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Investigation on the Social Impact of Green Hydrogen Adoption: Case Study of Energy Transition in Oman

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Abstract

The energy transition in Oman considers green hydrogen as an initial element for its orderly transition to a net zero emission national strategy released in November 2022, in alignment with the Paris Agreement for zero carbon emissions by the year 2050. Considering this goal, the Oman government introduced five guidelines to fully establish the energy transition: energy system cost, environmental impact, social impact, economic impact, and security of supply. This study focuses on the social impact, where it aims to investigate the social impact of green hydrogen initiatives in Oman, measuring the green hydrogen technology adoption from three different aspects: public acceptance, private sector and investor trust, and infrastructure readiness. This study utilised a questionnaire approach for a random population to understand the social perceptions of the community. This study on the social impact in Oman seeks critical findings that influence public behaviours and beliefs toward green hydrogen technology, investor willingness and private sector trust to participate in the field, and infrastructure impacts. The outcome of this research was evaluated to identify the current social impact in Oman and provide recommendations that attempt to support this energy transition.

Keywords: Green Hydrogen, Social Impact, Social Awareness, Social acceptation, Infrastructure, Investor Trust

Paper type – Research paper

1. Introduction:

The environment and natural resources are a crucial priority in the Oman vision for 2024, in which careful consideration is needed to strengthen the economy and boost productivity through

natural resources involving the development of non-traditional natural resources. This is essential to lower overhead expenses and, therefore, increase the effectiveness of economic sectors where this strategy should be implemented to promote environmental sustainability.

The Paris Agreement and its outcome demand to decarbonise and improve the entire economy towards environmentally friendly energy is becoming more important as the implications of worldwide climate change emerge become obvious. The Paris Agreement is a remarkable deal that runs in a positive direction to prevent catastrophic consequences that negatively impact lives and economies. This is a preliminary step toward solving a universal environmental issue that transcends territorial limitations, necessitating multinational cooperation and arranging measures across all levels. COP21, the United Nations Climate Change Conference, was held in Paris on 12 December 2015 to discuss climate change. The agreement long-term climate lowers emission levels of greenhouse gases globally to maintain a worldwide temperature rise at 2 °C alongside initiatives to limit it to 1.5 °C (United Nations Climate Change [UNFCCC], 2016). The Paris Agreement establishes a solid foundation that will guide global collaboration in the coming years. This leads to an era of zero emissions in the future. Governments have provided an enhanced transparency framework with the Paris Agreement beginning in 2024, requiring nations to openly report their progress and activities in addressing climate change, including any adjustment strategy implementation or any help given or received (UNFCCC, 2023; United Nations, 2023).

The global interest in fresh hydrogen technology development is growing because of the practical prescription for current uncertainties and to boost economic and energy stability. Hydrogen (H2) is a highly abundant substance throughout the earth and generally exists in water and organic substances in the environment. A single electron with a proton has an elemental structure. Although hydrogen is not easily accessible, it is found in various chemical substances, including hydrocarbons. Hydrogen has the maximum power density among chemical fuels. Because of this characteristic, it is utilised as an energy transporter and releases higher temperatures during burning than other fuels. It is considered to be a possible replacement for fossil fuels. Significant research is ongoing to develop hydrogen-generating systems. The restructuring of hydrocarbon fuels is an approach that is highly sophisticated and utilised. Significant progress has been made in various hydrogen-generating methods using renewable resources such as biomass and water to minimise reliance on fossil fuels. Given the increased focus on limiting greenhouse gas emissions, renewable resources are quickly beginning to show promise as alternative means of producing hydrogen (Holladay et al., 2009; Dawood et al., 2020; Ourya & Abderafi, 2023).

In the ultimate devotion and encouragement of His Majesty Sultan Haitham bin Tariq to enhance environmental sustainability and minimise the negative impacts of climate change, in conjunction with the Paris Agreement, the Sultanate of Oman is dedicated to achieving net zero emissions in the energy sector by the year 2050, which was declared a few weeks before COP27, the Sultanate of Oman's new climate commitment and its ambitious green hydrogen strategy (Ministry of Energy and Minerals, 2022), making it the third oil and gas producer country from the Middle East to announce its commitment to achieving net zero emissions by 2050, following Saudi Arabia and the United Arab Emirates in 2021.

