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REGULATORY AND ENVIRONMENTAL CHALLENGES OF DECOMMISSIONING THE OIL AND GAS INDUSTRY IN BRAZIL

DESAFÍOS NORMATIVOS Y MEDIOAMBIENTALES DEL DESMANTELAMIENTO DE LA INDUSTRIA DEL PETRÓLEO Y EL GAS EN BRASIL

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Abstract
Offshore decommissioning has become a strategic issue for Brazil's oil and gas sector, requiring alignment between industrial practices, environmental regulation, and international standards. This study critically analyzes ANP Resolution No. 817/2020, highlighting its advances and limitations in comparison with international instruments such as IMO guidelines, the OSPAR Convention, the Basel Convention, and the Hong Kong Convention. The research adopts a qualitative approach, based on literature review, documentary analysis, and a survey applied to sector specialists. The findings indicate progress in consolidating technical and environmental criteria and incorporating the concept of sustainable decommissioning. However, significant gaps remain, including the absence of standardized methodologies for cumulative impact assessment, insufficient guidelines for the management of naturally occurring radioactive materials (NORM), institutional fragmentation, and limited incentives for circular economy practices. The study concludes that, although it represents a relevant regulatory milestone, RANP 817/20 requires normative updating and stronger international convergence to ensure

Resumo
O descomissionamento offshore consolidou-se como tema estratégico para o setor de petróleo e gás no Brasil, exigindo alinhamento entre práticas industriais, normas ambientais e referenciais internacionais. Este estudo analisa criticamente a Resolução ANP nº 817/2020 (RANP 817/20), destacando seus avanços e limitações frente a instrumentos internacionais como as diretrizes da IMO, a Convenção OSPAR, a Convenção da Basileia e a Convenção de Hong Kong. A pesquisa adota abordagem qualitativa, baseada em revisão bibliográfica, análise documental e aplicação de questionário a especialistas do setor. Os resultados indicam avanços na consolidação de critérios técnicos e ambientais e na incorporação do conceito de descomissionamento sustentável. Persistem, contudo, lacunas relevantes, como a ausência de metodologias padronizadas para avaliação de impactos cumulativos, diretrizes insuficientes para a gestão de materiais radioativos de ocorrência natural (NORM), fragmentação institucional e limitada indução à economia circular. Conclui-se que, embora represente marco regulatório relevante, a RANP 817/20 demanda atualização normativa e maior

environmental sustainability, legal certainty, and alignment with the Sustainable Development Goals.
Keywords: Offshore Decommissioning. Oil and Natural Gas Industry. Regulatory Framework. Environmental Management

convergência internacional, a fim de assegurar sustentabilidade ambiental, segurança jurídica e alinhamento com os Objetivos de Desenvolvimento Sustentável.

Palavras-chave: *Descomissionamento Offshore. Indústria do Petróleo e Gás Natural. Arcabouço Regulatório. Gestão Ambiental*

1 INTRODUCTION

The decommissioning of oil and gas installations represents a critical stage in the end-of-life cycle of offshore infrastructure and has become a central issue in the regulatory and environmental agenda of Brazil's petroleum industry. As producing fields mature—particularly in offshore basins—both the State and industry stakeholders face the challenge of establishing robust regulatory mechanisms capable of ensuring the safe. efficient. and environmentally responsible closure of production activities.

In Brazil. the growing number of assets approaching the end of their operational life highlights the magnitude of this regulatory challenge. Fixed platforms. floating units. pipelines. and subsea infrastructure require comprehensive solutions that extend beyond the physical removal of structures. Effective decommissioning must also address hazardous waste management. ecosystem restoration. and the mitigation of environmental risks over short-. medium-. and long-term horizons. Consequently. the impacts associated with decommissioning extend beyond the technical-operational domain and encompass legal. environmental. economic. and socio-institutional dimensions.

The National Agency of Petroleum. Natural Gas and Biofuels (ANP) estimates that Brazil will mobilize approximately BRL 70.2 billion in investments in decommissioning activities by 2030. with annual expenditures reaching tens of billions of reais. These investments include well abandonment and plugging. removal of equipment and structures. environmental remediation. and other associated operations. A significant portion of these activities will be concentrated in offshore assets located in Brazil's main producing basins. including fixed platforms. floating production storage and offloading units (FPSOs). and subsea pipelines.

This trajectory is reinforced by Petrobras. whose Business Plan 2026–2030 projects total investments of USD 109 billion. Of this amount. approximately USD 9.7 billion is allocated specifically to the sustainable disposal of equipment and the permanent abandonment of wells during the five-year period. positioning decommissioning as a central component of the company's exploration and production strategy (PETROBRAS. 2025).

The absence of integrated planning for end-of-life infrastructure management may generate significant environmental liabilities. legal uncertainty. and substantial increases in operational costs. Conversely. proactive decommissioning policies offer an important opportunity to promote sustainability by encouraging circular economy practices. technological innovation. and more efficient resource management.

However. realizing this potential depends on the existence of a coherent and coordinated regulatory framework capable of guiding technical and legal decision-making while integrating the multiple public institutions and policy instruments involved in the process. In Brazil. institutional fragmentation and overlapping regulatory competencies remain significant barriers to regulatory effectiveness.

