



SUSTAINABLE OIL AND GAS ISSUES: DECOMMISSIONING, CCUS, AND CIRCULAR ECONOMY

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It is without dispute that the oil and gas industry generally contribute to the national growth and economic development of oil-rich countries across the globe. It is also trite that the positive contribution of the industry comes at a cost to the environment and the society. Meanwhile, the contemporary sustainable development agenda emphasizes a balance between the triple bottom-line consisting of the environment, society and economy, in a manner that economic benefits do not come at environmental and social costs. Hence, this paper explores some significant issues relevant for sustainable oil and gas development globally to wit: decommissioning; carbon capture, utilization and storage (CCUS); and circular economy. The paper finds that decommissioning constitutes an integral aspect of environmental remediation and restoration required for proper and adequate environmental management in the oil and gas industry. Second, the paper finds that the implementation of CCUS can help tackle carbon emissions from existing oil and gas facilities while allowing for continued oil and gas production. The paper further finds that circular economy practices, such as reusing and recycling production infrastructure and materials, can significantly reduce waste and adverse environmental impacts from oil and gas production. This approach not only extends the lifecycle of existing assets but also creates new economic opportunities, such as the repurposing of offshore platforms into artificial reefs to enhance marine biodiversity. Premised on these various findings, the paper concludes that decommissioning, CCUS, and circular economy present some of the most pressing sustainability issues for the oil and gas industry globally.

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1. INTRODUCTION

As a result of the global sustainable development agenda, sustainable oil and gas development has increasingly grown in significance globally. The reason for this is not far-fetched; it is trite that activities within the oil and gas industry pose various adverse effects on all aspects of sustainable development, including environmental pollution and degradation, climate change, public health hazards, and displacement of Indigenous communities, among others.¹ Notwithstanding the various adverse impacts of the oil and gas industry, the industry nevertheless contributes to the realization of some aspects of the sustainable development agenda particularly, the realization of national energy requirements, as well as improvement of the national GDP of oil-rich countries with a resultant positive effect on the economic growth and development of such countries.²

In other words, even though the oil and gas industry contribute to national growth and economic development, the latter comes at a cost to the environment and society. Meanwhile, the sustainable development agenda emphasizes an integrated management system whereby environmental, social and economic issues are strategically integrated in business decision-making processes.³ This connotes a balance between the triple bottom-line; environment, society and economy; in a manner that economic benefits do not come at social and environmental costs.⁴ Hence, sustainable oil and gas development will primarily entail the integration of environmental, social, and economic concerns into all aspects of oil and gas operations, as well as throughout the life-cycle of oil and gas development. This emphasizes the need for the deployment of sustainability practices and strategies in all phases of oil and gas operations, from the commissioning to the decommissioning of an oilfield. Therefore, issues such as

¹ Chijioke-Churuba J., 'Energy Sustainability: Bridging the Gap Between Oil and Gas Operations and Community Well-being in the Niger Delta Region, Nigeria' (2023) 27(11) *Journal of Applied Science and Environmental Management* 2503-2507; Opeyemi Yetunde Omotuyi & Ada Ordor, 'An Evaluation of the Regulatory Framework for Environmental Management in the Nigerian Petroleum Industry' (2019) 6(2) *Journal of Comparative Law in Africa*, 32-55; Jacqueline B. Mariano & Emilio L. La Rovere, 'Environmental Impacts of the Oil Industry' UNESCO Encyclopedia of Life Support Systems (EOLSS), available at <https://www.eolss.net/sample-chapters/c08/e6-185-18.pdf> [accessed 27 April 2024].

² Mohamad D. Anis & Tauseef Z. Siddiqui, 'Issues Impacting Sustainability in the Oil and Gas Industry' (2015) 5(4) *Journal of Management and Sustainability* 115; Ali S. Mojarad, Vahid Atashbari & Adrian Tantau, 'Challenges for Sustainable Development Strategies in Oil and Gas Industries' (2018) *Proceedings of the International Conference on Business Excellence* 626-638.

³ David W. Pearce, Edward Barbier & Anil Markandya. *Sustainable Development: Economics and Environment in the Third World* (Earthscan Publications 1990) 4; Susan Baker, *Sustainable Development* (Routledge 2006) 5.

⁴ Stephan Schmidheiny, *Changing Course: A Global Business Perspective on Development and the Environment* (MIT Press, 1992); Ian Moffatt, *Sustainable Development: Principles, Analysis and Policies* (Parthenon Publishing Group 1996); Bob Giddings, Bill Hopwood & Geoff O'Brien, 'Environment, Economy and Society: Fitting them together into Sustainable Development' (2002) 10(4) *Sustainable Development* 187.

sustainable decommissioning, development and deployment of carbon capture, utilization and storage techniques, and implementation of a circular economy system in the oil and gas industry may be of significant value to enhancing sustainable oil and gas development.

Hence, this paper examines these critical aspects of sustainable oil and gas development: decommissioning, CCUS, and circular economy principles. Subsequent sections of the paper are structured as follow:

Section two, which focuses on decommissioning, explores the final phase of oil and gas projects, discussing its importance, challenges, and relationship to sustainable development principles. It examines various decommissioning options and their potential environmental and economic impacts. This section also highlights the need for proper planning and management to mitigate risks associated with decommissioning activities.

Section three borders on CCUS; the section analyzes the importance of the development and deployment of CCUS technologies as a means of reducing emissions from oil and gas operations. It discusses the potential of CCUS in balancing energy security with environmental sustainability, while also examining the challenges and opportunities in its implementation. This section explores how CCUS can contribute to achieving climate goals while allowing for continued oil and gas production.

Section four, which focuses on circular economy, examines the application of circularity principles to the oil and gas industry. It focuses on strategies for waste reduction, resource optimization, and the extension of product lifecycles. This section discusses how circular economy practices can minimize environmental impacts while potentially creating new economic opportunities within the sector.

2. DECOMMISSIONING

Decommissioning refers to the final phase of an oil and gas exploration and production project whereby, decisions are made and procedures undertaken to manage or dispose of installations and other facilities used in the course of oil and gas exploration and production.⁵ There are various decommissioning options available for oil and gas facilities, including complete or partial removal, leaving in place, leaving in place and

⁵ The Commonwealth, “Oil and Gas Decommissioning Toolkit: Practical Guidance for Governments”, available at <https://thecommonwealth.org/oil-and-gas-decommissioning-toolkit#:~:text=At%20the%20end%20of%20a,safer%20and%20environmentally%20acceptable%20condition> [accessed 27 April 2024]. See also Asset Integrity Engineering, ‘Unveiling the Challenges of Decommissioning in the Oil and Gas Industry’, available at <https://www.assetintegrityengineering.com/unveiling-the-challenges-of-decommissioning-in-the-oil-and-gas-industry/> [accessed 27 April 2024].

repurposing, and recycling part or all of an oil and gas infrastructure.⁶ Notwithstanding the various options, decommissioning activities are generally undertaken to ensure that an oilfield is left in a safe and environmentally acceptable condition after production has ceased.⁷

For various reasons, decommissioning constitutes a pressing and contemporary sustainability issue for the oil and gas sector globally. First, the oil and gas sector is generally notorious for the adverse environmental and social impacts its activities pose to the world including rapid climate change, other forms of environmental pollution and degradation, public health and safety issues, among several others. This has given rise to an increasing energy transition agenda whereby governments are expected to encourage fuel-switching within their jurisdictions, by promoting a switch from fossil fuel production and consumption to renewable energy systems. Such energy transition is posited as capable of playing a significant role in achieving and realizing the global sustainable development agenda, particularly the climate goals and environmental sustainability generally.⁸ This will by implication, necessitate a wave of decommissioning activities in the oil and gas industries around the world as countries begin to move towards realizing the energy transition agenda within their jurisdictions.⁹ However, despite the various decommissioning options available, where not properly planned and managed, decommissioning could pose significant sustainability risks to the oil and gas sector.

