NOTEBOOK

anp | FGV ENERGIA

JANUARY 2021 | YEAR 8 | Nº 11 | ISSN 2358-5277

DECOMMISSIONING IN BRAZIL

OPPORTUNITIES, CHALLENGES AND SOLUTIONS

FGV ENERGIA

DIRECTOR

Carlos Otavio de Vasconcellos Quintella

TECHNICAL TEAM

Organization

Fernanda Delgado – FGV Energia

Raphael Moura - ANP

Mariana França - ANP

Authors

ANP

Karen Alves de Souza

Livia Cartolano da Silva

Luciene Ferreira Pedrosa

Ludmyla Carolina Mariano Barbosa

Nilce Olivier Costa

Tabita Yaling Cheng Loureiro

Tiago Machado de Souza Jacques

UFRJ - COPPE

Giselle Távora

Jean-David Caprace

Luisa Nogueira

Marcelo Igor Lourenço de Souza

PETROBRAS

Eduardo Nicolosi

Eduardo Stein

SHELL

SHELL TEAM

Coordination

George Oliva

ABESPETRO

FGV ENERGIA

Fernanda Delgado

Gabriela Roman Michalowski (UDESC)

ESTALEIRO ATLANTICO SUL

Carlos Inácio

Nicole Mattar Haddad Terpins

Mauricio Almeida (SIGMA CONSULTORIA)

CNEN

Claudia Vaillant Alves Cunha

Flávia Schenato

Nerbe José Ruperti Júnior

ABPIP

Anabal Santos Jr (ABPIP)

Clarissa Thomson (PETRORIO)

Mauro Destri (PERENCO)

Nathan Biddle (PREMIER OIL)

PRODUCTION TEAM

Operational Coordination

Simone Corrêa Lecques de Magalhães

Execution

Thatiane Araciro

Translated by

Danilo Destri

Layout

Bruno Masello e Carlos Quintanilha

RESEARCH TEAM

General Coordination
Carlos Otavio de Vasconcellos Quintella

Electricity Sector Research Coordination
Luiz Roberto Bezerra

O&G Research Coordination
Magda Chambriard

Researchers
Acacio Barreto Neto
Adriana Ribeiro Gouvêa
Angélica dos Santos
Ana Costa Marques Machado
Flávia Porto
Gláucia Fernandes
João Teles
Kárys Prado
Marina de Abreu Azevedo
Melissa Prado
Paulo César Fernandes da Cunha
Rodrigo Lima

PRODUCTION

Coordenation
Simone C. Lecques de Magalhães

Execution
Thatiane Araciro

Layout
Bruno Masello e Carlos Quintanilha

FAZER **DIFERENTE** FAZ TODA A DIFERENÇA.

Contents

DESTRI ENERGY

Presentation

FGV Energia, within the scope of its research activities, has the FGV Energia Booklet as one of its main tools for investigating the obstacles and opportunities for specific segments of the energy sector. This booklet presents an in-depth diagnosis of the decommissioning activity in Brazil, through a survey of the perspectives of different players and aims to address opportunities, challenges and solutions, as well as to clarify society about the possibilities that are opening up with this activity in the country.

Thus, the booklet Offshore Decommissioning in Brazil - Opportunities, Challenges & Solutions presents the results of research conducted by FGV Energia, in conjunction with the National Agency of Petroleum, Gas and Biofuels - ANP, and entities related to this task in the country, invited to contribute to the discussion. They are: COPPE of the FEDERAL UNIVERSITY OF RIO

DE JANEIRO, UFRJ, the Brazilian Association of Petroleum Service Companies, ABESPETRO, PETROBRAS, SHELL, the National Nuclear Energy Commission, CNEN, the Brazilian Association of Independent Petroleum Producers ABPIP and Estaleiro Atlantico Sul, Premier Oil, Perenco and PetroRio. As in any work resulting from the contribution of several actors, this collection contains imperfections, overlapping of issues and ideas, and even some contradictions. The reader should read each chapter as if it were a separate universe, keeping the individuality of the author in question. It is also worth adding that each chapter reflects the position of its authors independently, and the information contained in it is the sole responsibility of the authors.

In general, this work seeks to:

i. Create a structured framework on decommissioning in Brazil regarding challenges, opportunities and solutions;
ii. Provide an overview of the scale and nature of the decommissioning market in the coming years, highlighting the opportunities and challenges in the supply chain of goods and services;
iii. To raise awareness among decision makers about the importance of consolidated and organized knowledge about standards, procedures and jurisdiction on the subject in the country.

FGV Energia understands that the dissemination of knowledge and long-term planning are imperative for scientific and technical progress, for competitiveness gains and, consequently, for economic development and social welfare. In this sense, it is expected that this study will be a relevant contribution not only to the development of the oil sector, but also to the improvement of the Public Administration and its tools to stimulate the economy.

This is our work.

Enjoy your reading.

FGV ENERGIA

1

CHAPTER

Fernanda Delgado – FGV Energia
Gabriela Roman Michalowski – UDESC

Introduction

Decommissioning of offshore production systems is understood as the safe destination of structures for exploration and production of oil platforms after the end of their production phase. The decommissioning of unserviceable oil and gas facilities is a duty related to the end of the useful life of a field and, consequently, of its production facilities.

This occurs when the field becomes uneconomical for the operator, making it necessary to deactivate, decontaminate and remove the appropriate equipment (RUIVO, MOROOKA, 2001). Thus, the decommissioning procedure of oil platforms materializes the sustainable development in the light of the principles of intergenerational equity, equitable access to natural resources, prevention and social and environmental function of property.

When designing an offshore project, the projected production life cycle is generally 20 to 25 years on average. This period coincides with that of the installation responsible for that production. After the end of the platforms' life cycle, they can be disposed of, recovered, or undergo a life extension process. This process is an attempt to avoid interrupting production from a field.

A total of 7053 structures were installed in the Gulf of Mexico and 5048 structures were decommissioned by 2017, leaving an active (or "permanent") inventory of 7053- 5048 = 2005 structures by 2017. In the North Sea, also in

2016, there were 1,357 platforms operating in this area, and by that year, 157 had already been decommissioned. It is estimated that between 2017 and 2025 another 206 units will be decommissioned (OIL & GAS UK, 2017).

The forecasts for these regions are high largely because of the average age of the remaining installations. In the North Sea, this age is over 20 years, with 26 years for the UK platforms and 24 years for the Norwegian platforms (ALMEIDA et al., 2017; p.11). Brazil also fits into this scenario of production systems in mature fields. According to ANP (2021), in January 2021, 33% of existing offshore production units had been in operation for more than 25 years and 20% of the production units were between 15 and 25 years old.

In a preview of the 2018 World Energy Outlook publication, the International Energy Association (IEA) has put together an average forecast of decommissioning projects in South America and worldwide for the coming decades. Central and South America have seven projects until 2030 and another nine between 2030-2040. This estimate represents 6-7% of the global demand for decommissioning.

Another recent challenge peculiar to Brazil, according to the IEA (2019), is that 34% of the Brazilian production systems are in Deepwater[1] and this considerably increases the difficulty and cost of this activity. By comparison, in the North Sea, most of the European continental shelf is 90 meters deep. The decommissioning projects in the Gulf of Mexico are at depths of less than 122 meters.

Despite the growing global concern about decommissioning and the observed growth of legislation around this topic, partly due to pressure from public opinion and environmental movements, the corresponding regulatory framework, even in developed countries, is far from being complete, homogeneous, and satisfactory. Therefore, the debate about national sustainable development in oil platform decommissioning operations is extensive.

Most decommissioning regulations, especially those in the United Kingdom, Norway and the United States, establish fines and obstacles to access to financing as punishment for companies that do not follow safe procedures regarding abandonment or cause negative externalities to the exploited sites (MENDES et al., 2014).

1. According to the ANP, shallow waters are areas with water depths generally less than 300 m and deep waters are areas with water depths generally between 300 m and 1,500 m.

TABLE 1: PLATFORM TYPES AND FEATURES.

	Fixed	jack-up	Semi-submersible	FPSO	TLWP
How it is	Rigid structure	Mobile structure with a mechanism for raising and lowering the legs	Floating structure, anchored or kept stable by a dynamic positioning system	Floating structure, anchored or kept stable by a dynamic positioning system	Floating structure, anchored to the seabed
Water depth	Until 300 meters	Until 150 meters	Over 2000 meters	Over 2000 meters	Until1500 meters
Drilling/ prod uction activity	Yes/Yes	Yes/No	Yes/Yes; it can be just one type	No/Yes	Yes(well maintenance) /Yes
Advantages	Simple installation and surface control of wells	Ease to change location and surface control of wells	Specially designed for little movement	Competence to operate long distances from shore due to storage capacity	Surface control of wells
Examples	Garoupa	P-59	P-51	Cidade Angra dos Reis	P-61

Source: PETROBRAS, 2018.

There are, on the other hand, some interesting alternatives to the traditional command and control regulatory mechanism, such as regulations that suggest the creation of compulsory contribution funds for all companies involved in E&P activities, aiming, for example, to cover bankruptcy cases or to avoid that the taking over of the activity by a new concessionaire implies the transfer of responsibility to the new operator or the government (PARENTE et al., 2006). This would be more efficient and would stimulate the development of economic activity.

As is well known, most of the Brazilian E&P facilities are located offshore. Table 1 shows these offshore structures found in Brazil, classified by structure, water depth on which they are installed, activities, and advantages offered. According to Petrobras (2018) there are six main exploration and/or production systems:

In addition to the production systems called topside, there is also the entire subsea system, i.e., the set of equipment located in the seabed or along the waterline, such as manifolds, templates, risers, Christmas trees, and anchor cables[2]. Pipelines enable the transfer of production fluids between platforms or processing units at sea and distribution on land. Besides this, they can be used to drain water produced from wells (RUIVO and MOROOKA, 2001)).

The subsea[3] system also requires decommissioning activities, often more complex than the topside[4] portion. However, the removal and disposal options for pipelines and cables do not have sufficiently comprehensive and detailed technical regulations for decision making.

According to Ruivo e Morooka (2001), the techniques that can be used in decommissioning platforms are complete removal (reverse installation) with disposal on land or on the ocean floor, partial removal, on-site tipping (first there is the removal of the topside and later the tipping of the entire structure(Rig to Reef)) or leaving the structure in place for alternative use.

The stationary production units of the FPSO and semi-submersible type present easy demobilization because they are mobile floating units. Thus, their main operational operational difficulties in decommissioning are in relation to subsea systems.

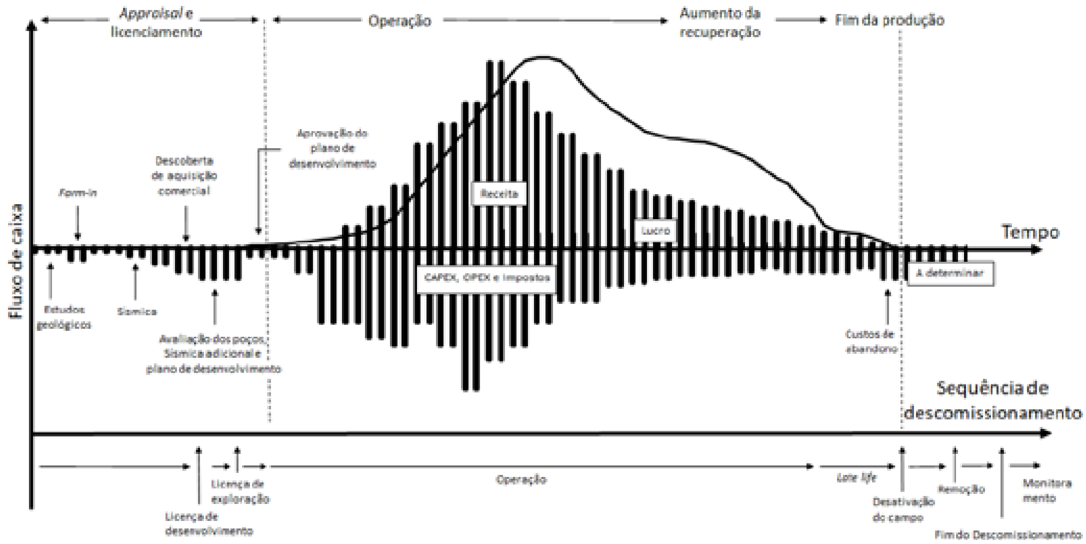
In decommissioning subsea systems, the most common removal techniques are: by reverse spooling (in which the pipeline is lifted from the seabed and reeled onto the reel located on the vessel), by S-lay and J-Lay (in which the pipeline is lifted from the seabed, cut into sections and stored), cutting and lifting, and abandonment without or with intervention (such as rock deposition, entrenchment/burial of sections, removal of pipeline sections, manifold modules and separators).

Unlike most other productive activities, in E&P projects the investment period occurs in the first years of project implementation, followed immediately by years of payback through positive cash flows. However, offshore E&P projects subsequently have an additional, and unavoidable, period of negative cash flow, which refers to decommissioning expenses at the end of the life cycle of the units.

It is worth mentioning that a stage prior to decommissioning is the attempt to increase the decayed production through techniques to increase the recovery factor of the fields. These techniques allow the fields to survive for longer and provide relief for the company's cash flow.

2. The equipment is described in the chapter 3.
3. Ditto.
4. Ditto.

FIGURE 2: CASH FLOW, TIMELINE, AND PRODUCTION CURVE OF A STANDARD OIL & GAS PROJECT.



Source: Adapted from Suslick *et al.* (2009).

Expenditures occur precisely when capital inflows have not been positive for some time. In Figure 2, it can be seen that a company's cash flow starts negative, due to the need to implement geological studies, acquire seismic, farm-in[5] and evaluate the wells. Subsequently, the project's CAPEX inflow and subsequent OPEX and tax payments alternate with the inflows related to revenue generated by the assets. Finally, there are the abandonment and field monitoring costs (SUSLICK et al., 2009). On the second horizontal axis of Figure 3.1 we observe the activities linked to decommissioning sequenced over time. In this way, the logic of the activities can be correlated with the stages of the total project, so that the burden on the cash flow is already known from the beginning of the project. In the Brazilian case, the biggest obstacles have been those related to the economic issue, especially in the prediction of costs related to the activity. Currently, these forecasts have already been incorporated into the new contracting models, but were absent in the older fields, precisely those whose decommissioning phase is approaching. The lack of predictability in the decommissioning operation leads to a lower attractiveness of the economic activity of production in mature fields and, consequently, to lower economic growth.

5. Eventually, when a company acquires areas that belonged to another operator, the acquisition process is called farm-in.

Added to this problem is the environmental issue, mostly related to questions of environmental imbalance due to the introduction of foreign species that threaten native species, such as sun coral and NORM[6], and the fact that the physical side of production is concentrated in deep waters. In this regard, it is worth mentioning that, although most of the facilities that will be decommissioned in the short term in Brazil are in shallow waters, it is necessary to reflect on the next steps.

In the light of the prevention and precautionary principles, one may experience a possible lack of technical knowledge about decommissioning since the activity is relatively new here. A doubt that permeates the market lies in the lack of infrastructure of the Brazilian shipyards to meet this demand, which is likely to be inconstant and relatively small.

There is also a degree of difficulty in determining the right moment to start the activity and, therefore, to define that this is the correct strategic action for the E&P company at that time- because there is always, at least in theory, a latent possibility of seeking to prolong the lifespan of the field. In this sense, there is no clear methodology available in the country to determine the end of the lifespan of offshore structures.

Based on the English experience, there are study groups investigating the criteria and sub-criteria relevant to the decommissioning scenario in Brazil as well, and a trend towards the adoption of multi-criteria analysis has been noted. The use of this methodology allows the evaluation for decommissioning to be adjusted to different contexts (such as shallow or deep waters, greater or lesser distances from the coast, types of production system), since the criteria and weights can be adjusted to these different realities.

Moreover, it is essential that regulators ensure that production will not generate environmental damage as a result of poorly managed decommissioning permits. According to Teixeira (2013), a solution to this issue would involve amending Laws 9478/97 and 12351/10 to include, among other elements, express provisions for decommissioning, as well as the publication of a CONAMA resolution on the licensing of this activity.

Although the environmental risks involved are a typical problem in virtually all oil producing countries, interesting dilemmas arise from an analysis of offshore E&P in emerging economies such as Brazil. The fact that this country holds the record for deep-water operations makes it more difficult and more expensive to carry out complex decommissioning processes due to the greater technical complexity. Brazil has more than

6. NORM: Radioactive material occurring naturally

122 offshore facilities in production (ANP, 2018) in a wide range of depths, which demands the development of technology and human resources in the planning of the State as a regulatory agent of the economic activity.

The deactivation and safe destination of decommissioned platforms in Brazil merits reflection. When there is an opportunity to reuse the topside, there are a number of alternatives for the use of these structures. They can, for example, be relocated to other production fields, usually after a complete life extension service, adaptation, revitalization and upgrading. There is also the option of using these facilities for purposes other than production, such as the creation of artificial reefs, offshore wind power generation (COSTA, 2018) and use for research development and military use.

It is observed, in Brazil, the absence of a coordinated networked and more detailed normalization on this complex operation, due to the little experience of extensive decommissioning projects, which can generate legal insecurity for investment agents.

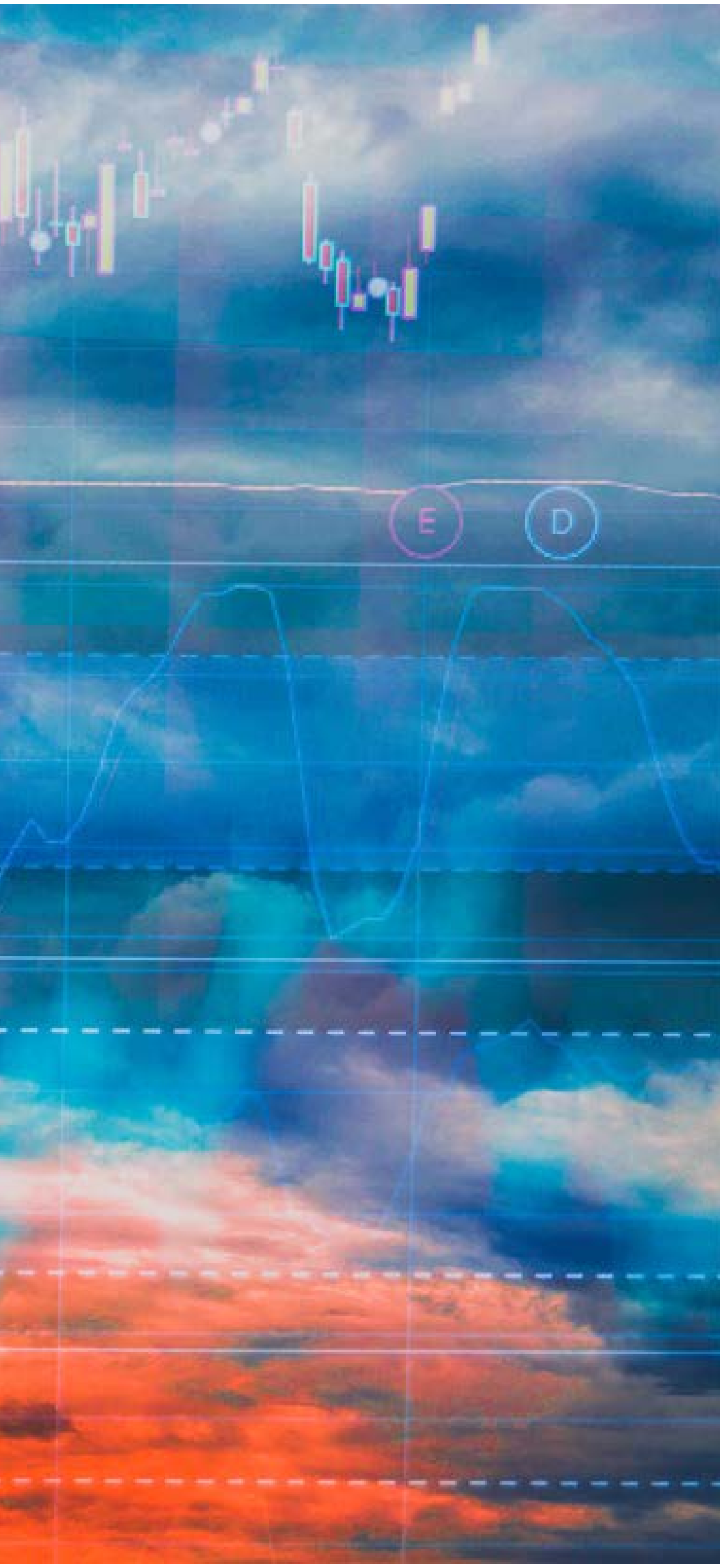
In addition, it was found that older fields may not have been accompanied by the structuring of financial mechanisms that would allow the funding of the complete decommissioning.

Drawing on an international example, such as the Guidance Notes prepared by DECC[7] in the UK, would be a useful suggestion for regulators. A document of this type speeds up the verification process, clarifies the responsibilities of each of those involved, and makes it easier for operators to manage the issue, since they can provide guidance and thus reduce legal and economic uncertainty about the process. Besides making the process simpler, the adoption of a common guide allows the creation of a database for the companies and the government, contributing to learning and a greater experience in decision making.

Another aspect that deserves to be highlighted is the macroeconomic verification of the insertion of an industry around the activity in the country, given that the demand for a considerable time horizon proves to be small. The propagated socioeconomic impacts resulting from the activity, such as catalyzing the shipyard industry and the generation of jobs, may prove to be small scale, and these are still sectored by the regions where the activity is prominent.

In the investment planning of the oil companies that operate in the country is the investment in the revitalization of mature fields, w ith a primary focus on increasing its recovery factor and improving the efficiency of the production process. With this element happening via

7. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760560/Decom_ Guidance_Notes_November_2018.pdf



transfer of operation or even assignment of portions of it to more experienced operators in the revitalization activity. This is a measure that fosters the market and should be encouraged, but its success depends on greater legal certainty in terms of the acquirer's responsibilities for decommissioning when this was not contractually addressed and its costs were not considered over the production life of the oil field.

Thus, investments directed to the clarification and improvement of the decision-making process contribute to reduce the burden of opting for decommissioning itself. To this end, the articulation among the competent agencies (such as IBAMA, ICMBio, ANP, Navy) as well as with the inspection and supervisory agencies (such as the Public Ministry and the "Tribunal de Contas da União" (Federal Audit Court)) is fundamental to build a solution capable of leading the country to a meritorious trajectory in dealing with the decommissioning issue.

This publication aims to contribute to the national debate on the decommissioning of these facilities and is divided into the following chapters: After this introduction, in Chapter 2 the ANP dedicates itself to contextualizing the theme, bringing the new regulatory instrument to the debate.

