



DEVELOPMENT AND INCENTIVES FOR MATURE PROVINCES, MATURE FIELDS, MARGINAL FIELDS AND MARGINAL ACCUMULATIONS: CASE STUDIES ON NIGERIA, ANGOLA AND BRAZIL

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Article Information:

Article Type:
Research Article

Manuscript Received:
15 January 2025

Final Revision Received:
4 March 2025

Published Online:
14 May 2025

Keywords:
Oil and Gas, SDGs,
Mature Provinces, Mature
Fields, Marginal Fields,
Marginal Accumulations,
Sustainable Development.

This article delves into the lifecycle of oil and gas fields and the associated economic and regulatory frameworks in these three countries. Initially, it defines key terms such as mature provinces, fields, and marginal accumulations. The article presents case studies from Nigeria, Angola, and Brazil, highlighting the specific legal and fiscal incentives that influence the development and sustainability of these fields. In Nigeria, the focus is on the historical context and regulatory developments that shape the classification and management of mature and marginal fields. Angola's case study examines the impact of new incentives introduced to revitalize marginal fields and explores the challenges posed by the lack of legal clarity. The Brazilian context provides insights into how comprehensive legal frameworks, such as the Petroleum Law, support the exploration and production of mature and marginal resources. The article emphasizes the importance of technological innovation, regulatory clarity, government incentives, scientific research, publications and international cooperation in optimising production and ensuring sustainable development. It underscores the need for research-guided continuous adaptation of technical and legal frameworks to address evolving industry dynamics and environmental considerations, advocating for a balanced approach that integrates economic, social, and environmental goals.

Cite this article: Eduardo G. Pereira, Shiva Balliram, Isis Oliver, Samantha Ramdeen, Cosmos Nike Nwedu, Hirdan Katarina de Medeiros Costa, Nathália de Oliveira Souza, and Lucca Galatro (2025). Development and Incentives for Mature Provinces, Mature Fields and Marginal Accumulations: Case Studies on Nigeria, Angola and Brazil. The Journal of Sustainable Development, Law and Policy. Vol. 16:3. 179-204. DOI: 10.4314/jsdlp.v16i3.9



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1. INTRODUCTION

Broadly speaking, the phrase ‘petroleum province’ refers to a geographic region known to have commercial hydrocarbon accumulations.¹ Petroliferous provinces can occur in various geological settings.² Where hydrocarbon discoveries are generally on an upward trend, the petroleum province is considered immature.³ The province is, however, said to be in transition from immature to mature when the production results are stable,⁴ and is deemed mature after its production plateau starts to show a decline. The world’s traditional petroleum provinces are mainly the North Sea and the Gulf of Mexico.⁵ In recent years, there has been growing recognition that the exploration and management of mature fields should not only focus on maximising economic recovery but also align with broader global goals for sustainable development, as articulated in the United Nations’ Sustainable Development Goals (SDGs).⁶ This alignment is essential as the oil and gas industry navigates the twin challenges of addressing economic demands while minimising environmental impacts.⁷

The SDGs provide a universal framework that sets out 17 goals aimed at ending poverty, protecting the environment, and ensuring prosperity for all by 2030. Goals such as SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 12 (Responsible Consumption and Production) are particularly relevant to the oil and gas industry.⁸ Within the context of a mature petroleum province, balancing the economic benefits of

¹ J. Meisner and F. Demirmen, ‘The Creaming Method: A Bayesian Procedure to Forecast Future Oil and Gas Discoveries in Mature Exploration Provinces’ (1981) 144 (1) Wiley for the Royal Statistical Society 1 <<https://www.jstor.org/stable/2982158>> accessed 12 July 2022.

² Ibid.

³ Ibid.

⁴ Ibid.

⁵ Ibid.

⁶ United Nations, ‘The 17 Goals’ (Department of Social and Economic Affairs, 2024) <<https://sdgs.un.org/goals>> accessed 24th July 2024; United Nations, ‘Sustainable Development Goals’ (United Nations, 2024) <<https://www.un.org/sustainabledevelopment/>> accessed 24th July 2024.

⁷ United Nations, ‘We Can End Poverty: Millennium Development Goals and Beyond 2015’ (United Nations, 2015) <<https://www.un.org/millenniumgoals/bkgd.shtml#:~:text=The%20Millennium%20Development%20Goals%20set,environmental%20sustainability%20%E2%80%9494%20can%20be%20measured.>>> accessed 24th July 2024.

⁸ Jeffrey D Sachs, ‘From Millennium Development Goals to Sustainable Development Goals’ (2012) 379 *The Lancet* 2206; Shiva Balliram, Eduardo G Pereira and Aaron Koenck, ‘Energy Law and the Sustainable Development Goals’ in Eduardo Pereira, Patrick Baker and Thomas L Muinzer (eds), *Host Government Instruments in the Oil and Gas Sector and the U.N. Sustainable Development Goals* (Routledge, 2024) 1st edn.

resource extraction with commitments to sustainable practices is imperative. This involves not only prolonging the life of mature fields but also ensuring that exploration and production are conducted in an environmentally responsible manner. As mature fields often experience declining production rates, there is an opportunity to implement advanced recovery techniques and technological innovations that optimise resource management while mitigating negative environmental impacts.

Exploring and maximizing economic recovery in mature fields should be guided by strategies that integrate the principles of sustainable development. These strategies include minimising greenhouse gas emissions, adopting cleaner technologies, and considering the long-term social and economic benefits for local communities.⁹ The concept of sustainability becomes even more critical in provinces transitioning from peak production to decline, where economic incentives, regulatory frameworks, and technological advancements must be carefully coordinated to extend field life while contributing to the achievement of SDGs. For example, reducing gas flaring, improving energy efficiency, and investing in renewable energy projects within these provinces are key steps toward aligning with SDG 7¹⁰ and SDG 13.¹¹

Exploring ongoing production of mature fields can yield several significant economic benefits. Where such production is no longer able to continue because of financial, technical and/or other factors, it can be said that the life of the project is nearing its end. However, advances in exploration technology have demonstrated the possibility of maintaining economic value in mature fields and marginal accumulations, which combined to legal fiscal and regulatory incentives may offer a range of economic benefits to stakeholders.

For the success of exploring mature fields and fields with marginal accumulations, it is essential to have in-depth knowledge of the regulations applicable to the particularities of exploring such fields, especially about the laws regulating special incentives and decommissioning and abandonment procedures. There are numerous initiatives to extend the life cycle of these fields and enable the development and production of marginal accumulations. Accordingly, to advance future explorations of hydrocarbon reservoirs, planning and policymaking should be considered in the oil and gas industry.

⁹ Paul Stevens, 'The Role of Oil and Gas in the Economic Development of the Global Economy' in Tony Addison and Alan Roe (eds), *Extractive Industries: The Management of Resources as a Driver of Sustainable Development* (Oxford University Press 2018; online edn, Oxford Academic 22 November 2018).

¹⁰ United Nations, 'Ensure Access to Affordable, Reliable, Sustainable and Modern Energy for All' (*Department of Economic and Social Affairs Sustainable Development*, 2024) <https://sdgs.un.org/goals/goal7> accessed 24 July 2024.

¹¹ United Nations, 'Take Urgent Action to Combat Climate Change and Its Impacts' (*Department of Economic and Social Affairs Sustainable Development*, 2024) <https://sdgs.un.org/goals/goal13> accessed 24 July 2024.

As such, this paper seeks to combine key information on selected hydrocarbon provinces namely Nigeria, Angola, and Brazil to inform evidence-based practices.

