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Risk Management in The Transition to Sustainable Energy: Lessons from Petroleum Investment Projects

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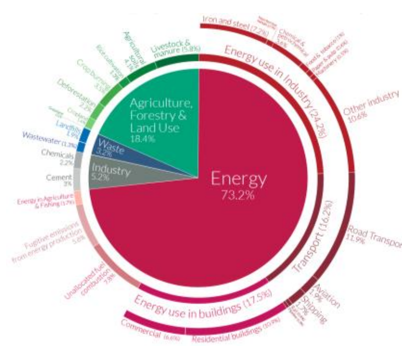
Abstract- The transition to sustainable energy systems is a defining challenge of the 21st century, requiring innovative approaches to address the multifaceted risks associated with green energy investments. This study explores risk and scope management strategies, drawing lessons from petroleum investment projects to guide the shift toward renewable energy solutions. This research highlights the potential of aligning stakeholder expectations with evolving project goals by analyzing technical, financial, and regulatory risks, and emphasizing the importance of integrated frameworks. Case studies from both petroleum and renewable energy sectors emphasize the value of lessons learned in managing large-scale, complex projects. These insights demonstrate how the expertise and methodologies developed in the petroleum industry can be adapted to mitigate uncertainties and optimize outcomes in renewable energy ventures. The findings affirm that effective risk and scope management enhance the feasibility of sustainable energy projects and contribute to broader objectives such as reducing carbon emissions, bolstering energy security, and ensuring economic growth. This work provides actionable guidelines for policymakers, investors, and industry practitioners aiming to achieve a resilient

Indexed Terms- Sustainable Energy Investments, Risk Management, Scope Management, Petroleum Industry Lessons, Renewable Energy Transition, Stakeholder Collaboration, Energy Security, Economic Growth.

I. INTRODUCTION

The global transition to sustainable energy has emerged as an urgent imperative in addressing the escalating threats of climate change. This movement is reinforced by international agreements, such as the Paris Agreement, which aims to limit global temperature rise to 1.5°C above pre-industrial levels. According to the World Economic Forum, the top three greenhouse gas emitters — China, the European Union, and the United States — are responsible for 41.5% of global emissions, while the bottom 100 countries contribute just 3.6%. Since 1990, the energy sector has been the largest source of GHG emissions, accounting for 73% of global emissions in 2017 (WEF, 2020).

Fig 1: Global Greenhouse Gas Emissions by Sector in 2016 (Total: 49.4 Billion Tonnes CO_2eq)



Source: OurWorldInData.org

In 2023, clean electricity comprised 80% of new capacity additions, and electric vehicles accounted for 20% of cars sold globally. Investment in clean energy manufacturing is booming, with employment in clean energy surpassing fossil fuels since 2021. Clean energy also contributed to 10% of global GDP growth, highlighting its growing economic role (IEA, 2024). Petroleum-based energy systems have significantly influenced industrialization and economic growth, shaping energy investments' strategic, operational, and financial frameworks. To achieve a transformative shift to renewable alternatives like wind, solar, and hydrogen, these established systems must be reconsidered (Yongjun, 2023). As such, the petroleum industry offers a rich repository of lessons for navigating the complexities of large-scale energy projects, particularly in areas such as capital allocation, market volatility, and regulatory compliance.

Despite the momentum toward sustainable energy, managing risks during the transition poses significant challenges. These risks span technological uncertainty, fluctuating market conditions, geopolitical tensions, and environmental concerns (Saleh & Hassan, 2024). For instance, the International Renewable Energy Agency (IRENA) highlights that global investment in energy transition technologies hit a record USD 1.3 trillion in 2022, but this is insufficient to achieve the 11.2 Terawatts pledged by countries for 2030. In contrast, fossil fuel capital investments in the same year were nearly double those of renewables (IRENA, 2024). However, this investment comes with heightened exposure to risks such as supply chain disruptions, integration with existing energy systems, and evolving regulatory landscapes (Bassey et al., 2024). Without a structured framework tailored to the nuances of sustainable energy, the transition could result in inefficiencies, cost overruns, and project delays that hinder global decarbonization efforts.

This article aims to analyze risk management practices within petroleum investment projects, distilling insights that can be applied to green energy technologies. Specifically, it will examine how principles such as scope definition, risk identification, and mitigation strategies have been employed in petroleum projects and their relevance to renewable energy systems. By exploring international case studies—ranging from offshore wind farms in Europe to solar megaprojects in Asia—it will provide actionable recommendations for investors, policymakers, and project managers. The scope includes identifying common risks, evaluating the effectiveness of existing mitigation frameworks, and proposing strategies to ensure the financial and operational viability of green energy projects. Ultimately, this analysis seeks to contribute to the global effort to ensure a more sustainable and resilient energy future.

II. LITERATURE REVIEW

- Risk Management in Energy Projects

The energy sector is inherently high-risk, characterized by its capital intensity, long project timelines, and sensitivity to external factors such as market dynamics and regulatory changes. These challenges are further amplified as the sector transitions from fossil fuels to sustainable energy sources, necessitating robust risk management frameworks.