Within this context. ANP Resolution No. 817/2020 (RANP 817/20) constitutes a key regulatory instrument. establishing guidelines for the planning. execution. and monitoring of decommissioning activities associated with oil and natural gas exploration and production facilities. Although the resolution represents an important regulatory advance. its practical implementation has revealed institutional tensions and regulatory gaps that become increasingly evident in light of the anticipated growth of decommissioning activities and the need to align domestic regulation with evolving international standards.

Against this background. the present study critically examines the regulatory framework governing offshore decommissioning in Brazil. focusing on RANP 817/20 and its articulation with national legislation and international governance instruments. The underlying premise is that strengthening regulatory arrangements is essential to ensure legal certainty. environmental protection. and institutional coherence. thereby enabling decommissioning to evolve from a purely legal obligation into a strategic instrument for marine governance and sustainable development in the oil and gas sector.

2 METHODOLOGY

This study adopts a qualitative methodological approach to examine the legal and regulatory framework governing offshore platform decommissioning in Brazil. The research design combines systematic literature review with documentary analysis in order to assess the structure. coherence. and international alignment of the Brazilian regulatory framework.

Document retrieval was conducted using the Scopus. Web of Science. and SciELO databases. complemented by official normative documents available on the institutional websites of the National Agency of Petroleum. Natural Gas and Biofuels (ANP). the International Maritime Organization (IMO). and the OSPAR Commission. The search strategy employed combinations of specific keywords—such as decommissioning. oil and gas. and regulation—together with their corresponding thesaurus terms.

To evaluate the degree of convergence between the Brazilian offshore decommissioning regulatory framework and international benchmarks. a comparative documentary analysis was conducted between national regulations and normative instruments developed by the IMO and the OSPAR Convention. The analytical process was systematized through comparative matrices designed to identify regulatory similarities. divergences. and institutional gaps.

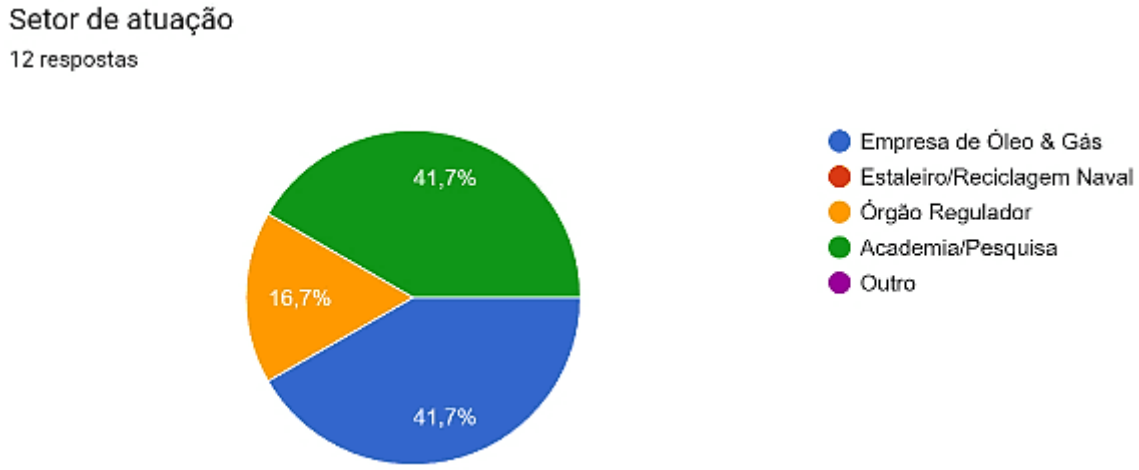
In addition. an expert survey was conducted involving professionals from the oil and gas industry. academia. and regulatory institutions. Participants were selected through purposive sampling based on their demonstrated expertise in offshore decommissioning and regulatory governance. The structured questionnaire was previously subjected to content validation and pilot testing to ensure clarity. reliability. and methodological consistency.

Although the sample size is limited (N = 12). its scope is justified by the high degree of technical specialization required to assess regulatory frameworks in highly regulated sectors. Such sample characteristics are consistent with exploratory studies that rely on expert knowledge to evaluate complex governance arrangements.

3 RESULTS AND DISCUSSION

The analysis presented in this section synthesizes the international and national standards that regulate the decommissioning process. articulating them with insights from industry experts gathered through empirical research targeting 12 specialists. professionals working in the oil and gas industry. academic research. and regulatory bodies (Figure 1). Internationally. this activity is regulated by various conventions. regulations. and global agreements focused on navigational safety. environmental protection. and process sustainability. At the national level. the analysis emphasizes RANP 817/20 as a fundamental regulatory framework for structuring the Decommissioning Process of Installations in Brazil.

Figure 1 – Sectors targeted for empirical research via questionnaire.



Source: Author's own elaboration.

