Report

ESSG Framework for Green Hydrogen Development in Jordan

According to PtX hub

Friedrich Ebert Stiftung

Regional Competence Center for Energy and Climate Justice MENA

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Friedrich Ebert Stiftung

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Acronyms

EESG	*Economic, Environmental, Social, and Governance*
NDCs	*Nationally Determined Contributions*
LCOH	*Levelized Cost Of Hydrogen*
GDP	*Gross Domestic Product*
NGO	*Non-Governmental Organization*
MoWI	*The Ministry of Water and Irrigation*
WAJ	*The Water Authority of Jordan*
GIZ	*Deutsche Gesellschaft für Internationale Zusammenarbeit*
ESIA	*Environmental Social Impact Assessments*
CSR	*Corporate Social Responsibility*
ASEZA	*The Aqaba Special Economic Zone Authority*
ADC	*Aqaba Development Corporation*
ISO	*International Organization for Standardization*
MOUs	*Memoranda of Understanding*
KPIs	*Key Performance Indicators*
EBRD	*European Bank for Reconstruction and Development*
PPPs	*Public-Private Partnerships*
LLC	*A Limited Liability Company*
UAE	*The United Arab Emirates*
USAID	*The United States Agency for International Development*
CO2e	*Carbon dioxide equivalents*
PV	*Photovoltaics*
NCP	*National Conveyance Project*
PSH	*Pumped-Storage Hydropower*
RED II	*The Renewable Energy Directive*
EU	*The European Union*
DAC	*Direct Air Capture*
MWh	*Megawatt Hour*
WWTP	*Wastewater Treatment Plant*

CCU	*Carbon Capture and Usage*
GHG	*Greenhouse Gases*
IRENA	*The International Renewable Energy Agency*
RSS	*The Royal Scientific Society*
MENA	*The Middle East and North Africa*
PEM	*Polymer Electrolyte Membrane*
AEL	*Alkaline Electrolysis*
CRM	*Critical Raw Materials*
EIAs	*Environmental Impact Assessments*
PPE	*Personal Protective Equipment*
ILO	*International Labor Organization*
SMART	*Specific, Measurable, Achievable, Relevant, and Time-Bound*
MOEE	*Ministry of Digital Economy and Entrepreneurship*

Perface

The transition to a low-carbon energy future presents meaningful opportunities for the Kingdom of Jordan and for the broader Middle East and North Africa (MENA) region. In particular, the development of a green-hydrogen economy, harnessing the region's abundant renewable energy potential holds promise for economic diversification, job creation and sustainable growth. At the same time, however, this promise must be approached with caution and a clear sense of justice, responsibility and long-term national and local interest.

There is significant interest in green-hydrogen exports and a strong potential for Jordan to play a key role in emerging regional value chains. However, if these projects develop purely as resource-extraction ventures; deploying renewable energy assets solely for hydrogen production destined for export, then national value addition, local community benefit, and the broader domestic energy transition may be marginalized.

the hydrogen economy should be built as a partnership of equals, not as a new enclave of extraction, where foreign capital and a privileged few captures most of the value. It must create quality local jobs, promotes technology and knowledge transfer, involves civil society, and supports sustainable growth in local communities. This includes a special focus on youth employment in regions of high unemployment, ensuring fairness, inclusion, and long-term national benefit.

Beyond climate goals, the global push for renewable hydrogen is also reshaping economic power; countries and companies are racing to dominate electrolyzer manufacturing and green-tech value chains. Without a robust national strategy, Jordan risks being sidelined as other global powers scale up. Therefore, its hydrogen journey should prioritize technology transfer, skills development and strong governance.

At the same time, the geopolitical and strategic dimensions must be taken into consideration, as hydrogen infrastructure is built, important questions arise—on whom will Jordan depend for supply, technology, finance, and infrastructure; Experiences in other regions show that energy contracts signed without a robust national strategy can expose countries to strategic vulnerabilities. long-term national benefit and meaningful local participation must be prioritized. Jordan's own path to decarbonization cannot be compromised. The Principle of Additionality must be non-negotiable Any renewable energy deployed for hydrogen production must come from new capacity. Moreover, direct electrification remains more energy-efficient than hydrogen for many applications, policy should continue to prioritize electrification wherever technically and economically feasible.

Water is a critical input to green-hydrogen production: around nine liters of high-purity water are required to produce 1 kg of hydrogen, with real-world consumption often higher. In Jordan and other water-stressed MENA countries, introducing a large industrial hydrogen-priority extraction of water without commensurate benefit to local communities would be imprudent. If desalination or other additional infrastructure is built to support hydrogen, it must also deliver access, reliability and quality of water to local populations as part of the arrangement.

This report therefore provides an analytical foundation to assess risks and opportunities, environmental, economic, social and governance (EESG) associated with developing green-hydrogen projects in Jordan. The findings and recommendations presented in this report are intended to support decision-makers, industry stakeholders, local communities, and civil society in guiding the development of a hydrogen economy that is technologically and commercially viable, socially equitable, environmentally responsible, and aligned with the national interest.

1. Executive Summary

This sustainability assessment report utilizes the EESG (Economic, Environmental, Social, and Governance) framework to identify the dimension and concerns associated with the development of green hydrogen in Jordan. This framework was developed by the PtX Hub, an international initiative dedicated to advancing sustainable Power-to-X technologies globally. The report offers a thorough examination of the concerns, opportunities, and suggestions related to the development of green hydrogen in Jordan, in an effort to guarantee its efficiency, sustainability, and compliance with international standards.

Jordan presents good potential for the deployment of green hydrogen projects due to its abundant renewable energy resources, especially solar and wind, and its advantageous location close to important export markets. The report highlights important issues that need to be addressed, such as governance, social, environmental, and economic issues. A framework of practical mitigation techniques is used to manage risks associated with high investment needs, water scarcity, biodiversity impacts, social inclusion, and transparency in governance. Simultaneously, prospects for workforce development, economic expansion, community advantages, and global collaborations are investigated as crucial success factors.

The results in this report were reached using a robust methodology based on the collection of data from reputable sources regarding global best practices, existing challenges, and potential risk factors. Additionally, one-on-one online meetings were held with key stakeholders to refine and enhance our findings. Findings were discussed with technical experts, hydrogen investors, and government representatives during workshops held in Aqaba on December 11th–12th, 2024.

The report’s findings highlight the challenges of balancing societal equity with environmental sustainability and economic gains. Building trust among stakeholders and attracting investment requires a strong focus on transparent decision-making processes, strong governance structures, and adherence to international frameworks. Furthermore, proactive stakeholder involvement, thorough impact assessments, and capacity-building programs are essential for reducing risks and optimizing co-benefits for both the national economy and local communities.

It is crucial to acknowledge that this report illustrates the present state of analysis and may be revised or updated in the future as the hydrogen market, technologies, and local circumstances change. This adaptability guarantees that Jordan's green hydrogen development will remain responsive to new opportunities and unanticipated difficulties. Through this dynamic approach, stakeholders will be able to successfully respond to future developments and continuously improve their strategies.

2. Context of Green Hydrogen Development in Jordan

2.1 The National Green Hydrogen Strategy for Jordan

Jordan's capacity for green hydrogen development is supported by various strategic advantages that position it favorably for engagement in the global energy transition. The country's renewable energy potential, particularly in solar and wind, ranks among the best globally, with high solar irradiation and strong wind corridors, especially in the south and northeast. Jordan benefits from an **average of 316 sunny days annually and favourable wind speeds ranging from 7 to 8.5 m/s**, making it an ideal environment for renewable energy generation. These renewable resources are essential for the affordable production of green hydrogen, with a **projected levelized cost of hydrogen (LCOH) potentially reaching $3.20 per kilogram by 2030**. Moreover, Jordan has demonstrated its commitment to renewable energy implementation, **increasing its contribution to power generation from under 1% in 2014 to 29% in 2022**. The country aims to further **increase the share of renewables to 50% by 2030**, establishing a robust foundation for integrating green hydrogen into the national energy framework. Jordan's strategic geographic location also positions it as a promising hub for green hydrogen exports, with close proximity to key markets in Europe and the Middle East.