In Chapter 3 COPPE talks about the multicriteria analysis tool and its functionality in the decision- making process. Chapter 4 provides the reader with real case studies of companies that have already carried out decommissioning operations, Petrobras and Shell, bringing important considerations on lessons learned, opportunities and challenges for the national supply chain. In the sequence, ABESPETRO reviews the capacity of the national supply chain, highlighting its potential and bottlenecks to meet this new market niche. In Chapter 6, the "Estaleiro Atlântico Sul" presents the real case of how it is prepared to meet the needs of this industry and is ready for the opportunities of the domestic market. Next, CNEN, talks about the legislation and regulatory framework applicable to radioactive waste from decommissioning activities. And finally, in the last chapter, ABPIP, together with its consortium members Perenco, PetroRio and Premier Oil bring together the vision of the small independent operator, responsible for numerous revitalization operations that have been taking place in oil fields of various basins, extending the lifespan of the assets and thus postponing the decommissioning activities. For these players, and for the industry in general, decommissioning is a strategic issue, since it will be a critical success factor in the decision-making of the company and may create competitive advantages for the acquisition of a new investment opportunity in the current scenario of the Brazilian market.

Investments directed to the clarification and improvement of the decision-making process contribute to reduce the burden of the decommissioning option itself. The articulation between the competent agencies (such as IBAMA, ICMBio, ANP, Navy) as well as with the inspection and supervision agencies (such as Ministério Público and Tribunal de Contas da União) is fundamental to build a solution that is capable of taking the country to a worthy path in dealing with the decommissioning issue.

2

CHAPTER

Karen Alves de Souza – ANP
Luciene Ferreira Pedrosa – ANP
Ludmyla Carolina Mariano Barbosa – ANP
Nilce Olivier Costa – ANP
Tabita Yaling Cheng Loureiro – ANP
Tiago Machado de Souza Jacques – ANP

Contextualization

2.1 NEW REGULATORY INSTRUMENT ON DECOMMISSIONING OF ASSETS IN BRAZIL

The recent Resolution ANP 817/2020[8], published in April 2020, establishes the Technical Regulation for Decommissioning of Oil and Natural Gas Exploration and Production Installations in Brazil, in addition to disciplining the decommissioning in the assignment of contracts, the inclusion of onshore area under contract in the production phase in a bidding process, the divestiture and reversion of assets, the fulfillment of obligations remaining in the exploration stage and the return of area in the production stage.

This is a regulatory instrument that aims to foster the sector's business environment and to adapt to internationally recognized technical standards for decommissioning exploration and production installations, thus contributing to the development of safe activities that consider environmental aspects and, at the same time, attract greater investment to the country.

Decommissioning is the last stage in the life cycle of oil and natural gas exploration and production areas. It is an engineering project, consolidated in the Installations Decommissioning Program (PDI as an acronym in Portuguese) and consists of a set of

8. Available here: https://www.in.gov.br/web/dou/-/resolucao-n-817-de-24-de-abril-de-2020-254001378.

activities associated with the definitive interruption of the installations' operations, the permanent abandonment and plugging of wells, the removal of installations, the proper disposal of materials, waste and residues, and the environmental recovery of the area. The resolution, which establishes the procedures for the preparation and evaluation of decommissioning projects, was prepared jointly by the National Agency of Petroleum, Natural Gas and Biofuels (ANP), the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and the Brazilian Navy (MB) with the aim of encompassing in a single instrument the provisions for the decommissioning of facilities, providing greater legal certainty, regulatory simplification, and speed in the process. The joint preparation of the standard, a resolution by ANP, allowed the harmonization of the procedural aspects in the analysis of the assets decommissioning programs by the three institutions, in the exercise of their specific legal powers.

The ANP is responsible for evaluating the appropriateness of the proposed decommissioning, the status of the reservoirs in terms of resource recovery, and the scope of the project, i.e. the inventory of facilities that will be decommissioned. IBAMA's legal attribution is to guarantee that the decommissioning alternatives proposed are the ones with the least environmental impact and that mitigation measures for this impact are contemplated in the project. The Brazilian Navy supervises the naval aspects for the safe removal of the floating units and the appropriate mapping and signaling of equipment that may be left at the site and that, therefore, may interfere with other uses of the marine space.

The new regulatory instrument is also focused on creating a market for goods and services for the activity that begins in the country and, moreover, conditions the execution of activities, where relevant, to the 17 Sustainable Development Goals of the United Nations (SDGs), stipulating that the contractor must have a management system of social responsibility and sustainability adherent to the best practices of the oil industry. This reinforces the importance of the topic for society and for the industry, making it part of the strategic planning of both segments, thus contributing to companies leaving a legacy for society after the exploration and production of oil and natural gas.

Social responsibility has become, in many cases, a reference of excellence in the business world based on the perspective of sustainable development that results from the harmony between the economic, social and environmental aspects.

2.2 CENÁRIO GERAL DO DESCOMISSIONAMENTO NO BRASIL

One of the ANP's priorities is to extend the lifespan of the oil and natural gas producing fields, bearing in mind that the Brazilian recovery factor, currently at 21%, is significantly lower than the global average, of 35%. Therefore, it is essential to stimulate the redevelopment of producing fields and expand the Brazilian reserves, absorbing the expertise of companies specialized in maximizing recovery and fostering this entire business chain, generating local investments, income, revenues, and jobs.

In order to guarantee the attractiveness of investing in the oil and gas sector in Brazil, the ANP has been implementing the Permanent Offering of exploratory blocks and areas with marginal accumulations, a modality that consists of the continuous offering of the areas. With each inclusion of blocks and areas under study, the ANP publishes those that have already obtained the environmental guidelines and that may be offered. For each set to be included in the announcement, the ANP holds a public hearing.

The opportunities in this type of concession are in blocks and areas located in different exploratory environments, which allows the participation of companies of different sizes.

The attractiveness in the Permanent Offer is in:

- Continuous offer of blocks and areas with marginal accumulations;
- Single registration, with a reduced participation fee;
- Optional access fee to the technical data package and by sector;
- Reduction of the financial guarantee for the Minimum Exploratory Program;
- Reduction of the signature bonus for mature basins;
- Reduction of the minimum equity for non-operators;
- Distinct royalties for new frontier areas and mature basins.

It is worth noting that the first and second cycle of the Permanent Offer were considered a success. In the first cycle 33 blocks were offered in the Sergipe-Alagoas offshore basin and in the onshore basins of Parnaíba, Potiguar and Recôncavo, totaling an area of 16,730.43 km². In the second cycle, 17 blocks located in the Amazonas, Campos, Espírito Santo, Paraná, Potiguar and Tucano basins were auctioned, totaling an area of 19,818.09 km². Furthermore, 13 areas with marginal accumulations were acquired in the two cycles. For more information about the Permanent Offering, see: http://rodadas.anp.gov.br/pt/oferta-permanente.

On December 28, 2020, the National Energy Policy Council (CNPE) published Resolution 10/2020, which created the Program for Revitalization and Incentive to Production in Maritime Fields (PROMAR).

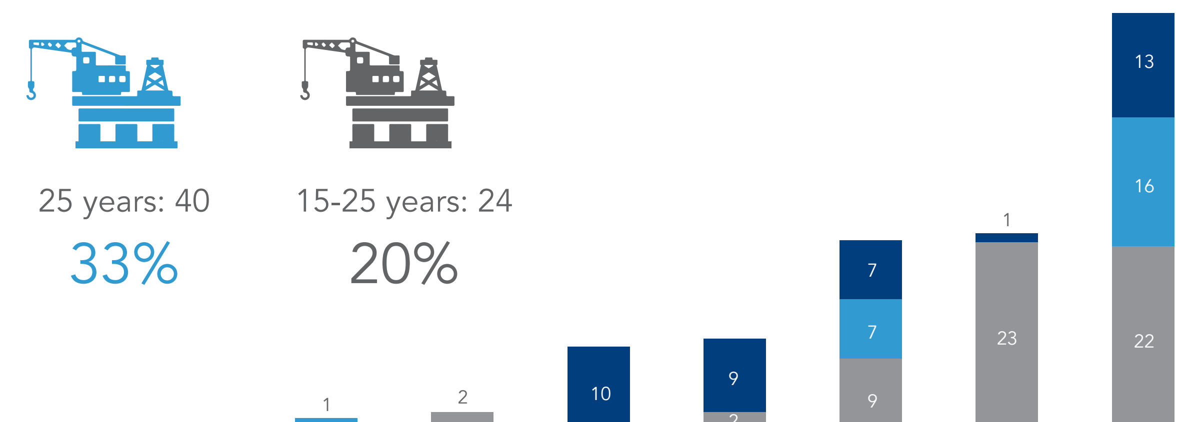
The program aims to propose measures to create conditions for the revitalization of mature oil and natural gas fields located offshore, with the objective of extending their productive life, increasing the recovery factor, continuity in the payment of government take, generating jobs and maintaining the local goods and services industry. In addition, it will propose measures to create better conditions for the economic use of offshore oil and natural gas accumulations, considered to be of marginal economic importance.

From January 2010 to date, 97 Discovery Assessment Plans have been submitted to the National Agency of Petroleum, Natural Gas and Biofuels (ANP) in offshore basins. Of these, 73 have already been completed, resulting in 28 Declarations of Commerciality and 45 full area devolutions, i.e., more than 60% of the evaluated discoveries were considered economically unviable under the conditions offered by the country. Regarding the fields in production, the same factors may cause their premature abandonment, in case there are no more conditions for commerciality, or additional development projects, such as drilling new wells and installing new production units.

The CNPE resolution now published has the potential to allow the identification of the main points for legal and regulatory improvement, aiming to attract investment to these opportunities of lesser importance, but that, together, may bring important results in terms of increased production, government participation collection, movement in the goods and services supply industry, employment and income.

On the other hand, as shown in figure 3, there are currently 40 platforms older than 25 years old, representing 33% of all platforms in operation in the country, most of them in the Campos basin (13), followed by the basins of Ceará (10), Sergipe-Alagoas (9) and Potiguar (7).

FIGURE 3: AGE OF THE BRAZILIAN PLATFORMS.



	Camamu	Espírito Santo	Ceará	Sergipe/ Alagoas	Potiguar	Santos	Campos
Over or equal to 25	0	0	10	9	7	1	13
Between 15 and 25	1	0	0	0	7	0	16
Under 15	0	2	0	2	9	23	22

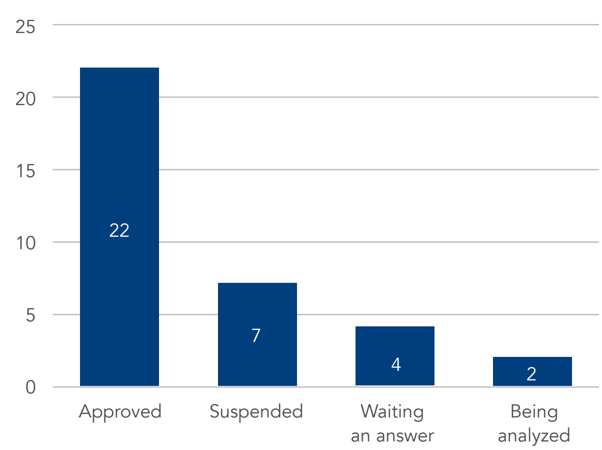
Source: ANP – DSO – January, 2021.

Therefore, one can observe that in the Brazilian scenario the platforms and fields at the end of their life cycle are heading towards the decommissioning stage, which will provide a new business niche, the dismantling of these facilities, and the steel industry can recycle and reuse the materials from these facilities, adopting the circular economy model.

The ANP will publish the Installations Decommissioning Programs (PDIs in the Portuguese acronym) submitted to the Agency by contractors at least five years before the end of production for offshore fields and two years before the end of production for onshore fields. It is expected that the greater predictability will enable market planning for the offer of the associated services.

According to the ANP's Dynamic Decommissioning Panel (https://www.gov.br/anp/pt-br/central-de-conteudo/paineis-dinamicos-da-anp/painel-dynamic-panel-of-decommissioning-of-installations-of-exploration-and-production), there are 77 PDIs filed with the ANP (Figure 2). In relation to the offshore environment, 35 PDIs were filed, of which 22 were approved, 7 suspended (with the analysis interrupted waiting for some event), 4 awaiting response and 2 under analysis. These fields with protocoled offshore PDIs are located in the Campos, Santos, Potiguar, Recôncavo, Camamu, Espírito Santo and Sergipe-Alagoas basins. The panel is public and may be consulted at any time, showing the status, in real time, of decommissioning in Brazil.

FIGURE 4: PR DECOMMISSIONING PROGRAM FOR OFFSHORE FACILITIES .



Source: ANP (Painel Dinâmico de Descomissionamento – Consulted in Nov/09/2020).

It is noteworthy that 15 platforms were part of the scope of these 22 approved PDIs, of which, nine platforms will still be decommissioned, as shown in table 2.

TABLE 2: PLATFORMS THAT HAVE NOT YET BEEN DECOMMISSIONED.

PDI	Field	Basin	Main Facilities
Cação	Cação	Espírito Santo	PCA-01, PCA-02, PCA-03
FPSO Piranema Spirit	Piranema	Sergipe-Alagoas	FPSO Piranema Spirit
P-15	Piraúna	Campos	P-15
P-07	Bicudo, Pampo e Enchova Oeste	Campos	P-07
P-12	Linguado, Badejo, Trilha, Bicudo e Enchova Oeste	Campos	P-12
P-32	Marlim	Campos	P-32
FPSO Fluminense (Conceitual)	Bijupirá e Salema	Campos	FPSO Fluminense

Source: ANP - Painel Dinâmico de Descomissionamento - Consulted in Nov/09/2020

2.3 OPPORTUNITIES IN BRAZIL

According to information presented by the operators to the regulator, it is estimated that, in the period from 2020 to 2025, 51 PDIs will be delivered, with decommissioning forecasts for 31 fixed and 20 floating platforms, besides several pieces of equipment.

These numbers are still subject to the uncertainties related to the extension of the useful lifespan of the installations.

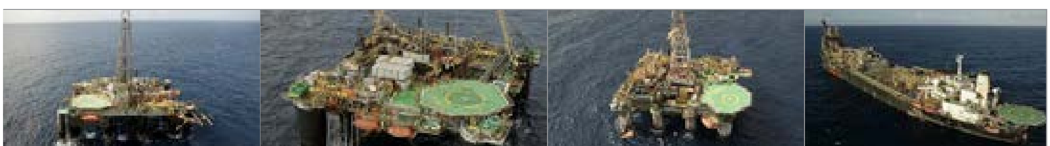
Figures 5 and 6 show the opportunities listed in the recently approved PDIs, whose installations should be decommissioned.

FIGURE 5: OPPORTUNITIES IN THE APPROVED OFFSHORE DECOMMISSIONING PROGRAMS.

Facility	PCA-01, PCA-02, PCA-03 LDA: 19 m Cação Field	FPSO Piranema Spirit LDA: 1.090 m Piranema Field	FPSO Fluminense LDA: 705 m Bijupirá and Salema Fields
Platform weight	1.800 t	26.523 t	52.301 t
Wells	13	11	22
Pipelines (Rigid)	27 km	–	21 km
Pipelines (Flexible)	–	75 km	43,4 km

Source: ANP (PDIs).

FIGURE 6: OPPORTUNITIES IN THE APPROVED OFFSHORE DECOMMISSIONING PROGRAMS.



Facility	P-07 LDA: 200 m Bicudo Field	P-12 LDA: 100 m Linguado, Badejo and Trilha Fields	P-15 LDA: 240 m Piraúna Field	P-32 LDA: 160 m Viola Field
Platform weight	10.240 t	11.801 t	13.155 t	137.086 t
Wells	47	41	28	–
Pipelines (Rigid)	12,6 km	–	9,5 km	2,9 km
Pipelines (Flexible)	187,4 km	209,9 km	181,1 km	–

Source: ANP (PDIs).

As shown in Table 3, 694 development and production wells are expected to be decommissioned between 2021 and 2025.

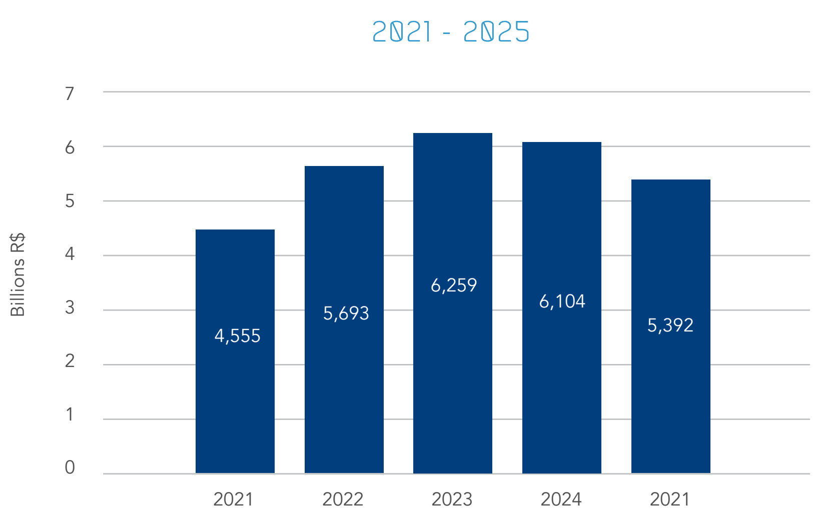
According to what is also observed in the Decommissioning Dynamic Panel, it is expected that between 2021 and 2025, total investment in decommissioning is expected to reach R$ 28 billion (Figure 5). As shown in Table 3, R$ 18.69 billion will correspond to well abandonment and plugging activities, R$ 8.92 billion to the removal of equipment, R$ 290.06 million to the recovery of areas and R$ 106.93 million to other activities.

TABLE 3: WELL PLUGGING AND ABANDONMENT FORESCAST (2021 - 2025)

	2021	2022	2023	2024	2025	Total
Quantity	102	132	135	168	157	694

Source: ANP (SIGEP – Programa Anual de Trabalho [PAT 2021])

FIGURE 7: EXPECTED INVESTIMENT FOR DECOMMISSIONING.



Source: ANP-SIGEP-Programa Anual de Trabalho-PAT 2021.

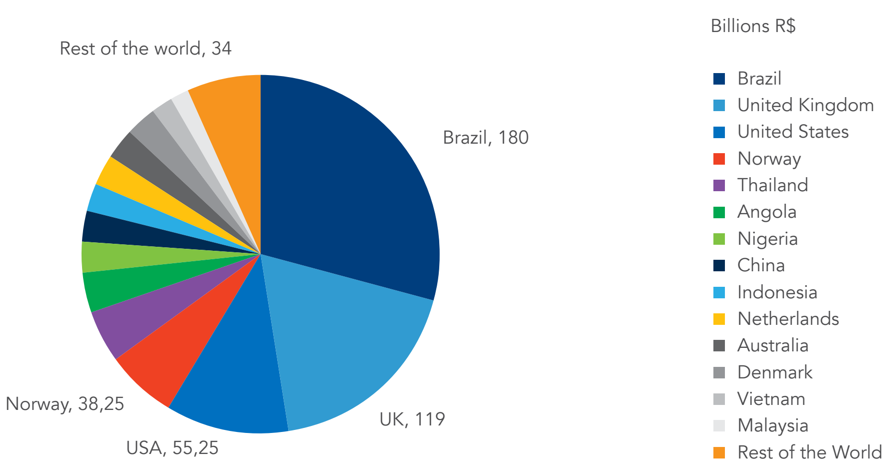
TABLE 4: EXPECTED INVESTIMENT FOR DECOMMISSIONING (2021- 2025).

Activity	Total investment (in billions of reais)					
	2021	2022	2023	2024	2025	Total
Well Plugging and Abandonment	2,87	3,29	3,70	4,82	4,00	18,69
Equipament Removal	1,64	2,29	2,49	1,18	1,31	8,92
Area Recovery	0,03	0,03	0,06	0,09	0,08	0,29
Others	0,01	0,08	0,01	0,00	0,00	0,10
Field Deactivation	4,55	5,69	6,26	6,10	5,39	28,00

Source: ANP (SIGEP – Programa Anual de Trabalho - PAT 2021)

According to figure 8, it is estimated that Brazil will be one of the world leaders in volume of investment in decommissioning (Figure 8). These numbers corroborate the values presented in PAT 2021, where it is observed that the total investment in decommissioning for the period after 2025 may exceed 180 billion reais (Table 5), considering the large quantity of facilities that will be decommissioned in the next years.

FIGURE 8: EXPECTED GLOBAL INVESTIMENT FOR DECOMMISSIONING.



Source: Information adapted from oilandgasuk.co.uk/wp-content/uploads/2019/09/OGUK-Decommissioning-Call-for-Evidence-Response.pdf. Considered exchange rate was R$ 5,00/US$.

TABLE 5: EXPECTED INVESTIMENT FOR DECOMMISSIONING (POST 2025).

Activity	Total investment (in billions of reais)
Well Plugging and Abandonment	115,96
Equipament Removal	56,02
Area Recovery	6,82
Others	0,93
TOTAL	179,73

It is important to inform that the information of the Decommissioning Dynamic Panel is extracted directly from the Annual Work and Budget Programs (PATs), which are presented by the contractor with the set of activities to be performed during a calendar year. The physical quantities, the expected schedule for the decommissioning of the field, and the total investments are detailed by stage, such as the plugging and abandonment of wells, removal of equipment, and recovery of areas, among others.

Many opportunities will arise from the information made available by the Brazilian regulator, especially regarding the predictability of activities such as the removal of structures and equipment, the recycling and disposal of materials, and the abandonment and plugging of wells, which will allow the service market to prepare to meet this new demand.

This is an opportunity for the service sector, which may be complemented by the development of facilities for dismantling of units, and recycling of pipelines, equipment, and materials.

Considering that decommissioning is a strategic issue for the country, the government should encourage the entire chain of technological innovations, research, and development, as well as new stakeholder networks, which could provide a reduction in the costs associated with the projects.

Moreover, it will be a great opportunity to collaborate on social issues, as companies are expected to integrate the SDGs into their business by incorporating them into their corporate systems, policies, and processes.

Socially responsible actions go beyond compliance with the law, contributing to the management of community relations and sustainable development and, consequently, positively impacting a company's business through a better relationship with stakeholders and enhancement of institutional image.

2.4 CHALLENGES

Currently, the decommissioning of offshore facilities can be considered a major challenge for the oil and natural gas production industry in Brazil, as it is a complex issue that involves legal challenges (convergence between government and industry interests), environmental challenges (coral fouling and disposal of naturally occurring radioactive materials - NORM) and economic challenges (costs of the activities and financial guarantees).

The need for the expansion of technical capacity and the development of the service chain with specific solutions for decommissioning are very relevant issues.