3.1 International regulatory frameworks

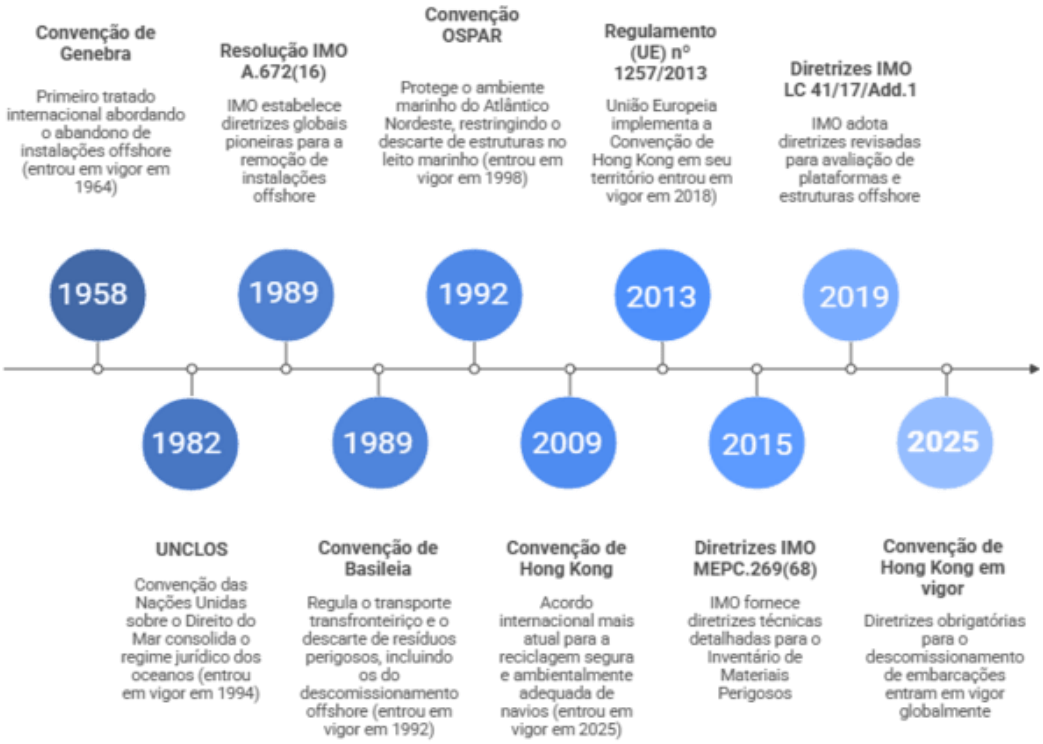
In the global context. the Geneva Convention (1958) was the first international treaty to address the decommissioning of offshore oil installations. establishing the sovereign rights of coastal States to the continental shelf. including the prerogative to install and remove structures associated with the exploitation of natural resources (GENEVA CONVENTION. 1958). The IMO. through Resolution A.672(16) of 1989. consolidated global guidelines for the total or partial removal of offshore installations.

prioritizing operational safety. environmental preservation and the possibility of reusing structures as artificial reefs (IMO. 1989; 2015). The Oslo-Paris Convention (OSPAR). in turn. imposes strict restrictions on the disposal of structures on the seabed of the Northeast Atlantic. allowing exceptions only with rigorous technical and environmental justifications (OSPAR COMMISSION. 1998).

The Basel Convention (1989) regulates the transboundary transport and environmentally sound disposal of hazardous waste. The European Union defines procedures to mitigate environmental and occupational risks. and establishes parameters for the safe and environmentally responsible recycling of maritime assets. including FPSOs and other floating units (BASEL CONVENTION. 1989; EUROPEAN UNION. 2013). Regarding the transit of hazardous waste or Naturally Occurring Radioactive Materials (NORM). the International Atomic Energy Agency (IAEA) has a mature framework with guiding technical standards for radioactive waste management. Of particular note are the documents GSR Part 3 (Basic Radiological Safety Standards). RS-G-1.7 (Application of the concepts of exclusion. exemption and release). and GSR Part 7 (Preparedness and response to radiological emergencies). which advocate the application of the ALARA principle (As Low As Reasonably). Achievable). seeking to minimize exposures even below legal limits (IAEA. 2011; 2014; 2018).

The most recent international agreement for offshore decommissioning is the Hong Kong Convention (HKC). initiated by the IMO in 2009 and in force since June 2025. The convention has already been ratified by at least 15 countries that together represent 40% of the world's merchant fleet in gross tonnage and a recycling capacity of at least 3% of that fleet in the last ten years (IMO. 2009; 2025). The HKC establishes mandatory guidelines for the decommissioning of vessels. including FPSOs and other floating units. aiming to mitigate risks to human health and the environment. constituting a reference in debates on decommissioning. dismantling and recycling. The convention determines the preparation of a Hazardous Materials Inventory (HMI). an individualized recycling plan and the indication of the company responsible for dismantling. which must be certified to prevent clandestine operations. Figure 2 shows the chronology of the main international standards in the decommissioning sector.

Figure 2 - Timeline of the main international regulatory milestones for decommissioning. *offshore*.



Source: Author's own elaboration.