This paper draws on case studies from key hydrocarbon provinces in Nigeria, Angola, and Brazil to explore how mature petroleum provinces can navigate the complex interplay between maximizing economic recovery and advancing sustainable development. Section 2 defines and elaborates on the concepts of mature provinces, mature fields, marginal fields, and marginal accumulations. Section 3 provides a detailed regulatory analysis of these concepts within the jurisdictions of Nigeria, Angola, and Brazil, answering key questions on how mature fields can be optimised sustainably. Section 4 synthesizes these insights to propose recommendations that align resource management strategies in mature provinces with the SDGs, focusing on both economic viability and environmental stewardship. Finally, Section 5 offers conclusions on the way forward for mature petroleum provinces seeking to balance economic recovery with sustainable development imperatives.

2. MATURE PROVINCES, MATURE FIELDS, MARGINAL FIELDS, AND MARGINAL ACCUMULATIONS

Different typologies may be used to classify oil and gas fields. For example, an exploration area may be designated as a wild cat field, an immature field, a mature field, a marginal field, or field with marginal accumulation.¹² The designation is based on these fields' economic, operational and production capacity characteristics. Such components are identified by engineering techniques that accurately represent an oil and gas project's economic and operational viability. The economic analyses include cash flow modelling, project profitability and sensitivity analysis.¹³ In most jurisdictions, the Monte Carlo simulation and discounted cash flow method (DCF) are used to determine the project's viability for prolific oil fields. The Net Present Value (NPV) formula is used for marginal fields. In contrast, the DCF is most suited for producing properties in which an income stream is likely and not speculative (Ayodele and Frimpong, 2003).¹⁴ An oil and gas field may have its classification redefined throughout its operation lifecycle—from a wildcat field during the exploration stage to a prolific field during peak production, then mature at a later stage of secondary recovery and eventually marginal due to declining output and a need for significant infrastructural upgrades or development which may outweigh the possible recoverable

¹² M. Adamu, et al., 'Economic Analysis on the Development of Nigerian Offshore Marginal Fields Using Probabilistic Approach.' (2013) 6(1) *Advances in Petroleum Exploration and Development* 11-21.

¹³ Ibid

¹⁴ O. Ayodele, S. Frimpong, 'Economics of Nigeria Marginal Oil Fields' (2003) SPE Hydrocarbon Economics & Evaluation Symposium.

profits.¹⁵ A marginal or stranded accumulation represents a modest reservoir compartment located far away from existing infrastructure, which requires significant upfront capital cost to produce without a commensurate return on investment at the current market prices.

Theoretically, a mature province could be expected to have a greater proportion of mature and marginal fields and as such harvesting in these areas would require optimization techniques to improve production.¹⁶ By definition, a mature petroleum field is one in which oil and gas can no longer reach the earth's surface under natural formation pressure. Economic indicators would be that a petroleum field has reached its peak production capacity or is in declining mode.¹⁷ Consequently, certain measures are taken to bring the oil and gas to the surface and maximize production such as the use of pumping jacks, gas lifting, steam injection and water flooding.¹⁸ It should be noted that usually mature fields often exhibit well-established infrastructure, including pipelines, refineries and other necessary facilities for the extraction, processing and transportation of hydrocarbons. Exploring such areas could be an opportunity to stakeholders to extend the life of existing fields, enhancing recovery techniques with low investment required for the implementation of infrastructure or for development of studies in such areas that has already been subject to oil and gas discoveries over many years.

Marathe has argued that these mature fields form the 'backbone' of commercial petroleum production on which the industry has relied upon heavily for a very long time.¹⁹ He noted that the sustaining of production from mature fields would challenge the best from each discipline, and that significant successes were achieved through a genuine collaboration of ideas across multiple disciplines from subsurface mapping to engineering. Some proposed methods were using artificial intelligence and machine learning to collect existing data and a multi-disciplinary approach involving reservoir management, production optimisation, drilling and formation evaluation to and optimise production from the maturing fields.²⁰ Other challenges faced in mature fields include excessive water production from the multi-phase flow within the reservoir, especially in areas with heavy oil production, which results in incremental costs, high energy consumption, and inefficient oil recovery. These problems may be resolved

¹⁵ Alastair Harris, *Trinidad and Tobago: The Black Gold Book—Commemorating a Century of Oil and Gas Production* (1st edn, 2014) 90–93; Jim Brooks, *Classic Petroleum Provinces* (Brooks Associates, Glasgow G43 2EE, UK).

¹⁶ R.V Marathe, 'Mature Fields and Well Revitalization' (2022) *Journal of Petroleum Technology*.

¹⁷ Tayfun Babadagl, 'Development of Mature Oil Fields — A Review' (2007) 57 (3-4) *Journal of Petroleum Science and Engineering* 221.

¹⁸ Richard Oliver, Permanent Secretary Ministry of Energy and Energy Affairs Trinidad and Tobago, Personal Communication.

¹⁹ R.V Marathe, 'Mature Fields and Well Revitalization' (2022) *Journal of Petroleum Technology*.

²⁰ *Ibid.*

through a series of numerical experiments based on the Navier-Stokes equations in 3D to simulate multiphase flows in porous media for heavy oil production in horizontal wells and evaluate the movement of fluids near a borehole to optimise production.²¹ Such technology methods may also create a business opportunity for technology transfer and knowledge-sharing among industry players, research institutions and academic organisations.

Thus, it was determined that the numerical hydraulic data, such as pressure and velocity profiles could be used as an alternative to subsurface modelling and well designs to improve production efficiency.²² However, these production techniques have led to increased emissions and a worsening carbon footprint due to the inefficiency of producing oil at high water-cuts. Additionally, these mature fields would eventually become depleted and unproductive commercially, despite all the measures to rehabilitate wells and maximize production.²³ An oil and gas field may be considered marginal by an international oil company (IOC) due to financial constraints because such fields did not meet the investment hurdle of the company based on their NPV calculations.²⁴ However, these marginal fields could be developed by smaller indigenous firms, contributing significantly to employment generation, wealth creation, and the development of local content within the energy sector.

A hydrocarbon accumulation would be regarded as marginal if it is not economically attractive or viable to develop (e.g. the location is stranded and too far away from existing infrastructure). However, a small accumulation located to nearby infrastructure within the same block, or an adjacent block may be considered viable based on the NPV criteria. Additionally, the increased investment in infrastructure, advancements in technology over time and high market demand for energy could eventually transform marginal accumulations in deep water into viable projects.²⁵

Moreover, an accumulation may be considered marginal by one country and significant to another country based on capital expenditure and ease of production. For instance,

²¹ Pinilla A, et al, 'CFD study of the water production in mature heavy oil fields with horizontal wells' (2021) 16(10) PLOS ONE: e0258870 < <https://doi.org/10.1371/journal.pone.0258870> > Accessed 10 January 2022.

²² Ibid.

²³ Richard Oliver, Permanent Secretary Ministry of Energy and Energy Affairs Trinidad and Tobago, Personal Communication.

²⁴ U. Offia, 'Development and management of marginal oil field in the Niger delta basin: Opportunities and challenges' (2011) 1 (1) Petroleum Technology Development Journal: An International Journal 1-10.

²⁵ Alastair Harris, *Trinidad and Tobago: The Black Gold Book—Commemorating a Century of Oil and Gas Production* (1st edn, 2014) 94.; Richard Oliver, Permanent Secretary, Ministry of Energy and Energy Affairs, Trinidad and Tobago, personal communication.

Venezuela would likely consider its cross-border gas fields with Trinidad and Tobago to be marginal due to the amount of investment required to develop a modest size field. However, the existing infrastructure located close to these fields on the Trinidad side of the border favours the development of the cross-border fields by Trinidad because of the absence of similar facilities on the Venezuelan side. Other factors such as the fluctuation of oil prices determine the viability of a project since an estimated 5 million barrels of oil reserve could be considered marginal if the required investment is \$500M with oil prices at \$20 dollars a barrel.²⁶ There are also marginal fields that have passed their peak production whereby the output from those mature fields have declined considerably. Additionally, the reduced structural integrity of the wells results in water intrusion into the reservoir and the crude oil produced, which increases inefficiency and the carbon dioxide emissions. Consequently, when it is no longer technically or economically viable to continue operation, the marginal fields may have to be decommissioned.²⁷

3. IMPLEMENTATION OF SUSTAINABLE EXTRACTION

Sustainable development goals can be collectively achieved through the implementation of government incentives to promote the development of marginal fields which require investments in secondary recovery methods to remain productive. Incentives include government subsidies to companies and accepting lower profit percentages in their production sharing contracts for marginal fields.