The large number of production systems that will undergo decommissioning processes, whether partial decommissioning to adapt to the redevelopment of the fields, with or without the transfer of rights, or total decommissioning for the end of production, will represent a great challenge for the regulator's analysis capacity. At the same time, it will be up to the same team to coordinate with other competent authorities for the adequacy and supervision of the execution of the activities.

Outside the scope of its final attribution, the sector regulator is also responsible for the incentive to create a market for goods and services in the country, in order to maximize the social gain from the activity, providing qualified information to the interested parties and to the other entities of the Administration.

It is also important to mention the commitment to the elaboration of regulations that establish clear and transparent rules that aim to extend the lifespan, maximize production and inhibit premature decommissioning, besides the guarantee that the execution of decommissioning activities is done safely, minimizing the risks to people, the environment and other affected parties.

For the Brazilian government, a major challenge is to generate indicators of positive socio- economic impacts for the country, in terms of job creation, business attractiveness and environmental sustainability, and to ensure that companies committed to sustainable development can better evaluate, measure and demonstrate to stakeholders their social responsibility practices.

Finally, fostering a predictable and sustainable regulatory environment to attract new investment and accelerate the country's development must be a priority for the state. Providing structuring and balancing actions between governance, social and economic issues will be key to attract new business.

3

CHAPTER

Giselle Távora – COPPE
Jean-David Caprace – COPPE
Luisa Nogueira – COPPE
Marcelo Igor Lourenço de Souza – COPPE

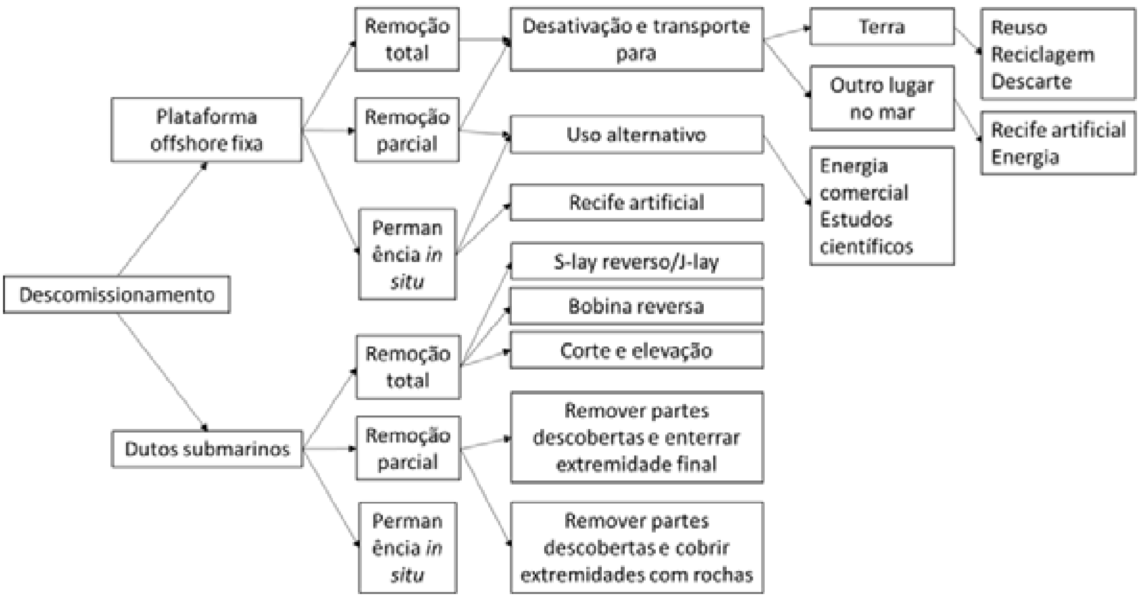
Evaluation of Decommissioning Alternatives and ANP Resolution 817/2020

When we talk about decommissioning, we refer to the deactivation and subsequent destination of facilities, structures and equipment that served an end during their productive life. In the O&G sector, decommissioning gained importance as the oil fields and consequently their production facilities began to reach the end of their productive life.

Focusing on offshore production systems, we can mention three major groups that will be subject to decommissioning processes: wells, subsea systems, and production units. In the case of subsea systems, these are composed of export pipelines[9], production lines[10], injection lines[11] and equipment such as manifolds,[12] PLEMs[13], and PLETs[14]. There are several applicable decommissioning alternatives, depending on the structure to be decommissioned, as shown in the figure below. In general, these alternatives follow two possible paths, removal, or permanence *in situ*.

9. Pipelines used for exporting oil and gas production from the field to the shore.
10. Flexible or rigid lines responsible for the flow of production from a field.
11. Flexible or rigid lines responsible for the flow of injection fluids in a field.
12. Equipment composed of pipes or valves designed to control, distribute and monitor fluid flow, usually.
13. Equipment responsible for receiving production pipelines and interconnecting them to other pipelines, separating them into distinct routes.
14. Equipment that enables subsea interconnection between rigid and flexible pipelines or between a pipeline and subsea equipment.

FIGURE 9: DECOMMISSIONING ALTERNATIVES



Source: Adapted from MARTINS et al, 2019

According to ANP Resolution No. 817/2020, any facilities should be removed from the area under concession, and the alternatives of partial removal or permanence in situ are allowed as an exception once the applicable requirements are met and duly justified. The decision to choose an alternative different from removal must be justified and based on a comparative analysis considering at least five criteria: technical, environmental, social, safety and economic. Also according to the resolution, the mentioned criteria must evaluate the following aspects:

- **techinical:** evaluation of the feasibility and technical complexity of the alternatives considering the characteristics of the facilities and the existing technologies;
- **environmental:** assessment of risks and environmental impacts of the alternatives on the marine, terrestrial and atmospheric environments;
- **social:** evaluation of the impacts of the alternatives on the communities and other users of the sea and the perspective of variation of jobs;
- **safety:** evaluation of the risks of the alternatives to workers in the marine and terrestrial environments, to other users of the sea and to third parties;
- **economic:** estimation of the costs of the alternative projects.

These five evaluation criteria are commonly used by the industry in making decisions on decommissioning projects, e.g. program reports submitted for North Sea fields. It is worth emphasizing that the analysis of a single criterion separately to justify alternatives of partial removal or permanence in situ is not enough. A holistic evaluation is required to indicate the most appropriate alternative for a given decommissioning scenario. In this context, the application of a multi-criteria decision analysis (MCDA) methodology is a robust option for application in the decision-making process.

3.1 MULTI-CRITERIA DECISION ANALYSIS - MCDA

But what is Multi-Criteria Decision Analysis? MCDA, is a subdiscipline of operations research that explicitly evaluates multiple conflicting criteria in decision making. When buying a car, cost, comfort, safety and fuel economy may be some of the main criteria we consider - it is unusual that the cheapest car is the most comfortable and the safest. The criteria are conflicting, resulting in a trade-off situation.

MCDA is concerned with structuring and solving decision and planning problems involving multiple criteria. The goal is to support decision makers facing such problems. Usually, there is no single optimal solution to such problems, and it is necessary to use the decision maker's preferences to differentiate solutions. To solve this problem, certain MCDA techniques use a set of tools aiming to provide a general ordering of alternatives from most preferred to least preferred. The difficulty of the problem stems from the presence of more than one criterion. There is no longer a single optimal solution to an MCDA problem that can be obtained without incorporating preference information.

MCDA techniques were developed to provide analysis alternatives for complex problems, which are usually characterized by some combination of monetary and non-monetary objectives. In general, the problem is divided into manageable parts to allow data and judgments to be provided in a coherent way to decision makers.

The MCDA methodology can be used retrospectively, to assess items for which resources have already been allocated, or prospectively, to support future decisions, as is the case with its application to decommissioning projects.

Many projects in the North Sea adopt a simpler form of analysis, considered by several regulatory agencies and the ANP to be an appropriate method for listing the best decommissioning options. The comparative assessment (CA) has the advantage of being simple, as it is a predominantly qualitative method. However, in the Brazilian context, where the complexity of production arrangements and the environmental and social dimensions are of great relevance, an MCDA analysis can offer the traceability and depth of analysis necessary for a good understanding among decision makers.

For decommissioning, the application of the MCDA process can be divided into the following stages:

FIGURE 10: APPLICATION STAGES OF THE MCDA PROCESS FOR DECOMMISSIONING.

PRELIMINARY STAGE	Study of the literature and choice of the multi-criteria
STAGE 1	Setting the decision context
STAGE 2	Identifying the alternatives for the decision
STAGE 3	Establishing the criteria and objectives for the decision
STAGE 4	Analyzing the performance of the alternatives for each criterion
STAGE 5	Analyzing the criteria weights
STAGE 6	Analyzing the results
STAGE 7	Analyzing Sensitivity of results

Source: adapted from BRANS, 2002.

The result of the comparative evaluation, in the context of decommissioning, should demonstrate and justify the existence of significant reasons why an alternative is preferable to others. It is worth emphasizing that the multicriteria decision methods do not aim to find a solution that is a single truth, but to support the decision process by indicating the preferable alternative.

With an initial study of the available literature and knowing the decision context, it is possible to determine which MCDA approach will be adopted, the initial objectives that will be pursued and that will direct the following stages in the formulation of the decision making process.

The first step in the stage of identifying alternatives is to exclude unrealistic alternatives from the analysis, documenting properly the reasons for exclusion. For example, an alternative may be excluded for causing very high environmental or social impacts or for technical impossibility of implementation. At the end of this first analysis, it is expected to generate a list of feasible decommissioning alternatives that can be considered without restrictions.

The stages related to the establishment of criteria define the attributes (criteria and sub-criteria) that should guide the decision-making process. Criteria are the attributes by which to judge each viable alternative. Through criteria and sub-criteria, clearly described and defined, and with appropriate evaluation metrics, it is possible to evaluate one alternative against another. According to ANP Resolution No. 817/2020, a MCDA analysis for a decommissioning scenario in Brazil should at least assess the five criteria presented above and contain sub-criteria that assess in more detail the relevant aspects of each criteria.

A shared research project (JIP) developed in Brazil by DNV-GL[15]. The project involved the participation of oil operators and service providers. For the safety criterion, the JIP identifies sub-criteria related to offshore and onshore workers and the public affected by decommissioning activities. In the social criterion, there are sub-criteria that seek to identify impacts on job creation and fishing, among other social impacts. In the environmental criterion, sub- criteria related to waste generation, greenhouse gas emissions, dissemination of invasive species, among others, are pointed out. The technical and economic feasibility of each decommissioning alternative is also considered, in accordance with the international experience and ANP resolution 817/2020.

In this process of defining sub-criteria, it is possible and desirable to include stakeholders to ensure that different points of view are captured, as well as stakeholders' understanding of why certain facts they consider important may not be significant in the context of a specific decision. However, it is important that the sub-criteria are reviewed on a case-by-case basis to ensure that they are appropriate to the situation being evaluated. Furthermore, sub-criteria may change over time as the context of the decision evolves or if new viable decommissioning alternatives emerge, for example.

International experience shows that the best way to resolve conflicts is to use MCDA integrated into an interested parties' engagement process, where the listening process should be implemented before the study is completed. This is the most appropriate way to ensure that the selected alternative reflects the wishes and expectations of society.

A stage considered crucial is the definition of criteria weights, for it will consider the perception of the decision maker as to the contribution of each criterion in the MCDA result. These weights can be defined in several ways: equally distributed weights among criteria, equally distributed weights among subcriteria, application of methods where the perception of experts and stakeholders is considered, application of the AHP method, and others. These various forms of distributing weights should be incorporated into the MCDA assessment by demonstrating how the ranking of alternatives is influenced by the weight assigned to each criterion. Instead of providing the decision maker with a single alternative, the MCDA method should provide an overview of the performance of the alternatives as a function of the weights and identify which aspects of the analysis were most significant. It is with this overview that it is hoped to support decision making.

15. DNV-GL, together with companies in the oil and gas industry, has developed a guideline within a JIP (Joint Industry Project) proposing a benchmarking methodology based on five criteria: technical, environmental, social, safety, and economic.

The traceability, impartiality, and credibility of the information used in MCDA studies are crucial to ensure their use as a tool in the search for widely accepted solutions. It is with the aim of pursuing these aspects that independent review groups (IRGs) are often involved, working together with the companies in conducting the studies. The purpose of the IRG is to ensure the completeness and quality of the studies conducted, suggest different alternatives or conduct additional research, promote stakeholder engagement, among others.

An example of the use of MCDA in decommissioning is the Osprey oil production field, operated by the company FairField Betula Limited, located in the North Sea at a water depth of 159 m and whose production ceased in 2015. In its decommissioning program, a benchmarking process was used to assist in decision making regarding the subsea infrastructure. To develop this analysis, the structures were grouped by similarity, into different groups. All possible decommissioning alternatives were identified, evaluated, classified, and selected in order to carry out only the alternatives that were effectively viable for each group. Three groups went through the entire evaluation process: bundles, flexible risers and umbilicals, entrenched umbilicals with rock deposition[16]. For the other groups, the decision was made at the identification and screening stage of the alternatives where it was considered that there were no doubts, therefore, opting not to perform a full analysis and adopting total removal as the chosen alternative.

This multi-criteria analysis process used the five evaluation criteria already mentioned, weighted to balance and represent the views of the associated key stakeholders.

An independent consulting firm was hired to facilitate the alternatives evaluation process. The evaluation team was composed of experts from the operator itself and industry experts, including O&G sector regulation. The assessment was performed based on the multi-territory AHP (Analytical Hierarchy Process) technique.

For each criterion evaluated, the team analyzed the relative importance of each alternative in relation to the others, both quantitatively and qualitatively. This judgment allowed numerical weightings to be derived for the various competing criteria, a standard step in MCDA. After all alternatives were evaluated and compared, ranking of the alternatives was completed to allow the assessment team, including key external interested parties, to select the preferred decommissioning alternative for each grouping evaluated.

16. Bundles: a set of production, injection and control lines isolated in a single structure, minimizing heat transfer and avoiding hydrate and paraffin deposition.
Flexible Risers: dynamic stretches of flexible lines (production or injection) that connect the seabed to the stationary production unit (UEP).
Umbilical Risers: dynamic sections of control/injection lines that connect the seabed to the PSU. Entrenched and rock-filled umbilicals: control/injection lines installed in seabed trenches or covered by rock-filled deposition.

We can cite the example of the group consisting of flexible pipeline risers and control umbilicals installed in J-pipes. Two alternatives were included in the analysis. One considering the total removal of the pipelines and umbilicals and the second considering the permanence in-situ of the riser sections installed inside the J-pipe. The decision, after analysis, was for the second alternative, subject to re-analysis when the platform is decommissioned[17].

Given the relevance of the topic and the decommissioning scenario in Brazil for the coming years, there is a wide range of studies and projects that can be developed, ranging from the improvement of MCDA techniques to logistical analysis, structural integrity, technologies for the safe removal of invasive species, low-cost technologies for removing structures, artificial reefs, and opportunities for reuse of structures, among others.

Regarding specifically the decision-making processes, the continuous improvement of methodologies for the application of MCDA techniques to support and ground future decommissioning programs is a promising field. In addition, residual strength analysis to verify structural integrity given the high uncertainty associated with older structures is another area where there is opportunity for research and development.

Another opportunity can be found in the evaluation of logistical aspects, since the supply chain has significant importance in the analysis of decommissioning alternatives, where artificial intelligence techniques could be applied.

Regarding environmental aspects, major challenges are encountered such as the impact of NORM on the marine ecosystem and of sediment dispersion in decommissioning operations on marine invertebrates and, therefore, research in this area is relevant for the industry.

It can be concluded that the opportunities and challenges are numerous, highlighting the importance of an increasingly significant cooperation between the O&G industry and academia so that together they can develop projects resulting in innovation and advances regarding not only decommissioning, but the development of the sector as a whole.

Pode-se concluir que as oportunidades e os desafios são inúmeros evidenciando a importância de haver uma cooperação cada vez mais expressiva entre a indústria de O&G e a academia para que juntos possam desenvolver projetos resultando em inovação e avanços no que tange não só ao descomissionamento, mas ao desenvolvimento do setor como um todo.

17. More information and details of this case study can be found in the document Osprey Field Subsea Infrastructure Comparative Assessment – available at http://www.fairfield-energy.com/assets/documents/ FFL- DUN-OSP-HSE-01-RPT-00001-Osprey-Field-Subsea-Infrastructure-Comparative-Assessment.pdf.

4

CHAPTER

Eduardo Nicolosi – Petrobras
Eduardo Stein – Petrobras
Equipe Shell coordenada por **George Oliva** – Shell

Case Study

4.1 EXPERIENCE AND CHALLENGES OF THE BRAZILIAN INDUSTRY

The number of decommissioning projects of offshore systems in the Brazilian scenario is small when compared to other regions that stand out for offshore production, such as the Gulf of Mexico and the North Sea. According to information contained in the ANP's Dynamic E&P Facilities Decommissioning Panel, several Installations Decommissioning Programs (PDI) associated with offshore facilities have already been forwarded to the agency, 22 of which have "approved" status, and part of these have already been executed.

Here are some examples of platforms in Brazil that have already been decommissioned and some projects in progress:

- **Platforms already removed from the location:** P-27, P-34, FPSO Brasil, FPSO Marlim Sul e FPSO Cidade de Rio das Ostras, all associated with Petrobras decommissioning projects;

- **Examples of decommissioning projects in progress:** P-07, P-12, P-15, P-32, e fixed rigs of Cação (PCA-1, PCA-2 e PCA-3), from Petrobras, and FPSO Fluminense, of Shell Brasil

18. http://www.anp.gov.br/exploracao-e-producao-de-oleo-e-gas/seguranca-operacional-e-meio-ambiente/descomissionamento-de-instalacoes

FIGURE 11: DECOMMISSIONING PROJECTS UNDERWAY IN THE CAMPOS BASIN

(P-07: LDA = 200 m; P-12: LDA = 100 m; P-15: LDA = 242 m; P-32: LDA - 160m).

However, the particularities of the national oil and gas industry, especially in the Campos Basin, mean that decommissioning projects in Brazil present several technical challenges, such as (i) large variation of water depth (LDA) in which the subsea systems are located, ranging from shallow to ultra-deep waters; (ii) extensive use of flexible pipelines and subsea umbilicals, whose total lengths can exceed 300 km in a single project; (iii) large number of subsea wells; (iv) existence of production systems, especially subsea lines and equipment, installed many years ago, some as early as the 1980s; (v) local logistical infrastructure being adapted for decommissioning operations; (vi) limited regional availability of specialized vessels (e.g. heavy lift support vessel); (vii) wide variety of environmental scenarios, including areas with the presence of calcareous algae beds and deep-water corals; and (viii) occurrence of Sun coral, a species classified as an invasive and alien.

4.2 MAIN STAGES OF A DECOMMISSIONING PROJECT

Due to the complexity, diversity of possible alternatives and the need to ensure compliance with the strictest standards of safety and socio-environmental responsibility, the decommissioning projects are planned from an evaluation of conceptual alternatives that are detailed until the definition of the best form of execution, based on environmental, risk, technical, economic, social and logistical evaluations, and are always previously approved by the competent bodies before the start of operations.

The conceptual assessment aims to detail the scope of the decommissioning project, to generate an initial schedule, to plan the stages and phases that follow, performing inspections to survey the conditions of the structures and to perform the environmental characterization, analyzing the different decommissioning alternatives of the facilities (e.g.: destinations of the platform and subsea system) considering the technical, economic and socio-environmental aspects. Finally, the most suitable alternative is defined for submission of the "Conceptual Installations Decommissioning Program (PDI)" to the regulatory/licensing agencies.

In this stage of conceptual evaluation of decommissioning alternatives, it is common to have different levels of maturity of information and analysis for planning and evaluation of decommissioning alternatives for each of the main areas of the project: surface facilities, wells, and subsea system. The implication of this is that, for the mitigation of risks and gain of scale, the decommissioning of platforms, subsea systems and wells have their own specific chronologies and, consequently, the ideal is that the scope of decommissioning projects is divided into these three areas, ensuring, of course, the correct treatment of interfaces between them.

For the detailing of the selected alternative, the in-depth technical analyses are carried out and the executive procedures are generated, as well as the risk analyses and environmental impact assessments. This project detailing phase, which also includes the generation of the executive budget and schedule, culminates in the presentation of the "Executive PDI" to the agencies.

Once the planning stage is complete, and with the PDI approval process finalized, the project moves on to execution, which involves, in the case of deactivation of floating platforms (i) the definitive stop of production; (ii) preparation of the production system for decommissioning (e.g., cleaning of pipelines and subsea equipment and conditioning of the processing plant); (iii) de-anchoring and removal of the platform from the location, for reuse in another project, sale or dismantling; (iv) decommissioning of the wells; and (v) final destination of the subsea system (pipelines and equipment).

In the execution stage of the decommissioning project, the strictest standards of safety and socio-environmental responsibility are followed, including the appropriate disposal of facilities, waste and residues, in accordance with the applicable regulations. Local industry capacity, notably for recycling of large structures, is still developing and may not be available or meet all industry standards.

At the end of the execution, the post-decommissioning monitoring plan (PMPD) begins and the performance of the project is analyzed, as well as the lessons learned are identified and registered, which will be applied in future projects.

The project ends with the forwarding of the Facilities Decommissioning Report (RDI) to the regulatory/licensing agencies.

4.3 DESCOMISSIONING OF FLOATING PLATFORMS

After years of operation, when there is no longer viability to continue production, the production systems are decommissioned. The wells are properly decommissioned and plugged to ensure the isolation of the reservoirs, and the pipelines and subsea equipment are properly cleaned, thus allowing the disconnection and proper disposal of the platform.

The floating platforms, mainly FPSO's (Floating Production Storage and Offloading) and SS's (semi-submersible platforms) in the case of the Brazilian scenario, are installations whose exit stage from the location is not very complex, if compared to fixed platforms, since, being vessels, they are inherently easy to disconnect and mobile. The very design philosophy of these units makes their removal and eventual reuse simple, since they can be reconverted and adapted for production in a new area.

Considering that decommissioning operations of floating platforms aim to disconnect the units from the rest of the production system and remove them from their location, decommissioning activities can be divided into four stages: (i) conducting inspections and technical assessments; (ii) stopping production and preparing the process plant; (iii) disconnecting the risers (after cleaning the pipelines) and the anchor lines; and (iv) final destination, which consists of the tow to a new location (temporary or definitive).

During the first stage, inspections and assessments are conducted to gather the necessary information to create the decommissioning procedures and to obtain authorization for decommissioning. At this moment the unit's conditions of navigability are evaluated, the integrity conditions are analyzed, and the operational status of the equipment and systems that will be used for cleaning, disconnection, and towing are assessed. With this information, it is possible to draw up a plan for shutdown, cleaning, preparation, and disconnection of the unit. In this initial phase it is also important to perform radiometric measurements to ascertain the presence of NORM (Naturally Occurring Radioactive Materials) in the process plant and tanks, so that waste removal and management can be planned, according to existing operational procedures applied throughout the production phase. It is also in this first stage that the presence of invasive alien species on the platforms' hulls is detected as for example the sun coral (Tubastraea spp.), an important factor in defining the final destination strategy for the units.