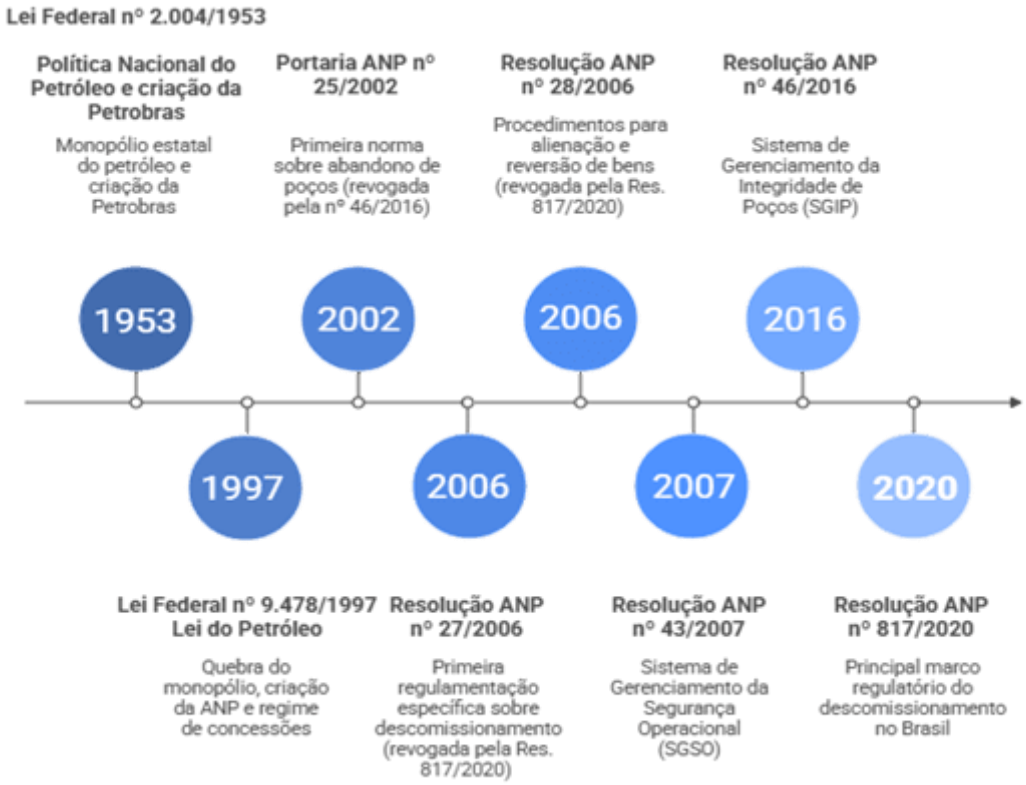
International experiences reveal different normative and institutional arrangements. reflecting not only environmental and technical constraints. but also the political and economic specificities of each country or region. The European Union addresses the issue through the SRR Regulation (1257/2013). which defines global procedures to mitigate environmental and occupational risks associated with naval decommissioning (RAMOS; PEREIRA. 2025).

In the United Kingdom. *Petroleum The Act* (1998) and *the Energy Act* (2016). implemented by the OGA and BEIS. provide for mandatory notification assigning joint and several liability to all parties involved. guaranteeing financial coverage (IOGP. 2017; WARNE *et al*.. 2016). The implementation of fiscal devices such as *Decommissioning Relief Deeds* reinforce economic predictability (HM TREASURY. 2017; WOOD. 2014). In Norway. the Petroleum Law (1996) establishes subsidiary liability in the transfer of assets. requiring bank or corporate guarantees (IOGP. 2017; BUSTNESLI. 2016).

3.2 Brazilian legal framework

The evolution of the Brazilian regulatory framework for decommissioning demonstrates a gradual improvement that reflects the complexity of the oil and gas sector. in which legal and regulatory frameworks have been created to respond to both technical demands and environmental and economic pressures. Figure 3 shows this evolution. from the creation of Petrobras to the creation of the specific resolution in 2020.

Figure 3 – Evolution of the main laws and regulations for the sector.



Source: Author's own elaboration.

The timeline highlights the evolution of the Brazilian regulatory framework aligned with decommissioning. starting with Law No. 2.004/1953. which created Petrobras. and progressing to RANP 817/20. currently the main regulatory framework for the sector. Key highlights include Law No. 9.478/1997. which established the ANP and opened the market; ANP Ordinance No. 25/2002. the first regulation on well abandonment; and ANP Resolutions No. 27/2006. 43/2007. and 46/2016. which

structured the Operational Safety Management System (SGSO). incorporating the Well Integrity Management System (SGIP) and the Solidary Barrier System (CSB). RANP 817/20 consolidated technical. environmental and operational guidelines. establishing the Facility Decommissioning Program (PDI) as a mandatory instrument for planning and monitoring closure activities (ANP. 2020).

Alongside regulatory advancements for decommissioning. the Brazilian legal framework has also been consolidated in environmental and customs dimensions. The Brazilian Institute of Environment and Renewable Natural Resources (IBAMA). through technical information and opinions issued since 2019. has emphasized the need for environmental liability assessment. proper disposal of hazardous waste. and post-decommissioning monitoring. demonstrating that the cessation of activities is not limited to physical abandonment. but requires continuous monitoring of impacts (IBAMA. 2019).

After 2020. new regulations expanded governance and financial security mechanisms. such as ANP Resolution No. 854/2021. which defines the mandatory establishment of guarantees and progressive contributions throughout the field's lifespan. so that the resources necessary for decommissioning are fully secured before contract termination. Similarly. the Special Customs Regime for Export and Import of Goods Intended for Oil and Natural Gas Exploration and Production Activities (REPETRO). updated to the REPETRO-SPED model. provides for specific termination scenarios. such as re-export. transfer to the domestic market. or destruction. each with distinct tax implications. which directly influences the alternatives for reuse or disposal of structures at the end of their useful life (Brazilian Federal Revenue Service. 2023).