The commitment was confirmed and supported by the release of The Sultanate of Oman's National Strategy for an Orderly Transition to Net Zero. The national plan explains the initiatives taken to achieve this goal. According to this publication, the primary sources of emissions in Brazil are the industrial sector, oil and gas, and transportation. Oman's nature and environment are well-endowed by its natural resource wealth that can assist in the transition, including more than 50000

km2 of undeveloped land, 3165 km of beaches, and excellent wind speeds exceeding 8 m/s. offers an outstanding opportunity to leverage its resources in developing a reliable and clean economy. Therefore, the International Energy Agency [IEA] published a comprehensive study on Renewable Hydrogen from Oman in June 2023. According to the analysis, by 2030, Oman ranks as the largest exporter in the Middle East and the sixth largest hydrogen exporter internationally, representing 61% of all Middle East hydrogen trade.

Through this commitment, Oman adopts different routes toward net zero by 2050, considering the following five objectives: environmental sustainability, energy system costs, economic impact, social impact, and supply security. The purpose of this research is to concentrate on the social impact of this determination to pursue a net zero pathway and transition to a green hydrogen economy, taking into account the social acceptance of the industry, employment opportunities, and citizen qualifications, as well as the degree of confidence investors and the private sector in the business future, and the readiness of the infrastructure to accommodate such green hydrogen transition.

2. Literature Review

With the growing concern about the damaging impacts of pollution-related and changes in the climate on ecosystems imposed by the global population continually growing and the Industrial Revolution, in addition to the expected petroleum resources (Ourya & Abderafi, 2023), various countries mutually agreed on the seriousness of decreasing energy-based greenhouse gas (GHG) emissions. To accomplish this, investigators and professionals should prioritise technological development to drive clean and renewable alternative energy sources. The Paris Agreement was embraced during the twenty-first session of the Conference of the Parties by the United Nations Framework Convention on Climate Change scheduled in Paris between 30 November and 13 December 2015 (United Nations, 2016), and the agreement's primary objective seems to be to minimise GHG emissions immediately to attain the ultimate average temperatures worldwide target of approximately 2 ◦C higher than pre-industrial times along with attempt initiatives to mitigate the rise of average temperature by 1.5 ◦C globally (Liu et al., 2020b). Targets are set to decrease the potential dangers and implementation of global warming throughout every country obligate to understand, make plans, and share ongoing efforts to accomplish it (Vrontisi et al., 2020).

Hydrogen offers a sustainable option for the decarbonised community movement, as a replacement for the current fossil fuel power generated once it develops utilising renewable energy sources given its zero-carbon release, excellent conversion rates, and substantial energy content. It provides adjustable abilities and high-energy conservation, making it easier to completely decarbonise the energy sector (Damman et al., 2021). According to the Hydrogen Council investigation (2021), by 2050, hydrogen-based energy utilisation projects account for 22% of the global cumulative energy demand and up to 80 gigatons of carbon dioxide releases, corresponding to 20% of the total mitigation measures. The transformational scenario is based on attaining net-zero emission levels by 2050, anticipating hydrogen technology to adopt an unprecedentedly positive approach. The progressive situation includes more cautious estimates of the implementation of hydrogen and the subsequent pollution reduction. Various government and industry agencies worldwide have concentrated on the possibilities for hydrogen to contribute to decarbonising the field of energy (ZEN, 2020). In inline with the above, Zhu & Wei (2022) emphasize that hydrogen could supplement or outperform renewable energy in various applications. More than 30 countries and territories have launched hydrogen roadmap strategies,

which indicate a hybrid of green and gray hydrogen while varying in direction, degree, and magnitude. Green hydrogen offers advantages as a solution to the current recession, although its implementation might prove challenging given its social and environmental effects and reliance on environmentally friendly production practices. In this respect, the social sciences using a careful evaluation of positive and negative aspects and their potential dangers might assist in smooth change and help minimise its impacts on society and the environment. Despite a considerable amount of scientific work on renewable energy, the social science investigation of green hydrogen is still in its early stages (Vallejos-Romero et al., 2022; Hanusch & Schad, 2021; Royston & Foulds, 2021).