After the production stoppage, the subsea pipelines connecting the wells to the platform are cleaned, which consists of performing routine operations in the production phase and, therefore, their risks are well mapped out and known. Then the cleaning of the process plant (drainage, ventilation, purging and washing of vessels, equipment and lines) and of the cargo tanks is carried out to comply with regulatory requirements, removing hydrocarbons and other substances (including NORM) and isolating the systems to prevent contamination. Chemical products (lubricants, corrosion inhibitors, demulsifiers, etc.) are also unloaded.

With the tanks and plant cleaned, structural reinforcements and adjustments are made, if necessary, for the vessel's navigation. Even before the disconnection and in parallel with the cleaning and shutdown activities, if necessary, systems that will still be used after the shutdown are prepared, such as riser pull-out winches, anchor winches and towing accessories.

The disconnection phase consists, in short, of pulling out the risers (pipelines and umbilicals) and de-anchoring the unit. These activities require the programming of specialized vessels, as PLSV's (Pipe Laying Support Vessels) and AHTS's (Anchor Handling Tug Supply Vessels), and therefore require advance planning. Before the complete disconnection of the anchoring system, some complementary actions may be required in case the unit is towed uninhabited, such as the installation of emergency access and marine signaling lights, which must be foreseen in the unit's decommissioning plan. All safety and integrity requirements of the platforms are met until the end of decommissioning, ensuring the maintenance of the vessel's class certificate and the feasibility of reuse or destination to other uses.

Finally, the unit will be towed to its destination, here in Brazil or abroad, for reuse in another project, and may require a temporary stop at a shipyard for final cleaning activities and adequacy works, or for dismantling at a shipyard. To perform these activities, the shipyards must strictly follow all the national and international legislations and regulations, guaranteeing total compliance with good safety and sustainability practices, i.e., reduction of environmental impacts/risks and social responsibility. It is noteworthy that the destination of the platform may be carried out by the operator itself or by third parties, since the sale of the unit, which can be carried out even in the location itself, is an alternative that seeks the best use of the vessels, when there is no compatibility of reuse by the initial owner.

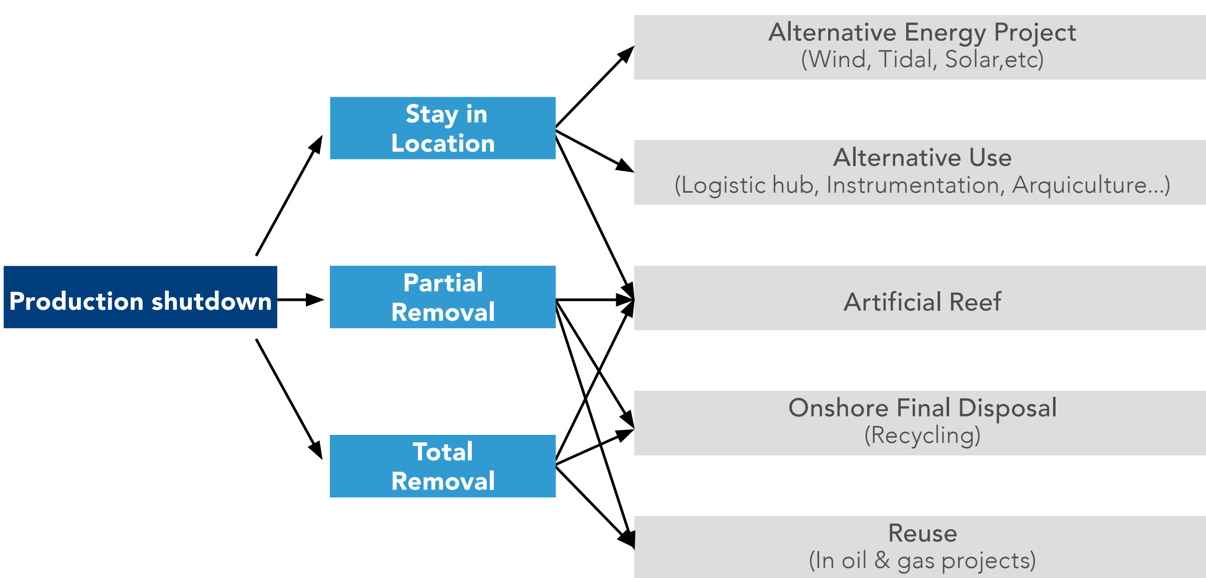
4.4 DECOMMISSIONING OF FIXED PLATFORMS

Fixed platforms, especially jackets, are the most common type of offshore oil and gas production platform in the world. Most of these structures are small to medium sized, many with masses of less than 4000 tons, and are located in shallow waters. However, regardless of size and weight, the decommissioning project of these structures presents a larger number of alternatives to be evaluated, especially regarding the final destination, when compared to floating platforms.

BOX 1

In the North Sea, Shell used innovative technology to decommission part of the Delta, Bravo and Alpha platforms in the Brent field in a 140 m depth. The topsides were safely and successfully removed in a single lifting operation. When the decommissioning was carried out in 2017, the removal of the Delta Brent topside was considered the largest single lift operation in the world: 24,200 tons. Notably, more than 97% of the Delta and Bravo topsides were recycled.

FIGURE 12: REPRESENTATION OF THE WORLD ANALYZED JACKET DECOMMISSIONING ALTERNATIVES CONSIDERED



The analytical project structure (EAP) for decommissioning a fixed platform is also quite different from that used in a floating unit, mainly due to the existence of dry completion wells, which do not allow the total decommissioning of the wells and deactivation/destination of the platform. In this case, the scopes can be managed separately, but the well decommissioning operations will precede the sequence of activities for final disposal of the platform.

Usually, the decommissioning projects of fixed platforms can be segmented, in simplified form, into the following categories/steps, several of which are also present in the decommissioning of floating platforms: (i) project management, with the preparation of the decommissioning plan, obtaining licenses and engaging interested parties; (ii) decommissioning of dry completion wells and, if any, also wet completion wells; (iii) "making safe", which consists of the removal of hydrocarbons and hazardous materials; (iv) preparation stage, which involves, for example, the installation of structural reinforcements, removal of equipment and the division of modules; (v) removal of the topside and substructures, which usually requires the use of special vessels (heavy lift); (vi) final disposal of the topside and substructures; and finally, (vii) environmental monitoring of the area. It is noteworthy that there are multiple options for steps (v) and (vi), for which the use of multi-criteria methodologies for comparative evaluation has been used worldwide to assist in decision making regarding the best alternatives to be adopted, which will vary for each project.

A very common "contracting model" (and project management) in the decommissioning of fixed platforms is the EPRD (Engineering, Preparation, Removal and Disposal). In this case, the operator has the support of specialized company(ies) with experience in the decommissioning area to, for example: (i) carry out the planning of the activities; (ii) prepare the studies and evaluations of alternatives for final disposal; (iii) prepare the engineering projects and executive procedures; (iv) execute the preparation phase, including all the activities necessary to make the platform ready for decommissioning; (v) performing the removal tasks, including cutting the conductors and structural elements, as well as removing the decks and the jacket; (vi) transport to the base/yard on the coast; and finally, (vii) proper disposal of the waste, seeking to maximize reuse and recycling.

4.5 WELL DECOMMISSIONING

Well decommissioning operations, commonly referred to in the industry by the technical term "well abandonment", refer to the deactivation and permanent plugging activities that ensure the safety of wells by blocking fluid flow from reservoirs. Usually, these operations are concentrated at the end of the economic life of a field, but they can also occur throughout its productive life, for strategic reasons for the operator or as a solution to correct well failures. Knowing that every oil well will need to be decommissioned and plugged at some point, the number of well decommissioning operations in Brazil is expected to gradually increase over the next few years.

This is a commonplace activity and widely known by the industry, but it still has potential for major technical developments for gains in the performance of large-scale operations and the development of new technologies. In this sense, the investment in research and development (R&D) in this area has been strengthened, continuously seeking to reduce operational / environmental risks and costs of the activities. Examples of technologies with great potential are: decommissioning of wells without the use of BOP (Blowout Preventer) and the use of "light well intervention vessels" (LWIV) for temporary decommissioning that precedes the cementing operation (permanent abandonment) or for complete decommissioning if it is "through tubing".

Abandonment "through tubing" is performed without removing the entire column, allowing the cementing operation to be performed while the well is still equipped. In this scenario, the operation becomes 20% to 50% faster and additionally excludes steps that can add unexpected risks and scopes to the overall operation. The use of this abandonment method can be increased through the development of a wide range of combined technical solutions, including the use of dedicated vessels, special tools and alternative methods of checking the elements that form the well's solidary barrier assembly (CSB).

The reduction in the duration of well decommissioning operations has also been achieved through alternative ways of managing the abandonment portfolio, with an integrated view of the portfolio in which operations occur by clusters, grouping nearby wells with similar characteristics, in order to optimize logistics. Additionally, optimization can also occur through the use of specific service contracting models and the application of customized vessels / resources for decommissioning.

4.6 DECOMMISSIONING OF SUBSEA SYSTEMS

The decommissioning project of a subsea system begins with the inventory data compilation stage, which consists of analyzing all the technical information of the components to be decommissioned (pipelines, umbilicals and equipment) and the environmental characteristics of the region where the subsea system is located. This stage involves, for example: (i) evaluation of the characteristics of the components; (ii) survey of the operational and integrityhistory; (iii) geological/ geomorphological characterization of the region; (iv) carrying out specific inspections, when necessary, to identify the situation of the structures (e.g.: presence of crossings and existence of buried sections) and environmental characterization; (v) identification of viable logistical resources (e.g.: vessels and bases); and (vi) mapping of fishing and environmental protection areas in the region.

The preparation of the subsea system inventory is essential to identify and evaluate alternatives for decommissioning subsea lines and equipment, analyzing not only the question of the final destination of the structures (total/partial removal or definitive permanence in situ), but also the possibilities of performing the operations in different ways. To assist in this, the offshore industry worldwide has used multi-criteria methods, which must consider environmental, social, technical, safety, economic and sustainability aspects.

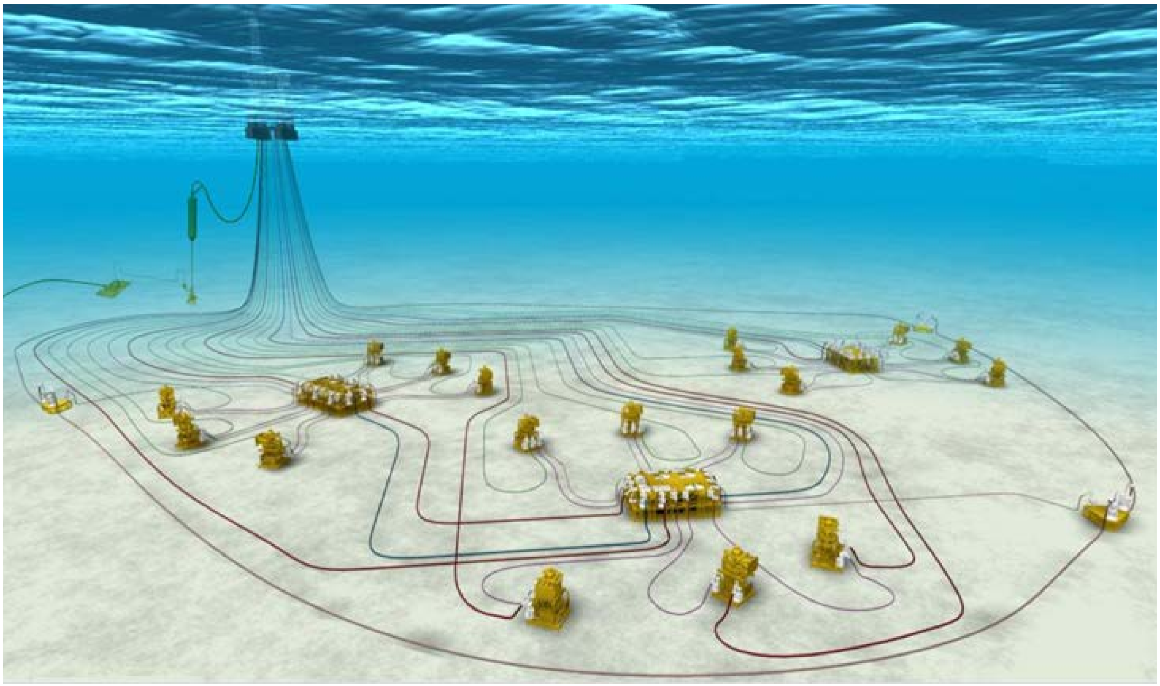
Regarding the pull out of the risers, the following alternatives should be evaluated: (i) immediate withdrawal of the riser and the flowline section (integral withdrawal of the line, for example, for reuse); (ii) immediate withdrawal of the riser and permanence of the flowline section on the seabed (partial withdrawal of the line); (iii) deposition of the riser on the seabed, which may be temporary or permanent. The most suitable option may be different for each line connected to the platform and should be defined, going through the analysis and approval of the regulatory/licensing agencies, considering factors such as, for example: (i) the available/employed resource (e.g. PLSV or AHTS); (ii) the bottom faciology (e.g. existence / absence of riser deposition route without interference with sensitive environment, such as coral banks); (iii) the technical aspects (e.g. presence of crossings in the touchdown point (TDP) region and/or riser tension zone); and (iv) the presence of sun coral on the riser, considering that deposition on the seabed may be a way to promote the death of colonies of this species, due to the low temperature near the bottom.

BOX 1

Studies by Batista et al. (2017)[19] indicate that the sun coral (Tubastrea coccinea, also known more specifically as Orange cup coral) does not survive temperatures below 12.5°C, dying within 48 h under this condition. The death of colonies of sun coral has been proven in inspections of risers, in which the species was encrusted, which were temporarily deposited on the seabed, in a region of low temperature.

19. Batista, D.; Gonçalvez, J. E. A.; Messano, H. F.; Altvater, L.; Candella, R.; Elias, L. M. C.; Messano, L. V. R.; Apolinário, M.; Coutinho, R. Distribution of the invasive Orange cup coral Tubastrea coccínea Lesson, 1982 in na upwelling area in the South Atlantic Ocean fifteen years after its first record. Aquatic Invasions (2017). Volume 12, Issue 1: 23-32.

FIGURE 13: EXAMPLE OF A SUBSEA OIL AND GAS PRODUCTION SYSTEM COMPRISING LINES (PIPELINES AND UMBILICALS/RISER AND FLOWLINE SECTIONS) AND SUBSEA EQUIPMENT SUBSEA EQUIPMENT (MANIFOLDS AND WET CHRISTMAS TREES - ANMS)



Finally, the last step in the decommissioning of subsea systems is the execution of the operations, following the proper cleaning of the pipelines. This moment of execution should consider factors such as: (i) synergy with other projects; (ii) interference with facilities in production (e.g.: crossing between lines to be decommissioned and lines interconnected to platforms in operation); (iii) capacity of the logistics infrastructure; (iv) possibility of reusing components in other projects, if they have characteristics, structural integrity and remaining lifespan compatible with the new application.

The world practice points to the execution of decommissioning activities of subsea systems in periods that commonly exceed five years and that the removal of the platform from the location occurs before the final destination operations of subsea lines and equipment, motivated by safety aspects, logistics optimization and cost reduction, without the generation of additional environmental impacts resulting from this separation of scope.

4.7 EXAMPLES OF DECOMMISSIONING PROJECTS

To illustrate the points described in the previous items and indicate best practices and lessons learned, five decommissioning projects, abroad and in Brazil, are presented in the following pages: (1) Popeye Field, (2) Curlew Field, (3) Cação Field, (4) Piranema Field and (5) rigid section of the FPSO Cidade do Rio de Janeiro export pipeline.

Decommissioning In Situ: Popeye (Mexico Gulf)

Operator Shell *Offshore* Inc.

Depth 620 meters

Scope Subsea system, including the following equipment:

01 Manifold

02 UTA
(Umbilical Termination Assembly)

04 PLETS
(Pipeline End Terminations)

04 Christmas Trees

Field Description

The Popeye Field is located in Green Canyon Block 116, Gulf of Mexico (GOM) approximately 225 km off the coast of New Orleans, Louisiana (USA).

In May 2015, Shell Offshore, operator of the field, submitted to the Bureau of Safety and Environmental Enforcement (BSEE), the regulatory agency for the Gulf of Mexico region, the application for the decommissioning of the Popeye Field without removal of the infrastructure associated with the subsea system. The regulator approved the definitive permanence in situ of flowlines and umbilicals but required Shell to provide additional information to justify not removing the remaining structures (PLETs, manifolds and other equipment). Specifically, the regulator requested that Shell provide a risk assessment of the removal of this equipment versus in situ decommissioning.

Decommissioning Execution

In response to BSEE's request, the Shell team prepared a Comparative Assessment (CA) of the two decommissioning alternatives of the subsea system - total removal and permanence in situ, based on three main criteria: safety, environment and future use of the area.

The CA identified that the removal of the equipment would involve several activities such as (i) the lifting of the structures installed on the seabed, (ii) the navigation and simultaneous operation of vessels in the field, (iii) the helicopter transport of the workforce between the onshore base and the location, and (iv) ground transportation and proper final disposal of the large equipment, which could result in hundreds of hours of exposure of workers to the risk of accidents.

As part of the analysis, the carbon footprint of the total equipment removal operations was modeled. The studies pointed out that the removal of the equipment would require the burning of more than 378 m^3 of diesel, resulting in relevant emission of atmospheric pollutants (values in ton/year: 0.5 SOx; 29.1 NOx; 0.9 VOC; 6.3 CO). The emission estimates were considered conservative since emissions and burns derived from the transport of the workforce or land transport of the equipment to the final destination site were not included. Also, during visual inspections with ROV (Remotely Operated Vehicle), a well-developed marine ecosystem associated with the equipment was recorded, including invertebrates, fish, and the iconic deep-water coral Lophelia pertusa. The CA emphasized the dual opportunity, by not removing the equipment, to keep this ecosystem intact and to conduct research on how the subsea equipment could contribute to enriching local marine biodiversity.

With regard to future use of the area by the fishing community, the studies and surveys conducted showed that the Popeye Field area was not used by the local fishing fleet, which was primarily shrimp fishing and concentrated to the north and east of the field. With this, the Comparative Analysis demonstrated that the option of decommissioning the equipment in situ after cleaning would have minimal impact on future use of the area.

Lesson Learned

Following the presentation of the Comparative Analysis and all the evidence, studies and surveys that supported it, the decommissioning without removal of the Popeye Field subsea equipment was authorized by the BSEE in June 2016. In addition to strengthening the relationship with the regulator, the project helped Shell understand the implications of the alternatives for decommissioning deep-water subsea systems in the Gulf of Mexico.

Shipyard Selection: FPSO Curlew FPSO (UK)

Operator Shell UK

Depth 93 meters

Scope Floating production storage and offloading(FPSO) and 03 subsea tiebacks

Field Description

The Curlew oil and gas field was located in the central part of the North Sea on the United Kingdom (UK) continental shelf, approximately 210 km east of the coast of Aberdeen County, Scotland, and 55 km west of the UK/Norway border. The producing system consisted of an FPSO-type unit, with tieback to three subsea systems, connected by the Fulmar pipeline to the onshore St Fergus unit.

The Curlew FPSO was originally built in Denmark in 1983 as a tanker. In 1997 it was converted to an FPSO to support the production, storage, processing, and export of fluids originating from producing wells. The main deck measured 236 m long and 40 m wide. The turret was located at the stern of the FPSO, including the flaring tower.

The Curlew FPSO operated for about 20 years, until the field's production shutdown - CoP (Cessation of Production) was declared on March 31, 2019. In June of the same year, the FPSO was disconnected from the field and towed to a shipyard in Scotland for cleaning, before being sent to the yard where it would be dismantled and recycled. Shell UK's main objective and compromise was to ensure that the recycling of the Curlew FPSO was safe, environmentally responsible, and economically effective.

Decommissioning Execution

In Decommissioning projects, Shell is committed to the decommissioning, dismantling, and recycling of its offshore production facilities in full compliance with legislation and the highest national and international standards of the oil and gas industry. Shell works with third party companies, specialized in their areas of expertise, to oversee and execute the entire process. Shell also performs, as part of the selection process of the yard for dismantling platforms, HSSE (Health, Safety and Environment) audits to verify adherence to standards and relevant legislation.

At a minimum, any shipyard to be selected must present:

- Policies that ensure worker safety and protection of human health and the environment;
- Programs providing appropriate information and training of workers for safe and environmentally sound operation;
- Plans and preparation for emergency response;
- Monitoramento de desempenho e sistemas manutenção de registros;
- Systems to report releases, emissions, incidents and accidents that cause harm or have the potential to cause harm to worker safety, human health and the environment;
- Systems to report occupational diseases, accidents, injuries, and other adverse effects on worker health and safety.

An important initial step in Shell's planning for the decommissioning of Curlew, while the FPSO was still on lease and producing, was to agree a strategy with BEIS (Department for Business, Energy & Industrial Strategy - UK regulator) that would allow the FPSO to be quickly disconnected and removed from the field, regardless of final approval of the decommissioning plan, in the event of an emergency or technical problem that would not be economically feasible to solve, leading to early closure of production (CoP). The objective of this agreement was to reduce exposure to safety risks and costs associated with a prolonged stay of the FPSO at the location after production shutdown.

Lesson Learned

In the original strategy, local requirements required that the FPSO be cleaned prior to being exported for recycling in Turkey. However, it was not possible to obtain an accurate assessment of the full scope of the clean-up to be performed while the Curlew FPSO was still in production.

Significant progress has been made in removing hydrocarbon residues from the vessel. However, as work progressed at the shipyard, it became clear that the scope of removal of naturally occurring Radioactive Materials (NORM) exceeded the local capacity. The residual removal of NORM from the FPSO, without sectioning it, had not previously been carried out in the UK and proved to be a complex process.

So in July 2020 Shell changed plans and transported the FPSO to another yard in Norway, which met all the requirements set by the company, including the cleanup of residual NORM and waste management, where the vessel could be dismantled, cleaned and recycled safely, environmentally and cost-effectively.

Decommissioning of fixed platforms in Brazil:Cação (Espírito Santo coast)

Operator Petrobras

Depth 19 meters

Scope Three fixed platforms (PCA-1, PCA-2 e PCA-3)

57 km of rigid pipelines

13 dry completion wells

Field Description

The Cação field is located on the coast of the state of Espírito Santo, about 47 km southeast of the city of São Mateus-ES and 7 km from the coastline, in a depth of approximately 19 meters. Production started in 1978 and was ceased in 2010, with an accumulated production of 20.57 million boe.

