Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/GC02.20240101
Published: December 01, 2024

Analyzing the Hydrogen Economy and Sustainable Development in Oman Through Social Life Cycle Assessment (SLCA)

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Abstract

The United Nations' sustainability goals have emerged as a crucial roadmap for monitoring decarbonization efforts. Oman's strategic focus lies in the realm of hydrogen, particularly Green Hydrogen, which harnesses renewable energy sources like solar and wind. Projections suggest that in the coming years, Oman could become one of the world's major hydrogen exporters, given its ample potential for harnessing high-quality renewable energy and its expansive land resources. The primary objective of this research is to scrutinize the social and socio-economic implications across the entire life cycle of Green Hydrogen in Oman, using the Social Life Cycle Assessment tool (SLCA). The SLCA comprises four primary phases: Goal and Scope, Inventory Analysis, Social Impact Assessment, and Interpretation Analysis. In the initial phase, the assessment's goals were delineated. Subsequently, an inventory analysis was conducted, systematically modeling the process of hydrogen production and identifying input and output inventory components. To assess social impacts, a combination of literature analysis and questionnaires was employed to generate a matrix encompassing all the social considerations relevant to the Green Hydrogen life cycle in Oman. This matrix, in turn, facilitated the final phase of Interpretation Analysis, where the identification of critical social factors requiring attention. The findings of this study underscore the efficacy of the SLCA as an essential tool for assessing the Green Hydrogen life cycle in Oman. Yet, it is crucial to acknowledge that various challenges still need to be addressed to advance the cause of sustainable hydrogen development in the region.

Keywords

Hydrogen Economy, Green Hydrogen, Sustainable Development, Social Life Cycle Assessment

1. Introduction

In light of hydrogen's emergence as an alternative energy source to fossil fuels, Oman's strategic focus lies in the realm of hydrogen, particularly Green Hydrogen, which harnesses renewable energy sources like solar and wind. Projections suggest that in the coming years, Oman could become one of the world's major hydrogen exporters, given its ample potential for harnessing high-quality renewable energy and its expansive land resources. As hydrogen and its applications serve as alternatives to fossil fuels, this research investigates the positive and negative social and socio-economic effects throughout the entire life cycle of hydrogen as an energy source, from raw material extraction to waste recycling. The findings of this study aim to provide valuable insights for society and companies, enhancing their understanding of hydrogen's impact on the sustainability of the social pillar in Oman.

1.1 Objectives

The study examines the hydrogen economy in Oman, focusing on its current status, growth potential, and alignment with national energy strategies. It analyzes the hydrogen life cycle, assessing environmental and socio-economic impacts, and conducts a Social Life Cycle Assessment (S-LCA) to evaluate social effects. The research also explores public perceptions, community acceptance, and social implications of hydrogen projects to support informed decision-making.

2. Literature Review

2.1 Hydrogen Production as Energy

Hydrogen, found in bonded form, requires energy for release. It is produced using fossil fuels, biomass, and nuclear power. While natural gas reforming and coal gasification are established, biomass methods are still under research. Water electrolysis, powered by renewables, is the leading method. Global production, around 600-720 billion Nm3 annually, supports 80%-95% of fuel cell vehicles but accounts for under 2% of global energy use. Fossil fuels dominate hydrogen production (96%), with natural gas at 48%, followed by oil (30%) and coal (18%), while electrolysis contributes 4%, especially in regions with cheap hydroelectricity (Table 1).

Table 1.Planned Hydrogen and Ammonia Projects in Oman, 2022-2030

Name of project	Status	Date online	Electrolysis capacity (MW)	Production capacity (kt H_2) per year	Export-oriented
Hyport@Dqum, Phase I	Feasibility study	2026	500	87	Yes
Green Hydrogen Oman (GEO) project	Feasibility study	2028	4 700	809	Yes
Salalah H_2	Feasibility study	2024	400	69	Yes
Sohar port, Phase I	Concept	2024	35	6	No
Green Hydrogen and Chemicals SPC	Feasibility study	2026	300	52	Yes
Sur Hydrogen Cluster	Pre-feasibility study	2030	1 300	225	No
H_2Oman (Dhofar)	Concept	2030	1 040	180	Yes
Sur Hydrogen Cluster	Pre-feasibility study	2030	1 300	225	No
BP Alternative Energy Investments Limited-Dqm	Feasibility study	2030	-	150	No
BP Alternative Energy Investments Limited-Dhofar	Feasibility study	2030	-	150	No