Traditional energy projects, particularly in oil and gas, face numerous risks tied to market volatility and regulatory changes. According to the International Energy Agency (IEA, 2024), global investment in clean energy has nearly doubled that of fossil fuels, with solar PV now surpassing all other generation technologies in terms of investment. However, Emerging Markets and Developing Economies (EMDEs), excluding China, account for only 15% of global clean energy spending, reflecting persistent disparities in investment allocation. For fossil fuel projects, crude oil price volatility remains a major concern, as fluctuating prices influence production costs and complicate investment decisions. This uncertainty often leads to project delays or scaled-down investments, as businesses seek to minimize financial exposure (Chen et al., 2024).

Regulatory risks add another layer of complexity. Changes in tax policies, environmental standards, and compliance requirements can disrupt project feasibility and long-term planning. Jahidi et al. (2024) emphasized how non-compliance with evolving regulatory policies in the oil and gas sector often stems from unclear guidelines, enforcement inconsistencies, or a lack of capacity to meet new standards. While such policies aim to improve environmental performance and operational efficiency, they can inadvertently create significant obstacles for project execution.

The transition to sustainable energy introduces distinct risks, particularly in emerging technologies like green hydrogen and carbon capture, utilization, and storage (CCUS). A study by the International Renewable Energy Agency (IRENA, 2024) identifies technology uncertainty as a key challenge, where unproven or rapidly evolving technologies make accurate cost projections and long-term reliability assessments difficult. Additionally, the policy landscape for renewable energy is often inconsistent. Rollbacks of subsidies or incentives, for example, can abruptly halt project development, undermining investor confidence.

Permitting and regulatory delays are significant hurdles for renewable energy projects. Research by Hanger-Kopp et al. (2021) and Susskind et al. (2022) found that 34% of renewable energy projects experienced major delays due to challenges in obtaining permits, while 49% were canceled outright. These delays and cancellations have led to an estimated loss of generating capacity of 4600 MW globally. The researchers attribute these outcomes to fragmented regulatory frameworks, insufficient coordination between local and national authorities, and resistance from community stakeholders.

- Adaptive Risk Management Strategies

The energy transition presents a spectrum of risks, encompassing both traditional fossil fuel investments and emerging renewable energy projects. These diverse challenges necessitate adaptive risk management strategies designed to address the distinct characteristics and complexities of each energy source.

In traditional petroleum investment projects, market volatility is a significant risk, often stemming from fluctuating oil and gas prices influenced by geopolitical events, supply-demand imbalances, and technological disruptions. To mitigate this, dynamic financial modeling and hedging strategies, such as forward contracts and futures, are employed to stabilize revenues and safeguard against price shocks. Regulatory risks, on the other hand, are mitigated through proactive compliance planning, robust environmental assessments, and strategic stakeholder engagement. Project stakeholders can navigate the complex regulatory landscape more effectively by anticipating policy shifts and fostering transparent communication with regulators and local communities.

For renewable energy investments, adaptive risk management takes on a different focus. Public-private partnerships (PPPs) are pivotal in de-risking investments by sharing financial burdens and leveraging the strengths of both sectors. These collaborations encourage the development of large-scale renewable projects, such as wind farms and solar installations, while reducing exposure to upfront capital costs. Furthermore, leveraging data-driven tools, including predictive analytics and machine learning, enhances project predictability by improving resource assessment, operational efficiency, and maintenance planning. Adaptive risk management strategies must account for the distinct challenges of petroleum and renewable energy investments, particularly in the U.S., where energy transition policies and market dynamics are rapidly evolving. The U.S. Department of Energy (DOE) emphasizes the significance of stakeholder engagement in energy projects, stating that active community participation can enhance results and minimize delays. Additionally, research from the Lawrence Berkeley National Laboratory revealed that increased engagement leads to a 75% reduction in project cancellations (Lawrence Berkeley National Laboratory, 2024).

Policy stability emerges as a critical enabler for renewable energy investments, given the reliance on long-term commitments and subsidies to ensure project viability. Advocacy efforts directed toward maintaining consistent and supportive policies—such as feed-in tariffs, tax incentives, and renewable energy standards—help build investor confidence and encourage sustained investment in sustainable energy. Additionally, adaptive strategies include diversifying project portfolios to spread risks across different energy sources, geographic regions, and technologies, minimizing exposure to localized disruptions. In renewable energy, diversifying project portfolios and leveraging public-private partnerships mitigate financial risks, while federal initiatives like the Inflation Reduction Act have enhanced policy stability, boosting investor confidence (IRENA, 2023; Yale Environment 360, 2022). Comparing petroleum and renewables, the former faces higher regulatory penalties, whereas the latter benefits from declining costs, reflecting their contrasting risk profiles. These data-driven strategies position U.S.

energy leaders to resolve uncertainties effectively and capitalize on emerging opportunities.

Finally, successful adaptive risk management incorporates continuous learning and flexibility. By analyzing past projects and integrating lessons learned, energy stakeholders can refine their approaches and respond to the evolving dynamics of the energy sector. These adaptive strategies not only mitigate risks but also position energy investors and policymakers to capitalize on opportunities within the transition to a more sustainable energy future.

