343	63.685	132,20	6,83	41.574	419	4.199	8.188	0	2.181	25.690	16.954	18.689	1.426
2046	28	296	277.765	123.372	154.393	179.068	24.674	154.393	296	55.086	134,90	6,96	36.629	370	3.700	7.927	0	2.697	21.622	14.269	15.322	1.062
2047	29	253	242.360	107.688	134.672	156.210	21.538	134.672	253	48.083	137,60	7,10	31.869	329	3.220	7.135	0	2.861	18.220	12.025	12.787	806
2048	30	219	226.665	100.531	126.134	146.240	20.106	126.134	219	44.887	140,30	7,25	28.214	314	2.853	6.751	0	3.176	15.294	10.094	10.548	604
2049	31	188	194.910	86.255	108.655	125.906	17.251	108.655	188	38.513	143,10	7,39	24.649	274	2.492	6.230	0	3.632	12.424	8.200	8.346	435
2050	32	164	171.550	75.871	95.679	110.854	15.174	95.679	164	33.876	146,00	7,54	21.868	246	2.211	5.707	0	3.706	10.469	6.909	6.931	328
2051	33	142	149.650	66.025	83.625	96.830	13.205	83.625	142	29.480	148,90	7,69	19.406	219	1.962	5.237	0	3.912	8.854	5.844	5.503	237
2052	34	126	132.130	58.234	73.896	85.543	11.647	73.896	126	26.002	151,90	7,84	17.456	197	1.765	4.591	0	4.131	7.289	4.811	4.687	183
2053	35	90	91.980	40.082	51.898	59.915	8.016	51.898	90	17.897	154,90	8,00	12.797	138	1.293	3.253	0	3.382	5.288	3.490	3.209	114
2054	36	58	59.860	25.502	34.358	39.458	5.100	34.358	58	11.387	158,00	8,16	8.405	90	849	2.319	0	2.447	3.303	2.180	1.756	57
2055	37	35	35.770	15.748	20.022	23.172	3.150	20.022	35	7.031	161,20	8,32	5.205	56	526	1.577	0	1.621	1.729	1.141	950	28
2056	38	17	18.615	8.087	10.528	12.145	1.617	10.528	17	3.611	164,40	8,49	2.545	30	257	1.006	0	1.204	309	204	2	0
2057	39	10	9.855	4.254	5.601	6.452	851	5.601	10	1.900	167,70	8,66	1.468	16	148	654	0	922	11	3	-248	-6
2058	40	5	5.540	2.393	3.147	3.626	479	3.147	5	1.068	171,00	8,83	865	9	87	340	0	628	781	582	-380	-8
Total		19.607	21.224.085	9.575.222	11.648.863	13.563.907	1.915.044	11.648.863	19.607	4.275.337	119,48	6,16	1.956.056	22.898	197.895	200.097	190.066	40.385	1.338.647	883.561	895.423	182.308

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 42 - Continuation of Figure 41, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

vi. Case 2.1: 20% injection, Expected GOR and CO_2
Collect system data – Ten Selected Fields in Santos Basin Pre-salt Cluster
Step 2 – Expected scenario

Figure 43 - Sixth scenario section, Case 2.1, with 20% gas injection, natural gas selling at well head and base case assumptions

Case 2.1: 20% injection, sale of NG at whellhead, Expected GOR and CO2, WAG

Year		Oil production year MMbbl	Gas Production year MMscf	Natural Gas production year MMscf	CO2 production day MMscf	CO2 production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 50,00	Natural Gas price USD/M 5,50	Oil revenue MM USD 7,90%	Natural Gas Revenue MM USD 0,00%	Royalties MM USD	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	Net income before tax MM USD	NET CASH FLOW MM USD
2020	1	32	0	0	0	0	0	0	0	0	32	0	51,00	5,61	1.492	0	149	140	1.910	0	1.162	-1.103
2020	2	31	0	0	0	0	0	0	0	0	31	0	53,33	5,72	1.542	0	154	115	2.789	0	1.082	-1.884
2021	3	69	73.492	38.233	97	35.258	12.617	42.905	7.647	35.258	69	17.071	55,44	5,84	3.487	96	358	540	1.150	0	1.955	870
2022	4	33	48.589	26.058	62	22.531	8.599	27.742	5.212	22.531	33	11.635	56,49	5,95	1.728	67	179	296	408	0	1.174	511
2023	5	238	346.097	156.125	520	189.972	51.521	221.197	31.225	189.972	238	69.710	57,21	6,07	12.445	408	1.285	1.023	17.831	0	8.171	-10.064
2024	6	439	584.137	277.530	840	306.607	91.585	362.113	55.506	306.607	439	123.917	58,07	6,19	23.352	740	2.409	1.964	25.965	0	15.687	-11.580
2025	7	647	1.041.186	478.476	1.542	562.711	157.897	658.406	95.695	562.711	647	213.639	58,92	6,32	34.909	1.302	3.621	2.904	27.566	0	23.364	-5.824
2026	8	833	1.464.870	672.387	2.171	792.483	221.888	926.960	134.477	792.483	833	300.221	59,91	6,44	45.729	1.866	4.760	3.828	27.354	0	30.197	1.386
2027	9	948	1.822.696	835.995	2.703	986.700	275.878	1.153.900	167.199	986.700	948	373.272	60,96	6,57	53.000	2.366	5.537	4.543	21.123	0	34.414	12.463
2028	10	1.020	2.072.456	946.025	3.086	1.126.431	312.188	1.315.636	189.205	1.126.431	1.020	422.400	62,15	6,70	58.148	2.731	6.088	5.130	16.133	0	37.212	20.876
2029	11	1.052	2.279.610	1.032.307	3.417	1.247.303	340.661	1.453.764	206.461	1.247.303	1.052	460.925	63,40	6,84	61.213	3.040	6.425	5.585	11.578	0	38.617	27.535
2030	12	1.066	2.524.644	1.134.353	3.809	1.390.290	374.337	1.617.161	226.871	1.390.290	1.066	506.489	64,65	6,98	63.285	3.407	6.669	5.958	8.400	0	39.883	32.105
2031	13	1.082	2.798.635	1.248.193	4.248	1.550.442	411.904	1.800.080	249.639	1.550.442	1.082	557.318	65,96	7,11	65.540	3.824	6.936	6.341	8.333	0	40.955	33.829
2032	14	1.065	2.921.296	1.298.414	4.446	1.622.881	428.477	1.882.564	259.683	1.622.881	1.065	579.742	67,28	7,26	65.843	4.057	6.990	6.589	3.811	0	40.557	38.719
2033	15	1.039	3.082.070	1.365.508	4.703	1.716.562	450.618	1.989.664	273.102	1.716.562	1.039	609.699	68,66	7,40	65.522	4.352	6.987	6.816	3.123	0	40.579	39.151
2034	16	1.013	3.269.380	1.443.958	5.001	1.825.422	476.506	2.114.214	288.792	1.825.422	1.013	644.727	69,98	7,55	65.139	4.694	6.983	7.059	3.455	0	41.851	38.107
2035	17	988	3.494.677	1.539.320	5.357	1.955.357	507.976	2.263.221	307.864	1.955.357	988	687.307	71,43	7,70	64.839	5.104	6.994	7.292	2.975	0	43.483	37.898
2036	18	952	3.738.718	1.642.060	5.744	2.096.659	541.880	2.425.071	328.412	2.096.659	952	733.180	72,81	7,86	63.654	5.554	6.921	7.522	2.754	0	44.580	36.854

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 44 - Sixth scenario section, Case 2, which considers 20% gas injection and base case assumptions

Case 2.1: 20% injection, sale of NG at whellhead, Expected GOR and CO2, WAG

Year	Oil production	Gas Production	Natural Gas production	CO2 production	CO2 production	Natural Gas Demand (fuel)	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas price	Oil revenue	Natural Gas Revenue	Royalties	OPEX	CAPEX	Aband. costs	Net income before tax	NET CASH FLOW
	year MMbbl	year MMscf	year MMscf	day MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMbbl	year MMscf	USD/bbl 50,00	USD/M 5,50	MM USD 7,90%	MM USD 0,00%	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD
2042 24	523	2.777.082	1.197.166	4.329	1.579.917	395.065	1.819.350	239.433	1.579.917	523	534.535	82,00	8,85	39.375	4.560	4.393	8.396	0	462	26.100	21.736
2043 25	456	2.463.943	1.061.694	3.842	1.402.248	350.359	1.614.587	212.339	1.402.248	456	474.047	83,64	9,02	35.028	4.125	3.915	8.404	0	1.057	22.212	18.158
2044 26	396	2.163.312	932.213	3.373	1.231.099	307.630	1.417.542	186.443	1.231.099	396	416.233	85,29	9,20	30.996	3.694	3.469	8.337	0	1.665	18.595	14.833
2045 27	343	2.214.076	952.687	3.456	1.261.390	314.387	1.451.927	190.537	1.261.390	343	425.375	87,00	9,39	27.357	3.851	3.121	8.188	0	2.181	15.983	12.223
2046 28	296	1.303.432	562.760	2.029	740.672	185.711	853.224	112.552	740.672	296	251.272	88,77	9,58	24.103	2.320	2.642	7.927	0	2.697	12.104	8.943
2047 29	253	253.826	113.707	384	140.119	37.523	162.861	22.741	140.119	253	50.770	90,55	9,77	20.971	478	2.145	7.135	0	2.861	8.545	6.358
2048 30	219	231.188	103.674	349	127.514	34.212	148.249	20.735	127.514	219	46.290	92,33	9,96	18.566	445	1.901	6.751	0	3.176	6.729	4.848
2049 31	188	206.161	92.438	312	113.722	30.505	132.210	18.488	113.722	188	41.274	94,17	10,16	16.220	404	1.662	6.230	0	3.632	4.955	3.365
2050 32	164	185.120	82.852	280	102.268	27.341	118.838	16.570	102.268	164	36.994	96,08	10,36	14.390	370	1.476	5.707	0	3.706	3.849	2.521
2051 33	142	162.890	72.600	247	90.291	23.958	104.811	14.520	90.291	142	32.416	97,99	10,57	12.770	330	1.310	5.237	0	3.912	2.982	1.579
2052 34	126	134.106	62.293	197	71.814	20.557	84.272	12.459	71.814	126	27.814	99,96	10,78	11.486	289	1.178	4.591	0	4.131	2.000	1.161
2053 35	90	93.549	43.330	138	50.219	14.299	58.885	8.666	50.219	90	19.347	101,93	11,00	8.421	205	863	3.253	0	3.382	1.410	649
2054 36	58	48.761	22.685	71	26.076	7.486	30.613	4.537	26.076	58	10.129	103,97	11,22	5.531	110	564	2.319	0	2.447	735	61
2055 37	35	21.877	10.154	32	11.723	3.351	13.754	2.031	11.723	35	4.534	106,08	11,44	3.425	50	348	1.577	0	1.621	121	-130
2056 38	17	8.816	3.988	13	4.828	1.316	5.626	798	4.828	17	1.781	108,19	11,67	1.674	20	169	1.006	0	1.204	-483	-685
2057 39	10	0	0	0	0	0	0	0	0	10	0	110,36	11,91	966	0	97	654	0	922	-455	-707
2058 40	5	0	0	0	0	0	0	0	0	5	0	112,53	12,14	569	0	57	340	0	628	507	-724
Total	19.607	62.018.430	27.387.542	94.879	34.630.888	9.037.889	40.108.397	5.477.508	34.630.888	19.607	12.228.538	65,65	7,63	1.287.144	93.304	138.045	200.097	190.066	40.385	799.993	538.696

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 45 - Continuation of Figure 44, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

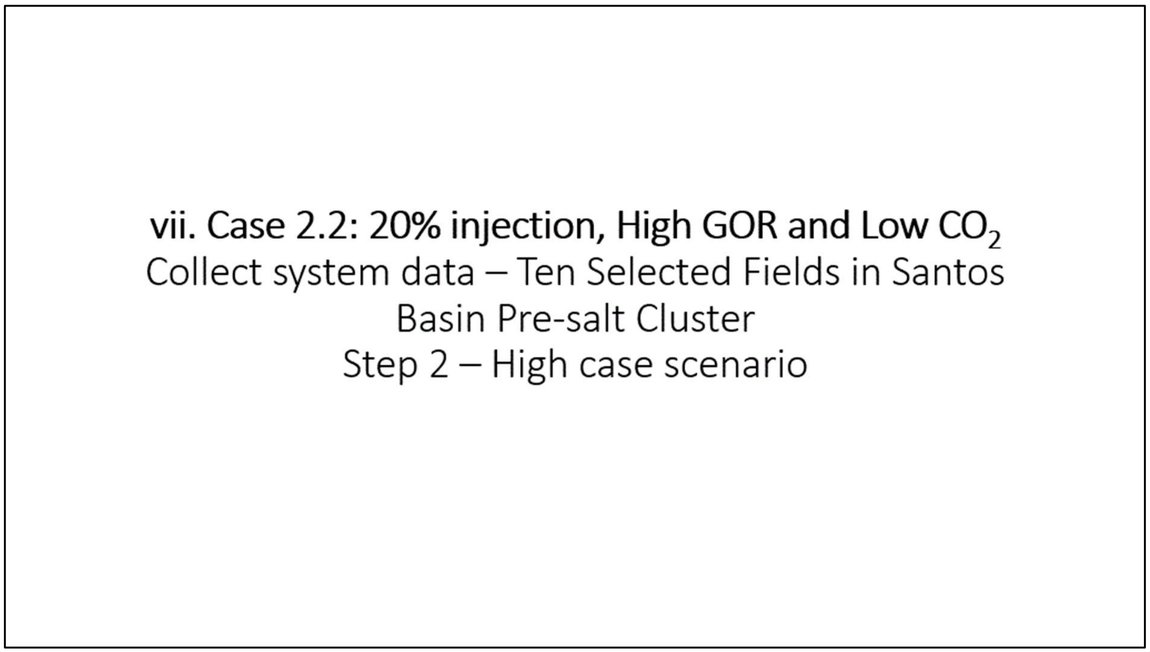


Figure 46 - Seventh scenario section, Case 2, with 20% gas injection, natural gas selling at well head and base case assumptions.

Case 2.2: 20% injection, sale of NG at whellhead, High GOR and Low CO2, WAG

Year		Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMbbl	year MMscf	USD/bbl 75,00	USD/MM 8,25	MM USD 7,90%	MM USD	MM USD 10%	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD 10,00%
2020	1	32	41.610	26.174	15.436	1.536	20.671	5.235	15.436	32	11.687	76,50	8,42	2.237	95	233	140	1.910	0	1.959	-604	-549
2020	2	31	40.880	25.715	15.165	2.380	20.308	5.143	15.165	31	11.482	79,99	8,58	2.313	95	241	115	2.789	0	2.052	-1.370	-1.132
2021	3	69	39.055	24.567	14.488	5.173	19.401	4.913	14.488	69	10.969	83,15	8,75	5.230	93	532	540	1.150	0	4.250	1.903	1.430
2022	4	33	39.420	24.797	14.623	7.003	19.583	4.959	14.623	33	11.072	84,73	8,93	2.592	95	269	296	408	0	2.122	1.041	711
2023	5	238	732.042	412.300	319.742	14.833	402.202	82.460	319.742	238	184.092	85,82	9,11	18.668	1.617	2.028	1.023	17.831	0	17.233	-5.650	-3.508
2024	6	439	1.490.876	833.409	657.467	9.973	824.149	166.682	657.467	439	372.117	87,10	9,29	35.027	3.334	3.836	1.964	25.965	0	32.561	-3.104	-1.752
2025	7	647	2.268.164	1.267.118	1.001.046	14.155	1.254.469	253.424	1.001.046	647	565.768	88,39	9,48	52.363	5.170	5.753	2.904	27.566	0	48.876	6.842	3.511
2026	8	833	2.999.666	1.673.424	1.326.242	14.511	1.660.927	334.685	1.326.242	833	747.184	89,87	9,67	68.594	6.965	7.556	3.828	27.354	0	64.175	17.997	8.396
2027	9	948	3.573.221	1.989.220	1.584.001	15.174	1.981.845	397.844	1.584.001	948	888.187	91,45	9,86	79.500	8.445	8.795	4.543	21.123	0	74.607	31.815	13.492
2028	10	1.020	4.031.008	2.233.278	1.797.730	15.562	2.244.385	446.656	1.797.730	1.020	997.159	93,22	10,06	87.222	9.670	9.689	5.130	16.133	0	82.074	42.268	16.296
2029	11	1.052	4.449.908	2.455.259	1.994.649	15.943	2.485.701	491.052	1.994.649	1.052	1.096.273	95,10	10,26	91.820	10.844	10.266	5.585	11.578	0	86.813	50.351	17.648
2030	12	1.066	4.797.250	2.639.325	2.157.925	16.681	2.685.790	527.865	2.157.925	1.066	1.178.458	96,97	10,46	94.927	11.890	10.682	5.958	8.400	0	90.178	55.940	17.824
2031	13	1.082	5.133.702	2.818.467	2.315.235	17.088	2.878.928	563.693	2.315.235	1.082	1.258.446	98,95	10,67	98.311	12.951	11.126	6.341	8.333	0	93.795	58.716	17.008
2032	14	1.065	5.118.320	2.807.595	2.310.725	17.588	2.872.244	561.519	2.310.725	1.065	1.253.591	100,92	10,89	98.764	13.159	11.192	6.589	3.811	0	94.142	63.683	16.770
2033	15	1.039	5.072.035	2.781.094	2.290.941	18.185	2.847.160	556.219	2.290.941	1.039	1.241.758	102,99	11,10	98.283	13.296	11.158	6.816	3.123	0	93.605	63.923	15.303
2034	16	1.013	5.055.925	2.770.778	2.285.147	19.210	2.839.303	554.156	2.285.147	1.013	1.237.152	104,97	11,33	97.709	13.511	11.122	7.059	3.455	0	93.040	62.691	13.643
2035	17	988	5.051.337	2.767.276	2.284.062	20.289	2.837.517	553.455	2.284.062	988	1.235.589	107,14	11,55	97.258	13.764	11.102	7.292	2.975	0	92.628	62.299	12.326
2036	18	952	4.875.103	2.670.522	2.204.581	20.942	2.738.686	534.104	2.204.581	952	1.192.388	109,21	11,78	95.482	13.549	10.903	7.522	2.754	0	90.605	60.508	10.883

Figure 47 - Seventh scenario, Case 2.2, which considers 20% gas injection and high case assumptions.

Case 2.2: 20% injection, sale of NG at whellhead, High GOR and Low CO2, WAG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 75,00	Natural Gas Price USD/MM 8,25	Oil revenue MM USD 7,90%	Nautral Gas revenue MM USD	Royalties MM USD 10%	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	EBITDA MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2042	24	523	2.552.257	1.398.401	1.153.856	19.359	1.433.536	279.680	1.153.856	523	624.386	122,99	13,27	59.062	7.990	6.705	8.396	0	462	51.951	35.541	3.608
2043	25	456	2.148.121	1.177.022	971.099	20.069	1.206.503	235.404	971.099	456	525.540	125,46	13,53	52.542	6.859	5.940	8.404	0	1.057	45.057	30.252	2.792
2044	26	396	1.820.874	998.148	822.726	20.402	1.022.356	199.630	822.726	396	445.673	127,93	13,81	46.494	5.933	5.243	8.337	0	1.665	38.848	25.433	2.134
2045	27	343	1.536.999	842.773	694.225	22.295	862.780	168.555	694.225	343	376.298	130,49	14,08	41.035	5.110	4.615	8.188	0	2.181	33.343	21.157	1.614
2046	28	296	1.293.832	709.738	584.094	18.008	726.042	141.948	584.094	296	316.898	133,16	14,36	36.155	4.389	4.054	7.927	0	2.697	28.563	17.429	1.209
2047	29	253	1.109.321	607.991	501.329	10.120	622.928	121.598	501.329	253	271.468	135,83	14,65	31.456	3.835	3.529	7.135	0	2.861	24.627	14.625	922
2048	30	219	1.051.901	576.094	475.808	10.342	591.026	115.219	475.808	219	257.226	138,49	14,94	27.849	3.707	3.156	6.751	0	3.176	21.649	12.346	708
2049	31	188	893.105	488.816	404.289	9.753	502.053	97.763	404.289	188	218.256	141,25	15,24	24.330	3.208	2.754	6.230	0	3.632	18.555	9.899	516
2050	32	164	775.159	424.152	351.007	9.843	435.837	84.830	351.007	164	189.384	144,12	15,55	21.584	2.839	2.442	5.707	0	3.706	16.275	8.303	393
2051	33	142	672.262	367.719	304.543	9.856	378.087	73.544	304.543	142	164.187	146,98	15,86	19.155	2.511	2.167	5.237	0	3.912	14.262	6.715	289
2052	34	126	585.981	320.492	265.490	7.008	329.588	64.098	265.490	126	143.100	149,94	16,18	17.230	2.232	1.946	4.591	0	4.131	12.925	5.762	226
2053	35	90	436.011	238.343	197.668	5.176	245.336	47.669	197.668	90	106.420	152,90	16,50	12.631	1.693	1.432	3.253	0	3.382	9.639	4.034	144
2054	36	58	293.600	159.350	134.250	4.367	166.120	31.870	134.250	58	71.150	155,96	16,83	8.296	1.155	945	2.319	0	2.447	6.187	2.324	75
2055	37	35	192.413	104.900	87.513	3.698	108.493	20.980	87.513	35	46.838	159,12	17,17	5.138	775	591	1.577	0	1.621	3.745	1.337	39
2056	38	17	108.040	58.726	49.313	2.874	61.059	11.745	49.313	17	26.221	162,28	17,51	2.512	443	295	1.006	0	1.204	1.653	228	6
2057	39	10	59.636	32.299	27.337	1.163	33.797	6.460	27.337	10	14.421	165,54	17,86	1.449	248	170	654	0	922	873	-117	-3
2058	40	5	38.493	20.764	17.728	0	21.881	4.153	17.728	5	9.271	168,79	18,22	854	163	102	340	0	628	575	-366	-8
Total		**19.607**	**89.377.312**	**49.152.553**	**40.224.759**	**533.798**	**50.055.270**	**9.830.511**	**40.224.759**	**19.607**	**21.946.615**	**98,47**	**11,28**	**1.930.717**	**247.459**	**217.818**	**200.097**	**190.066**	**40.385**	**1.760.261**	**1.013.702**	**207.556**

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 48 - Continuation of Figure 47, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

viii. Case 2.3: 20% injection, Low GOR and High CO_2
Collect system data – Ten Selected Fields in Santos Basin Pre-salt Cluster
Step 2 – Low case scenario

Figure 49 - Eighth scenario section, Case 2, with 20% gas injection, natural selling at well head and base case assumptions.

Case 2.3: 20% injection, sale of NG at whellhead, Low GOR and High CO2, WAG

Year		Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand	Gas injection	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	day MMscf	year MMscf	year MMscf	year MMscf	year MMbb	year MMscf	USD/bbl 25,00	USD/MM 2,75	MM USD 0,079	MM USD 0	MM USD 0,1	MM USD 0	MM USD 0	MM USD 0	MM USD 0	MM USD 0	MM USD 10,00%
2020	1	32	41.610	18.457	23.153	6.091	74	26.845	3.691	23.153	32	8.241	25,50	2,81	746	22	77	140	1.910	0	551	-1.533	-1.394
2020	2	31	40.880	18.133	22.747	5.984	72	26.374	3.627	22.747	31	8.096	26,66	2,86	771	22	79	115	2.789	0	599	-2.329	-1.925
2021	3	69	39.055	17.323	21.732	5.717	69	25.196	3.465	21.732	69	7.735	27,72	2,92	1.743	22	177	540	1.150	0	1.048	-267	-201
2022	4	33	39.420	17.485	21.935	5.770	70	25.432	3.497	21.935	33	7.807	28,24	2,98	864	22	89	296	408	0	501	-29	-20
2023	5	238	311.005	128.575	182.430	42.430	570	208.145	25.715	182.430	238	57.409	28,61	3,04	6.223	168	639	1.023	17.831	0	4.729	-13.920	-8.643
2024	6	439	593.922	227.721	366.202	75.148	1.128	411.746	45.544	366.202	439	101.677	29,03	3,10	11.676	304	1.198	1.964	25.965	0	8.817	-18.791	-10.607
2025	7	647	882.097	322.672	559.425	106.482	1.709	623.959	64.534	559.425	647	144.073	29,46	3,16	17.454	439	1.789	2.904	27.566	0	13.200	-16.741	-8.591
2026	8	833	1.148.018	413.652	734.365	136.505	2.239	817.096	82.730	734.365	833	184.696	29,96	3,22	22.865	574	2.344	3.828	27.354	0	17.267	-13.062	-6.094
2027	9	948	1.328.235	471.201	857.034	155.496	2.606	951.274	94.240	857.034	948	210.391	30,48	3,29	26.500	667	2.717	4.543	21.123	0	19.907	-4.526	-1.919
2028	10	1.020	1.449.725	508.071	941.654	167.663	2.858	1.043.268	101.614	941.654	1.020	226.854	31,07	3,35	29.074	733	2.981	5.130	16.133	0	21.697	2.069	798
2029	11	1.052	1.552.167	534.513	1.017.654	176.389	3.081	1.124.557	106.903	1.017.654	1.052	238.660	31,70	3,42	30.607	787	3.139	5.585	11.578	0	22.669	7.512	2.633
2030	12	1.066	1.635.510	555.025	1.080.485	183.158	3.264	1.191.490	111.005	1.080.485	1.066	247.819	32,32	3,49	31.642	833	3.248	5.958	8.400	0	23.271	11.046	3.520
2031	13	1.082	1.715.887	575.918	1.139.969	190.053	3.439	1.255.152	115.184	1.139.969	1.082	257.147	32,98	3,56	32.770	882	3.365	6.341	8.333	0	23.946	11.536	3.342
2032	14	1.065	1.700.897	567.860	1.133.037	187.394	3.415	1.246.609	113.572	1.133.037	1.065	253.549	33,64	3,63	32.921	887	3.381	6.589	3.811	0	23.838	15.876	4.181
2033	15	1.039	1.682.862	560.010	1.122.853	184.803	3.383	1.234.855	112.002	1.122.853	1.039	250.044	34,33	3,70	32.761	892	3.365	6.816	3.123	0	23.472	16.211	3.881
2034	16	1.013	1.673.838	555.061	1.118.777	183.170	3.369	1.229.789	111.012	1.118.777	1.013	247.835	34,99	3,78	32.570	902	3.347	7.059	3.455	0	23.066	15.337	3.338
2035	17	988	1.670.457	552.376	1.118.080	182.284	3.366	1.228.556	110.475	1.118.080	988	246.636	35,71	3,85	32.419	916	3.334	7.292	2.975	0	22.710	15.320	3.031
2036	18	952	1.615.641	533.433	1.082.208	176.033	3.257	1.188.894	106.687	1.082.208	952	238.178	36,40	3,93	31.827	902	3.273	7.522	2.754	0	21.934	14.733	2.650

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 50 - Eight scenario section, Case 2.3, which considers 20% gas injection and high case assumptions.