2.2 Hydrogen Economy in Oman

Ahead of COP27 in 2022, Oman committed to achieving net zero emissions by 2050, becoming the third Middle Eastern oil and gas producer to do so after the UAE and Saudi Arabia. Supported by its National Strategy for a Smooth Transition to Net Zero, Oman aims to invest around USD 190 billion in cleaner energy, focusing on upgrading the electricity grid, hydrogen infrastructure, electric vehicle charging, and energy storage. The plan also emphasizes economic benefits, including GDP growth, job creation, and improved energy security.

Oman is developing its hydrogen export capabilities through the 'Hy-Fly' National Hydrogen Alliance, formed in 2021, and has set ambitious green hydrogen production targets: 1-1.25 million tons annually by 2030, scaling to 7.5-

8.5 million tons by 2050, requiring an additional USD 140 billion in investment. Coastal regions Duqm, Dhofar, and Al-Jazir have been designated for hydrogen production, with the potential to generate 25 million tons annually from 500 GW of renewable energy.

Hydrogen Oman (HYDROM) was established to manage hydrogen projects, land allocation, and infrastructure development. In March 2023, HYDROM awarded six hydrogen projects worth USD 20 billion, advancing Oman's goal to become the world's sixth-largest hydrogen exporter by 2030. Oman's hydrogen exports are projected to account for 61% of the Middle East's total, with a focus on European and Asian markets. Many projects are based in shared industrial hubs, offering integrated energy systems and minimizing environmental impact.

2.3 Social Life Cycle Assessment (SLCA)

Among the three dimensions of sustainability—environment, economy, and social—the social pillar often receives less attention. Since 2009, Social Life Cycle Assessment (SLCA) has aimed to address this by evaluating the social and socio-economic effects across a product's entire life cycle. Developed by the UN Environment Programme and the Society of Environmental Toxicology and Chemistry (UNEP/SETAC), SLCA differs from other social impact tools by focusing specifically on products and services and their life cycles. SLCA's growth has been driven by key UNEP/SETAC documents, such as the "Guidelines for Social Life Cycle Assessment of Products" (2009) and "Methodological Sheets for Subcategories in SLCA" (2013), which align SLCA with ISO 14040 and 14044 standards. SLCA follows similar phases to Life Cycle Assessment (LCA), including goal definition, inventory analysis, impact assessment, and interpretation. It enhances LCA by incorporating social factors, serving as a valuable tool for understanding the social aspects of sustainability in product life cycles.

3. Methods

This research was conducted in several stages using a scientific approach. It starts by defining the goals and objectives of the study. A literature review on the hydrogen economy, UN Sustainable Development Goals (SDGs), Oman's sustainable future plans, green energy, and the Social Life Cycle Assessment (S-LCA) was done to understand and analyze the current state of hydrogen energy.

Hydrogen energy, a new decarbonized source, addresses climate needs. Both qualitative and quantitative methods, including interviews and surveys, were used to gather data, which was then analyzed to evaluate its social impact. A forecasting tool was applied to assess the social aspects of hydrogen energy as an economic resource in Oman.

The study also examined Oman's progress towards achieving the UN SDGs, using data from case studies, prior research, and articles. The S-LCA was employed to evaluate the social effects of hydrogen energy across its life cycle, using literature reviews, surveys, and interviews to gather information.
All data collected aim to answer the research questions and achieve the study's objectives.

4. Results and Discussion

As the literature indicates the Sultanate of Oman will be utilizing electrolysis technology driven by renewable energy sources to extract hydrogen from desalinated seawater. Oman has a high potential to use high-quality solar photovoltaic and onshore wind resources, along with extensive available land for extensive projects. Additionally, its strategic location along key trade routes between Europe and Asia, coupled with pre-existing fossil fuel infrastructure that can be adapted for environmentally friendly fuels, further enhances its advantageous position (IEA, 2023). Therefore, Oman will be producing Green Hydrogen in the coming years to reduce the usage of fossil fuel energy. The Social Life Cycle Assessment serves as a tool to inform decision-making and foster discussions regarding the social and socio-economic dimensions of production and consumption. Its primary aim is to enhance the performance of organizations and, in turn, the well-being of stakeholders. It's important to note that S-LCA does not seek to determine whether a product should or should not be produced. Instead, it focuses on improving the existing social impacts of a product within a given context, thereby facilitating informed decisions. SLCA is divided into four phases: Goal and Scope, Inventory, Impact assessment, and results and Interpretation. (UNEP.2023).