III. SCOPE MANAGEMENT PRINCIPLES IN LARGE-SCALE PROJECTS

Scope management forms the foundation for effective planning in large-scale projects, influencing cost estimation, scheduling, and work breakdown structures. Poorly defined scopes often lead to cost overruns and schedule delays, with misaligned stakeholder expectations increasing project risks (Althiyabi et al., 2021). In petroleum investments, front-end loading (FEL) processes emphasize rigorous planning and early stakeholder alignment, ensuring project objectives are clearly defined and risks minimized (Angus MacLeod21, 2023).

Similarly, renewable energy projects have benefited from scope management principles as outlined in the Project Management Body of Knowledge (PMBOK), which includes processes such as Collect Requirements, Define Scope, and Control Scope (iCert, 2024). For instance, engaging stakeholders early in the planning phase of Germany's Energiewende initiatives helped mitigate policy and market risks, demonstrating the effectiveness of clear scope definition in green energy transitions (IEA, 2022). By integrating these principles, green energy projects can enhance operational efficiency, reduce uncertainties, and improve their chances of success

- Lessons from International Energy Transitions

Global case studies offer valuable insights into the successes and failures of energy transitions. Denmark's transition to wind energy, which began in the 1970s, is often cited as a success story. A review by Katinka (2021) attributes this success to consistent policy support, community engagement, and strategic investments in research and development. By 2022, wind energy accounted for over 54% of Denmark's electricity consumption, demonstrating the effectiveness of these strategies (IEA, 2023).

Conversely, South Africa's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) highlights the challenges of energy transitions. As of 2023, 123 projects have been awarded to the private sector, with investments totaling R256 billion (US$17.32 billion) (Prescient, 2024). Despite inconsistent government policies and delays in power purchase agreements hindering progress, policy stability and strong institutional capacity remain essential for managing risks during energy transitions (Todd & McCauley, 2021).

IV. RISK ASSESSMENT IN THE TRANSITION TO SUSTAINABLE ENERGY

- Identifying Risks in Green Energy Projects

The transition to sustainable energy systems introduces several complex and interrelated risks. According to Mohanasundaram et al. (2024), producing green hydrogen on a global scale could meet up to 24% of the world's energy needs by 2050. This would potentially reduce greenhouse gas emissions by 60 gigatons, which is equivalent to 6% of the total cumulative CO_2 emission reductions. Technical risks, such as the reliability and scalability of new technologies, remain a significant challenge. Green hydrogen, although promising, faces efficiency constraints during production, storage, and transportation (100RE Lab, 2023). A study by Hassan et al., (2024) noted that to fully realize the potential of green hydrogen, various factors should be examined, including technological limitations, infrastructure development, costs and economic feasibility, regulatory and policy frameworks, as well as public perception and acceptance

Financial risks are equally critical, as green energy projects often involve substantial upfront investments. Johnson et al. (2022) presented their analysis, revealing that the mean levelized cost of offshore wind in Ireland could be as low as 122 €/MWh. However, when accounting for variables such as capital expenditure, financing costs, capacity factors, and commodity price fluctuations, simulations indicate a wide range of potential outcomes. Approximately 60% of the scenarios fall between 108 €/MWh and 137 €/MWh. These costs create financing challenges, particularly in emerging markets, where access to affordable capital is limited. Political and regulatory risks further complicate green energy transitions such as abrupt changes in subsidies or tariffs, which can destabilize investment flows (Gourinchas et al., 2024). The pursuit of energy security, the increasing risk of geoeconomic fragmentation, political resistance to climate policies, and slowing economic growth are all significant challenges. These risks highlight the need for stable and supportive policy environments to encourage sustainable energy investments.

- Risk Assessment Tools and Techniques

Effective risk assessment requires employing a combination of quantitative and qualitative tools. Quantitative methods, such as Monte Carlo simulations, allow project managers to model the impact of various risks and determine probabilities of cost overruns or project delays (Qazi & Simsekler, 2021; Abolghasemian et al., 2024). Monte Carlo simulations in renewable energy projects reduced overall risk exposure (Hashish et al., 2023). Scenario Analysis is another quantitative technique essential in risk assessment for understanding the impact of uncertainty on complex systems. It helps decision-makers develop resilient plans by analyzing multiple potential future scenarios and considering different factors, assumptions, and trends (Imarticus, 2023).
Qualitative methods, including SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis and expert consultations. SWOT analysis is effective in energy transition projects, complementing quantitative tools by incorporating strategic insights. Germany's Energiewende exemplifies this, using expert panels to guide policy reforms and competitive auctions, enabling over 40% renewable electricity. The SWOT analysis helps assess strengths and threats, adapt strategies to external crises, such as the Russia-Ukraine conflict, and highlight the importance of integrating expert opinions in planning (WEF, 2023).