Second, the sustainable development agenda recognizes environmental remediation and restoration as an integral aspect of sustainable development.¹⁰ Environmental remediation refers to removing, treating and containing environmental pollutants or any other hazardous substances from the environment to restore the environment to a

⁶ The Australian Energy Producers, 'Offshore Oil and Gas Decommissioning Decision-making Guidelines' July 2016, available at <https://www.appea.com.au/wp-content/uploads/2016/12/APPEA-Decommissioning-Guidelines.pdf> [accessed 27 April 2024]. See also Pattaramon Vuttipittayamongkol, Aaron Tung, and Eyad Elyan, 'Towards Machine Learning-Driven Practices for Oil and Gas Decommissioning- Introduction of a New Offshore Pipeline Dataset' (2021) 9th International Conference on Computer and Communications Management, Singapore 16-18 July 2021.

⁷ The Commonwealth, 'Oil and Gas Decommissioning Toolkit: Practical Guidance for Governments', op cit.

⁸ United Nations, 'Theme Report on Energy Transition: Towards the Achievement of SDG 7 and Net-Zero Emissions' United Nations High-Level Dialogue on Energy 2021, available at <https://www.greengrowthknowledge.org/research/theme-report-energy-transition-towards-achievement-sdg-7-and-net-zero-emissions> [accessed 27 April 2024]. See also A Ilyas *et al.* 'Natural Resource Management for Sustainable Development in Managing Environmental Permit' (2019) *Earth and Environmental Science* 343; Manjeet K Kaushal, 'Resource Management and Sustainable Development' (2010) 1(1) *International Research Journal of Management Sociology & Humanity* 122.

⁹ Omotuyi Y. Opeyemi, 'A Critical Assessment of the Regulatory Framework for Oil and Gas Decommissioning in Nigeria' (2023) 14(1) *Journal of Sustainable Development Law and Policy* (The) 140-163.

¹⁰ See for instance, sustainable development goals 6, 14 & 15.

good condition.¹¹ In other words, environmental remediation describes the correction of environmental damage by removing the damaging substances or materials introduced to the environment. Similarly, environmental restoration entails the process of revitalizing and rehabilitating degraded, damaged, or altered environments to return the environment to its original or natural state as much as possible.¹² From these definitions, it is clear that decommissioning entails the remediation and restoration of licenced oil and gas areas by the management or removal of all installations and other facilities that are no longer in use.¹³ Therefore, decommissioning constitutes an integral aspect of sustainable oil and gas development.¹⁴

Moreover, sustainable development encompasses the principle of intra and intergenerational equity, which connotes a fair access to the use and benefits of the environment by persons of all generations.¹⁵ This emphasizes the need for environmental protection and conservation so that all persons across all generations may have equitable access to the use and benefits of the environment. Since decommissioning entails the removal of oil and gas facilities at the maturity of an oilfield, this ensures that such facilities are not left in place to degrade the environment and prevent equitable access to its use and benefits by persons of all generations.¹⁶ Aside from intra and intergenerational equity, decommissioning may be further premised on other sustainable development principles including the polluter-pays principle, as well as the prevention and precautionary principle.¹⁷ The polluter-pays principle connotes that polluters¹⁸ should be responsible for bearing the costs of their pollution rather than imposing such costs on local communities or the environment.¹⁹ While the prevention

¹¹ Christopher P. Evans, 'The Contours and Limits of Environmental remediation Under the Treaty on the Prohibition of Nuclear Weapons' (2022) 69 *Netherlands International Law Review* 115-152.

¹² Emily Greenfield, 'Principles of Environmental Restoration' *SIGMA Earth* (18 January 2024) <https://sigmaearth.com/principles-of-environmental-restoration/> accessed 29 April 2024.

¹³ Ngozi Chinwa Ole, 'The Financial Securities for Decommissioning of Offshore Installations in Nigeria: A Review of The Legal and Contractual Regime' (2017) 15 (1) *OGE L* 1.

¹⁴ J. Komugisa and N. Chinwa Ole, 'Ugandan Legal Framework on Decommissioning Fund: Is There an Achilles Heel, and Can Lessons from the UK Help?' (2019) 16(2) *OGE L* 1.

¹⁵ Max Valverde Soto, 'General Principles of International Environmental Law' (1996) 3 *ILSA Journal of International & Comparative Law* 193; Dire Tladi, 'Intragenerational Equity: A New Name for International Environmental Justice' (2003) 9 *Fundamina* 199.

¹⁶ Opeyemi Y. Omotuyi, 'A Critical Assessment of the Regulatory Framework for Oil and Gas Decommissioning in Nigeria' *op cit*.

¹⁷ Ngozi Chinwa Ole and Hemen Faga Philip, 'Assessing the Impact of the Brent Spar Incident on the Decommissioning Regime in the North East Atlantic' (2017) 3(2) *Hasanuddin Law Review* 141.

¹⁸ That is, persons who introduce polluting, contaminating, damaging, or altering materials and substances to the environment.

¹⁹ Report of the United Nations Conference on Environment and Development 'Rio Declaration on Environment and Development' (1992) principle 16.

principle connotes that environmental pollution should be prevented where possible, the precautionary principle connotes that lack of full scientific certainty should not be a reason to postpone cost-effective measures to prevent environmental pollution especially where there are threats of serious or irreversible environmental damage.²⁰

Leaving oil and gas facilities and installations unaddressed upon the maturity of an oilfield has been noted to pose enormous adverse environmental effects. For instance, such installations and facilities could constitute a major source of invasive species capable of endangering the natural environment.²¹ Oil and gas infrastructures left indiscriminately also contribute to the surge in the numbers of jellyfish and harmful algal blooms.²² Because of the susceptibility of oil and gas infrastructures to contaminations from the presence of hazardous materials such as trace metals and naturally occurring radioactive materials while in use, leaving such infrastructures indiscriminately poses adverse impact on the marine ecosystem including, reduced fishery productivity, creation of contaminated waters and marine sediments, *etc.*²³ In other words, contaminations from oil and gas infrastructures may alter the health and reduce the productivity of marine organisms, alter the composition of the species at oil and gas sites, or even alter the safety of the environment for the exploitation of various plants and seafoods for human consumption.²⁴

Hence, premised on the polluter-pays principle, decommissioning ensures that contractors who have undertaken and benefitted from oil and gas operations bear the responsibility for the costs of restoring the environment by removing all installed infrastructures and facilities capable of degrading the environment. Likewise, premised on the prevention and precautionary principles, decommissioning ensures that oil and gas facilities are not left unattended at the end of an oilfield's lifespan, but are rather addressed in a manner that prevents or minimizes environmental risks from such

²⁰ Ibid, principle 15.

²¹ Braga M.D.A. *et al.*, 'Retirement Risks: Invasive Coral on Old Oil Platform on the Brazilian Equatorial Continental Shelf' (2021) 165 Marine Pollution Bulletin 112156.