2.1. Green Hydrogen Social Acceptability

Various stakeholder categories may be influenced either directly or indirectly by hydrogen initiatives that exhibit diverse public perspectives, understanding, assessments, behaviours, and ultimate support. As an illustration, whereas government officials might vote to encourage hydrogen, citizens may protest the construction of infrastructure and plants, whereas hydrogen using reservations occur by users regarding the expense or security hazards associated with using hydrogen. Huijts et al. (2012) elaborate that the acceptance range of hydrogen varies based on different category levels dealing with hydrogen initiatives. Studies on hydrogen perception provide an opportunity to discover what individuals feel regarding hydrogen energy system applications. This contributes to understanding end-user attitudes and boosting the social acceptance of unusual energy sources such as hydrogen. An individual, organisation, or group of persons with an interest in, or engagement with, and some time investment in a particular activity is considered a "stakeholder" (Ahmed et al., 2020; Emodi et al., 2021).

Currently, the public's judgment of green hydrogen suggests a lack of understanding of how it produces and the overall positive effects result from it (Ingaldi & Klimecka-Tatar, 2020), especially in different countries such as Eastern Europe, where hydrogen energy is underutilised and has insufficient infrastructure. Folks are hesitant and apprehensive, according to Flynn et al. (2013), and an awareness shortage among the public is usually observed in various situations once people have neutral or unfavourable attitudes. The public requested further details regarding the advantages and benefits of switching to this energy source. This supports the findings of Ono et al. (2019), who discovered that public acceptance and awareness are raised by discussing concepts of risk or confusion regarding the hazards involved with green hydrogen technologies (such as hydrogen refuelling stations). Emphasise how essential communication is to alleviate worries about this technology; hence, as individuals are knowledgeable, their thoughts are positive. However, investigations have demonstrated that the citizens' familiarity with green hydrogen is tenuous. Therefore, it is important to include several parties and institutions to produce shared arenas (Vallejos-Romero et al., 2022; Ingaldi & Klimecka-Tatar, 2020).

2.2. The Investor Trust and Private Sector Confidence in Green Hydrogen Projects

Hydrogen is currently gaining recognition as a viable option for use as an environmentally friendly power source. Authorities and corporations are confident that the hydrogen business offers incredible opportunities beyond national boundaries. Australia and Norway target rapidly developing Asian markets because of their enormous renewable energy opportunities (Taibi et al., 2018). Since the funding of such initiatives depends on hydrogen earnings from the consumer's sale, the hydrogen cost is still an essential variable in determining the rate deployment of electrolytic systems. Although the hydrogen roadmap is fully uncovered, according to Taibi et al. (2020), the European Commission has highlighted hydrogen as a primary investment, which is

considered a critical channel for all energy industries. for example, due to COVID-19, the government recommends allocating EUR 9 billion to hydrogen projects as part of its economic recovery strategy, with EUR 2 billion earmarked for global cooperation (Panah et al., 2022). Additionally, in July 2020, while establishing the European Hydrogen Strategy, the European Commission encouraged union countries to utilise green hydrogen to accomplish the union's target of becoming carbon-free by the year 2050, in which 57% of global investment expenditure comes from the European Union by 2030 (Okonkwo et al., 2021).

Massive investments in hydrogen have been launched worldwide, providing a crucial sustainable solution for multiple industries. The positive effects of hydrogen require being taken seriously immediate consideration owing to the swiftness of the worldwide decarbonisation target. However, for hydrogen to attain widespread distribution and growth through business initiatives, appropriate financial, infrastructural, and governmental support is still needed (Council, 2020).