The development of green hydrogen is consistent with Jordan's national climate and energy policies, including the National Energy Sector Strategy 2020–2030 and the revised Nationally Determined Contributions (NDCs). These policies prioritize decreased dependency on imported fossil fuels, enhanced energy self-sufficiency, and the **achievement of a 31% decrease in greenhouse gas emissions by 2030**. In 2022, Jordan's energy composition was primarily dependent on imported fossil fuels, with **oil accounting for 47% and natural gas for 41% of the overall energy supply**. To diminish this reliance and achieve its energy transition objectives, Jordan is emphasizing the incorporation of renewable energy and green hydrogen into its energy framework.

Jordan's strategic geographic location strengthens its role as a promising hub for green hydrogen exports, benefiting from close proximity to key markets in Europe and the Middle East. Additionally, Jordan's current **fertilizer manufacturing and export infrastructure** creates a viable market for green ammonia, while the **Port of Aqaba serves as an eco-certified conduit** for exporting green hydrogen and ammonia to international markets.

Furthermore, Jordan is implementing large-scale initiatives to address water scarcity, such as the **Aqaba-Amman Water Desalination and Conveyance Project**, which not only mitigates water challenges but also supports the demands of industrial-scale hydrogen production. By incorporating green hydrogen into its energy transition strategy, Jordan aims to reduce domestic emissions while fostering economic growth through **job creation, improved energy security, and the development of a competitive export market** for green hydrogen and its derivatives. This combined strategy of domestic use and export-focused manufacturing establishes Jordan as a significant participant in the burgeoning global hydrogen economy.

While Jordan's strategic initiatives and renewable energy potential establish a strong foundation for green hydrogen development, several risks must be addressed to ensure a successful transition. These challenges fall under four main categories: **institutional and regulatory obstacles, human and intellectual capital, infrastructure and resource constraints, and economic competitiveness.**

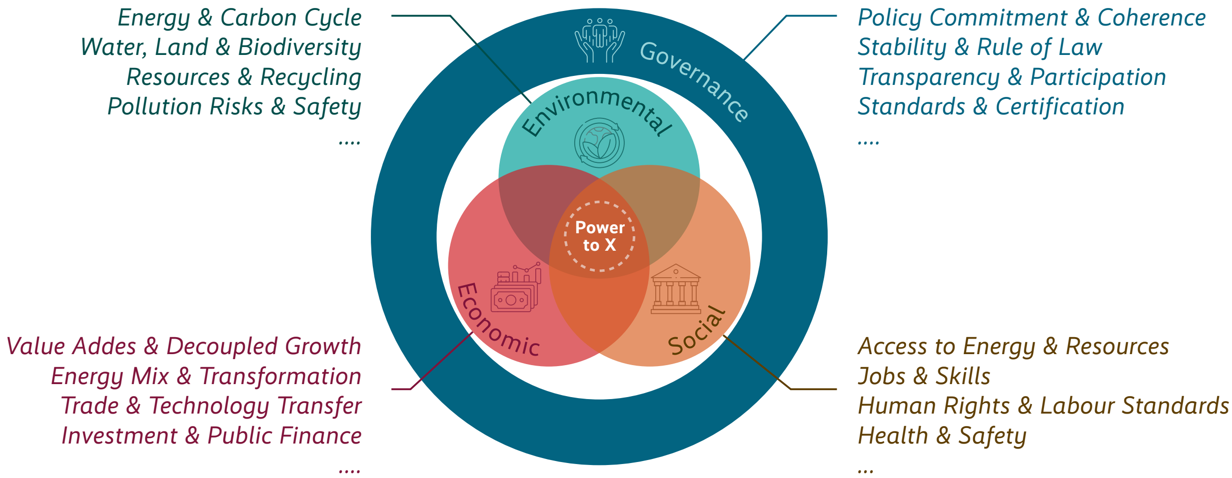
A key concern is the necessity of **robust regulatory frameworks** to oversee hydrogen production and export. The **absence of a unified and well-defined regulatory framework** could lead to investor uncertainty, delays in project implementation, and difficulties in aligning with international market requirements. Additionally, **compliance with international sustainability standards and certification processes** poses challenges that must be addressed to ensure seamless integration into global hydrogen supply chains.

Another critical challenge is Jordan's **water scarcity**, as it remains **one of the most water-scarce countries globally**. Large-scale green hydrogen production requires significant water resources, necessitating careful planning and proactive resource management. Addressing these concerns through **sustainable water solutions, such as desalination projects and water recycling initiatives**, will be essential to long-term hydrogen development.

To guarantee long-term sustainability, Jordan must adopt a proactive approach that includes **comprehensive environmental impact assessments, transparent regulatory frameworks, and strong public-private partnerships**. Coordinated efforts between government agencies, investors, and industry stakeholders will be necessary to unlock the full economic potential of the green hydrogen economy while ensuring environmental and social responsibility.

2.2 Understanding the EESG Framework for Sustainable Development

The EESG framework, which was created as part of the PtX Hub initiative, is intended to guarantee the sustainability of Power-to-X (PtX) projects in four critical areas: Economic, Environmental, Social, and Governance.



PtX Sustainability - The EESG Framework

As shown in the figure above, each dimension addresses specific sustainability concerns, as follows:

1. Economic: The production of green hydrogen provides Jordan with opportunities for economic growth in both its upstream and downstream industries, including manufacturing, services, and logistics. This dimension prioritizes the development of value, the promotion of fair growth, and the creation of trade opportunities. Thus, this aspect emphasizes the significance of local economic benefits, the decoupling of GDP growth from emissions, and the risks associated with the promotion of global technology transfer, energy mix and transfer, and the potential of investment and public finance.

2. Environmental: Evaluating the environmental footprint of Power-to-X (PtX) is essential for ensuring sustainability across the entire value chain. To achieve this, renewable and additional electricity should be used in critical processes such as electrolysis, synthesis, and refinement, within a closed carbon cycle. It is equally important to assess carbon sources, considering options such as direct air capture, biogenic sources, or carbon capture and utilization. In parallel, hydrogen and PtX production must adhere to responsible water, land, and biodiversity management practices to mitigate broader environmental impacts. A comprehensive analysis should also consider the demand for rare raw materials and the potential for recycling, and should address any pollution and safety risks associated with production, storage, transportation, and usage. By establishing these guidelines, the framework seeks to reduce environmental and ecological impacts, ensuring that PtX technologies can contribute to a more sustainable future.

3. Social: The development of green hydrogen has the potential to generate positive social impacts by creating a substantial number of high-quality jobs across various sectors, requiring a skilled workforce for hydrogen production, storage, and distribution. This, in turn, can enhance the quality of life in local areas through the creation of well-paying employment opportunities. Moreover, the region has the potential to become a hub of hydrogen expertise, attracting significant global investment, particularly from within the Middle East. However, these opportunities are accompanied by significant social challenges, including inequitable access to energy and resources, the lack of availability of jobs and skills, and difficulties in adhering to human rights standards and implementing stringent health and safety measures. Projects must support community development, respect cultural and customary rights, and provide fair job opportunities without exacerbating social inequalities.