Case 2.3: 20% injection, sale of NG at whellhead, Low GOR and High CO2, WAG																							
Year		Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand	Gas injection	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	day MMscf	year MMscf	year MMscf	year MMscf	year MMbb	year MMscf	USD/bbl 25,00	USD/MM 2,75	MM USD 0,079	MM USD 0	MM USD 0,1	MM USD 0	MM USD 0	MM USD 0	MM USD 0	MM USD 0	MM USD 10,00%
2042	24	523	862.218	284.530	577.688	93.895	1.739	634.594	56.906	577.688	523	127.042	41,00	4,42	19.687	542	2.023	8.396	0	462	9.811	7.207	732
2043	25	456	728.527	240.481	488.045	79.359	1.469	536.142	48.096	488.045	456	107.375	41,82	4,51	17.514	467	1.798	8.404	0	1.057	7.779	5.102	471
2044	26	396	622.259	205.649	416.610	67.864	1.254	457.740	41.130	416.610	396	91.822	42,64	4,60	15.498	407	1.591	8.337	0	1.665	5.978	3.128	262
2045	27	343	529.210	175.183	354.027	57.810	1.066	389.064	35.037	354.027	343	78.219	43,50	4,69	13.678	354	1.403	8.188	0	2.181	4.441	1.465	112
2046	28	296	447.717	148.334	299.383	48.950	902	329.050	29.667	299.383	296	66.231	44,39	4,79	12.052	306	1.236	7.927	0	2.697	3.195	14	1
2047	29	253	384.140	126.796	257.344	41.843	775	282.703	25.359	257.344	253	56.615	45,28	4,88	10.485	267	1.075	7.135	0	2.861	2.541	-544	-34
2048	30	219	360.674	118.669	242.005	39.161	728	265.738	23.734	242.005	219	52.986	46,16	4,98	9.283	255	954	6.751	0	3.176	1.833	-1.403	-80
2049	31	188	308.335	101.407	206.928	33.464	622	227.210	20.281	206.928	188	45.278	47,08	5,08	8.110	222	833	6.230	0	3.632	1.269	-2.363	-123
2050	32	164	269.532	88.430	181.102	29.182	545	198.788	17.686	181.102	164	39.484	48,04	5,18	7.195	197	739	5.707	0	3.706	946	-2.759	-131
2051	33	142	235.327	77.242	158.085	25.490	475	173.533	15.448	158.085	142	34.489	48,99	5,29	6.385	176	656	5.237	0	3.912	668	-3.245	-140
2052	34	126	206.526	67.641	138.885	22.322	418	152.413	13.528	138.885	126	30.202	49,98	5,39	5.743	157	590	4.591	0	4.131	720	-3.412	-134
2053	35	90	150.314	48.238	102.075	15.919	306	111.723	9.648	102.075	90	21.538	50,97	5,50	4.210	114	432	3.253	0	3.382	639	-2.742	-98
2054	36	58	96.132	30.031	66.101	9.910	198	72.107	6.006	66.101	58	13.409	51,99	5,61	2.765	73	284	2.319	0	2.447	235	-2.216	-72
2055	37	35	58.995	18.961	40.034	6.257	120	43.826	3.792	40.034	35	8.466	53,04	5,72	1.713	47	176	1.577	0	1.621	6	-1.614	-47
2056	38	17	32.155	10.192	21.963	3.363	66	24.001	2.038	21.963	17	4.551	54,09	5,84	837	26	86	1.006	0	1.204	-229	-1.433	-38
2057	39	10	16.694	5.215	11.479	1.721	34	12.522	1.043	11.479	10	2.329	55,18	5,95	483	13	50	654	0	922	-208	-1.129	-27
2058	40	5	11.053	3.686	7.367	1.217	22	8.104	737	7.367	5	1.646	56,26	6,07	285	10	29	340	0	628	-75	-968	-21
Total		19.607	30.768.066	10.414.256	20.353.809	3.436.705	61.470	22.436.660	2.082.851	20.353.809	19.607	4.649.966	32,82	3,73	643.572	17.338	66.091	200.097	190.066	40.385	394.722	91.408	-3.050

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 51 - Continuation of Figure 50, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

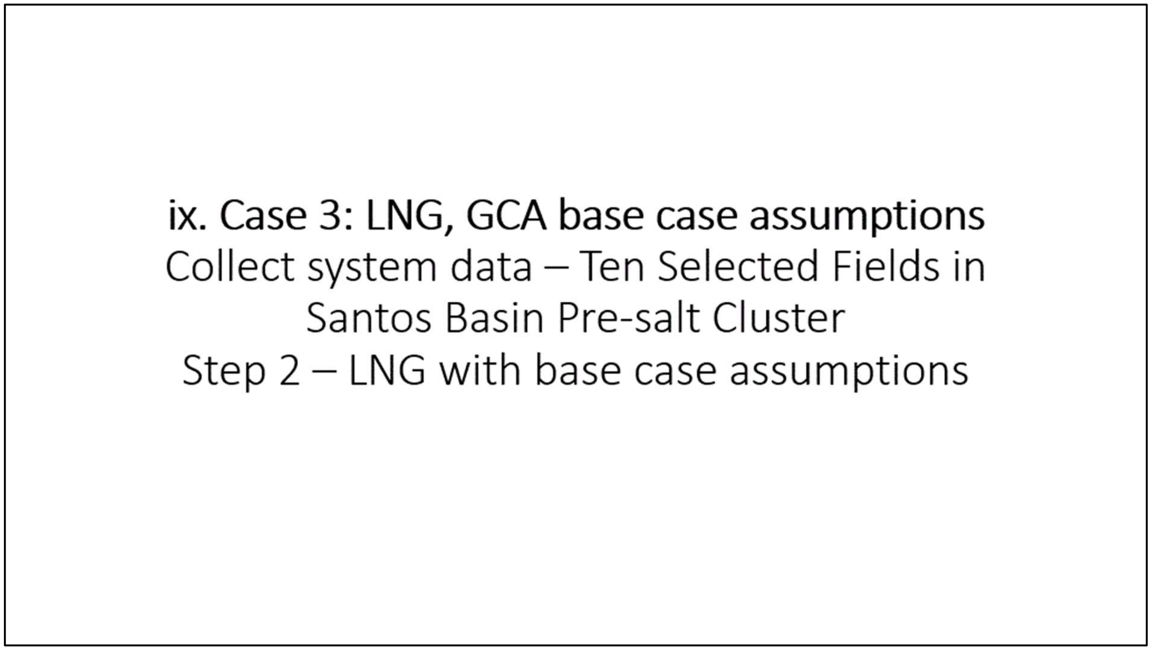


Figure 52 - Ninth scenario section, Case 3, which considers application of Liquefied Natural Gas (LNG) and base case assumptions.

3 Case 3: LNG

Year		Oil production	Gas production	Natural Gas production	CO2 production	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Natural Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	Net income before tax	NIAT	NET CASH FLOW	Discounted Cash Flow
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMbbl	year MMscf	USD/bb 75,98	USD/MMBT 4,00	MM USD 7,90%	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD 10,00%
2019	1	32	41.610	22.315	19.295	23.758	4.463	19.295	32	0	77,50	4,08	2.267	0	227	135	1.836	0	1.864	1.230	-565	-513
2020	2	31	40.880	21.924	18.956	23.341	4.385	18.956	31	0	81,04	4,16	2.343	0	234	110	2.691	0	1.808	1.193	-1.307	-1.080
2021	3	69	39.055	20.945	18.110	22.299	4.189	18.110	69	0	84,24	4,24	5.299	0	530	523	1.109	0	3.516	2.321	1.942	1.459
2022	4	33	39.420	21.141	18.279	22.507	4.228	18.279	33	0	85,84	4,33	2.626	0	263	286	391	0	1.932	1.275	1.030	703
2023	5	238	274.845	133.153	141.692	168.323	26.631	141.692	238	16.928	86,94	4,42	18.913	72	1.898	1.040	18.278	0	13.622	8.990	-6.864	-4.262
2024	6	439	509.175	240.355	268.820	316.891	48.071	268.820	439	75.502	88,24	4,50	35.487	328	3.582	2.001	27.107	0	26.051	17.194	-5.732	-3.236
2025	7	647	746.425	347.990	398.435	468.033	69.598	398.435	647	139.608	89,54	4,59	53.050	619	5.367	2.909	28.640	0	38.821	25.622	3.554	1.824
2026	8	833	958.125	444.643	513.482	602.411	88.929	513.482	833	184.962	91,04	4,69	69.494	836	7.033	3.799	28.365	0	50.338	33.223	14.018	6.539
2027	9	948	1.087.335	503.003	584.332	684.932	100.601	584.332	948	214.354	92,64	4,78	80.544	988	8.153	4.385	20.276	0	57.771	38.129	29.076	12.331
2028	10	1.020	1.170.190	537.406	632.784	740.266	107.481	632.784	1.020	232.108	94,44	4,88	88.367	1.091	8.946	4.945	15.399	0	62.769	41.427	38.827	14.970
2029	11	1.052	1.207.055	549.754	657.301	767.252	109.951	657.301	1.052	240.175	96,34	4,97	93.025	1.152	9.418	5.480	13.051	0	65.203	43.034	44.059	15.443
2030	12	1.066	1.211.800	548.028	663.772	773.378	109.606	663.772	1.066	241.400	98,24	5,07	96.173	1.181	9.735	5.737	8.033	0	67.250	44.385	50.984	16.245
2031	13	1.082	1.219.465	548.433	671.032	780.719	109.687	671.032	1.082	243.148	100,24	5,17	99.601	1.213	10.081	6.104	7.965	0	69.047	45.571	53.188	15.407
2032	14	1.065	1.171.285	525.028	646.257	751.263	105.006	646.257	1.065	233.406	102,24	5,28	100.061	1.188	10.125	6.342	3.632	0	68.568	45.255	57.836	15.230
2033	15	1.039	1.134.785	507.592	627.193	728.711	101.518	627.193	1.039	226.077	104,34	5,38	99.573	1.174	10.075	6.559	2.964	0	68.171	44.993	57.970	13.878
2034	16	1.013	1.106.680	493.761	612.919	711.671	98.752	612.919	1.013	220.636	106,34	5,49	98.992	1.168	10.016	6.791	3.276	0	68.963	45.515	56.630	12.324
2035	17	988	1.077.480	479.716	597.764	693.707	95.943	597.764	988	214.787	108,54	5,60	98.535	1.160	9.969	7.014	2.827	0	70.087	46.257	56.055	11.090
2036	18	952	1.023.095	454.860	568.235	659.207	90.972	568.235	952	203.960	110,64	5,71	96.735	1.124	9.786	7.235	2.621	0	70.202	46.333	54.348	9.775

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 53: Ninth scenario, Case 3, which considers 20% gas injection and high case assumptions

3 Case 3: LNG

Year		Oil production	Gas production	Natural Gas production	CO2 production	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Natural Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	Net income before tax	NIAT	NET CASH FLOW	Discounted Cash Flow
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMbbl	year MMscf	USD/bb 75,98	USD/MMBT 4,00	MM USD 7,90%	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD 10,00%
2042	24	523	512.825	227.226	285.599	331.044	45.445	285.599	523	100.812	124,60	6,43	59.838	625	6.046	8.073	0	464	40.848	26.960	31.991	3.248
2043	25	456	438.000	194.058	243.942	282.753	38.812	243.942	456	85.920	127,10	6,56	53.231	544	5.378	8.080	0	1.062	35.296	23.295	27.255	2.516
2044	26	396	374.855	166.186	208.669	241.906	33.237	208.669	396	73.311	129,60	6,69	47.105	473	4.758	8.014	0	1.677	30.216	19.943	22.855	1.918
2045	27	343	321.565	142.633	178.932	207.459	28.527	178.932	343	62.751	132,20	6,83	41.574	413	4.199	7.870	0	2.200	25.802	17.029	18.945	1.445
2046	28	296	277.765	123.372	154.393	179.068	24.674	154.393	296	54.086	134,90	6,96	36.629	363	3.699	7.618	0	2.720	21.825	14.404	15.534	1.077
2047	29	253	242.360	107.688	134.672	156.210	21.538	134.672	253	47.225	137,60	7,10	31.869	323	3.219	6.849	0	2.890	18.401	12.144	12.978	818
2048	30	219	226.665	100.531	126.134	146.240	20.106	126.134	219	44.239	140,30	7,25	28.214	309	2.852	6.479	0	3.208	15.462	10.205	10.726	615
2049	31	188	194.910	86.255	108.655	125.906	17.251	108.655	188	37.691	143,10	7,39	24.649	269	2.492	5.980	0	3.664	12.669	8.362	8.475	442
2050	32	164	171.550	75.871	95.679	110.854	15.174	95.679	164	32.923	146,00	7,54	21.868	239	2.211	5.476	0	3.739	10.693	7.057	7.046	334
2051	33	142	149.650	66.025	83.625	96.830	13.205	83.625	142	28.663	148,90	7,69	19.406	213	1.962	5.026	0	3.942	9.060	5.980	5.609	241
2052	34	126	132.130	58.234	73.896	85.543	11.647	73.896	126	25.115	151,90	7,84	17.456	190	1.765	4.406	0	4.163	7.468	4.929	4.774	187
2053	35	90	91.980	40.082	51.898	59.915	8.016	51.898	90	18.164	154,90	8,00	12.797	140	1.294	3.116	0	3.419	5.427	3.582	3.262	116
2054	36	58	59.860	25.502	34.358	39.458	5.100	34.358	58	11.664	158,00	8,16	8.405	92	850	2.218	0	2.467	3.407	2.249	1.804	58
2055	37	35	35.770	15.748	20.022	23.172	3.150	20.022	35	7.401	161,20	8,32	5.205	59	526	1.503	0	1.635	1.806	1.192	987	29
2056	38	17	18.615	8.087	10.528	12.145	1.617	10.528	17	3.801	164,40	8,49	2.545	31	258	956	0	1.215	360	238	25	1
2057	39	10	9.855	4.254	5.601	6.452	851	5.601	10	2.000	167,70	8,66	1.468	17	148	623	0	930	43	28	-231	-6
2058	40	5	5.540	2.393	3.147	3.626	479	3.147	5	1.026	171,00	8,83	865	9	87	325	0	633	796	597	-371	-8
Total		19.607	21.224.085	9.575.222	11.648.863	13.563.907	1.915.044	11.648.863	19.607	4.098.202	119,48	6,16	1.956.056	22.112	197.817	192.859	191.706	40.730	1.336.178	881.947	900.824	182.226

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 54 - Continuation of Figure 53, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

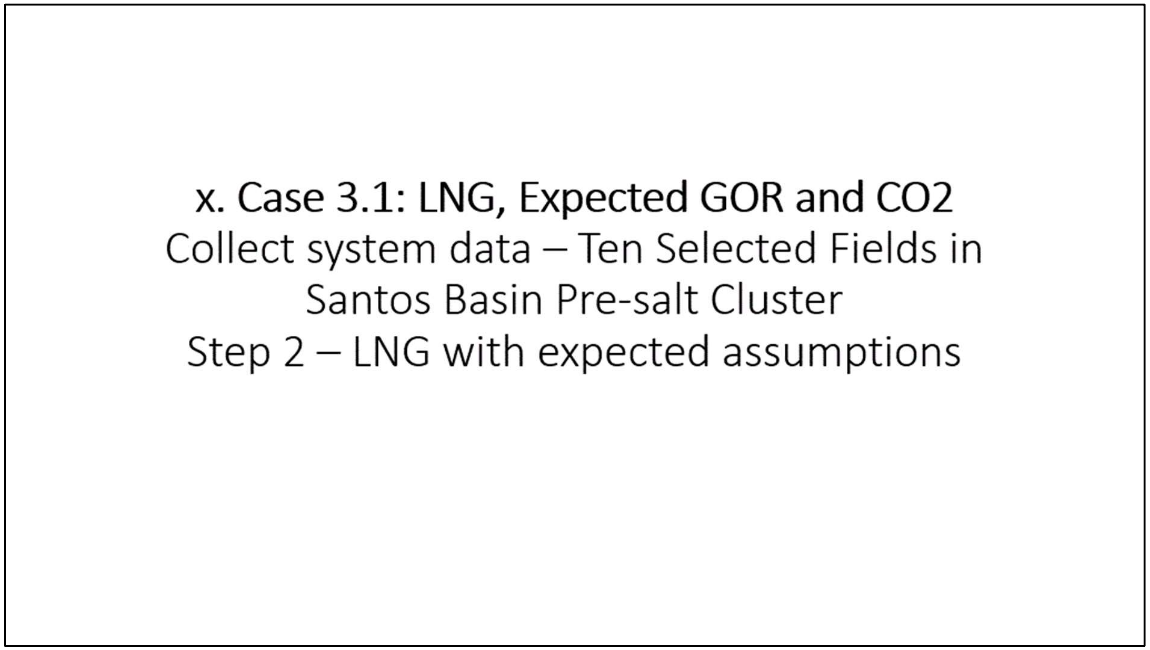


Figure 55 - Tenth scenario section, Case 3.1, which considers application of Liquefied Natural Gas (LNG) and expected assumptions.

Case 3.1: LNG, Expected GOR and CO2, WAG

Year		Oil production year MMbbl	Gas Production year MMscf	Natural Gas production year MMscf	CO2 production year MMscf	Natural Gas Demand year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 50,00	Natural Gas price USD/MM 5,50	Oil revenue MM USD 7,90%	Natural Gas Revenue MM USD	Royalties MM USD	OPEX MM USD	CAPEX MM	Aband. costs MM USD	Net income before tax MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2020	1	32	0	0	0	0	0	0	0	32	0	51,00	5,61	1.492	0	149	135	1.836	0	1.166	-1.025	-932
2020	2	31	0	0	0	0	0	0	0	31	0	53,33	5,72	1.542	0	154	110	2.691	0	1.087	-1.783	-1.474
2021	3	69	73.492	38.233	35.258	12.617	42.905	7.647	35.258	69	0	55,44	5,84	3.487	0	349	523	1.109	0	1.885	865	650
2022	4	33	48.589	26.058	22.531	8.599	27.742	5.212	22.531	33	0	56,49	5,95	1.728	0	173	286	391	0	1.124	496	339
2023	5	238	327.012	156.083	170.928	51.508	202.145	31.217	170.928	238	0	57,21	6,07	12.445	0	1.245	990	17.278	0	7.836	-9.732	-6.043
2024	6	439	646.815	299.327	347.488	98.778	407.353	59.865	347.488	439	79.164	58,07	6,19	23.352	473	2.382	2.051	28.107	0	15.209	-13.888	-7.839
2025	7	647	1.033.061	474.722	558.339	156.658	653.284	94.944	558.339	647	196.126	58,92	6,32	34.909	1.195	3.610	3.009	30.640	0	22.813	-8.912	-4.573
2026	8	833	1.456.701	669.313	787.388	220.873	921.251	133.863	787.388	833	287.314	59,91	6,44	45.729	1.785	4.751	3.849	29.365	0	29.604	-516	-241
2027	9	948	1.816.284	834.222	982.062	275.293	1.148.907	166.844	982.062	948	366.660	60,96	6,57	53.000	2.324	5.532	4.435	21.276	0	33.935	12.544	5.320
2028	10	1.020	2.067.007	944.648	1.122.359	311.734	1.311.288	188.930	1.122.359	1.020	419.925	62,15	6,70	58.148	2.715	6.086	5.045	17.399	0	36.633	19.878	7.664
2029	11	1.052	2.278.508	1.031.638	1.246.870	340.440	1.453.198	206.328	1.246.870	1.052	462.635	63,40	6,84	61.213	3.051	6.426	5.430	12.051	0	38.082	27.407	9.606
2030	12	1.066	2.527.016	1.134.297	1.392.719	374.318	1.619.578	226.859	1.392.719	1.066	512.348	64,65	6,98	63.285	3.446	6.673	5.787	9.033	0	39.339	31.863	10.152
2031	13	1.082	2.801.175	1.248.249	1.552.925	411.922	1.802.575	249.650	1.552.925	1.082	568.108	65,96	7,11	65.540	3.898	6.944	6.204	9.965	0	40.309	32.621	9.449
2032	14	1.065	2.923.306	1.298.270	1.625.036	428.429	1.884.690	259.654	1.625.036	1.065	593.267	67,28	7,26	65.843	4.152	6.999	6.392	4.632	0	39.990	38.371	10.104
2033	15	1.039	3.084.969	1.365.945	1.719.024	450.762	1.992.213	273.189	1.719.024	1.039	626.542	68,66	7,40	65.522	4.472	6.999	6.609	3.964	0	40.044	38.807	9.290
2034	16	1.013	3.271.228	1.444.039	1.827.189	476.533	2.115.997	288.808	1.827.189	1.013	664.639	69,98	7,55	65.139	4.839	6.998	6.841	4.276	0	41.349	37.805	8.227
2035	17	988	3.495.711	1.538.972	1.956.739	507.861	2.264.533	307.794	1.956.739	988	710.561	71,43	7,70	64.839	5.277	7.012	7.114	4.827	0	42.966	36.555	7.232
2036	18	952	3.740.176	1.641.970	2.098.206	541.850	2.426.600	328.394	2.098.206	952	760.245	72,81	7,86	63.654	5.759	6.941	7.285	3.621	0	44.152	36.554	6.575

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 56 - Tenth scenario, Case 3.1, which considers 20% gas injection and high case assumptions.

Case 3.1: LNG, Expected GOR and CO2, WAG

Year		Oil production year MMbbl	Gas Production year MMscf	Natural Gas production year MMscf	CO2 production year MMscf	Natural Gas Demand year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 50,00	Natural Gas price USD/MM 5,50	Oil revenue MM USD 7,90%	Natural Gas Revenue MM USD	Royalties MM USD	OPEX MM USD	CAPEX MM	Aband. costs MM USD	Net income before tax MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2042	24	523	2.777.515	1.197.018	1.580.497	395.016	1.819.901	239.404	1.580.497	523	555.301	82,00	8,85	39.375	4.737	4.411	8.073	0	472	25.732	22.333	2.267
2043	25	456	2.463.010	1.060.941	1.402.069	350.111	1.614.257	212.188	1.402.069	456	492.086	83,64	9,02	35.028	4.282	3.931	8.080	0	1.101	21.827	18.709	1.727
2044	26	396	2.162.679	931.683	1.230.996	307.455	1.417.332	186.337	1.230.996	396	431.845	85,29	9,20	30.996	3.833	3.483	8.014	0	1.753	18.342	15.279	1.282
2045	27	343	2.214.277	952.702	1.261.575	314.392	1.452.115	190.540	1.261.575	343	442.301	87,00	9,39	27.357	4.004	3.136	7.870	0	2.313	15.938	12.562	958
2046	28	296	1.303.384	562.674	740.710	185.682	853.245	112.535	740.710	296	259.374	88,77	9,58	24.103	2.395	2.650	7.618	0	2.869	12.130	9.136	634
2047	29	253	252.493	113.031	139.463	37.300	162.069	22.606	139.463	253	49.556	90,55	9,77	20.971	467	2.144	6.849	0	3.070	8.521	6.430	405
2048	30	219	229.784	102.932	126.852	33.968	147.438	20.586	126.852	219	45.164	92,33	9,96	18.566	434	1.900	6.479	0	3.421	6.790	4.840	277
2049	31	188	206.191	92.348	113.844	30.475	132.313	18.470	113.844	188	40.232	94,17	10,16	16.220	394	1.661	5.980	0	3.960	5.046	3.244	169
2050	32	164	170.846	79.404	91.441	26.203	107.322	15.881	91.441	164	36.224	96,08	10,36	14.390	362	1.475	5.476	0	4.041	3.973	2.365	112
2051	33	142	149.271	69.279	79.992	22.862	93.848	13.856	79.992	142	31.611	97,99	10,57	12.770	322	1.309	5.026	0	4.250	3.186	1.381	59
2052	34	126	134.106	62.293	71.814	20.557	84.272	12.459	71.814	126	28.301	99,96	10,78	11.486	294	1.178	4.406	0	4.505	2.189	911	36
2053	35	90	93.549	43.330	50.219	14.299	58.885	8.666	50.219	90	20.365	101,93	11,00	8.421	216	864	3.116	0	3.734	1.557	394	14
2054	36	58	48.761	22.685	26.076	7.486	30.613	4.537	26.076	58	10.662	103,97	11,22	5.531	115	565	2.218	0	2.734	841	-156	-5
2055	37	35	21.877	10.154	11.723	3.351	13.754	2.031	11.723	35	4.772	106,08	11,44	3.425	53	348	1.503	0	1.835	198	-282	-8
2056	38	17	8.816	3.988	4.828	1.316	5.626	798	4.828	17	1.874	108,19	11,67	1.674	21	170	956	0	1.380	-432	-810	-22
2057	39	10	0	0	0	0	0	0	0	10	0	110,36	11,91	966	0	97	623	0	1.063	-424	-816	-20
2058	40	5	0	0	0	0	0	0	0	5	0	112,53	12,14	569	0	57	325	0	733	522	-813	-18
Total		19.607	62.018.430	27.387.542	34.630.888	9.037.889	40.108.397	5.477.508	34.630.888	19.607	12.381.485	65,65	7,66	1.287.144	94.883	138.203	193.609	206.706	43.947	790.902	529.523	93.109

Steps 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 57 - Continuation of Figure 56, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

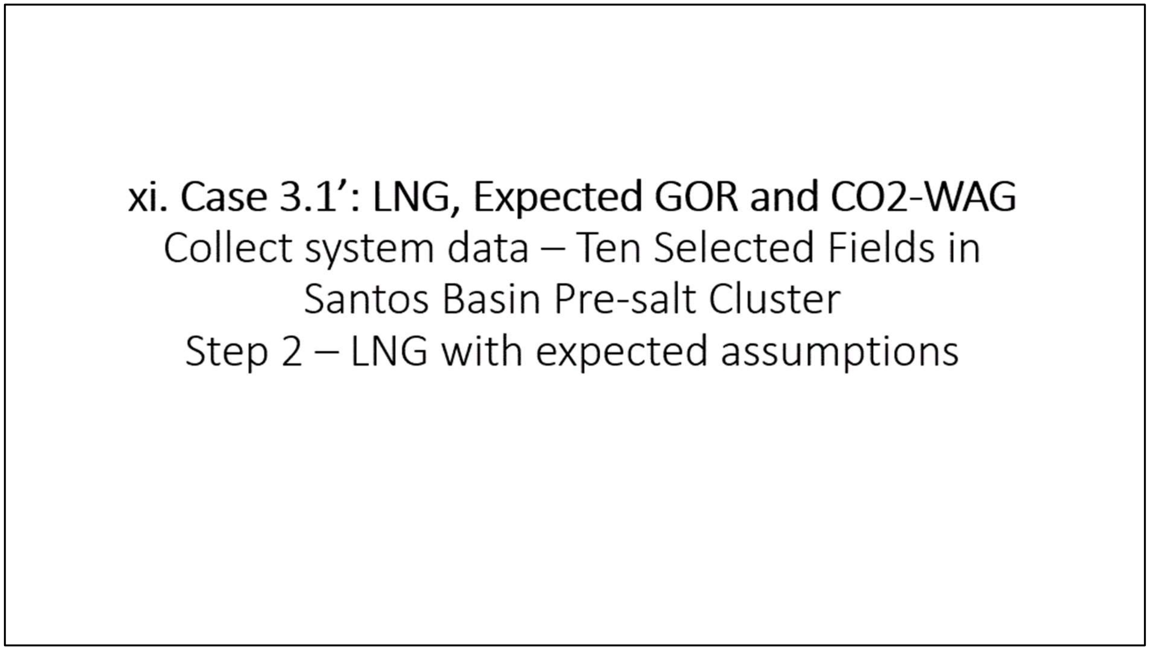


Figure 58 - Eleventh scenario section, Case 3.1’, which considers application of Liquefied Natural Gas (LNG) combined with CO_2-WAG and expected assumptions

Case 3.1': LNG, Expected GOR, CO2 and WAG-CO2

Year		Oil production year MMbbl	Gas Production year MMscf	Natural Gas production year MMscf	CO2 production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 50,00	Natural Gas price USD/M 5,50	Oil revenue MM 7,90%	Natural Gas Revenue MM USD 0,00%	Royalties MM USD	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2020	1	0	0	0	0	0	0	0	0	0	0	51,00	5,61	0	0	0	0	0	0	-19	-18
2020	2	0	0	0	0	0	0	0	0	0	0	53,33	5,72	0	0	0	0	1.507	0	-1.507	-1.246
2021	3	0	0	0	0	0	0	0	0	0	0	55,44	5,84	0	0	0	0	531	0	-531	-399
2022	4	617	981.494	443.979	537.515	146.513	626.311	88.796	537.515	617	0	56,49	5,95	32.104	0	3.210	6.093	23.306	0	-8.208	-5.606
2023	5	1.178	2.074.744	938.511	1.136.234	309.708	1.323.936	187.702	1.136.234	1.178	0	57,21	6,07	62.093	0	6.209	11.636	37.029	0	-7.045	-4.374
2024	6	1.151	2.180.658	986.420	1.194.237	325.519	1.391.521	197.284	1.194.237	1.151	79.164	58,07	6,19	61.560	473	6.203	11.366	40.712	0	-9.952	-5.618
2025	7	1.124	2.310.833	1.045.305	1.265.528	344.951	1.474.589	209.061	1.265.528	1.124	196.126	58,92	6,32	60.984	1.195	6.218	11.096	31.561	0	316	162
2026	8	1.096	2.428.196	1.098.394	1.329.801	362.470	1.549.480	219.679	1.329.801	1.096	287.314	59,91	6,44	60.498	1.785	6.228	10.826	21.877	0	11.135	5.194
2027	9	1.069	2.509.074	1.134.980	1.374.094	374.543	1.601.090	226.996	1.374.094	1.069	366.660	60,96	6,57	60.028	2.324	6.235	10.557	16.771	0	17.177	7.285
2028	10	1.042	2.571.394	1.163.170	1.408.224	383.846	1.640.858	232.634	1.408.224	1.042	419.925	62,15	6,70	59.630	2.715	6.234	10.287	9.057	0	25.639	9.885
2029	11	1.014	2.640.604	1.194.477	1.446.127	394.177	1.685.022	238.895	1.446.127	1.014	462.635	63,40	6,84	59.234	3.051	6.229	10.017	8.828	0	26.418	9.259
2030	12	987	2.748.244	1.243.168	1.505.076	410.245	1.753.709	248.634	1.505.076	987	512.348	64,65	6,98	58.776	3.446	6.222	9.747	10.982	0	24.619	7.844
2031	13	960	2.770.564	1.253.265	1.517.299	413.577	1.767.952	250.653	1.517.299	960	568.108	65,96	7,11	58.313	3.898	6.221	9.477	2.041	0	34.091	9.875
2032	14	933	2.881.278	1.303.346	1.577.932	430.104	1.838.601	260.669	1.577.932	933	593.267	67,28	7,26	57.783	4.152	6.193	9.208	0	0	36.360	9.575
2033	15	905	3.028.875	1.370.112	1.658.764	452.137	1.932.786	274.022	1.658.764	905	626.542	68,66	7,40	57.242	4.472	6.171	8.938	0	0	36.316	8.694
2034	16	878	3.174.487	1.435.979	1.738.508	473.873	2.025.703	287.196	1.738.508	878	664.639	69,98	7,55	56.578	4.839	6.142	8.668	0	0	35.790	7.789
2035	17	851	3.374.302	1.526.365	1.847.936	503.701	2.153.209	305.273	1.847.936	851	710.561	71,43	7,70	55.952	5.277	6.123	8.398	0	0	35.255	6.975
2036	18	823	3.498.026	1.582.332	1.915.694	522.170	2.232.160	316.466	1.915.694	823	760.245	72,81	7,86	55.202	5.759	6.096	8.128	0	0	34.598	6.223
2037	19	796	3.741.238	1.692.349	2.048.889	558.475	2.387.359	338.470	2.048.889	796	768.980	74,30	8,01	54.460	5.942	6.040	7.859	0	0	34.176	5.588

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 59 - Tenth scenario, Case 3.1', which considers 20% gas injection and high case assumptions.