2.3. Green Hydrogen Infrastructure

As the world is going toward a green energy shift, an expected increase in hydrogen demand will occur, which requires an expansion into the current infrastructure to facilitate accommodation. The limitations currently reside in whether hydrogen can be carried in large quantities responsibly, inexpensively, and safely, which is a requirement for its acceptance. The initial step in releasing the hydrogen economy is a secure, small, and cheap hydrogen storage technology source (Abe et al., 2019). Currently, the available infrastructure for hydrogen carrying includes pipelines, liquid hydrogen trucks, and gas trucks (Okonkwo et al., 2021). Countries throughout the earth are working hard to establish hydrogen infrastructure, which is important for the growth of the hydrogen sector.

3. Research Design and Method

The main research aspect is to make thoughtful judgments and record them as well as the outcomes, irrespective of the technique implemented. The goal of the research methodology is to be careful, reduce misconceptions, and generate results that reflect the real world as much as possible by excluding some of the underlying presumptions which impact the outcomes when we are not cautious. This research can be classified as exploratory and descriptive research, involving an overview of the literature and/or data accessible worldwide regarding the adoption of green hydrogen techniques. Exploratory analysis by developing assumptions of public reaction or identifying an issue with the current situation enables a more focused study, in which the outcome finding is helpful for our case. The descriptive examination focuses on the representation of the actual perspective of Oman communities toward green hydrogen initiatives, which contain data-gathering methods such as surveys, through which the researcher has no impact on the studied variables.

3.1. Data gathering

In this investigation, collecting information related to the research objectives, a questionnaire was structured to obtain societal feedback across large geographic areas, and a survey was sent to participants to provide their answers related to the social impact of the green hydrogen industry. A random unit's sample is selected from citizens or non-citizens from the age of 18 to 64 representing an Oman population for measurement reasons, where everyone has the same comparable likelihood of being chosen to represent the participants for this research, allowing the researcher to generalise the results of the outcomes to the entire population. Through this population, the researcher aims to address the diversity of subject matter to discover and investigate the societal implications of green hydrogen in Oman, along with the advantages,

difficulties, and actions necessary to achieve a stable and orderly transition to net-zero emissions by 2050. A total of 407 participants relied on a research questionnaire that analysed the input to share the study findings.

4. Data Analysis

4.1. The Connection Found from Survey Question Between Social Acceptance and Investor and Private Sector Trust

37% of the replies indicated the criticality of increasing public knowledge of green hydrogen and its benefits in various aspects. 25% of participants thought there was a demand to learn at an early phase about the advantages and prospects associated with green hydrogen usage, while 20% were undecided about this matter. However, 18% of respondents either do not care about green hydrogen or are unsure how important it is (Refer to Figure 1).

Figure 1 Importance of being informed at an early stage of Green Hydrogen in the country.

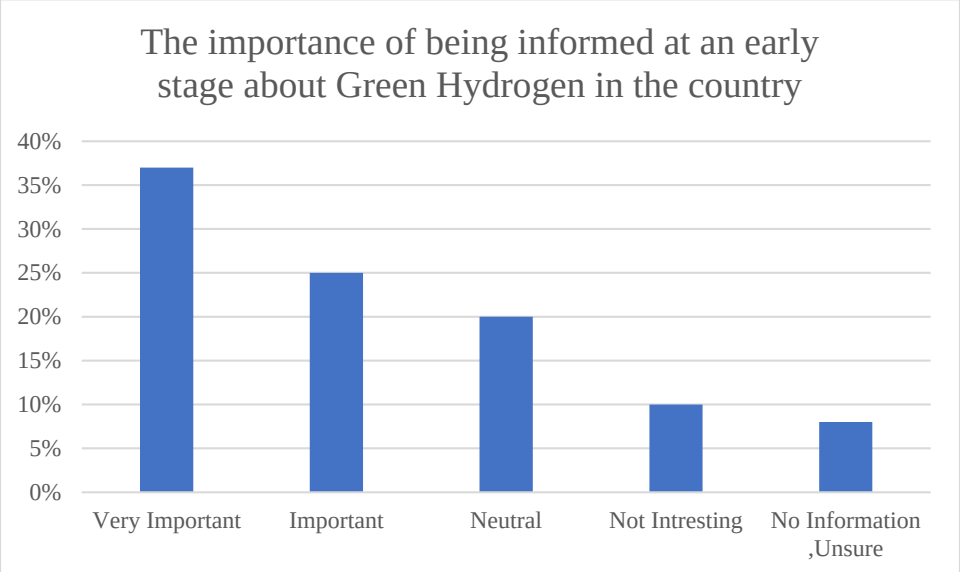

Table 1 Correlation analysis of trustworthy sources to gather information about green hydrogen technology and the impact of knowing about it in the early stages.