4. Governance: Good governance of hydrogen development is crucial to its successful integration into global energy systems. Key pillars of good governance include:

- Policy commitment and coherence, ensuring that governments adopt clear, consistent, and long-term policies to drive hydrogen adoption and integration.
- Stability and rule of law, enabling a predictable and secure environment for investments and innovation, and providing confidence to stakeholders that regulations will be applied fairly and consistently.
- Transparency and participation, facilitating open dialogue and inclusive decision-making, and allowing all relevant parties, including industry, civil society, and the public, to contribute to the development of hydrogen strategies.
- Standards and certification, establishing reliable frameworks for safety, performance, and sustainability, and ensuring that hydrogen technologies meet established benchmarks and are trusted by consumers and investors alike.

These pillars establish the governance framework for a sustainable hydrogen economy, emphasizing transparency, accountability, and stakeholder engagement. The EESG framework ensures that PtX initiatives, like green hydrogen development, align with sustainability goals, promoting economic growth, environmental protection, social equity, and good governance.

2.3 Ongoing Development Activities for Green Hydrogen in Jordan

The Ministry of Energy and Mineral Resources (MEMR) is at the forefront of the government's efforts to establish a strong foundation for investment in and development of green hydrogen initiatives. These efforts include a broad range of actions, such as enhancing communication and transparency, updating regulations, and conducting feasibility studies. Presented below is a detailed overview of these ongoing initiatives, supported by real-world examples:

Aspect #1
***Environment** – Ongoing Actions:*

- The Port of Aqaba is already a key hub for hydrogen end uses, including heavy-duty transportation applications and ammonia production. The Port provides substantial experience in managing safety risks associated with hydrogen usage.
- Jordan’s National Green Hydrogen Draft Strategy outlines an action plan to guide the development of the hydrogen sector, highlighting the need for updated regulations and health and safety standards that align with evolving international norms.
- The World Bank is actively supporting Jordan in the development of green hydrogen legislation and the establishment of sector-specific environmental standards.
- The Ministry of Water and Irrigation (MoWI) and the Water Authority of Jordan (WAJ), in collaboration with GIZ, have developed a ‘Guideline for Environmental Social Impact Assessments’ (ESIA) for sea and brackish water desalination plants. This guideline outlines all necessary components to be addressed in an ESIA for desalination projects planned in Jordan, including in relation to brine management.

Aspect #2
***Economic** – Ongoing Actions:*

- Development of Ports for Hydrogen Exports: Jordan is developing a new port dedicated to hydrogen exports, and is leveraging the current infrastructure at the Aqaba deep water port to facilitate the export of green hydrogen and ammonia.
- Hydrogen Supply Integrated Infrastructure: Hydrogen committees have established a unified infrastructure plan to develop shared intake pipelines for investors, thereby minimizing operational and capital expenditures.
- The Jordan Green Ammonia Company has established agreements to initiate projects in the Aqaba Special Economic Zone, aiming for an annual production capacity of up to 300,000 tons of green ammonia.
- Moreover, government and investor engagement actions include:
    - The Ministry of Energy and Mineral Resources has executed multiple Memoranda of Understanding (MoUs) with both international and domestic investors to conduct feasibility studies and advance project development.

- The recent general electricity law promotes investment in green hydrogen and energy storage projects via public-private partnerships.
- Jordan is partnering with international energy companies to utilize global expertise, secure funding, and facilitate technology transfer. Hynfra[1] company, in collaboration with local entities, is developing green hydrogen and ammonia production facilities adjacent to the Port of Aqaba.

Aspect #3
Social *– Ongoing Actions:*

- A study plan developed by a Japanese NGO is currently being implemented to assess the influence of new hydrogen projects on population growth in Aqaba, with projections extending to 2030.
- ASEZA and ADC have undertaken initiatives to involve local communities impacted by new projects in Aqaba, including:
  - The establishment of local communication committees to tackle social responsibility issues (CSR activities).
  - The provision of ongoing financial and health assistance to affected communities.
  - The raising of awareness around hydrogen-related initiatives via development institutions, committees, and public communication platforms.
  - The selection of designated land-use sites for hydrogen initiatives, taking into account geographic characteristics and closeness to communities to reduce disturbances.
  - The provision of ongoing training programs for in-demand occupations in Aqaba via ASEZA's employment and training department. A vocational training center has been established in partnership with the MAERSK company to enhance skills and provide upskilling support.
  - The hydrogen upskilling and training proposal contained in this report was conceived and developed by Al Hussein Technical University.
  - The development of a database for students, job seekers, and trainees registered during training programs and projects, which is regularly updated.
  - The development of policies supporting human rights, safe environmental practices, and labor standards through ISO certifications, influenced by lessons learned from significant investments in steel and ammonia production.

Aspect #4
Governance *– Ongoing Actions:*

- National and Technical Committees:
  - National and technical committees involving all relevant governmental institutions have been established. This collaborative effort has led to the creation of a Green Hydrogen Unit.
  - MEMR is influential in Jordan's efforts to promote the development of green hydrogen. The green hydrogen unit responsible for coordinating the efforts of stakeholders, ensuring alignment with national strategies, and driving policy

[1] *Hynfra Company: Hynfra is a Polish firm that develops, designs, and integrates systems for green hydrogen and ammonia and it is a partner in Jordan Green Ammonia LLC (JGA), which is developing a green ammonia plant in the Aqaba Special Economic Zone.*

development to establish Jordan as a key participant in the global hydrogen economy.
   - The unit has facilitated the signing of Memoranda of Understanding (MOUs) with 12 potential investors and has introduced land use incentives, including a waiver of fees for up to three years to allow for the conduction of feasibility studies on hydrogen production.
   - The primary objectives of these committees are to resolve regulatory obstacles, promote collaboration, and offer technical expertise in order to establish a hydrogen development framework that is both inclusive and robust.
   - Workshops and roundtable discussions have been arranged to facilitate the exchange of ideas with investors, donors, and financing bodies in order to create a suitable and comprehensive model that promotes investment in this sector. Recently, all parties discussed the common use infrastructure approach due to the limitation in available area at the port, giving investors a chance to build their feasibility studies and plans accordingly and encouraging alignment on opportunities between investors.

- The National Hydrogen Strategy: MEMR is leading the development of a national plan to establish Jordan as a hub for competitive green hydrogen production. A thorough regulatory framework covering all aspects of the hydrogen value chain—from infrastructure development to production and supply—is part of this strategy and to be included in the energy strategy.
- Regulatory Reforms and Policies:
   - The government is revising its regulatory framework, including through a new electricity law implemented in 2024 to promote green hydrogen and energy storage investments through public-private partnerships. Endorsement of the new electricity law will be a step forward to develop the gas law as well.
   - National and technical committees are currently reviewing a draft policy that is being developed in collaboration with the World Bank to ensure alignment with global standards.
   - Jordan aims to standardize incentives for hydrogen projects across all locations and allow investors flexibility in selecting their business models.
   - Jordan aims to establish comprehensive regulatory benchmarks, encompassing KPIs for hydrogen certifications, sustainability standards, and investor confidence to guarantee conformity with global sustainability goals.

- Infrastructure Development and International Collaboration: Partnerships with the European Bank for Reconstruction and Development (EBRD) and the World Bank focus on improving infrastructure, reducing costs, and increasing the competitiveness of green hydrogen production projects. Examples include:
   - Feasibility Study with HDsolar (2024): Intended to generate 400,000 tons of green ammonia per annum.
   - Collaboration with China Three Gorges International (CTGI)[2] (2024): Investigating the production of 200,000 tons of green ammonia.
   - Hydrogen Export Studies: Evaluating infrastructure requirements and export capabilities with assistance from the EBRD and the World Bank.

[2] *China Three Gorges International Renewable Energy: A company from China, who signed MOU to produce green hydrogen in Jordan.*

- Public-Private Partnerships (PPPs): Memoranda of Understanding have been signed with both national and global developers to encourage investments. Examples include:
    - Mass Group Holding (2024): Aiming for an annual production of 180,000 tons of green ammonia.
    - Jordan Green Ammonia LLC (2023): Feasibility studies supported by UAE-based Fidelity Group for initiatives in close proximity to Aqaba.
    - Enertrag (2023): Engaging with German renewable energy specialists to develop hydrogen production facilities in Jordan.
- Land Use Agreements: Designated land has been assigned for green hydrogen initiatives, with contracts permitting investors a maximum of three years for feasibility assessments and project development.