Case 3.1': LNG, Expected GOR, CO2 and WAG-CO2

Year		Oil production year MMbbl	Gas Production year MMscf	Natural Gas production year MMscf	CO2 production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 50,00	Natural Gas price USD/MM 5,50	Oil revenue MM USD 7,90%	Natural Gas Revenue MM USD 0,00%	Royalties MM USD	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2040	22	714	3.842.215	1.738.026	2.104.189	573.549	2.451.794	347.605	2.104.189	714	726.506	78,84	8,50	51.837	5.957	5.779	7.049	0	117	31.797	3.906
2041	23	687	3.394.971	1.535.715	1.859.256	506.786	2.166.399	307.143	1.859.256	687	611.942	80,42	8,67	50.852	5.118	5.597	6.779	0	482	30.369	3.392
2042	24	659	3.378.211	1.528.134	1.850.077	504.284	2.155.704	305.627	1.850.077	659	555.301	82,00	8,85	49.788	4.737	5.452	6.510	0	472	29.624	3.008
2043	25	613	3.194.947	1.445.234	1.749.713	476.927	2.038.759	289.047	1.749.713	613	492.086	83,64	9,02	47.224	4.282	5.151	6.062	0	1.101	27.353	2.525
2044	26	0	68	31	37	10	43	6	37	0	431.845	85,29	9,20	6	3.833	384	1	0	1.753	1.464	123
2045	27	0	0	0	0	0	0	0	0	0	442.301	87,00	9,39	0	4.004	400	0	0	2.313	890	68
2046	28	0	0	0	0	0	0	0	0	0	259.374	88,77	9,58	0	2.395	240	0	0	2.869	-741	-51
2047	29	0	0	0	0	0	0	0	0	0	49.556	90,55	9,77	0	467	47	0	0	3.070	-2.651	-167
2048	30	0	0	0	0	0	0	0	0	0	45.164	92,33	9,96	0	434	43	0	0	3.421	-3.030	-174
2049	31	0	0	0	0	0	0	0	0	0	40.232	94,17	10,16	0	394	39	0	0	3.960	-3.606	-188
2050	32	0	0	0	0	0	0	0	0	0	36.224	96,08	10,36	0	362	36	0	0	4.041	-3.715	-176
2051	33	0	0	0	0	0	0	0	0	0	31.611	97,99	10,57	0	322	32	0	0	4.250	-3.960	-171
2052	34	0	0	0	0	0	0	0	0	0	28.301	99,96	10,78	0	294	29	0	0	4.505	-4.240	-166
2053	35	0	0	0	0	0	0	0	0	0	20.365	101,93	11,00	0	216	22	0	0	3.734	-3.539	-126
2054	36	0	0	0	0	0	0	0	0	0	10.662	103,97	11,22	0	115	12	0	0	2.734	-2.630	-85
2055	37	0	0	0	0	0	0	0	0	0	4.772	106,08	11,44	0	53	5	0	0	1.835	-1.788	-53
2056	38	0	0	0	0	0	0	0	0	0	1.874	108,19	11,67	0	21	2	0	0	1.380	-1.361	-36
2057	39	0	0	0	0	0	0	0	0	0	0	110,36	11,91	0	0	0	0	1	1.063	-1.063	-26
2058	40	0	0	0	0	0	0	0	0	0	0	112,53	12,14	0	0	0	0	8	733	-1.001	-22
Total		19.607	64.459.284	29.158.157	35.301.127	9.622.192	41.132.758	5.831.631	35.301.127	19.607	12.381.485	62,04	7,66	1.216.503	94.883	131.139	193.611	204.211	43.947	478.682	98.021

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 60 - Continuation of Figure 59, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

xii. Case 3.2: LNG, High GOR and Low CO2
Collect system data – Ten Selected Fields in
Santos Basin Pre-salt Cluster
Step 2 – LNG with high case assumptions

Figure 61- Twelfth scenario section, Case 3.2, which considers application of Liquefied Natural Gas (LNG) and high case assumptions

Case 3.2: LNG, High GOR and Low CO2, WAG

Year		Oil production year	Gas production year	Natural Gas production year	CO2 production year	Natural Gas Demand (fuel) year	Gas injection year	Natural Gas injection year	CO2 injection year	Oil sale year	Natural Gas Sale year	Oil price	Natural Gas price	Oil revenue	Natural Gas revenue (CH4+)	Royalties	OPEX	CAPEX	Aband. costs	NET CASH FLOW	Discounted Cash Flow
		MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMbbl	MMscf	USD/bbl	USD/MM	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD
												75,00	8,25	0,05	0	0,1	0	0	0	0,00	10,00%
2020	1	32	41.610	26.174	15.436	1.536	20.671	5.235	15.436	32	0	76,50	8,42	2.237	0	224	135	1.836	0	-582	-529
2020	2	31	40.880	25.715	15.165	2.380	20.308	5.143	15.165	31	0	79,99	8,58	2.313	0	231	110	2.691	0	-1.325	-1.095
2021	3	69	39.055	24.567	14.488	5.173	19.401	4.913	14.488	69	0	83,15	8,75	5.230	0	523	523	1.109	0	1.901	1.428
2022	4	33	39.420	24.797	14.623	7.003	19.583	4.959	14.623	33	0	84,73	8,93	2.592	0	259	286	391	0	1.009	689
2023	5	238	732.042	412.300	319.742	12.976	402.202	82.460	319.742	238	163.632	85,82	9,11	18.668	1.437	2.010	1.214	22.878	0	-10.835	-6.728
2024	6	439	1.490.876	833.409	657.467	13.260	824.149	166.682	657.467	439	365.069	87,10	9,29	35.027	3.271	3.830	2.029	28.307	0	-5.377	-3.035
2025	7	647	2.268.164	1.267.118	1.001.046	13.827	1.254.469	253.424	1.001.046	647	568.696	88,39	9,48	52.363	5.197	5.756	3.001	31.440	0	3.150	1.617
2026	8	833	2.999.666	1.673.424	1.326.242	14.231	1.660.927	334.685	1.326.242	833	758.699	89,87	9,67	68.594	7.072	7.567	3.859	30.365	0	15.328	7.151
2027	9	948	3.573.221	1.989.220	1.584.001	14.909	1.981.845	397.844	1.584.001	948	910.127	91,45	9,86	79.500	8.653	8.815	4.481	22.676	0	30.767	13.048
2028	10	1.020	4.031.008	2.233.278	1.797.730	15.389	2.244.385	446.656	1.797.730	1.020	1.026.531	93,22	10,06	87.222	9.955	9.718	5.073	18.599	0	40.403	15.577
2029	11	1.052	4.449.908	2.455.259	1.994.649	15.779	2.485.701	491.052	1.994.649	1.052	1.132.691	95,10	10,26	91.820	11.204	10.302	5.476	13.451	0	49.200	17.244
2030	12	1.066	4.797.250	2.639.325	2.157.925	16.557	2.685.790	527.865	2.157.925	1.066	1.220.934	96,97	10,46	94.927	12.319	10.725	5.801	9.633	0	55.527	17.693
2031	13	1.082	5.133.702	2.818.467	2.315.235	17.080	2.878.928	563.693	2.315.235	1.082	1.306.696	98,95	10,67	98.311	13.448	11.176	6.232	11.165	0	56.768	16.444
2032	14	1.065	5.118.320	2.807.595	2.310.725	17.549	2.872.244	561.519	2.310.725	1.065	1.302.920	100,92	10,89	98.764	13.677	11.244	6.342	3.632	0	64.849	17.077
2033	15	1.039	5.072.035	2.781.094	2.290.941	18.411	2.847.160	556.219	2.290.941	1.039	1.291.343	102,99	11,10	98.283	13.827	11.211	6.559	2.964	0	65.084	15.581
2034	16	1.013	5.055.925	2.770.778	2.285.147	19.216	2.839.303	554.156	2.285.147	1.013	1.287.547	104,97	11,33	97.709	14.062	11.177	6.791	3.276	0	63.890	13.904
2035	17	988	5.051.337	2.767.276	2.284.062	20.243	2.837.517	553.455	2.284.062	988	1.286.788	107,14	11,55	97.258	14.335	11.159	7.046	3.627	0	62.665	12.398
2036	18	952	4.875.103	2.670.522	2.204.581	20.913	2.738.686	534.104	2.204.581	952	1.242.186	109,21	11,78	95.482	14.114	10.960	7.235	2.621	0	61.684	11.094
2037	19	893	4.532.832	2.482.642	2.050.190	21.211	2.546.718	496.528	2.050.190	893	1.154.686	111,44	12,02	91.411	13.383	10.479	7.440	1.871	0	59.178	9.676
2038	20	824	4.197.333	2.299.163	1.898.170	23.394	2.358.003	459.833	1.898.170	824	1.069.063	113,62	12,26	85.986	12.638	9.862	7.631	818	0	55.712	8.281

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 62 - Tenth scenario, Case 3.2, which considers 20% gas injection and high case assumptions.

Case 3.2: LNG, High GOR and Low CO2, WAG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas production year MMscf	CO2 production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 75,00	Natural Gas price USD/MM 8,25	Oil revenue MM USD 0,05	Natural Gas revenue (CH4+) MM USD 0	Royalties MM USD 0,1	OPEX MM USD 0	CAPEX MM USD 0	Aband. costs MM USD 0	NET CASH FLOW MM USD 0,00	Discounted Cash Flow MM USD 10,00%
2040	22	675	3.437.078	1.882.289	1.554.790	23.829	1.931.248	376.458	1.554.790	675	874.704	118,25	12,75	73.301	10.758	8.406	7.937	0	118	47.040	5.779
2041	23	596	2.978.207	1.631.405	1.346.801	20.613	1.673.083	326.281	1.346.801	596	757.485	120,62	13,01	65.982	9.503	7.548	8.044	0	502	41.334	4.616
2042	24	523	2.552.257	1.398.401	1.153.856	19.653	1.433.536	279.680	1.153.856	523	648.780	122,99	13,27	59.062	8.302	6.736	8.073	0	490	36.424	3.698
2043	25	456	2.148.121	1.177.022	971.099	19.506	1.206.503	235.404	971.099	456	545.597	125,46	13,53	52.542	7.121	5.966	8.080	0	1.150	30.944	2.856
2044	26	396	1.820.874	998.148	822.726	19.897	1.022.356	199.630	822.726	396	462.226	127,93	13,81	46.494	6.154	5.265	8.014	0	1.816	25.993	2.181
2045	27	343	1.536.999	842.773	694.225	22.830	862.780	168.555	694.225	343	389.816	130,49	14,08	41.035	5.293	4.633	7.870	0	2.392	21.550	1.644
2046	28	296	1.293.832	709.738	584.094	18.504	726.042	141.948	584.094	296	327.809	133,16	14,36	36.155	4.540	4.070	7.618	0	2.944	17.694	1.227
2047	29	253	1.109.321	607.991	501.329	9.338	622.928	121.598	501.329	253	280.770	135,83	14,65	31.456	3.967	3.542	6.849	0	3.141	14.789	932
2048	30	219	1.051.901	576.094	475.808	9.506	591.026	115.219	475.808	219	266.306	138,49	14,94	27.849	3.838	3.169	6.479	0	3.509	12.393	710
2049	31	188	893.105	488.816	404.289	9.708	502.053	97.763	404.289	188	225.461	141,25	15,24	24.330	3.314	2.764	5.980	0	4.090	9.750	508
2050	32	164	775.159	424.152	351.007	7.014	435.837	84.830	351.007	164	195.572	144,12	15,55	21.584	2.932	2.452	5.476	0	4.173	8.097	383
2051	33	142	672.262	367.719	304.543	6.930	378.087	73.544	304.543	142	169.405	146,98	15,86	19.155	2.591	2.175	5.026	0	4.385	6.429	277
2052	34	126	585.981	320.492	265.490	7.008	329.588	64.098	265.490	126	147.380	149,94	16,18	17.230	2.299	1.953	4.406	0	4.657	5.398	211
2053	35	90	436.011	238.343	197.668	5.176	245.336	47.669	197.668	90	110.613	152,90	16,50	12.631	1.760	1.439	3.116	0	3.878	3.668	131
2054	36	58	293.600	159.350	134.250	4.367	166.120	31.870	134.250	58	73.927	155,96	16,83	8.296	1.200	950	2.218	0	2.862	2.003	65
2055	37	35	192.413	104.900	87.513	3.698	108.493	20.980	87.513	35	49.303	159,12	17,17	5.138	816	595	1.503	0	1.932	1.098	32
2056	38	17	108.040	58.726	49.313	2.874	61.059	11.745	49.313	17	27.601	162,28	17,51	2.512	466	298	956	0	1.463	16	0
2057	39	10	59.636	32.299	27.337	1.163	33.797	6.460	27.337	10	15.180	165,54	17,86	1.449	261	171	623	0	1.130	-297	-7
2058	40	5	38.493	20.764	17.728	0	21.881	4.153	17.728	5	9.660	168,79	18,22	854	170	102	325	0	782	-506	-11
Total		19.607	89.377.312	49.152.553	40.224.759	526.682	50.055.270	9.830.511	40.224.759	19.607	22.646.513	98,47	11,29	1.930.717	255.709	218.643	193.657	213.906	45.529	1.004.196	199.691

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 63 - Continuation of Figure 62, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

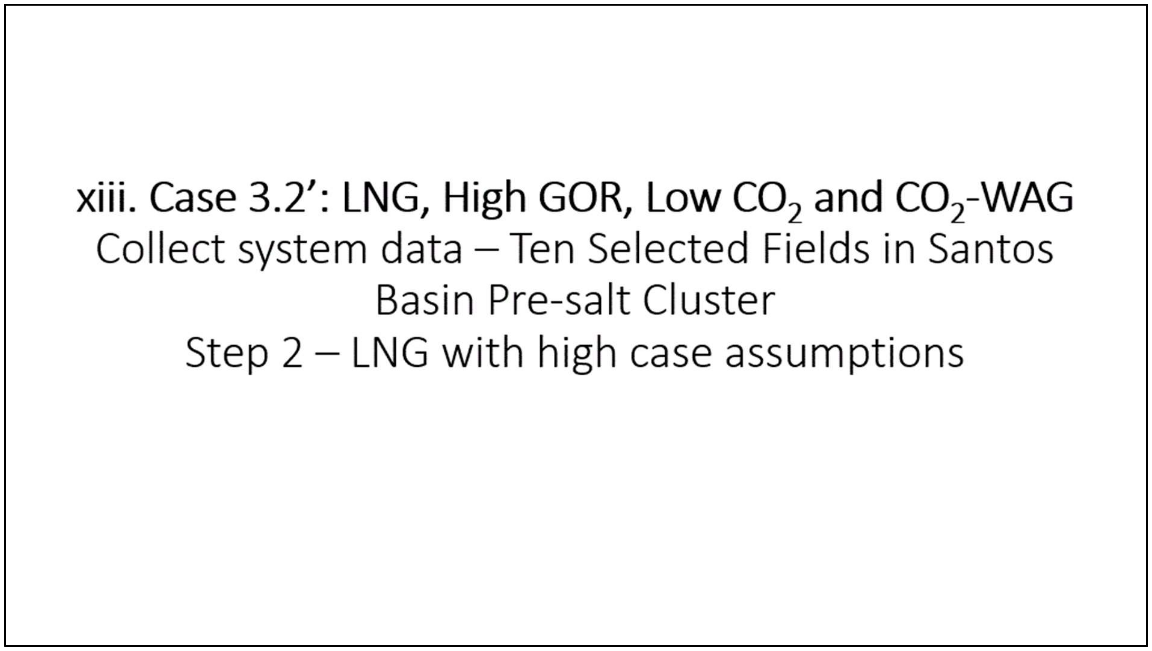


Figure 64 -Thirteenth scenario section, Case 3.2’, which considers application of Liquefied Natural Gas (LNG) and high case assumptions

Case 3.2': LNG, High GOR, Low CO2 and High WAG-CO2

Year		Oil production year	Gas production year	Natural Gas production year	CO2 production year	Natural Gas Demand (fuel) year	Gas injection year	Natural Gas injection year	CO2 injection year	Oil sale year	Natural Gas Sale year	Oil price	Natural Gas price	Oil revenue	Natural Gas revenue (CH4+)	Royalties	OPEX	CAPEX	Aband. costs	NET CASH FLOW	Discounted Cash Flow
		MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMbbl	MMscf	USD/bb 75,00	USD/MM 8,25	MM USD 5,00%	MM USD 0,00%	MM USD 10,00%	MM USD 0,00%	MM USD 0,00%	MM USD 0,00%	MM USD 0,00	MM USD 10,00%
2019	1	0	0	0	0	0	0	0	0	0	0	76,50	8,42	0	0	0	0	2.683	0	-2.703	-2.457
2020	2	0	0	0	0	0	0	0	0	0	0	79,99	8,58	0	0	0	0	3.933	0	-3.933	-3.250
2021	3	0	0	0	0	0	0	0	0	0	0	83,15	8,75	0	0	0	0	1.621	0	-1.621	-1.218
2022	4	741	363.083	204.009	159.074	981.494	199.876	40.802	159.074	741	0	84,73	8,93	57.802	0	5.780	7.316	571	0	28.984	19.796
2023	5	1.414	4.522.955	2.541.358	1.981.597	2.074.744	2.489.869	508.272	1.981.597	1.414	163.632	85,82	9,11	111.769	1.437	11.321	13.967	32.714	0	26.215	16.277
2024	6	1.381	3.460.093	1.944.157	1.515.936	2.180.658	1.904.768	388.831	1.515.936	1.381	365.069	87,10	9,29	110.810	3.271	11.408	13.643	38.133	0	22.147	12.502
2025	7	1.349	4.354.438	2.446.672	1.907.767	2.310.833	2.397.101	489.334	1.907.767	1.349	568.696	88,39	9,48	109.774	5.197	11.497	13.319	44.739	0	17.143	8.797
2026	8	1.316	4.606.194	2.588.128	2.018.066	2.428.196	2.535.691	517.626	2.018.066	1.316	758.699	89,87	9,67	108.899	7.072	11.597	12.995	30.236	0	33.369	15.567
2027	9	1.283	5.513.174	3.097.742	2.415.432	2.509.074	3.034.980	619.548	2.415.432	1.283	910.127	91,45	9,86	108.052	8.653	11.671	12.672	23.010	0	41.987	17.806
2028	10	1.250	5.654.467	3.177.132	2.477.335	2.571.394	3.112.762	635.426	2.477.335	1.250	1.026.531	93,22	10,06	107.337	9.955	11.729	12.348	17.164	0	48.985	18.886
2029	11	1.217	5.786.532	3.251.337	2.535.196	2.640.604	3.185.463	650.267	2.535.196	1.217	1.132.691	95,10	10,26	106.625	11.204	11.783	12.024	11.382	0	55.740	19.537
2030	12	1.185	6.012.260	3.378.169	2.634.091	2.748.244	3.309.725	675.634	2.634.091	1.185	1.220.934	96,97	10,46	105.800	12.319	11.812	11.700	7.720	0	60.005	19.119
2031	13	1.152	6.050.562	3.399.690	2.650.872	2.770.564	3.330.810	679.938	2.650.872	1.152	1.306.696	98,95	10,67	104.966	13.448	11.841	11.376	0	0	68.491	19.839
2032	14	1.119	6.287.768	3.532.971	2.754.797	2.881.278	3.461.391	706.594	2.754.797	1.119	1.302.920	100,92	10,89	104.013	13.677	11.769	11.053	0	0	68.490	18.036
2033	15	1.086	6.614.551	3.716.584	2.897.967	3.028.875	3.641.284	743.317	2.897.967	1.086	1.291.343	102,99	11,10	103.040	13.827	11.687	10.729	0	0	68.122	16.308
2034	16	1.053	6.941.813	3.900.466	3.041.347	3.174.487	3.821.440	780.093	3.041.347	1.053	1.287.547	104,97	11,33	101.846	14.062	11.591	10.405	0	0	67.238	14.633
2035	17	1.021	7.388.849	4.151.646	3.237.202	3.374.302	4.067.532	830.329	3.237.202	1.021	1.286.788	107,14	11,55	100.718	14.335	11.505	10.081	0	0	66.344	13.126
2036	18	988	7.660.839	4.304.472	3.356.367	3.498.026	4.217.261	860.894	3.356.367	988	1.242.186	109,21	11,78	99.369	14.114	11.348	9.757	0	0	64.949	11.682
2037	19	955	8.225.530	4.621.761	3.603.769	3.741.238	4.528.121	924.352	3.603.769	955	1.154.686	111,44	12,02	98.034	13.383	11.142	9.434	0	0	63.667	10.410
2038	20	922	8.486.120	4.768.181	3.717.939	3.858.317	4.671.575	953.636	3.717.939	922	1.069.063	113,62	12,26	96.514	12.638	10.915	9.110	0	0	61.809	9.187

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 65 - Thirteenth scenario, Case 3.2', which treats raw gas and produces CH_4 and CO_2-rich streams. CH_4 rich stream is liquefied and sold and the CO_2 rich stream is reinjected

Case 3.2': LNG, High GOR, Low CO2 and High WAG-CO2

Year	Oil production year MMbbl	Gas production year MMscf	Natural Gas production year MMscf	CO2 production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bb 75,00	Natural Gas price USD/MM 8,25	Oil revenue MM USD 5,00%	Natural Gas revenue (CH4+) MM USD 0,00%	Royalties MM USD 10,00%	OPEX MM USD 0,00%	CAPEX MM USD 0,00%	Aband. costs MM USD 0,00%	NET CASH FLOW MM USD 0,00	Discounted Cash Flow MM USD 10,00%
2040 22	0	0	0	0	3.842.215	0	0	0	0	874.704	118,25	12,75	0	10.758	1.076	0	0	118	8.380	1.029
2041 23	0	0	0	0	3.394.971	0	0	0	0	757.485	120,62	13,01	0	9.503	950	0	0	502	7.029	785
2042 24	0	0	0	0	3.378.211	0	0	0	0	648.780	122,99	13,27	0	8.302	830	0	0	490	6.191	629
2043 25	0	0	0	0	3.194.947	0	0	0	0	545.597	125,46	13,53	0	7.121	712	0	0	1.150	4.648	429
2044 26	0	0	0	0	68	0	0	0	0	462.226	127,93	13,81	0	6.154	615	0	0	1.816	3.224	271
2045 27	0	0	0	0	0	0	0	0	0	389.816	130,49	14,08	0	5.293	529	0	0	2.392	1.966	150
2046 28	0	0	0	0	0	0	0	0	0	327.809	133,16	14,36	0	4.540	454	0	0	2.944	789	55
2047 29	0	0	0	0	0	0	0	0	0	280.770	135,83	14,65	0	3.967	397	0	0	3.141	111	7
2048 30	0	0	0	0	0	0	0	0	0	266.306	138,49	14,94	0	3.838	384	0	0	3.509	-416	-24
2049 31	0	0	0	0	0	0	0	0	0	225.461	141,25	15,24	0	3.314	331	0	0	4.090	-1.294	-67
2050 32	0	0	0	0	0	0	0	0	0	195.572	144,12	15,55	0	2.932	293	0	0	4.173	-1.688	-80
2051 33	0	0	0	0	0	0	0	0	0	169.405	146,98	15,86	0	2.591	259	0	0	4.385	-2.216	-95
2052 34	0	0	0	0	0	0	0	0	0	147.380	149,94	16,18	0	2.299	230	0	0	4.657	-2.619	-103
2053 35	0	0	0	0	0	0	0	0	0	110.613	152,90	16,50	0	1.760	176	0	0	3.878	-2.294	-82
2054 36	0	0	0	0	0	0	0	0	0	73.927	155,96	16,83	0	1.200	120	0	0	2.862	-1.782	-58
2055 37	0	0	0	0	0	0	0	0	0	49.303	159,12	17,17	0	816	82	0	0	1.932	-1.198	-35
2056 38	0	0	0	0	0	0	0	0	0	27.601	162,28	17,51	0	466	47	0	0	1.463	-1.044	-28
2057 39	0	0	0	0	0	0	0	0	0	15.180	165,54	17,86	0	261	26	0	0	1.130	-894	-22
2058 40	0	0	0	0	0	0	0	0	0	9.660	168,79	18,22	0	170	17	0	0	782	-889	-20
Total	19.607	99.599.780	55.963.125	43.636.656	64.459.284	54.829.281	11.192.625	43.636.656	19.607	22.646.513	89,46	77,45	1.754.026	255.709	200.974	193.659	213.906	45.529	890.963	259.964

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 66 - Continuation of Figure 65, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

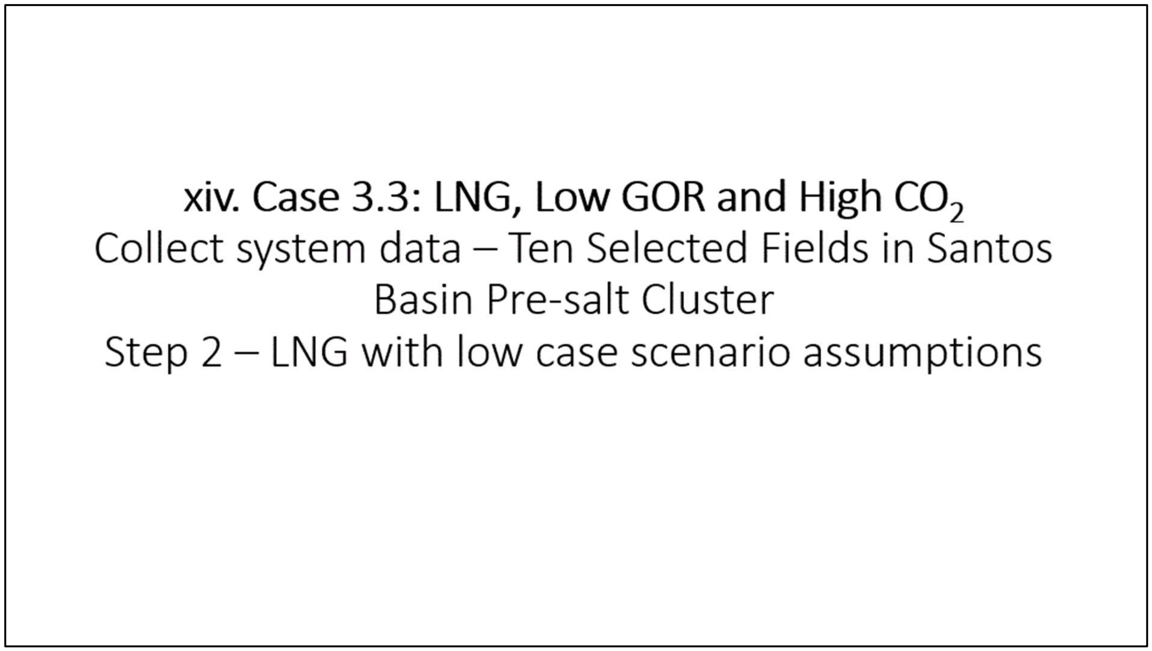


Figure 67 - Fourteenth scenario section, Case 3.3, which considers application of Liquefied Natural Gas (LNG) and base case assumptions.