V. MITIGATION STRATEGIES FOR SUSTAINABLE ENERGY INVESTMENTS

- Technological Innovation and Diversification

Investing in a diverse portfolio of green technologies is a cornerstone of risk mitigation in sustainable energy projects. Proven renewable technologies, such as wind and solar energy, offer stable returns despite their challenges and have offered alternatives to energy sources and contributed to economic growth (Lv Y, 2023). While emerging technologies like hydrogen energy and carbon capture systems provide opportunities for growth and resilience. Hydrogen has a high energy density of 120 MJ/kg, making it a strong alternative to fossil fuels. Large-scale adoption could reduce global CO_2 emissions by up to 830 million tonnes per year (Abdellatif et al., 2024). Carbon capture and storage (CCS) technology has also emerged as a powerful and innovative method for reducing carbon emissions and advancing toward net-zero targets. The CCS market is rapidly expanding, with a projected compound annual growth rate of 6.2% from 2023 to 2030. (World Economic Forum, 2023). Diversification spreads technical risks across various innovation pathways, reducing dependency on any single solution (Gitelman et al., 2023). Research and development (R&D) are important in minimizing technical risks by accelerating advancements in efficiency, reliability, and scalability. Such as the recent breakthroughs in battery storage technology that have addressed intermittency issues in renewable energy systems, making them more viable for large-scale adoption (Vedhanarayanan & Seetha Lakshmi, 2024).

- Financial Instruments for Risk Mitigation

Financial strategies play a critical role in reducing exposure to risks in sustainable energy investments. Instruments such as green bonds provide access to capital while ensuring alignment with environmental goals. To achieve the 1.5° climate goal, it is estimated that USD 131 trillion will be needed by 2050, averaging over USD 4 trillion annually. Green bonds, which fund environmentally beneficial projects, could play a significant role in raising this capital. In 2021, green bond issuance surpassed USD 500 billion and is projected to exceed USD 1 trillion by 2023 (ElBannan & Löffler, 2024). Insurance products designed for renewable energy projects provide a safety net against operational uncertainties. Transitioning to new energy types involves identifying standard corporate and specific risks, understanding various insurance contract requirements and structures, and evaluating the financial condition (Kirillova et al., 2021). Weather risk insurance is effective in promoting renewable energy by mitigating weather-related risks like wind speed, solar radiation, and precipitation. A notable example in 2016, is a solar energy project in Rajasthan, India, which received a $750,000 payout from its weather insurance policy after a severe sandstorm, allowing the project to continue operating and generating renewable energy (Goda & Jha, 2022). Public-private partnerships (PPPs) are another effective model, enabling risk-sharing between governments and private investors. These partnerships distribute financial burdens and leverage public sector support to de-risk innovative projects. Public-Private Partnerships (PPPs) are vital in developing clean energy infrastructure in the U.S. They leverage government incentives and private investment to advance renewable energy projects like wind farms and solar installations, ensuring innovation and stability through long-term contracts (Ugwu et al., 2024).

- Regulatory and Policy Alignment

A stable regulatory and policy framework is essential for ensuring investor confidence and mitigating risks associated with policy volatility. The government's role is essential in creating consistent regulations, offering subsidies, and providing tax incentives for green projects. The Inflation Reduction Act of 2022, a landmark climate legislation in U.S. history, provides funding, programs, and incentives to accelerate the clean energy transition. Effective from 1/1/2023, it reduces renewable energy costs for various organizations through incentives like tax credits, crucial for lowering GHG emissions and speeding up the clean energy shift (EPA, 2024). Also, engaging with policymakers through industry alliances and advocacy groups ensures that regulatory changes are informed by on-ground realities, aligning market needs with legislative priorities (GACD, 2024; EFInA, 2024).

Lessons from Petroleum Investment Projects: A Case Study on Mitigating Risks in Large-Scale Oil Extraction Projects

The Kashagan oil field in Kazakhstan, one of the largest and most technically challenging offshore oil projects globally, offers valuable lessons in risk management. This project faced an array of significant challenges, including technical complexities, environmental sensitivities, and regulatory hurdles. Located approximately 15,000 feet beneath the seabed, Kashagan's reservoir contains high levels of hydrogen sulfide (H_2S), a corrosive and toxic gas that necessitates specialized equipment, advanced safety protocols, and significant investment in infrastructure.

To address these challenges, project managers employed advanced monitoring technologies to track real-time operational parameters, reducing the likelihood of accidents. Modular engineering designs were implemented to adapt to the extreme weather conditions of the Caspian Sea, where temperature fluctuations and seasonal ice formation posed logistical difficulties. Moreover, strategic collaborations with local governments ensured alignment between regulatory requirements and operational practices, which helped mitigate delays and enhance compliance.

However, Kashagan has not been without controversy. Environmental regulations have played a central role in shaping the project's operational strategies, as its location in an ecologically sensitive zone demands rigorous adherence to environmental standards. Non-compliance has led to substantial penalties, including a $5 billion lawsuit in 2023 filed by Kazakhstan's ecology ministry for alleged environmental violations. These issues underline the importance of incorporating robust environmental risk mitigation strategies into large-scale energy projects.