3. Methodology

Sustainability assessment was conducted in accordance with the EESG (Economic, Environmental, Social, and Governance) framework provided by PtX Hub. The approach followed was systematic and structured. This methodology facilitated the holistic assessment of risks and opportunities across all pertinent dimensions, with an emphasis on sustainability, inclusivity, and adherence to global green hydrogen standards. The objective of the process was to identify, analyze, and suggest mitigations for primary risks, while simultaneously emphasizing the opportunities presented by Jordan's green hydrogen ecosystem.

3.1. Framework Alignment

A comprehensive analysis of risks associated with economic, environmental, social, and governance factors was facilitated by the EESG framework, which served as the foundation for the risk assessment. This framework established explicit criteria for risk assessment in accordance with sustainability dimensions and guaranteed compliance with international standards for green hydrogen development.

3.2. Data Collection and Review

In order to guarantee the precision and relevance of the risk assessment, a comprehensive data collection process was implemented. The PtX Hub Scoping Paper on Sustainability Dimensions and Concerns, the USAID Draft Hydrogen Strategy, and other national and international studies were among the key documents reviewed. This phase encompassed the following activities:

- Validation of data and statistics to guarantee their consistency and accuracy.
- Evaluation of the credibility of references and citations.
- Cross-referencing with technical documents, such as global PtX initiatives.

3.2.1 Literature Review

A literature review was conducted in order to identify and analyze the risks associated with the development of green hydrogen in Jordan. Secondary data from reputable sources including policy frameworks, technical feasibility studies, and international case studies, provided insights into global best practices, existing challenges, and potential risk factors. The review focused on the economic, environmental, social, and governance aspects of sustainability, as delineated in the EESG framework. By adapting key findings to Jordan's distinctive context, this analysis informed the subsequent stages of the assessment process and the identification of critical risks.

3.2.2 Consultation with Stakeholders

The methodology was significantly influenced by stakeholder engagement. Technical experts, hydrogen investors, and government representatives participated in workshops and consultations held in Aqaba on December 11–12, 2024. The sessions were centered on the EESG dimensions, and discussions were facilitated to validate findings, identify high-priority risks, and collaboratively develop mitigation strategies. This participatory approach guaranteed that the risk assessment was rooted in Jordan's distinctive socio-economic and environmental context and reflected the perspectives of key national stakeholders.

Additionally, one-on-one online meetings were held with key stakeholders to better understand the context surrounding green hydrogen development and to refine and enhance the risk matrices. These discussions addressed governance, regulatory frameworks, and investment challenges specific to green hydrogen development in Jordan.

3.3. Formulating the Risk Assessment Matrices

A structured process was employed to develop the risk assessment matrices:

- Risk Identification: Insights from the literature review, stakeholder consultations, and international best practices were employed to identify risks for each EESG dimension. Relevant risks, including regulatory barriers, investment gaps, and water scarcity, were prioritized according to their national significance.
- Risk Assessment: Probability and impact were evaluated for each identified risk:
  - Probability: The likelihood of the risk occurring, classified as low, medium, or high.
  - Impact: The severity of the risk's effects on economic, environmental, social, or governance dimensions, also classified as low, medium, or high.
  - Influence Period: Risks were classified as short-term (0–10 years), mid-term (11–20 years), or long-term (21–30 years), to allow for the prioritization of mitigation efforts.
- Optimization and Mitigation: Risk mitigation strategies were devised in accordance with local capacity, stakeholder feedback, and best practices. Strategies included investments in technology, policy reform, and capacity building. Additionally, opportunities were identified, including the promotion of innovation and the exploitation of Jordan's renewable energy potential.

3.4. Iterative Review Process

The risk assessment was iterative, enabling continuous updates based on stakeholder contributions and new data. This dynamic approach encouraged adaptability within the methodology, allowing for future risks and opportunities to be addressed as the green hydrogen sector evolves.

4. Risks Assessment According to the EESG Framework

4.1 Environmental Aspect

I. Energy and Carbon

Electricity

PtX production depends on electric power as a main supply that must be sustainable and characterized by both renewability and additionality.

Renewability

To be considered sustainable, PtX products and their processes should be fossil-free. As such, they should be produced using electricity generated from renewable sources. A loss of available energy will result from converting electricity into hydrogen and PtX products. The electricity required to produce 1 TWh of hydrogen is 1.4 TWh; therefore, power-based hydrogen from water electrolysis will always have a higher greenhouse gas (GHG)-intensity than that of the electricity used for its production. Electricity-based hydrogen is only preferable if the carbon intensity of the electric current used is significantly below 200g CO2/kWh. In 2020, the carbon intensity of power from the Jordan electricity grid was 435 g CO2e/kWh. Therefore, by using electricity from the grid, emissions would not be reduced.

In 2020, 80% of Jordan's electricity generated from natural gas and 20% from renewables. By 2022, renewable energy production has raised to 29%, with a national goal of reaching 50% by 2030. Jordan had over than 30 renewable energy companies in 2020, operating 40 renewable energy projects including a mix of wind, solar, biomass, and some hydropower projects. As a result, renewable energy's share rose from 2% in 2015 to 11% in 2020.

In Jordan, solar and wind resources are of good quality and can boost green hydrogen's production and export potential due to Jordan's proximity to ports and European markets. The production of green hydrogen could reduce Jordan's dependency on fossil fuels (the country currently imports 91% of its energy supply in the form of fossil fuels), increase renewable energy production, and drive the country towards climate neutrality by enabling the de-fossilization of hard-to-electrify sectors such as crude oil refining, fertilizer production, gas-fired thermal power plants, urban buses and heavy-duty trucks and port logistics.

However, the lack of a comprehensive regulatory framework and water scarcity are crucial issues which must be considered prior to the uptake of PtX production in Jordan

Renewability alone, however, is not sufficient to qualify PtX as sustainable, as additionality is also required.

Additionality

Additional renewable capacity should be dedicated for the energy used for PtX production. Adequate policies and regulations have been established in Jordan to support renewable energy sources, such as solar photovoltaic (PV) energy and wind energy on seashores. Seven main action areas were highlighted in the Draft National Green Hydrogen Strategy, with the goal of encouraging the development of the renewable energy sector in Jordan, accelerating the uptake of renewables and increasing their share of the country's energy mix:

- Provide the conditions for renewables to grow in the power sector.
- Foster continued growth of renewable power generation.
- Plan for the integration of higher shares of renewable power.
- Incentivize the use of renewables for heating and cooling.
- Support renewable options for transport and mobility.
- Catalyze renewable energy investment.
- Strengthen local industries and create jobs in renewables.

Medium-term (in process/in the pipeline) opportunities for renewable energy generation in Jordan are outlined below:

- National Conveyance Project (NCP): This project aims to provide 300 million m3 of desalinated water from the Gulf of Aqaba to Amman per year. It is expected to produce desalinated water by 2028 and aims to reduce carbon emissions through the use of alternative energy sources.
- Energy Storage Technologies: Jordan is exploring various energy storage solutions, such as pumped-storage hydropower (PSH). A storage project at Al-Mujib dam is planned for implementation before 2030.

Jordan can export green hydrogen to European countries in order to meet its climate targets and commitments under the Paris Climate Agreement, and as a new income source. However, additional specifications will be required to provide renewability and additionality, depending on the type of electricity sourced for PtX. The Renewable Energy Directive (RED II) establishes the definition of additionality for the EU market; in case there is a direct connection of new local off-grid installations generating renewable electricity to the PtX unit, electricity supply can be clearly considered renewable, as long as installation is not benefiting from government policies that were designed to shift the country's overall power to renewable energy.