Case 3.3: LNG, Low GOR and High CO2, WAG

Year		Oil production year	Gas production year	Natural Gas Production year	CO2 Production year	Natural Gas Demand (fuel) year	Gas injection year	Natural Gas injection year	CO2 injection year	Oil sale year	Natural Gas Sale year	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMbb	MMscf	USD/bbl 25,00	USD/MM 2,75	MM USD 0,079	MM USD 0	MM USD 10%	MM USD 0	MM USD 0	MM USD 0	MM USD 0	MM USD 0	MM USD 10%
2020	1	32	41.610	18.457	23.153	6.091	26.845	3.691	23.153	32	0	25,50	2,81	746	0	75	135	1.836	0	536	-1.468	-1.335
2020	2	31	40.880	18.133	22.747	5.984	26.374	3.627	22.747	31	0	26,66	2,86	771	0	77	110	2.691	0	584	-2.241	-1.852
2021	3	69	39.055	17.323	21.732	5.717	25.196	3.465	21.732	69	0	27,72	2,92	1.743	0	174	523	1.109	0	1.046	-226	-170
2022	4	33	39.420	17.485	21.935	5.770	25.432	3.497	21.935	33	0	28,24	2,98	864	0	86	286	391	0	492	-17	-12
2023	5	238	311.005	128.575	182.430	42.430	208.145	25.715	182.430	238	29.776	28,61	3,04	6.223	87	631	1.134	19.678	0	4.545	-15.850	-9.841
2024	6	439	593.922	227.721	366.202	75.148	411.746	45.544	366.202	439	59.952	29,03	3,10	11.676	179	1.185	1.901	25.107	0	8.768	-17.928	-10.120
2025	7	647	882.097	322.672	559.425	106.482	623.959	64.534	559.425	647	128.219	29,46	3,16	17.454	391	1.784	3.025	30.240	0	13.035	-19.425	-9.968
2026	8	833	1.148.018	413.652	734.365	136.505	817.096	82.730	734.365	833	171.228	29,96	3,22	22.865	532	2.340	3.771	27.565	0	17.286	-13.140	-6.130
2027	9	948	1.328.235	471.201	857.034	155.496	951.274	94.240	857.034	948	200.481	30,48	3,29	26.500	635	2.714	4.457	21.476	0	19.965	-4.699	-1.993
2028	10	1.020	1.449.725	508.071	941.654	167.663	1.043.268	101.614	941.654	1.020	218.265	31,07	3,35	29.074	706	2.978	4.945	15.399	0	21.857	3.046	1.175
2029	11	1.052	1.552.167	534.513	1.017.654	176.389	1.124.557	106.903	1.017.654	1.052	233.017	31,70	3,42	30.607	768	3.137	5.524	13.451	0	22.713	5.830	2.043
2030	12	1.066	1.635.510	555.025	1.080.485	183.158	1.191.490	111.005	1.080.485	1.066	244.994	32,32	3,49	31.642	824	3.247	5.737	8.033	0	23.483	11.691	3.725
2031	13	1.082	1.715.887	575.918	1.139.969	190.053	1.255.152	115.184	1.139.969	1.082	256.577	32,98	3,56	32.770	880	3.365	6.176	9.165	0	24.109	10.973	3.179
2032	14	1.065	1.700.897	567.860	1.133.037	187.394	1.246.609	113.572	1.133.037	1.065	254.177	33,64	3,63	32.921	889	3.381	6.342	3.632	0	24.088	16.381	4.314
2033	15	1.039	1.682.862	560.010	1.122.853	184.803	1.234.855	112.002	1.122.853	1.039	251.452	34,33	3,70	32.761	897	3.366	6.559	2.964	0	23.734	16.705	3.999
2034	16	1.013	1.673.838	555.061	1.118.777	183.170	1.229.789	111.012	1.118.777	1.013	250.208	34,99	3,78	32.570	911	3.348	6.791	3.276	0	23.342	15.863	3.452
2035	17	988	1.670.457	552.376	1.118.080	182.284	1.228.556	110.475	1.118.080	988	249.759	35,71	3,85	32.419	927	3.335	7.014	2.827	0	22.998	15.824	3.131
2036	18	952	1.615.641	533.433	1.082.208	176.033	1.188.894	106.687	1.082.208	952	241.755	36,40	3,93	31.827	916	3.274	7.235	2.621	0	22.234	15.230	2.739
2037	19	893	1.503.235	495.947	1.007.288	163.662	1.106.477	99.189	1.007.288	893	224.803	37,15	4,01	30.470	868	3.134	7.440	1.871	0	20.765	14.673	2.399
2038	20	824	1.397.284	461.032	936.251	152.141	1.028.458	92.206	936.251	824	208.964	37,87	4,09	28.662	823	2.949	7.631	818	0	18.906	14.135	2.101

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 68 - Fourteenth scenario section, Case 3.3, which considers application of Liquefied Natural Gas (LNG) and base case assumptions.

Case 3.3: LNG, Low GOR and High CO2, WAG

Year		Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand (fuel)	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		year	year	year	year	year	year	year	year	year	year	USD/bbl	USD/MM	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD
		MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMbb	MMscf	25,00	2,75	0,079	0	10%	0	0	0	0	0	10%
2040	22	675	1.144.802	377.192	767.610	124.473	843.048	75.438	767.610	675	171.031	39,42	4,25	24.434	701	2.513	7.937	0	115	14.684	11.399	1.400
2041	23	596	998.491	329.017	669.475	108.576	735.278	65.803	669.475	596	149.106	40,21	4,34	21.994	624	2.262	8.044	0	480	12.312	9.179	1.025
2042	24	523	862.218	284.530	577.688	93.895	634.594	56.906	577.688	523	128.717	41,00	4,42	19.687	549	2.024	8.073	0	466	10.140	7.591	771
2043	25	456	728.527	240.481	488.045	79.359	536.142	48.096	488.045	456	108.670	41,82	4,51	17.514	473	1.799	8.080	0	1.072	8.108	5.454	503
2044	26	396	622.259	205.649	416.610	67.864	457.740	41.130	416.610	396	92.778	42,64	4,60	15.498	412	1.591	8.014	0	1.695	6.305	3.464	291
2045	27	343	529.210	175.183	354.027	57.810	389.064	35.037	354.027	343	78.884	43,50	4,69	13.678	357	1.404	7.870	0	2.225	4.762	1.741	133
2046	28	296	447.717	148.334	299.383	48.950	329.050	29.667	299.383	296	66.655	44,39	4,79	12.052	308	1.236	7.618	0	2.752	3.505	272	19
2047	29	253	384.140	126.796	257.344	41.843	282.703	25.359	257.344	253	57.692	45,28	4,88	10.485	272	1.076	6.849	0	2.927	2.832	-319	-20
2048	30	219	360.674	118.669	242.005	39.161	265.738	23.734	242.005	219	54.110	46,16	4,98	9.283	260	954	6.479	0	3.250	2.109	-1.199	-69
2049	31	188	308.335	101.407	206.928	33.464	227.210	20.281	206.928	188	45.999	47,08	5,08	8.110	225	834	5.980	0	3.724	1.522	-2.201	-115
2050	32	164	269.532	88.430	181.102	29.182	198.788	17.686	181.102	164	40.214	48,04	5,18	7.195	201	740	5.476	0	3.799	1.180	-2.620	-124
2051	33	142	235.327	77.242	158.085	25.490	173.533	15.448	158.085	142	35.047	48,99	5,29	6.385	179	656	5.026	0	4.004	882	-3.122	-134
2052	34	126	206.526	67.641	138.885	22.322	152.413	13.528	138.885	126	30.682	49,98	5,39	5.743	160	590	4.406	0	4.233	907	-3.326	-130
2053	35	90	150.314	48.238	102.075	15.919	111.723	9.648	102.075	90	22.659	50,97	5,50	4.210	120	433	3.116	0	3.478	781	-2.697	-96
2054	36	58	96.132	30.031	66.101	9.910	72.107	6.006	66.101	58	14.106	51,99	5,61	2.765	76	284	2.218	0	2.515	340	-2.179	-70
2055	37	35	58.995	18.961	40.034	6.257	43.826	3.792	40.034	35	8.912	53,04	5,72	1.713	49	176	1.503	0	1.672	83	-1.589	-47
2056	38	17	32.155	10.192	21.963	3.363	24.001	2.038	21.963	17	4.790	54,09	5,84	837	27	86	956	0	1.246	-178	-1.424	-38
2057	39	10	16.694	5.215	11.479	1.721	12.522	1.043	11.479	10	2.451	55,18	5,95	483	14	50	623	0	956	-176	-1.132	-28
2058	40	5	11.053	3.686	7.367	1.217	8.104	737	7.367	5	1.560	56,26	6,07	285	9	29	325	0	654	-61	-979	-22
Total		19.607	30.768.066	10.414.256	20.353.809	3.436.705	22.436.660	2.082.851	20.353.809	19.607	4.529.536	32,82	3,76	643.572	17.021	66.059	193.129	194.706	41.377	401.405	94.254	-4.214

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 69 - Continuation of Figure 68, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

xv. Case 3.3’: LNG, Low GOR, High CO_2 and $C0_2$-WAG
Collect system data – Ten Selected Fields in Santos Basin Pre-salt Cluster
Step 2 – LNG with low case scenario assumptions

Figure 70 - Fifteenth scenario section, Case 3.3’, which considers application of small-scale mobile Floating Liquefied Natural Gas (ssm-FLNG) combined with CO_2-WAG method as enhanced oil recovery method

Case 3.3': LNG, Low GOR, High CO2 and Low WAG-CO2

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf
2019	1	0	0	0	0	0	0	0	0	0	0
2020	2	0	0	0	0	0	0	0	0	0	0
2021	3	0	0	0	0	0	0	0	0	0	0
2022	4	514	95.753	32.826	62.927	10.833	69.492	6.565	62.927	514	0
2023	5	982	1.066.072	365.471	700.601	120.605	773.695	73.094	700.601	982	29.776
2024	6	959	666.484	228.484	438.000	75.400	483.696	45.697	438.000	959	59.952
2025	7	936	896.634	307.384	589.250	101.437	650.727	61.477	589.250	936	128.219
2026	8	914	941.829	322.878	618.951	106.550	683.527	64.576	618.951	914	171.228
2027	9	891	1.224.583	419.812	804.772	138.538	888.734	83.962	804.772	891	200.481
2028	10	868	1.244.102	426.503	817.599	140.746	902.899	85.301	817.599	868	218.265
2029	11	845	1.256.433	430.730	825.702	142.141	911.849	86.146	825.702	845	233.017
2030	12	823	1.297.473	444.800	852.674	146.784	941.634	88.960	852.674	823	244.994
2031	13	800	1.302.937	446.673	856.264	147.402	945.599	89.335	856.264	800	256.577
2032	14	777	1.345.286	461.191	884.095	152.193	976.333	92.238	884.095	777	254.177
2033	15	754	1.404.158	481.373	922.785	158.853	1.019.059	96.275	922.785	754	251.452
2034	16	732	1.460.225	500.594	959.630	165.196	1.059.749	100.119	959.630	732	250.208
2035	17	709	1.537.354	527.036	1.010.318	173.922	1.115.726	105.407	1.010.318	709	249.759
2036	18	686	1.584.179	543.088	1.041.090	179.219	1.149.708	108.618	1.041.090	686	241.755
2037	19	663	1.678.515	575.429	1.103.087	189.891	1.218.172	115.086	1.103.087	663	224.803
2038	20	641	1.723.837	590.966	1.132.871	195.019	1.251.064	118.193	1.132.871	641	208.964

Year		Oil price USD/bbl 25,00	Natural Gas Price USD/MM 2,75	Oil revenue MM USD 7,90%	Nautral Gas revenue MM USD 0,00%	Royalties MM USD 10,00%	OPEX MM USD 0,00%	CAPEX MM USD 0,00%	Aband. costs MM USD 0,00%	EBITDA MM USD 0,00%	NET CASH FLOW MM USD 0	Discounted Cash Flow MM USD 10,00%
2019	1	25,50	2,81	0	0	0	0	2.967	0	0	-2.986	-2.715
2020	2	26,66	2,86	0	0	0	0	1.223	0	0	-1.223	-1.011
2021	3	27,72	2,92	0	0	0	0	431	0	0	-431	-324
2022	4	28,24	2,98	13.379	0	1.338	5.066	23.742	0	6.975	-19.089	-13.038
2023	5	28,61	3,04	25.872	87	2.596	9.673	29.948	0	13.691	-20.328	-12.622
2024	6	29,03	3,10	25.650	179	2.583	9.448	34.150	0	13.798	-23.981	-13.536
2025	7	29,46	3,16	25.411	391	2.580	9.224	33.688	0	13.997	-22.818	-11.709
2026	8	29,96	3,22	25.208	532	2.574	9.000	22.761	0	14.166	-11.447	-5.340
2027	9	30,48	3,29	25.012	635	2.565	8.776	19.293	0	14.307	-7.523	-3.191
2028	10	31,07	3,35	24.847	706	2.555	8.552	14.166	0	14.445	-1.976	-762
2029	11	31,70	3,42	24.682	768	2.545	8.327	9.107	0	14.578	3.518	1.233
2030	12	32,32	3,49	24.491	824	2.531	8.103	3.230	0	14.680	9.671	3.081
2031	13	32,98	3,56	24.298	880	2.518	7.879	0	0	14.781	13.259	3.841
2032	14	33,64	3,63	24.077	889	2.497	7.655	0	0	14.815	13.460	3.544
2033	15	34,33	3,70	23.852	897	2.475	7.430	0	0	14.844	13.608	3.258
2034	16	34,99	3,78	23.576	911	2.449	7.206	0	0	14.832	13.529	2.944
2035	17	35,71	3,85	23.314	927	2.424	6.982	0	0	14.836	13.445	2.660
2036	18	36,40	3,93	23.002	916	2.392	6.758	0	0	14.769	13.131	2.362
2037	19	37,15	4,01	22.693	868	2.356	6.533	0	0	14.672	12.950	2.117
2038	20	37,87	4,09	22.341	823	2.316	6.309	0	0	14.539	12.268	1.823

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 71 - Fifteenth scenario section, Case 3.3', which considers application of Liquefied Natural Gas (LNG) combined with CO_2-WAG method as enhanced oil recovery method and low case scenario assumptions

Case 3.3': LNG, Low GOR, High CO2 and Low WAG-CO2																								
Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 25,00	Natural Gas Price USD/MM 2,75	Oil revenue MM USD 7,90%	Nautral Gas revenue MM USD 0,00%	Royalties MM USD 10,00%	OPEX MM USD 0,00%	CAPEX MM USD 0,00%	Aband. costs MM USD 0,00%	EBITDA MM USD 0,00%	NET CASH FLOW MM USD 0	Discounted Cash Flow MM USD 10,00%		
2040	22	595	1.713.059	587.271	1.125.788	193.799	1.243.243	117.454	1.125.788	595	171.031	39,42	4,25	21.601	701	2.230	5.861	0	115	14.211	11.410	1.402		
2041	23	572	1.523.372	522.242	1.001.129	172.340	1.105.578	104.448	1.001.129	572	149.106	40,21	4,34	21.190	624	2.181	5.636	0	480	13.996	10.708	1.196		
2042	24	549	1.512.272	518.437	993.835	171.084	1.097.522	103.687	993.835	549	128.717	41,00	4,42	20.747	549	2.130	5.412	0	466	13.754	10.491	1.065		
2043	25	527	1.476.062	506.023	970.038	166.988	1.071.243	101.205	970.038	527	108.670	41,82	4,51	20.286	473	2.076	5.188	0	1.072	13.495	9.555	882		
2044	26	504	1.662.278	569.862	1.092.416	188.054	1.206.388	113.972	1.092.416	504	92.778	42,64	4,60	19.791	412	2.020	4.964	0	1.695	13.219	8.650	726		
2045	27	481	1.171.560	401.634	769.926	132.539	850.253	80.327	769.926	481	78.884	43,50	4,69	19.276	357	1.963	4.739	0	2.225	12.931	7.742	591		
2046	28	458	387.687	132.907	254.780	43.859	281.362	26.581	254.780	458	66.655	44,39	4,79	18.739	308	1.905	4.515	0	2.752	12.627	6.925	480		
2047	29	436	367.451	125.970	241.481	41.570	266.675	25.194	241.481	436	57.692	45,28	4,88	18.165	272	1.844	4.291	0	2.927	12.302	6.473	408		
2048	30	413	360.074	123.440	236.633	40.735	261.321	24.688	236.633	413	54.110	46,16	4,98	17.554	260	1.781	4.067	0	3.250	11.965	5.931	340		
2049	31	390	344.998	118.272	226.726	39.030	250.380	23.654	226.726	390	45.999	47,08	5,08	16.917	225	1.714	3.842	0	3.724	11.585	5.215	272		
2050	32	367	311.706	106.859	204.847	35.263	226.219	21.372	204.847	367	40.214	48,04	5,18	16.252	201	1.645	3.618	0	3.799	11.190	4.855	230		
2051	33	202	168.496	57.764	110.732	19.062	122.285	11.553	110.732	202	35.047	48,99	5,29	9.111	179	929	1.992	0	4.004	6.369	1.338	58		
2052	34	0	0	0	0	0	0	0	0	0	30.682	49,98	5,39	0	160	16	0	0	4.233	144	-4.089	-160		
2053	35	0	0	0	0	0	0	0	0	0	22.659	50,97	5,50	0	120	12	0	0	3.478	108	-3.370	-120		
2054	36	0	0	0	0	0	0	0	0	0	14.106	51,99	5,61	0	76	8	0	0	2.515	69	-2.446	-79		
2055	37	0	0	0	0	0	0	0	0	0	8.912	53,04	5,72	0	49	5	0	0	1.672	44	-1.628	-48		
2056	38	0	0	0	0	0	0	0	0	0	4.790	54,09	5,84	0	27	3	0	0	1.246	24	-1.222	-33		
2057	39	0	0	0	0	0	0	0	0	0	2.451	55,18	5,95	0	14	1	0	0	956	13	-944	-23		
2058	40	0	0	0	0	0	0	0	0	0	1.560	56,26	6,07	0	9	1	0	0	654	8	-906	-20		
Total		19.607	33.454.092	11.468.732	21.985.360	3.784.682	24.279.107	2.293.746	21.985.360	19.607	4.529.536	32,81	3,76	643.313	17.021	66.033	193.131	194.706	41.377	401.169	93.474	-28.630		

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 72 - Continuation of Figure 71, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

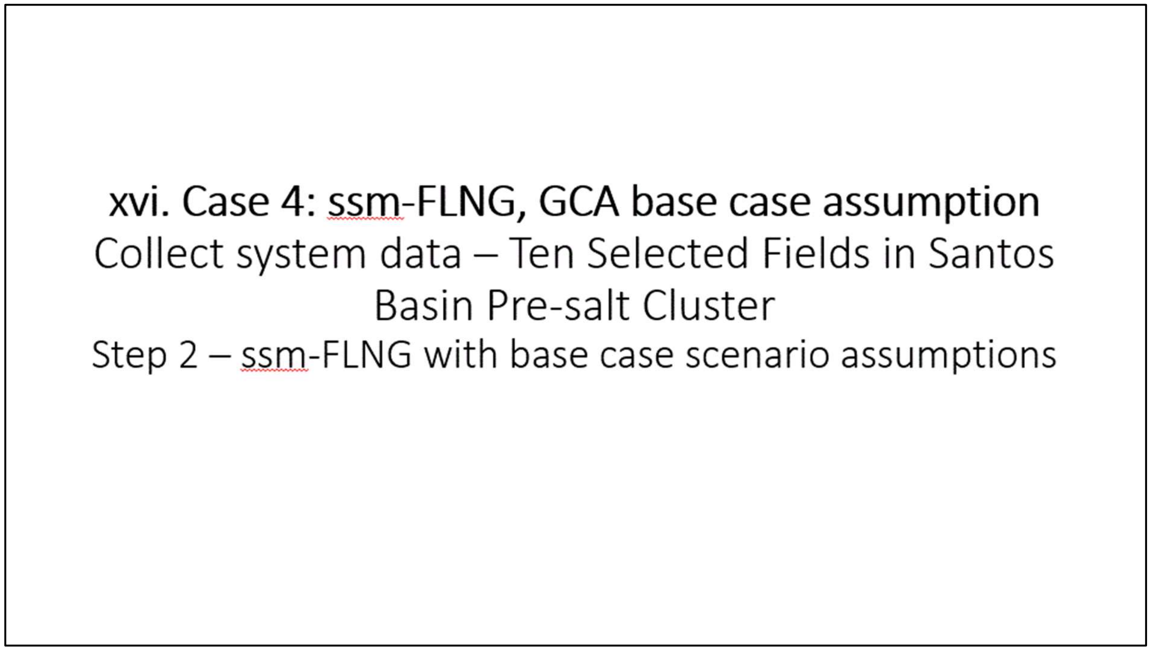


Figure 73 - Sixteenth scenario section, Case 4, which considers application of small-scale mobile Floating Liquefied Natural Gas (ssm-FLNG) and base case scenario assumptions

Case 4: s-FLNG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbb	Natural Gas Sale year MMscf	Oil price USD/bbl 75,98	Natural Gas Price USD/MM 4,00	Oil revenue MM USD 7,90%	Natural Gas revenue MM USD	Royalties MM USD 10%	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	EBITDA MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2019	1	32	41.610	18.822	22.788	6.211	26.552	3.764	22.788	32	0	77,50	4,08	2.267	0	227	135	1.836	0	1.905	-565	-513
2020	2	31	40.880	18.492	22.388	6.102	26.086	3.698	22.388	31	0	81,04	4,16	2.343	0	234	110	2.691	0	1.999	-1.307	-1.080
2021	3	69	39.055	17.667	21.388	5.830	24.922	3.533	21.388	69	0	84,24	4,24	5.325	0	532	523	1.109	0	4.269	1.957	1.470
2022	4	33	39.420	17.832	21.588	5.884	25.155	3.566	21.588	33	0	85,84	4,33	2.626	0	263	286	391	0	2.077	1.030	703
2023	5	238	274.845	124.326	150.519	41.028	175.384	24.865	150.519	238	43.729	86,94	4,42	19.055	186	1.924	1.097	19.418	0	16.220	-7.870	-4.887
2024	6	439	509.175	230.325	278.850	76.007	324.915	46.065	278.850	439	103.479	88,24	4,50	35.718	450	3.617	2.008	27.782	0	30.542	-6.172	-3.484
2025	7	647	746.425	337.645	408.780	111.423	476.309	67.529	408.780	647	148.048	89,54	4,59	53.372	656	5.403	2.861	27.710	0	45.764	4.743	2.434
2026	8	833	958.125	433.408	524.717	143.025	611.399	86.682	524.717	833	193.299	91,04	4,69	69.875	874	7.075	3.753	27.435	0	59.921	15.226	7.103
2027	9	948	1.087.335	491.856	595.479	162.312	693.850	98.371	595.479	948	222.588	92,64	4,78	80.914	1.026	8.194	4.439	21.346	0	69.307	28.230	11.972
2028	10	1.020	1.170.190	529.335	640.855	174.681	746.722	105.867	640.855	1.020	239.107	94,44	4,88	88.709	1.124	8.983	4.945	15.399	0	75.905	39.067	15.062
2029	11	1.052	1.207.055	546.011	661.044	180.184	770.246	109.202	661.044	1.052	240.175	96,34	4,97	93.343	1.152	9.450	5.396	12.121	0	79.650	45.236	15.855
2030	12	1.066	1.211.800	548.158	663.642	180.892	773.274	109.632	663.642	1.066	241.400	98,24	5,07	96.472	1.181	9.765	5.737	8.033	0	82.151	51.163	16.302
2031	13	1.082	1.219.465	551.625	667.840	182.036	778.165	110.325	667.840	1.082	243.148	100,24	5,17	99.885	1.213	10.110	6.112	8.500	0	84.877	52.827	15.302
2032	14	1.065	1.171.285	529.831	641.454	174.844	747.420	105.966	641.454	1.065	233.406	102,24	5,28	100.332	1.188	10.152	6.342	3.632	0	85.026	58.008	15.275
2033	15	1.039	1.134.785	513.320	621.465	169.396	724.129	102.664	621.465	1.039	226.077	104,34	5,38	99.832	1.174	10.101	6.559	2.964	0	84.346	58.135	13.917
2034	16	1.013	1.106.680	500.607	606.073	165.200	706.195	100.121	606.073	1.013	220.636	106,34	5,49	99.243	1.168	10.041	6.791	3.276	0	83.579	56.790	12.359
2035	17	988	1.077.480	487.398	590.082	160.841	687.562	97.480	590.082	988	214.787	108,54	5,60	98.778	1.160	9.994	7.003	2.827	0	82.941	56.217	11.122
2036	18	952	1.023.095	462.797	560.298	152.723	652.857	92.559	560.298	952	203.960	110,64	5,71	96.970	1.124	9.809	7.221	2.621	0	81.063	54.507	9.804
2037	19	893	947.540	428.620	518.920	141.445	604.644	85.724	518.920	893	188.669	112,90	5,83	92.840	1.060	9.390	7.428	1.871	0	77.082	52.362	8.562
2038	20	824	872.350	394.608	477.742	130.220	556.664	78.922	477.742	824	173.461	115,10	5,94	87.336	994	8.833	7.620	818	0	71.877	49.252	7.321

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 74 - Sixteenth scenario section, case 4, which considers application of small-scale mobile Floating Liquefied Natural Gas (LNG) and base case scenario assumptions