The production system is composed of three fixed integrated units, interconnected by footbridges, and 13 dry completion wells and 57 km of rigid pipelines, with underwater and onshore sections.

Decommissioning Execution

The Decommissioning Project can be divided into the following stages: (i) the preparation of the facilities for decommissioning, with the cleaning with water of the process plant equipment and the subsea transfer pipelines aiming at removing the hydrocarbons; (ii) the removal of the subsea pipelines that would interfere with the approach of the rig responsible for performing the wells decommissioning; (iii) the plugging of the thirteen wells; (iv) the permanent decommissioning of the three rigid transfer pipelines; (v) the dismantling of the decks; and (vi) the cutting, removal and final disposal of the deck and jacket structures.

To date the process plant equipment has been cleaned and all 13 wells have been permanently decommissioned and plugged. The transfer pipelines were duly cleaned and conditioned to comply with environmental legislation and will be kept in place.

The next steps of the project are the dismantling of the decks of PCA-1-2-3, with the removal of equipment and piping, the removal of the conductors from the 13 wells, the removal of the decks and jackets, and finally the final disposal onshore for recycling of the structures. These steps will be carried out through an EPRD (Engineering, Preparation, Removal and Disposal) type contract model, commonly adopted in fixed platform decommissioning projects.

Lesson Learned

The main lesson learned in this project was the reduction of approximately 50% in duration, in relation to what had been considered at the beginning of the project, in the permanent plugging stage of the 13 dry completion wells. This was achieved by planning the operations considering execution in phases and serial work, allowing for optimized use of resources and significant gains from the learning curve. This good practice should be replicated in future projects, whenever possible, allowing the acceleration of the conclusion of operations, lower consumption of critical resources and cost reduction.

Separation of Scope - Platform, Wells and Subsea System: FPSO Piranema (Sergipe coast)

Operator Petrobras

Depth 1090 meters

Scope FPSO (chartered unit),
124 km of flexible lines and
11 wet completion wells

Field Description

The Piranema Field is located approximately 20 km off the coast of Sergipe, in water depths ranging from 1,000 to 2,100 m, in the Sergipe-Alagoas Basin. Oil production in the field began in October 2007, with the start of operations of FPSO Piranema, the only production unit operating in the Piranema Field. Subsequently, between 2010 and 2013, complementary development of the field occurred. Throughout 2016, Petrobras evaluated alternatives for the field, both for the implementation of complementary projects and in an attempt to divest it to new operators, but none became feasible, leading to a definitive production cessation in April 2020.

Decommissioning Execution

The project to execute the decommissioning of the Piranema field was approved by the regulatory/licensing bodies in 2019.

The project contemplates the following stages: (i) Plugging of the wells and production stoppage of the platform; (ii) Cleaning of the subsea lines and equipment; (iii) Disconnection of the subsea lines in the Wet Christmas Trees (WCT); (iv) Pull out and temporary deposition of the risers on the seabed; (v) Depressurization, drainage, cleaning and inerting of equipment and piping of the platform's oil and gas processing plant; (vi) Cleaning of the platform's cargo tanks; (vii) removal and transportation of chemicals on board the platform; (viii) disconnection of the anchoring system and disposal of the platform; (ix) disposal of 124 km of subsea lines (flexible ducts and electro-hydraulic umbilicals); and (x) decommissioning (permanent plugging) of 11 wells.

At the moment, the operations for cleaning and preparing the platform and cleaning and disconnection of the submarine lines are underway, in accordance with the requirements of environmental legislation. It should be noted that the final destination of the platform (chartered unit) is the responsibility of the FPSO owner.

Lesson Learned

The separation of the execution of the decommissioning scope (platform, wells and subsea system) implies a reduction in costs and operational / environmental risks. In this sense, the operations associated with the conditioning of the processing plant / platform tanks and cleaning of subsea systems were prioritized to allow the disconnection and demobilization of the platform as soon as possible, without losses to the operations of decommissioning and permanent plugging of wells and decommissioning of the subsea system, to be performed later.

The risers will be deposited on the seabed, without causing environmental impact, enabling greater agility in the platform's exit. To this end, ROV imaging was carried out for environmental characterization, mainly to assess the occurrence of sensitive environments in the riser deposition areas. After the inspection, no coral banks and/or occurrence of live or dead forming corals were found. As the water temperature near the seabed at the location of the FPSO Piranema is about 4°C, due to the great depth, the risers deposition on the bottom guarantees the death of the sun coral colonies present in the lines.

With the unit already decommissioned, well plugging operations will continue unhampered by the FPSO's presence. Likewise, the destination of the subsea system (risers and flowlines) is not affected by the demobilization of the platform.

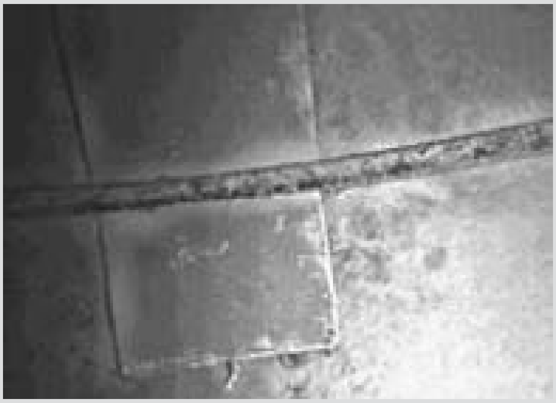
Finally, the main lesson learned is that the separation of scopes for the execution of activities enables segmented service contract models and allows better management of all project risks.

Decommissioning of Rigid Pipeline: FPSO Cidade do Rio de Janeiro (Campos Basin)

Operator Petrobras

Depth Between 241 and 545 meters

Scope Decommissioning of the rigid section of the FPSO Cidade do Rio de Janeiro export pipeline



Project Description

The FPRJ (FPSO Cidade do Rio de Janeiro), which has already been decommissioned, operated in the Espadarte Field, in the Campos Basin. Among the items in the Decommissioning Project scope of the FPRJ production system is the export pipeline, which was responsible for draining the FPSO gas to the P-15 platform, located in the Piraúna Field. The pipeline has a stretch of rigid pipeline with a length of 9,425 m, nominal diameter of 8", thickness of 0.5" and occurrence of several points in which the pipeline is partially/fully buried, due to the natural movement of sediments on the bottom of the pipeline.

Evaluation of Decommissioning Alternatives

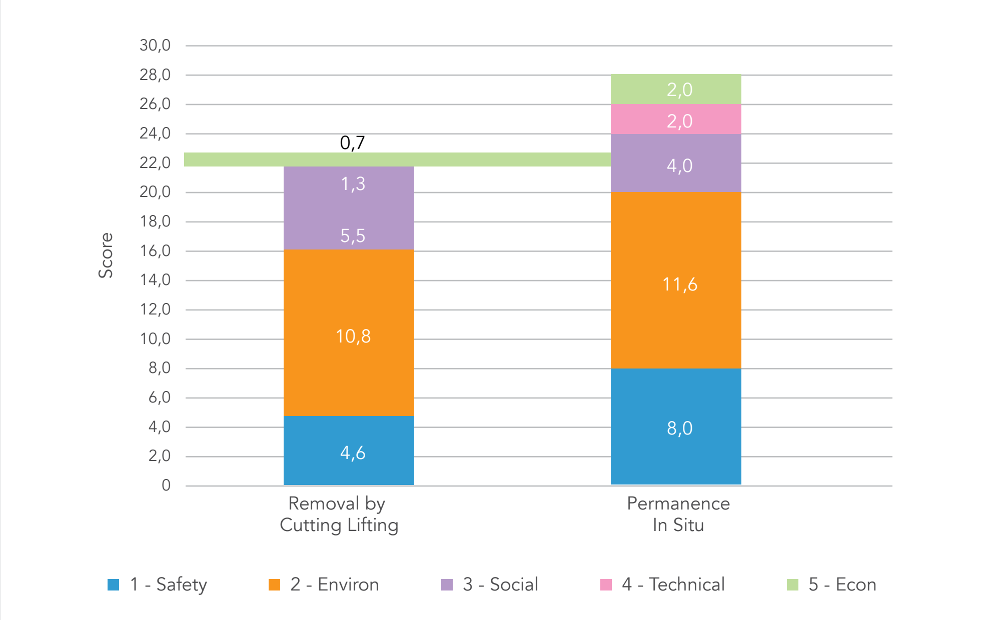
Due to the complexity and risks to workers and the environment associated with rigid pipeline reconditioning, a comparative assessment, based on a multi-criteria methodology, of the decommissioning alternatives for the rigid section of the FPRJ export pipeline was performed.

The analyses had as reference the document "Guidelines for Risk-Based Comparative Assessment of Options for Decommissioning of Subsea Facilities in Brazil", the first version of which was published in September 2018 as a result of a JIP (Joint Industry Project) coordinated by DNV-GL and which included the participation of companies from the oil and gas area (operators and service providers).

Two alternatives for decommissioning the rigid pipeline were evaluated: total removal (cut and lift method) and definitive permanence in situ (after cleaning). The comparative evaluation was carried out based on a qualitative risk/impact analysis and the performances (pros and cons) of the two alternatives were measured in five decision criteria: safety, environmental, social, technical, and economic. To facilitate the evaluation, reduce subjectivity and increase the traceability of the results, the criteria were subdivided into 16 sub-criteria, composed of a total of 71 analysis factors, which were analyzed and evaluated in a workshop with the participation of experts from several areas (subsea engineering, operational safety, environment, and socio-economics).

As shown in the figure on the next page, the alternative of permanently keeping the rigid pipeline in situ performed better in the "safety", "technical" and "economical" criteria, as well as in the "environmental" one. Particularly in the "safety" and "economic" criteria, the advantage of this alternative was significantly higher due to the high risks for workers (large amount of hoisting, multiple material handling activities on the vessel deck, and long duration of activities) and high cost associated with the total removal of the structure option. Therefore, as a result of the comparative evaluation, the definitive permanence in situ proved to be the most suitable decommissioning alternative for the rigid section of the FPRJ export pipeline.

The Decommissioning Project of FPSO Cidade do Rio de Janeiro, containing the comparative evaluation of decommissioning alternatives of the rigid section of the pipeline, was presented to the environmental agency, which authorized the definitive permanence in situ of the structure.



Lesson Learned

The comparative assessment methodology of decommissioning alternatives used allowed a clear differentiation between the two "destination options" (removal or permanence in situ) of the rigid duct, since the scoring procedure adopted (assigning scores to the risks / impacts) allowed a direct comparison of the performance of the alternatives in each criterion.

The "comparison of decommissioning alternatives" performed on a case by case basis, and based on multi-criteria analysis, as established in Resolution ANP No. 817/2020, allows operators and regulatory / licensing bodies to clearly identify the pros and cons of each decommissioning alternative (not limited to comparing "removal" to "non-removal"), identifying the most appropriate one. Thus, the comparative evaluation of decommissioning alternatives is proving to be an indispensable decision-making tool in decommissioning projects of subsea systems.

4.8 MAIN CHALLENGES AND PROPOSED SOLUTIONS

The great challenge for operators, service providers and regulatory/licensing agencies is to deal with the need to treat each project according to its particularities and demand for customized technical solutions, while seeking to optimize the processes of planning, evaluation and execution with the adoption of standardized solutions, which increase predictability, synergy and gain of scale in decommissioning projects.

To overcome this challenge, several solutions must be put into practice, such as:

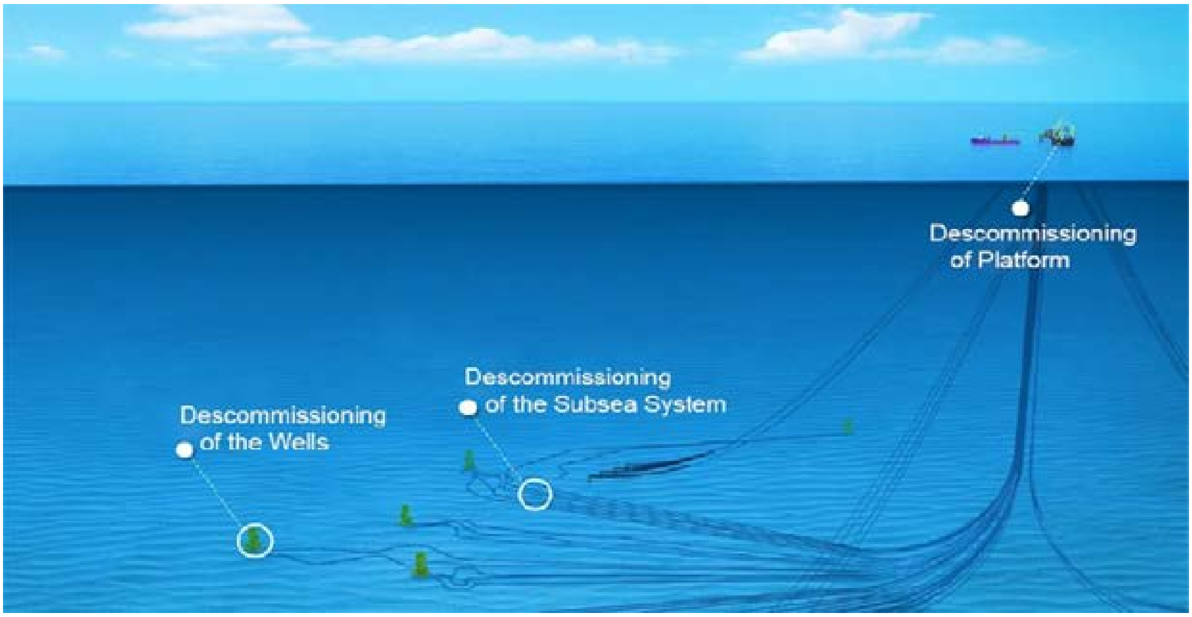
- Collaboration between key industry players, through partnerships to share knowledge, equipment, and successful solutions.
- Service providers with the appropriate technical capacity, focused on safety, with collaborative mindset and cost-efficient processes for decommissioning activities.
- Investment in R&D, aimed at developing innovative / disruptive technical solutions, as well as expanding scientific knowledge about the environmental impacts and risks associated with different decommissioning alternatives.
- Holding technical events to exchange experiences and discussions on the planning and execution of decommissioning projects of offshore production systems.
- Development of guides, with participation of the industry, academic/scientific and regulatory/licensing bodies, with indication of best practices and guidelines for the planning and execution of decommissioning projects of offshore production systems. Thus, it is possible to identify successful solutions already applied, with the possibility of coverage in future projects, speeding up the planning and approval of proposals, in addition to increasing predictability for the service chain.
- Availability of contracting models and specialized resources for integrated decommissioning services.
- Aggregation of scopes of different projects aiming at optimizing logistics and obtaining economies of scale, with consequent cost reductions.
- Definition of requirements for navigation and berthing of platforms encrusted with sun coral on the Brazilian coast and preparation of shipyards to receive floating platforms with sun coral and perform activities related to decommissioning of the units, minimizing environmental impacts/risks and ensuring the highest world standard of sustainability.
- Continuous search for sustainable decommissioning solutions, along the entire chain, fully aligned with the 17 Sustainable Development Goals of the United Nations, with emphasis on the following goals:

  - Goal 9 - Industry, Innovation and Infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation;

- Goal 13 - Action Against Global Climate Change: Take urgent action to combat climate change and its impacts;
- Goal 14 - Life on Water: Conserve and sustainably use oceans, seas and marine resources for sustainable development.

■ Due to the different levels of maturity, particularities of the challenges and existence of specific chronologies of the main disciplines (platforms, wells and subsea system) throughout a decommissioning project, it is essential that the scope is divided, both for approval by the regulatory/licensing bodies and for the execution of operations independently. This results in anticipation and ease of planning, optimization of logistics and critical resources (e.g., predictability for hiring vessels), cost reduction and increased operational safety. It is noteworthy that this separation of scope, with subdivision of the decommissioning project into three large independent areas (destination of the platform, decommissioning of wells and destination of the subsea system), does not entail operational risks and additional environmental impacts.

FIGURE 14: TYPICAL SCOPE OF A DECOMMISSIONING PROJECT FOR AN OFFSHORE OIL AND GAS PRODUCTION SYSTEM DECOMMISSIONING PROJECT, DIVIDED INTO THE THREE MAJOR DISCIPLINES/AREAS: PLATFORM, SUBSEA SYSTEM AND WELLS .



5

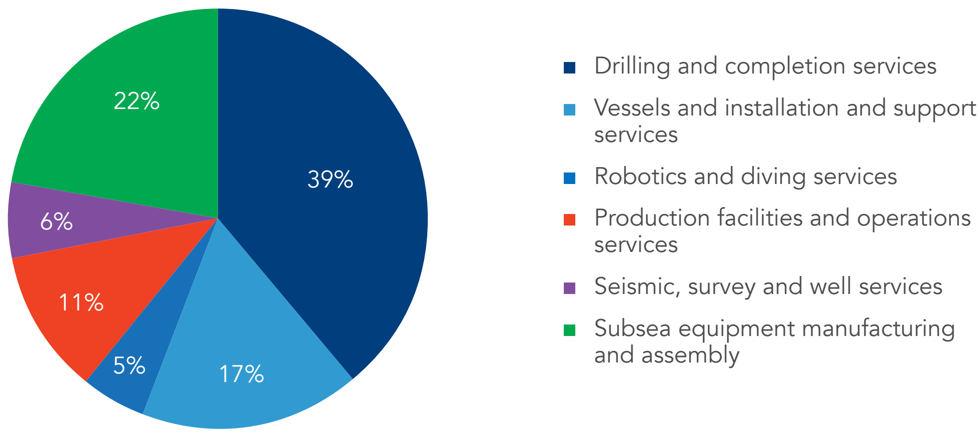
CHAPTER

Analyzing the Supply Chain

ABESPetro reviews the capacity of the national supply chain, highlighting its potential and bottlenecks to meet this new market niche.

ABESPetro (Brazilian Association of Oil Services Companies) is a non-profit civil association that represents the 1st link in the supply chain of the Oil & Gas market specialized in goods and services for Exploration and Production. Its role is to promote the defense of general and legitimate interests of the Associated Companies before the public authorities linked to the Federal, State and Municipal spheres, agencies and/or regulatory bodies and other entities of direct or indirect Public Administration, as well as other entities and the industry in general. Currently, there are 49 companies associated with ABESPetro that operate in the segments of drilling rigs and drilling and completion services; production units and operation services; vessels and installation and support services; seismic, survey and well services; robotic and diving services; and manufacturing and assembly of subsea equipment. Figure 15 shows the percentage of each segment among the associated companies.

FIGURE 15: SEGMENTS REPRESENTED BY ABESPETRO.



Source: internal research with ABESPETRO associates

5.1 0 THE DECOMMISSIONING MARKET AND ITS OPPORTUNITIES

To date, Brazil has 57 Installations Decommissioning Programs (PDIs) approved by the National Petroleum, Natural Gas and Biofuels Agency (ANP), 35 onshore and 22 offshore, of which 20 belong to Petrobras. The Campos Basin concentrates most of the approved PDIs, 11 programs, followed by 5 from the Santos Basin.

The ANP foresees that, between 2021 and 2025, the Brazilian market will invest more than R$31 billion in decommissioning; of this amount, R$6 billion correspond to the amount announced by Petrobras for its facilities by 2024. The main activities responsible for raising these resources are Well Abandonment and Plugging activities, with expected investments of around R$ 21 billion, and Equipment Removal, with R$9 billion.

Wood Mackenzie estimates that, between 2019 and 2018, US$85 billion will be spent on decommissioning globally. Brazil represents the third largest market, behind only the United Kingdom and the United States, and accounts for 11% of global spending.

The activities associated with decommissioning can generate services ranging from the removal of topside structures and subsea facilities to the abandonment of wells, removal, operational logistics, to the proper disposal of materials, waste and environmental recovery.

Given this scenario, the decommissioning market can generate many business opportunities to ABESPetro's associates that operate in the segments of Platforms and Rigs, FPSOs, Services, Equipment Manufacturing, Vessels, Underwater Construction, and Diving.

Seeking to understand the expectations of the members in relation to this new market and aiming to find ways to stimulate cooperation between the different segments of the industry, ABESPetro conducted, among its members, a benchmark survey related to decommissioning.

The results show that most of the associated companies are positive about the possibilities of the new decommissioning market. In the survey, 63% of the members who responded see this market as a trigger for the growth of their business; 31% are attentive to the generation of jobs and 6% think that innovation and technology should be stimulated with the development of the sector in the country.

5.2 CHAIN OF SUPPLIERS, GOODS AND SERVICES

Decommissioning projects are, in general, made up of the stages of Planning; Well Plugging and Abandonment; Preparation and Making Safe; Topside and Substructure Removal; Subsea Infrastructure; Site Remediation; Waste Disposal, Reuse or Recycling; and Monitoring.

From the supply chain point of view, some of these stages present critical elements. These elements are so named because they are also in demand in other industries, had shortages in the past or expect shortages in the future and are not easily substitutable, and/or present challenges in growth capacity. This criticality has a direct impact on the delivery of a decommissioning project.

The well abandonment stage is highly critical, since the rigs and platforms used for this purpose are also required by other E&P activities and cannot be replaced by other processes. Besides this, these infrastructures are mobile and meet a global demand, being subject to greater price volatility.

In the Topside and Substructure Removal stage, the critical element is the removal vessels, whose high price and availability substantially impact the overall costs of the project. Vessels with very high lifting capacities are required, which are not unique to the decommissioning market.

Other points worth mentioning concern logistics and waste management. The legislation and the installed capacity to treat radioactive materials; few specialized players (fleet of specialized vessels is limited) were also mentioned in the survey.

Operational skills and engineering can be considered critical elements that cut across all aspects of the decommissioning process. The development of these capabilities represents a significant challenge, as it requires not only investment in a physical resource, but a collaborative process between operators, the goods and services chain, academia, and government.

Among the associates consulted, many affirm having knowhow, technology, and expertise developed through services performed in other countries in decommissioning activities, besides strong partnerships that facilitate the acquisition of equipment that can be used in the various stages of the process.

Taking into account their core business, these companies consider that they have the capacity to provide one or more services, which can be related to wells, rig dismantling, subsea services, dismantling of offshore facilities, treatment and disposal of facilities' scrap, for example.

The fact that ABESPetro is composed of members from different segments of the oil and gas industry, favors eventual partnerships to complement specific scopes. The decommissioning projects are highly complex and require multisectoral efforts, therefore, synergy between companies is fundamental for an efficient and cost-effective delivery.

The companies are preparing themselves while seeking more information and trying to understand the business environment. ABESPetro is aware of the requirements for the advancement of this market and works together with its associates and the government agencies to make the decommissioning activity become an excellent business environment in Brazil.