Carbon Cycle

Sustainable energy works to reduce the effects of climate change by stabilizing the carbon cycle, as it is derived from natural processes that regenerate faster than they are depleted. These sustainable energy sources, which include solar, wind, hydro, and bioenergy, are key to a clean and sustainable future (BECIS, 2023). The most important PtX products that consist of hydrogen and carbon are hydrocarbons such as methane, synthetic e-kerosene, and polyethylene. Only when the hydrogen is green can climate-neutrality be achieved by these synthetic products. Moreover, the carbon component should be generated from a closed carbon cycle.

Ambient Air

Capturing carbon from ambient air through Direct Air Capture (DAC) of carbon ensures a closed carbon cycle as a clean source of carbon to be used in fuel production with the use of hydrogen. CO_2 concentration in ambient air is not expected to decrease significantly in the long-term, making DAC a viable long-term solution. DAC technologies are currently expensive and energy intensive, and are still not ready for use in PtX production in the short term. Ersoy, S.R. et al., 2024 studied the use of low-temperature DAC technology in Jordan and stated that it was more advanced than high-temperature DAC technology and could be used if upscaled and more affordable.

Biogenic Sources

Carbon captured from biogenic sources represented by biogas, bioethanol, solid biomass combustion or fermentation processes can ensure a closed carbon cycle. However, biomass is known to be rare and unevenly distributed. The use of biogenic carbon sources thus has limited scalability and will not be able to satisfy future demand on its own, although it could play an important role in kick-starting the PtX market as it provides sustainable CO_2 for PtX processes, enabling the production of carbon neutral fuels and chemicals. This synergy supports decarbonization and makes the PtX market more sustainable and scalable.

The biomass energy sector is expanding steadily and is currently providing Jordan around 0.1% of its total energy needs (equal to 3.5 MWh of electricity from biomass resources). Jordan is producing biogas energy from Al-Samra Wastewater Treatment Plant WWTP Biogas (Zarqa Governorate), Wadi Shallala WWTP Biogas (Irbid Governorate), Al-Russaifah Landfill Biogas (Zarqa Governorate) and Al-Ghabawi landfill (Amman). There is great potential for the production of biomass in Jordan in the future, although this potential is not currently being exploited. About 96.5% of the biomass produced is composed of animal manure, olive trees and pomace (1.8%), slaughterhouse waste (0.1%), blood (0.5%) and sludge (1.1%).

Increasing biomass generation in Jordan could result in the following environmental benefits:

- Increased natural capital.
- Potential to produce biofuels from municipal, agricultural and industrial waste.
- Effective use of resources.
- Mitigation and adaptation to climate change.
- Decreased dependency on imported fossil fuels.

Industrial Point Sources

Industrial point sources can assist with the collection of CO2 via Carbon Capture and Usage (CCU) technologies, although they are unable to produce a closed carbon cycle. The use of CCU technologies affects industrial processes, but does present the advantage of lower energy requirements compared to DAC. Recycling industrial carbon emissions may be a viable option for enhancing PtX production. CO2 point sources in Jordan could include the chemical and mining industries. This option would benefit from further study to establish its viability for PtX production.

Outlined below are the results of our risk assessment for energy and carbon:

Risks	Impact	Mitigation
Hydrogen leakage and release into the atmosphere. Probability Impact Period of Influence **Long-term**	Indirect global warming effect by extending the lifetime of other greenhouse gases (GHG), offsetting GHG emission reduction gains.	• Application of high-integrity storage and transportation systems, leak detection technologies, and emergency response plans. • Adoption of hydrogen blends (up to 20% volume) instead of pure hydrogen to lessen leakage risks. • Implementation of monitoring and reporting systems for effectively tracking and measuring hydrogen leakage rates. • Conduction of research and development regarding hydrogen storage and transportation technologies.
Hydrogen is not produced from additional renewable electricity. Probability Impact Period of Influence **Long-term**	No reduction in GHG emissions; the impact is the same as if the green hydrogen were produced using already-planned or existing renewable electricity.	• Usage of new-to-the-system renewable electricity for hydrogen production (established in less than 36 months). • Production of renewable electricity and hydrogen locally or in neighboring zones.
Overheating of PV panels during summertime. Probability Impact Period of Influence **Mid-term**	Air temperature increases around the PV solar system in specific areas reduces the electrical output of the module, influencing the microclimate of the site and generating a heat island effect.	The overheating of the PV arrays can be avoided by passive cooling (e. g., through natural circulation cooling with air, water or phase-change materials).

II. Water, Land and Biodiversity

Overview - Water

Along with electricity, water is a key input (during the water electrolysis step) when producing green hydrogen and PtX. To ensure sustainability in green hydrogen production, an analysis of water stress and conflicts, water availability and solutions is needed. In addition, the impacts of using water for this process on the surrounding ecosystem have to be considered. The regular supply of pure water for electrolysis is a main challenge, as 9 liters of high purity water is required to create 1 kg of hydrogen.

Water Stress

In general, many of the countries that present promising potential for renewable energy generation through solar and wind power also face severe water stress. At particular risk is Jordan, as the fourth most water-scarce country in the world. Desert areas in Jordan occupy more than 80% of the country's total land area and receive no more than 100 mm of precipitation per year. Moreover, only 4% of the country's total area receives over 300 mm of precipitation per year. Limited amounts of water are available for Jordan from international rivers that are used other riparian countries, while population growth and climate change negatively affect water availability in the country.

Water Footprint

In 2022, water use by the agricultural, municipal/domestic, and industrial sectors reached 1,127 million cubic meters. The agricultural sector has the highest water consumption rates, followed by the domestic and industrial sectors. According to an estimate from IRENA, the global annual demand of 409 million tonnes of green hydrogen needed in 2050 requires 7 to 9 billion cubic meters of water yearly - less than 0.3% of current freshwater consumption. In addition, the agricultural and municipal/industrial sectors currently consume over 100 times and 50 times more water, respectively, than the expected water needs for hydrogen production in 2050. Moreover, compared to fossil thermal power generation or to blue hydrogen, the water usage intensity of green hydrogen from wind, sun and electrolysis is substantially lower. Even when factoring in the water required to clean and cool solar systems (around 70 liters per liter of fuel), the water demand posed by green hydrogen production remains lower than the demand produced by fossil thermal power generation. Therefore, shifting to green hydrogen improves water management and lessens water stress.

Desalination

Water desalination has presented itself as an ideal solution for reducing hydrogen's 'water footprint'. Around 85% of planned green hydrogen projects may need an additional water source, such as desalination. Desalination requires intensive energy usage; to be sustainable, the electricity produced must be from renewable resources and abide by the same standards of electrolysis. Jordan can address and reduce the effects of water scarcity in the country through future sea water desalination and water efficiency projects. Desalination plants built for hydrogen production could also satisfy local demands for drinking water and irrigation. However, desalination raises serious environmental issues with respect to the disposal of brine. In Jordan, the Groundwater Management Policy encourages water desalination by the private sector, while stressing its environmental impacts and the need for proper brine disposal. However, brine disposal generated from inland desalination remains an issue in Jordan.

The Aqaba-Amman Water Desalination and Conveyance Project will supply 300 million cubic meters of water a year through a 450-kilometer channel north of the capital Amman and its surrounding area. Water will be collected and desalinated from the Red Sea at the Gulf of Aqaba in the south. This project mainly aims to secure future supplies of drinking water in Aqaba, Amman, and other areas, and to increase the private sector's involvement in water management. However, additional desalination projects will be needed in Jordan for hydrogen and PtX production.