	Trustworthy sources of information on hydrogen energy and its technology	*The importance of knowing about hydrogen energy at early stages and being aware*
Trustworthy sources of information on hydrogen energy and its technology	1	
The importance of knowing about hydrogen energy at early stages and being aware	0.624276564	1

Table 1 represents the relationship between the two variables that shows the importance of gaining trustworthy sources of information from various sectors to enhance the awareness volume about hydrogen energy and its technology that impacts the Oman net zero transition. The correlation coefficient (0.6243) shows a strong positive relationship between the two variables to successfully establish the Oman emission strategy by 2050 and raise awareness of green hydrogen within society and industry.

4.2. The Connection Found in the Survey Question Between Social Acceptance and Infrastructure Readiness.

Table 2 describes the collaboration factor for investors and the private sector to encourage the development of proper infrastructure for green hydrogen. The data gathered indicate that, on average, respondents agree that a favourable public influence improves the process, supporting the private sector in attracting investors to seize and acquire essential resources and improve the production and utilisation of green hydrogen. The Majority hesitated to trust the private sector and investors because of unfinished projects in the country connected to this aspect.

Table 2 Descriptive Statistics of the factors that influence the private sector's readiness to invest in green hydrogen.

The factors that influence the readiness of the private sector to invest in green hydrogen	
Mean	3.024570025
Standard Error	0.070691175
Median	3
Mode	5
Standard Deviation	1.426140801
Sample Variance	2.033877586
Kurtosis	-1.321054529
Skewness	-0.002451197
Range	4
Minimum	1
Maximum	5
Sum	1231
Count	407

The survey participants indicated that 30% were concerned about retrofitting costs and complexities as an obstacle, and 20% agreed that the compatibility of the green hydrogen requirements is an industry-introducing challenge. Others (25%) support that capacity-limiting expansion to accommodate green hydrogen technology instalments and infrastructure is a primary challenge. The remaining respondents are unaware of the Oman readiness challenge to adopt green hydrogen technology and its aspects. (Refer to Figure 2).

Figure 2 The primary challenge for the green hydrogen technology infrastructure

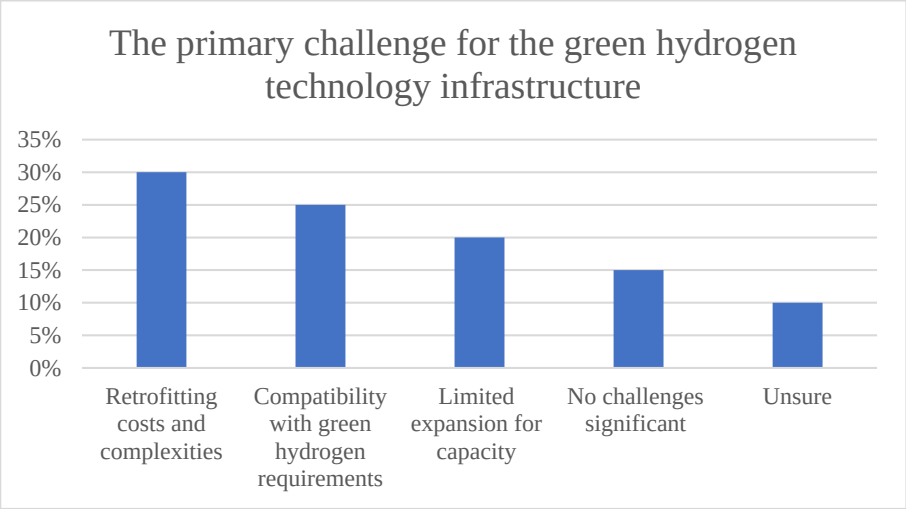

Table 3 Correlations Analysis about the impact of green hydrogen projects on the job opportunities creation through the introduction of green hydrogen projects