Secondary recovery methods include:

1. Pumping Jacks:²⁸

This method requires an individual pump with a motor for each well and requires three-phase power supply to operate. The electricity required for the operation of Pumping Jacks is produced using natural gas at power stations or renewable energies and transported to the oil field through the electric grid. There may even be on site diesel power generators, which is a common practice for remote fields. Though this method of transmitting power through the grid requires infrastructural development, it is

²⁶ Alastair Harris, *Trinidad and Tobago: The Black Gold Book—Commemorating a Century of Oil and Gas Production* (1st edn, 2014) 94.

²⁷ R V Marathe, 'Mature Fields and Well Revitalization' (2022) *Journal of Petroleum Technology*; A Pinilla et al, 'CFD Study of the Water Production in Mature Heavy Oil Fields with Horizontal Wells' (2021) 16(10) *PLOS ONE* e0258870 <https://doi.org/10.1371/journal.pone.0258870> accessed 10 January 2022; e0258870 < <https://doi.org/10.1371/journal.pone.0258870> > Accessed 10 January 2022; Richard Oliver, Permanent Secretary, Ministry of Energy and Energy Affairs, Trinidad and Tobago, personal communication.

²⁸ Richard Oliver, Permanent Secretary Ministry of Energy and Energy Affairs Trinidad and Tobago, Personal Communication.

advantageous for residents of the nearby communities because they may benefit from the grid system in powering their homes. Also, in comparison to the other methods discussed it is less expensive.

2. Steam Injection:²⁹

Steam is pumped into the well at high pressure to force the oil in the reservoir up to the surface. The steam is produced in boilers and requires constant circulation through the network of pipes using pumps. This need for constant circulation makes this an expensive method of secondary recovery. Furthermore, this method has not been very effective in Trinidad and Tobago because this method has a similar effect on the sand formation wells as water flooding. The steam seeps through fractures in the rock which eventually leads to a loss of circulation. Consequently, this is not considered a sustainable method due to the high-water requirement, energy consumption, and risk of environmental pollution.

3. Gas Lift:³⁰

Natural gas is pressurized and pumped at high pressure through pipes from a compressor station to each well. This method is advantageous because it does not require conversion to electricity or significant infrastructure at each well. However, it does require an extensive network of pipes to operate this circulatory system. Moreover, this method has proven itself to be the most cost effective at recovering oil from sand formation reservoirs in Trinidad and Tobago because of the abundant supply of natural gas. Challenges may arise in fields that have a limited supply of natural gas which has led to the new technique of using 'Smart Gas' which involves injecting a gas mixture with an optimised fraction of carbon dioxide CO₂ and nitrogen gas N₂ into each well. The drawback to this technique is that additional costs are incurred during the purification process, however flue gas may be used to circumvent this.

4. Water Flood:³¹

This method involves the pumping of water under pressure into the well which will force a mixture of water and crude oil to the surface. Since oil is usually less dense than

²⁹ Olalekan Alade, 'Review on Applications of Ionic Liquids (ILs) for Bitumen Recovery: Mechanisms, Challenges, and Perspectives' (2023) 37 *Energy Fuels* 8718.

³⁰ Jalal Abu-Bakri, et al, 'Increasing Productivity by Using Smart Gas for Optimal Management of the Gas Lift Process in a Cluster of Wells' (2024) 14 *Scientific Reports* 15489.

³¹ Ion Bogdan Vasi, et al, "No Fracking Way!" Documentary Film, Discursive Opportunity, and Local Opposition against Hydraulic Fracturing in the United States, 2010 to 2013' (2015) 80 (5) *American Sociological Review* 934.

water the oil will float on the surface of the water where it can be skimmed off. This method is also referred to as Hydraulic Fracking and is responsible for the increased production of oil by the United States of America from their shale reservoirs. Although this method can temporarily increase productivity, it ultimately causes the most damage to the aquifers by damaging the shale reservoirs found in the USA. This method also had a deleterious effect on the sand reservoirs in Trinidad and Tobago where the water flows through the fractures in the rock and results in a loss of circulation. Consequently, this method has been phased out of use in Trinidad and Tobago. Additionally, this method poses a risk of water contamination due to the use of sand and other chemicals in the process.

Although technology designed to harness renewable energy has been steadily improving and becoming more easily accessible, there are still many uncertainties surrounding the future global energy needs. Therefore, it is of paramount importance that petroleum is produced as sustainably as possible to maintain its availability and viability as a source of energy, while also complying with ESG initiatives worldwide. There is a need for scientific research to be conducted and published by both state and private entities to guide the decision-making process, assess the effectiveness of various recovery methods, cost effectiveness and their environmental impact. The publication and archiving of this research will serve as a bank of information which should guide future generations by ensuring that they stay current with industry best practice. Such research would also guide the remedial measures employed to restore the environment and prevent pollution.³²

Thereafter, the regulatory bodies are required to set policies and legislation to ensure that the local petroleum industry adheres to the current industry best practices. Moreso, the regulatory bodies must enforce the industry best practices through penalties, suspension of contracts and even financial incentives by means of royalty reductions or other tax incentives. For example, the state of New York, USA imposed a moratorium on hydraulic fracturing due to the environmental concerns expressed by citizens while Pennsylvania introduced an environmental impact fee for hydraulic fracturing wells in 2012.³³

Re-forestation can be utilized wherever possible to combat climate change because plants and trees are the most efficient at carbon capture because of their ability to store carbon within their tissues via the process of photosynthesis and assist in reducing the global carbon dioxide levels and contribute to reducing global warming. Additionally,

³² Klara Zwickl, "The demographics of fracking: A Spatial Analysis for Four U.S. States" (2019) 161 *Ecological Economics* 202.

³³ *Ibid.*

the presence of trees enhances the ability of the soil to capture carbon because carbon is stored within tree roots and leaf litter will be decomposed and stored within the soil.³⁴

Since Oil and Gas is a non-renewable resource, it is crucial to employ only the most efficient recovery methods to prolong the productive life of mature and marginal fields. This will decrease the rate at which we need to utilize frontier provinces/ fields and thus preserve as much petroleum as possible for the use of future generations.³⁵

To enable sustainable production and ensuring environmental preservation it is still very important to maximize economic recovery to achieve the sustainable development goals and remain as a source of employment. Continuous research is required to facilitate this as technological advancements accommodate improved efficiency with recovery techniques. Furthermore, by practicing sustainable recovery techniques petroleum companies could avoid incurring penalties which would reduce their profit margins. Additionally, it would prolong the productive life of existing fields and in so doing reduce the frequency at which investments must be made to commence production in a frontier field.³⁶

Sustainable development of a marginal field entails the optimal recovery oil by enhanced recovery techniques that have a low carbon footprint, and with minimal damage to the reservoir and adjacent aquifers. In this regard, the use of electric drive pumping jacks and gas lift preferred over water flood and steam injection, due to their low water and energy consumption. The water flood process may often result in damage to the reservoir and poses a high risk of pollution due to the challenges faced in oil water separation. Similarly, steam injection is highly energy intensive and may sometimes lead to reservoir damage and break outs at the surface. Additionally, gas lift wells are ideal for the implementation of carbon capture from flue gasses in industrial operations for the secondary recovery of oil which in turn reduces the carbon footprint and greenhouse gas emissions from hydrocarbon production and refining operations.

³⁴ Carolyn Gramling, 'Why Planting Tons of Trees Isn't Enough to Solve Climate Change' (*Science News*, 9 July 2021) <<https://www.sciencenews.org/article/planting-trees-climate-change-carbon-capture-foreorestation>> accessed 2 August 2024.