4.1 Goal and Scope Phase

Per UNEP/SETAC (2009), the goal and scope phase in Social Life Cycle Assessment (SLCA) involves defining assessment objectives, specifying activity variables, devising a data collection strategy, and identifying stakeholders across the life cycle stages (Du et al., 2014).

4.1.1 Goal

The goal of the study should provide a clear explanation of the assessment's purpose and the specific areas it seeks to investigate. It also outlines the target audience interested in the results of the Social Life Cycle Assessment (SLCA) and who it is intended for. The purpose of the study can vary widely, ranging from comparing products and obtaining information or insights about a product to educating stakeholders about social impacts and identifying significant social concerns. (Du, Chongyang & Freire, Fausto & Dias, Luis. 2014)

For this research, the assessment is conducted to evaluate potential positive or negative effects of Green Hydrogen in its whole life cycle in social aspect in Oman. As the literature shows Oman will be one of the biggest exporters of Hydrogen Energy in the future. Therefore, this new energy carrier will be the new green economy for the country instead of the petroleum and gas industry. The sustainable source is the main concern in this case, Hydrogen energy is 100% Sustainable, therefore, Oman is achieving the seventh UN Sustainability Development Goal, which is Affordable and Clean Energy. However, all UN sustainability development goals are related to each other. If an economic goal is achieved, then environmental and social goals will be affected as well. Henceforth, the Social Life Cycle Assessment is conducted to study the social aspects; assessing labour conditions, evaluating human rights impacts, evaluating the society contribution, evaluating all the consequences that might occur while constructing the infrastructure of the Hydrogen project, production phase, and evaluating stakeholder well-being .

The assessment will help understand the consequences of alternative energy production and make good decisions to involve the society, human force, and individuals in the Hydrogen production industry. The assessment is conducted to assess social impacts over a Hydrogen project's entire life cycle; from raw sources, generating phase, storage, and transporting, to the end user phase.

4.1.2 Scope

The scope provides insights into the depth, breadth, and comprehensiveness of the study. It outlines the boundaries of the life cycle under assessment, as well as the specific details to be gathered and assessed. It also allocates the sources for data collection, data handling procedures, and the intended applications of the study's outcomes. In accordance with ISO 14044 (2006), which is an environmental management standard, with some modifications from UNEP/SETAC initiatives, the scope of an SLCA assessment should encompass and describe the following elements (Du, Chongyang & Freire, Fausto & Dias, Luis. 2014). Table 2 lists the description of each element along with the Hydrogen study information that being studied:

Table 2. Scope's Elements

Scop Elements	Description	Hydrogen Study
System Boundaries	System boundaries establish the segments of a product's life cycle that must be considered in the analysis. This determination could extend beyond the available resources for the assessment.	This study will emphasize all Hydrogen production phases. Also, the circular economy of the Hydrogen economy will be evaluated.
Functional Unit	Quantified description of the function of a service/product used as the fundamental reference point for all impact assessment calculations. A function may be based on various aspects of the product being analysed, including its performance, visual appeal, technical excellence, supplementary services, expenses, etc.	This study is conducted to cover the life cycle of Hydrogen energy and the sustainability impact of it in Oman's sustainability development, till 2030 as the UN SDGs are to be seen in reality by 2030.
Social Aspects and Indicators	Social indicators that are considered in the study (such as working conditions, human rights, health, and safety). A list is generated of all social metrics under this study.	Social Indicators: • Labor conditions. • Human rights. • Society contribution.