	The impact of green hydrogen production on the job security	*The following actions to implement the green hydrogen projects*
The impact of green hydrogen production on the job security	1	
The following actions to implement the green hydrogen projects	0.564378394	1

Table 3 illustrates the relationship between the increase in job demand in the Oman market and green hydrogen projects that provide new working opportunities for Omani residents to enhance the economy and balance the ecosystem. The extraction, storage, and export of green hydrogen are driven faster by better infrastructure, thereby increasing the national income and allowing for investment in better technologies. An extremely moderately favourable association between the two parameters was observed using the correlation coefficient (0.5644).

5. Findings

5.1. Age and Education Background Effects

The results demonstrate that younger participants (age 24-34) had a better understanding of the Paris Agreement and the National Net Zero Emission Transition Strategy, where a considerable positive relationship was found between age and awareness of hydrogen technologies (p-value < 0.05). In their study on the social acceptance of green hydrogen in Germany, Häußermann et al. (2023) noticed significant variations in social acceptance between age groups, with older adults being more familiar with hydrogen than youngsters. However, this finding does not apply to Oman, as our research found that the youth were more familiar with green hydrogen. Both the German study and this finding agree that individual educational backgrounds have some impact on familiarity with green hydrogen technologies. Lee et al. (2021) highlights that active education enhances the likelihood of a person's hydrogen technology purchase choice.

5.2. Trust and Green Hydrogen Acceptance

77% of the research participants considered the Government Sector as a trustworthy source of information on energy technologies as their first source of trust, or within the first three sources, following the Educational and Research Institution. Häußermann et al. (2023) research concluded that the research participant's significant trustworthy institutions for green hydrogen acceptance were the governments, science, and media. Moreover, Kim et al. (2018) emphasised the protective role that governments play in raising the social acceptance of renewable technology as a reliable source.

5.3. The Role of Communication in Green Hydrogen

The positive evaluations of green hydrogen's dependability and safety are strongly related to the importance placed on early knowledge of hydrogen, which refers to a tendency (p-value < 0.05). People who recognise the necessity of an initial knowledge of green hydrogen projects tend to be more driven to believe in the reliability of the technology. This relationship between knowledge and opinions shows that knowledgeable people are likely to have a promising view of green hydrogen. Hienuki et al. (2019) discussed the role of communication in raising public knowledge and acceptance of green hydrogen initiatives, wherein educating participants strengthened green hydrogen acceptance. Smaragdakis et al. (2020) mentioned that customers' lack of knowledge about fuel-cell hydrogen vehicles prevented them from purchasing cars.

5.4. Social Acceptance and Willingness to Invest

According to the relationship between Oman citizens' favourable opinions of green hydrogen and their prior experience with Oman's national net-zero emission transition strategy, a Pearson correlation coefficient of 0.278 supports this positive relationship, where those in the business community are more willing to participate if the technology is seen enthusiastically by the public. A positive awareness of green hydrogen makes it more likely that the private sector will investigate funding-associated initiatives. Market uncertainty is an investor concern regarding green hydrogen projects and technology, and according to Anjanappa and Bhattacharya (2023), financial institutions and investors might seem cautious about approving funds given low market demand risk. Thus, a growing market can promote green hydrogen production. Based on the Hydrogen Council report in 2020, one of the strategies for boosting the demand for hydrogen and developing a market is to mitigate market insecurity for participants by establishing long-term purchase agreements that reduce market risk.

5.5. Green Hydrogen and Government Support

Given 25.3% of respondents, the likelihood that "Favourable government policies and incentives" are among the most significant considerations for private sector preparation demonstrates how vital governmental assistance is. Creating a regulatory environment that promotes business engagement and devotion to green hydrogen endeavours may be adequate for government regulations and benefits. To emphasize how critical a supportive regulatory environment is to investment in green hydrogen, as reported by Vallejos-Romero et al. (2022) and depending on the findings, individual opinions on green hydrogen along with willingness to adopt those technologies change because of circumstances including the availability of energy-efficiency regulations in the country of living, demographics, emotional, cost, technical details, especially those related to the infrastructure, and risks.