Further compounding these challenges are legal disputes between Kazakh authorities and international oil companies involved in the consortium. Arbitration claims exceeding $150 billion have been filed, primarily centered on production cost disputes and alleged revenue losses. Such legal uncertainties not only escalate operational risks but also deter potential investors, highlighting the critical role of transparent and fair contractual agreements in managing financial risks.

Operational setbacks have also tested the resilience of Kashagan's management strategies. Shortly after production commenced in September 2013, operations were halted due to pipeline corrosion caused by high H_2S content, resulting in gas leaks. This necessitated the replacement of approximately 200 kilometers of pipeline, delaying production and significantly increasing costs. Despite these setbacks, Kashagan achieved operational stability through the persistent application of advanced engineering solutions and proactive risk management practices.

Beyond oil extraction, the Kashagan project illustrates the importance of corporate social responsibility in large-scale industrial ventures. Investments in community infrastructure, including schools, hospitals, roads, and water supply systems, have strengthened relations with local communities, fostering social acceptance and goodwill. Such initiatives are crucial for ensuring long-term project sustainability and reducing community opposition.
The Kashagan project exemplifies the multifaceted nature of risk in petroleum investments, encompassing technical, environmental, legal, and social dimensions. While initial cost overruns and operational delays posed significant challenges, the implementation of advanced risk mitigation strategies ultimately ensured the project's viability. These lessons are invaluable for guiding the energy sector's transition to sustainable practices, as they underscore the importance of technological innovation, stakeholder engagement, and regulatory compliance in achieving long-term success (ENI, 2024; Kangze, 2023).

Successful Scope Management in Offshore Drilling Ventures

The Johan Sverdrup oil field in Norway exemplifies effective scope management in petroleum investments. Managed by Equinor, the project emphasized a clear definition of objectives and extensive stakeholder engagement to prevent scope creep. Utilizing digital twins, Microsoft 3D Hololens technology, and Omega 365's digital Workflow ensured that project management maintained attention to detail —a digital representation of physical assets—the project optimized design and operation phases, Daily production at plateau reached 755,000 barrels of oil equivalent per day, accounting for up to 30% of the total oil output from the Norwegian continental shelf (Omega 365, 2023). This project reduces carbon emissions by 80-90% compared to standard developments using gas turbines during the first development phase, enhancing safety, cutting costs, boosting returns, and reducing emissions (Equinor, 2023). Digital twin technology is improving operations in a field that is set to contribute up to 25% of Norway's total offshore production (Fawthrop, 2020). These practices ensured the project was delivered on time and within budget while maintaining high safety and environmental standards .

Adaptation of Petroleum Strategies to Sustainable Energy

The expertise gained in managing risks in complex petroleum projects can be directly applied to sustainable energy investments. Modular engineering and digital twins, as utilized in the Johan Sverdrup project, are being increasingly adopted in offshore wind projects to enhance efficiency and reduce uncertainties. Although digital twin technology has seen widespread adoption across various industries, its definition and application in the wind farm sector are still evolving, making digitalization crucial for managing large offshore wind turbines and improving safety while reducing operational and maintenance costs (Ambarita et al., 2024; Haghshenas et al., 2023). Similarly, the regulatory engagement strategies seen in Kashagan can guide renewable energy developers in aligning projects with local policies, particularly in regions with nascent renewable energy regulations. By leveraging these frameworks, the renewable energy sector can avoid common pitfalls and accelerate project implementation.

VI. PRACTICAL GUIDELINES FOR GREEN ENERGY INVESTMENTS

- Integrated Risk and Scope Management Framework

Project planning allows teams to break down complex tasks, identify necessary steps, and determine dependencies for milestones. A well-designed plan helps manage risks, establish contingency plans, and allocate resources strategically. Effective stakeholder management and developing a comprehensive framework for risk and scope are crucial for the success of green energy investments and IT projects (Sanyaolu et al., 2023; Scheepers et al., 2022; Menon, 2023) Regularly updating risk assessments is an essential role of AI in risk management, contrasting traditional methods with AI-enhanced approaches and identifying the emerging challenges and opportunities. Integrated Risk and Scope Management Frameworks that use AI methodologies like convolutional neural networks (CNNs) are crucial for extracting insights and managing risks, with regular updates needed due to fluctuating market conditions and evolving technologies (Yazdi et al., 2024).

- Stakeholder Collaboration

Effective green energy projects require strong collaboration among stakeholders, including governments, private investors, and local communities (Adesusi et al., 2024). Transparent communication encourages trust and minimizes misunderstandings that can delay project timelines (Shakeri & Khalilzadeh, 2020). A prominent example is the Hornsea One offshore wind farm in the UK, developed by Ørsted. The project successfully engaged local communities through consistent dialogue, addressing concerns about environmental impact and economic benefits. Additionally, partnerships with private investors and governmental bodies helped secure financial backing and streamlined regulatory approvals, exemplifying the importance of collaboration (WoREA, 2024).
Monitoring and Evaluation

Regular audits and performance monitoring are vital for tracking the progress of green energy projects against predefined Key Performance Indicators (KPIs). These KPIs should include metrics such as energy output, cost efficiency, and environmental impact (Klimaitienė et al., 2020). Flexibility to adapt to emerging risks is equally crucial. The Block Island Wind Farm in the U.S. is a notable example of this, it demonstrated adaptive project management by revising its operational plans in response to unforeseen environmental challenges. This adaptability ensured the project's completion within budget while maintaining compliance with environmental regulations (Carey et al., 2020).