Case 4: s-FLNG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbb	Natural Gas Sale year MMscf	Oil price USD/bbl 75,98	Natural Gas Price USD/MM 4,00	Oil revenue MM USD 7,90%	Natural Gas revenue MM USD	Royalties MM USD 10%	OPEX MM USD	CAPEX MM	Aband. costs MM USD	EBITDA MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2040	22	675	695.325	314.530	380.795	103.795	443.701	62.906	380.795	675	137.719	119,80	6,18	74.470	821	7.529	7.937	0	112	59.825	41.485	5.096
2041	23	596	598.600	270.777	327.823	89.356	381.979	54.155	327.823	596	118.150	122,20	6,31	67.047	719	6.777	8.036	0	489	52.954	36.413	4.067
2042	24	523	512.825	231.976	280.849	76.552	327.244	46.395	280.849	523	100.812	124,60	6,43	60.028	625	6.065	8.066	0	475	46.522	32.100	3.259
2043	25	456	438.000	198.129	239.871	65.383	279.497	39.626	239.871	456	85.920	127,10	6,56	53.413	544	5.396	8.080	0	1.085	40.481	27.322	2.522
2044	26	396	374.855	169.566	205.289	55.957	239.202	33.913	205.289	396	73.311	129,60	6,69	47.275	473	4.775	8.004	0	1.699	34.970	22.921	1.923
2045	27	343	321.565	145.460	176.105	48.002	205.197	29.092	176.105	343	62.751	132,20	6,83	41.734	413	4.215	7.870	0	2.221	30.063	19.016	1.450
2046	28	296	277.765	125.647	152.118	41.464	177.247	25.129	152.118	296	48.106	134,90	6,96	36.782	323	3.710	7.618	0	2.741	25.776	15.592	1.081
2047	29	253	242.360	109.632	132.728	36.178	154.655	21.926	132.728	253	41.981	137,60	7,10	32.013	288	3.230	6.849	0	2.897	22.222	13.029	821
2048	30	219	226.665	102.532	124.133	33.836	144.639	20.506	124.133	219	39.639	140,30	7,25	28.349	277	2.863	6.479	0	3.214	19.284	10.775	617
2049	31	188	194.910	88.168	106.742	29.095	124.376	17.634	106.742	188	34.195	143,10	7,39	24.778	244	2.502	5.979	0	3.673	16.540	8.537	445
2050	32	164	171.550	77.601	93.949	25.608	109.469	15.520	93.949	164	23.648	146,00	7,54	21.991	172	2.216	5.476	0	3.747	14.470	7.079	335
2051	33	142	149.650	67.694	81.956	22.339	95.495	13.539	81.956	142	20.437	148,90	7,69	19.525	152	1.968	5.026	0	3.951	12.683	5.634	243
2052	34	126	132.130	59.769	72.361	19.724	84.315	11.954	72.361	126	17.670	151,90	7,84	17.569	134	1.770	4.406	0	4.172	11.526	4.798	188
2053	35	90	91.980	41.607	50.373	13.730	58.694	8.321	50.373	90	8.351	154,90	8,00	12.865	64	1.293	3.116	0	3.410	8.520	3.267	116
2054	36	58	59.860	27.078	32.782	8.936	38.198	5.416	32.782	58	0	158,00	8,16	8.448	0	845	2.218	0	2.465	5.385	1.778	58
2055	37	35	35.770	16.181	19.589	5.340	22.826	3.236	19.589	35	0	161,20	8,32	5.205	0	520	1.503	0	1.633	3.182	953	28
2056	38	17	18.615	8.420	10.195	2.779	11.879	1.684	10.195	17	0	164,40	8,49	2.545	0	254	956	0	1.214	1.334	8	0
2057	39	10	9.855	4.458	5.397	1.471	6.289	892	5.397	10	0	167,70	8,66	1.468	0	147	623	0	929	698	-241	-6
2058	40	5	5.540	2.506	3.034	827	3.535	501	3.034	5	0	171,00	8,83	863	0	86	325	0	633	452	-381	-8
Total		19.607	21.224.085	9.600.715	11.623.370	3.168.236	13.543.513	1.920.143	11.623.370	19.607	4.105.017	100,11	5,33	1.962.826	21.892	198.472	192.721	192.336	40.868	1.593.525	904.229	182.958

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 75: continuation of figure 74, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

xvii. Case 4.1: ssm-FLNG, Expected GOR and CO_2
Collect system data – Ten Selected Fields in Santos Basin Pre-salt Cluster
Step 2 – ssm-FLNG with expected assumptions

Figure 76 - Seventeenth scenario section, Case 4.1, which considers application of small-scale mobile Floating Liquefied Natural Gas (SSM-FLNG) and expected assumptions

Case 4.1': s-FLNG, Expected GOR, CO2 and CO2-WAG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl	Natural Gas Price USD/MM	Oil revenue MM USD	Nautral Gas revenue MM USD	Royalties MM USD	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	EBITDA MM	NET CASH FLOW MM USD	Discounted Cash Flow MM USD
												50,00	5,50	7,90%	0,00%	10,00%	0,00%	0,00%	0,00%	0,00%	0,0%	10,00%
2019	1	0	0	0	0	0	0	0	0	0	0	51,00	5,61	0	0	0	0	3.657	0	0	-3.676	-3.342
2020	2	0	0	0	0	0	0	0	0	0	0	53,33	5,72	0	0	0	0	3.657	0	0	-3.657	-3.022
2021	3	0	0	0	0	0	0	0	0	0	0	55,44	5,84	0	0	0	0	1.498	0	0	-1.498	-1.126
2022	4	617	877.553	396.961	480.592	130.997	559.984	79.392	480.592	617	0	56,49	5,95	32.104	0	3.210	6.085	531	0	22.809	14.572	9.953
2023	5	1.178	2.077.074	939.564	1.137.510	310.056	1.325.423	187.913	1.137.510	1.178	8.737	57,21	6,07	62.093	51	6.214	11.621	23.257	0	44.309	6.767	4.202
2024	6	1.151	2.184.903	988.341	1.196.562	326.152	1.394.230	197.668	1.196.562	1.151	79.164	58,07	6,19	61.560	473	6.203	11.351	35.241	0	44.478	-4.486	-2.532
2025	7	1.124	2.315.945	1.047.618	1.268.327	345.714	1.477.851	209.524	1.268.327	1.124	204.964	58,92	6,32	60.984	1.249	6.223	11.082	40.893	0	44.928	-8.994	-4.615
2026	8	1.096	2.443.327	1.105.239	1.338.088	364.729	1.559.136	221.048	1.338.088	1.096	296.045	59,91	6,44	60.498	1.840	6.234	10.813	30.162	0	45.292	2.849	1.329
2027	9	1.069	2.544.939	1.151.203	1.393.736	379.897	1.623.976	230.241	1.393.736	1.069	375.283	60,96	6,57	60.028	2.379	6.241	10.543	21.912	0	45.623	12.037	5.105
2028	10	1.042	2.624.084	1.187.004	1.437.079	391.711	1.674.480	237.401	1.437.079	1.042	434.067	62,15	6,70	59.630	2.806	6.244	10.274	16.234	0	45.919	18.504	7.134
2029	11	1.014	2.675.803	1.210.399	1.465.403	399.432	1.707.483	242.080	1.465.403	1.014	469.521	63,40	6,84	59.234	3.096	6.233	10.004	9.807	0	46.093	25.464	8.925
2030	12	987	2.789.819	1.261.975	1.527.845	416.452	1.780.240	252.395	1.527.845	987	519.232	64,65	6,98	58.776	3.493	6.227	9.735	8.923	0	46.307	26.713	8.512
2031	13	960	2.816.790	1.274.175	1.542.615	420.478	1.797.450	254.835	1.542.615	960	568.108	65,96	7,11	58.313	3.898	6.221	9.465	11.172	0	46.524	24.970	7.233
2032	14	933	2.933.775	1.327.093	1.606.682	437.941	1.872.101	265.419	1.606.682	933	593.267	67,28	7,26	57.783	4.152	6.193	9.196	1.976	0	46.546	34.395	9.057
2033	15	905	3.087.992	1.396.853	1.691.139	460.962	1.970.509	279.371	1.691.139	905	626.542	68,66	7,40	57.242	4.472	6.171	8.926	0	0	46.617	36.325	8.696
2034	16	878	3.235.991	1.463.800	1.772.190	483.054	2.064.950	292.760	1.772.190	878	664.639	69,98	7,55	56.578	4.839	6.142	8.657	0	0	46.619	35.799	7.791
2035	17	851	3.435.994	1.554.272	1.881.722	512.910	2.192.577	310.854	1.881.722	851	710.561	71,43	7,70	55.952	5.277	6.123	8.387	0	0	46.718	35.264	6.977
2036	18	823	3.558.874	1.609.857	1.949.017	531.253	2.270.989	321.971	1.949.017	823	760.245	72,81	7,86	55.202	5.759	6.096	8.118	0	0	46.747	34.607	6.224
2037	19	796	3.800.161	1.719.003	2.081.158	567.271	2.424.958	343.801	2.081.158	796	768.980	74,30	8,01	54.460	5.942	6.040	7.849	0	0	46.513	34.185	5.589
2038	20	769	3.920.866	1.773.604	2.147.262	585.289	2.501.983	354.721	2.147.262	769	796.701	75,74	8,17	53.615	6.279	5.989	7.579	0	0	46.326	33.334	4.955

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 77 - seventeenth scenario section, Case 4.1, which considers application of small-scale mobile Floating Liquefied Natural Gas (ssm-FLNG) and expected assumptions.

Case 4.1: s-FLNG, Expected GOR and CO2, WAG

Year	Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas year MMscf	Gas injection year MMscf	Natural Gas year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 50,00	Natural Gas Price USD/MM 5,50	Oil revenue MM USD 7,90%	Nautral Gas MM USD 0,00%	Royalties MM USD 10,00%	OPEX MM USD 0,00%	CAPEX MM 0,00%	Aband. costs MM USD 0,00%	EBITDA MM USD 0,00%	NET CASH MM USD 0,0%	Discounted Cash Flow MM USD 10,00%
2039 21	751	3.841.883	1.679.320	2.162.563	554.176	2.498.427	335.864	2.162.563	751	780.152	77,26	8,34	53.309	6.271	5.958	7.785	556	114	45.837	32.023	4.327
2040 22	675	3.578.003	1.563.533	2.014.471	515.966	2.327.177	312.707	2.014.471	675	726.506	78,84	8,50	48.867	5.957	5.482	7.921	0	116	41.421	29.431	3.615
2041 23	596	3.058.941	1.318.825	1.740.117	435.212	2.003.882	263.765	1.740.117	596	611.942	80,42	8,67	43.988	5.118	4.911	8.006	0	494	36.190	25.390	2.835
2042 24	523	2.776.566	1.196.856	1.579.710	394.962	1.819.081	239.371	1.579.710	523	555.301	82,00	8,85	39.375	4.737	4.411	8.055	0	481	31.646	22.328	2.267
2043 25	456	2.462.560	1.060.865	1.401.695	350.085	1.613.868	212.173	1.401.695	456	492.086	83,64	9,02	35.028	4.282	3.931	8.046	0	1.124	27.333	18.702	1.726
2044 26	396	2.162.330	931.623	1.230.706	307.436	1.417.031	186.325	1.230.706	396	431.845	85,29	9,20	30.996	3.833	3.483	7.979	0	1.778	23.367	15.285	1.282
2045 27	343	2.214.033	952.661	1.261.372	314.378	1.451.904	190.532	1.261.372	343	442.301	87,00	9,39	27.357	4.004	3.136	7.897	535	2.340	20.328	11.995	915
2046 28	296	1.303.250	562.651	740.599	185.675	853.129	112.530	740.599	296	259.374	88,77	9,58	24.103	2.395	2.650	7.598	0	2.901	16.250	9.144	634
2047 29	253	252.781	113.080	139.701	37.316	162.317	22.616	139.701	253	49.556	90,55	9,77	20.971	467	2.144	6.796	0	3.094	12.498	6.467	408
2048 30	219	230.019	102.972	127.047	33.981	147.641	20.594	127.047	219	45.164	92,33	9,96	18.566	434	1.900	6.479	0	3.449	10.620	4.835	277
2049 31	188	205.937	92.304	113.633	30.460	132.094	18.461	113.633	188	40.232	94,17	10,16	16.220	394	1.661	5.980	0	4.002	8.973	3.214	167
2050 32	164	182.761	81.437	101.324	26.874	117.611	16.287	101.324	164	36.224	96,08	10,36	14.390	362	1.475	5.476	0	4.083	7.800	2.325	110
2051 33	142	160.568	71.206	89.362	23.498	103.603	14.241	89.362	142	31.611	97,99	10,57	12.770	322	1.309	5.026	0	4.294	6.757	1.337	58
2052 34	126	134.106	62.293	71.814	20.557	84.272	12.459	71.814	126	28.301	99,96	10,78	11.486	294	1.178	4.379	0	4.553	6.223	880	34
2053 35	90	93.549	43.330	50.219	14.299	58.885	8.666	50.219	90	14.300	101,93	11,00	8.421	152	857	3.116	0	3.765	4.599	324	12
2054 36	58	48.761	22.685	26.076	7.486	30.613	4.537	26.076	58	6.905	103,97	11,22	5.531	75	561	2.218	0	2.768	2.827	-214	-7
2055 37	35	21.877	10.154	11.723	3.351	13.754	2.031	11.723	35	0	106,08	11,44	3.425	0	343	1.503	0	1.861	1.580	-355	-10
2056 38	17	8.816	3.988	4.828	1.316	5.626	798	4.828	17	0	108,19	11,67	1.674	0	167	956	0	1.403	551	-852	-23
2057 39	10	0	0	0	0	0	0	0	10	0	110,36	11,91	966	0	97	623	0	1.082	246	-835	-20
2058 40	5	0	0	0	0	0	0	0	5	0	112,53	12,14	569	0	57	325	0	746	187	-827	-18
Total	19.607	62.018.430	27.387.542	34.630.888	9.037.889	40.108.397	5.477.508	34.630.888	19.607	12.486.153	65,65	7,65	1.287.144	95.467	138.261	193.360	208.921	44.448	1.050.991	527.237	92.764

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 78: continuation of Figure 77, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

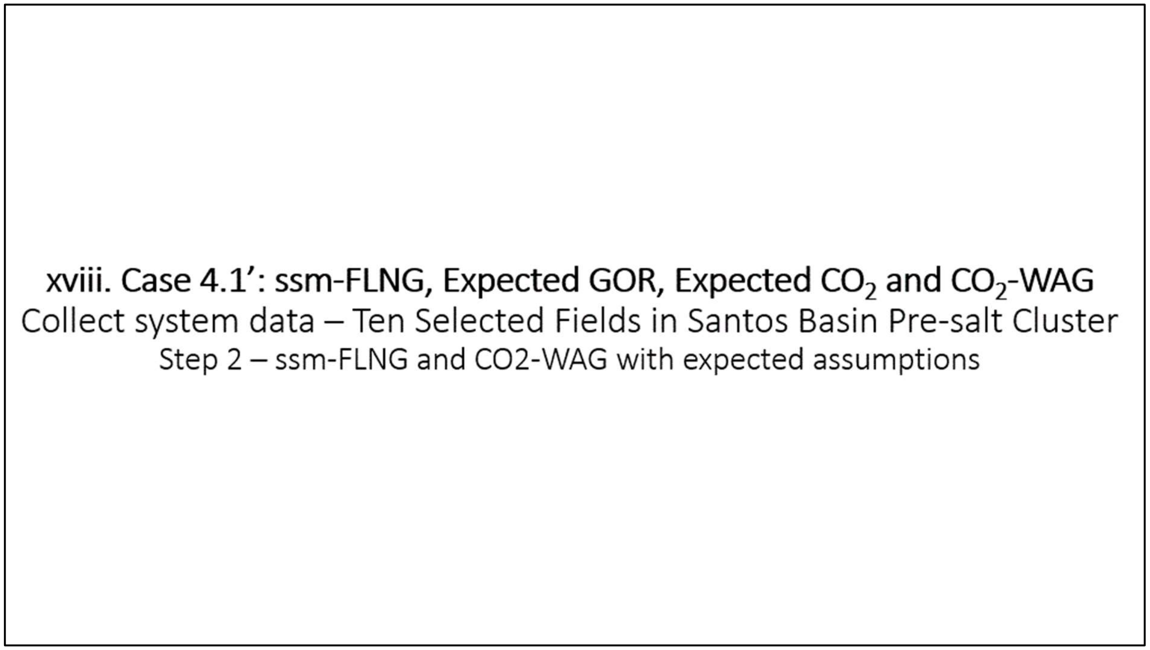


Figure 79 - Eighteenth scenario section, Case 4.1’, which considers application of small-scale mobile Floating Liquefied Natural Gas (ssm-FLNG) combined with CO_2-WAG as an enhanced oil recovery method and expected assumptions.

Case 4.1': s-FLNG, Expected GOR, CO2 and CO2-WAG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf
2019	1	0	0	0	0	0	0	0	0	0	0
2020	2	0	0	0	0	0	0	0	0	0	0
2021	3	0	0	0	0	0	0	0	0	0	0
2022	4	617	877.553	396.961	480.592	130.997	559.984	79.392	480.592	617	0
2023	5	1.178	2.077.074	939.564	1.137.510	310.056	1.325.423	187.913	1.137.510	1.178	8.737
2024	6	1.151	2.184.903	988.341	1.196.562	326.152	1.394.230	197.668	1.196.562	1.151	79.164
2025	7	1.124	2.315.945	1.047.618	1.268.327	345.714	1.477.851	209.524	1.268.327	1.124	204.964
2026	8	1.096	2.443.327	1.105.239	1.338.088	364.729	1.559.136	221.048	1.338.088	1.096	296.045
2027	9	1.069	2.544.939	1.151.203	1.393.736	379.897	1.623.976	230.241	1.393.736	1.069	375.283
2028	10	1.042	2.624.084	1.187.004	1.437.079	391.711	1.674.480	237.401	1.437.079	1.042	434.067
2029	11	1.014	2.675.803	1.210.399	1.465.403	399.432	1.707.483	242.080	1.465.403	1.014	469.521
2030	12	987	2.789.819	1.261.975	1.527.845	416.452	1.780.240	252.395	1.527.845	987	519.232
2031	13	960	2.816.790	1.274.175	1.542.615	420.478	1.797.450	254.835	1.542.615	960	568.108
2032	14	933	2.933.775	1.327.093	1.606.682	437.941	1.872.101	265.419	1.606.682	933	593.267
2033	15	905	3.087.992	1.396.853	1.691.139	460.962	1.970.509	279.371	1.691.139	905	626.542
2034	16	878	3.235.991	1.463.800	1.772.190	483.054	2.064.950	292.760	1.772.190	878	664.639
2035	17	851	3.435.994	1.554.272	1.881.722	512.910	2.192.577	310.854	1.881.722	851	710.561
2036	18	823	3.558.874	1.609.857	1.949.017	531.253	2.270.989	321.971	1.949.017	823	760.245
2037	19	796	3.800.161	1.719.003	2.081.158	567.271	2.424.958	343.801	2.081.158	796	768.980
2038	20	769	3.920.866	1.773.604	2.147.262	585.289	2.501.983	354.721	2.147.262	769	796.701

Year		Oil price USD/bbl 50,00	Natural Gas Price USD/MM 5,50	Oil revenue MM USD 7,90%	Nautral Gas revenue MM USD 0,00%	Royalties MM USD 10,00%	OPEX MM USD 0,00%	CAPEX MM USD 0,00%	Aband. costs MM USD 0,00%	EBITDA MM 0,00%	NET CASH FLOW MM USD 0,0%	Discounted Cash Flow MM USD 10,00%
2019	1	51,00	5,61	0	0	0	0	3.657	0	0	-3.676	-3.342
2020	2	53,33	5,72	0	0	0	0	3.657	0	0	-3.657	-3.022
2021	3	55,44	5,84	0	0	0	0	1.498	0	0	-1.498	-1.126
2022	4	56,49	5,95	32.104	0	3.210	6.085	531	0	22.809	14.572	9.953
2023	5	57,21	6,07	62.093	51	6.214	11.621	23.257	0	44.309	6.767	4.202
2024	6	58,07	6,19	61.560	473	6.203	11.351	35.241	0	44.478	-4.486	-2.532
2025	7	58,92	6,32	60.984	1.249	6.223	11.082	40.893	0	44.928	-8.994	-4.615
2026	8	59,91	6,44	60.498	1.840	6.234	10.813	30.162	0	45.292	2.849	1.329
2027	9	60,96	6,57	60.028	2.379	6.241	10.543	21.912	0	45.623	12.037	5.105
2028	10	62,15	6,70	59.630	2.806	6.244	10.274	16.234	0	45.919	18.504	7.134
2029	11	63,40	6,84	59.234	3.096	6.233	10.004	9.807	0	46.093	25.464	8.925
2030	12	64,65	6,98	58.776	3.493	6.227	9.735	8.923	0	46.307	26.713	8.512
2031	13	65,96	7,11	58.313	3.898	6.221	9.465	11.172	0	46.524	24.970	7.233
2032	14	67,28	7,26	57.783	4.152	6.193	9.196	1.976	0	46.546	34.395	9.057
2033	15	68,66	7,40	57.242	4.472	6.171	8.926	0	0	46.617	36.325	8.696
2034	16	69,98	7,55	56.578	4.839	6.142	8.657	0	0	46.619	35.799	7.791
2035	17	71,43	7,70	55.952	5.277	6.123	8.387	0	0	46.718	35.264	6.977
2036	18	72,81	7,86	55.202	5.759	6.096	8.118	0	0	46.747	34.607	6.224
2037	19	74,30	8,01	54.460	5.942	6.040	7.849	0	0	46.513	34.185	5.589
2038	20	75,74	8,17	53.615	6.279	5.989	7.579	0	0	46.326	33.334	4.955

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 80 - Eighteenth scenario section, Case 4.1', which considers application of small-scale mobile Floating Liquefied Natural Gas (LNG), combined with CO_2-WAG as an enhanced oil recovery method a and high assumptions

Case 4.1': s-FLNG, Expected GOR, CO2 and CO2-WAG

Year	Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 50,00	Natural Gas Price USD/MM 5,50	Oil revenue MM USD 7,90%	Nautral Gas revenue MM USD 0,00%	Royalties MM USD 10,00%	OPEX MM USD 0,00%	CAPEX MM USD 0,00%	Aband. costs MM USD 0,00%	EBITDA MM 0,00%	NET CASH FLOW MM USD 0,0%	Discounted Cash Flow MM USD 10,00%
2040 22	714	3.910.821	1.769.060	2.141.761	583.790	2.495.573	353.812	2.141.761	714	726.506	78,84	8,50	51.837	5.957	5.779	7.040	0	116	44.975	31.807	3.907
2041 23	687	3.469.048	1.569.224	1.899.824	517.844	2.213.669	313.845	1.899.824	687	611.942	80,42	8,67	50.852	5.118	5.597	6.771	0	494	43.602	30.366	3.391
2042 24	659	3.456.153	1.563.391	1.892.762	515.919	2.205.440	312.678	1.892.762	659	555.301	82,00	8,85	49.788	4.737	5.452	6.501	0	481	42.571	29.622	3.007
2043 25	613	3.272.077	1.480.124	1.791.953	488.441	2.087.978	296.025	1.791.953	613	492.086	83,64	9,02	47.224	4.282	5.151	6.054	0	1.124	40.301	27.337	2.523
2044 26	0	68	31	37	10	43	6	37	0	431.845	85,29	9,20	6	3.833	384	1	0	1.778	3.454	1.449	122
2045 27	0	0	0	0	0	0	0	0	0	442.301	87,00	9,39	0	4.004	400	0	0	2.340	3.604	871	66
2046 28	0	0	0	0	0	0	0	0	0	259.374	88,77	9,58	0	2.395	240	0	0	2.901	2.156	-757	-53
2047 29	0	0	0	0	0	0	0	0	0	49.556	90,55	9,77	0	467	47	0	0	3.094	420	-2.674	-169
2048 30	0	0	0	0	0	0	0	0	0	45.164	92,33	9,96	0	434	43	0	0	3.449	391	-3.059	-175
2049 31	0	0	0	0	0	0	0	0	0	40.232	94,17	10,16	0	394	39	0	0	4.002	355	-3.647	-190
2050 32	0	0	0	0	0	0	0	0	0	36.224	96,08	10,36	0	362	36	0	0	4.083	326	-3.758	-178
2051 33	0	0	0	0	0	0	0	0	0	31.611	97,99	10,57	0	322	32	0	0	4.294	290	-4.004	-172
2052 34	0	0	0	0	0	0	0	0	0	28.301	99,96	10,78	0	294	29	0	0	4.553	265	-4.288	-168
2053 35	0	0	0	0	0	0	0	0	0	14.300	101,93	11,00	0	152	15	0	0	3.765	137	-3.628	-129
2054 36	0	0	0	0	0	0	0	0	0	6.905	103,97	11,22	0	75	7	0	0	2.768	67	-2.701	-87
2055 37	0	0	0	0	0	0	0	0	0	0	106,08	11,44	0	0	0	0	0	1.861	0	-1.861	-55
2056 38	0	0	0	0	0	0	0	0	0	0	108,19	11,67	0	0	0	0	0	1.403	0	-1.403	-38
2057 39	0	0	0	0	0	0	0	0	0	0	110,36	11,91	0	0	0	0	0	1.082	0	-1.082	-26
2058 40	0	0	0	0	0	0	0	0	0	0	112,53	12,14	0	0	0	0	0	746	0	-1.006	-22
Total	19.607	65.376.195	29.572.922	35.803.273	9.759.064	41.717.857	5.914.584	35.803.273	19.607	12.427.858	62,04	7,65	1.216.503	95.101	131.160	193.362	208.921	44.448	987.082	473.621	102.999

Figure 81 - Continuation of Figure 80, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

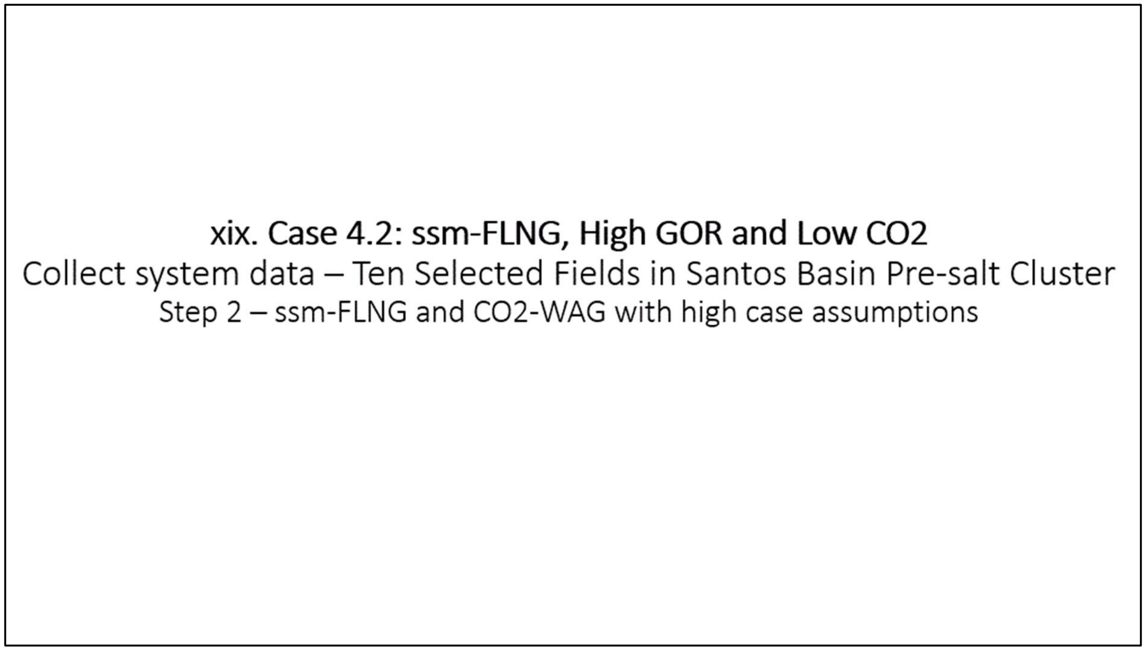


Figure 82 - Nineteenth scenario section, Case 4.2, which considers application of small-scale mobile Floating Liquefied Natural Gas (ssm-FLNG) and high case scenario assumptions