²² Carlos M. Duarte *et al.*, 'Is Global Ocean Sprawl a Cause of Jellyfish Blooms?' (2013) 11(2) Frontiers in Ecology and the Environment 91; Martin Vodopivec, Alvaro J. Peliz and Alenka Malej, 'Offshore Marine Constructions as Propagators of Moon Jellyfish Dispersal' (2017) 12(8) Environmental Research Letters 084003; Anja Schulze *et al.*, 'Artificial Reefs in the Northern Gulf of Mexico: Community Ecology Amid the "Ocean Sprawl"' (2020) 7 Frontiers in Marine Science 447.

²³ Johannessen D. *et al.*, 'Marine Environmental Quality in the Pacific North Coast Integrated Management Area (Pncima), British Columbia, Canada: A Summary of Contaminant Sources, Types, and Risks' (2007) Canadian Technical Report of Fisheries and Aquatic Sciences no. 2716; Almeda R. *et al.*, 'Dispersant Corexit 9500a and Chemically Dispersed Crude Oil Decreases the Growth Rates of Meroplanktonic Barnacle Nauplii (*Amphibalanus improvisus*) and Tornaria Larvae (*Schizocardium* sp.)' (2014) 99 Marine Environmental Research 212.

²⁴ Codi S. King *et al.*, 'Field Evaluation of a Suite of Biomarkers in an Australian Tropical Reef Species, Stripey Seaperch (*Lutjanus carponotatus*): Assessment of Produced Water from the Harriet A Platform' in Lee K. and Neff J. (eds), *Produced Water* (New York: Springer, 2011) 261.

facilities. Therefore, decommissioning constitutes an integral aspect of sustainable oil and gas development.

However, even though decommissioning has been shown as capable of positively impacting sustainable development in the oil and gas sector, it is noteworthy that it could also pose a negative impact on sustainable development if not properly planned and managed. For instance, decommissioning processes could pose various technical and environmental hazards, such as the release of toxic and/or explosive materials, as well as hazardous microbiological substances.²⁵ Decommissioning activities could also adversely affect marine ecosystems as a result of physical impacts and contaminations from residual hydrocarbons.²⁶ Hence, properly planning and managing decommissioning activities is essential for sustainable development of oil and gas. Such planning and management ensure that decommissioning activities are carried out effectively and in a manner that mitigate the risk of negative environmental, social and economic impacts.²⁷ This will however require an understanding of the various decommissioning issues and challenges, as well as the integration of these issues and challenges in the decommissioning planning and management processes. Some significant decommissioning issues and challenges relevant for sustainable oil and gas development include, environmental and safety risks, huge decommissioning costs, complex social and economic impact of decommissioning, and public acceptance of decommissioning options.²⁸

As already stated, decommissioning poses significant environmental and safety risks from the hazardous nature of hydrocarbons and decommissioning processes. Hence, environmental impacts, public health and safety risks, among others, should constitute key considerations in the selection of decommissioning options. Also, an adequate post-decommissioning monitoring system must be established to address the residual risks from decommissioning processes.²⁹ Second, decommissioning constitutes a cost-intensive project, especially since it usually occurs when an oilfield is no longer commercially viable. As a result of huge decommissioning costs, therefore, financial assurance mechanisms must be implemented to ensure the availability of sufficient funds for implementing requisite decommissioning plans at the end of the lifespan of

²⁵ Amy MacIntosh *et al.*, 'Ecotoxicological Effects of Decommissioning Offshore Petroleum Infrastructure: A Systematic Review' (2021) Critical Reviews in Environmental Science and Technology 1.

²⁶ D Burdon, *et al.*, 'Oil and Gas Infrastructure Decommissioning in Marine Protected Areas: System Complexity, Analysis and Challenges' (2018) 135 Marine Pollution Bulletin 739.

²⁷ Eduardo Pereira and others, 'Addressing Residual Liability and Insolvency in Disused Oil and Gas Infrastructure Left in Place: The Cases of Brazil, Nigeria, and Trinidad and Tobago Addressing Residual Liability and Insolvency in Disused Oil and Gas Infrastructure Left in Place: The Cases of Brazil, Nigeria, and Trinidad and Tobago' (2020) 11(2) Journal of Sustainable Development Law and Policy 327.

²⁸ The Commonwealth, 'Oil and Gas Decommissioning Toolkit: Practical Guidance for Governments', *op cit.*

²⁹ *Ibid.*

an oilfield.³⁰ Financial assurance mechanisms may take different forms such as letters of credit, cash deposits in escrow accounts, insurance and bonds, among others. Where such financial assurance mechanisms are not properly implemented, a possibility may arise whereby an oil and gas contractor is unable to fund the decommissioning costs either due to financial distress or bankruptcy or due to the decommissioning costs rising higher than the anticipated or estimated costs.³¹

Third, due to the reliance on the oil and gas sector for national economic growth and development by many oil-producing nations, the decommissioning of oil and gas facilities may pose significant socio-economic impacts to these nations, ranging from loss of jobs to reduced national GDP, among others.³² However, depending on the scale of the industry as well as available national skills and capacity, decommissioning could present novel business and employment opportunities for nations around the world. For instance, existing oil and gas capacities could be leveraged to develop technical expertise along the decommissioning value chain.³³ This may, however, require stakeholders' participation to be able to ascertain stakeholders' vulnerabilities from decommissioning and to aid the development and implementation of strategies for the mitigation of the socio-economic impacts of decommissioning.³⁴ Furthermore, public acceptance of various decommissioning options poses a major challenge to oil and gas decommissioning.³⁵ Decommissioning planning and management should be carried out in consultation with local communities and other relevant stakeholders. Such stakeholder participation could aid the improvement of public acceptance of decommissioning options.³⁶

Therefore, a viable and sustainable decommissioning plan and management framework will generally include a summary of the proposed decommissioning program, an identification of facilities to be decommissioned, and the proposed decommissioning options; environmental, social, as well as health and safety impact assessment of proposed decommissioning options; post-decommissioning environmental restoration and rehabilitation plan; stakeholder consultations; and assignment of decommissioning roles and responsibilities.³⁷ Governments may adequately address such

³⁰ Ngozi Chinwa Ole and others, 'Decommissioning Oil and Gas Installations: The Challenge of Residual Liability' in Eduardo G. Pereira and others (eds) *The Regulation of Decommissioning, Abandonment and Reuse Initiatives in the Oil and Gas Industry From Obligation to Opportunities* (Wolter Kluwer 2021).

³¹ *Ibid.*

³² *Ibid.*

³³ Ngozi Chinwa Ole and Dickson Omukoro, 'Decommissioning of Offshore Oil and Gas Installations in Nigeria: An Analysis of Current and Emerging Governance Practise' in *Laws on Oil and Gas Law Exploration in Nigeria: Essays in Honour of Austin Avuru* (Princeton Pub 2021) 132.

³⁴ *Ibid.*

³⁵ *Ibid.*

³⁶ *Ibid.*

³⁷ Stakeholder Democracy Network, 'White Paper on Sustainable Closure and Decommissioning of Oil and Gas Assets in Nigeria' (2015), available at <https://www.stakeholderdemocracy.org/wp->

decommissioning planning and management through well-implemented regulatory regimes and requirements on decommissioning.