5.6. Green Hydrogen and Existing Infrastructure

Utilising existing infrastructure could ultimately result in greater acceptance of the incorporation of green hydrogen, depending on the relationship between employing existing infrastructure for green hydrogen and having a more positive impact on society. This relationship emphasises the significance of environmental sustainability and the minimisation of community disturbance while implementing new technologies. Devine-Wright and Howes (2010) suggest that the interruption condition to the location might explain how more intense feelings of locale connection are tied to unpleasant reactions to certain infrastructure developments and considered threats.

5.7. Green Hydrogen and Job Creation

Job creation plays an essential role in determining infrastructure preparedness through a connection between expectations regarding the influence of green hydrogen on work opportunities and perceptions regarding the impact on local employment possibilities. The expected result of green hydrogen adoption is an increase in jobs, which increases preparedness to develop the required infrastructure. Emodi et al. (2021) research addresses that hydrogen in energy-consuming countries, such as China, Japan, and South Korea, helps in new employment opportunities developments, alongside increases in energy availability and business investment. This result promotes economic improvement.

6. Conclusion

Green hydrogen project integration in Oman demands considerable social acceptance given its potential to achieve sustainable energy goals, where general knowledge of green hydrogen benefits needs to be incorporated. This energy transaction's costs, benefits, investment facts, job creation, and economic growth could help enlighten public beliefs. Supporting public participation and presenting successful case studies using suitable statistical data can be vital components of efforts to increase social acceptance. Furthermore, investor faith and confidence in Oman's green hydrogen projects are critical to their success, as accessible regulatory frameworks, political stability, economic viability, and partnerships between the public and private sectors significantly impact investor decisions. Finally, the exploration of Oman's existing infrastructure capabilities to determine the viability of creating green hydrogen projects, suitability of hydrogen transportation and storage systems, and existence of a qualified workforce and research institutes are all being scrutinised. Challenges such as attracting funding and changing regulatory regimes are significant concerns for assessing Oman's potential in the sustainable energy field, and it is crucial to look at the infrastructural capacity for green hydrogen projects and mitigate the green hydrogen social impact in Oman's energy transaction energy direction.

The recommendations are as follows.

The following recommendations for this study's goals depend on the existing literature evaluation of the social impact of green hydrogen as well as the research questionnaire data analysis performed in this research:

- Sharing knowledge and transferring information will support increasing Oman's public awareness of green hydrogen technologies, areas of work, and field engagement. Focusing on the most utilised social media app technology while illustrating friendly promotion methods.

- Increasing the awareness and implementation of the Oman National Net Zero Emissions Transition Strategy to boost the local population's comprehension and adapt to the inevitable changes in their standard of living methods, increasing the discussion on the Paris Agreement in a non-technical forum to allow people to experience and understand the background of this energy transaction.
- To build understanding and confidence in the green hydrogen field, governments should empower locals and regular people to participate in the green hydrogen decision-making procedure by implementing open discussions, in-depth workshops, national programs, and other activities where younger participants can be involved in finding solutions.
- Green hydrogen technologies and energy-related topics should be introduced at the educational level through specific programs. Likewise, explain it in an approachable manner at the school level to encourage participation and engagement from younger generations to ensure the availability of the Omani expertise workforce and develop human resources to meet the change in market demands.
- Formulate measures and policies to encourage investor participation in green hydrogen projects, offering complete assurance of government backing, funding support, and advance rewards when necessary.
- The best optimisation of current infrastructure can be achieved by introducing sufficient renewable facilities to generate green hydrogen projects to power the energy process and develop an approach for transforming and exploring hydrogen, along with providing a storage method to save the extra energy generated.
- Secure market demand, consumer interest, and investor willingness to develop the workforce before introducing green hydrogen projects. Therefore, foreign investors should be encouraged to establish green hydrogen infrastructure requirements.

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