Case 4.2: s-FLNG, High GOR and Low CO2, WAG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 75,00	Natural Gas Price USD/MM 8,25	Oil revenue MM USD 7,90%	Nautral Gas revenue MM USD	Royalties MM USD 10%	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	EBITDA MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2020	1	32	41.610	26.174	15.436	8.638	20.671	5.235	15.436	32	0	76,50	8,42	2.237	0	224	135	1.836	0	1.879	-582	-529
2020	2	31	40.880	25.715	15.165	8.486	20.308	5.143	15.165	31	0	79,99	8,58	2.313	0	231	110	2.691	0	1.971	-1.325	-1.095
2021	3	69	39.055	24.567	14.488	8.107	19.401	4.913	14.488	69	0	83,15	8,75	5.230	0	523	523	1.109	0	4.184	1.901	1.428
2022	4	33	39.420	24.797	14.623	8.183	19.583	4.959	14.623	33	0	84,73	8,93	2.592	0	259	286	391	0	2.047	1.009	689
2023	5	238	732.042	412.300	319.742	136.059	402.202	82.460	319.742	238	209.541	85,82	9,11	18.668	1.841	2.051	1.195	22.414	0	17.262	-10.127	-6.288
2024	6	439	1.490.876	833.409	657.467	275.025	824.149	166.682	657.467	439	403.042	87,10	9,29	35.027	3.611	3.864	2.074	29.815	0	32.701	-6.695	-3.779
2025	7	647	2.268.164	1.267.118	1.001.046	418.149	1.254.469	253.424	1.001.046	647	598.575	88,39	9,48	52.363	5.470	5.783	2.982	31.348	0	49.068	3.433	1.762
2026	8	833	2.999.666	1.673.424	1.326.242	552.230	1.660.927	334.685	1.326.242	833	788.774	89,87	9,67	68.594	7.352	7.595	3.853	30.217	0	64.499	15.660	7.306
2027	9	948	3.573.221	1.989.220	1.584.001	656.443	1.981.845	397.844	1.584.001	948	940.397	91,45	9,86	79.500	8.941	8.844	4.505	23.272	0	75.092	30.350	12.871
2028	10	1.020	4.031.008	2.233.278	1.797.730	736.982	2.244.385	446.656	1.797.730	1.020	1.059.148	93,22	10,06	87.222	10.271	9.749	5.052	18.395	0	82.693	40.830	15.742
2029	11	1.052	4.449.908	2.455.259	1.994.649	810.236	2.485.701	491.052	1.994.649	1.052	1.167.457	95,10	10,26	91.820	11.548	10.337	5.486	14.047	0	87.546	48.832	17.115
2030	12	1.066	4.797.250	2.639.325	2.157.925	870.977	2.685.790	527.865	2.157.925	1.066	1.257.264	96,97	10,46	94.927	12.685	10.761	5.823	10.173	0	91.029	55.230	17.598
2031	13	1.082	5.133.702	2.818.467	2.315.235	930.094	2.878.928	563.693	2.315.235	1.082	1.344.003	98,95	10,67	98.311	13.832	11.214	6.192	10.533	0	94.736	57.684	16.709
2032	14	1.065	5.118.320	2.807.595	2.310.725	926.506	2.872.244	561.519	2.310.725	1.065	1.341.010	100,92	10,89	98.764	14.077	11.284	6.332	3.632	0	95.225	65.122	17.149
2033	15	1.039	5.072.035	2.781.094	2.290.941	917.761	2.847.160	556.219	2.290.941	1.039	1.330.019	102,99	11,10	98.283	14.241	11.252	6.565	3.392	0	94.706	64.927	15.543
2034	16	1.013	5.055.925	2.770.778	2.285.147	914.357	2.839.303	554.156	2.285.147	1.013	1.304.051	104,97	11,33	97.709	14.242	11.195	6.770	3.276	0	93.986	64.040	13.937
2035	17	988	5.051.337	2.767.276	2.284.062	913.201	2.837.517	553.455	2.284.062	988	1.303.683	107,14	11,55	97.258	14.523	11.178	7.021	3.255	0	93.582	63.194	12.503
2036	18	952	4.875.103	2.670.522	2.204.581	881.272	2.738.686	534.104	2.204.581	952	1.236.713	109,21	11,78	95.482	14.052	10.953	7.220	2.621	0	91.360	61.685	11.095
2037	19	893	4.532.832	2.482.642	2.050.190	819.272	2.546.718	496.528	2.050.190	893	1.149.603	111,44	12,02	91.411	13.324	10.474	7.423	1.871	0	86.839	59.183	9.677
2038	20	824	4.197.333	2.299.163	1.898.170	758.724	2.358.003	459.833	1.898.170	824	1.064.371	113,62	12,26	85.986	12.583	9.857	7.613	818	0	81.098	55.720	8.282
2039	21	751	3.854.334	2.111.007	1.743.327	696.632	2.165.528	422.201	1.743.327	751	977.205	115,89	12,50	79.963	11.783	9.175	7.784	556	115	74.787	51.394	6.945

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 83 - Nineteenth scenario section, Case 4.2, which considers application of small-scale mobile Floating Liquefied Natural Gas (LNG) and high case scenario assumptions

Case 4.2: s-FLNG, High GOR and Low CO2, WAG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bbl 75,00	Natural Gas Price USD/MM 8,25	Oil revenue MM USD 7,90%	Nautral Gas revenue MM USD	Royalties MM USD 10%	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	EBITDA MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD 10,00%
2039	21	751	3.854.334	2.111.007	1.743.327	696.632	2.165.528	422.201	1.743.327	751	977.205	115,89	12,50	79.963	11.783	9.175	7.784	556	115	74.787	51.394	6.945
2040	22	675	3.437.078	1.882.289	1.554.790	621.155	1.931.248	376.458	1.554.790	675	870.990	118,25	12,75	73.301	10.713	8.401	7.922	0	117	67.690	47.052	5.780
2041	23	596	2.978.207	1.631.405	1.346.801	538.364	1.673.083	326.281	1.346.801	596	754.162	120,62	13,01	65.982	9.461	7.544	8.029	0	495	59.870	41.352	4.618
2042	24	523	2.552.257	1.398.401	1.153.856	461.472	1.433.536	279.680	1.153.856	523	645.848	122,99	13,27	59.062	8.264	6.733	8.058	0	483	52.536	36.441	3.700
2043	25	456	2.148.121	1.177.022	971.099	388.417	1.206.503	235.404	971.099	456	543.056	125,46	13,53	52.542	7.088	5.963	8.065	0	1.138	45.601	30.986	2.860
2044	26	396	1.820.874	998.148	822.726	329.389	1.022.356	199.630	822.726	396	459.880	127,93	13,81	46.494	6.122	5.262	8.009	0	1.809	39.346	25.994	2.181
2045	27	343	1.536.999	842.773	694.225	278.115	862.780	168.555	694.225	343	387.861	130,49	14,08	41.035	5.267	4.630	7.857	0	2.386	33.815	21.560	1.645
2046	28	296	1.293.832	709.738	584.094	234.213	726.042	141.948	584.094	296	326.050	133,16	14,36	36.155	4.516	4.067	7.605	0	2.974	28.999	17.671	1.225
2047	29	253	1.109.321	607.991	501.329	200.637	622.928	121.598	501.329	253	263.815	135,83	14,65	31.456	3.727	3.518	6.847	0	3.184	24.818	14.610	921
2048	30	219	1.051.901	576.094	475.808	190.111	591.026	115.219	475.808	219	250.764	138,49	14,94	27.849	3.614	3.146	6.479	0	3.554	21.837	12.223	700
2049	31	188	893.105	488.816	404.289	161.309	502.053	97.763	404.289	188	211.333	141,25	15,24	24.330	3.106	2.744	5.979	0	4.144	18.714	9.571	499
2050	32	164	775.159	424.152	351.007	139.970	435.837	84.830	351.007	164	182.680	144,12	15,55	21.584	2.739	2.432	5.465	0	4.228	16.426	7.924	375
2051	33	142	672.262	367.719	304.543	121.347	378.087	73.544	304.543	142	151.134	146,98	15,86	19.155	2.311	2.147	5.026	0	4.441	14.294	6.207	267
2052	34	126	585.981	320.492	265.490	105.762	329.588	64.098	265.490	126	130.853	149,94	16,18	17.230	2.041	1.927	4.406	0	4.716	12.938	5.185	203
2053	35	90	436.011	238.343	197.668	78.653	245.336	47.669	197.668	90	99.723	152,90	16,50	12.631	1.587	1.422	3.116	0	3.903	9.679	3.540	126
2054	36	58	293.600	159.350	134.250	52.585	166.120	31.870	134.250	58	69.511	155,96	16,83	8.296	1.128	942	2.200	0	2.885	6.281	1.949	63
2055	37	35	192.413	104.900	87.513	34.617	108.493	20.980	87.513	35	42.781	159,12	17,17	5.138	708	585	1.503	0	1.947	3.759	1.020	30
2056	38	17	108.040	58.726	49.313	19.380	61.059	11.745	49.313	17	24.841	162,28	17,51	2.512	419	293	956	0	1.475	1.682	-24	-1
2057	39	10	59.636	32.299	27.337	10.659	33.797	6.460	27.337	10	15.180	165,54	17,86	1.449	261	171	623	0	1.140	917	-307	-7
2058	40	5	38.493	20.764	17.728	6.852	21.881	4.153	17.728	5	0	168,79	18,22	854	0	85	325	0	790	443	-618	-14
		19.607	89.377.312	49.152.553	40.224.759	16.220.343	50.055.270	9.830.511	40.224.759	19.607	22.905.320	98,47	11,24	1.930.717	257.450	218.817	193.416	215.662	45.924	1.775.934	1.003.801	199.830

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 84 - Continuation of Figure 83, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

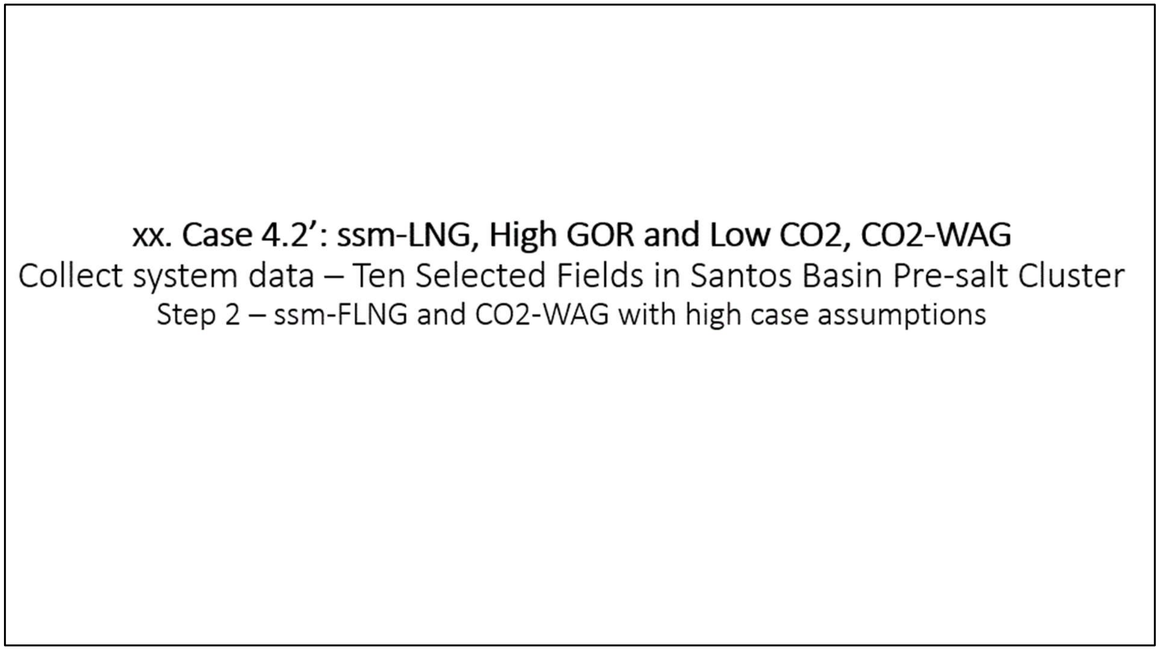


Figure 85 - Twentieth scenario section, Case 4.2, which considers application of small-scale mobile Floating Liquefied Natural Gas (ssm-FLNG) and high case scenario assumptions

Case 4.2': s-FLNG, High GOR, Low CO2 and CO2-WAG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bb 75,00	Natural Gas Price USD/MM 8,25	Oil revenue MM USD 7,90%	Nautral Gas revenue MM USD 0,00%	Royalties MM USD 10,00%	OPEX MM USD 0,00%	CAPEX MM USD 0,00%	Aband. costs MM USD 0,00%	EBITDA MM USD 0,00%	NET CASH FLOW MM USD 0,00	Discounted Cash Flow MM USD 10,00%
2019	1	0	0	0	0	0	0	0	0	0	0	76,50	8,42	0	0	0	0	2.669	0	0	-2.688	-2.444
2020	2	0	0	0	0	0	0	0	0	0	0	79,99	8,58	0	0	0	0	3.506	0	0	-3.506	-2.898
2021	3	0	0	0	0	0	0	0	0	0	0	83,15	8,75	0	0	0	0	1.762	0	0	-1.762	-1.324
2022	4	741	363.083	204.009	159.074	67.323	199.876	40.802	159.074	741	0	84,73	8,93	57.802	0	5.780	7.307	541	0	44.715	29.021	19.822
2023	5	1.414	4.556.510	2.560.212	1.996.298	844.870	2.508.340	512.042	1.996.298	1.414	177.914	85,82	9,11	111.769	1.563	11.333	13.949	30.456	0	88.049	28.550	17.728
2024	6	1.381	3.428.697	1.926.517	1.502.181	635.750	1.887.484	385.303	1.502.181	1.381	379.243	87,10	9,29	110.810	3.398	11.421	13.626	41.599	0	89.161	18.785	10.604
2025	7	1.349	4.351.985	2.445.293	1.906.692	806.947	2.395.750	489.059	1.906.692	1.349	579.166	88,39	9,48	109.774	5.293	11.507	13.303	46.038	0	90.257	15.928	8.174
2026	8	1.316	4.605.998	2.588.018	2.017.980	854.046	2.535.583	517.604	2.017.980	1.316	771.104	89,87	9,67	108.899	7.188	11.609	12.979	31.184	0	91.499	32.514	15.168
2027	9	1.283	5.513.255	3.097.788	2.415.467	1.022.270	3.035.025	619.558	2.415.467	1.283	921.213	91,45	9,86	108.052	8.759	11.681	12.656	25.003	0	92.474	40.090	17.002
2028	10	1.250	5.714.372	3.210.791	2.503.581	1.059.561	3.145.739	642.158	2.503.581	1.250	1.036.033	93,22	10,06	107.337	10.047	11.738	12.332	18.190	0	93.313	48.044	18.523
2029	11	1.217	5.798.071	3.257.820	2.540.251	1.075.081	3.191.815	651.564	2.540.251	1.217	1.141.489	95,10	10,26	106.625	11.291	11.792	12.009	12.650	0	94.116	54.564	19.125
2030	12	1.185	6.044.588	3.396.333	2.648.255	1.120.790	3.327.521	679.267	2.648.255	1.185	1.229.292	96,97	10,46	105.800	12.403	11.820	11.686	8.616	0	94.697	59.208	18.866
2031	13	1.152	6.101.249	3.428.170	2.673.079	1.131.296	3.358.713	685.634	2.673.079	1.152	1.314.614	98,95	10,67	104.966	13.529	11.850	11.362	898	0	95.284	67.680	19.605
2032	14	1.119	6.359.586	3.573.324	2.786.262	1.179.197	3.500.927	714.665	2.786.262	1.119	1.310.486	100,92	10,89	104.013	13.757	11.777	11.039	872	0	94.954	67.703	17.828
2033	15	1.086	6.707.227	3.768.657	2.938.570	1.243.657	3.692.302	753.731	2.938.570	1.086	1.298.558	102,99	11,10	103.040	13.904	11.694	10.715	804	0	94.534	67.402	16.135
2034	16	1.053	7.041.702	3.956.592	3.085.110	1.305.675	3.876.429	791.318	3.085.110	1.053	1.288.047	104,97	11,33	101.846	14.067	11.591	10.392	775	0	93.930	66.504	14.473
2035	17	1.021	7.490.447	4.208.733	3.281.715	1.388.882	4.123.461	841.747	3.281.715	1.021	1.287.415	107,14	11,55	100.718	14.342	11.506	10.069	747	0	93.485	65.638	12.986
2036	18	988	7.762.730	4.361.723	3.401.007	1.439.368	4.273.352	872.345	3.401.007	988	1.236.713	109,21	11,78	99.369	14.052	11.342	9.745	394	0	92.334	64.555	11.611
2037	19	955	8.324.911	4.677.601	3.647.310	1.543.608	4.582.830	935.520	3.647.310	955	1.149.603	111,44	12,02	98.034	13.324	11.136	9.422	0	0	90.800	63.669	10.410
2038	20	922	8.595.406	4.829.587	3.765.819	1.593.764	4.731.737	965.917	3.765.819	922	1.064.371	113,62	12,26	96.514	12.583	10.910	9.099	0	0	89.088	61.812	9.188

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 86 - Twentieth scenario section, Case 4.2', which considers application of small-scale mobile Floating Liquefied Natural Gas (LNG), combined with CO_2-WAG as an enhanced oil recovery method and high case scenario assumptions

Case 4.2': s-FLNG, High GOR, Low CO2 and CO2-WAG

Year		Oil production year MMbbl	Gas production year MMscf	Natural Gas Production year MMscf	CO2 Production year MMscf	Natural Gas Demand (fuel) year MMscf	Gas injection year MMscf	Natural Gas injection year MMscf	CO2 injection year MMscf	Oil sale year MMbbl	Natural Gas Sale year MMscf	Oil price USD/bb	Natural Gas Price USD/MM	Oil revenue MM USD	Nautral Gas revenue MM USD	Royalties MM USD	OPEX MM USD	CAPEX MM USD	Aband. costs MM USD	EBITDA MM USD	NET CASH FLOW MM USD	Discounted Cash Flow MM USD
												75,00	8,25	7,90%	0,00%	10,00%	0,00%	0,00%	0,00%	0,00%	0,00	10,00%
2040	22	0	0	0	0	0	0	0	0	0	870.990	118,25	12,75	0	10.713	1.071	0	0	117	9.641	8.355	1.026
2041	23	0	0	0	0	0	0	0	0	0	754.162	120,62	13,01	0	9.461	946	0	0	495	8.515	7.014	783
2042	24	0	0	0	0	0	0	0	0	0	645.848	122,99	13,27	0	8.264	826	0	0	483	7.438	6.179	627
2043	25	0	0	0	0	0	0	0	0	0	543.056	125,46	13,53	0	7.088	709	0	0	1.138	6.379	4.652	429
2044	26	0	0	0	0	0	0	0	0	0	459.880	127,93	13,81	0	6.122	612	0	0	1.809	5.510	3.223	270
2045	27	0	0	0	0	0	0	0	0	0	387.861	130,49	14,08	0	5.267	527	0	0	2.386	4.740	1.965	150
2046	28	0	0	0	0	0	0	0	0	0	326.050	133,16	14,36	0	4.516	452	0	0	2.974	4.064	750	52
2047	29	0	0	0	0	0	0	0	0	0	263.815	135,83	14,65	0	3.727	373	0	0	3.184	3.354	-136	-9
2048	30	0	0	0	0	0	0	0	0	0	250.764	138,49	14,94	0	3.614	361	0	0	3.554	3.252	-656	-38
2049	31	0	0	0	0	0	0	0	0	0	211.333	141,25	15,24	0	3.106	311	0	0	4.144	2.796	-1.530	-80
2050	32	0	0	0	0	0	0	0	0	0	182.680	144,12	15,55	0	2.739	274	0	0	4.228	2.465	-1.922	-91
2051	33	0	0	0	0	0	0	0	0	0	151.134	146,98	15,86	0	2.311	231	0	0	4.441	2.080	-2.523	-109
2052	34	0	0	0	0	0	0	0	0	0	130.853	149,94	16,18	0	2.041	204	0	0	4.716	1.837	-2.911	-114
2053	35	0	0	0	0	0	0	0	0	0	99.723	152,90	16,50	0	1.587	159	0	0	3.903	1.428	-2.475	-88
2054	36	0	0	0	0	0	0	0	0	0	69.511	155,96	16,83	0	1.128	113	0	0	2.885	1.015	-1.869	-60
2055	37	0	0	0	0	0	0	0	0	0	42.781	159,12	17,17	0	708	71	0	0	1.947	637	-1.310	-39
2056	38	0	0	0	0	0	0	0	0	0	24.841	162,28	17,51	0	419	42	0	0	1.475	377	-1.098	-29
2057	39	0	0	0	0	0	0	0	0	0	15.180	165,54	17,86	0	261	26	0	0	1.140	235	-904	-22
2058	40	0	0	0	0	0	0	0	0	0	0	168,79	18,22	0	0	0	0	0	790	0	-1.050	-23
		19.607	100.455.006	56.443.659	44.011.347	18.626.407	55.300.079	11.288.732	44.011.347	19.607	22.592.931	89,46	11,26	1.754.026	254.356	200.838	193.418	226.704	45.924	1.614.126	876.997	255.858

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 87 - continuation of Figure 86, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

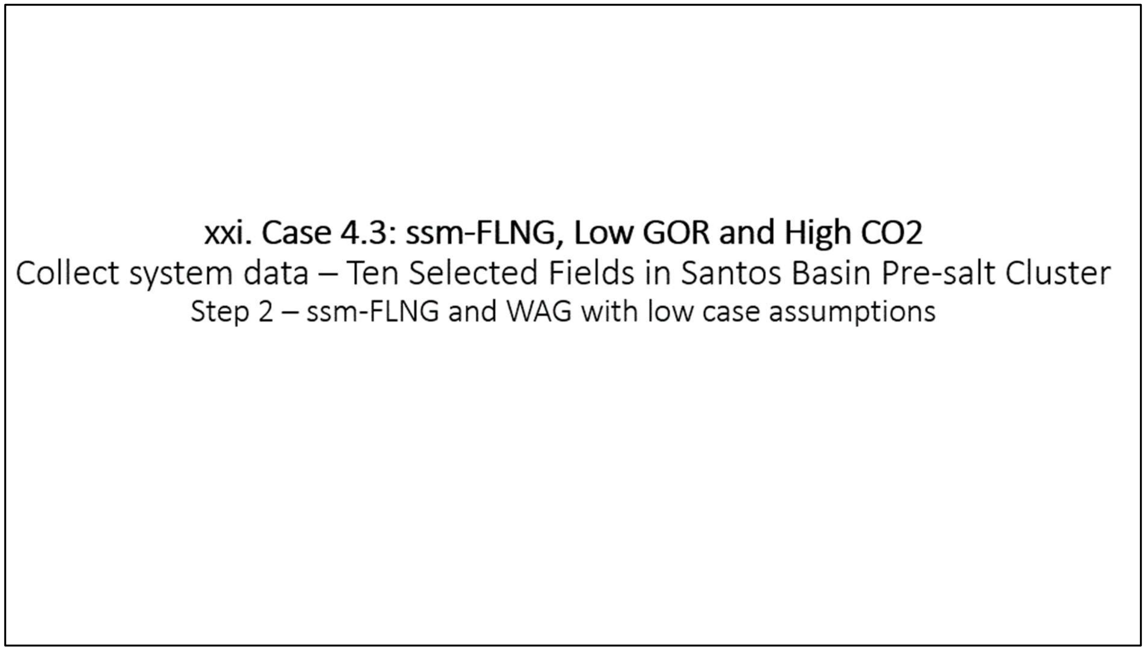


Figure 88 - Twenty first scenario section, Case 4.3, which considers application of small-scale mobile Floating Liquefied Natural Gas (ssm-FLNG) and low case scenario assumptions

Case 4.3': s-FLNG, Low GOR, High CO2 and Low CO2-WAG

Year		Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand (fuel)	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		year	year	year	year	year	year	year	year	year	year	USD/bbl	USD/MM	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD
		MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMbbl	MMscf	25,00	2,75	7,90%	0,00%	10,00%	0,00%	0,00%	0,00%	0,00%	0	10,00%
2019	1	0	0	0	0	0	0	0	0	0	0	25,50	2,81	0	0	0	0	1.709	0	0	-1.728	-1.571
2020	2	0	0	0	0	0	0	0	0	0	0	26,66	2,86	0	0	0	0	1.035	0	0	-1.035	-856
2021	3	0	0	0	0	0	0	0	0	0	0	27,72	2,92	0	0	0	0	1.064	0	0	-1.064	-799
2022	4	514	95.753	32.826	62.927	10.833	69.492	6.565	62.927	514	0	28,24	2,98	13.379	0	1.338	5.066	475	0	6.975	4.177	2.853
2023	5	982	1.063.164	364.474	698.690	120.276	771.585	72.895	698.690	982	40.484	28,61	3,04	25.872	119	2.599	9.673	21.456	0	13.718	-11.829	-7.345
2024	6	959	666.342	228.436	437.907	75.384	483.594	45.687	437.907	959	100.757	29,03	3,10	25.650	301	2.595	9.449	31.046	0	13.907	-20.762	-11.720
2025	7	936	896.957	307.495	589.462	101.473	650.961	61.499	589.462	936	146.410	29,46	3,16	25.411	446	2.586	9.225	31.134	0	14.046	-20.233	-10.383
2026	8	914	941.859	322.888	618.971	106.553	683.549	64.578	618.971	914	189.766	29,96	3,22	25.208	590	2.580	9.001	31.728	0	14.217	-20.359	-9.498
2027	9	891	1.216.545	417.056	799.489	137.628	882.900	83.411	799.489	891	217.165	30,48	3,29	25.012	688	2.570	8.776	19.899	0	14.354	-8.088	-3.430
2028	10	868	1.254.646	430.118	824.528	141.939	910.552	86.024	824.528	868	228.534	31,07	3,35	24.847	739	2.559	8.552	16.974	0	14.475	-4.749	-1.831
2029	11	845	1.253.009	429.557	823.452	141.754	909.364	85.911	823.452	845	242.259	31,70	3,42	24.682	799	2.548	8.328	12.938	0	14.605	-299	-105
2030	12	823	1.301.470	446.170	855.300	147.236	944.534	89.234	855.300	823	252.915	32,32	3,49	24.491	851	2.534	8.104	8.089	0	14.704	4.833	1.540
2031	13	800	1.312.538	449.964	862.574	148.488	952.567	89.993	862.574	800	263.472	32,98	3,56	24.298	904	2.520	7.879	8.149	0	14.802	5.118	1.482
2032	14	777	1.361.926	466.895	895.030	154.075	988.409	93.379	895.030	777	254.177	33,64	3,63	24.077	889	2.497	7.655	3.471	0	14.815	9.976	2.627
2033	15	754	1.427.684	489.439	938.245	161.515	1.036.133	97.888	938.245	754	251.452	34,33	3,70	23.852	897	2.475	7.431	2.179	0	14.844	11.416	2.733
2034	16	732	1.486.532	509.613	976.919	168.172	1.078.842	101.923	976.919	732	250.208	34,99	3,78	23.576	911	2.449	7.207	2.223	0	14.831	11.293	2.458
2035	17	709	1.564.440	536.321	1.028.119	176.986	1.135.383	107.264	1.028.119	709	249.759	35,71	3,85	23.314	927	2.424	6.982	1.534	0	14.835	11.897	2.354
2036	18	686	1.611.083	552.312	1.058.772	182.263	1.169.234	110.462	1.058.772	686	241.755	36,40	3,93	23.002	916	2.392	6.758	0	0	14.768	13.115	2.359
2037	19	663	1.704.374	584.294	1.120.081	192.817	1.236.940	116.859	1.120.081	663	224.803	37,15	4,01	22.693	868	2.356	6.534	0	0	14.672	12.943	2.116
2038	20	641	1.753.476	601.127	1.152.349	198.372	1.272.575	120.225	1.152.349	641	208.964	37,87	4,09	22.341	823	2.316	6.310	0	0	14.539	12.259	1.822

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 89 - Twenty first scenario section, Case 4.2’, which considers application of small-scale mobile Floating Liquefied Natural Gas (LNG) and low case scenario assumptions