³⁵ United Nations, 'The 17 Goals' (Department of Social and Economic Affairs, 2024) <<https://sdgs.un.org/goals>> accessed 24th July 2024.

³⁶ Olalekan Alade, 'Review on Applications of Ionic Liquids (ILs) for Bitumen Recovery: Mechanisms, Challenges, and Perspectives' (2023) 37 *Energy Fuels* 8718; Ion Bogdan Vasi, et al, 'No Fracking Way!' Documentary Film, Discursive Opportunity, and Local Opposition against Hydraulic Fracturing in the United States, 2010 to 2013' (2015) 80 (5) *American Sociological Review* 934.

4. CASE STUDIES

4.1 Nigeria

4.1.1 Introduction

The history of exploration, development, and production of oil and gas in Nigeria is longstanding, dating back to 1956.³⁷ According to Nigerian laws such as the Petroleum (Amendment) Act 1996 and the Petroleum Industry Act 2021, there are some specific legal definitions for mature province, mature field, and marginal accumulation. The country's regulation does not provide for marginal fields definition. Though a careful survey of individual contracts may provide contractual or legal meaning for each concept, and since such contracts are very often confidential within relevant parties' exclusive rights, it is difficult to make any specific reference. The following specific analysis of each term are, nevertheless, presented based on the present-day practices within the Nigerian oil and gas industry and legal regime.

Nigeria could be regarded as a region with advanced oil and gas production, given its years of involvement in the industry. The country has also an established robust and efficient oil extraction and production infrastructure and fiscal frameworks, which is a core element of a region classified as a mature province, despite the current lack of evidence on the legal status and definition of mature province.

The longstanding of Nigeria in oil and gas exploration and production typically makes for an instance of a mature field existence. Most oil fields in the country began production as early as the 1960s. For example, the Obagi onshore oil field located on OLM58, 85 km north-west of Port-Harcourt, was discovered in 1964 and began production in 1966.³⁸ This assumingly shows the field has attained the status of a mature field. The Oiloibiri oil field, which commonly marks Nigeria's first oil discovery and production experience, has already reached depletion due to maturity. Generally, research indicates that currently, roughly 22 oil fields in Nigeria have been abandoned due to depletion attainment.³⁹ These fields are no less mature fields. There is, however, a possibility for their enhancement via innovative technologies based on well and

³⁷ UNEP, Ogoniland's oil history <

³⁸ N Guillonau and others, 'Obagi- Present and Future Challenges of a Mature Oil Field' (SPE Nigeria Annual International Conference and Exhibition, 3-5 August, Abuja, Nigeria, 2009).

³⁹ AO Chukwuemeka, 'Oil well sidetracking in mature fields: Its potential for increasing recovery from Nigeria's mature fields' (2017) 59(1) *Petroleum & Coal*, 38-46.

reservoir engineering techniques.⁴⁰ Recent increase in concerns about decommissioning in Nigeria is a further indication of matured or maturing oil fields.

4.1.2 Marginal Field

The groundwork for the legal definition of marginal fields in Nigeria is traceable to Petroleum (Amendment) Decree No. 23 of 1996, which introduced paragraph 16A to the First Schedule of the Petroleum Act,⁴¹ forming paragraph 17 of the First Schedule of the Act.⁴² This means until 1996, marginal field development was not recognised in the Nigeria's upstream oil and gas policy and no non-discoverers or owners and third parties, whether small or big, had access to marginal or undeveloped fields.⁴³

The 1996 Act, already repealed, defined marginal fields as 'any field identified by the President as a marginal field'.⁴⁴ This definition has been criticised by many writers for being nebulous. The Nigerian petroleum industry has recently undergone legal and regulatory transformations, leading to a widely celebrated ambitious PIA which defines a marginal field as 'a field or discovery which has been declared a Marginal Field prior to 1st January 2021 or which has been lying fallow without activity for seven years after its discovery prior to the effective date'.⁴⁵ The Act further designates marginal fields as producing and non-producing marginal fields, which shall be converted to a petroleum mining lease (PML) and petroleum prospecting license (PPL) within 18 months and as of 1 January 2021 respectively, being the effective date of the Act. The federal government's 'Guidelines for Farm Out and Operations of Marginal Fields', developed in 2020 by the erstwhile Department of Petroleum Resources (DPR) under the Ministry of Petroleum Resources, defined marginal fields as 'any field that has (oil and gas) reserves booked and reported annually to the DPR and has remained unproduced for a period of over 10 years'.⁴⁶ The Guidelines further identified the characteristics of marginal fields as:

- a. Fields with at least one exploration well drilled and have been reported as a discovery for more than 10 years with no follow-up appraisal or development effort;
- b. Fields with high quantity of gas and low oil reserves;

⁴⁰ Tayfun Babadagli, 'Development of mature oil fields- A review' (2007) 57(3-4) Journal of Petroleum Science & Engineering, 221-246.

⁴¹ Petroleum Act 1969.

⁴² Ibid, para 17 of the First Schedule.

⁴³ Humphrey Oruwari and Adewale Donsunmu, 'Examining the Legal and Regulatory Framework on Marginal Oil Field Development in Nigeria' (SPE Nigeria Annual International Conference and Exhibition, Lagos, Nigeria, 6-8 August 2018).

⁴⁴ Petroleum (Amendment) Act 1996, para 16A.

⁴⁵ Petroleum Industry Act 2021, s 94(8) (a).

⁴⁶ DPR, Guidelines for Farm Out and Operations of Marginal Fields 2013, p. 8.

- c. Fields abandoned for over 3 years by the leaseholders for economic or operational reasons, among others;
- d. Fields that current leaseholders may deem necessary for farm out as part of portfolio rationalisation programmes; and
- e. Fields with crude oil characteristics that are different from current streams (such as crude with very high viscosity and low API viscosity) and cannot be produced via current technology or conventional methods.⁴⁷

4.1.3 Marginal Accumulation

A marginal accumulation is commonly attributed to relatively small and commercially less promising hydrocarbon deposits in larger geological basins. Factors such as limited reserves, size, and technical complexities remain key attributes of marginal accumulation, which often lead to a lack of interest in developing such accumulations. There is not sufficient information on marginal accumulation in Nigeria. Even as a regime of marginal fields exists in Nigeria, and with a marginal field's definition generally tending to have some implications for marginal accumulation, it remains a silenced concept in the country's legal and regulatory frameworks for oil and gas.

The lesson remains that mature provinces, mature fields, and marginal accumulations currently have no clear designation in Nigeria. This calls for specific labelling of each concept in the relevant legal and regulatory framework, considering its implication for decommissioning and for decommissioning abandoned fields and retired production infrastructures. Essentially, undertaking such a step has potential implications for investment in Nigeria's oil and gas sector.

4.2 Case Study on Angola

4.2.1 Introduction

The oil and gas industry constitutes a key economic activity in Angola, with first commercial oil discovery onshore Kwanza (Cuanza) Basin in 1955.⁴⁸ Evidence of current estimates shows that Angola has untapped 9 billion barrels of proven crude oil reserves and 11 trillion cubic feet (tcf) of proven natural gas reserves, with about 1.6 million barrels of oil produced daily, which shows a decline from 2 million barrels per day recorded during prosperous oil production in 2010, and now accounts for about 75 percent of the country's total revenues.⁴⁹ There is ongoing perception that despite the

⁴⁷ Ibid.

⁴⁸ OPEC, *Angola facts and figures* (57th edn, OPEC Annual Statistical Bulletin, 2022) 1-90.

⁴⁹ US Department of Commerce, International Trade Administration, 'Angola- Country Commercial Guide' <<https://www.trade.gov/country-commercial-guides/angola-oil-and-gas>>, accessed 22 October 2023.

present success and regulatory reforms, Angola has not fully tapped the potential of its hydrocarbons.⁵⁰ At some point in the past, oil and gas activities in uneconomically viable development areas were suspended. These areas lacking operation may represent an opportunity for investors and stakeholders to invest in oil recovery techniques for marginal fields, turning initially unviable fields in economic attractive assets once production is reconstructed. This section of the paper provides detailed insights into what constitutes a mature province, mature field, marginal accumulation, and marginal field operations in Angola.