In the context of global energy transition, repurposing decommissioned oil and gas infrastructure for offshore wind energy presents a compelling opportunity. As countries seek to expand renewable energy sources, utilizing existing oil and gas platforms for offshore wind turbines can offer significant economic and environmental benefits.³⁸ The infrastructure, originally designed to withstand harsh marine conditions, provides a ready-made foundation for wind turbines, reducing both the financial and environmental costs of new construction.³⁹ This approach supports the circular economy by extending the lifecycle of existing assets and avoiding the complete removal of platforms, which can be resource-intensive and disruptive to marine ecosystems. Additionally, this strategy aligns with climate goals by contributing to the reduction of greenhouse gas emissions while maintaining energy production.⁴⁰

In regions where full removal of oil and gas infrastructure may pose high environmental or economic costs, "rig-to-reef" programs offer an innovative solution. These programs involve converting decommissioned offshore platforms into artificial reefs, which can provide significant ecological benefits by fostering marine biodiversity.⁴¹ The structural complexity of the platforms creates habitats for various marine species, promoting fish populations and enhancing local ecosystems. By leaving platforms in place under carefully managed conditions, these programs support the goals of the circular economy by repurposing materials and extending their environmental utility.⁴² This option is not only a more sustainable decommissioning strategy but also reduces the cost and environmental impact associated with complete removal. However, it is essential that regulatory frameworks ensure that only non-hazardous platforms are used for such purposes, and continuous monitoring is conducted to prevent any potential long-term negative impacts.⁴³

3. CCUS

One of the goals of the sustainable development agenda is the achievement of a climate neutral world and to this end, the agenda specifically calls for the execution of relevant actions to combat climate change and its impacts.⁴⁴ A primary action required to combat

content/uploads/2016/06/Sustainable-Closure-and-Decommissioning-of-Oil-and-Gas-Assets-in-Nigeria.pdf [accessed 29 April 2024].

³⁸ International Energy Agency, *Offshore Wind Outlook 2019* (2019).

³⁹ DNV GL, *Repurposing Oil and Gas Infrastructure for Offshore Wind* (2020).

⁴⁰ United Nations Environment Programme, *Circular Economy in the Energy Sector* (2021).

⁴¹ National Oceanic and Atmospheric Administration, *Rig-to-Reef Policy and Guidelines* (2020).

⁴² John S Page and Helen T Kirby, 'Ecological Benefits of Rig-to-Reef Programs' (2021) 45 *Marine Ecology* 331.

⁴³ Ocean Studies Board, *Transitioning to Sustainable Ocean Uses* (2021).

⁴⁴ United Nations, 'Sustainable Development Goals', goal 13.

climate change is the prevention of greenhouse gases emissions to the atmosphere thereby significantly cutting down global atmospheric carbon concentrations.⁴⁵ The exploitation of fossil fuels, including oil and gas, is notably one of the primary contributors to the increase in global greenhouse gases emissions, as well as other forms of environmental degradation and social injustices plaguing the world.⁴⁶ Notwithstanding its adverse impacts, the oil and gas industry have continued to be of significant value to nations around the world. This is because of the industry's contribution to national energy requirements and the economy, as many countries worldwide exploit fossil fuels as a primary source of energy production and consumption within their jurisdictions.⁴⁷ This poses a conflict between the climate goal and other aspects of the sustainable development agenda, particularly energy security and economic growth and development. Therefore, sustainable oil and gas development entails a balance between energy security and economic development on one hand and environmental sustainability and social protection on the other. This highlights the significance of developing and deploying sustainable strategies and technologies in oil and gas development.

CCUS is increasingly accepted as one of the most advanced technologies available for the reduction of emissions and the reduction of carbon levels in the atmosphere. CCUS involves the capture of carbon from emitting sources or direct carbon capture from the atmosphere, and subsequent compression and transportation of captured carbon for use in a range of applications, or injection into deep geological formations for permanent storage.⁴⁸ In other words, CCUS encompasses different phases including carbon capture, carbon transportation, carbon utilization, and carbon storage. Carbon capture involves the separation of carbon from other gases emitted during industrial operations. Such captured carbon is either utilized directly on-site in other applications, such as enhanced oil recovery (EOR), or compressed and transported to be used in a

⁴⁵International Energy Forum, 'What is CCUS and Why Is It Necessary' (20 July 2021) <https://www.ief.org/news/what-is-ccus-and-why-is-it-necessary> accessed 24 January 2024.

⁴⁶The CCUS Hub, 'CCUS Basics: Understanding CCUS' <https://ccushub.ogci.com/ccus-basics/understanding-ccus/> accessed 24 January 2024; Chijioke-Churuba J., 'Energy Sustainability: Bridging the Gap Between Oil and Gas Operations and Community Well-being in the Niger Delta Region, Nigeria' *op cit.*; Jacqueline B. Mariano & Emilio L. La Rovere, 'Environmental Impacts of the Oil Industry' *op cit.*; Opeyemi Yetunde Omotuyi, Olamide Mohammed & Adetola Paul Adebawo 'A Review of the Legal Framework for Marine Environmental Protection and Sustainable Development in Nigeria: Case Study of the Niger Delta region and Upstream Petroleum Development' (2024) 4(1) *Humanus Discourse* 1-22.

⁴⁷ United Nations Economic Commission for Europe, 'Carbon Capture, Use and Storage (CCUS)' <https://unece.org/sustainable-energy/cleaner-electricity-systems/carbon-capture-use-and-storage-ccus> accessed 12 February 2024.

⁴⁸International Energy Agency, 'Carbon Capture, Utilisation and Storage' 17 October 2022, available at <https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage> [accessed 19 January 2024].

range of other industrial applications, such as power generation and low-carbon hydrogen production, among others.⁴⁹

Where captured carbon remains unutilized, it is injected into deep geological formations for storage.⁵⁰ Where captured carbon is not utilized but stored permanently in deep geological formations, the process is generally described as carbon capture and storage (CCS). Carbon capture may also entail the removal of carbon directly from the atmosphere to balance emissions that are unavoidable or technically difficult to abate.⁵¹ This process of direct carbon removal from the atmosphere is generally referred to as direct air capture (DAC). Thus, CCUS, CCS and DAC are related carbon capture processes generally aimed at a reduction in atmospheric carbon concentrations, and the enhancement of the achievement of the global climate goals.

CCUS is capable of different functions in sustainable oil and gas development including, tackling carbon emissions from existing oil and gas facilities, as well as directly removing already emitted carbons from the atmosphere so as to balance atmospheric carbon concentrations from emissions that cannot be abated or avoided.⁵² In addition to its positive contribution to the climate agenda, CCUS can also contribute to the realization of other aspects of sustainable development especially, affordable and clean energy, decent work and economic growth, sustainable industrialization, innovation and infrastructure. For instance, fitting new oil and gas plants and retrofitting existing plants with CCUS technologies may allow for the continued operation of such plants albeit with significant emissions reduction. This may contribute to preserving employment and other economic opportunities presented by the oil and gas sector particularly in countries and regions that depend on the sector for economic growth.⁵³ Hence, the deployment of CCUS technologies may significantly improve corporate environmental, social and governance (ESG) performance in the oil and gas industry. Beside the potential maximum economic output from oil and gas operations through enhanced oil recovery (EOR), CCUS poses positive value to the

⁴⁹ Pereira EG, A Fossa, CEP Cerri, Opeyemi Omotuyi, H Hylton-Edwards, E Moutinho dos Santos, A Gallo, C Liaw & B Toguedani 'Advancing Sustainability through Carbon Capture, Utilization and Storage (CCUS) Technologies: The Hydrogel Case Study' (2023) 14(1) *Journal of Sustainable Development Law and Policy* 218-250.

⁵⁰ International Energy Agency, 'Carbon Capture, Utilisation and Storage', available at <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage> [accessed 19 January 2024].