CONCLUSION

The transition to sustainable energy demands meticulous attention to risk and scope management, as these elements significantly impact project viability and success. Drawing from risk management practices in petroleum investment projects, green energy initiatives can adopt advanced tools such as scenario analysis and modular engineering to mitigate technical, financial, and regulatory uncertainties. The lessons learned from the petroleum sector, particularly in managing complex and large-scale energy systems, provide a solid foundation for managing the unique challenges of renewable energy projects. The alignment of risk and scope management principles ensures that sustainable energy investments can achieve their immediate objectives and contribute to broader goals such as energy security, emissions reduction, and economic growth. The application of frameworks that integrate stakeholder collaboration, technological innovation, and policy alignment reinforces the transformative potential of green energy projects. These initiatives, as evidenced by successful ventures like Ørsted's offshore wind farms, exemplify how thoughtful planning and execution can yield substantial environmental and economic benefits. By leveraging risk management frameworks and lessons from petroleum projects, green energy initiatives can drive a future of cleaner energy, enhanced resilience, and shared prosperity.

REFERENCES

[1] Abdellatif M. Sadeq, Raad Z. Homod, Ahmed Kadhim Hussein, Hussein Togun, Armin Mahmoodi, Haytham F. Isleem, Amit R. Patil, Amin Hedayati Moghaddam. (2024). Hydrogen energy systems: Technologies, trends, and future prospects. Science of The Total Environment. https://doi.org/10.1016/j.scitotenv.2024.173622.

[2] Althiyabi, Theyab & Qureshi, M. Rizwan. (2021). Predefined Project Scope Changes and its Causes for Project Success. International Journal of Software Engineering & Applications. 12. 45-56. 10.5121/ijsea.2021.12304.

[3] Ambarita, E.E., Karlsen, A., Scibilia, F. et al. (2024). Industrial digital twins in offshore wind farms. Energy Inform. https://doi.org/10.1186/s42162-024-00306-6

[4] Angus MacLeod21 (2023). COMBINED VALUE ASSURANCE PRESENTATION OF CAPITAL PROJECTS BY FRONT-END LOADING.pdf. https://www.slideshare.net/slideshow/combined-value-assurance-presentation-of-capital-projects-by-frontend-loadingpdf/262162465

[5] Bassey, Kelvin & Aigbovbiosa, Jolly & Agupugo, Chijioke. (2024). Risk Management Strategies in Renewable Energy Investment. 11. 138-148. 10.5281/zenodo.13311076.

[6] Chen Y, Dong S, Qian S, Chung K. 2024 Impact of oil price volatility and economic policy uncertainty on business investment - Insights from the energy sector. Heliyon.Feb 15;10(5):e26533. doi: 10.1016/j.heliyon. 2024.e26533. PMID: 38455578; PMCID: PMC10918019.

[7] Drew A. Carey, Dara H. Wilber, Lorraine B. Read, Marisa L. Guarinello, Matthew Griffin, and Steven Sabo. (2020). Effects of the Block Island Wind Farm on Coastal Resources: Lessons Learned. https://doi.org/10.5670/oceanog.2020.407

[8] EFInA. (2024). Policy Advocacy & Stakeholder Engagement Manager. https://efina.org.ng/publication/policy-advocacy-stakeholder-engagement-manager/

[9] ENI. (2024). Kashagan, offshore oil and gas in Kazakhstan. Retrieved from https://www.eni.com/en-IT/actions/global-activities/kazakhstan/kashagan.html

[10] Equinor. (2023). Johan Sverdrup. https://www.equinor.com/energy/johan-sverdrup

[11] GACD, (2024). Engaging with policymakers. https://www.gacd.org/resources/researchers-and-students/stakeholder-engagement/engaging-with-policymakers

[12] Gitelman, L., Kozhevnikov, M., & Visotskaya, Y. (2023). Diversification as a Method of Ensuring the Sustainability of Energy Supply within the Energy Transition. Resources, 12(2), 19. https://doi.org/10.3390/resources12020019

[13] Haghshenas, Amirashkan & Hasan, Agus & Osen, Ottar & Mikalsen, Egil. (2023). Predictive digital twin for offshore wind farms. Energy Informatics. 6. 10.1186/s42162-023-00257-4.

[14] Hashish, M. S., Hasanien, H. M., Ji, H., Alkuhayli, A., Alharbi, M., Akmaral, T., Turky, R. A., Jurado, F., & Badr, A. O. (2023). Monte Carlo Simulation and a Clustering Technique for Solving the Probabilistic Optimal Power Flow Problem for Hybrid Renewable Energy Systems. Sustainability, 15(1), 783. https://doi.org/10.3390/su15010783

[15] Helana Scheepers, Stuart McLoughlin, Ravinda Wijesinghe. (2022). Aligning stakeholders perceptions of project performance: The contribution of Business Realisation Management. International Journal of Project Management. https://doi.org/10.1016/j.ijproman.2022.03.002.