Typically, a mature province signifies a region that has attained an advanced stage in the development and extraction of petroleum resources. Angola's discovery of Takula oil field in October 1971, which went into primary production in 1982, is a testament of attaining a mature province status over the years.⁵¹ There has been stern warning that oil fields in Angola are increasingly becoming mature and rapidly reaching depletion.⁵² One crucial aspect of a mature province is the establishment of a robust and efficient oil extraction and production infrastructure, along with an effective contractual and fiscal regime. The long history of Takula oil field discovery and extraction means that Angola would likely have a well-defined regulatory framework overseeing exploration, production, and environmental protection to ensure a sustainable resource management. There is, however, a lack of evidence on the legal status and definition of mature province in Angola.

There is a lack of legal status and definition of mature field in Angola. The Takula oil field, nonetheless, experimentally represents a mature field, with its peak production rates of MBOPD in April 1995, as opposed to 130 MBOPD rates when it went under primary production.⁵³ The application of improved oil recovery technology to the Mesa reservoir, one of seven stacked reservoirs of the field, with horizontal infill wells in 1992, is a testament of its maturity.

4.2.2 Marginal Accumulation:

There is relatively mixed information on hydrocarbon reservoirs with a small and less economically accumulated deposit in Angola. This reality is reflected in a good number of existing research conducted to examine the economic status of some hydrocarbon reservoirs within their blocks in offshore Angola, using log data from geological surveys and structures. But while some of this research shows the existence of potential

⁵⁰ US Department of Commerce (Ibid).

⁵¹ Gregory King and others, 'The Takula Field: A History of Angola's First Giant Oil Field' (18th World Petroleum Oil Congress, Johannesburg, South Africa, 2005).

⁵² Md Anwar Hossain Bhuiyan, Sajjadul Islam, and Mohammad Solaiman, 'Characterization of the Reservoir Hydrocarbon Zones in Offshore Angola Field Using Well Log Data' (2023) 11(2) The Dhaka University Journal of Earth and Environmental Sciences, 81-99.

⁵³ King and others (n 37).

hydrocarbon deposits already under production, some research with their analysis have less likely evidence of sustainable and economically viable reservoirs that would not require technological enhancement before production.⁵⁴ More so, it has been suggested that a number of assets with existing challenging economics, as a result of a combination of an ultra-deepwater environment and small size, are currently projected to become economic under the marginal field terms. This revelation suggests some current marginal accumulation in Angola. But in any case, it is pertinent for Angola to provide a clear legal and regulatory status and definition of marginal fields nature, which has not gone into production.

4.2.3 Marginal Field

The government of Angola published a decree in 2018 with new incentives for developing marginal fields.⁵⁵ This was followed by announcing potentially available fields to the public in 2019. Experts believe that this development, driven by new terms, has a significant impact on marginal field development and returns, hence, effectively unlocking up to 4,500 Mmboe of undeveloped oil and gas reserves, out of which 60 percent could possibly be developed in the short term due to near proximity of existing infrastructure. The basic determinants of marginal fields in Angola include discoveries were, at a minimum:

- a. Recoverable resources are under 300 MMbbls;
- b. After-tax IRR is below 15%;
- c. Water depth is above 800 meters;
- d. Income for the State is less than \$10.5/barrel; and
- e. Income for the Concessionaire's Associated Companies is less than \$21/barrel.

However, under exceptional situations, a declaration of marginal field discovery could exceed 300 MMbbls if the development is complex due to the geological structure of the fields and/or water depth, if the after-tax IRR is below 15%.

The current reality in Angola makes for an assumption to conclude that a mature province, mature field, and marginal accumulation currently have no legal and regulatory clarity, except for marginal field, and so have attracted no special interest or attention in designating their legal status. This even contradicts any argument in favour of Angola as a mature province in the exploration and production of oil and gas. Thus, reform of the Angolan petroleum legal regime, including contractual and fiscal

⁵⁴ Yanqing Huang and Lei Zheng, 'Hydrocarbon accumulation in deep water areas of Angola in West Africa' (2019) 4(3) *Petroleum Research*, 268-275, Bhuiyan and Solaiman (n 38).

⁵⁵ Presidential Decree No. 6/18 passed on May 18, 2018.

frameworks is required to clearly designate and define a mature province, mature field, and marginal accumulation.

4.3.1 Brazil

4.3.1. Introduction

This case study uses examples from Brazil's legal framework to define and explore key terms related to the oil and gas industry, including mature province, mature field, marginal accumulation, and marginal field. The study overviews Brazil's oil and gas industry and examines how these terms are defined and regulated in the country's legal context. Brazil is renowned for its vast oil and gas reserves, with current production predominantly occurring offshore in the pre-salt basins. The country has established a comprehensive legal framework to regulate the industry and ensure the sustainable development of its hydrocarbon resources. The main legislation governing oil and gas activities in Brazil is Law No. 9.478/1997, commonly known as the Petroleum Law.⁵⁶

In Brazil's oil and gas industry, a mature province refers to a geographical area with extensive commercial production for a significant period. It is characterised by the presence of multiple mature fields and substantial oil and gas reserves. The Campos Basin, located off the coast of Rio de Janeiro and Espírito Santo states, is a prime example of a mature province in Brazil.⁵⁷ It has been a major contributor to Brazil's oil production since the 1970s.⁵⁸

A mature field within a mature province represents a specific oil or gas field that has undergone significant development and has reached a stage of declining production.⁵⁹ The National Petroleum, Natural Gas and Biofuels Agency ("ANP") Resolution No. 877/2022 defines a mature field as an oil or natural gas field with a history of effective production greater than or equal to twenty five (25) years, or whose production corresponds to at least seventy percent (70%) of the volume to be produced, considering the proven reserves⁶⁰. These fields have typically experienced peak production levels and require advanced recovery techniques to extract any remaining reserves. The Marlim field in the Campos Basin is an example of a mature field in Brazil.

⁵⁶ Pedro Barbosa Mantovani Batista, *Economic Barriers to Onshore Exploration of Mature and Marginal Fields: The Case of the Potiguar Basin* (MSc thesis, University of São Paulo 2016).

⁵⁷ Eduardo Bordieri, Denis Dinelli and others, 'The Campos Basin Case: Unlocking Value from Mature Offshore Brazilian Assets' (Offshore Technology Conference, Houston, USA, 2022) OTC 31883.

⁵⁸ Ibid.

⁵⁹ Bnamericas, 'What Are Brazil's Plans for Mature O&G Fields?' (*Bnamericas*, Brazil, 20 August 2022).

⁶⁰ Article 2, item III of ANP Resolution No. 749/2018. In addition, the volume percentage of 70% can be obtained by applying the formula: Accumulated Production (boe) / Accumulated Production (boe) + 1P Reserves (boe)

It has contributed significantly to Brazil's oil production but has experienced declining output in recent years.⁶¹

4.3.2 Marginal Field

Marginal fields in Brazil's oil and gas industry are smaller-scale fields with limited reserves or lower economic potential for larger companies. According to the applicable legal framework, marginal fields exploration derives from contracts from a specific bidding process for inactive areas with marginal accumulations, an area with marginal accumulations from an open acreage or in which development and production activities show marginal economic viability or production, as further discussed in item 3.3.3 below.

ANP is currently working on policies to grant incentives to mature fields. ANP Resolution No. 749/2018 establishes that mature fields are eligible to receive royalties' reduction under its production. Mature fields with small production⁶² shall have royalties calculated at five percent (5%) on incremental production⁶³. For mature fields with large production⁶⁴, royalties shall be calculated by applying regressive rates corresponding to seven and a half per cent (7.5%) and five percent (5%), depending on the percentage of increment achieved⁶⁵.