Regarding the manpower capacity for this market, the most significant challenge involves the need for better and more secure pricing of the services aimed at public bids, considering the enormous technical challenges that decommissioning imposes.

The companies are analyzing very carefully the choice of model and workforce training to be used, national or foreign, working to find the balance point between being competitive and generating local jobs in the face of the enormous difficulties and regulatory implications that exist.

Based on the ARUP report, Decommissioning in the North Sea - Review of Decommissioning Capacity[20], the stages that have critical elements in their scope have been analyzed in more detail.

20. ARUP. Decommissioning in the North Sea - Review of Decommissioning Capacity. [S. l.], n. 1, p. 1–5, 2014.

5.2.1 PLUGGING AND ABANDONMENT OF WELLS

The purpose of the Well Plugging and Abandonment stage is to ensure the integrity of the well, keeping it in a safe condition, as well as preventing the flow of fluids from the well or annular to the seabed and avoiding the contamination of aquifers.

This stage accounts for 46% of the total costs of decommissioning projects[21], so investments in research, innovation, and technology are even more necessary in order to reduce the expenditures.

Among the technical skills that are required at this stage of the project, there are: project management, engineering, waste management, operations support, specialized services in inspection and well intervention, for example.

Among the equipment that is usually needed are: abandonment materials such as cement and silicone rubber, drilling rigs, intervention vessels, transshipment vessels, among others.

Well abandonment can be carried out through the use of mobile drilling units such as drillships, fixed rigs and light intervention units. Each of the options has its advantages and disadvantages and the choice must be made carefully, taking into consideration aspects such as well conditions, type of completion and costs of each option.

For deep water and more aggressive environments, drillships and semi-submersible rigs are the most appropriate options. Jack-up rigs, on the other hand, may be a cheaper alternative for smaller water depths and less severe environments. The operating time of fixed drilling rigs is estimated to be twice as long as when using mobile units.

Light intervention vessels, on the other hand, are used in operations that do not require the use of risers and do not have the capacity to remove very heavy structures, not being indicated for very deep-water depths. Although not suitable for all procedures, these vessels can carry out some operations, which, besides being cheaper, reduce the time of use of a rig that will be available for drilling.

Regardless of the type, the units used to perform the plugging and well abandonment operations are the critical elements of this stage of the project. This is due to the sharing of this equipment with other segments of the oil and gas industry, mainly drilling.

21. OIL & GAS UK. Decommissioning Insight 2019. [s.l: s.n.].

Analyzing the panorama of offshore activities made available by the ANP, Table 6, it is possible to observe that the most critical period will be between 2021 and 2022, since well abandonment activities are growing, but drilling activities still present high prospects. It is worth noting that the numbers presented in the table do not include exploration data, only the forecasts for drilling for production.

TABLE 6: OVERVIEW OF PRODUCTION ACTIVITIES 2019- 2023.

Activities	2019	2020	2021	2022	2023
Stationary Production Units	4	2	3	3	2
Completation	78	67	74	73	20
Field Deactivation - Well Plugging and Abandonment	27	46	51	56	71
Artificial Lifting	20	23	27	9	11
Drilling	69	72	74	59	10

Source: ANP[22]

Analyzing the ability of the North Sea supply chain to support well-abandonment activities, a low/medium rating is given. Although well services are considered quite mature, specific skills for plugging and well abandonment are not considered strong.

Alternatives that do not require a rig, whether fixed or mobile, such as light intervention vessels can be more significantly cost-effective options. With investments in these technologies, more wells can be abandoned using them and lowering the cost of the project.

The investments in equipment, technology, and services for this stage were also classified as low/ medium, due to the uncertainties associated with the timing of the decommissioning, as well as the quantities of facilities that will undergo this process.

The analysis of all variables, capacity, demand and investments, resulted in the red classification, since the stage of plugging and abandonment of wells can result in limitations in the supply chain involved in this stage. This analysis can be considered as a basis for assessing the supply chain in Brazil, since the technologies used are shared by a global market.

22. https://www.gov.br/anp/pt-br/assuntos/exploracao-e-producao-de-oleo-e-gas/previsao-de-producao-e-atividades. Acessado em 22/12/2020.

5.2.2 REMOVAL OF TOPSIDES AND SUBSTRUCTURES

In this stage, the topside, its modules and substructures are removed, as well as their transportation and disposal onshore. This activity is responsible for approximately 20% of the total costs of decommissioning projects.

Among the skills demanded in this decommissioning stage are: transportation, naval architecture, engineering specialized in topsides and substructures, and offshore operations. Equipment such as removal vessels, transport barges, and support vessels are the most demanded.

The Brazilian offshore scenario is mostly composed of FPSOs, jacket-type fixed platforms and semi-submersible platforms (SS). Among the platforms that have already been decommissioned, 5 are FPSOs and 1 is a semi- submersible, and among those that already have their PDI approved there are 3 FPSOs, 3 SSs, and 3 fixed platforms. The weight and material quantity estimates of these structures have not been disclosed.

Fixed Jacket platforms consist of latticed steel structures supported on the sea floor, called jackets, and a topside placed under the top. They are most suitable and common at low water depths of less than 450 meters. From the decommissioning point of view, these platforms offer an extra challenge, as they require vessels for the removal of the topside and for the removal of all or part of the jacket.

FPSOs are generally converted oil tankers, while Semi-submersibles are stabilized by columns, both of which can be anchored or dynamically positioned. Because of their structures, they can be used in deep and ultra-deep waters. Because they are based on ships and their concepts, and are thus floating, they can be easily moved. By comparison, decommissioning these types of facilities is cheaper and easier to carry out.

The methods and vessels to be used to remove these facilities depend on factors such as the type and location of the facility and market availability. Vessels with high lifting capacities can be used to remove topsides and substructures using approaches such as single or multi-lift, or "small pieces".

The single lift approach requires structures that are capable of lifting the entire topside. Depending on the weight and size of this structure, there are only a few vessels that can do this. The multiple lift and the small pieces technique, on the other hand, provide more flexibility in the choice of vessel.

Steel jackets are often removed in their entirety, as cutting the structure into pieces for removal may pose safety risks and be more costly. On the other hand, leaving part of the jacket *in situ* may be an alternative when total removal is not feasible for technical, economic, or safety reasons.

The criticality of the removal stage stems from the vessels used, which have few units, and these meet a global demand, not only from the oil and gas industry. Another factor is the high cost of these vessels.

The ability of the supply chain to provide the necessary support for removal activities in the North Sea was rated as low/medium, because there are not yet many experiences related to structures with high weight. This rating was also attributed to the status of investments, as with well abandonment, the associated uncertainties are responsible for holding up investments. Pressures and/or synergies from other industries were rated medium, due to shared global demand.

The result of the complete analysis was rated orange, due to the moderate potential of the activity to cause bottlenecks in the supply chain, taking into account the aspects raised above.

5.2.3 REUSE AND RECYCLING OF TOPSIDES AND SUBSTRUCTURES

The decommissioning project should aim for maximum material reuse and recycling. Although the investments in this stage represent only 2% of the total, this stage has a great potential to stimulate the local supply chain. There is a great expectation that this activity will help to move the national shipyards that are with reduced activities due to the recent crisis in the sector.

The first option is always the reuse of topsides and substructures in subsequent projects. This reuse even makes possible marginal basin projects that would not be possible if it were necessary to build a new platform, besides being used for long duration tests (LCT). When this is not possible, material recycling should be prioritized.

This step requires technical skills such as waste characterization and management, dismantling of structures, and hazardous material management and disposal. It also requires cutting and handling equipment, large quayside and yard spaces, and logistics and metal recycling facilities.

The choice of the site to receive the decommissioned structures depends on parameters related to processing capacity, environmental footprint, material handling capacity, lifting capacity, quay strength, draft, waste processing, for example.

The size of the facility and the removal method used in the previous step also have an influence. For very large facilities or single/ multiple lifting approaches, the functional requirements are significantly more expensive and there are less viable facilities in the current supply chain.

Ports, wharves, and shipyards are considered critical elements of this stage due mainly to the lack of sites with experience in decommissioning and adequate to regulatory requirements, especially those related to waste management. In the case of FPSOs, in Brazil there are also problems related to the lack of dry docks capable of supporting these vessels.

With regard to decommissioning waste, Brazil has two major challenges: the presence of exogenous corals, especially sun coral, and the accumulation of naturally occurring radioactive materials (NORMs) in the removed structures.

The sun coral is an invasive species, present in a large part of the Brazilian coast, which spreads very easily and quickly, competing for nutrients and harming the development of native species. Joint efforts between regulatory agencies and research centers are studying what can be done to deal with the exogenous corals present in a large part of our vessels and structures.

NORMs, on the other hand, present in small quantities in the oil produced, accumulate in the structures during the productive life of the field, increasing its radioactive potential.

These accumulations occur mainly in the production risers, as well as in storage tanks and production plants. These materials have a life span of 16,000 years, requiring adequate disposal and storage. So far, Brazil has no regulation for disposal of radioactive waste, only storage until decay, until another solution is proposed. The body that regulates radioactive waste is the National Nuclear Energy Commission (CNEN).

In this sense, it is necessary that the national ports and shipyards adapt their structures, mainly by providing solutions for the sun-coral and NORMs, in order to obtain the necessary certifications to take advantage of the opportunities coming from this market. And for this to happen, it is essential to have incentives from the government and regulatory agencies.

The capacity of the supply chain to meet these demands was classified as medium, because despite the difficulties encountered in relation to large structures, the performance relative to smaller structures is quite satisfactory. The pressures and/or synergies were considered high, due to the use of the ports and shipyards by several other activities, such as the naval industry, offshore renewables and platform construction. Given the investments made in port and yard improvements, the rating is high. The overall status assigned to this step was green, as the potential to cause bottlenecks in the supply chain is low.

The analysis of the links in the supply chain involved in the abandonment of wells and the removal of topsides for decommissioning in the North Sea can easily support the analyses for the Brazilian chain. However, the reuse and recycling stage has a greater number of particularities, and for this reason, caution is needed when extending the analyses of the North Sea chain to the Brazilian reality.

5.2.4 PEOPLE

The potential for job creation in the decommissioning market is unquestionable. In Espírito Santo alone, the expectation is that 2 thousand jobs, direct and indirect, will be generated due to the activities related to onshore and offshore decommissioning in the next years[23]. In the state of Rio de Janeiro, the numbers are even more expressive, 50 thousand jobs originating from the decommissioning of 21 offshore platforms[24].

Qualified labor is necessary in all stages of decommissioning projects and can be considered a critical element present in all of them. Because it is a nascent market, it is common that there is a shortage of workers with experience in the area, and an alternative to this issue is to seek analogous skills within the oil and gas industry itself and in other industries and adapt them to the new needs.

The ability of the available workforce in the North Sea to provide the necessary support for decommissioning development was rated medium, due to the market being in its early stages and not yet having an experienced workforce. The rating obtained for pressures and/or synergies from other industries was low/medium, as the decommissioning market is seen as less attractive compared to E&P. Investments in manpower were rated medium/high, recognizing the efforts made to leverage the potential of this resource. The overall analysis resulted in an orange rating, due to the moderate potential of the activity to cause a bottleneck in the goods and services chain.

However, it is worth noting that as with reuse and recycling, there are many factors that differentiate the Brazilian supply chain from that of the North Sea, thus a focused analysis of the Brazilian chain becomes necessary.

5.3 BRAZILIAN INDUSTRY BOTTLENECKS AND CHALLENGES

The decommissioning activity in Brazil is promising. However, because it is a market in its infancy in Brazil, it has some very evident bottlenecks. The need for investments is one of them. The capacity of the small companies that currently operate in the sector cannot support such a growing market, while the large ones have hesitated to invest in this sector.

23. https://clickpetroleoegas.com.br/2-mil-empregos-serao-criados-no-espirito-santo-decorrentes-de-desativacoes-de-campos-de-petroleo-e-descomissionamento-de-plataformas/. Acessado em 24/12/2020.
24. https://clickpetroleoegas.com.br/5o-mil-empregos-serao-gerados-no-rio-de-janeiro-com-o-descomissionamento-de-21-plataformas-na-bacia-de-campos/. Acessado em 24/12/2020.

Another critical point is the available technology dedicated to the activity, which today is somewhat limited.

Dependence on external engineering is a critical element in reducing the competitiveness and efficiency of local companies operating in this sector. For companies, the regulatory framework should stimulate the rapid development of local decommissioning engineering.

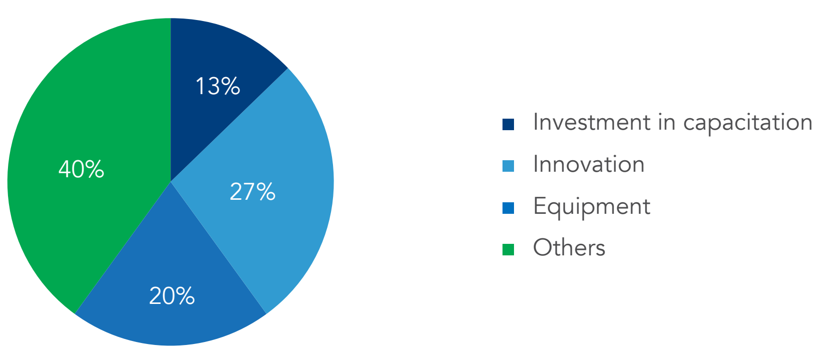
The assessment of environmental impacts should be integrated and consider the various environments and ecosystems affected, as well as the results of environmental assessments of the entire decommissioning process, including impacts on atmospheric emissions of greenhouse gases (GHG) of each alternative, impacts on the waste generated and its proper treatment, for example. These impacts should be considered as well as the economic and social costs for each decommissioning alternative.

5.4 WHAT HAS BEEN DONE?

In view of the great challenges posed and the critical elements of this new market, the associated companies have sought to prepare themselves to face them and take advantage of the opportunities offered. The search for and creation of services based on innovation account for 27% of the general interest of the companies interviewed, while 20% indicate investing in the acquisition of equipment and 13% in the training of their professionals.

Another 40% are dedicated to various tasks, which they consider contribute to better market performance, such as monitoring potential tenders and analyzing synergies with other potential suppliers; evaluating new equipment for decommissioning activities; and searching for technology and structuring a specific department. These percentages are illustrated in Figure 6.2.

FIGURE 16: INVESTMENTS MADE BY THE ASSOCIATES .



Source: Internal research with ABESPETRO associates

5.5 COMPETITIVE ADVANTAGES OF BRAZIL

It is also necessary to highlight the strengths of Brazil in terms of its competitiveness in the context of this market. During the entire decommissioning process, vessels and equipment are needed to monitor the activities, such as ROV's and support vessels to change the crew, transport the ranch, remove waste from the vessels, and so on.

Brazil today has a large capacity to supply drillships, semi-submersibles, workover vessels, offshore construction vessels (OCV and OSV), vessels with fishing and hoisting capabilities, PLSV's, well stimulation vessels, as well as winch barges with high hoisting capacity, barges with deck space to take topside parts onshore, and heavy-lift vessels, which can be directed to operations such as well abandonment, removal of flexibles and subsea structures, and topside and jacket removal.

To meet the demands, shipyards and wharves, storage area for the metallic structures, umbilicals and products contaminated with radioactive waste, lifting capacity of the terminals, ground resistance and metal-mechanic services are needed.

Ports such as those of Rio de Janeiro, Açu, Vitória, Enseada, Atlântico Sul, and several other shipyards spread throughout Brazil, are able to receive this demand. However, they have positive and negative points, which may, in some cases, make it necessary to invest in structures so that suppliers are better qualified, making room for the creation of a new market niche in the chain with the generation of more jobs and services.

5.6 AND WHAT DOES IT TAKE FOR THE MARKET TO MOVE FORWARD?

The large number of units operating in mature fields and producing in depleting reservoirs will need to be decommissioned soon, which proves the need to develop this market in Brazil. However, due to the current circumstances of the price of a barrel of oil and, more recently, Covid-19, private companies have been hesitant to invest in new business and/or additional resources, which has a direct impact.

The survey conducted by ABESPetro identified that 54% of the interviewees consider that there is a need to move forward, working on improving the legislation that governs the market, including environmental legislation.

According to the majority, it is necessary that the legal conditions placed on decommissioning projects are not an inhibitor to the activity by the operators. They allege that there are many regulations and difficulties to comply with the legislation. And there is still vagueness, which potentially motivates the companies to send decommissioned units and equipment abroad. In addition, there are the risks of delays in the clearance by environmental agencies to start work due to obstacles in environmental legislation.

With a clearer, faster and feasible legislation it will be possible to unlock a series of investments related to decommissioning and encourage the development of this still incipient industry in the country, which stimulates technology, RD&I, besides generating jobs and income.

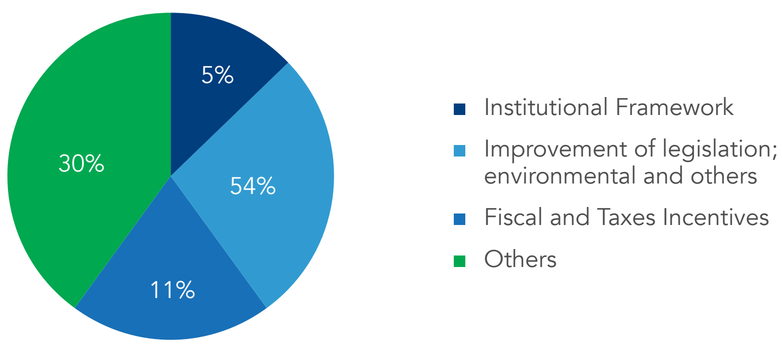
Another 5% understand that aspects related to the institutional framework can also be improved in order to provide new dynamics and contribute to the development of this business in the companies.

Lack of fiscal and tax incentives to leverage the activity is a very complex factor for 11% of the organizations. In the opinion of this group, this is a nascent industry in Brazil and, for this reason, it needs the adoption of institutional instruments of a technical, environmental, fiscal and other nature that, while protecting the maritime and terrestrial environment, also induce the creation of knowledge and local capacity for decommissioning. In other words, it is necessary that the instruments induce the development of national decommissioning engineering.

Figure 17 shows the needs indicated by the companies to advance the decommissioning market in Brazil.

Another fundamental factor for the progress of the decommissioning market is the constancy in the approval of the PDIs, which generates greater predictability and reliability so that companies can see long-term opportunities, generate investments, and so that the supply chain of specialized goods and services can find stability and grow in a sustainable manner.

FIGURE 17: IMPROVEMENTS NEEDED AS INDICATED BY ASSOCIATES



Source: Internal research with ABESPETRO associates

6

CHAPTER

Nicole Mattar Haddad Terpins – Estaleiro Atlântico Sul[25]
Mauricio Almeida –Sigma Consultoria[26]
Carlos Inácio – Estaleiro Atlântico Sul

Analyzing the Supply Chain

In the last five years Brazil has seen the need to dismantle several maritime units of the oil and gas production platform type, and this activity is still embryonic in the country.

Dismantling a production unit is understood as the execution of reverse engineering, which is the dismantling of the unit in the reverse sequence of its construction.

The international requirements necessary for the development of companies that have an interest in this activity are:

- High lifting capacity;
- Draft (depth) at its wharf and access channel;
- A dry dock with large dimensions; To possess environmental doctrine implemented according to international conventions;
- To possess the national and international environmental licenses and certifications;
- To have the necessary technical capacity and

25. Estaleiro Atlântico Sul | Home (estaleiroatlanticosul.com.br)
26. www.sigmaconsultoriarj.com.br - Consulting, expertise and judicial technical assistance in the Maritime and Environmental segments and in the Naval, Oil & Gas and Nuclear industries.

structure to remove and dispose of the sun-coral;

- To have an adequate place and technology to treat the NORM[27].

The main purpose and motivation of the EAS management is to create an alternative in Brazil to carry out decommissioning activities in accordance with national and international requirements, and to serve this growing market.

Recently, an enormous range of oil production units have had their activities interrupted and are starting the decommissioning processes and their consequent dismantling. This market is estimated to be worth 26 billion Reais (ANP, 2020).

Thus, this case study aims to demonstrate how Estaleiro Atlântico Sul S.A ("EAS") is preparing and adapting its procedures within the Regulation (EU) No. 1257/2013 of the Council of the European Parliament of 20 November 2013 on ship recycling. In this context, it has completed its Maritime Unit Recycling Manual, incorporating all operational, occupational safety, environmental and health procedures in accordance with the best applicable standards and regulations.

We emphasize that for the case study we considered the dismantling of a 52,000 tons FPSO. Finally, it is important to emphasize that this work was focused on the approach of the main processes involved in a decommissioning project, without, however, being exhaustive, not comprising a detailed description of all the activities, besides the possible variations according to the weight and type of asset.

6.1 THE SOLUTION

In order to achieve the levels of excellence, EAS conducted several studies, especially addressing the following issues:

- Evaluation of its facilities in IPOJUCA, PE for this activity
- Decontamination and treatment of NORM
- Removal and disposal of the Sun Coral
- Final destination of waste
- Regulatory compliance according to Regulation (EU) No. 1257/2013 of the Council of the European Parliament and the Hong Kong Convention.

27. NORM – Materials present in the oil extraction process. NORM stands for Naturally Occurring Radioactive Materials.

6.2 INTRODUCTION TO THE EAS

EAS is a shipyard[28] with an installed processing capacity of 100,000 tons of steel per year, and a total area of 1,620,000 m². Among the current structures of the plant, the main shed (with 130 thousand square meters and extension of one kilometer), the dry dock (with 400 meters of extension, 73 meters wide and 12 meters deep) and a finishing dock (with 730 meters of extension) stand out. These characteristics allow EAS to produce a wide portfolio of ships up to 500 thousand tons deadweight (DWT).

Focused on large vessels in general for the oil and gas industry, such as construction, repair, dismantling and recycling.

The EAS is also distinguished by its lifting capacity, which greatly contributes to the reduction of time for the conclusion of recycling processes. It has two Goliath-type gantry cranes[29], with lifting capacity of 1,500 tons each, and four ZPMC[30] cranes for 35 tons and 50 tons. EAS has the largest lifting capacity in Brazil today.

FIGURE 18: AERIAL PHOTO OF THE SHIPYARD

Source: EAS.

28. The 4th generation shipyard layout has incorporated the principles of technology, characterized by great planning flexibility. Production is synchronized to minimize intermediate inventory and transportation demands.
29. Gantry cranes feature vertical legs on the wheels that move along fixed tracks, usually at ground level. They are highly efficient at moving heavy loads at high speeds and are used largely outdoors.
30. Chinese brand of rolling cranes.