		• Health and Safety of Human force and neighbourhoods by the infrastructure construction areas. • Stakeholders' well-being. • Environmental-social impacts.
Data Sources	The data sources indicators are used to define the method of collecting data; this can involve surveys, interviews, analysis of existing literature, involvement of stakeholders, or alternative information sources.	Data collection method: • Literature review. • Interview with individuals who are involved in companies related to Hydrogen production and studies. • A survey will be conducted.
Exclusion	Stating any social aspect or a life cycle phase that will not be considered throughout the assessment, and a justification should be provided for these exclusions.	This study will exclude the social impact of how the individuals will be managing to deal with the new source of power in residential areas.

4.2 Life Cycle Inventory Analysis

Life Cycle Inventory (LCI) analysis involves the creation of a complete study of an inventory of flows from and to nature (ecosphere) for a product system. This process involves quantifying the demands for raw materials and energy, emissions to the atmosphere, land and water, resource utilization, and other discharges throughout the entire life cycle of a product or process. Furthermore, LCI is the summation of all elementary exchanges associated with each individual step within a product system. (Hosseinijou, Mansour, and Shirazi. 2013) (University Galgotias.2016)

To implement this analysis, it is commonly advised to begin with a flow model of the technical system, utilizing data on the inputs and outputs of the product system. This flow model is typically illustrated through a diagram that encompasses the activities within the relevant supply chain that will be evaluated, offering a clear representation of the technical system's boundaries. A life cycle inventory analysis was conducted to analysis the green hydrogen production calculation in Oman. At first, a flow model of the technical green hydrogen production process was constructed; flow information was gathered through literature analysis. As it can be seen in Figure 3. In general, for the electrolysis process, the input of 70% to 80 % electricity.

According to IEA's (International Energy Agency) analysis by 2030, Oman will be one of the biggest exporters of Hydrogen in the area based on planned projects. Around 1953kt of Hydrogen capacity will be produced annually, as shown in Table (1) from the Literature review. In order to produce 1953kt, a capacity of 9575 MW will be needed as input for the electrolysis phase. Oman has a high potential to produce an enormous amount of electricity power from renewable energy, therefore, land that is sized as Slovakia's area will be used to construct the infrastructure and facilities needed in order to initiate the production of green hydrogen. Oman is considering working with a whole green infrastructure, thus, the distilled seawater that will be used in green hydrogen production will be produced from green desalination centers. (IEA, 2023). Figure (1) shows the inputs and outputs of the green Hydrogen production life cycle as planned in Oman.

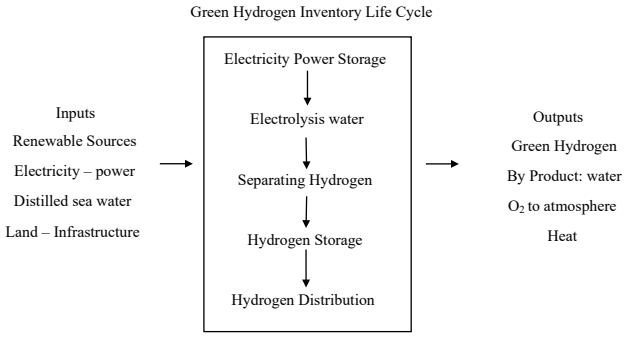

Figure 1. Inputs and Outputs of the Green Hydrogen Production Life Cycle.

4.3 Social Impact Assessment

Social impact assessment involves the identification and control of the societal consequences associated with industrial projects. This assessment is not limited to industrial projects; it can also be extended to include policies, plans, and programs. SIAs purpose is to forecast and address adverse effects while simultaneously recognizing chances to enhance advantages for both local communities and the larger society.

Central to the principles and application of SIA is the active participation of impacted communities and other relevant stakeholders throughout the procedure. The primary objective of SIA is to provide valuable insights for decision-makers in government and corporations, starting from the initial phases of a project. (James D. Wright, 2015) (Hosseinijou, S.A., Mansour, S. and Shirazi, M.A. 2013). Various Stakeholders will be involved in the new projects of Green Hydrogen that Oman is planning to invest in. Figure 2 shows all the stakeholders involved.

Figure 2. Stakeholders.