In the field of maritime safety. the Maritime Authority Standards (NORMAM). especially NORMAM-07/DPC. NORMAM-08/DPC. and NORMAM-11/DPC. regulate inspections. traffic. stay. and intervention in jurisdictional waters. aligning with international conventions ratified by Brazil. Regulations for the recycling of vessels and offshore structures in Brazil are part of a normative framework influenced by international commitments and ongoing legislative debates. Brazil. as a signatory member of the Basel Convention. had to create its own legislation (BRASIL. 1993; 2024) to establish limits on the transboundary movement of hazardous waste. prohibiting the export of this material from developed countries to poorer countries. Thus. Ibama acts as the national enforcement authority. in accordance with the National Solid Waste Policy -

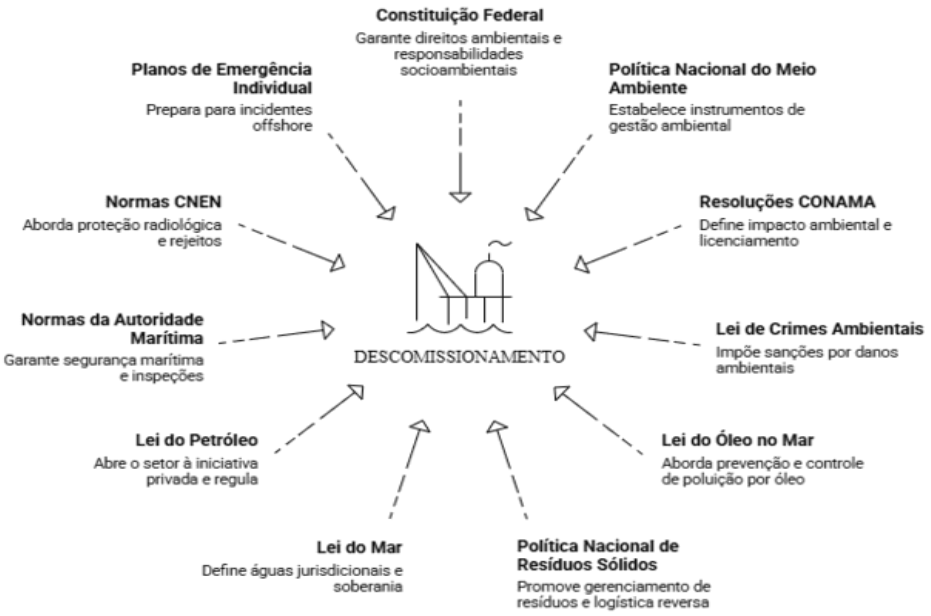
PNRS (Law No. 12.305/2010). which prohibits the importation of hazardous waste (IBAMA. 2022).

3.3 Legal basis of resolution 817

The formulation of standards and ethics in the decommissioning sector in Brazil stems from the constitutional and environmental principles of Article 225 of the 1988 Federal Constitution. which establishes the right to an ecologically balanced environment and assigns to the public authorities and the community the duty of its defense and preservation (BRAZIL. 1988). This precept underpins the polluter-pays principle. incorporated into RANP No. 817 through the imposition of financial and operational responsibilities on companies responsible for the decommissioning of oil installations.

Figure 4 summarizes convergent and divergent aspects. as well as the intersection between Brazilian environmental law and RANP 817/20. It highlights the multifaceted nature of the regulatory scope. encompassing environmental. economic. safety. technical. and operational dimensions related to the decommissioning of offshore assets.

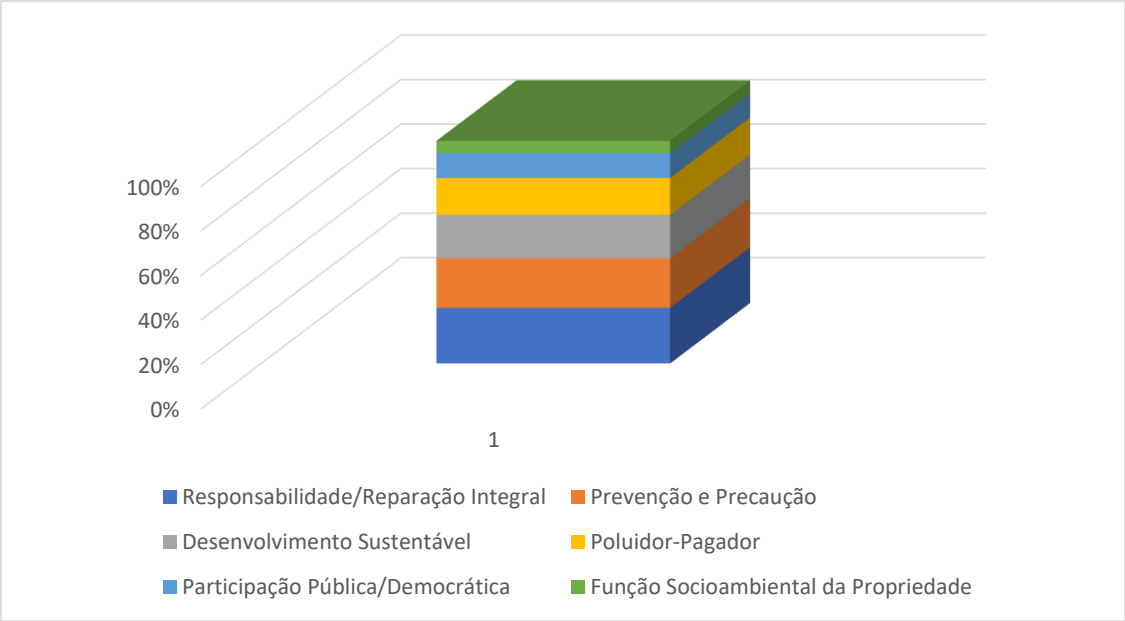
Figure 4 - Main legislation related to ANP Resolution 817/2020



Source: Author's own elaboration.

