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Developing Guarantee of Origin Scheme as Part of Regulatory Framework to Enable Innovation in Neom's Green Hydrogen Ecosystem: Practical Insights

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Abstract

This paper explores the development of a Guarantee of Origin (GoO) scheme within Neom's green hydrogen ecosystem, aiming to enhance innovation and sustainability in the renewable energy sector. Through qualitative research, including in-depth interviews with 15 experts in renewable energy policy and green hydrogen, the study provides a comprehensive analysis of the challenges, opportunities, and strategic implications of implementing a GoO scheme. Key findings indicate a diversity of approaches to GoO implementation, emphasizing the need for a balance between standardization and flexibility, the importance of robust verification and transparency, and the necessity of aligning with international standards. The study recommends developing a GoO framework that combines consistent international practices with adaptability to local dynamics, underpinned by stringent verification processes and collaborative problem-solving. Future research directions include comparative studies of global GoO schemes, technological advancements in GoO implementation, long-term impact assessments, and the evolution of international policy frameworks. The paper concludes that establishing a GoO scheme in Neom's green hydrogen project is crucial for market competitiveness, consumer trust, and investment attraction, with broader implications for global renewable energy initiatives. This research contributes to the discourse on renewable energy regulation and sustainable innovation, offering practical insights and recommendations for policymakers, industry stakeholders, and researchers in the field.

Keywords: *Guarantee of Origin (GoO), Neom's Green Hydrogen Ecosystem.*

1. Introduction

The advent of green hydrogen as a cornerstone of the global energy transition marks a critical juncture in our pursuit of sustainable solutions. At the forefront of this transformative shift is Neom, a visionary city in Saudi Arabia, poised to establish a new paradigm in renewable energy through its groundbreaking green hydrogen project. This paper examines the pivotal role of a Guarantee of Origin (GoO) scheme within Neom's

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regulatory framework, exploring its potential to drive innovation and shape the future of the green hydrogen ecosystem.

The significance of green hydrogen in today's energy discourse cannot be overstated. Produced through the electrolysis of water using renewable energy sources, green hydrogen presents a carbon-neutral alternative that addresses the twin challenges of climate change and energy security. Its potential to decarbonize industries notoriously difficult to electrify, including transportation and heavy manufacturing, positions it as a game-changer in our global energy narrative.

Neom's green hydrogen project, a collaborative endeavor between ACWA Power, Air Products, and NEOM Co., epitomizes this shift. Set to host the world's largest green hydrogen plant, Neom is not just a regional beacon of innovation but also a global trailblazer. The project's success could redefine renewable energy standards and demonstrate the feasibility of large-scale green hydrogen production, leveraging Saudi Arabia's abundant solar and wind resources.

However, integrating green hydrogen into the global energy mix is a complex challenge, replete with regulatory, technical, and economic obstacles. A key hurdle is the absence of a robust regulatory framework that can foster innovation while ensuring sustainability and market integrity. This research, therefore, focuses on the development of a GoO scheme, a critical tool in verifying the green credentials of hydrogen production, which is essential for building trust among consumers and investors alike.

In navigating these uncharted waters, this paper aims to offer practical insights and a structured pathway for the implementation of the GoO scheme within Neom's green hydrogen project. By doing so, it seeks to contribute not only to the success of Neom's ambitious endeavor but also to the broader discourse on renewable energy, offering a blueprint for other green hydrogen initiatives globally.

2. Literature Review:

2.1 Regulatory Frameworks in Renewable Energy

The global shift to renewable energy is significantly influenced by evolving regulatory frameworks, which are instrumental in accelerating the adoption of renewable technologies (Tzankova., 2020). These frameworks vary widely, from feed-in tariffs, which have been highly successful in countries like Germany in incentivizing renewable energy production, to tax incentives and carbon pricing mechanisms that have been effective in Nordic countries (Abdmouleh et al., 2015). The adaptability of these regulations is crucial, as exemplified by the European Union’s Renewable Energy Directive (RED), which continually evolves to incorporate emerging technologies and market changes (European Commission, 2021). The RED's approach demonstrates the importance of dynamic, responsive policy-making in accommodating the rapid advancements and varying needs of the renewable sector.

2.2 Guarantee of Origin Schemes: Global Perspectives

Guarantee of Origin (GoO) schemes, critical in certifying the sustainability of renewable energy, differ in their implementation across regions. The European model is noted for its success in enhancing transparency and fostering consumer trust (Gangjee., 2017). These schemes operate on the principles of traceability and verifiability, setting a precedent for other regions. However, the challenges, including the risk of double counting and maintaining the integrity of the certification process, are significant considerations. Comparatively, the US Renewable Energy Certificate (REC) system is market-based and varies by state, creating a more fragmented but flexible approach (Abad and Dodds, 2020). The International Renewable Energy Certificate (I-REC) system, while offering global applicability, faces the challenge of maintaining uniformity across diverse

regulatory environments (Snoeck, 2019). These varied approaches reflect the complexity of implementing GoO schemes and the need for region-specific adaptations.