⁵¹ *Ibid.*

⁵² International Energy Agency, 'Special Report on Carbon Capture Utilisation and Storage: CCUS in Clean Energy Transitions' (2020), available at https://iea.blob.core.windows.net/assets/181b48b4-323f-454d-96fb-0bb1889d96a9/CCUS_in_clean_energy_transitions.pdf, [accessed 15 February 2024]; The CCUS Hub, 'CCUS Basics: Understanding CCUS', available at <https://ccushub.ogci.com/ccus-basics/understanding-ccus/> [accessed 24 January 2024].

⁵³ International Energy Agency, 'Special Report on Carbon Capture Utilisation and Storage: CCUS in Clean Energy Transitions' *ibid.*

environment and society by reducing the carbon footprint of oil and gas operations, and enhancing affordable and reliable energy source.⁵⁴

While the deployment of CCUS is paramount for ensuring reduced carbon emissions, the potential adverse effects of carbon storage including the risk of carbon leakage, impacts of CCUS installations on groundwater resources among others, has been a source of public concern.⁵⁵ Likewise, the storage of large volume of carbon is perceived as capable of affecting the physical and chemical properties of a reservoir's rocks thereby posing adverse impacts on the local ecosystems. In addition, the transportation and storage of carbon may pose significant risks to public health where not adequately managed.⁵⁶ Thus, the potential adverse impacts of CCUS, in addition to other factors such as regulatory uncertainty, long-term liability for carbon storage sites, among others, constitute some of the major factors that may hinder the successful deployment of CCUS in the oil and gas industry.⁵⁷ The successful deployment of CCUS to enhance sustainable oil and gas development will therefore depend on the availability of adequate legal and regulatory frameworks to sustain CCUS applications in the oil and gas industry. Such frameworks must address salient issues including the safety and security of permanently stored carbon in geological formations, environmental and public health protection, clarification of the rights and responsibilities of CCUS stakeholders, as well as the long-term management of carbon storage sites.⁵⁸ In addition, such frameworks must establish clear systems of administrative oversight, and facilitate transparency through systems of information disclosure and public participation.⁵⁹

Beyond regulation, there are other technical and operational challenges associated with CCUS deployment in the oil and gas industry including, the high cost of CCUS operation, limited commercial incentives to deploy CCUS, public acceptance of CCUS as a viable technology for the mitigation of climate change.⁶⁰ Aside regulatory support therefore, the successful deployment of CCUS in the oil and gas industry may also

⁵⁴ Ibid.

⁵⁵ Hisham Eldardiry & Emad Habib, 'Carbon Capture and Sequestration in Power Generation: Review of Impacts and Opportunities for Water Sustainability' (2018) 8 *Energy, Sustainability and Society* 1-15.

⁵⁶ Mohammed D. Aminu, 'A Review of Developments in Carbon Dioxide Storage' (2017) 208 *Applied Energy* 1389-1419.

⁵⁷ World Bank, *Decarbonizing Natural Gas through Carbon Capture, Utilization, and Storage (CCUS)* op cit., 85-86; Siyuan Chen *et al.*, 'A Critical Review on Deployment Planning and Risk Analysis of Carbon Capture, Utilization, and Storage (CCUS) Toward Carbon Neutrality' (2022) 167 *Renewable and Sustainable Energy Reviews* 112537.

⁵⁸ International Energy Agency, *Legal and Regulatory Frameworks for CCUS: An IEA CCUS Handbook* (IEA Publications 2022) 7.

⁵⁹ Ibid.

⁶⁰ Sara Yasemi, *et al.*, 'Carbon Capture and Storage: Application in the Oil and Gas Industry' (2023) 15(19) *Sustainability* 14486.

require significant public and private investments in CCUS technologies and innovation, as well as public outreach and education on the value of CCUS.⁶¹

The deployment of carbon capture and storage (CCS) technologies in repurposed oil and gas infrastructure offers a practical approach to mitigating climate change while extending the usefulness of existing assets.⁶² Decommissioned oil and gas wells, for instance, can be adapted to store captured carbon dioxide in geological formations, helping to reduce atmospheric carbon levels. This approach not only contributes to achieving climate goals but also leverages the expertise and infrastructure of the oil and gas industry, reducing the costs and time associated with building new CCS facilities from scratch.⁶³ However, ensuring the safety and effectiveness of these CCS projects requires robust regulatory oversight to prevent issues like carbon leakage or groundwater contamination. Additionally, governments must provide economic incentives to make CCS a financially viable option for companies.⁶⁴

4. CIRCULAR ECONOMY

The concept of circular economy describes a sustainable model of production and consumption involving the reduction of waste generation from the production and consumption of products by the reuse and recycling of waste materials and products so as to extend their lifecycle.⁶⁵ In other words, a circular economy entails production and consumption patterns that maximizes resource use, while minimizing waste generation from resource use. A well-designed circular economy could pose significant positive impact to sustainable development generally because the manner of production, consumption and waste disposal may have implications on different aspects of sustainable development especially, environmental protection and social well-being. For instance, communities around the world may suffer the adverse environmental and health impacts of improper waste management as a result of large volumes of wastes generated and unavailability of adequate waste disposal system. A well-implemented circular economy also has the potential to improve economic growth and development, as well as social justice.⁶⁶ For instance, circular economy could contribute to the creation of green jobs, and improvement of national economic revenue, among others.

⁶¹ Sonja Thielges, *et al.*, 'Committed to Implementing CCU? A Comparison of the Policy Mix in the US and the EU' (2022) 4 *Frontiers in Climate* 943387.

⁶² Intergovernmental Panel on Climate Change, *Special Report on Carbon Capture and Storage* (2021).

⁶³ Global CCS Institute, *Repurposing Oil and Gas Infrastructure for CCS* (2020).

⁶⁴ United Nations Environment Programme, *Carbon Markets and CCS: Opportunities and Challenges* (2020).

⁶⁵ The European Parliament, 'Circular Economy: Definition, Importance and Benefits' (2023), available at <https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefits> [accessed 1 May 2024].

⁶⁶ US Environmental Protection Agency, 'What is a Circular Economy?', available at <https://www.epa.gov/circulareconomy/what-circular-economy> [accessed 1 May 2024].

In addition, the principle of circularity enhances sustainable materials management by ensuring a reduction of the negative lifecycle impacts of materials on the environment.

Recognizing the value of a circular economy, the sustainable development agenda encourages the promotion of sustainable consumption and production patterns in countries around the world. Specifically, the agenda seeks a substantial reduction of waste generation through strategies such as prevention, reduction, recycling and reuse.⁶⁷ In other words, the agenda recognizes the potential contribution of recycling and reusing waste materials to the prevention and reduction of waste generation. Hence, the agenda encourages industries across the world to integrate systems of recycling and reuse into their production patterns in order to ensure sustainable production and consumption.⁶⁸

With regard to sustainable oil and gas development therefore, a circular economy can minimize the volume of waste materials from oil and gas production through methods such as the reuse and recycling of production infrastructure and facilities, among others. For instance, offshore oil and gas platforms maybe converted or repurposed into artificial reefs for the benefit of marine ecosystems. Such rigs-to-reef program may contribute to ameliorating the adverse environmental effects, as well as the high costs associated with the complete removal of such platforms. Likewise, such program appears to be a more sustainable decommissioning option for offshore oil and gas platforms as a result of the environmental and economic value of artificial reefs.⁶⁹ To ensure the efficacy of such circularity programs however, the oil and gas industry must embrace circular sourcing which entails the replacement of finite resources or materials with renewable or recyclable resources in oil and gas production process, and sustainable design whereby raw materials are selected and products designed in a manner that they can be dis-assembled, reused or recycled effectively.⁷⁰

Further circular economy initiatives in the oil and gas sector may include resource efficiency, by which the usage of oil and gas resources is optimized in a manner that minimize waste in oil and gas production processes, and industrial symbiosis and recycling from manufacturing, whereby wastes or by-products from oil and gas production are optimized as raw materials for other products.⁷¹ Thus, circular economy within the scope of sustainable oil and gas development may entail the elimination of

⁶⁷ The Sustainable Development Goals, goal 12.