6.3 STAGE 1: PREPARATION FOR DISMANTLING

In this stage, the activities to be developed will be planned, the recycling manual for the unit in question (SRP - Ship Recycling Plan) will be prepared according to the guidelines of the Hong Kong Convention[31] and the European Union Regulation n1257 of 2013[32], and the Balanced Score Card for the project will be created, which is necessary to monitor the development of the project throughout its execution.

With the FPSO already inside the dike, the following activities will be carried out:

The decontamination of NORM will be carried out by a company specialized in this type of work holding all the necessary and mandatory licenses, certifications and authorizations (CNEN, IRD, IBAMA, ANP, MTE) to carry out these activities of high risk and complexity that is the identification and integral removal of the marine unit. After the decontamination service, the collected contaminated material will be loaded onto specialized trucks, which will transport it to a treatment area inside the EAS facilities specifically prepared and licensed for NORM (Radioactive Material Treatment and Storage Unit) handling and storage.

The removal of the sun-coral33 will be done by EAS with the consulting and monitoring of the company specialized in environmental solutions, based on the environmental license already obtained from the Pernambuco State agency CPRH. The sun-coral removed from the vessel will be properly packed and transported to the EAS' Material Disposal Center, for disposal according to the environmental regulations.

The identification, inspection, separation, and packaging of HMI - Hazardous Material Inventory34 for storage in the designated area of the EAS for this category of hazardous material must also be performed.

During the above activities, the reverse engineering department staff will develop the planning for the Stage 2 and Stage 3 cuts, and the supporting accessories for the cuts will be manufactured.

In these stages the shipyard will operate with two areas for loading equipment by specialized trucks according to their hazardousness, which will be

31. C31. Hong Kong Convention - Document that standardized the recycling process with a focus on safety, incorporating requirements and certifications that consider the entire life cycle of the ship.
32. Regulation (EU) No 1257/2013 of the Council of the European Parliament of November 20, 2013 on ship recycling which amended Regulation (EC) No 1013/2006 and Directive 2009/16/EC.
33. The sun coral (Tubastraea spp.) is a marine invader that is threatening the biodiversity of the Brazilian coastal zone. It was introduced to Brazil in the late 1980s via oil/gas platforms and has invaded rocky shores along 900 km of coastline.
34. HMI – *Hazardous Material Inventary which are devided in 2 classes (I e II)*

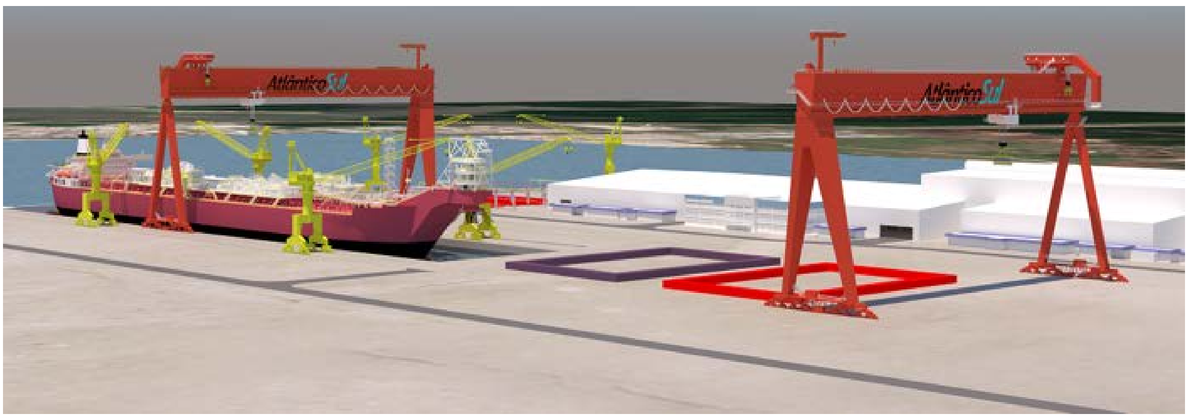
defined as per Figure 19:

NORM contaminated material (purple box)[35],

HMI-rated material (red box)[36]

The vessel will be located within the dike.

FIGURE 19: SIMULATION OF THE SHIP INSIDE THE EAS .



Source: EAS.

6.4 STAGE 2: REMOVAL OF EQUIPMENT ABOVE THE MAIN DECK

Items such as modules, superstructure, flare, pipe rack, helideck, and others will be removed in two stages - disconnection/disassembly of the FPSO and temporary storage, handling, and segregation.

The disassembled material will be destined to the temporary storage area, green area (Figure 22), lateral to the dry dock, used to move equipment and blocks disassembled from the ship, and segregate potentially hazardous material from non-hazardous material.

Segregation of potentially hazardous and non-hazardous material will be stored in the blue (non-hazardous cutting area) or red (hazardous) areas.

The heavy transport vehicles that the EAS has, will be used to move the materials from the green area towards the designated areas.

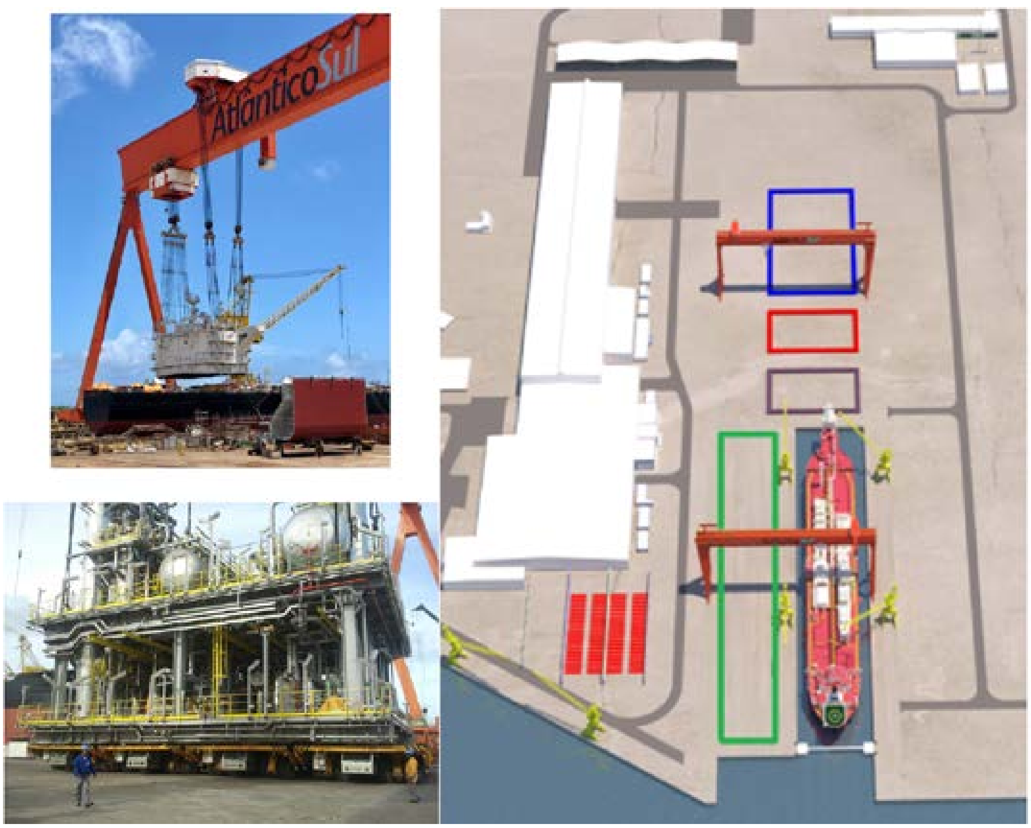
35. Purple area - defined for disposal of trucks that will transport NORM packages removed from the ship. This area is classified as segregated and frequency controlled.

36. Red area - set for truck loading of material removed from the unit

The materials extracted from the vessels will receive special treatment in accordance with IMO, Brazilian Nuclear Affairs Agency (CNEN), Class and other applicable international regulations.

Modules and superstructure will be transported from the green area to the blue area, previously prepared with the supports designed by reverse engineering. After storage in the designated areas, the materials will be properly cleaned and decontaminated. Steel will then be separated from other types of material (polymers, insulation, E&I items, wiring, aluminum, among others).

FIGURES 20, 21 E 22: SIMULATION OF THE MOVEMENT OF A SUPERSTRUCTURE INSIDE THE DIKE, MOVEMENT OF A MODULE IN THE GREEN AREA LATERAL TO THE DIKE AND A TOP VIEW OF THE DIKE WITH THE PURPLE, RED AND BLUE GREEN AREAS .



Source: EAS.

6.5 STAGE 3: REM REMOVAL OF THE MAIN AND AUXILIARY ENGINES, SHAFT LINE, PROPELLER, RUDDER AND THE HULL CUT INTO BLOCKS

Normally, the ship is cut from the deck to the double bottom in blocks according to the shipyard's internal lifting capacity and heavy transport for dismantling.

All blocks will be similarly placed in the green area and immediately after will be taken to the shipyard's steel shop for cutting to the appropriate dimensions, for destination that will be in an area previously defined for steel mill destination.

The cutting plan established by the EAS engineer will take into consideration the guidelines of a maritime unit classifier. The cutting procedures should guarantee that:

- The stability, tilt, and offset of the vessel will be maintained.
- The blocks will not move when released, due to the displaced forces and the progressive build-up of tension during cutting.
- No primary cutting blocks will be dropped or left directly in the green area and consequently, no secondary cuts will be performed in this area.
- The entire cutting system will be inspected daily to ensure safety.
- Procedures are subject to continuous improvement based on lessons learned.

6.6 STAGE 4: CONCLUSION OF THE WORK

In stages 2 and 3 all (HMI) material such as asbestos, heavy metals, batteries, firefighting liquids, solvents will be segregated and temporarily stored in separate areas in item 16 of the drawing above until final disposal. Similarly, the NORM type material collected will be treated inside the building shown in item six of the figure below.

During the whole process of the stages, from the signing of the contract for the dismantling of a maritime unit until the receipt of the last waste disposal certificate, we will have a team preparing a data-book with all the documentation of inspections, filming, photos, and certificates of the environmental destination documentation done, so that it can be delivered to the client and made available for inspection agencies.

According to the client's interest, EAS may be responsible for the destination and sale of the residues, having developed partnership with important steel mills, interested in acquiring the materials.

FIGURE 23: AERIAL PHOTO OF THE SHIPYARD WITH THE BUILDINGS AND AREAS INVOLVED IN THE DISMANTLING OPERATION OF A MARITIME UNIT .

Source: EAS.

7

CHAPTER

Claudia Vaillant Alves Cunha – CNEN
Flávia Schenato – CNEN
Nerbe José Ruperti Júnior – CNEN

Management of radioactive materials

7.1 LEGISLATION AND REGULATORY FRAMEWORK APPLICABLE TO RADIOACTIVE WASTE

The Brazilian government, through CNEN - Comissão Nacional de Energia Nuclear, in the exercise of the competencies attributed to it (Laws n° 4.118/1962, n° 6189/1974 and n° 7781/1989), is responsible for the final destination of the radioactive waste produced in the country. Therefore, CNEN is responsible for the design, construction and operation of radioactive waste disposal facilities, as provided in the Federal Law 10.308, of 2001 [1].

Law 10,308 establishes general requirements for the disposal of radioactive waste and the rules for site selection, construction, operation, licensing, financing, civil liability and guarantees related to the storage and deposition of radioactive waste. CNEN is responsible for granting licenses to radioactive waste storage and deposition facilities, with respect to aspects relating to transportation, handling and treatment, as well as safety and radiological protection, without excluding applicable environmental licenses and other legal requirements.

Federal Law prohibits the deposit of waste of any nature on oceanic islands, on the continental shelf and in Brazilian territorial waters, as well as the importation of radioactive waste. The types of radioactive waste deposits foreseen by law are the initial, intermediate and final deposits, whose legal criteria and procedures for the installation and operation are established in CNEN's norms.

In order to comply with federal legislation, Norm CNEN-NN-8.02 (2014) [2] establishes general criteria and basic safety and radiological protection requirements for the licensing of facilities for the storage and deposition of Low and Medium Level Radiation (LBNR) waste. The licensing process for radioactive waste facilities is a "step by step" process, involving administrative licenses for Site Approval and Permits for Construction, Operation, Decommissioning and Closure (required only for final repositories). Each act is conditional upon meeting specific requirements presented in the Site Report (SLR), Preliminary Safety Analysis Report (RPAS), Final Safety Analysis Report (RFAS), and Final Site Closure Analysis Report (RFAEL).

The requirements for licensing, established in CNEN-NN-8.02, apply to waste facilities in the country, as defined by law:

1. **Initial repository**: intended for storage of radioactive waste, whose holder of the facility generating the waste is the legal entity responsible for the construction, administration and operation of the repository, with a license granted by CNEN.

2. **Intermediate repository:** intended to receive and, eventually, condition radioactive waste, in order to remove it to the final repository, in compliance with the acceptance criteria established in CNEN-NN-6.09. CNEN is the legal entity responsible for the administration and operation of these repositories, through its research and nuclear technology institutes.

3. **Final repository:** intended for final disposal of Low and Medium Level Radiation Waste.

The CNEN-NN-8.02 standard applies only to the licensing of Low and Medium Level of Radiation (Class 2) waste facilities, according to the classification adopted in the country (Table 7), which takes into account the level and nature of the radiation and the half-life of the radio-nuclides.

TABLE 7. CLASSIFICATION, CHARACTERISTICS AND DISPOSAL METHODS FOR RADIOACTIVE WASTE.

CLASS	CHARACTERISTICS	METHODS OF DISPENSING OR DEPOSITING
0. Exempted Waste	Wastes containing radionuclides with activity or activity concentration values, by mass or volume, less than or equal to the respective clearance levels. [1]	No restriction
1. Very Short Half-Life Waste	Wastes with a half-life ≤ 100 days, with activity levels or activity concentration levels higher than the respective dispensation levels. [1]	Stored for decay and later dispensing
2. Low and Medium Level Radiation Waste	Wastes with a half-life greater than that of Class 1 waste. Activity or activity concentration levels greater than the exemption levels and with a thermal input of less than 2 kW/m3.	
2.1. Short Half-Life	Beta/gamma emitters with half-lives ≤ 30 years and with long half-life alpha-emitting radionuclide concentrations < 3700 kBq/kg, packaged in individual packages and averaging 370 kBq/kg for the package set.	Near Surface Depositing
2.2. and 2.3 Containing Natural Radionuclides	Wastes from petroleum exploration and from natural or industrialized mineral raw materials, respectively, containing U and Th series radionuclides in activity or activity concentrations above the exemption levels. [1]	Near-surface deposits or at a depth defined by the Safety Analysis
2.4. Long Half-Life	Wastes not in Classes 2.2 and 2.3, with concentrations of alpha-emitting radionuclides with long half-lives greater than those established in 2.1.	Geological Deposits
3. High Radiation Level Waste	Thermal power greater than 2kW/m3 and alpha-emitting radionuclide concentrations greater than those established for short half- life waste.	Geological Deposits

1 Norma CNEN-NN-8.01 "Gerência de Rejeitos Radioativos de Baixo e Médio Níveis de Radiação" - Low and Medium Level Radioactive Waste Management.

NORM waste, i.e. materials containing naturally occurring radionuclides from the uranium and thorium decay series are classified in Classes 2.2 and 2.3 from, respectively, the oil and gas E&P industries and the mining and/or ore processing industries.

For all classes of low and intermediate level waste (Classes 2.1 to 2.4), the national regulations provide specific provisions and requirements for the permitting process, including the construction period, operation and decommissioning program, applicable to initial and interim repositories, the purpose of which is to safely store and manage the waste for a specified time. Specifically, for Classes 2.2 and 2.3, these requirements are applicable provided that these wastes are packaged in packages (Art. 2; §3º). With regard to long term deposition, CNEN Standard NN 8.02 does not establish specific requirements for the licensing of final deposits for Classes 2.2 and 2.3.

For classes 2.2 and 2.3, the regulation requires near surface disposal or at depths defined by the safety analysis (see Table 9.1), but the licensing procedures for final repositories are not established. In general, the characteristics of these classes of waste involve aspects that may require disposal at greater depths than those provided for near surface facilities, mainly related to the presence of long half- life radionuclides and/or high activity concentration levels.

Therefore, different types of NORM waste may require different options for deposition. Depending on the radiological characteristics of the NORM waste, such as fouling with relatively high activity concentration of Ra-226 and Ra- 228, depositions at greater depths have been considered as an alternative, whose intrinsic advantages and disadvantages, regarding safety aspects and technical and economic feasibility, should be considered, for licensing purposes. [3, 4, 5, 6, 7].

The management of NORM and the alternatives for their safe, long-term deposition are complex and involve several aspects to be considered, such as the establishment of specific regulations and safety and radiological protection requirements that should guide the construction, operation and closure of the repositories, the containment of NORM waste for long periods, their institutional control, permanent monitoring and restricted future uses of the site, after closure, among others.

7.2. RADIOACTIVE WASTE EXEMPTION AND CLEARANCE CRITERIA

The concepts of exemption and waiver of regulatory control adopted in the country are in the CNEN-NN-3.01 standard [8] and are the same as those recommended internationally [9, 10]. Exemption is the regulatory act that exempts a practice, or a source associated with a practice from further regulatory control, from the radiological protection point of view, while clearance is the removal from regulatory control of radioactive materials or objects associated with an authorized practice, which allows these materials or objects to be removed from the site without further restrictions.

As a general principle for exemption or waiver of regulatory control of a radiation source, the risks associated with radiation are considered to be irrelevant (sufficiently low so as to be related to irrelevant radiological damage) such that compliance with radiological protection requirements is not necessary. The probability of scenarios leading to noncompliance with this general principle should be irrelevant. Another criterion would be met when control or continued regulatory control of the source adds no additional benefit, in which no reasonable measure for regulatory control would have a significant result in terms of reducing individual doses or health risks.

In order to consider low probability scenarios, an additional criterion can be adopted whereby the expected effective dose to be received by any individual from the public for these low probability scenarios does not exceed 1 mSv in a year.

In Brazil, radioactive materials will be exempt from radiological protection requirements when the total activity of a given radionuclide (artificial or natural) present at any time or the activity concentration used does not exceed the exemption levels presented in Annex VI of CNEN-NN-8.01 [ ], both for moderate (below one ton) and large quantities of materials (above one ton).

Thus, for the disposal of large quantities of materials containing natural radionuclides, from a given practice (planned situation), such as NORM wastes from the oil and gas industry, activity concentration limits should be below 10 Bq/g for K-40 and 1 Bq/g for each radionuclide in the radioactive decay chain of the uranium and thorium series, so as to satisfy the criterion, in all reasonable situations, that the effective dose expected to be received by any individual in the public does not exceed 1 mSv in a year.

7.3 DECOMMISSIONING OPERATIONS OF OFFSHORE UNITS

For the decommissioning of offshore units, aspects related mainly to radiological protection of workers, members of the public and the environment should be observed, as well as the management of NORM waste generated during the operation, such as equipment, pipes, contaminated oily/sandy sludge, contaminated PPE, among others, which should cover all actions until their final disposal.

In 2011, CNEN/DRS/DIREJ monitored an FPSO decommissioning operation, performed at Mauá Shipyard / RJ.

Two documents were previously presented and analyzed by CNEN/DRS/DIREJ: a HSE Plan for Mauá Shipyard and a Transportation Plan for all NORM materials generated.

Besides these, a project was presented to obtain decommissioning authorization, which described all the procedures that would be performed, including radiation monitoring, use of PPE, cutting procedures, NORM storage plan, environmental care and health care.

The CNEN/DRS/DIREJ, in addition to having analyzed and issued technical opinions for the documents mentioned above, inspected the execution "in loco" of the decommissioning operation, in order to verify the operation regarding aspects related to radiological protection, waste management, and transportation plan.

Therefore, two plans must be prepared by the operators and forwarded for evaluation and approval by CNEN for decommissioning operations:

- Radioprotection Plan
- Waste Management Plan

The minimum requirements for the Radioprotection Plan are:

1. preparation of ALARA planning for the entire decommissioning operation that may involve exposure to ionizing radiation;
2. Identification of the offshore Unit and its Owner (operator);
3. Function, classification, description of the decommissioning areas, presenting clear delineation of supervised, controlled and free areas and, if necessary, locations reserved for individual monitoring and decontamination;
4. Description of the team and equipment of the Radioprotection Service;
5. Role and qualification of OEIs (Occupationally Exposed Individuals);
6. Procedure described involving individual, area, and environmental monitoring during operations;
7. Estimation of dose rates during activities involved in the cleaning of tanks and equipment, as well as during the entombment of NORM radioactive materials to be stored until their final disposal;
8. Description of the medical service and control of OEIs, including medical planning in case of accidents;
9. Training program for OEIs and other workers involved in the activities;
10. Description of the types of admissible accidents and actions to be implemented, including *modus operandi*, instrumentation, and necessary devices for delimitation and signaling of the emergency area;
11. Interference planning in emergencies until normality is reestablished;
12. Radioprotection and safety instructions provided in writing to the workers.

The minimum requirements for the Waste Management Plan are:

1. Minimization of the volume of radioactive waste generated during operation shall be ensured;
2. Radioactive waste should be segregated from any other materials;
3. The segregation of the waste must be carried out in the same location where it was generated or in an appropriate environment, taking into account the following characteristics, as applicable:
    a) physical state (solid, liquid or gaseous),
    b) compactable or non-compactable,
    c) organic and inorganic,
    d) other hazardous characteristics (explosivity, combustibility, flammability, corrosivity, and chemical toxicity);
4. After segregation, the waste must be packed in packages that meet the requirements set forth in CNEN-NN-8.01. The packages intended for waste segregation, collection, transportation and storage must bear the international symbol for the presence of radiation, fixed in a clear and visible manner;
5. The integrity of the storage packages shall be ensured;
6. The packages for transportation shall not present external surface contamination in levels higher than those specified in CNEN-NN-8.01 (ANNEX V);
7. The packages containing radioactive waste must have appropriate sealing to prevent spillage of their contents (including sealing of tubes, equipment and drums);
8. O The waste packages must bear the symbol indicating the presence of radiation and must have identification sheets, externally affixed, informing:
    a) data on contents, as specified in CNEN-NN-8.01 (ANNEX IV),
    b) activity concentration (Bq/g) of the main radionuclides present in the waste,
9. The waste storage site must be informed in the decommissioning planning;
10. Document the entire decommissioning process and inventory of the radioactive waste generated, origin and destination;

The external transportation of radioactive waste must be carried out in accordance with the Transport of Radioactive Materials Standard (CNEN NN 5.01), as well as with the other transport standards and regulations in force.

CHALLENGES IN THE MANAGEMENT OF NORM IN THE OIL AND GAS INDUSTRY IN BRAZIL

NORM waste management should contemplate a "cradle to grave" strategy, i.e., it should consider all steps from its generation to its disposal as radioactive waste, if its exemption from regulatory control is not possible..