Case 4.3': s-FLNG, Low GOR, High CO2 and Low CO2-WAG

Year	Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand (fuel)	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
	year	year	year	year	year	year	year	year	year	year	USD/bbl	USD/MM	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD
	MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMbbl	MMscf	25,00	2,75	7,90%	0,00%	10,00%	0,00%	0,00%	0,00%	0,00%	0	10,00%
2040 22	595	1.749.996	599.933	1.150.062	197.978	1.270.049	119.987	1.150.062	595	171.031	39,42	4,25	21.601	701	2.230	5.861	0	113	14.211	11.403	1.401
2041 23	572	1.566.026	536.865	1.029.161	177.165	1.136.534	107.373	1.029.161	572	149.106	40,21	4,34	21.190	624	2.181	5.637	0	493	13.996	10.687	1.193
2042 24	549	1.559.966	534.788	1.025.179	176.480	1.132.136	106.958	1.025.179	549	128.717	41,00	4,42	20.747	549	2.130	5.412	0	480	13.754	10.470	1.063
2043 25	527	1.526.053	523.161	1.002.891	172.643	1.107.523	104.632	1.002.891	527	108.670	41,82	4,51	20.286	473	2.076	5.188	0	1.099	13.495	9.528	879
2044 26	504	1.716.588	588.481	1.128.107	194.199	1.245.803	117.696	1.128.107	504	92.778	42,64	4,60	19.791	412	2.020	4.964	0	1.719	13.219	8.582	720
2045 27	481	1.228.433	421.131	807.301	138.973	891.528	84.226	807.301	481	72.868	43,50	4,69	19.276	330	1.961	4.740	0	2.246	12.906	7.712	588
2046 28	458	450.241	154.352	295.889	50.936	326.760	30.870	295.889	458	61.371	44,39	4,79	18.739	283	1.902	4.515	0	2.772	12.605	6.875	477
2047 29	436	429.145	147.119	282.025	48.549	311.449	29.424	282.025	436	46.712	45,28	4,88	18.165	220	1.838	4.291	0	2.929	12.255	6.434	406
2048 30	413	418.956	143.627	275.330	47.397	304.055	28.725	275.330	413	44.229	46,16	4,98	17.554	212	1.777	4.067	0	3.250	11.922	5.886	337
2049 31	390	401.336	137.586	263.750	45.403	291.267	27.517	263.750	390	37.622	47,08	5,08	16.917	184	1.710	3.843	0	3.722	11.548	5.193	271
2050 32	367	367.831	126.100	241.731	41.613	266.951	25.220	241.731	367	32.625	48,04	5,18	16.252	163	1.642	3.618	0	3.798	11.155	4.824	228
2051 33	202	209.734	71.901	137.833	23.727	152.214	14.380	137.833	202	28.326	48,99	5,29	9.111	144	926	1.992	0	4.003	6.338	1.319	57
2052 34	0	0	0	0	0	0	0	0	0	24.602	49,98	5,39	0	128	13	0	0	4.231	115	-4.116	-161
2053 35	0	0	0	0	0	0	0	0	0	12.701	50,97	5,50	0	67	7	0	0	3.455	61	-3.395	-121
2054 36	0	0	0	0	0	0	0	0	0	0	51,99	5,61	0	0	0	0	0	2.501	0	-2.501	-81
2055 37	0	0	0	0	0	0	0	0	0	0	53,04	5,72	0	0	0	0	0	1.662	0	-1.662	-49
2056 38	0	0	0	0	0	0	0	0	0	0	54,09	5,84	0	0	0	0	0	1.238	0	-1.238	-33
2057 39	0	0	0	0	0	0	0	0	0	0	55,18	5,95	0	0	0	0	0	950	0	-950	-23
2058 40	0	0	0	0	0	0	0	0	0	0	56,26	6,07	0	0	0	0	0	651	0	-911	-20
Total	19.607	34.300.026	11.758.735	22.541.291	3.880.383	24.893.038	2.351.747	22.541.291	19.607	4.566.082	32,81	3,71	643.313	16.930	66.024	193.143	195.102	41.422	401.075	92.765	-16.473

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 90 - Continuation of Figure 89, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

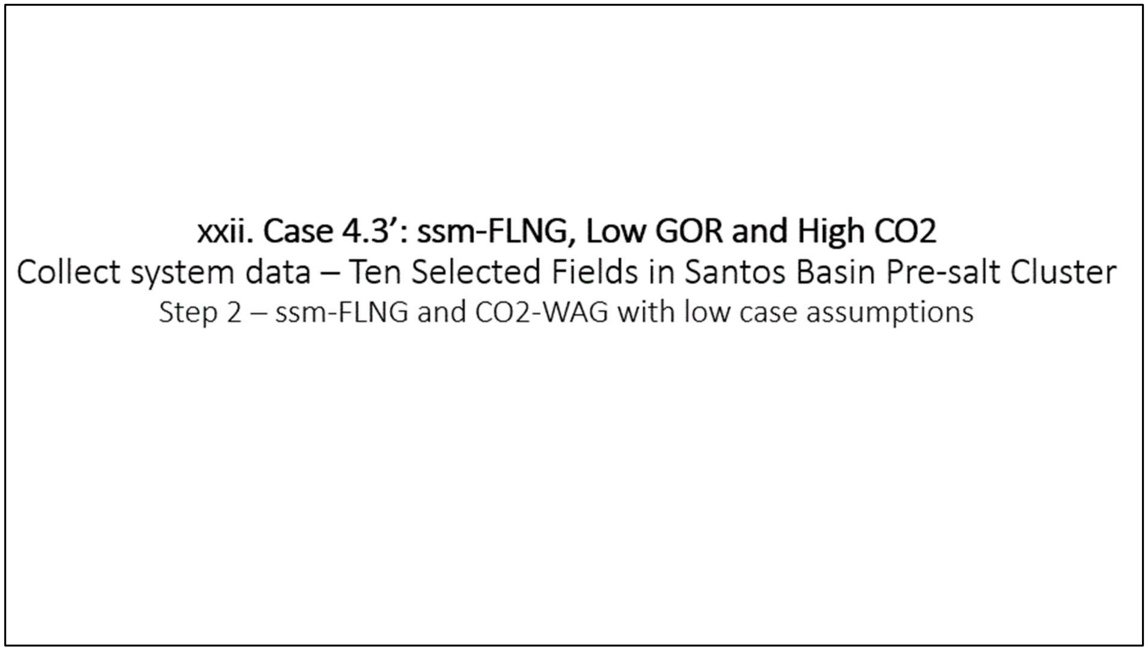


Figure 91 - Twenty second scenario section, Case 4.3’, which considers application of small-scale mobile Floating Liquefied Natural Gas (ssm-FLNG), combined with CO_2-WAG as an enhanced oil recovery method and low case scenario assumptions

Case 4.3': s-FLNG, Low GOR, High CO2 and Low CO2-WAG

Year		Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand (fuel)	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		year MMbbl	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMscf	year MMbbl	year MMscf	USD/bbl 25,00	USD/MM 2,75	MM USD 7,90%	MM USD 0,00%	MM USD 10,00%	MM USD 0,00%	MM USD 0,00%	MM USD 0,00%	MM USD 0,00%	MM USD 0	MM USD 10,00%
2019	1	0	0	0	0	0	0	0	0	0	0	25,50	2,81	0	0	0	0	1.709	0	0	-1.728	-1.571
2020	2	0	0	0	0	0	0	0	0	0	0	26,66	2,86	0	0	0	0	1.035	0	0	-1.035	-856
2021	3	0	0	0	0	0	0	0	0	0	0	27,72	2,92	0	0	0	0	1.064	0	0	-1.064	-799
2022	4	514	95.753	32.826	62.927	10.833	69.492	6.565	62.927	514	0	28,24	2,98	13.379	0	1.338	5.066	475	0	6.975	4.177	2.853
2023	5	982	1.063.164	364.474	698.690	120.276	771.585	72.895	698.690	982	40.484	28,61	3,04	25.872	119	2.599	9.673	21.456	0	13.718	-11.829	-7.345
2024	6	959	666.342	228.436	437.907	75.384	483.594	45.687	437.907	959	100.757	29,03	3,10	25.650	301	2.595	9.449	31.046	0	13.907	-20.762	-11.720
2025	7	936	896.957	307.495	589.462	101.473	650.961	61.499	589.462	936	146.410	29,46	3,16	25.411	446	2.586	9.225	31.134	0	14.046	-20.233	-10.383
2026	8	914	941.859	322.888	618.971	106.553	683.549	64.578	618.971	914	189.766	29,96	3,22	25.208	590	2.580	9.001	31.728	0	14.217	-20.359	-9.498
2027	9	891	1.216.545	417.056	799.489	137.628	882.900	83.411	799.489	891	217.165	30,48	3,29	25.012	688	2.570	8.776	19.899	0	14.354	-8.088	-3.430
2028	10	868	1.254.646	430.118	824.528	141.939	910.552	86.024	824.528	868	228.534	31,07	3,35	24.847	739	2.559	8.552	16.974	0	14.475	-4.749	-1.831
2029	11	845	1.253.009	429.557	823.452	141.754	909.364	85.911	823.452	845	242.259	31,70	3,42	24.682	799	2.548	8.328	12.938	0	14.605	-299	-105
2030	12	823	1.301.470	446.170	855.300	147.236	944.534	89.234	855.300	823	252.915	32,32	3,49	24.491	851	2.534	8.104	8.089	0	14.704	4.833	1.540
2031	13	800	1.312.538	449.964	862.574	148.488	952.567	89.993	862.574	800	263.472	32,98	3,56	24.298	904	2.520	7.879	8.149	0	14.802	5.118	1.482
2032	14	777	1.361.926	466.895	895.030	154.075	988.409	93.379	895.030	777	254.177	33,64	3,63	24.077	889	2.497	7.655	3.471	0	14.815	9.976	2.627
2033	15	754	1.427.684	489.439	938.245	161.515	1.036.133	97.888	938.245	754	251.452	34,33	3,70	23.852	897	2.475	7.431	2.179	0	14.844	11.416	2.733
2034	16	732	1.486.532	509.613	976.919	168.172	1.078.842	101.923	976.919	732	250.208	34,99	3,78	23.576	911	2.449	7.207	2.223	0	14.831	11.293	2.458
2035	17	709	1.564.440	536.321	1.028.119	176.986	1.135.383	107.264	1.028.119	709	249.759	35,71	3,85	23.314	927	2.424	6.982	1.534	0	14.835	11.897	2.354
2036	18	686	1.611.083	552.312	1.058.772	182.263	1.169.234	110.462	1.058.772	686	241.755	36,40	3,93	23.002	916	2.392	6.758	0	0	14.768	13.115	2.359
2037	19	663	1.704.374	584.294	1.120.081	192.817	1.236.940	116.859	1.120.081	663	224.803	37,15	4,01	22.693	868	2.356	6.534	0	0	14.672	12.943	2.116
2038	20	641	1.753.476	601.127	1.152.349	198.372	1.272.575	120.225	1.152.349	641	208.964	37,87	4,09	22.341	823	2.316	6.310	0	0	14.539	12.259	1.822

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 92 - Twenty second scenario section, Case 4.2', which considers application of small-scale mobile Floating Liquefied Natural Gas (LNG), combined with CO_2-WAG as an enhanced oil recovery method and high case scenario assumptions

Case 4.3': s-FLNG, Low GOR, High CO2 and Low CO2-WAG

Year		Oil production	Gas production	Natural Gas Production	CO2 Production	Natural Gas Demand (fuel)	Gas injection	Natural Gas injection	CO2 injection	Oil sale	Natural Gas Sale	Oil price	Natural Gas Price	Oil revenue	Nautral Gas revenue	Royalties	OPEX	CAPEX	Aband. costs	EBITDA	NET CASH FLOW	Discounted Cash Flow
		year	year	year	year	year	year	year	year	year	year	USD/bbl	USD/MM	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD	MM USD
		MMbbl	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMscf	MMbbl	MMscf	25,00	2,75	7,90%	0,00%	10,00%	0,00%	0,00%	0,00%	0,00%	0	10,00%
2040	22	595	1.749.996	599.933	1.150.062	197.978	1.270.049	119.987	1.150.062	595	171.031	39,42	4,25	21.601	701	2.230	5.861	0	113	14.211	11.403	1.401
2041	23	572	1.566.026	536.865	1.029.161	177.165	1.136.534	107.373	1.029.161	572	149.106	40,21	4,34	21.190	624	2.181	5.637	0	493	13.996	10.687	1.193
2042	24	549	1.559.966	534.788	1.025.179	176.480	1.132.136	106.958	1.025.179	549	128.717	41,00	4,42	20.747	549	2.130	5.412	0	480	13.754	10.470	1.063
2043	25	527	1.526.053	523.161	1.002.891	172.643	1.107.523	104.632	1.002.891	527	108.670	41,82	4,51	20.286	473	2.076	5.188	0	1.099	13.495	9.528	879
2044	26	504	1.716.588	588.481	1.128.107	194.199	1.245.803	117.696	1.128.107	504	92.778	42,64	4,60	19.791	412	2.020	4.964	0	1.719	13.219	8.582	720
2045	27	481	1.228.433	421.131	807.301	138.973	891.528	84.226	807.301	481	72.868	43,50	4,69	19.276	330	1.961	4.740	0	2.246	12.906	7.712	588
2046	28	458	450.241	154.352	295.889	50.936	326.760	30.870	295.889	458	61.371	44,39	4,79	18.739	283	1.902	4.515	0	2.772	12.605	6.875	477
2047	29	436	429.145	147.119	282.025	48.549	311.449	29.424	282.025	436	46.712	45,28	4,88	18.165	220	1.838	4.291	0	2.929	12.255	6.434	406
2048	30	413	418.956	143.627	275.330	47.397	304.055	28.725	275.330	413	44.229	46,16	4,98	17.554	212	1.777	4.067	0	3.250	11.922	5.886	337
2049	31	390	401.336	137.586	263.750	45.403	291.267	27.517	263.750	390	37.622	47,08	5,08	16.917	184	1.710	3.843	0	3.722	11.548	5.193	271
2050	32	367	367.831	126.100	241.731	41.613	266.951	25.220	241.731	367	32.625	48,04	5,18	16.252	163	1.642	3.618	0	3.798	11.155	4.824	228
2051	33	202	209.734	71.901	137.833	23.727	152.214	14.380	137.833	202	28.326	48,99	5,29	9.111	144	926	1.992	0	4.003	6.338	1.319	57
2052	34	0	0	0	0	0	0	0	0	0	24.602	49,98	5,39	0	128	13	0	0	4.231	115	-4.116	-161
2053	35	0	0	0	0	0	0	0	0	0	12.701	50,97	5,50	0	67	7	0	0	3.455	61	-3.395	-121
2054	36	0	0	0	0	0	0	0	0	0	0	51,99	5,61	0	0	0	0	0	2.501	0	-2.501	-81
2055	37	0	0	0	0	0	0	0	0	0	0	53,04	5,72	0	0	0	0	0	1.662	0	-1.662	-49
2056	38	0	0	0	0	0	0	0	0	0	0	54,09	5,84	0	0	0	0	0	1.238	0	-1.238	-33
2057	39	0	0	0	0	0	0	0	0	0	0	55,18	5,95	0	0	0	0	0	950	0	-950	-23
2058	40	0	0	0	0	0	0	0	0	0	0	56,26	6,07	0	0	0	0	0	651	0	-911	-20
Total		19.607	34.300.026	11.758.735	22.541.291	3.880.383	24.893.038	2.351.747	22.541.291	19.607	4.566.082	32,81	3,71	643.313	16.930	66.024	193.143	195.102	41.422	401.075	92.765	-16.473

Steps 1 | Step 2 | Step 2' (WAG-CO2) | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9

Figure 93 - Continuation of Figure 92, highlighting in black cells total revenues and sum of net present value cash flow (10.0% per year discount rate). Discount rate utilized by GCA ranged from 7,5% to 10,0% per year. Given the level of uncertainty of the exercise, it was adopted 10,0% per year.

6 APPENDIX B – OIL PRODUCTION CURVES

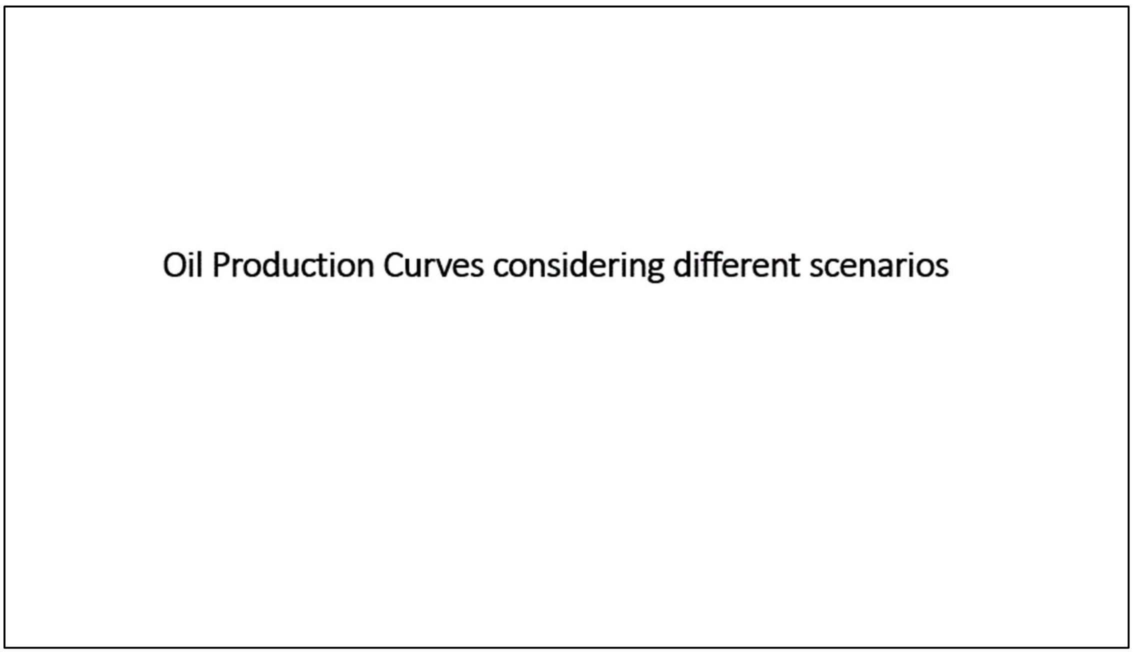


Figure 94 - Oil production curves section, considering CO_2-WAG

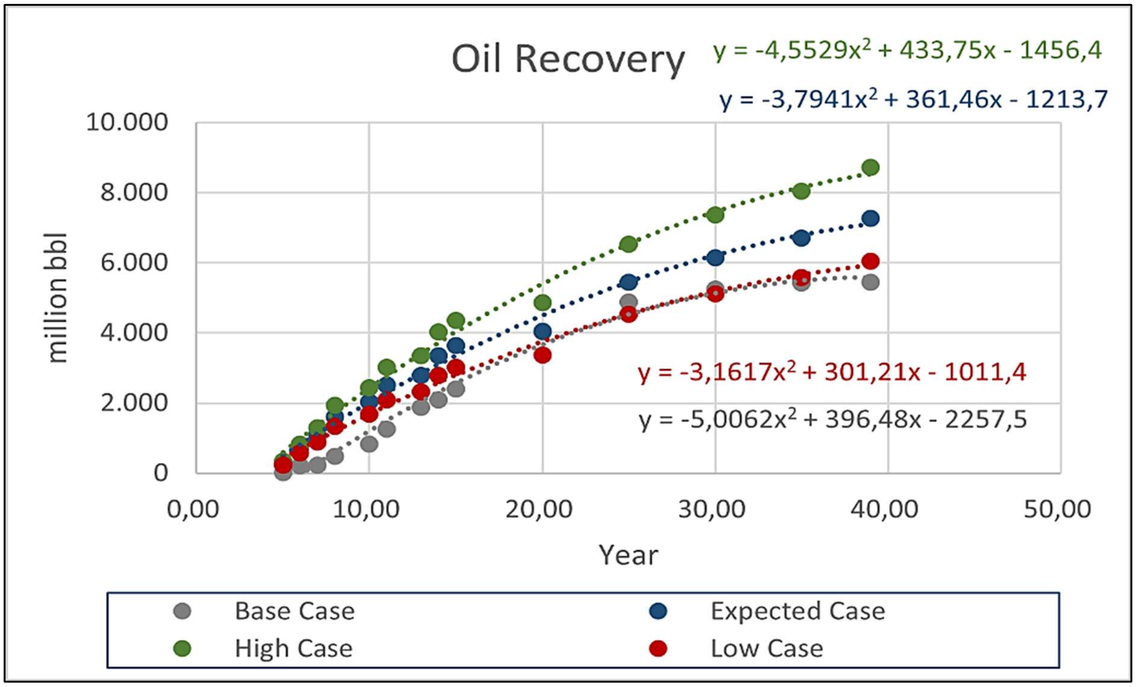


Figure 96 -Oil recovery curves of Búzios (former Franco field), considering CO_2-WAG