Other Options

DAC technologies are expected to reduce water demand in the future by collecting water to supply PtX production while partially closing the water cycle. The Royal Scientific Society (RSS) team has successfully developed, validated and obtained approval for a device that can contain drinkable water from the most arid air of the desert. To commercialize the device, a legal worldwide patent has been commissioned by the RSS.

Overview - Land and Biodiversity

Although PtX plants don't require large spaces, the renewable energy facilities that provide fossil- free energy do. The development of hydrogen projects and the production of renewable energy for their operation, including via PV solar panels and wind farms, will affect land use and biodiversity.

Land Use Footprint

In contrast to the densely populated northern regions almost no land use constraints are imposed in the southern arid regions as relates to PtX production from renewable electricity, as this region has vast unoccupied areas and no vegetation. To house hydrogen production facilities, sufficient land has to be available. The Aqaba Development Corporation has secured around 4.5 km2 of land in the industrial port that will be dedicated to green hydrogen production, demonstrating Jordan's commitment to developing the sector. However, additional land area will be required to reach future export and domestic targets with around 448 km2 by 2030, 1,205 km2 by 2040, and 2,613 km2 by 2050. Most of the land required is for wind energy production, which has a much lower power density than solar energy.

Based on the annual report of the World Wind Energy Council of 2019, Jordan came third in the MENA region in terms of wind energy production during the year 2019, with a total production of 190 MW. Since 2015, Jordan began to invest in wind energy as a renewable source of electricity production, with the opening of the first Tafila Wind Farm and Solar Plant (117 MW) in Tafila Governorate. In addition, 3 other wind farms were implemented in Irbid Governorate (Hofa and Al Ibrahimiyyah) and in Maan Governorate. However, despite the advantages associated with wind energy, adequate locations with large and sufficient land areas are required to house turbines and wind farms. Additionally, other factors, such as road accessibility, proximity to high-voltage power lines and flat areas, and distance from residential areas, must be considered. Jarrah & Dwairi (2024) concluded that the most suitable locations for investment in future large wind energy farms in Jordan are the farthest south Aqaba-shore at the border of Saudi Arabia and Sabha village in Mafraq at the Syrian border. Moreover, Jordan has several large-scale solar projects under construction or in the planning stages, such as Al-Dhafra Solar Project (800 MW), Al-Risha Solar Project (400 MW) and Quweira Solar Power Plant (200 MW). These projects promise a significant increase in solar energy capacity in the country.

Biodiversity Impact

Possible impacts on biodiversity due to land use changes caused by PtX may be relevant. Said impacts need careful monitoring, although in most instances PtX interference with landscape ecology and species diversity is not more drastic than the effects of biomass production. Wind turbines, on the other hand, are a frequent hazard for birds and bats. Off-shore wind parks also disrupt marine ecosystems and fish populations.

Outlined below are the results of our risk assessment for water, land and biodiversity:

Risk	Impact	Mitigation
Brine and chemicals improperly discharged into the sea from the desalination plant. Probability Impact Period of Influence **Long-term**	• Damage to marine ecosystems from contaminated water and temperature changes. • Negative impact on the Aqaba Marine Reserve.	• Use of brine management technologies that reduce concentrated brine and chemical discharge. • Exploration of options for recycling parts of the brine's minerals and chemicals. • Conduction of independent ecological assessments based on local indicators. • Dispersion of brine when it is discharged based on the results of ecological assessment and modeling.
Occupation of large areas for renewable energy production (wind and solar farms). Probability Impact Period of Influence **Long-term**	• Fragmentation of pristine territories. • Encroachment on natural habitats and agricultural areas.	• Avoidance of protected areas, nature reserves and cultural heritage sites. • Avoidance, whenever possible, of agricultural and forested lands. • Construction of electrolysers in industrial areas. • Building of understanding of local legal and regulatory frameworks and international standards governing land acquisition before allocation of land for green hydrogen projects.
Emissions of dust and particles during construction of solar facilities and wind farms. Probability Impact Period of Influence **Short-term**	Impact on the landscape and nearby communities during site preparation, grading, vegetation removal, and construction of roads, especially in desert and arid regions.	• Construction of PV facilities at a minimum of 100 m distance from populations and important facilities in line with national regulations (Regulation No. 69 of 2020). • Implementation of dust management measures, including watering the ground as needed.

Risk	Impact	Mitigation
Noise and light flickers generated by wind turbines. Probability Impact Period of Influence **Long-term**	• Decrease in value of nearby properties. • Disruption for nearby communities.	• Construction of wind farms at a 700 m distance from populations and important facilities and at 300 m from main roads in line with national regulations (Regulation No. 69 of 2020). • Optimization of the design of blades to reduce noise levels.
Use of chemicals such as antifreeze agents, herbicides, dust suppressants, and rust inhibitors during the maintenance of solar plants. Probability Impact Period of Influence **Long-term**	Contamination of soil, land and water negatively affecting local and regional biodiversity.	Use of environmentally-friendly products during maintenance of PV solar panels such as waterless based cleaning techniques.
Collision of birds and bats into wind turbines and high voltage transmission lines. Probability Impact Period of Influence **Long-term**	Bird and bat injuries and fatalities, especially during bird migratory seasons (500 million birds migrate through Jordan every year.	• Conduction of wildlife surveys to understand bird migration, breeding and feeding dynamics. • Design of wind turbines to reduce risk of collision, including the incorporation of larger and more visible blades. • Adoption of lower rotational speeds and scheduling to avoid migration season. • Use of tubular towers with a smooth exterior, internal ladders and underground wiring to prohibit roosting and nesting of birds on the tower and reduce the presence of birds in wind farms. • Use of advanced technologies such as acoustic deterrent devices to encourage birds and bats to move away from turbine areas. • Installation of an “early warning” system providing advance detection of bird and bat activity that can stop the movement of turbines.

Risk	Impact	Mitigation
Installation of high-voltage transmission lines in natural habitats including grading soils, use of herbicides for vegetation removal and road construction. Probability Impact Period of Influence **Long-term**	• Degradation and fragmentation of natural habitats. • Increase in species' mortality rates and extinction of native species. • Blocked movement and seasonal migration of wildlife species and their displacement.	• Only remove vegetation when necessary. • Conduction of wildlife surveys to understand bird migration routes and ensure the project does not include any traveling paths for wild animals.
Mismanagement of biomass during electricity production. Probability Impact Period of Influence **Short-term**	Land, soil and water contamination and indirect impacts on nearby communities and biodiversity.	• Production, storage and transportation of biomass in an environmentally-responsible way. • Implementation of good management practices during operation.

III. Resources and Recycling

The availability, use, dispersion or recycling of raw materials is an important aspect in assessing the sustainability of PtX production processes and technologies. This is particularly true for 'critical' raw materials, which are scarce, hard to replace or produced under conditions exposed to human rights challenges etc.

Resources for Renewables

The global shift in energies will necessarily cause major changes in resource uses and resource trade interdependencies. The use of some scarce raw materials will increase with renewables. The World Bank Group explains that, even today, more than 50 million tons of minerals are required. Figures projected for 2050 in line with the Paris Accord's 2-degree scenario are even higher, reaching 3.1 billion tonnes. Moreover, only a small number of countries have been shown to possess the highest amounts of available materials for energy transition.

Polymer Electrolyte Membrane electrolysis (PEM) and Alkaline Water electrolysis (AEL) represent two renowned electrolysis technologies that require the use of Critical Raw Materials (CRM) such as iridium, platinum, tantalum, cobalt, and nickel. PEM electrolysers demand significant amounts of rare CRM (mainly iridium and platinum-coated materials), which are energy and emission intensive. Each kilogram of metal produced by each of these materials releases over 20 tons of carbon dioxide into the atmosphere. When compared to the entire hydrogen production process, this would still translate into a relatively small emissions amount (about 0.01 kg CO_2-eq /kg H2), although it is nevertheless significant. On the other hand, nickel, platinum, and cobalt are used by the AEL electrolysers.