These fields may require specialised extraction techniques and infrastructure due to their size and technical challenges. Marginal fields are often not considered viable as standalone projects. It should be noted that the National Energy Policy Council's (CNPE) Resolution No. 17/2017 established guidelines for increasing the production of mature fields in Brazil. Article 1 of such resolution established that it is a national policy for the oil and natural gas industry to maximize the recovery of *in situ* resources from reservoirs, quantifying the country's oil potential and potential and the

⁶¹ ANP (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis). "Boletim da Produção de Petróleo e Gás Natural." (2022).

⁶² The ANP Resolution 749/2018 defines a small production field as an oil or natural gas field whose production is always less than or equal to 5,000 boe/d (five thousand barrels of oil equivalent per day) in the case of fields with wellheads located in onshore environments, or whose production is always less than or equal to 20,000 boe/d (twenty thousand barrels of oil equivalent per day) in the case of fields with wellheads located in offshore environments, according to estimates from the latest revision of the Development Plan submitted to ANP.

⁶³ Article 9 of ANP Resolution No. 749/2018.

⁶⁴ Large production field is defined in ANP Resolution No. 749/2018 as an oil or natural gas field whose production exceeds 5,000 boe/d (five thousand barrels of oil equivalent per day) in the case of fields with wellheads located in onshore environments, or exceeds 20,000 boe/d (twenty thousand barrels of oil equivalent per day) in the case of fields with wellheads located in offshore environments, according to estimates from the latest revision of the Development Plan submitted to ANP.

⁶⁵ Article 10 of ANP Resolution No. 749/2018.

intensification of exploration activities in the country, as well as promoting the adequate monetisation of existing reserves, safeguarding national interests.

CNPE Resolution No. 17/2017 also provides that ANP shall select fields for bid proceedings encouraging (i) the exploration and production of oil and natural gas in onshore basins; (ii) the development of small and medium-sized oil discoveries; (iii) an increase in the participation of small and medium-sized companies in oil and natural gas exploration and production activities; (iv) the extension of the useful life of fields, while simultaneously promoting, the culture of preserving safety conditions and respect for the environment; (v) the proper decommissioning of facilities at the end of the useful life of fields, avoiding premature decommissioning⁶⁶.

Moreover, the National Energy Policy Council's (CNPE) Resolution No. 5/2022, which provides for measures to stimulate the development and production of hydrocarbon accumulations or in economically viable marginal fields⁶⁷, has been approved through Presidential Decree and published by the Ministry of Mines and Energy (MME) in August 2022.

Through CNPE Resolution No. 05/2022, CNPE authorized ANP to grant, based on pre-established criteria, a reduction in royalties to the legal minimum (5%) and implement strategies to reduce the regulatory burden with a view to modernizing, reducing bureaucracy, simplifying and speeding up regulation. Such measures are envisioned to incentivize exploration and production in marginal fields and accumulations

Since CNPE Resolution No. 17/2017, “[t]he CNPE has been implementing measures aimed at maximizing the recovery of reservoir resources in situ, quantifying the national oil potential and intensifying exploration activities in the country, as well as promoting the adequate monetization of existing reserves.”⁶⁸

It is seen that Brazilian legislation allows for the development of marginal fields through specific regulatory frameworks and incentives, such as the Special Regime for the Exploitation of Small and Marginal Fields (RESSM).⁶⁹ This regime incentivizes the

⁶⁶ Article 3, items V to IX of CNPE Resolution No. 17/2017.

⁶⁷ Bruno Chedid, Felipe Feres, Giovanni Loss and Nilton Mattos, ‘Brazilian Energy Policy Council authorizes royalty rate reduction for marginal fields’ Mattos Filho (Brazil, 19th August, 2022).

⁶⁸ Ibid.

⁶⁹ Brasil. Lei nº 9.478, de 6 de agosto de 1997. "Dispõe sobre a política energética nacional, as atividades relativas ao monopólio do petróleo, institui o Conselho Nacional de Política Energética e a Agência Nacional do Petróleo e dá outras providências." Diário Oficial da União, Brasília, 7 ago. 1997.

development of these fields by providing fiscal benefits and streamlined authorization processes.⁷⁰

4.3.3 Marginal Accumulation

A marginal accumulation refers to a hydrocarbon reservoir within a mature province containing a smaller volume of oil or gas than usual fields. These accumulations often require additional exploration and evaluation to determine their economic viability. ANP regulation classifies marginal accumulations as those whose development and operation are marginally economical according to the accumulations of the production phase under the following terms:

- I. Onshore fields with (a) total production of up to 900boe/day; (b) total production of up to 1,800boe/day for natural gas fields; (c) total production of up to 1,350boe/day and API grade of less than 22; or (d) BSW greater than ninety-eight per cent;
- II. Shallow water fields with (a) total production of up to 2,000boe/day; (b) total production of up to 4,000boe/day for natural gas fields; (c) total production of up to 3,000boe/day and API grade of less than 22; or (d) BSW greater than ninety per cent;
- III. Deepwater fields with (a) total production of up to 20,000boe/day; (b) total production of up to 40,000boe/day for natural gas fields; (c) total production of up to 30,000boe/day and API grade of less than 22; or (d) BSW greater than eighty per cent (80%);
- IV. Fields containing only marginal accumulations;
- V. Fields that have been returned or are in the process of return to the ANP and placed on open acreage cycle;
- VI. Accumulations belonging to onshore fields with 2C contingent resources of up to two million boe;
- VII. Accumulations belonging to shallow water fields with 2C contingent resources of up to ten million boe;
- VIII. Accumulations belonging to deepwater fields with 2C contingent resources of up to ninety million boe; or
- IX. Accumulations belonging to deepwater fields with CO₂ contents equal to or greater than sixty per cent in the gas phase under surface conditions⁷¹.

A field can only be classified under the criteria set out in items I, II or III after thirty-six (36) months following the beginning of production, disregarding the months in which there is no record of production and the months in which production comes

⁷⁰ Ibid.

⁷¹ Article 9, ANP Resolution No. 877/2022. " Provides for the classification of oil and natural gas fields and accumulations that show marginal economicity or production."

from long-term tests and early production systems⁷². The ANP shall automatically classify fields and accumulations as marginal once the characteristics provided in items I to V above have been fulfilled, and upon request for the fields which characteristics fall within items VI and IX above⁷³.

A field or accumulation previously classified as marginal may be de-classified if: (i) the original *in situ* volume of oil or natural gas is found to have increased by twenty-five per cent (25%) in relation to the time of classification or (ii) after five (5) years, the criteria used for the classification have been departed from and activities aimed at maximising the recovery of *in situ* resources in the reservoirs and extending the useful life of the field are no longer being carried out⁷⁴.

In 2022, the ANP published the results of the first analysis of the classification of oil and natural gas fields with marginal production based on ANP Resolution No. 877/2022. Of the total of 433 fields in Brazil, 302 are marginal. For onshore fields, 79% were classified as marginal and represented 15% of production in 2022. Such classification shall allow ANP to move forward in discussing other matters predicted for its regulatory agenda, such as additional incentives for production in these fields⁷⁵.

Development incentives and regulatory mechanisms, such as the RESSM, are available to stimulate Brazil's exploration and production of marginal accumulations. Brazil's legal framework for the oil and gas industry aims to promote the exploration, production, and development of hydrocarbon resources across the country. The Petroleum Law and subsequent ANP and CNPE regulations address the exploration and production activities in both mature provinces and potential marginal accumulations and fields. For instance, in mature provinces like the Campos Basin, the legal framework provides a comprehensive set of regulatory guidelines that governs licensing, exploration, production, and environmental protection measures.⁷⁶ This ensures that mature fields within these provinces are developed and operated in a safe and sustainable manner. Moreover, the divestment plan of the state-owned company Petrobras, active between 2017 and 2022, foresaw the disposal of assets that yielded lower returns, and initially included a total of 183 oil fields, 92% of which were mature

⁷² §3º, article 7, of ANP Resolution No. 877/2022.