4.3.1 Social Impact Assessment Matrix

literature analysis, survey and call interviews with experts and researchers were conducted in order to gather information to ease an objective assessment of the magnitude of the social issues and their impacts on communities, and different stakeholders.

this assessment might be difficult to carry out for some social issues as there is not much information in regard to Green Hydrogen production or utilization in Oman. The Analytic Hierarchy Process (AHP) is an appropriate tool for objectively evaluating individual issues, and therefore, it is employed during the life cycle impact assessment phase for this study. (Hosseinijou, S.A., Mansour, S. and Shirazi, M.A. 2013). Graph (2) shows the matrix generated to evaluate social matters related to the Green Hydrogen life cycle for five stakeholders, in different life cycle phases of green hydrogen being the Raw material phase, production phase, and end-user phase.

4.4 Finding Evaluation

4.4.1 Interpretation Assessment

Life cycle interpretation involves the process of analyzing findings from the previous phase of Social Life Cycle Assessment to conclude, as outlined by ISO 14044 (2006) in three main steps :

- Identification of the substantial issues .
- Evaluating the quality of the study, which includes concerns of completeness and consistency.
- Conclusions, identifying recommendations, and reporting .

For the first step, an aggregated scores calculation is recommended for each impact category, subcategory, stakeholder group, and life cycle phase. By utilizing these aggregate scores, one might determine significant issues, primary areas of concern, and where these issues might hold the most impact within the product's life cycle. Furthermore, this approach facilitates the identification of stakeholders who are central to the primary concerns. In the second step, the evaluation of " Completeness" is carried out in order to determine whether the essential issues and aspects have been addressed in the study. An evaluation of "Consistency" is carried out, which aims to validate the suitability of modeling techniques and methodological decisions in accordance with the predefined goals and scope. In the third step, a

conclusion could be drawn about the final ranking of the alternatives related to all the factors considered. Recommendations are formulated as options for actions that might explain future public and private policies relating to the key stakeholders and impact categories identified in step 1 of the current phase. (Hosseinijou, Mansour, and Shirazi. 2013).

4.4.2 Step One – Aggregation

Before aggregation, the impact assessment matrix Figure 4 is normalized with impact scoring. This is a common practice in order to help express the impact of different categories in a common unit or relative to a reference value. Figure 4 illustrates the impact scoring. Following aggregation calculations were conducted for social matter, and for stages in the Hydrogen life cycle. Results can be seen in Figure 5 and 6.

As can be seen in Figure 6 the areas of the Green Hydrogen life cycle that have to be considered and might cause significant issues are (1) Transportation, (2) Storage, and (3) Production. Furthermore, Figure 5 shows the most significant social issues associated with the following subcategories: (1) Health and safety for workers, (2) Local community acceptance for the local community, and (3) Safe and healthy living conditions for the local community. These matters have to be considered by the Omani government and companies to improve the social sustainability concerns related to Green Hydrogen.

4.5 SLCA Quality Evaluation

The assessment was conducted according to the framework and guidelines of UNEP/SETAC. The study has considered all social matters in all stages of the Hydrogen life cycle, the indicators that have been determined at the first stages of the assessment were considered and evaluated within other social indicators in the impact assessment matrix. The matrix was helpful to visualize and assess the overall life cycle of Green Hydrogen according to social matters. Since Hydrogen is a new topic to the local community in Oman and the area, there was a lack of information and at some points, uncertainty occurred. However, the survey conducted with various individuals played a crucial role in the proposed framework; all the judgments taken especially in the impact matrix are within expert and individual opinions.

4.6 Assessment Conclusion

From a social life cycle perspective, the new energy carrier Green Hydrogen performs well when compared to other fossil fuel or gas energy that are currently the main economic sources for Oman. Since green hydrogen is produced using renewable energy the social impact related to the health and safety of workers and local community is positive, compared to the impact of fossil fuel. The main concerns that this assessment has determined are the storage and transportation of this new energy, as known about Hydrogen is an explosive substance, and the management after production of this substance could be challenging in the future. Another social concern is the acceptance of this new energy in the local community and the usage of this new source in the residential areas .

For Oman, the infrastructure might be ready for Green Hydrogen production within the Companies that are already dealing with natural gas in different industrial areas. However, a new infrastructure might be required in areas and companies that are willing to invest in green Hydrogen with no prior infrastructure for other gas. This might result in a negative impact in some areas especially areas that are populated with people .