⁶⁸ Ibid.

⁶⁹ Eduardo G. Pereira, *et al.*, 'Decommissioning Offshore Oil and Gas Platforms: Is the Rigs-To-Reefs Program a More Sustainable Alternative?' (2023) 14 *Journal of Sustainable Development Law and Policy* (The) 1-26.

⁷⁰ PwC, 'The Rise of Circularity: Oil and Gas' (2021), available at <https://www.pwc.com/m1/en/publications/the-rise-of-circularity/documents/the-rise-of-circularity-oil-gas.pdf> [accessed 1 May 2024].

⁷¹ Ibid.

associated gas flaring as well as the prevention of carbon emissions from oilfields, while promoting associated gas commercialization and utilization, and CCUS. This is because gas flaring constitutes one of the most oppressing challenges posed by the oil and gas industry to sustainable development. Such practice constitutes a major source of environmental and public health hazards in oil-producing countries around the world. In addition, gas flaring is perceived as an economic waste because of the potential contribution of natural gas in securing energy access and affordability, as well as the positive impact it could pose to the growth of the GDP of oil-producing countries.⁷² Similarly, carbon emissions from oil and gas operations negatively affect environmental quality while also constituting public health hazards. In fact, such emissions constitute a major source of the ongoing global warming and climate change.⁷³

Hence, instead of flaring, associated gas may be recovered, commercialized or utilized in various applications such as power generation, transportation, cooking, heating systems, etc. Such captured natural gas could also serve as raw material for various industrial processes such as blue hydrogen production, production of fertilizer, etc.⁷⁴ Similarly, rather than treating the carbon dioxide associated with oil and gas production as a waste that can be indiscriminately emitted to the atmosphere, it may be treated as a commodity that can be captured and commercialized or utilized. Such system of carbon recycling entails carbon capture from emission points or directly from the atmosphere, and the utilization of same in various industrial processes as raw materials for instance, in plastics production, in the creation of alternative fuels such as methanol and gasoline, etc.⁷⁵

5. LESSONS LEARNED AND RECOMMENDATIONS

At this critical juncture, the oil and gas industry must address urgent environmental concerns while also meeting global energy demands. According to the findings of this study, sustainable growth in this business requires a holistic plan that includes

⁷² Ismail Saheed & Ezaina Umukoro, 'Global Impact of Gas Flaring' (2012) 4(4) *Energy and Power Engineering* 290-302; Andrew Adewale Alola, *et al.*, 'The Effects of gas Flaring as Moderated by Government Quality in Leading Natural Gas Flaring Economies' (2023) 13 *Scientific Reports* 14394.

⁷³ United Nations, 'Causes and Effects of Climate Change', available at <https://www.un.org/en/climatechange/science/causes-effects-climate-change#:~:text=As%20greenhouse%20gas%20emissions%20blanket,the%20usual%20balance%20of%20nature> [accessed 1 May 2024].

⁷⁴ Artur Davtyan, 'Commercializing Flare Gas to Reduce Emissions and Develop Economies', available at <https://www.tetrattech.com/insights/commercializing-flare-gas-to-reduce-emissions-and-develop-economies/> [accessed 1 May 2024]. See also 'Natural Gas: Definitions, Sources and Explanatory Notes', available at https://www.eia.gov/dnav/ng/TblDefs/ng_cons_sum_tbldef2.asp [accessed 1 May 2024].

⁷⁵ Simone H. Stewart, 'Carbon Recycling: Reduce, Remove, Reuse' (2023), available at <https://blog.nwf.org/2023/06/carbon-recycling-reduce-remove-reuse/> [accessed 1 May 2024].

decommissioning, CCUS, and circular economy ideas. We present a comprehensive set of suggestions and lessons learned to guide the industry toward a more sustainable future based on the insights provided.

1. A key suggestion is to conduct integrated decommissioning planning throughout the lifespan of oil and gas installations. This method requires the establishment of comprehensive decommissioning frameworks that incorporate environmental, social, and economic aspects from the start of project planning.⁷⁶ Operators should be obliged to submit thorough decommissioning plans as part of the initial project approval process, ensuring that end-of-life concerns are addressed from the outset. This preemptive strategy can greatly decrease environmental hazards and the financial costs connected with decommissioning.⁷⁷ Furthermore, creating clear financial assurance methods is vital to ensure funding for decommissioning, avoiding the burden falling on governments or taxpayers.⁷⁸

2. Accelerating CCUS adoption is another essential piece of advice for the business. Governments and industry stakeholders should collaborate to create strong legislative frameworks and incentives that encourage the deployment of CCUS technology.⁷⁹ This effort should be supplemented with greater investment in R&D to lower costs and enhance the efficiency of CCUS technology.⁸⁰ Public-private partnerships may play an important role in sharing the risks and expenses of large-scale CCUS initiatives, easing their implementation and growth.⁸¹

⁷⁶ J Chandler, D White, EJ Techera, S Gourvenec & S Draper, 'Engineering and Legal Considerations for Decommissioning of Offshore Oil and Gas Infrastructure in Australia' (2017) 131 *Ocean Engineering* 338-347 <https://doi.org/10.1016/j.oceaneng.2016.12.030>.

⁷⁷ Priscila Vidal, Mario González, David Melo, Paula Ferreira, Priscila Sampaio & Lílían Lima, 'Conceptual Framework for the Decommissioning Process of Offshore Oil and Gas Platforms' (2022) 85 *Marine Structures* 103262 <https://doi.org/10.1016/j.marstruc.2022.103262>.

⁷⁸ Stella Sofia I Kyvelou and Dimitrios G Ierapetritis, 'Fisheries Sustainability through Soft Multi-Use Maritime Spatial Planning and Local Development Co-Management: Potentials and Challenges in Greece' (2020) 12(5) *Sustainability* 2026 <https://doi.org/10.3390/su12052026>.

⁷⁹ M Bui and others, 'Carbon Capture and Storage (CCS): The Way Forward' (2018) *Energy & Environmental Science* <https://pubs.rsc.org/en/content/articlelanding/2018/ee/c7ee02342a> accessed 15 October 2024.

⁸⁰ Dennis Y.C. Leung, Giorgio Caramanna and M. Mercedes Maroto-Valer, 'An Overview of Current Status of Carbon Dioxide Capture and Storage Technologies' (2014) 39 *Renewable and Sustainable Energy Reviews* 426-443 <https://doi.org/10.1016/j.rser.2014.07.093>.

⁸¹ A Zapantis (Global CCS Institute), *Policy Priorities to Incentivise the Large-Scale Deployment of CCS* <https://www.globalccsinstitute.com/wp-content/uploads/2019/04/TL-Report-Policy-priorities-to-incentivise-the-large-scale-deployment-of-CCS-digital-final-2019.pdf> accessed 15 October 2024.