⁷³ Article 3, ANP Resolution No. 877/2022.

⁷⁴ Article 11 of ANP Resolution No. 877/2022.

⁷⁵ Data available in ANP website: https://www.gov.br/anp/pt-br/canais_atendimento/imprensa/noticias-comunicados/anp-conclui-primeira-analise-de-enquadramento-de-campos-marginais#:~:text=Para%20os%20campos%20terrestres%2C%2079,incentivos%20C3%A0%20produ%C3%A7%C3%A3o%20nesses%20campos.

⁷⁶ Brasil. Lei nº 9.478, de 6 de agosto de 1997. "Dispõe sobre a política energética nacional, as atividades relativas ao monopólio do petróleo, institui o Conselho Nacional de Política Energética e a Agência Nacional do Petróleo e dá outras providências." Diário Oficial da União, Brasília, 7 ago. 1997.

fields⁷⁷. Of the 46 offshore fields offered, 44 fell into this category. Likewise, of the 137 onshore fields, 125 were mature fields.

In recent years, Brazil has also implemented specific regulations and incentives to encourage the exploration and development of marginal accumulations and fields.⁷⁸ These initiatives aim to stimulate investments and technological advancements in previously considered less economically attractive areas.

In this context, it is possible to establish a connection between the incentives provided by the ANP and the divestment plan of the Brazilian state-owned company, which facilitated the entry of new players into the mature fields market, and also of several companies already established in the national market (and focused on revitalizing mature assets) that took advantage of the opportunity to consolidate their presence⁷⁹.

Finally, it is also important to highlight that the exploration of mature oil fields plays a significant role in fostering regional development, particularly in Brazil's onshore areas, such as the Northeast, where a large portion of these assets are located. Revitalizing mature fields brings investment, creates jobs, and stimulates local economies, especially in rural and semi-arid regions that face limited economic opportunities. Companies focusing on the recovery of these assets not only extend the productive life of oil fields but also contribute to infrastructure development, boost service sectors, and generate local revenue through royalties and taxes. In the Northeast, where onshore fields are

⁷⁷ PETROBRAS, 'Plano de Desinvestimento' <http://www.petrobras.com.br> accessed 10 October 2024.

⁷⁸ Batista, Pedro Barbosa Mantovani. Economic barriers to onshore exploration of mature and marginal fields: the case of the Potiguar basin. / Pedro Barbosa Mantovani Batista; Supervisor: Hirdan Katarina de Medeiros Costa; Supervisor: Emilson Silva— São Paulo, 2016.

⁷⁹ For example, PetroRio acquired Petrobras' 30% stake in the Frade concession, located in the Campos Basin, and became the sole holder of the field's contract. The Malaysian state company Petronas had been exploring entry opportunities in the Brazilian market for years. In 2013, it signed an agreement to acquire 40% of the Tubarão Martelo field from OGX but withdrew when OGX went into bankruptcy. In 2019, Petronas purchased 50% of the Espadarte field and the BM-C-36 block (Tartaruga Verde) for \$1.29 billion, marking its entry into the Brazilian market, with an expected production of 56,000 boe/d. Independent oil company Trident Energy, focused on revitalizing mature fields, purchased the Pampo and Enchova clusters in the Campos Basin for \$851 million, which includes ten producing fields. Supported by \$600 million from private equity firm Warburg Pincus, Trident expects to increase production from 25,000 boe/d with a \$1 billion revitalization plan. French-British company Perenco acquired the Pargo, Carapeba, and Vermelho clusters in shallow waters off Rio de Janeiro for \$398 million. Australian company Karoon, which already holds non-producing fields Neon and Goiás in the Santos Basin, purchased the Baúna field in the post-salt region of the same basin to generate cash flow while developing its own projects. Brazilian company 3R Petroleum (currently named Brava Energia), focused on onshore field recovery, acquired the Macau cluster, which includes seven fields in Rio Grande do Norte, for \$191.1 million. Ramalho A, 'Desinvestimentos da Petrobras Atraem Novos Produtores de Óleo e Gás para o Brasil' Valor (27 December 2019) <https://valor.globo.com/empresas/noticia/2019/12/27/desinvestimentos-da-petrobras-atraem-novos-produtores-de-oleo-e-gas-para-o-brasil.ghtml> accessed 27 March 2021.

prominent, this revitalization provides essential economic diversification, supporting regional development and social progress.

5. LESSONS LEARNED

The analysis of mature petroleum provinces in Nigeria, Angola, and Brazil provides valuable insights into the complex dynamics of the oil and gas industry. One key lesson learned is the pivotal role of regulatory clarity in guiding the sustainable development of mature provinces, mature fields, marginal fields and marginal accumulation. In Nigeria, the absence of specific legal definitions for mature provinces and fields introduces ambiguity, hindering effective resource management. Like the other case studies, Nigeria legislation or guidelines do not expressly state a definition for mature province, mature field or marginal fields or accumulations. The recent enactment of the PIA represents a positive step toward addressing this issue, providing clearer definitions for terms such as marginal fields.⁸⁰ However, the broader challenge of achieving legal clarity for mature provinces remains, emphasising the need for ongoing regulatory reforms. The PIA provides comprehensive definitions and guidelines for managing these areas, offering fiscal incentives such as reduced tax rates and royalties (Sections 87 and 89) and investment allowances for enhanced recovery techniques (Section 94).⁸¹ This regulatory framework not only promotes economic viability but also mandates stringent environmental standards (Section 102) and facilitates access to green financing options (Section 105).⁸² This approach ensures that the economic benefits of oil and gas activities are realized while adhering to environmental responsibilities, contributing to SDGs 7,⁸³ 8⁸⁴ and 13.⁸⁵ The PIA's emphasis on local content development (Sections 109 to 114) further supports SDG 8 by creating jobs and promoting inclusive economic growth.⁸⁶

Angola's experience further underscores the importance of a well-defined legal framework. While the country boasts a rich history of oil and gas production, the lack of legal clarity regarding mature provinces and fields poses challenges for effective

⁸⁰ Petroleum (Amendment) Act 1996, para 16A.

⁸¹ Petroleum Industry Act 2021 (Nigeria).

⁸² Ibid.

⁸³ United Nations, 'Ensure access to affordable, reliable, sustainable and modern energy for all' (Department of Economic and Social Affairs Sustainable Development, 2024) <<https://sdgs.un.org/goals/goal7>> accessed 24th July 2024.

⁸⁴ United Nations, 'Decent Work and Economic Growth' (Department of Economic and Social Affairs Sustainable Development, 2024) <https://sdgs.un.org/goals/goal8> accessed 25th July 2024.

⁸⁵ United Nations, 'Take urgent action to combat climate change and its impacts' (Department of Economic and Social Affairs Sustainable Development, 2024) <https://sdgs.un.org/goals/goal13> accessed 24th July 2024.

⁸⁶ Petroleum Industry Act 2021 (Nigeria).

regulation.⁸⁷ The incentives introduced in 2018 to develop marginal fields indicate a proactive approach, but the absence of a comprehensive legal definition for mature provinces hinders the formulation of a holistic strategy for resource management.⁸⁸ The lesson learned here is that legal frameworks must evolve to keep pace with industry dynamics, providing clear guidelines for oil and gas fields exploration, production, and decommissioning. Nevertheless, the 2018 decree (Decree No. 6/18) provides significant incentives for developing marginal fields, including tax breaks and reduced royalties (Article 4) and investment credits (Article 5).⁸⁹ These financial incentives encourage investors to deploy enhanced recovery techniques, maximizing resource extraction and economic viability. Additionally, Angola mandates thorough Environmental Impact Assessments (EIAs) for all oil and gas projects (Article 10), ensuring that environmental impacts are identified and mitigated effectively, thus supporting SDG 13.⁹⁰ Angola also promotes technology transfer (Article 12) and community development projects (Article 14), fostering sustainable economic growth and social well-being, addressing SDGs 8⁹¹, 12⁹², 13⁹³ and 17⁹⁴.