Furthermore, there is a lack of studies on water usage in post-production of Green Hydrogen. Such studies could be beneficial to evaluate the circular economy option of this new economy. As a result, green hydrogen might offer economic growth opportunities, job creation, and diversification of income streams in the country. Additionally, this new economy will result in various social benefits to the community in Oman. The country has a vision to be one of the largest exporters of Green Hydrogen in the area, this will result in new job opportunities, increase the investment potential, improve stockholders' well-being, and help the country to reach their SDGs that the UN stated, and the country committed to by 2030.

Research on green hydrogen confronts the following obstacles in terms of risks, socioenvironmental consequences, and the general public's perception. The first is a lack of studies on the environmental and social impacts of hydrogen on the local population and indigenous communities, as well as a lack of local government authorities in related areas. Although some studies evaluated the environmental consequences of green Hydrogen, the social dimension evaluation is lacking. This necessitates the inclusion of economic and political elements.

4.7 Proposed Improvements

For future studies, the framework for Social Life Cycle Assessment (SLCA) developed in this research can be utilized to understand the social impact of the green hydrogen life cycle in Oman, particularly after the implementation of a live project and infrastructure in the country. This approach will allow for the visualization of public acceptance, local community safety concerns, and issues related to transportation and storage. Consequently, a streamlined assessment can be conducted to identify social sustainability concerns that the government and companies need to address for improvement (Figure 3).

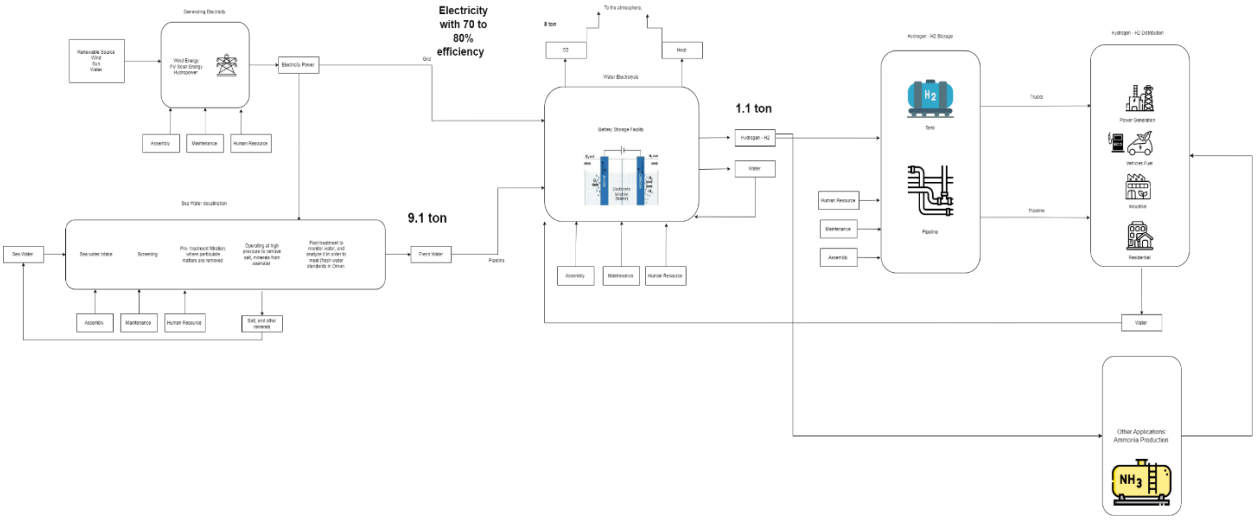

Figure 3. A Flow Model of Green Hydrogen Life Cycle

Stakeholder Categories	Subcategories	Inventory Indicators	Pre-Production	Production Phase			End-User	
			Raw Sources	Production	Storage	Transportation	Use	Recycle
Workers	Health and Safety	Occupational Accidents						
	Fair Salary	Living						
	Equal opportunity/discrimination	Discrimination among different groups of gender, age, etc.						
Local Community	Access to material resources	Changes in land ownership/ land use						
		Levels of industrial water use						
		Extraction of material resources						
	Safe and healthy living conditions	Burden of disease						
		Pollution levels						
		Waste generation						
	Local employment	Job Creation						
		Use of local labor						
		Use of technology that generate employment						
		Presence of local supply network						
	Local community acceptance	Presence of complaints by local community						
	Cultural heritage	Protection of cultural heritage						
Society	Technology development	Technology development						
		Technology transfer						
		Research and development						
	Contribution to economic development	Contribution of product to economic progress (GDP, revenue, wage level, unemployment, etc.)						
	Suppliers' development	Use and support of national suppliers						
Consumer	Health and safety	Presence of consumer complaints						
		Indoor air quality (IAQ)						
Value chain actors	Fair competition	anti-competitive behavior						
	Supplier relationship	Sufficient lead time						