Deposition is the last stage of radioactive waste management, when the waste cannot be exempted from regulatory control, and involves its containment in a final repository, without the intention of retrieving it and, preferably, without the need for long-term maintenance and surveillance of the repository. The isolation of the waste from the biosphere must be guaranteed through the use of engineering barriers, the action of natural barriers in delaying the migration of radio-nuclides in the geosphere, and a careful selection of the site for the construction of the final repository.

Deep deposition is an alternative to surface or near-surface deposition, the latter suitable for radioactive waste with a low activity concentration. Some options for deep deposition of NORM from the oil and gas industry are: in decommissioned mines, in salt caverns, by hydraulic injection and injection into rock formations, or by encapsulation and deposition in wells. Each option has its intrinsic advantages and disadvantages regarding safety aspects and economic viability. The radiological safety of the deposition system must be demonstrated in a Safety Analysis Report of the facility, which must be submitted to the nuclear regulator in the licensing process.

Brazil still does not have a final solution for the waste generated by the oil and gas industry, and this is one of the main problems encountered in the management of this class of waste in the country. Currently companies in the sector are opting to export their NORM wastes, which can only be done to countries that allow their importation for disposal in facilities licensed for this purpose. In the case of export, both the legislation in the country of origin and that of the destination country must be complied with.

Initial repositories are designed to last from a few years to a few decades and are options for the safe storage of wastes between their temporary storage at the generating facility and their final disposal. As Brazil still does not have a final repository for oil NORM and as the offshore facilities have a reduced storage capacity, it is important that the operators of these facilities license their initial repositories on the continent, and should initiate the licensing process as soon as the presence of waste with associated NORM is identified.

BOX 3

Sun Coral

Sun coral is the generic name for coral species of the genus Tubastraea, two of which were introduced into the Brazilian territorial sea. They are widely distributed species in the tropical and equatorial regions of the Indian and Pacific Oceans.

These species are displaced from their natural habitat by ballast water or organisms embedded in the hulls of ships and other vessels, such as drill ships and platforms that travel between different regions of the world and anchor off the Brazilian coast. It is believed that these exotic species first established themselves in the Campos Basin.

The sun coral reproduces sexually or asexually very efficiently, and its larvae settle very quickly. Asexual reproduction occurs before two months, and individuals reach the adult stage in a little over a year. The impact of the sun coral stems precisely from the species' aggressiveness, which competes with native species, taking their place in ecosystems.

Both in Brazil and in other regions affected by the bio invasion of sun coral, studies have been observing the potential and effective impacts of its introduction on native marine populations and communities, including habitat alteration, predation, displacement of native species, alteration in the food chain, and increased survivability of new invasive species. (ICMBio, 2018 and CROOKS, 2002).

In this context, the choice of the technique to be adopted for the management of sun coral is challenging. This decision should be made considering several factors, such as: species present, stage of colonization, location of the encrustation, whether the structure is natural or artificial, environmental sensitivity of the region, effectiveness of the cleaning method, risks involved with the absence of management, the risks of the management itself, risks to safeguard human life, public and collective interest, technical/ operational aspects, availability of resources, new technologies, costs and feasibility of implementation, among others. (ICMBIO, 2018).

The techniques used to remove sun coral on platforms and vessels, during decommissioning, are: blasting with water on the contaminated surfaces; scraping the organisms; exposing the vectors to the air (death by desiccation); immersing them in a dike with salinity contrary to that needed by the organisms (death by osmotic shock); and enveloping the structures (death by anoxia and starvation). (ICMBio 2018 apud IPIECA/OGP, 2010).

However, studies point out that there are still gaps in knowledge about the effectiveness of methods for controlling and eliminating bio-invasors (COUTINHO, 2019). In addition, at the operational level, depending on the chosen technique, difficulties related to the necessary logistical infrastructure may arise. These facts, in turn, may not only raise the costs for removal of the sun coral, but also for decommissioning as a whole.

8

CHAPTER

Anabal Santos Jr – ABPIP
Clarissa Thomson – PetroRio
Mauro Destri – Perenco
Nathan Biddle – Premier Oil

The view of operators of mature fields

We are an institution that for more than a decade has represented independent producers, having always acted for the development of the P&G industry in the onshore segment in Brazil and, more recently, incorporated the mature fields in the offshore environment. We have also led and congregated the efforts of several other institutions that over the years have joined this cause. This historical performance has allowed the market to recognize ABPIP as the association that best represents the business vision of independent operators in the Brazilian E&P industry[37].

37. ABPIP's membership includes operating companies (effective members), companies interested in becoming operators in the national market (aspiring members) and suppliers (supplier members), which allows it to have a broad vision of the sector. Within its mission and with this vision, it acts aiming at the sustainable creation of a market with multiple agents and generator of wealth for the country. Learn more about ABPIP at www.abpip.org.br

8.1 INTRODUCTION

For several years, since the publication of ANP Resolution No. 27/2006[38], the strategic decision on whether or not to decommission an offshore production system followed criteria such as the end of the economically viable production capacity, the useful life of the offshore installation versus its condition of integrity or the framework of natural accidents, for example.

With the divestment processes of Petrobras' mature and marginal fields in the offshore and onshore environments, coupled with the publication of the new ANP Resolution No. 817/2020[39], decommissioning in Brazil has become a process that requires a much broader approach.

The analysis of decommissioning projects of subsea structures and systems is based primarily on the productive capacity of the field and its facilities, the possibility of transferring the concession to independent companies with competence to revitalize them and the way in which the Brazilian regulatory framework contributes to the revitalization of these mature assets is attractive and able to capture new investments.

The revitalization that has been taking place in fields in several basins around the country, now operated by independent companies, managed to extend the useful life of these assets and, therefore, postponed their decommissioning, which would certainly have to be done, for the most part, by the year 2025[40], if they had not been bought by these operators.

But certainly, at some point, decommissioning will have to take place, and the regulatory requirements and planning criteria that the operators need to meet are as important and complex as the choices they make for the development of their own E&P projects.

Thus, decommissioning is a strategic issue, since it will be a critical success factor in the company's decision making and may create competitive advantages for the establishment of a new investment opportunity in the current Brazilian market scenario.

Therefore, decommissioning must be viewed with a much deeper vision than just as an environmental, technical, and cost challenge. Broader discussions must be held than those held so far, revolving around the capacity of the local supply chain for goods and services, regulatory incentives, tax reduction, operational safety, and social issues.

38. https://atosoficiais.com.br/anp/resolucao-n-27-2006?origin=instituicao&q=27/2006
39. https://atosoficiais.com.br/anp/resolucao-n-817-2020-dispoe-sobreo-descomissionamento-de-instalacoes-de-exploracao-e-de-producao-de-petroleo-e-gas-natural-a-inclusao-de-area-terrestre-sob-contrato-em-processo-de-licitacao-a-alienacao-e-a-reversao-de-bens-o-cumprimento-de-obrigacoes-remanescentes-a-devolucao-de-areae-da-outras-providencias?origin=instituicao
40. Deadline for fields acquired by Petrobras in ANP's "Round Zero" in 1997.

To bring predictability of the demands and requirements that allow for proper planning, over the past four years the topic of decommissioning has been the subject of constant debate among the stakeholders of the oil and gas industry in the main producing markets in the world, including Brazil.

The expectation in Brazil is that it is possible to evolve to the implementation of increasingly agile and flexible actions aimed at optimizing decommissioning activities, through regulatory improvement, market and supply chain evolution.

In Brazil, the ANP has received around 75 PDI's (Program for Decommissioning of Installations)[41] onshore and offshore from the Brazilian sedimentary basins, and 54 of these have been approved. In addition, a decommissioning cycle is currently underway in the country with approximately a dozen units installed in the Campos, Espírito Santo and Sergipe/Alagoas Basins, among others.

The Agency estimates for the period 2020-2024 an expenditure with decommissioning in the order of R$ 26 billion[42], although a movement to reduce these costs is perceived in the industry. This generation of wealth with decommissioning will move the market in the short term (starting in 2021), and part of the services is already available in the country. Another part, although there are material resources, needs to be effectively developed, since the expansion of the supply chain of goods and services of decommissioning in Brazil, according to ANP, will also be the role of other areas of Public Administration, especially the state governments, to create conditions for this market. It is also the industry's role to propose alternatives for local development of the activity.

8.2 REGULATORY CONTEXT

Within the regulatory perspective, there is no doubt that the greatest efforts should be directed to the continuity of operations of mature fields, aiming to attract new investments to ensure the maximization of resource extraction, given the low recovery factor (RR) rates in Brazil's oil reservoirs.[43]

41. https://www.in.gov.br/en/web/dou/-/resolucao-n-817-de-24-de-abril-de-2020-254001378
42. http://www.anp.gov.br/arquivos/palestras/descomissionamento/ssm.pdf
43. The average Brazilian FR is 21%, while the world average is 35%. http://www.anp.gov.br/images/Consultas_publicas/2018/n9/Nota_Tecnica-004-Regulamentacao_do_incentivo_de_reducao_de_royalties_sobre_a_producao_incremental_em_Campos_Maduros.pdf

Regulators and operators must work together to ensure that field life extension projects are implemented and are economically viable and safe to provide expected returns on invested capital. There are ways in which field life extension can be encouraged and thereby postpone decommissioning of facilities. These include the reduction of royalties for mature fields, the adaptation of regulations and requirements that aggravate the regulatory cost (transaction costs) and even incentives such as the use of RD&I funds (from the ANP itself or other development agencies) to implement secondary and tertiary recovery, as well as new production or operations technologies.

The incentive to continue production will certainly boost the generation of new opportunities for job creation, collection of royalties and government participation, and will increase income in several municipalities of the producing regions. In other words, all the oil and gas that can be produced should be produced, and the state should be a facilitator of this process, establishing a simple, clear and objective regulation that catalyzes the appetite of operators to inject new investments that can extend the production horizons of our mature fields for another three or four decades.

And regarding the decommissioning of fields subject to farm-out, a triple balance must be found between the interests of the operator selling, the operator buying, and the regulator to allow, among other things, that the financial guarantees required for future decommissioning do not excessively burden the buying company with commitments that result in an uneconomical project.

The national regulatory discussions began with the review process of ANP Resolution No. 27/2006, which gave rise to the new ANP Resolution No. 817/2020, marked by a long technical debate between ANP, IBAMA and the Brazilian Navy along with the market, about the best international practices, with a focus on technical operations of design, preparation and execution of decommissioning of facilities and equipment.

This integration and collaborative environment allowed the construction of important technical aspects for the regulation of decommissioning actions. The market expects to continue working in broad technical partnership in this environment of collaboration and integration of these authorities during the analysis of decommissioning programs and the continuous improvement of the regulation.

The anticipation of the approval process of the decommissioning plans to five years before they become effective and the use of multi-criteria tools for decision-making on the removal/ permanence of equipment in the field brought greater predictability and legal certainty to the market. However, the ANP's decision to include the areas to be returned in a Permanent Offer before the execution of the decommissioning program itself creates uncertainties and potential liabilities that increase the risk for the operators. In addition, the complexity of the rules established for the sale and reversion of assets certainly increases the legal insecurity of the process. It is worth noting that the regulated issue on reversion and disposal of assets in specific was poorly received by the market in light of the few opportunities to discuss the matter with the ANP, as was done with the technical requirements of the new regulation.

8.3 CHALLENGES AND OPPORTUNITIES IN THE VALUE CHAIN

As assets reach the end of their useful lives, operators' expenses tend to increase substantially and the activities required to cease production, safely remove surface and subsea infrastructure and ensure that wells are permanently abandoned, always meeting the criteria of ANP Resolution No. 817/2020, become increasingly technically complex.

If an operator is considering the purchase or transfer of an asset, it needs to understand its decommissioning liabilities and where it is exposed to cost escalation, and what opportunities it can see from the time of purchase both to avoid such escalation and to be able to drive technological innovation.

A preliminary assessment of the market also indicates the existence of several gaps in the supply chain, which may represent obstacles and risks to decommissioning activities, especially in a scenario of recovery of the industry. These are important bottlenecks in project planning and management, such as the availability of rigs, heavy-lift vessels for removal of subsea lines, waste recycling and treatment services, and the delimitation of licensed areas for packaging and dismantling of equipment.

Another critical factor is that, unlike development planning in the P&G industry, decommissioning activity is not yet guided by a clear schedule and therefore forecasts do not always correspond to reality. This causes frustration, particularly for the supply chain of goods and services, where companies wishing to invest seek clarity about scope, time and cost, especially so that they can justify the expenditures to serve the industry. In fact, without this clarity, the ability of the decommissioning industry to grow may be hindered.

It will be necessary to develop new technologies, new engineering and business arrangements with the establishment of partnerships, new networks of inter-relationships, and appropriate management systems, capable of substantially reducing prices, risks, and execution time for abandonment operations and removal of production systems. Certainly, the implementation of partnerships with the integration of processes will be determinant for the generation of scale and quality gains that will give robustness to the activities, thus allowing the consolidation of several local centers of excellence in decommissioning.

In this decommissioning scenario, special attention should be given to hibernated facilities, since structures in the offshore environment degrade at an accelerated rate due to their exposure to the highly inhospitable marine environment, which will lead to additional problems in the execution of a PDI.

8.4 CLOSING REMARKS OF THE CHAPTER

Brazil has made significant progress with regulations and implementation of decommissioning projects in recent years, but much more progress is needed. With these additional changes, the proper focus must be placed not only on reducing risks and liabilities for the country, but on how to effectively stimulate future investment in Brazil by the entire oil and gas industry.

It is essential to focus on these three vectors: i) extension of the life of producing fields, ii) creation of conditions to attract new investors and operators to Brazil and iii) creation of tax benefits in return for future post- decommissioning investments.

While most of the attention of the industry in the country is focused on the decommissioning challenges regarding credible timelines, environmental issues, and local supply chain challenges, decommissioning is in fact a strategic challenge for operators of mature fields offshore and onshore in Brazil. They must be careful and clear in their decision making and management efforts. They must consider their project portfolios and operational and asset life extension issues and possibilities.

Finally, there is room for regulatory improvements not yet addressed to optimize this decommissioning scenario for mature fields, such as:

- Reduction of the financial guarantees for abandonment as a counterpart to the contribution of new investments, aiming to increase the recovery factor and increase the useful life of the field.
- Possibility, in the case of mature fields acquired by an independent company through Petrobras' divestment program, of revising the abandonment value proposed by the previous operator to establish abandonment guarantees, considering the efficiency trend in the cost structure of independent operators.
- With respect to the environmental part, it is necessary to deepen studies regarding the possibility of tumbling equipment on the seabed as an environmentally sustainable alternative, aiming at reducing decommissioning costs.

In this sense, ABPIP intends to contribute through broad discussion to improve the regulation that increases the production life of mature fields, as well as through the sharing of contracting solutions for common demands among operators to reduce the production costs of the fields and, likewise, the costs resulting from decommissioning.

9

CHAPTER

Final Considerations

In view of what was presented throughout the Booklet Offshore Decommissioning in Brazil - Opportunities, Challenges and Solutions, one can observe economic and social opportunities arising from the Decommissioning activities, as well as the challenges and solutions that enable new business investments in Brazil.

The deactivation and safe disposal of decommissioned platforms in Brazil merits reflection. When there is an opportunity to reuse the topside, there are a number of alternatives for the use of these structures.

The revision of the regulatory framework for decommissioning activities of E&P facilities in Brazil was implemented not only as a rule to be followed, but as an important operationalization of a promising economic activity, providing the application of the best international practices and conferring legal security to the process. Although a more detailed coordinated normatization in network is complex to operate, due to the little experience of large decommissioning projects, which can create legal uncertainty for economic agents, it is already implemented and in operation in the country.

Furthermore, the intention of the new instrument was to foment sustainable development practices, aiming at the balance between the economic, social, and environmental dimensions of the activity, to contribute in a strategic way to the business environment.

The predictability, size and nature of the decommissioning market presented in this work consolidate the main opportunities and challenges for small, medium and large operators, as well as for the supply chain of goods and services, from different perspectives.

Such initiatives seek to provide transparency to the current decommissioning scenario, as well as to provide greater attractiveness to the economic activity in the country. All the information contained in this work aims to contribute to a more realistic planning, which results in the structuring of a robust decommissioning industry, in all the sectors of the chain. The data presented here also provide subsidies for investment decisions in projects in the country, which may result in the increase of employment and income.

Decommissioning projects are complex and involve many players, making it necessary to achieve greater synergy between companies and stakeholders, to leverage efficiency gains and cost reductions.

It is also suggested that operators share knowledge and solutions, in order to produce projects that are increasingly efficient and safe, in addition to favoring the adoption of new technologies, research and innovation.

From the point of view of resources available for financing and of investment policies for research, development and innovation in the sector, further discussions are needed to identify opportunities and reduce specific bottlenecks, promoting technological and scientific development to overcome challenges and to guarantee the necessary investment for the fulfillment of existing contracts.

As can be seen throughout this booklet, companies are getting ready, while seeking more information and trying to understand the business environment. It is important to pay attention to the requirements for the safe and sustainable advance of this market, together with associates and the government agencies, to ensure that decommissioning promotes an optimal business environment in Brazil.

Among the challenges cited by the services market, in relation to labor capacity, is the need to reduce uncertainties associated with the pricing of services.

Given the potential for investment and promotion of local industry, it is essential that the market is prepared and able to provide the necessary services to implement the Decommissioning Programs.

Ports, wharves and shipyards are considered critical facilities in this stage, due to the lack of places with knowledge and experience in decommissioning, and suited to the regulatory requirements, especially those related to waste management.

It is worth mentioning the need to establish clear rules and guidelines for the transfer of the units, from their location to terminals and national shipyards, paying attention to the presence of sun coral in the hulls and NORM. Besides this, it was identified the need for improvements in the legislation and in the tax and customs regulations, to simplify the procedures for the extinction of the regime applicable in the temporary importation of the facilities that, after decommissioned, will be dismantled in the country, as well as for tax exemption of the imported assets destined to the project in question.

As such, decommissioning should be approached in its broader aspects, beyond its environmental, technical, and economic challenges. These aspects are related to the capacity of the local supply chain of goods and services, regulatory incentives, tax reduction, operational safety, and its social and environmental impacts.

Meeting the regulation, from the project to the end of the useful life of the facilities, as well as planning for a profitable and efficient business environment is the industry's responsibility.

The articulation between the competent agencies and the market, in turn, is fundamental to the search for solutions that are capable of leading the country to the success that is expected with the decommissioning issue. Fostering a predictable and modern regulatory environment, to attract new investments and accelerate the sustainable development of the country, must be a priority for the State.

REFERÊNCIA BIBLIOGRÁFICAS:

CROOKS, J.A. Characterizing Ecosystem-Level Consequences of Biological Invasions: The Role of Ecosystem Engineers. Oikos, v.97, p. 153–166, 2002

COUTINHO, L A. 2019. **Mapeamento e Avaliação Preliminar da Duração das Principais Etapas do Processo de Descomissionamento de um FPSO**. Trabalho de Conclusão de Curso. Escola Politécnica, Universidade Federal do Rio de Janeiro. 2019

[1] LEI FEDERAL n°10.308 de 2001. Dispõe sobre a seleção de locais, a construção, o licenciamento, a operação, a fiscalização, os custos, a indenização, a responsabilidade civil e as garantias referentes aos depósitos de rejeitos radioativos, e dá outras providências.

[2] Norma CNEN-NN-8.02 "Licenciamento de depósitos de Rejeitos Radioativos de Baixo e Médio nível de radiação". Abril 2014 – Resolução CNEN 167/14.

[3] SMITH, K.P. *An Overview of Naturally Occuring Radioactive Materials (NORM) in Petroleum Industry*. ANL/EISA-7, Argonne, Illinois, Argonne National Laboratory (1992).

[4] SMITH, K.P., WILLIAMS, G.P; BLUNT, D.L. AND ARNISHET, J.J. *Radiological Dose Assessment of NORM Disposal in Class II Injection Wells*. ANL/EA CR, Argonne, Illinois, Argonne National Laboratory, 1997.

[5] VEIL, J.A., K.P. SMITH, D. TOMASKO, D. ELCOCK, D.L. BLUNT and G.P. W. *Disposal of NORM-Contaminated Oil Field Wastes in Salt Caverns* prepared for U.S. Department of Energy, Office of Fossil Energy, Argonne National Laboratory, Argonne, IL, August, 1998.

[6] IAEA Safety Reports Series n° 40. *Radiation Protection and Management of Radioactive Waste in the Oil and Gas Industry.* International Atomic Energy Agency, 2010.

[7] AMERICAN PETROLEUM INSTITUTE. *Bulletin on Management of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Production*, API Bulletin E2, Second Edition, April, 2006.

[8] Norma CNEN-NN-3.01 "Diretrizes Básicas de Proteção Radiológica". Janeiro de 2005.

[9] IAEA Safety Standards Series No. GSR Part 3 - Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. International Atomic Energy Agency, Vienna, 2014.

[10] IAEA Safety Standards Series No. RS-G-1.7. Application of the Concepts of Exclusion, Exemption and Clearance. IAEA, Vienna, 2004.

[11] Norma CNEN-NN-8.01 "Gerência de Rejeitos Radioativos de Baixo e Médio nível de radiação". Abril 2014 – Resolução CNEN 167/14.

Sponsors

Companies that believe and invest in research for the development of the Brazilian Energy Sector.

FGV Energia thanks its Sponsors for the support dedicated to its research and publications.


Usina Hidrelétrica de Funil
Resende - RJ
Transparência
& sustentabilidade
Furnas representa um complexo de 19 Usinas Hidrelétricas, 68 subestações e 43 parques eólicos.
• 40% da Energia do Brasil passa por Furnas.
• Energia para mais 60% dos domicílios brasileiros.
• 24.000 km de linhas de transmissão que interligam o Brasil.
• 100% na geração de energia limpa para o Brasil.
Eletrobras Furnas
Ministério de Minas e Energia
GOVERNO FEDERAL BRASIL PÁTRIA EDUCADORA
FURNAS


Ipiranga
JET OIL
RODO
REDE
ampm
WiFi
84

A Eletronuclear segue fornecendo a energia que o Brasil precisa!

Durante a pandemia, continuamos trabalhando atentos aos protocolos de prevenção ao novo coronavírus para que outros serviços essenciais também possam continuar.

Saiba mais: eletronuclear.gov.br

Eletrobras Eletronuclear | MINISTÉRIO DE MINAS E ENERGIA | PÁTRIA AMADA BRASIL GOVERNO FEDERAL

Mantenedores

Ouro

Prata

Apoio

ESTALEIRO AtlânticoSul

SIGMA CONSULTORIA Perícia & Avaliação

Patrocínio

PetroRio

Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

FGV ENERGIA