[16] Iain Todd, Darren McCauley. (2021). Assessing policy barriers to the energy transition in South Africa. Energy Policy. https://doi.org/10.1016/j.enpol.2021.112529.

[17] iCert(2024), PROJECT SCOPE MANAGEMENT AND ITS BENEFITS: What is Project Scope? https://www.icertglobal.com/project-scope-management-and-its-benefits/detail

[18] IEA (2024). Clean energy is boosting economic growth. https://www.iea.org/commentaries/clean-energy-is-boosting-economic-growth

[19] IEA. (2023). Enhancing infrastructure can help boost Denmark's clean energy investment. https://www.iea.org/news/enhancing-infrastructure-can-help-boost-denmark-s-clean-energy-investment.

[20] IEA (2020), Germany 2020, IEA, Paris https://www.iea.org/reports/germany-2020, Licence: CC BY 4.0

[21] IEA. (2024). World Energy Investment 2024: Overview and key findings. https://www.iea.org/reports/world-energy-investment-2024/overview-and-key-findings

[22] Imarticus. (2023). Scenario Analysis for Risk Assessment: Quantifying the Impact of Uncertainties. https://imarticus.org/blog/scenario-analysis-for-risk-assessment-quantifying-the-impact-of-uncertainties/

[23] IRENA. (2024). Key Enablers to Triple Renewables by 2030: Finance. https://www.irena.org/News/articles/2024/Aug/Key-Enablers-to-Triple-Renewables-by-2030-Finance

[24] IRENA (2024), Green hydrogen strategy: A guide to design, International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/Jul/IRENA_Green_hydrogen_strategy_design_2024.pdf

[25] Johansen, Katinka. (2021). Wind Energy in Denmark: A Short History [History]. IEEE Power and Energy Magazine. 19. 94-102. 10.1109/MPE.2021.3057973.

[26] Kirillova, Nadezda & Pukala, Ryszard & Janowicz-Lomott, Marietta. (2021). Insurance Programs in the Renewable Energy Sources Projects. Energies. 14. 6802. 10.3390/en14206802.

[27] Klimaitienė, Rūta & Derengovska, Eva & Rudzioniene, Kristina. (2020). APPLICATION OF KEY PERFORMANCE INDICATORS TO IMPROVE THE EFFICIENCY OF MONITORING OF THE ORGANISATION'S ACTIVITIES: THEORETICAL APPROACH. 25. 218-233. 10.13165/PSPO-20-25-20.

[28] Lawrence Berkeley National Laboratory. (2024). Large-scale wind and solar. Retrieved from https://emp.lbl.gov/news/larg-e-scale-wind-and-solar?

[29] Lawrence Susskind, Jungwoo Chun, Alexander Gant, Chelsea Hodgkins, Jessica Cohen, Sarah Lohmar. (2022). Sources of opposition to renewable energy projects in the United States. Energy Policy. https://doi.org/10.1016/j.enpol.2022.112922.

[30] Lv Y (2023) Transitioning to sustainable energy: opportunities, challenges, and the potential of blockchain technology. Front. Energy Res. 11:1258044. doi: 10.3389/fenrg.2023.1258044

[31] M. Abolghasemian , M. R. Nasiri Jan Agha, M. Vaseei, A. Pourghader Chobar, U. M. Modibbo. (2024). A Monte Carlo simulation to identify the effect of delays in construction project scheduling. International Journal of Applied Operational Research. http://ijorlu.liau.ac.ir/article-1-665-en.pdf

[32] M.Saleh, Hosam & I.Hassan, Amal. (2024). The challenges of sustainable energy transition: A focus on renewable energy. Applied Chemical Engineering. 7. 2084. 10.59429/ace.v7i2.2084.

[33] Madhushree Menon. (2023). 5 key elements of project management and planning. https://www.rocketlane.com/blogs/5-elements-of-project-planning

[34] Mohanasundaram, Jayachandran & Gatla, Ranjih & Flah, Aymen & Milyani, Ahmad & Milyani, Hisham & Blažek, Vojtěch & Prokop, Lukas & Kraiem, Habib. (2024). Challenges and Opportunities in Green Hydrogen Adoption for Decarbonizing Hard-to-Abate Industries: A Comprehensive Review. IEEE Access. PP. 1-1. 10.1109/ACCESS.2024.3363869.

[35] Mona A. ElBannan, Gunter Löffler. (2024). How effectively do green bonds help the environment? Journal of Banking & Finance. https://doi.org/10.1016/j.jbankfin.2023.107051.

[36] Munachi Chikodili Ugwu, Adefolake Olachi Adewusi, & Naomi Emeka Nwokolo (2024).

THE ROLE OF PUBLIC-PRIVATE PARTNERSHIPS IN BUILDING CLEAN ENERGY INFRASTRUCTURE IN THE UNITED STATES AND NIGERIA. International Journal of Management & Entrepreneurship Research. 10.51594/ijmer.v6i4.984

[37] Nirav Rashmikant Goda, Nishikant Jha. (2022). The Role Of Insurance In Promoting Sustainable Development: Challenges And Opportunities. Journal of Survey in Fisheries Sciences.