2.3 Innovation in Green Hydrogen

The intersection of regulatory frameworks and innovation in the green hydrogen sector is an emerging focus of research. Supportive regulatory environments, such as those in the European Union, are found to significantly boost innovation in green hydrogen production. This is evident in the EU's Hydrogen Strategy, which provides funding, sets targets, and establishes standards for the sector (Kovač et al, 2021). The strategy underscores the symbiotic relationship between regulation and innovation, where regulatory support is not just a facilitator but also a driver of technological advancements. Examples of this dynamic can be seen in initiatives like Norway's hydrogen-powered ferries and Germany's focus on hydrogen-powered trains, which illustrate the direct impact of policy support on green hydrogen technology development (Elavarasan et al, 2022).

2.4 Relevance to Neom’s Green Hydrogen Ecosystem

Adapting global insights to Neom’s unique context requires an innovative, tailored approach. While models like the European GoO provide a successful blueprint, Neom’s scheme must be customized to align with Saudi Arabia's renewable energy goals and market dynamics (Cheng and Lee, 2022). This involves not only replicating successful elements but also innovating to address local challenges, such as integrating the GoO scheme with existing energy infrastructure in the region (Hassan et al , 2023). For instance, leveraging Saudi Arabia's existing oil and gas infrastructure for hydrogen transportation and storage could provide a unique synergy, enhancing the feasibility and efficiency of the green hydrogen project. Furthermore, the GoO scheme in Neom has the potential to enhance the project’s reputation, attract investors, and ensure quality and transparency in green hydrogen production, thereby setting new standards in innovation and sustainability in the hydrogen sector (ibid).

This literature review highlights the importance of robust regulatory frameworks and GoO schemes in fostering innovation in the green hydrogen sector. Drawing lessons from global practices, particularly the nuanced approaches seen in EU's and other regions' policies, and tailoring them to Neom’s unique environment, the project can achieve its sustainability goals while setting new benchmarks in green hydrogen innovation. The next step involves a detailed exploration of Neom’s current regulatory landscape, identifying specific areas for integrating and optimizing the GoO scheme to maximize its impact and efficiency.

3. Research Methodology:

This study adopted a qualitative research methodology, centered around in-depth interviews with experts in the field of renewable energy, to explore the development and effectiveness of Guarantee of Origin (GoO) schemes in green hydrogen ecosystems (Rosenthal, 2016).

3.1 Research Design

The study was exclusively qualitative, designed to gain a deep understanding of the complexities, challenges, and best practices associated with GoO schemes. This approach allowed for a nuanced exploration of expert perspectives, providing rich, detailed data that is particularly suited to the exploratory nature of this research (Taylor et al, 2015).

3.2 Sampling and Data Collection

Expert Interviews: A total of 15 interviews were conducted with a diverse group of experts. These participants were selected based on their extensive knowledge and

experience in renewable energy, policy development, and environmental certification systems. The group included academic researchers, policy analysts, and professionals from international renewable energy organizations (Moser and Korstjens, 2018).

Interview Structure: The interviews were semi-structured, allowing for guided conversations while providing the flexibility for experts to share insights beyond the scope of the initial questions. This format facilitated an in-depth exploration of each expert's unique perspectives on GoO schemes (Turner and Hagstrom, 2022).

3.3 Data Analysis

Thematic Analysis: The interview data were analyzed using thematic analysis, a method well-suited to qualitative research. This involved transcribing the interviews, coding the data, and identifying key themes and patterns. The analysis focused on extracting insights related to the implementation challenges, success factors, and practical considerations of GoO schemes in the context of green hydrogen (Braun & Clarke, 2017).

3.4 Ethical Considerations

All interviews were conducted in accordance with ethical research standards. Participants were informed of the study's purpose, their rights as participants, and measures taken to ensure confidentiality and anonymity. Consent was obtained from all participants for the use of their insights in this research (Ainscough et al, 2018).

3.5 Limitations

The study acknowledges the inherent limitations of a qualitative approach. The findings are based on a limited number of expert opinions and may not capture all possible perspectives on GoO schemes. Additionally, the absence of quantitative data means that the conclusions are more interpretive and may require further empirical validation (Munthe-Kaas et al, 2019).