The structure of the aforementioned legal framework demonstrates the synergistic connection and influence of these regulations in the composition of the legal framework for decommissioning. The National Environmental Policy (Law No. 6.938/1981) structures the main regulatory instruments. licensing and monitoring. complemented by CONAMA resolutions. such as No. 1/1986 (EIA/RIMA). No. 398/2008 (contingency plans) and specific regulations on effluents and emissions (CONAMA No. 501/2021; No. 393/2007; No. 357/2005). The decommissioning regulations are anchored in principles that can be identified in their scope. in different proportions. as shown in Figure 5. which presents the experts' perception regarding the identification of these principles in the ANP resolution.

Figure 5 – Basic principles of ANP Resolution 817/20.



Source: Form applied to experts in the field. Own elaboration.

Brazilian National Petroleum Agency (ANNP) Resolution 817/20 aligns with this framework by incorporating risk assessment. recovery of degraded areas. post-decommissioning monitoring. and the mandatory implementation of Environmental Impact Assessments (EIAs) and Environmental Impact Reports (EIRs) (ANP. 2020). also aligning with the guidelines of the National Solid Waste Policy (PNRS) and the obligations for preventing oil pollution (Law No. 9.966/2000). The Environmental Crimes Law (Law No. 9.605/1998) reinforces administrative and criminal liability.

expanding the environmental adherence of the process. This is because. from an environmental perspective. the impacts of decommissioning include the release of contaminated sediments. the introduction of invasive species. and the disruption of sensitive ecosystems (BATISTA *et al*. 2020; ALMADA & BERNARDINO. 2017). Some studies highlight the importance of conserving deep-sea ecosystems. such as rhodolith beds and mesophytic reefs. for maintaining marine biodiversity and mitigating environmental impacts. Carvalho *et al*. (2020) emphasize that rhodolith beds function as highly productive habitats. fundamental for epiphytic communities in the Southwest Atlantic. Mesophytic reefs of high structural complexity have been identified on the Brazilian Continental Shelf. highlighting their role in protecting endemic species (CARVALHO *et al*. 2022). Studies like these reinforce the need for conservation strategies that consider local specificities and promote the strengthening of a sustainable production chain.

Destri (2024) reinforces that the correct disposal of materials is essential not only for legal compliance. but also for mitigating irreversible environmental damage. especially in sensitive areas such as mangroves and coral reefs. Inadequate waste management and carbon emissions during operations are critical factors that require attention.

3.4 Analysis between Brazilian and international standards and challenges of decommissioning in Brazil

Brazilian National Petroleum Agency Resolution 817/20 reveals partial convergence with international guidelines. especially with instruments developed by the International Maritime Organization (IMO) and the OSPAR Convention. notably regarding the removal of offshore structures and the protection of the marine environment. However. regulatory harmonization remains limited. Research conducted with 12 experts from regulatory bodies. industry. and academia indicates that 58% of respondents rate alignment with IMO guidelines as level 4 or 5 (Likert scale of 1 to 5). while the perception of alignment with OSPAR shows greater dispersion. with 50% assigning levels 3 or 4. Figure 6 illustrates the degree of synergy between the ANP resolution and these international regulatory instruments.

Figure 6 – Degree of synergy - Experts' perception.

Source: Form applied to experts in the field. Own elaboration.

This overview highlights that. although RANP 817/20 incorporates general principles of international best practices. divergences persist regarding its binding nature. financing mechanisms. and the technical depth of the requirements. since international treaties predominantly function as guiding references (ANP. 2020; IMO. 2015).

Despite some convergences with instruments such as OSPAR and European directives. the national regulatory framework presents structural gaps that compromise its effectiveness. Among the experts consulted. 75% agree fully or partially that these gaps hinder sustainable practices. highlighting deficiencies in hazardous waste management guidelines. lack of tax incentives. lack of sectoral regulation of the PNRS (National Solid Waste Policy) for the oil and gas sector. and scarcity of parameters for the removal and disposal of NORM (Normally Relevant. Radioactive. and Materials). Consistently. 58% state that the resolution does not adequately address radioactive waste. while 83% consider regulatory progress on this issue urgent.