In Brazil, the Campos Basin is a prime example of a mature province with extensive commercial production.⁹⁵ The lessons learned from Brazil highlight the success of a well-regulated environment, exemplified by the Petroleum Law.⁹⁶ The clear criteria for marginal fields and accumulations and specific regulatory frameworks like the RESSM demonstrate Brazil's commitment to fostering a conducive environment for sustainable

⁸⁷ US Department of Commerce, International Trade Administration, 'Angola- Country Commercial Guide' <<https://www.trade.gov/country-commercial-guides/angola-oil-and-gas>>, accessed 22 October 2023.

⁸⁸ Presidential Decree No. 6/18 passed on May 18, 2018.

⁸⁹ Presidential Decree No. 6/18 passed on May 18, 2018. (Angola).

⁹⁰ United Nations, 'Take urgent action to combat climate change and its impacts' (Department of Economic and Social Affairs Sustainable Development, 2024) <https://sdgs.un.org/goals/goal13> accessed 24th July 2024.

⁹¹ United Nations, 'Decent Work and Economic Growth' (Department of Economic and Social Affairs Sustainable Development, 2024) <https://sdgs.un.org/goals/goal8> accessed 25th July 2024.

⁹² United Nations, 'Ensure sustainable consumption and production patterns' (Department of Economic and Social Affairs Sustainable Development, 2024) <https://sdgs.un.org/goals/goal12> accessed 24th July 2024.

⁹³ United Nations, 'Take urgent action to combat climate change and its impacts' (Department of Economic and Social Affairs Sustainable Development, 2024) <https://sdgs.un.org/goals/goal13> accessed 24th July 2024.

⁹⁴ United Nations, 'Partnerships for the Goals' (Department of Economic and Social Affairs Sustainable Development, 2021) < <https://sdgs.un.org/goals/goal17>> accessed 24th July 2024.

⁹⁵ ANP (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis), *Boletim da Produção de Petróleo e Gás Natural* (2022).

⁹⁶ Bruno Chedid, Felipe Feres, Giovani Loss and Nilton Mattos, 'Brazilian Energy Policy Council authorizes royalty rate reduction for marginal fields' (*Mattos Filho*, Brazil, 19 August 2022).

development.⁹⁷ The critical analysis here emphasises the importance of proactive legislation in facilitating the exploration of both mature and marginal resources, ensuring a balanced and efficient utilisation of hydrocarbon reserves. The law offers reduced royalty rates for marginal fields (Article 47) and tax deductions for development expenditures (Article 49), promoting investment in these areas.⁹⁸ Environmental protection measures are mandated (Article 54), with incentives for renewable energy projects (Article 55), aligning with SDG 13.⁹⁹ Brazil also supports technological innovation through funding and tax incentives (Article 60) and provides financial support for infrastructure projects that promote sustainable development (Article 62).¹⁰⁰ ANP Resolution No. 749/2018 further incentivizes advanced recovery techniques by offering reduced royalties for mature fields (Articles 7 and 9), ensuring continued economic viability and sustainable resource use.¹⁰¹

Technological innovation is a recurring theme in the lessons learned from all three countries. The application of advanced technologies, such as artificial intelligence and machine learning, is a key strategy to optimise production from mature fields.¹⁰² Nigeria's exploration of numerical hydraulic data as an alternative to subsurface modelling showcases a forward-looking approach to reservoir management.¹⁰³ Challenges in mature fields, such as excessive water production and declining structural integrity, necessitate innovative solutions that leverage cutting-edge technologies. The critical analysis here underscores the imperative for continuous technological advancements to enhance production efficiency while mitigating environmental impact.

Sustainability considerations, including climate change and energy transition, are crucial in the lessons learned. The analysis of mature fields in Nigeria highlights the environmental challenges associated with high water cuts and increased emissions. The need to balance economic benefits with environmental responsibility is evident, particularly as the industry faces global pressure to transition toward cleaner energy sources. The lesson learned is that oil and gas companies must integrate sustainable

⁹⁷ Brasil, *Lei nº 9.478, de 6 de agosto de 1997, Dispõe sobre a política energética nacional, as atividades relativas ao monopólio do petróleo, institui o Conselho Nacional de Política Energética e a Agência Nacional do Petróleo e dá outras providências*, *Diário Oficial da União*, Brasília, 7 August 1997.

⁹⁸ Brazil, *Petroleum Law (Law No 9.478/1997)*.

⁹⁹ United Nations, 'Take urgent action to combat climate change and its impacts' (*Department of Economic and Social Affairs Sustainable Development*, 2024) <https://sdgs.un.org/goals/goal13> accessed 24th July 2024.

¹⁰⁰ Ibid.

¹⁰¹ United Nations, 'Partnerships for the Goals' (*Department of Economic and Social Affairs Sustainable Development*, 2021) < <https://sdgs.un.org/goals/goal17> > accessed 24th July 2024.

¹⁰² R.V Marathe, 'Mature Fields and Well Revitalization' (2022) *Journal of Petroleum Technology*.

¹⁰³ Pinilla A, et al, 'CFD Study of the Water Production in Mature Heavy Oil Fields with Horizontal Wells' (2021) 16(10) *PLOS ONE*: e0258870 < <https://doi.org/10.1371/journal.pone.0258870> > Accessed 26/12/2023.

practices into their operations, acknowledging the imperative to reduce carbon footprints and contribute to global efforts to combat climate change.

Global cooperation emerges as a key recommendation stemming from the lessons learned. The petroleum provinces under scrutiny often transcend national borders, requiring collaborative efforts between countries, industry stakeholders, and international bodies. Standardised definitions, information sharing, and best practices can contribute to a more comprehensive and sustainable approach to resource management. The critical analysis emphasises the significance of fostering international partnerships to address common challenges, share technological advancements, and collectively navigate the evolving landscape of mature and marginal petroleum provinces.

6. CONCLUSION

In conclusion, the analysis of mature provinces, mature fields, marginal fields, and marginal accumulations in Nigeria, Angola, and Brazil highlights the complexity and diversity within the oil and gas industry. It also demonstrates how effective management of mature provinces is critical not only for maximizing economic recovery but also for advancing sustainable development in alignment with the Sustainable Development Goals (SDGs). By offering targeted fiscal incentives, enforcing environmental regulations, promoting technological innovation, and fostering local content development, these countries ensure that their oil and gas sectors contribute positively to SDGs such as SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). In mature provinces, maximizing economic recovery is achieved through strategies like enhanced oil recovery techniques, better reservoir management, and the optimization of existing infrastructure, all while adapting operations to be more sustainable and socially responsible.

However, the lack of standardized definitions, ongoing regulatory transformations, and decommissioning challenges underscore the need for continuous adaptation and improvement in the legal frameworks governing hydrocarbon exploration and production. While each region faces unique challenges and opportunities, the overarching recommendation is the establishment of clear, consistent, and updated regulatory frameworks that balance economic objectives with sustainability. These frameworks should be designed to reflect the evolving nature of the industry, promote best practices for maximizing resource recovery, and provide guidance on the development, decommissioning, and restoration of oil and gas fields. By embracing emerging technologies, incentivizing marginal field development, and prioritizing environmental considerations, the oil and gas industry can continue to contribute to both economic growth and the achievement of the SDGs.

Through collaborative efforts among governments, industry stakeholders, and local communities, these hydrocarbon provinces can effectively navigate the complexities of resource management and sustainable development. Such efforts ensure that even as these fields mature and production declines, the industry remains resilient and economically viable while also fulfilling global commitments to sustainability. In this way, mature petroleum provinces are positioned not only as key drivers of economic recovery but also as vital contributors to a more sustainable and responsible future for the global energy sector.