Platinum consumption and production can support 200 GW of electrolyser deployment annually, increasing to 2000 GW in the next decade. However, iridium usage would support the deployment of 3-7.5 GW/year, meaning 30-75 GW of electrolyser capacity in the next decade, potentially worsening supply chain bottlenecks and hindering PtX's de-fossilization potential, necessitating redesign and recycling solutions.

Different approaches should be used in the hydrogen production process to ensure the sustainability of the mineral resources value chain and reduce the need for critical raw materials.

Outlined below are the results of our risk assessment for resources and recycling:

Risk	Impact	Mitigation
Additional water requirements for green hydrogen. Probability Impact Period of Influence **Long-term**	Exacerbated water stress (in an already water-scarce country).	• Seawater desalination and air-to-water generation (also using renewable energy). • Research into and development of advanced electrolysis technologies to improve efficiency and reduce water consumption. • Optimization of water management and sustainability of freshwater demand in the production process. • Exclusion of surface and ground water usage for H2 production in water-stressed areas.
Depletion of raw materials for production of electrolysers and renewable energy components. Probability Impact Period of Influence **Long-term**	Adverse impacts on human ecosystems linked to the sourcing of conflict minerals and other critical raw materials for electrolysers, mainly Iridium (PEM), Platinum (PEM&AEL), Raney-Nickel (AEL), Nickel (class 1) (AEL) and Cobalt (AEL).	• Analysis of the demand for critical materials/metals. • Reduction or substitution of the raw materials used. • Ensure that the project design adopts the most suitable techniques to limit use of critical materials/metals. • Use of a mix of different technologies. • Building of more durable electrolysers and improving process efficiency. • Increasing recycling rates to reduce increase of primary minerals mining.

Risk	Impact	Mitigation
Mismanagement of end-of-life stages of solar panels and wind turbines. Probability Impact Period of Influence **Long-term**	• As panel recycling is expensive and time consuming, panels are often disposed of into landfills, breaking down and leaching toxic chemicals such as lead and cadmium into the soil, potentially contaminating groundwater and affecting local ecosystems. • Although 80% to 85% of wind turbine elements can be recycled, the blades are difficult to recycle efficiently because they are made from composite materials (fiberglass, carbon fiber, resins), which end up in landfills, potentially leading to soil and ground water contamination.	• Use of enhanced recycling technologies to ensure effective separation of raw materials. • Extension of producer responsibility for the entire lifecycle of their products, including disposal and recycling. • Collaboration between the government, private sectors, and research institutions to foster innovation in recycling technology and develop sustainable practices for end-of-life panel and turbine/blade management. • Ensuring circularity is continued at the end of solar panel and turbine lifetimes. • Proper landfilling of hazardous materials in line with international best practice.

IV. Pollution and Safety

Risk and Impact Assessment

PtX production sites must be subject to thorough environmental impact assessments (EIAs) and regular inspections of their operation. Defined standards must be imposed on production, storage, transportation and final use of their outputs (hydrogen, ammonia, methanol or e-fuels). Jordan has been working on facilitating and accelerating the development of the Green Hydrogen industry both locally and internationally through proper policies, regulations and standards.

To ensure the success of this new sector, updated and new regulations and health, safety and technical standards are required in line with evolving international ones. For example, Jordan has issued a Guideline for EIAs for Sea and Brackish Water Desalination Plants, which is specifically targets this sector in Jordan. A similar guideline can be developed for the green hydrogen production sector, covering associated facilities.

The national EIA process in Jordan is managed by the MoEnv, who issue the final environmental approval for a project and are in charge of follow up during project implementation to ensure adherence to the approved Environmental Management Plan and other set environmental conditions. As decentralized production of green hydrogen is relatively new, the regulatory and environmental requirements and permitting regulations are non-existent or unclear. This adds significant uncertainty and additional time and overheads to the project development process.

According to Regulation No. 69/2020, the Environmental Classification & Licensing Regulation, sea and river water desalination plants, wind energy and solar PV energy generation plants (capacity exceeding 20 MW) are classified as Category 1 – (High Risk) Activities that pose severe threats to the environment and human health and require a comprehensive EIA as per Article 4 of this regulation. Building and operating green hydrogen and PtX production plants will likely also fall under this category, requiring formal public consultation and stakeholder engagement. Stakeholder consultation and engagement is an essential part of the comprehensive EIA process in Jordan through which the public is given the opportunity to engage and participate in new developments. There could be unfavorable public perceptions, such as worries over the potential safety risks of hydrogen production, storage and transport, the potential loss of jobs in other sectors, or the use of scarce land, power, and water resources in the production of hydrogen. Only through outreach and public awareness raising can these concerns be addressed.

Production, Transport and Storage Risks

The entire value chain of PtX, including logistics and infrastructures, must be taken into consideration for ensuring PtX sustainability, especially for internationally-traded PtX products. Impact assessments and safety standards are not only relevant for PtX production sites. Environmental and safety standards must be defined for every part of the value chain, such as storage, refinement, transportation via pipelines, shipping, rail or road. Three modes of hydrogen transportation are available in Jordan: via pipeline (blending into existing natural gas networks), by retrofitting current pipelines to accommodate hydrogen, or by building new dedicated hydrogen pipeline networks. In the medium to long term, Jordan may consider developing new dedicated hydrogen infrastructure along existing pipeline routes for pipeline export to key consumers. To achieve export goals, significant infrastructure investment and further studies are needed.

As the country continues to develop its industrial, commercial and energy sectors, it is essential for Jordan to strengthen its regulatory frameworks, improve safety protocols, and invest in better emergency response infrastructure to mitigate the risk of chemical spills and industrial accidents in the future.

Outlined below are the results of our risk assessment for pollution and safety:

Risk	Impact	Mitigation
Lack of environmental, health and safety standards and specifications related to green hydrogen production. Probability [yellow] [orange – selected] [red] Impact [yellow] [orange – selected] [red] Period of Influence **Short-term**	Inadequate environmental, health and safety measures adopted, risking worker, community and environmental wellbeing during hydrogen production.	• Development and adoption of environmental, health and safety standards (including emergency preparedness and response) for the production of hydrogen in line with international standards. • Collaborate with the private sector, academia, and international bodies to refine regulations, certification and safety standards as the market evolves, to ensure updated standards.

Risk	Impact	Mitigation
Lack of technical capacity to adequately manage environmental, health and safety issues during production, storage and transportation of green hydrogen and its derivatives. Probability Impact Period of Influence **Short-term**	Increased risk of accidents and injuries to workers and nearby communities.	• Cooperation with international hydrogen and standard-setting organizations and educational establishments to develop training curricula and evaluate the needs of the future workforce in the sector. • Ensure adequate training in environmental, health and safety practices for all workers on green hydrogen production plants during both construction and operation
Hydrogen leakage during production, storage and transport. Probability Impact Period of Influence **Short-term**	Hydrogen is highly flammable leading to fire and explosion hazards threatening workers and nearby communities	• Use of high-integrity storage and transportation systems, leak detection technologies, and emergency response protocols to minimize the likelihood of hydrogen release • Use of hydrogen blends (up to 20% volume) instead of pure hydrogen to reduce leakage potential. • Comprehensive monitoring and reporting mechanisms to track and quantify hydrogen leakage rates. • Implementation of strict procedures for design, testing, maintenance, and periodic verification of vehicles and infrastructure, and training of drivers and operators
Leakage of hydrogen derivative (ex. ammonia) releasing active nitrogen. Probability Impact Period of Influence **Short-term**	Air pollution adversely impacting human health, ecosystems, and climate, and may eventually lead to stratospheric ozone depletion	• Regular maintenance of the production plant and associated facilities • Implementing strict safety measures, including the use of fixed gas detection systems, PPE, proper ventilation, and effective emergency response plans

4.2 Economic Aspect

I. Value Added and Decoupled Growth

The concept of value-added and decoupled growth emphasizes the improvement of economic productivity alongside the reduction of environmental impacts, consistent with Jordan's dedication to the advancement of green hydrogen. In this context, green hydrogen represents a significant opportunity for separating economic growth from carbon-intensive activities, facilitating value creation through the establishment of a sustainable energy ecosystem.