Figure 4. Social Impact Assessment Matrix, and Impact Scoring Value

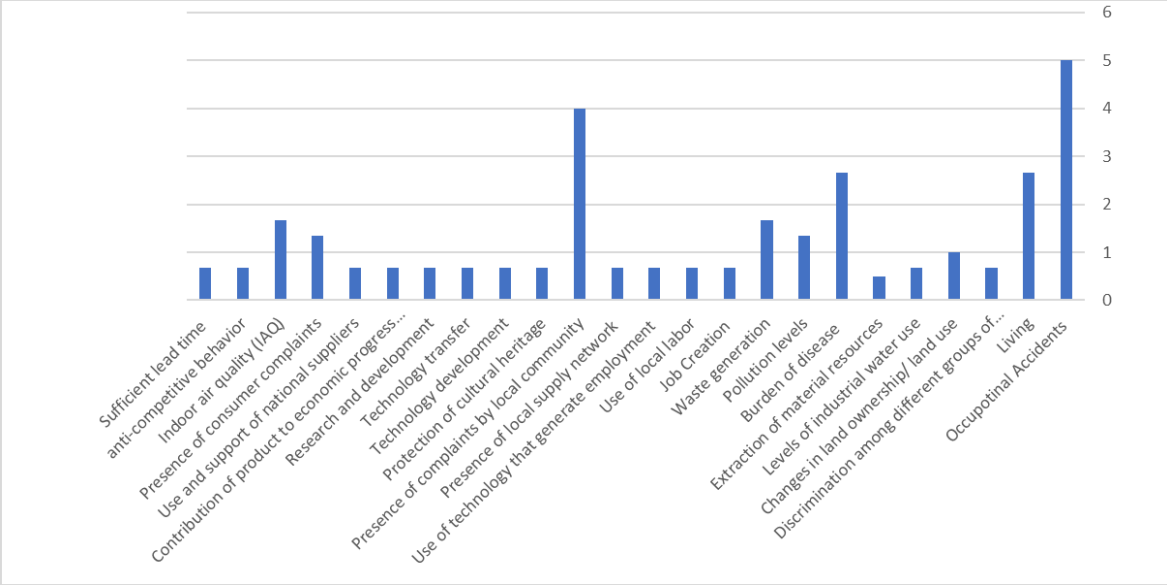

Figure 5. Aggregation Results for Subcategories - Social Matters

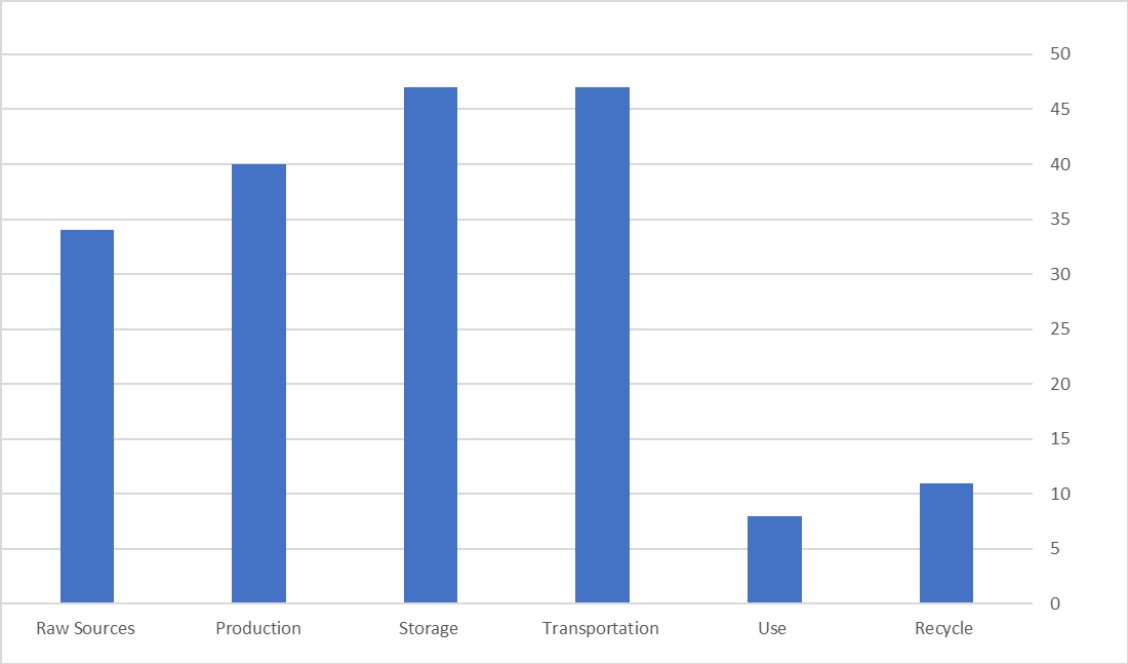

Figure 6. Aggregation Results for Hydrogen's Life Cycle Phases

6. Conclusion

Although the framework of this tool is under development. This study showed that the development of this tool is well suited for the Green Hydrogen Life cycle in Oman, however, various challenges persist. Scoring the social matters was a challenge as there is no live project for Green Hydrogen in Oman, therefore scoring social matters was based on experts and researchers' knowledge, who participated in the study and were the key certain to any uncertain

opinions. As well as the assumptions that Individuals have related to Green Hydrogen helped to study the acceptance and knowledge level. For future studies, the conducted framework for SLCA that has been developed in this study can be used in order to understand the Social Impact on the Green Hydrogen life cycle in Oman after having a live project, and infrastructure in the country. This way one can visualize the acceptance of the public, and local community safety concerns, transportation, and storage; therefore, an easy assessment could be conducted in order to find out the social sustainability concerns that the government and companies have to improve.

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Biographies

Ludina Al Bulushi earned her B.Sc. in Mechanical Engineering from the University of Malta, where she graduated as the first GCC woman from the Faculty of Engineering. She also holds an M.Sc. in Engineering Management from the Global College of Engineering and Technology (GCET), Muscat, in partnership with the University of the West of England (UWE), Bristol, UK. Her master's research was accepted for presentation as a technical session at the International Conference on Energy and