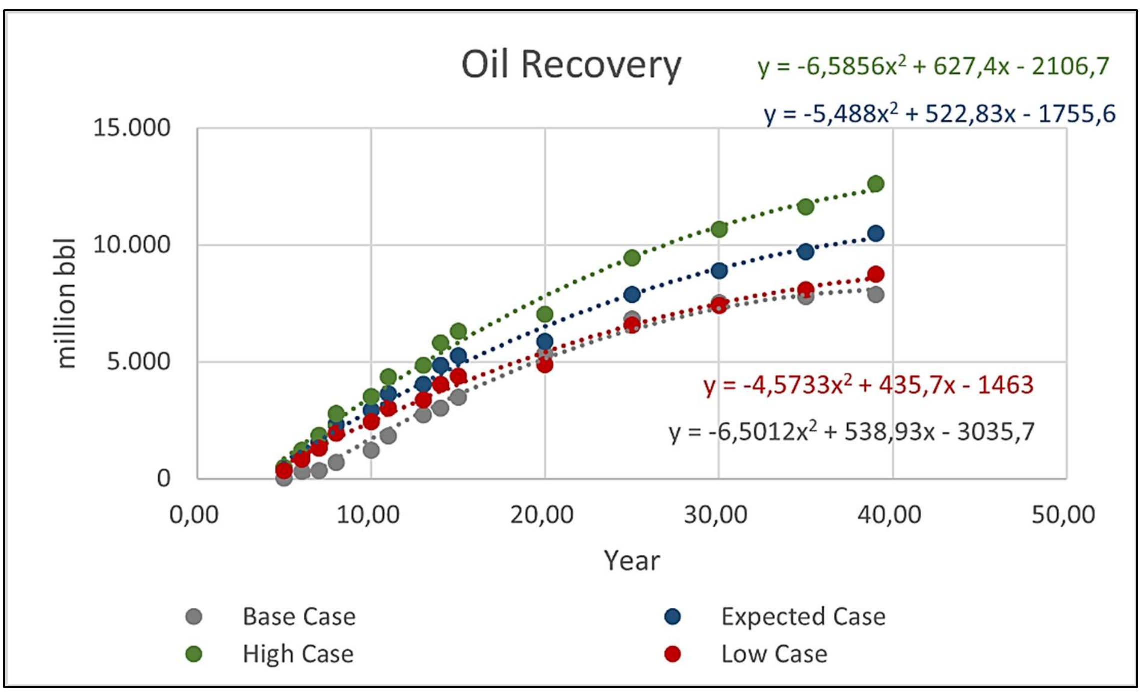


Figure 95 - Oil recovery curves of Libra field, considering CO_2-WAG

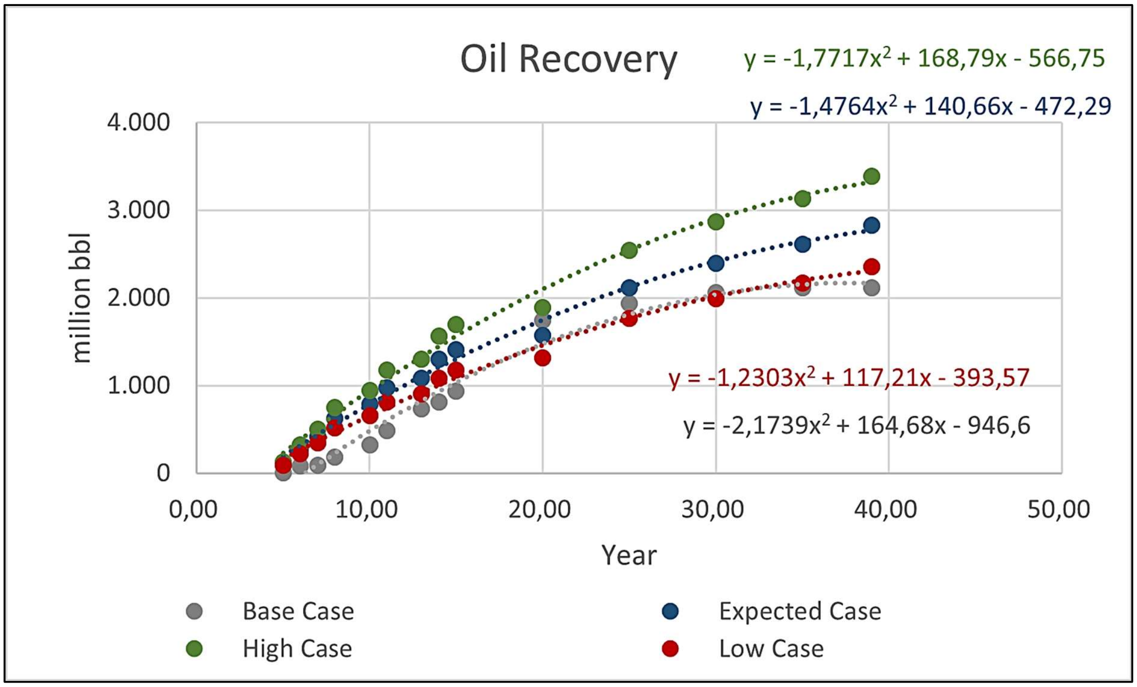


Figure 97 - Oil recovery curves of Lula South (former Tupi Extension), CO_2-WAG

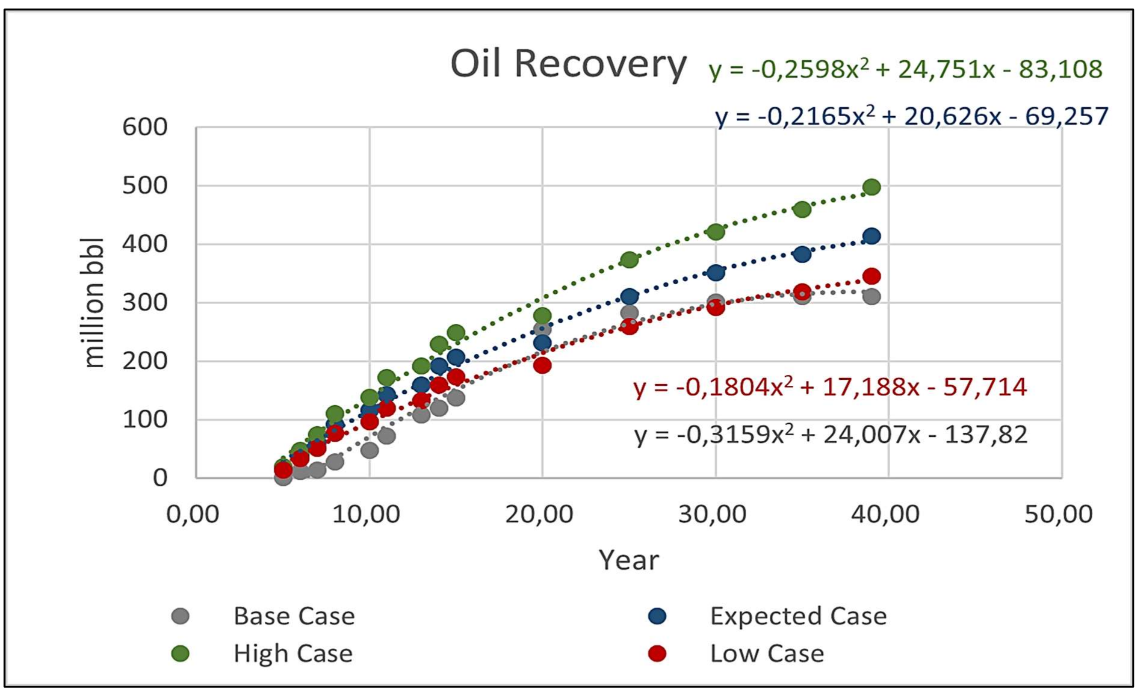


Figure 98 - Oil recovery curves Tupi extension (former Sépia field), CO_2-WAG

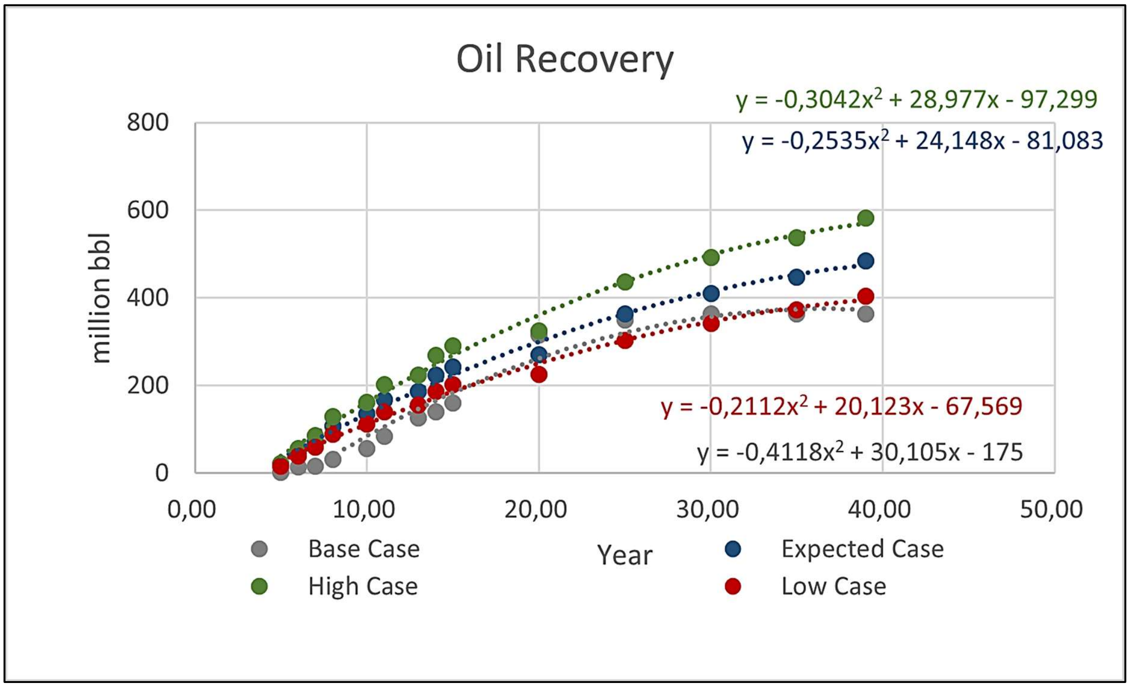


Figure 99 - Oil recovery curves of Peroba field, considering CO_2-WAG

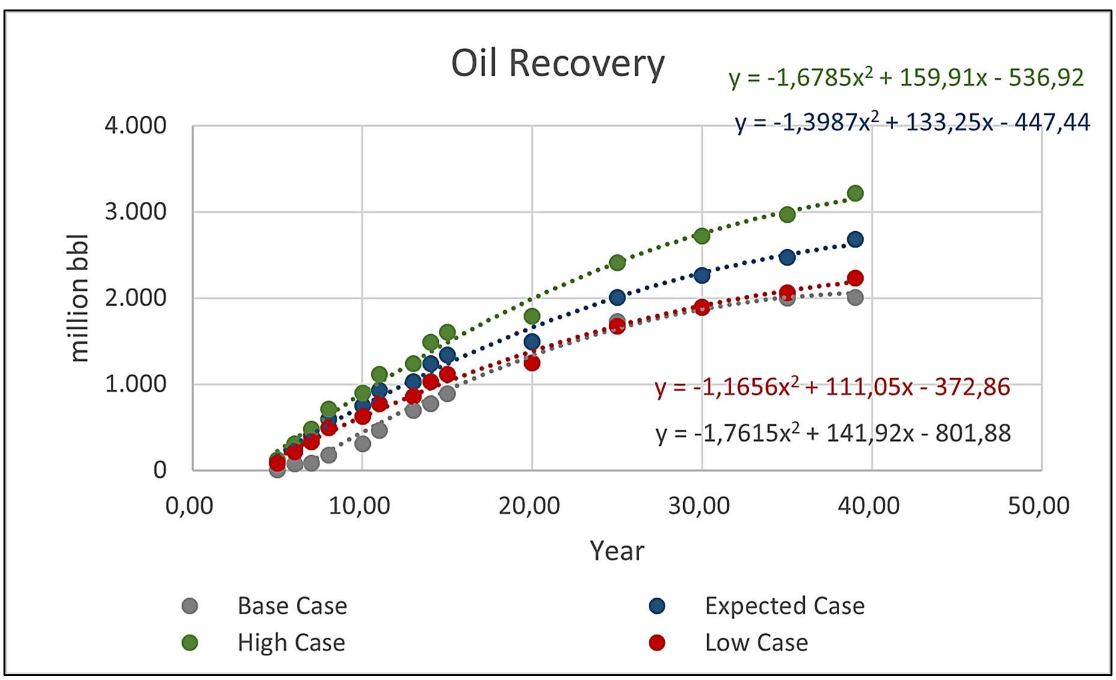


Figure 100 - Oil recovery curves of Atapu (former Iara extension), CO_2-WAG

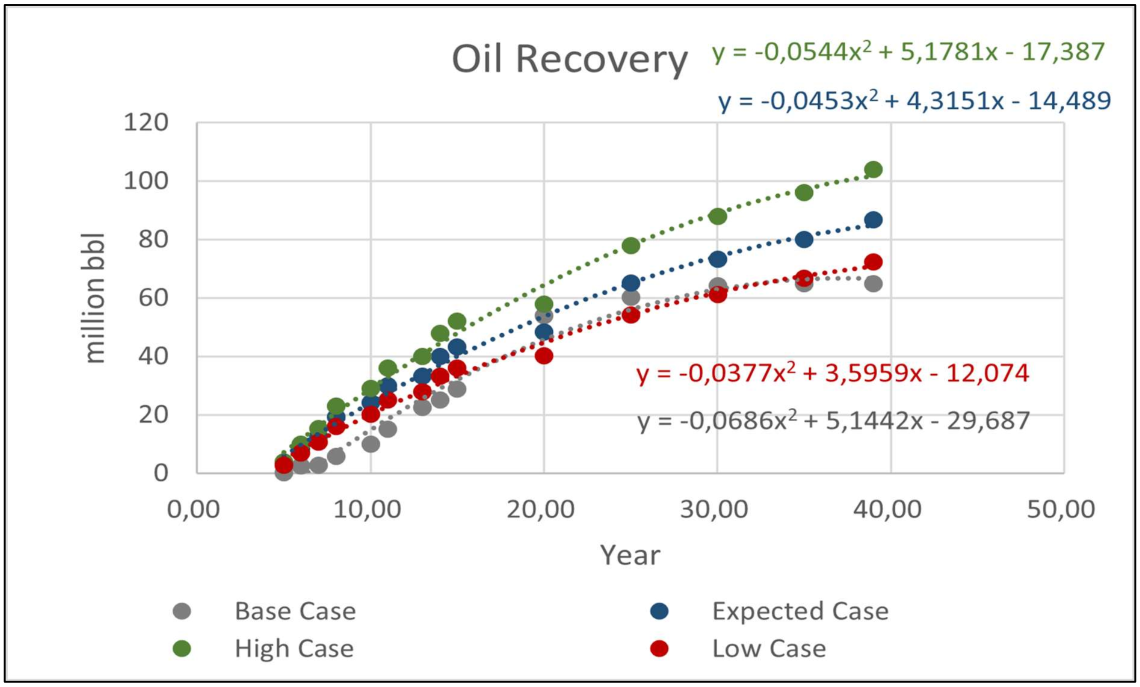


Figure 101 - Oil recovery curves of Florim, CO2-WAG

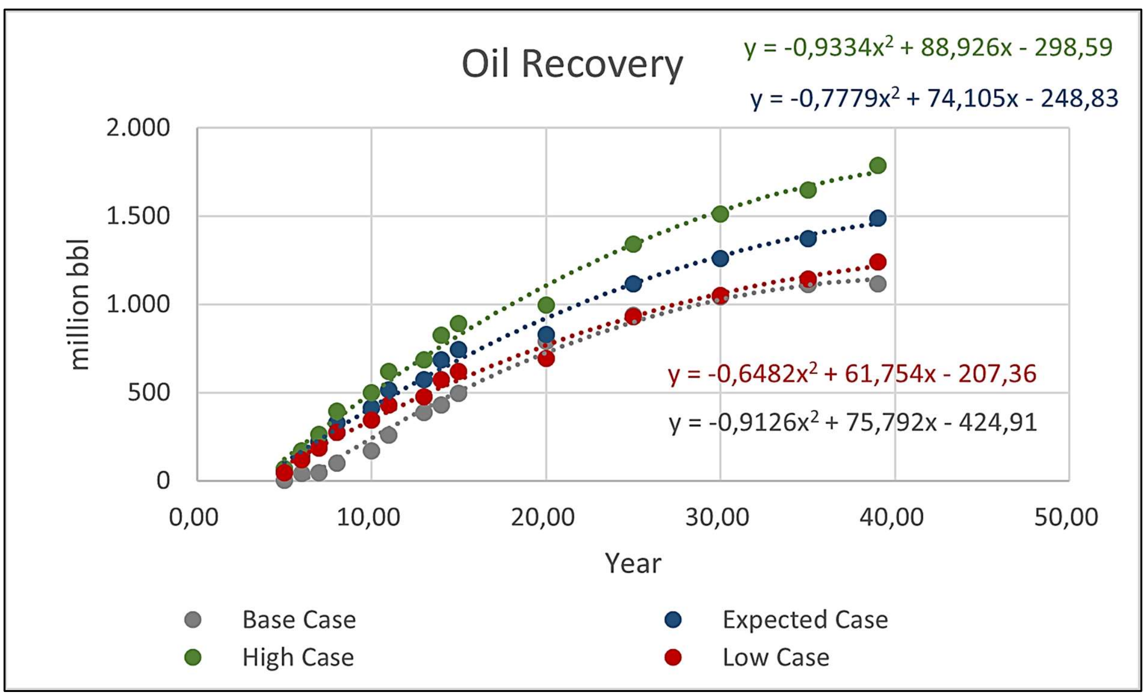


Figure 102 - Oil recovery curves of Jupiter extension, CO_2-WAG

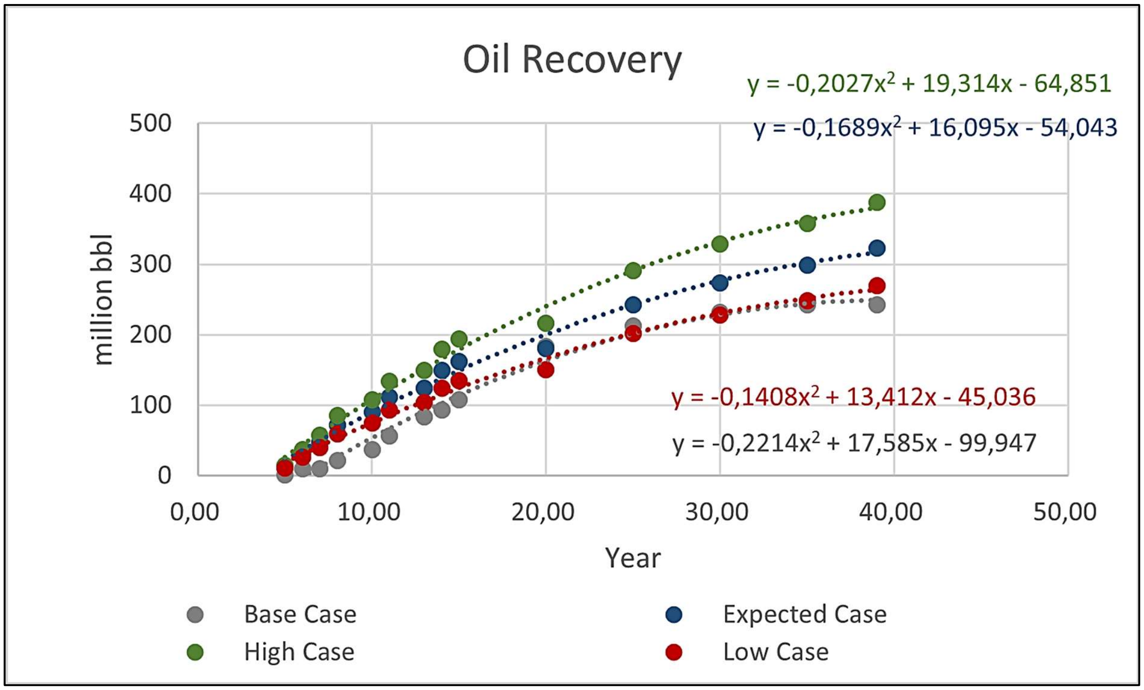


Figure 103 - Oil recovery curves of Pau Brasil, CO_2-WAG

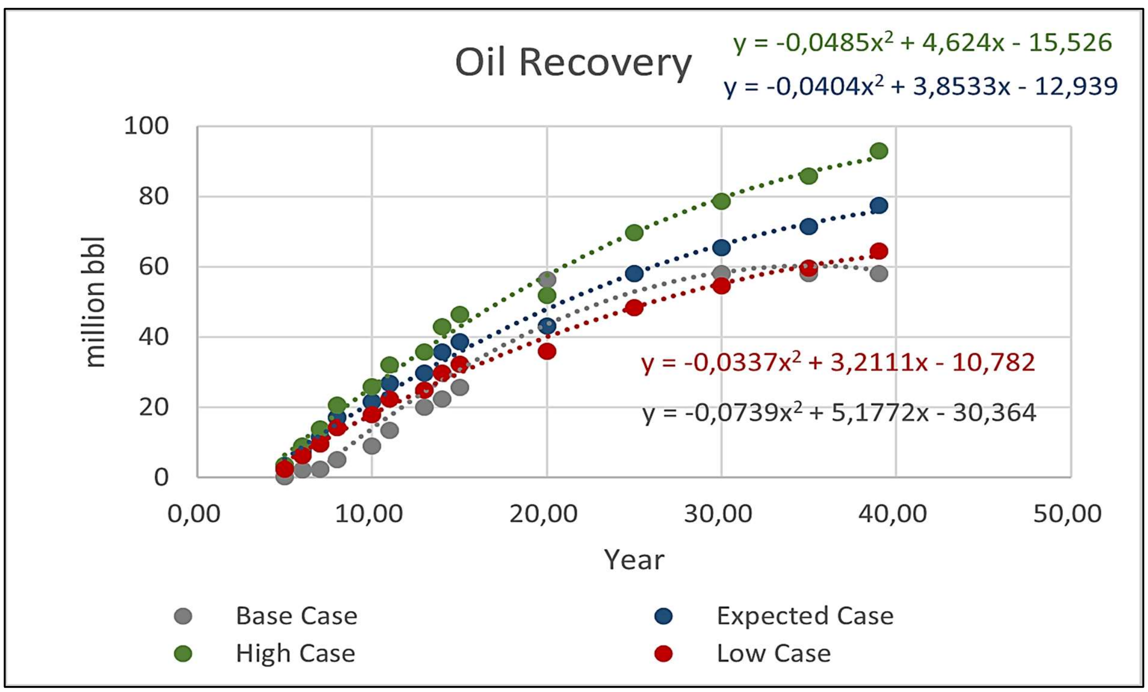


Figure 104 - Oil recovery curves of Sapinhoá South (former Guará South), CO_2-WAG

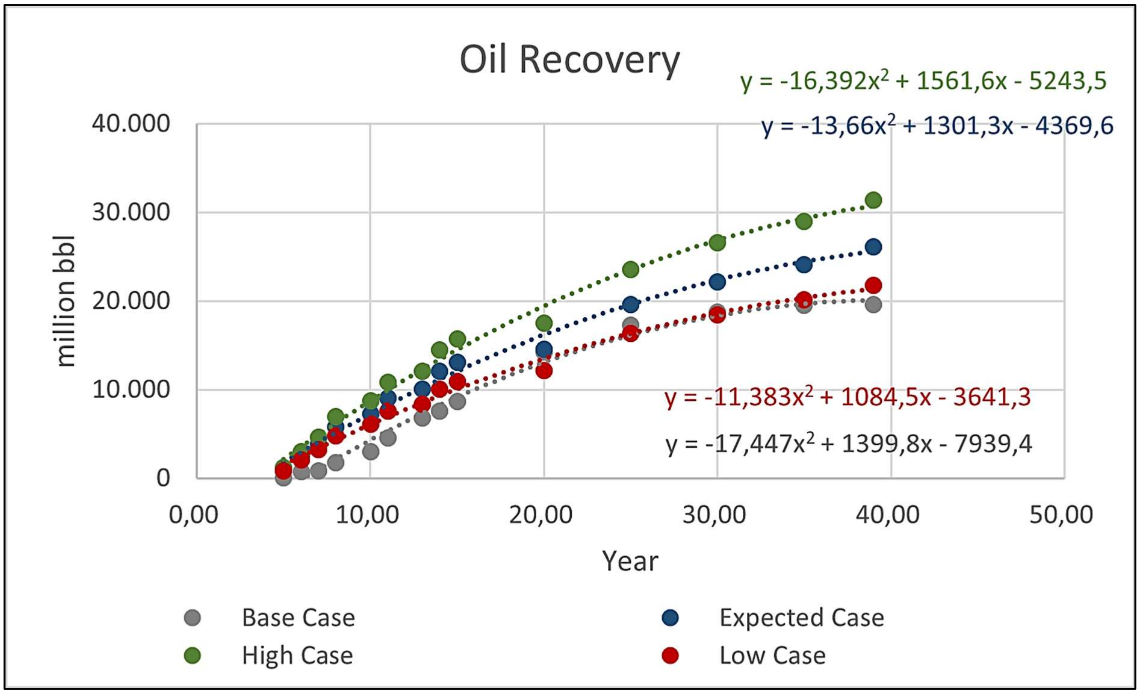


Figure 105 - Oil recovery curves Ten Selected Fields Santos Basin Pre-salt Cluster (SBPC), CO_2-WAG

7 APPENDIX C – REVENUE AND NPV CHARTS FOR HIGH AND LOW CASE SCENARIOS

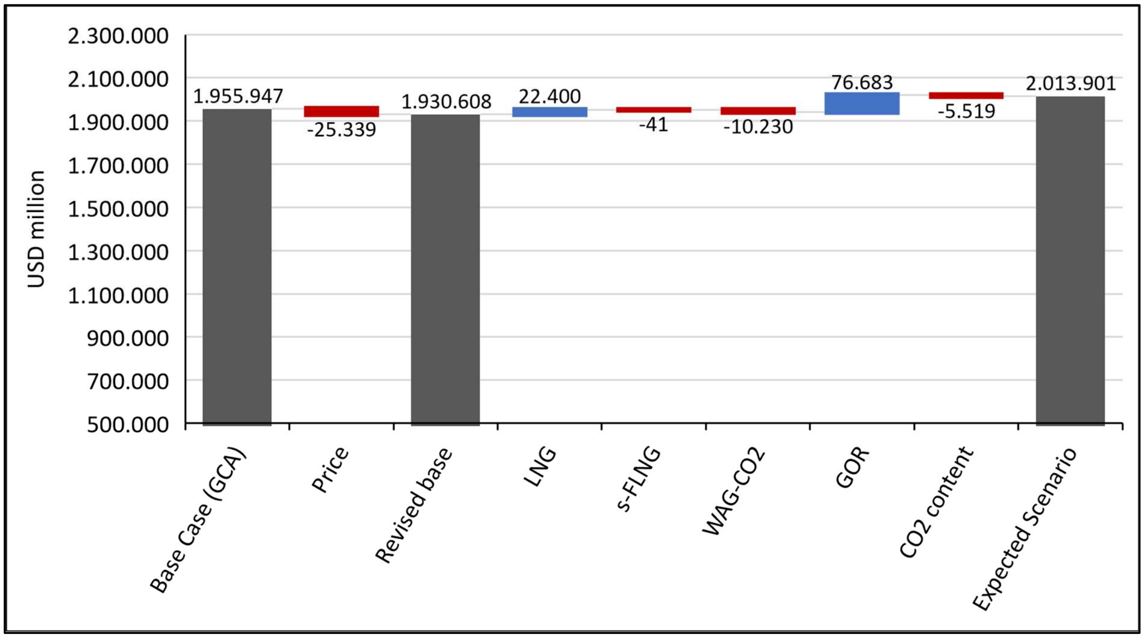


Figure 106: Revenue analysis considering high-case scenario. Ten selected fields in Santos Basin Pre-salt Cluster (SBPC)
Source: author's techno-economic model

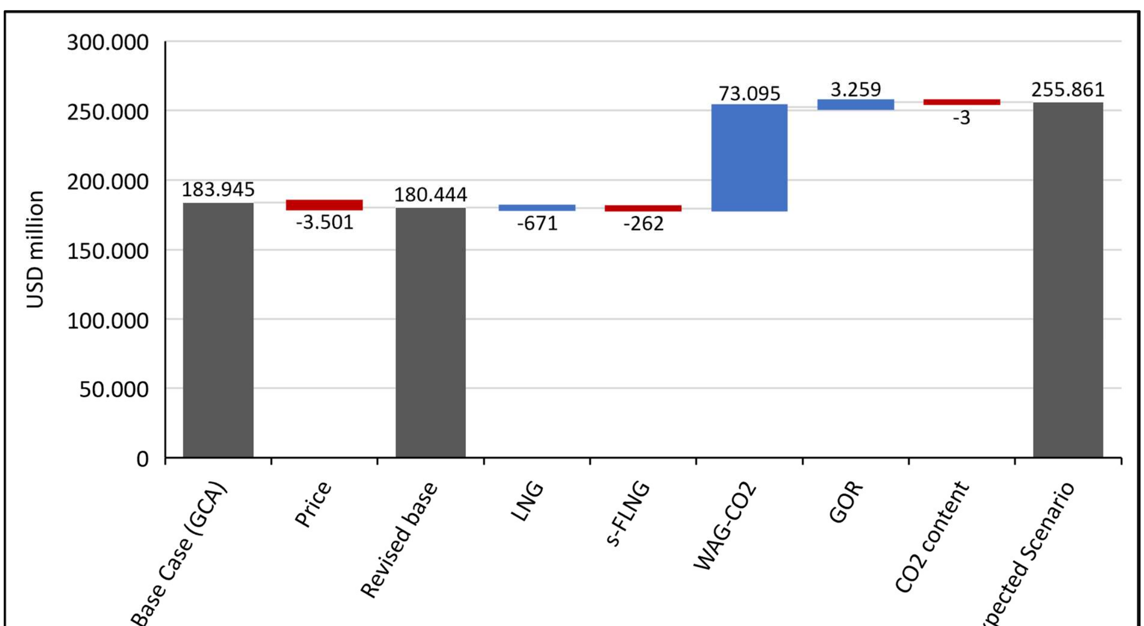


Figure 107: NPV analysis considering high-case scenario. Ten selected fields in Santos Basin Pre-salt Cluster (SBPC)
Source: author´s techno-economic model

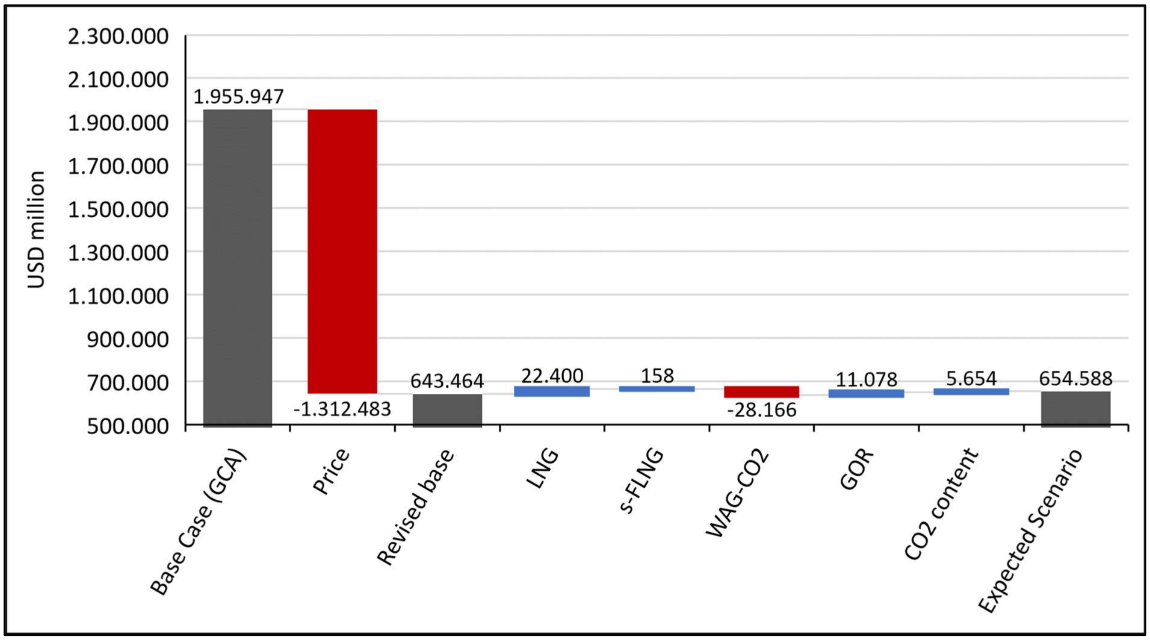


Figure 108 – Revenue analysis considering low-case scenario. Ten selected fiels in Santos Basin Pre-salt Cluster (SBPC)
Source: author's techno-economic model

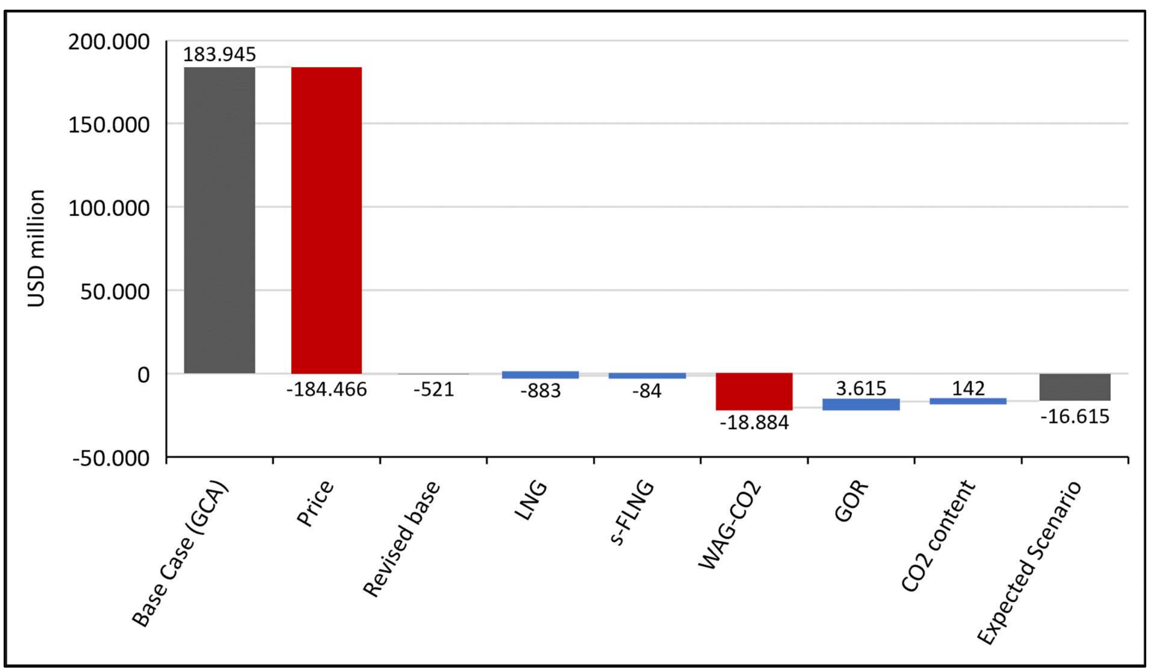


Figure 109 - NPV analysis considering low-case scenario. Ten selected fields in Santos Basin Pre-salt Cluster (SBPC)
Source: author's techno-economic model