4. Research Findings and Discussion:

This expanded section presents a detailed analysis of the insights gathered from the 15 expert interviews, focusing on the intricacies of developing Guarantee of Origin (GoO) schemes for green hydrogen, with comparisons to existing models and a deep dive into the implications for Neom’s green hydrogen project.

4.1 Comprehensive Analysis of Expert Insights

A. Varied Interpretations and Approaches to GoO: The interviews revealed diverse opinions on the design and implementation of GoO schemes. Some experts advocated for a strict, standardized approach to ensure consistency and reliability across different regions. Others emphasized the need for flexibility to accommodate the unique aspects of each green hydrogen project, suggesting that a one-size-fits-all model might be ineffective. This divergence in viewpoints underscores the challenge in striking a balance between uniformity and adaptability in GoO scheme development (Lebrouhi et al, 2022).

B. Emphasizing Transparency and Verification: A unanimous agreement among experts was the paramount importance of transparency and stringent verification mechanisms. This consensus aligns with the practices observed in successful GoO schemes in the European Union, where robust verification processes have been key to maintaining the integrity and credibility of renewable energy certifications. Experts cautioned that without rigorous verification, GoO schemes risk becoming mere formalities, losing their value in assuring the renewable origin of green hydrogen (Greenwood, 2017).

C. Integration with International Standards: The need for harmonizing Neom’s GoO scheme with international standards was another critical point raised. Experts referred to the Renewable Energy Directive (RED) in the EU as a potential model, noting its success

in creating a unified market for renewable energies. However, they also highlighted the challenge of aligning with such standards while catering to local market dynamics and regulatory environments (Pototschnig and Conti, 2021).

D. Implementation Challenges and Solutions: The complexities of implementing GoO schemes were a major focus of the discussions. Challenges such as regulatory coordination, technological infrastructure for tracking and certification, and international cooperation were highlighted. Experts suggested looking at the implementation strategies used in the EU and adapting those strategies to fit the specific needs and context of Neom's green hydrogen ecosystem (Abad and Dodds, 2020).

4.2 Comparative Analysis with Existing Models

A. Learning from the EU's Experience: The European Union's GoO system offers valuable lessons, particularly in terms of its comprehensive approach to certification and market integration. However, experts noted that the EU model, while successful, might not be directly replicable in Neom's context due to different market and regulatory landscapes (Wallace and Pollack, 2020).

B. Adapting Best Practices to Local Context: The discussion emphasized adapting the successful elements of existing GoO models to the local context of Neom. This adaptation involves not just replicating successful strategies but also innovating to overcome local challenges, such as integration with Saudi Arabia's existing energy infrastructure and regulatory frameworks (Amran at al, 2020).

4.3 Deep Dive into Strategic Implications for Neom

A. Establishing Market Trust and Credibility: The effective implementation of a GoO scheme in Neom is crucial for establishing the credibility of its green hydrogen in the global market. This credibility is essential for attracting investments and customers, particularly in international markets where environmental sustainability is a key decision-making factor(Saygin and Lee, 2023).

B. Balancing Standardization and Flexibility: The strategic importance of balancing standardization with flexibility emerged as a key theme. Neom's GoO scheme needs to adhere to international best practices to ensure market acceptance while being adaptable enough to respond to local needs and technological advancements (Hjeij et al, 2022).

C. Navigating Regulatory and Technological Landscapes: The successful development of a GoO scheme requires navigating complex regulatory and technological landscapes. This involves coordinating with various regulatory bodies, ensuring technological alignment for tracking and certification, and establishing international partnerships for cross-border recognition of GoO certifications (Hassan et al, 2023).

In Summary, the findings from expert interviews provide a comprehensive understanding of the factors critical to the success of a GoO scheme in Neom's green hydrogen project. The path forward involves integrating the best practices from existing models, ensuring rigorous transparency and verification, and aligning the scheme with international standards. This approach will not only validate Neom's sustainability claims but also position its green hydrogen project as a model of innovation and environmental stewardship in the renewable energy sector.

5. Implications of Developing a Guarantee of Origin Scheme for Neom's Green Hydrogen Ecosystem

This section discusses the broader implications of the study's findings, particularly focusing on how the development and implementation of a Guarantee of Origin (GoO) scheme can impact Neom's green hydrogen project, influence regulatory policies, and foster sustainable innovation in the renewable energy sector.

5.1 Implications for Neom’s Green Hydrogen Ecosystem

A. Enhancing Market Competitiveness: The introduction of a robust GoO scheme could significantly enhance the market appeal and competitiveness of Neom's green hydrogen. By certifying the renewable origin and sustainability of its hydrogen, Neom could tap into emerging markets where eco-conscious consumers and industries are increasingly prevalent (Saygin and Lee, 2023).