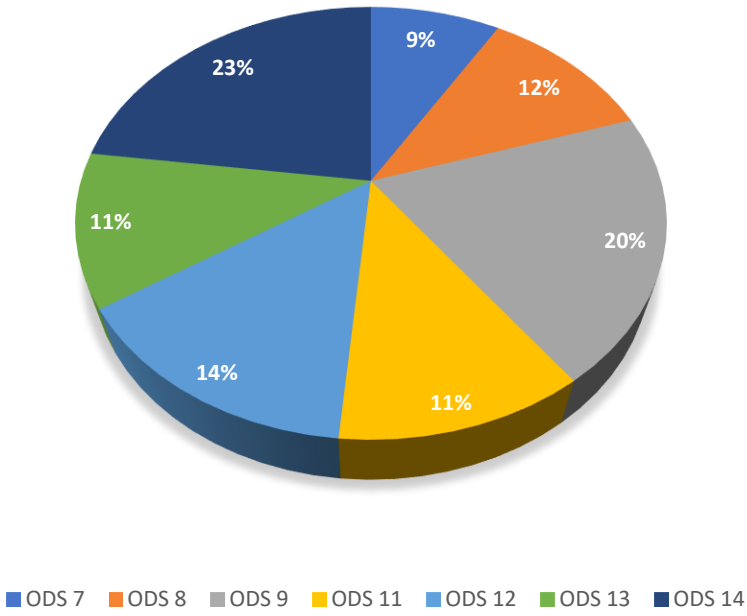
At the international level. the Basel Convention. ratified by Brazil through Decrees No. 875/1993 and No. 4.581/2003. constitutes the main legal instrument aimed at controlling hazardous waste internationally. Its influence is manifested in regulations such as the PNRS (National Solid Waste Policy) and CONAMA Resolution No. 452/2012. However. only 50% of experts perceive significant alignment between RANP 817/20 and the Basel principles. while 25% partially or totally disagree. The HKC (Hazardous Materials Convention). not yet ratified by Brazil. establishes systemic

requirements for risk assessment and hazardous materials inventories (HMI). consolidated by IMO Resolution MEPC 379(80/2023) (RAMOS; PEREIRA. 2025). In the survey. 42% identified partial alignment of the Brazilian Resolution with the HKC. while 25% totally disagreed. In this context. Bill No. 1.584/2021. supported by 75% of experts. emerges as a central mechanism to standardize decommissioning and recycling practices. especially given the estimated turnover of R$ 90 billion in the sector by 2035.

Regarding sustainability. the regulatory framework remains limited: only 8% perceive incentives for innovation and the circular economy. while 42% highlight losses of high-value materials and regulatory gaps concerning the reuse of structures. artificial reefs. and integration with renewable energies. Thus. it is understood that managing environmental impacts requires ecosystem-based approaches and continuous monitoring. especially in sensitive habitats such as reefs. rhodoliths. and areas invaded by sun coral (Tubastraea spp.) (SOMMER *et al*. 2019; CARVALHO *et al*. 2020; 2022). The presence of these invasive species in subsea structures to be decommissioned represents a significant ecological challenge. requiring specific management strategies (BATISTA *et al*. 2020). In Brazil. there is the National Action Plan for Coral Reef Conservation (PAN Corais). coordinated by the Chico Mendes Institute for Biodiversity Conservation (ICMBio. 2017). which highlights the importance of continuous monitoring to protect sensitive marine ecosystems.

Regarding alignment with the Sustainable Development Goals (SDGs). Figure 7 highlights the relevant inductive potential. indicating that the standard has significant environmental inductive potential. although dependent on progress in implementation. Experts highlighted SDG 14 (Life Below Water). SDG 9 (Industry. Innovation and Infrastructure). SDG 12 (Responsible Consumption and Production). and SDG 13 (Climate Action).

Figure 7 – Identification of the SDGs in ANP Resolution 817/20



Source: Form applied to experts in the field. Own elaboration.

The management of hazardous waste. especially Naturally Occurring Radioactive Materials (NORM). is governed by a set of environmental. radiological. and sectoral standards. including IBAMA Ordinance No. 2.334/2021. IBAMA Normative Instruction No. 24/2024. ABNT NBR 17100-1:2023. and ABNT NBR 10004:2024. These instruments establish conditions for the transit and transport of hazardous waste. imposing requirements for traceability. cross-border control. and classification as Class 1 (hazardous). in accordance with the Basel Convention and Decree No. 4.581/2003. In the field of radiology. the Brazilian framework is structured by the standards of the CNEN (National Nuclear Energy Commission). the Regulatory Standards of the Ministry of Labor (NR-7. NR-9. NR-15. NR-16 and NR-37). and the actions of the National Nuclear Safety Authority (ANSN). responsible since 2021 for nuclear and radiological regulation and oversight. The CNEN. in turn. has focused on research. development. and technical support for the management of radioactive waste.

Despite this framework. structural challenges persist due to regulatory fragmentation and gaps in current nuclear legislation (Law No. 4.118/1962; Law No. 10.308/2001; CNEN Resolution No. 288/2021). particularly regarding the definition of technical criteria for the final disposal of waste and the integration between environmental

and radiological monitoring. The research results confirm this perception: only 50% of experts consider RANP 817/20 adequate to the subject. while 41.7% disagree and 8.3% did not express an opinion. highlighting technical weaknesses. legal uncertainty. and operational gaps in the division of responsibilities between ANP. IBAMA. and ANSN/CNEN. Furthermore. 83% of respondents pointed to the urgent need for regulatory advancements.