3. Integrating the wider Sustainable Development Goals (SDGs) into oil and gas sector policies and practices is critical to aligning the business with global sustainability goals. Industry leaders should create sector-specific indicators and targets that align with national and global sustainability goals, such as climate action, clean energy, and responsible consumption and production.⁸² Improving environmental monitoring and repair operations is critical to reducing the industry's ecological imprint. Using modern monitoring technologies to detect and avoid environmental problems during oil and gas developments can reduce risks and improve reaction times.⁸³ To restore impacted ecosystems, strict remediation requirements for polluted areas must be established and enforced.⁸⁴

4. Adopting circular economy ideas has considerable potential to improve sustainability in the oil and gas sector. Industry leaders and governments should enforce circular economy methods in oil and gas operations, concentrating on waste reduction, resource efficiency, and extending the lives of materials and equipment.⁸⁵ Repurposing decommissioned infrastructure, including transforming offshore platforms into artificial reefs or renewable energy facilities, may improve the environment and create new economic opportunities.⁸⁶ Developing markets and infrastructure for reusing and

⁸² Frank Biermann, Norichika Kanie and Rakhyun E Kim, 'Global Governance by Goal-Setting: The Novel Approach of the UN Sustainable Development Goals' (2017) 26-27 *Current Opinion in Environmental Sustainability* 26-31 <https://doi.org/10.1016/j.cosust.2017.01.010>.

⁸³ Salvatore Manfreda, Matthew F. McCabe, Pauline E. Miller, Richard Lucas, Victor Pajuelo Madrigal, Giorgos Mallinis, Eyal Ben Dor, David Helman, Lyndon Estes, Giuseppe Ciraolo, and et al., 'On the Use of Unmanned Aerial Systems for Environmental Monitoring' (2018) 10(4) *Remote Sensing* 641 <https://doi.org/10.3390/rs10040641>.

⁸⁴ Helena I Gomes, William M Mayes, Mike Rogerson, Douglas I Stewart and Ian T Burke, 'Alkaline Residues and the Environment: A Review of Impacts, Management Practices and Opportunities' (2016) 112(4) *Journal of Cleaner Production* 3571-3582 <https://doi.org/10.1016/j.jclepro.2015.09.111>.

(<https://www.sciencedirect.com/science/article/pii/S0959652615013396>)

⁸⁵ Martin Geissdoerfer, Paulo Savaget, Nancy M.P. Bocken, Erik Jan Hultink, 'The Circular Economy – A New Sustainability Paradigm?' (2017) 143 *Journal of Cleaner Production* 757-768

<https://doi.org/10.1016/j.jclepro.2016.12.048>.

⁸⁶ A.M. Fowler, AM Jorgensen, AM Svendsen, JC Macreadie, PI Jones, DOB Boon, AR Booth, DJ Brabant, R Callahan, E Claisse, JT Dahlgren, TG Degraer, S Dokken, QR Gill, AB Johns, DG Leewis, RJ Lindeboom, HJ Linden, O May, R Coolen, and JWP, 'Environmental Benefits of Leaving Offshore Infrastructure in the Ocean' (2018) 16(10) *Frontiers in Ecology and the Environment* 571-578 <https://doi.org/10.1002/fee.1827>.

recycling commodities from the oil and gas sector is crucial to support circular economy activities.⁸⁷

5. Improving regulatory frameworks is critical to promoting sustainable practices in the oil and gas industry. Policymakers should create clear, consistent, and enforceable policies that address all aspects of sustainable oil and gas development, such as decommissioning, CCUS, and circular economy practices.⁸⁸ To stay up with increasing best practices and technology breakthroughs, regulatory frameworks must be reviewed and updated on a regular basis.⁸⁹ Harmonizing legislation across jurisdictions promotes international collaboration and information exchange, vital for tackling global concerns like climate change.⁹⁰

6. Stakeholder participation and openness should be at the forefront of every sustainable oil and gas development plan. Companies and regulators should demand thorough stakeholder engagement processes throughout the lifetime of oil and gas projects, including decommissioning planning and implementation.⁹¹ Transparent reporting on environmental performance, decommissioning, and CCUS projects can

⁸⁷ Julian Kirchherr, Denise Reike and Marko Hekkert, 'Conceptualizing the Circular Economy: An Analysis of 114 Definitions' (2017) 127 *Resources, Conservation and Recycling* 221-232

<https://doi.org/10.1016/j.resconrec.2017.09.005>.

(<https://www.sciencedirect.com/science/article/pii/S0921344917302835>)

⁸⁸ Rachel Tiller and Russell Richards, 'Ocean Futures: Exploring Stakeholders' Perceptions of Adaptive Capacity to Changing Marine Environments in Northern Norway' (2018) 95 *Marine Policy* <https://doi.org/10.1016/j.marpol.2018.04.001>.

⁸⁹ Raphael J Heffron and Kim Talus, 'The Evolution of Energy Law and Energy Jurisprudence: Insights for Energy Analysts and Researchers' (2016) 19 *Energy Research & Social Science* 1-10

<https://doi.org/10.1016/j.erss.2016.05.004>.

(<https://www.sciencedirect.com/science/article/pii/S2214629616301001>)

⁹⁰ Benjamin K Sovacool and Thijs Van de Graaf, 'Building or Stumbling Blocks? Assessing the Performance of Polycentric Energy and Climate Governance Networks' (2018) 118 *Energy Policy* 317-324.

⁹¹ Kieren Moffat and Airong Zhang, 'The Paths to Social Licence to Operate: An Integrative Model Explaining Community Acceptance of Mining' (2014) 39 *Resources Policy* 61-70 <https://doi.org/10.1016/j.resourpol.2013.11.003>.

(<https://www.sciencedirect.com/science/article/pii/S0301420713001141>)

enhance public trust and support for industry initiatives.⁹² Encouraging community involvement in decision-making, especially for initiatives with major local implications, is crucial for retaining a social license to operate.⁹³

7. Investing in staff development and promoting innovative practices are crucial to establishing sustainable practices in the oil and gas business. Training programs should focus on emerging technologies and techniques linked to sustainability, decommissioning, and CCUS. Partnerships between industry, academia, and government may provide a pipeline of trained experts to apply sustainable practices in the sector.⁹⁴ Promoting innovation and technology adoption is critical for advancing sustainability in the oil and gas business. Creating innovation hubs and incubators to create sustainable technology for the sector can speed the shift to environmentally friendly practices. Providing financial incentives and support to enterprises adopting innovative, sustainable technology and practices might help overcome hurdles to implementation.⁹⁵ Encouraging knowledge exchange and technology transfer inside and between industries can increase the effect of these advances.⁹⁶ To keep up with technology changes, legal frameworks must be clear, uniform, and adaptable.⁹⁷ Effective stakeholder participation is critical for project success and retaining a social

⁹² María Alonso-Almeida, Frederic Marimon, Fernando Casani and Jesus Rodriguez-Pomeda, 'Diffusion of Sustainability Reporting in Universities: Current Situation and Future Perspectives' (2014) 106 *Journal of Cleaner Production* <https://doi.org/10.1016/j.jclepro.2014.02.008>.

⁹³ Jason Prno and D. Scott Slocombe, 'Exploring the Origins of 'Social License to Operate' in the Mining Sector: Perspectives from Governance and Sustainability Theories' (2012) 37(3) *Resources Policy* 346-357.

⁹⁴ Shinyoung Jeon, Olga Strietska-Ilina, Christine Hofmann and Mercedes Haro, *Skills for Green Jobs: A Global View* (2011).

⁹⁵ Adam B Jaffe, Richard G Newell and Robert N Stavins, 'A Tale of Two Market Failures: Technology and Environmental Policy' (2005) 54(2-3) *Ecological Economics* 164-174

<https://doi.org/10.1016/j.ecolecon.2004.12.027>.
(<https://www.sciencedirect.com/science/article/pii/S0921800905000303>)

⁹⁶ R Lema, M Iizuka and R Walz, 'Introduction to Low-Carbon Innovation and Development: Insights and Future Challenges for Research' (2015) 5(2) *Innovation and Development* 173-187

<https://doi.org/10.1080/2157930X.2015.1065096>.