B. Fostering Consumer Trust: A credible GoO scheme acts as a seal of quality and sustainability, which is crucial in building consumer trust. This trust is not only vital for market acceptance but also for long-term customer relationships, contributing to the overall success and sustainability of Neom's green hydrogen ecosystem (ibid).

C. Attracting Investment: Demonstrating commitment to sustainability through a GoO scheme can attract investments from entities prioritizing environmental responsibility. This is particularly relevant as global financial trends shift towards green investments (ibid).

5.2 Implications for Regulatory Policies

A. Setting a Precedent for Green Hydrogen Regulation: The development of a GoO scheme in Neom could set a precedent for how green hydrogen is regulated and certified globally. It provides a model that other regions and countries could adopt or adapt, contributing to the standardization of green hydrogen certification (JONES et al, 2021).

B. Influencing Global Policy Dialogues: Neom’s approach to regulating green hydrogen through a GoO scheme could influence policy dialogues at international levels. By demonstrating the feasibility and benefits of such a scheme, Neom can play a pivotal role in shaping global policies around renewable energy certification (Bisong, 2019).

5.3 Implications for Sustainable Innovation

A. Driving Technological Advancements: The requirement for accurate tracking and certification of green hydrogen as part of the GoO scheme can spur technological innovations. This includes advancements in blockchain for tracking energy origins, improved methods for measuring environmental impact, and enhanced systems for data management and transparency (Mergelina and Lemus-Aguilar, 2021).

B. Promoting Sustainable Practices: Implementing a GoO scheme underlines the importance of sustainability in the energy sector. It encourages producers to adopt more sustainable practices, not only in hydrogen production but across the entire energy value chain (Hamburger, 2023).

D. Broadening the Impact of GoO Schemes

The implications of developing a GoO scheme for Neom’s green hydrogen project extend far beyond the immediate context. They contribute to shaping the future landscape of global renewable energy markets, influence regulatory frameworks, and drive sustainable innovation(Lebrouhi et al, 2022). The successful implementation of such a scheme in Neom has the potential to catalyze a broader shift towards sustainability and transparency in the renewable energy sector, setting new benchmarks and inspiring similar initiatives worldwide.

6. Conclusion

This paper has explored the development of a Guarantee of Origin (GoO) scheme as part of the regulatory framework to enable innovation in Neom's green hydrogen ecosystem. Drawing on expert insights and comparative analyses, it has highlighted the complexities, challenges, and strategic implications of implementing such a scheme. As we conclude,

we summarize the key findings, outline practical recommendations, and propose directions for future research.

6.1 Summary of Key Findings

- Diversity in Approaches to GoO: There is a range of perspectives on how best to implement GoO schemes, emphasizing a balance between standardization and adaptability.
- Importance of Transparency and Verification: The success of a GoO scheme hinges on robust verification processes and transparency, ensuring the credibility of green hydrogen claims.
- Alignment with International Standards: Harmonizing Neom's GoO scheme with international standards is crucial for global market integration and acceptance.
- Navigating Implementation Challenges: Addressing the multifaceted challenges in GoO implementation requires collaborative, innovative approaches tailored to local contexts.

6.2 Practical Recommendations

Based on these findings, the following recommendations are proposed for the development of Neom's GoO scheme:

- Adopt a Flexible Yet Standardized Approach: Develop a GoO framework that is consistent with international best practices but flexible enough to adapt to local market dynamics and technological advancements.
- Prioritize Transparency and Rigorous Verification: Implement stringent verification processes to ensure the integrity of the GoO scheme, building trust among consumers and stakeholders.
- Seek Alignment with Global Standards: Actively engage in international policy dialogues to align Neom's GoO scheme with global certification standards.
- Foster Collaborative Solutions to Challenges: Encourage collaboration among industry players, regulators, and technology providers to navigate the complexities of GoO scheme implementation.

6.3 Future Research Directions

Further research is needed to continue advancing the field. Potential areas of focus include:

- Comparative Studies of GoO Schemes: Investigate GoO schemes in different regions and industries to identify best practices and innovative approaches that could be applied to Neom's context.
- Technological Innovations in GoO Implementation: Explore emerging technologies, such as blockchain, for their potential to enhance the tracking, verification, and management of GoO schemes.
- Impact Assessment of GoO Schemes: Conduct longitudinal studies to assess the long-term impacts of GoO schemes on market dynamics, consumer behavior, and environmental outcomes.
- Policy Development and Global Standards: Examine the evolution of international policy frameworks governing green hydrogen to inform future regulatory developments.

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