Sustainability. Currently, she is the only Omani female pipeline engineer working across Oman in the oil, gas, and energy industry. She is a participant in the Sidrah 3.0 Program, a leadership Program for Omani women. Her dedication and enthusiasm for sustainability and Oman Vision 2040 goals was recognized, and as a result, she was chosen to take on the role of President of Sustainability and Community Service. In this leadership position, she now oversees and drives initiatives focused on promoting sustainability and community engagement within the program.

Dr. Sivasakthivel Thangavel is an associate professor in the Department of Mechanical Engineering at a partnership institute of the University of West England (UWE Bristol) in Oman, where he has been teaching since May 2018. He earned his Ph.D. in Mechanical Engineering from IIT Roorkee in 2015, an M. Tech in Thermal Engineering from NIT Silchar in 2011, and a B. Eng. in Mechanical Engineering from Anna University in 2008. Dr. Siva's research has taken him to various countries, including France and China, where he conducted part of his Ph.D. research under prestigious fellowships. He also worked as a JSPS Postdoctoral Fellow in Japan for two years. Dr. Siva is certified by the U.K. Higher Education Board and has published over 30 papers in academic journals and conferences. His research interests include sustainable engineering, energy management, hydrogen energy, and renewable energy sources.

Dr. Mira joined GCET as an Associate Professor in the Department of Mechanical Engineering in September 2021. Dr. Mira received her Ph.D. degree in Mechanical Engineering, specializing in Fluid mechanics from Paris-Saclay University in France in 2019. Dr. Mira has over 3 years of experience in the Industrial field in France, focusing on mechanics, measurements, and instrumentation on large geometries and projects. She has participated in many international conferences and has received several awards for her work.