⁹⁷ Benjamin K Sovacool and Michael H Dworkin, 'Energy Justice: Conceptual Insights and Practical Applications' (2015) 142 *Applied Energy* 435-444 <https://doi.org/10.1016/j.apenergy.2015.01.002>.

(<https://www.sciencedirect.com/science/article/pii/S0306261915000082>)

license to operate.⁹⁸ Financial certainty for decommissioning and environmental remediation is crucial to avoid socializing costs and liabilities.

8. Fostering international collaboration is critical to solving the worldwide issues faced by the oil and gas sector. So, collaboration among the oil and gas business, governments, academia, and other sectors has led to faster adoption of sustainable practices and technology.⁹⁹ International collaboration in research, policy creation, and best practices for sustainable oil and gas development may speed progress and assure a coordinated response to environmental concerns.¹⁰⁰ Establishing worldwide forums to share experiences and lessons learned in adopting sustainable practices, especially in decommissioning and CCUS, can benefit all stakeholders.¹⁰¹

Several major lessons have come from the industry's involvement in sustainability projects. Long-term planning is vital for the oil and gas sector to address the whole project lifespan, including decommissioning, from the start.¹⁰² Technological innovation is essential for balancing energy security and environmental sustainability, especially in CCUS.¹⁰³ Adopting circular economy ideas can improve waste management techniques and generate new economic possibilities in the industry.¹⁰⁴

⁹⁸ M Dare, J Schirmer and F Vanclay, 'Community Engagement and Social Licence to Operate' (2014) 32(3) *Impact Assessment and Project Appraisal* 188-197 <https://doi.org/10.1080/14615517.2014.927108>.

⁹⁹ Laura Diaz Anadon and others, 'Making Technological Innovation Work for Sustainable Development' (2016) 113(35) *Proceedings of the National Academy of Sciences of the United States of America* 9682-9690 <https://doi.org/10.1073/pnas.1525004113>.

¹⁰⁰ T Van de Graaf and J Colgan, 'Global Energy Governance: A Review and Research Agenda' (2016) 2(1) *Palgrave Communications* 1-12.

¹⁰¹ Benjamin K Sovacool, 'What Are We Doing Here? Analyzing Fifteen Years of Energy Scholarship and Proposing a Social Science Research Agenda' (2014) 1 *Energy Research & Social Science* 1-29 <https://doi.org/10.1016/j.erss.2014.02.003>.
(<https://www.sciencedirect.com/science/article/pii/S2214629614000073>)

¹⁰² Andrew Merrie and Per Olsson, 'An Innovation and Agency Perspective on the Emergence and Spread of Marine Spatial Planning' (2014) 44 *Marine Policy* 366-374.

¹⁰³ Mariana Mazzucato and Gregor Semieniuk, 'Financing Renewable Energy: Who is Financing What and Why It Matters' (2018) 127 *Technological Forecasting and Social Change* 8-22 <https://doi.org/10.1016/j.techfore.2017.05.021>.
(<https://www.sciencedirect.com/science/article/pii/S0040162517306820>)

¹⁰⁴ Patrizia Ghisellini, Catia Cialani and Sergio Ulgiati, 'A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems' (2016) 114 *Journal of Cleaner Production* 11-32 <https://doi.org/10.1016/j.jclepro.2015.09.007>.
(<https://www.sciencedirect.com/science/article/pii/S0959652615012287>)

Importantly, the sector has realized that sustainable methods may be commercially feasible. Investing in sustainable technology and practices may result in cost savings, increased efficiency, and new revenue sources, proving that sustainability and profitability are not mutually incompatible.¹⁰⁵ The oil and gas sector must prepare for a low-carbon future by expanding into renewable energy and sustainable business models.¹⁰⁶

Finally, by following these ideas and learning from previous experiences, the oil and gas sector can work toward a more sustainable future that balances energy security, environmental preservation, and social responsibility. This transformation is critical not just for the industry's long-term profitability, but also for tackling global issues like climate change and resource depletion. The way forward necessitates dedication, creativity, and collaboration from all stakeholders, but the potential benefits - for the business, society, and the environment - are enormous.

6. CONCLUSION

Decommissioning, CCUS, and circular economy constitute some of the most pressing sustainability issues for the oil and gas industry across the globe. While decommissioning constitutes an integral aspect of environmental remediation and restoration required for proper and adequate environmental management in the oil and gas industry, implementation of circular economy strategies support the minimization of the volume of waste materials generated from oil and gas production thereby, contributing to resource conservation and environmental protection. The deployment of CCUS techniques is paramount for ensuring reduced carbon emissions from oil and gas production on one hand, while also contributing to the realization of other aspects of sustainable development especially, affordable and clean energy, sustainable industrialization, innovation and infrastructure, among others.

Hence, sustainable oil and gas development requires the integration of decommissioning concerns into all aspects of oil and gas operations on a life-cycle basis. To ensure this, national governments must implement clear and coherent decommissioning frameworks including, a clear definition of decommissioning, as well

¹⁰⁵ N.M.P. Bocken, S.W. Short, P. Rana and S. Evans, 'A Literature and Practice Review to Develop Sustainable Business Model Archetypes' (2014) 65 *Journal of Cleaner Production* 42-56 <https://doi.org/10.1016/j.jclepro.2013.11.039>.

(<https://www.sciencedirect.com/science/article/pii/S0959652613008032>)

¹⁰⁶ Jochen Markard, Rob Raven and Bernhard Truffer, 'Sustainability Transitions: An Emerging Field of Research and Its Prospects' (2012) 41(6) *Research Policy* 955-967

(<https://www.sciencedirect.com/science/article/pii/S004873331200056X>)

as prescription of specific decommissioning requirements such as the submission and approval of a decommissioning plan, description of the responsibility for decommissioning liabilities, financial assurance requirements, among others. Also, such decommissioning frameworks must feature decommissioning as one of the criteria for the grant of operational licences and other key approvals required for oil and gas operations. In addition, to ensure sustainability, a sustainable decommissioning framework must integrate various environmental as well as socio-economic issues associated with decommissioning in its provisions.

Second, sustainable oil and gas development calls for the deployment of CCUS technologies in oil and gas operations. To ensure the efficacy of CCUS as a viable technology for sustainable oil and gas development however, there is need for strategic actions to be taken by relevant stakeholders including governments, oil and gas industries, and financial institutions. Actors in the oil and gas industry must undertake strategic actions to address the potential adverse impacts of CCUS including, conducting environmental impact assessments prior to the deployment of a CCUS technology, implementing a system of environmental monitoring and auditing to monitor the effect of carbon on the environment and communities around a carbon storage site, etc. On their part, governments must be willing to implement policy frameworks, as well as robust legal and regulatory regimes that drive CCUS deployment in the oil and gas industry. Premised on the principles of sustainable finance, financial institutions must be ready to channel relevant financial resources into the development and scaling up of CCUS technologies, as a complement to public finance.

Third, just as in any other industrial process, sustainable oil and gas development requires the implementation of systems that extend the lifecycle and maximize the use of oil and gas production facilities, as well as by-products from oil and gas production. This ensures that waste generation from oil and gas production is significantly reduced, with a positive multiplier effect on the environment and public health. The implementation of such circular economic system in the oil and gas sector will be enabled by the setting up of a robust regulatory framework that effectively drives such development.