Regarding the promotion of technological innovation. ANP Resolutions No. 918/2023 and No. 926/2023 expand the role of Research. Development and Innovation (R&D&I) in the formulation of technologies for removal. reuse and environmental remediation. aligning with the evidence of Oliveira *et al*. (2025). who highlight the role of the CT-PETRO Sectoral Fund as a strategic driver of patents and innovations in the sector. However. regulatory and institutional obstacles still limit the capacity to fully internalize emerging technologies in the decommissioning cycle. compromising the construction of a cohesive regulatory environment aligned with international best practices.

Table 1 – Summary of Research Findings by Thematic Area

Thematic Axis	Identified Gaps	Expert Evidence
NORM/TENORM	Lack of technical criteria. absence of guidelines for final disposal.	**83%** indicate regulatory urgency.
Sustainability	Lack of incentives and low encouragement of circularity.	**42%** disagree that the standard favors sustainable practices.
Governance	Fragmentation between ANP. IBAMA. the Navy. and ANSN/CNEN.	**43%** High qualitative consensus
Innovation and R&D	Low technological advancement linked to decommissioning.	Only **8%** see significant stimulus.

Source: Form applied to experts in the field. Own elaboration.

The consolidation of an effective regulatory framework for decommissioning in Brazil will depend on overcoming existing structural challenges. such as institutional fragmentation. gaps in nuclear legislation. and the absence of standardized protocols for assessing cumulative impacts and post-decommissioning monitoring.

Table 2 – Main Gaps Identified by Experts

CATEGORY	SPECIFIC GAPS / CRITICISMS	NUMBER OF MENTIONS
1. NORM/TENORM MANAGEMENT	Demand for approved sites for final disposal of NORM waste in Brazil.	2

	Lack of technical detail for NORM removal methodologies on equipment.	2
	Lack of a clear interface between CNEN and ABNT for classifying NORM as Class 1.	1
	Lack of clarity regarding costs and responsibilities for temporary storage/safekeeping.	1
2. INTERINSTITUTIONAL HARMONIZATION	Lack of alignment between ANP. IBAMA and the Navy.	2
	Lack of an interministerial decree clearly defining responsibilities.	1
	Parallel processes (PDI/ANP vs. licensing/IBAMA) without integration	1
	IBAMA may require changes after the PDI is approved. generating rework.	1
3. INFRASTRUCTURE AND TRAINING	Lack of certified infrastructure for decommissioning operations.	2
	Lack of certified shipyards for dismantling platforms.	1
	Need for specialized technical training	1
4. ECONOMIC INCENTIVES	Lack of tax incentives for the circular economy.	1
	Lack of clarity regarding the resale of equipment that is still in its useful life.	1
	Lack of operational planning tools (e.g.. 5W2H)	1
5. SPECIFIC TECHNICAL ASPECTS	Inadequate management of hazardous waste (non-NORM)	1
	Pull-outs require PDI only during decommissioning. but not during operation.	1
	There is a lack of integration between well abandonment (RFAP) and PDI.	1
	RFAP sent without prior approval. creating control gaps.	1
6. REGULATION OF THE PNRS	Lack of specific regulations for industrial recycling in the oil and gas sector.	1

Source: Form applied to experts in the field. Own elaboration.

In summary. comparative analysis and expert perception converge on the conclusion that. although RANP 817/20 represents a significant regulatory advance. the Brazilian regulatory framework still lacks modernization. institutional integration. and mechanisms to incentivize innovation. These weaknesses constitute the main structural challenges for offshore decommissioning in Brazil.

4 CONCLUSION

The decommissioning of offshore installations in Brazil is regulated by a complex regulatory framework. reflecting the interdisciplinary nature of the process and the need to reconcile operational safety. environmental protection. and economic efficiency. Although national standards and international commitments establish relevant

guidelines for the closure of activities. their practical application still reveals limitations related to institutional fragmentation. regulatory overlap. and the absence of more integrated operational instruments.

The analysis highlights the need to review and improve the legal instruments governing decommissioning. with a view to increasing their coherence. applicability. and capacity to induce sustainable practices. The results indicate the need to improve the regulatory framework. with a view to increasing its coherence. applicability. and capacity to induce sustainable practices. The adoption of technological solutions. combined with more integrated and participatory governance models. is presented as an essential strategy for mitigating environmental impacts. rationalizing costs. and reducing regulatory liabilities. considering that the advancement of the Brazilian regulatory framework depends on strengthening institutional coordination and greater convergence with consolidated international standards. especially with regard to waste management. the circular economy. and environmental monitoring.

In this sense. the construction of a regulatory paradigm guided by the principles of sustainability. operational efficiency. and legal certainty is recommended as an indispensable condition for decommissioning in Brazil to transcend mere regulatory compliance and consolidate itself as a strategic instrument for sustainable economic development and long-term environmental preservation. Additionally. the establishment of an interministerial decree is suggested to strengthen coordination among the main bodies involved in the regulatory process. as well as the development of digital integration mechanisms between ANP (National Agency of Petroleum. Natural Gas and Biofuels) and IBAMA (Brazilian Institute of Environment and Renewable Natural Resources). capable of improving data sharing. traceability of decommissioning stages. and the efficiency of licensing and inspection processes. This path. although complex. represents a unique opportunity to consolidate our position as a global reference in responsible and innovative decommissioning and makes this research an analytical and guiding tool for professionals directly or indirectly involved in the planning. execution. and monitoring of decommissioning. offering support for the implementation of more efficient models and practices.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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