[38] Pierre-Olivier Gourinchas, Gregor Schwerhoff, and Antonio Spilimbergo. (2024). 24-4 Energy transition: The race between technology and political backlash. https://www.piie.com/sites/default/files/2024-03/wp24-4.pdf

[39] Omega 365. (2023). A strategic approach to offshore completion. https://www.omega365.com/inside/case-study-the-johan-sverdrup-field-31251 Andrew Fawthrop (2020). Digital twins are propelling the oil and gas industry into the future of asset optimisation. https://www.nsenergybusiness.com/analysis/digital-twins-oil-gas/?cf-view

[40] Prescient Investment Management (2024). Navigating the twin challenges facing SA's renewable energy programme.https://www.prescient.co.za/news-and-resources/press-articles/navigating-the-twin-challenges-facing-sa-s-renewable-energy-programme/

[41] Qazi, A. and Simsekler, M.C.E. (2021), "Risk assessment of construction projects using Monte Carlo simulation", International Journal of Managing Projects in Business, Vol. 14 No. 5, pp. 1202-1218. https://doi.org/10.1108/IJMPB-03-2020-0097

[42] Qusay Hassan, Sameer Algburi, Aws Zuhair Sameen, Hayder M. Salman, Marek Jaszczur. (2024). Green hydrogen: A pathway to a sustainable energy future. International Journal of Hydrogen Energy. https://doi.org/10.1016/j.ijhydene.2023.08.321.

[43] Ren, Kangze. (2023). "Corrosion case study on pipeline". Corrosion Research. 9. https://ir.lib.uwo.ca/nserc_create_sci_institute/9

[44] Sanyaolu, Temitope & Adeleke, Adams & Efunniyi, & Akwawa, Lucy & Azubuko, Chidimma. (2023). Stakeholder management in IT development projects: Balancing expectations and deliverables.. 5. 1239-1255. 10.51594/ijmer.v5i12.1535.

[45] Shakeri H, Khalilzadeh M. (2020). Analysis of factors affecting project communications with a hybrid DEMATEL-ISM approach (A case study in Iran). Heliyon.. doi: 10.1016/j.heliyon.2020.e04430. PMID: 32793821; PMCID: PMC7408334.

[46] Terrascope. (2024). Which sector is responsible for the largest greenhouse gas emissions? Retrieved from https://www.terrascope.com/blog/which-sector-is-responsible-for-the-largest-greenhouse-gas-emissions

[47] The Paris Agreement? https://unfccc.int/process-and-meetings/the-paris-agreement

[48] United State Environmental Protection Agency (EPA) (2023). Summary of Inflation Reduction Act provisions related to renewable energy. https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy

[49] Vedhanarayanan B and Seetha Lakshmi KC (2024) Beyond lithium-ion: emerging frontiers in next-generation battery technologies. Front. Batteries Electrochem. 3:1377192. doi: 10.3389/fbael.2024.1377192

[50] World Economic Forum. (2020). CLIMATE ACTION: 3 charts that show countries and sectors with the highest greenhouse gas emissions. https://www.weforum.org/stories/2020/12/climate-change-greenhouse-gas-emissions-environment-paris-agreement/#:~:text=You%20can%20view%20an%20interactive,on%20a%20relatively%20high%20level.

[51] World Economic Forum, WEF. (2023). Forum Institutional: Why carbon capture is key to

reaching climate goals. https://www.weforum.org/stories/2023/10/why-carbon-capture-is-key-to-reaching-climate-goals/

[52] World Economic Forum. (2023). Fostering Effective Energy Transition 2023: Germany's Profile. Retrieved from https://www.weforum.org/publications/fostering-effective-energy-transition-2023/in-full/germany/.

[53] World of Renewables (2024). Case Study: Hornsea One Offshore Wind Farm. https://worldofrenewables.com/case-study-hornsea-one-offshore-wind-farm/

[54] Yale Environment 360. (2022). Examining IRA’s impact on clean energy future. Retrieved from https://environment.yale.edu/news/article/examining-iras-impact-clean-energy-future

[55] Yazdi, M., Zarei, E., Adumene, S., & Beheshti, A. (2024). Navigating the Power of Artificial Intelligence in Risk Management: A Comparative Analysis. Safety, 10(2), 42. https://doi.org/10.3390/safety10020042

[56] Youngjun (2023). Transitioning to sustainable energy: opportunities, challenges, and the potential of blockchain technology. https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2023.1258044/full

[57] Zahidah Jahidi, Mohd Suhaimi Mohd-Danuri , Saipol Bari Abd-Karim. (2024). Regulatory Non-Compliance and Its Limitations Towards Risk Minimisation in the Oil and Gas Industry. Journal of Project Management Practice. https://ejournal.um.edu.my/index.php/JPMP/

[58] 100RE Lab. (2023). Green Hydrogen Market: Potentials and Challenges. https://100re-map.net/green-hydrogen-market-potentials-and-challenges/