This dimension highlights the importance of addressing concerns associated with reliance on traditional energy exports, fluctuations in global energy markets, and possible regulatory limitations. The establishment of a strong green hydrogen sector has the potential to generate substantial value through the attraction of foreign investment, the promotion of innovation, and the creation of employment opportunities, especially within the renewable energy and advanced technology fields. Nonetheless, factors such as market constraints, substantial initial capital expenditures, and insufficient infrastructure may impede value enhancement and independent growth.

Mitigation strategies encompass the promotion of local production capabilities, enhancement of market access, and alignment of infrastructure investments with long-term economic and environmental objectives. Integrating value-added approaches within the green hydrogen framework allows Jordan to enhance its economic resilience sustainably, contributing to global decarbonization and addressing domestic challenges.

Outlined below are the results of our risk assessment for value-added and decoupled growth:

Risk	Impact	Mitigation
Over-reliance on hydrogen exports. Probability Impact Period of Influence **Mid-term**	• Economic vulnerability to global hydrogen market fluctuations. • Disregard for the need for a cohesive domestic energy transition.	• Diversify export destinations. • Balance export and domestic demand for hydrogen.
Inequitable income distribution. Probability Impact Period of Influence **Long-term**	Economic gains may disproportionately benefit certain groups or regions, causing social division and instability.	• Establish transparent revenue-sharing mechanisms to ensure fair distribution of economic benefits to all stakeholders, including marginalized groups.

Risk	Impact	Mitigation
Misalignment with sustainability goals and GHG emissions control. Probability Impact Period of Influence **Short-term**	Inadequate control over GHG emissions through the green hydrogen value chain may result in noncompliance with international market standards.	• Commit to using advanced, efficient electrolysis technologies, and tracking and reporting greenhouse gas emissions along the value chain
Under capture the economic benefits of green hydrogen. Probability Impact Period of Influence **Mid-term**	Lack of strategic reinvestment may lead to static growth or unbalanced economic development, in the case that the government decides to proceed with establishing a desalination plant, intake systems, or ammonia storage facilities.	• Create a sovereign wealth fund or similar mechanism to allocate revenues towards sustainable projects and infrastructure development.

II. Energy Mix and Transformation

A key component of Jordan's green hydrogen development strategy is a change in the country's energy mix, which aims to move away from fossil fuels and toward renewable energy sources like wind and solar. Although there are many chances for decarbonization and energy security with this shift, there are also serious concerns that need to be considered, such as potential imbalances in the national grid's integration of renewable energy, delays in the construction of infrastructure, and the financial difficulties of expanding renewable energy projects. Furthermore, there are governance concerns associated with relying on a strong regulatory structure to oversee this transition. To guarantee that the energy mix change meets Jordan's green hydrogen goals while minimizing potential disruptions to economic, social, and environmental sustainability, it is imperative to address these concerns with a thorough and proactive approach.

Outlined below are the results of our risk assessment for energy mix and transformation:

Risk	Impact	Mitigation
Limitations in feedstock availability, including land and other essential resources. Probability Impact Period of Influence **Long-term**	The limited availability of land allocated for renewable energy generation, coupled with Aqaba's limited coastal area and the considerable distances between designated energy production sites and Aqaba.	• Assess feedstock availability through resource mapping; invest in desalination facilities for water and expand solar and wind capacity specifically for hydrogen production.

Risk	Impact	Mitigation
Mandated adherence to existing fossil fuel agreements, and high costs of converting fossil fuel-based equipment to green hydrogen may deter domestic adoption. Probability Impact Period of Influence **Short-term**	Current investment in fossil fuel infrastructure during the transition phase could create stranded assets and limit long-term sustainability. This could hinder local market adoption of green hydrogen, delay national sustainability goals and reinforce reliance on fossil fuels.	• Encourage to develop adaptable systems to facilitate a gradual and seamless transition to renewable energy. • Subsidies or tax incentives to offset conversion costs. • Flexible financing options for beneficiaries in the local market. • Invest in cost-effective conversion technologies. • Phased transition and awareness campaigns.
Infrastructure bottlenecks (from an investor's perspective). Probability Impact Period of Influence **Mid-term**	Insufficient storage infrastructure may delay hydrogen production and export.	• Allow solo energy production and storage, encouraging common use infrastructure, and invest in scalable logistics systems.
Scalability and resilience challenges. Probability Impact Period of Influence **Long-term**	Lack of scalable designs may limit project expansion and adaptability to changing market demands, reducing long-term viability.	• Implement modular, scalable plant designs to adjust production volumes based on demand; ensure robust operational systems for uninterrupted production.

III. Trade and Technology Transfer

Trade and technology transfer are essential facilitators for Jordan to produce green hydrogen. The integration of cutting-edge technologies and cooperative efforts with international partners are necessary for the shift to green hydrogen. By taking advantage of Jordan's advantageous location, effective trade frameworks may be established to promote the export of green hydrogen. However, there are hazards that must be handled due to issues like logistical infrastructure, expensive shipping, and restricted technology capabilities. To guarantee smooth technology adoption and trade facilitation, effective risk management techniques include building global alliances, making infrastructural investments, and conforming to international standards.

Outlined below are the results of the risk assessment for trade and technology transfer:

Risk	Impact	Mitigation
Unclear roles in infrastructure provision and logistical limitations. Probability Impact Period of Influence **Mid-term**	Unclear responsibilities between the government and developers may delay project implementation and raise costs. Limited logistical infrastructure, such as port capacity, storage, and pipelines, may hinder hydrogen export operations and market reliability. Developers' need to expand their businesses must be clearly defined through government approvals, including capacity for desalination, production areas, etc.	• Establish clear roles and responsibilities between the government and developers, including approvals for infrastructure needs. • Invest in dedicated hydrogen ports, pipelines, and roadways for efficient transport. • Evaluate the feasibility of renting port storage for ammonia to reduce immediate logistical challenges. • Develop forward-looking plans to address future expansions in the hydrogen business.
High shipping costs. Probability Impact Period of Influence **Long-term**	Shipping hydrogen and its derivatives (e.g., ammonia) to distant global markets may result in significant logistical expenses, eroding profit margins and competitiveness in export markets. The high cost of marine insurance makes it very expensive to include the shipping cost within the service provided by the investors.	• Explore alternative transport methods such as ammonia shipping, which has lower costs. • Negotiate long-term shipping contracts to stabilize costs. • Assess opportunities for virtual trade via GHG certificates.
Limitations to technological innovation. Probability Impact Period of Influence **Mid-term**	The cost of required technology and innovation may reduce Jordan's competitive edge in the global hydrogen market. Reliance on external technology providers without sufficient knowledge transfer leads to limitations to self-innovation.	• Build partnerships with international technology providers to ensure local knowledge transfer to enhance capacity building for hydrogen expertise. • Support domestic R&D efforts to develop innovative technologies. • Include technology transfer clauses in bilateral agreements.
Intensified competition and trade challenges. Probability Impact Period of Influence **Long-term**	Increased competition from emerging exporters may limit market entry and erode Jordan's market share. High shipping costs and limited export readiness could amplify challenges. There is a risk of overdependence on limited bilateral and multilateral trade agreements.	• Emphasize Aqaba's proximity to European and Middle Eastern markets as a strategic advantage. • Strengthen compliance with global sustainability standards to attract eco-conscious buyers. • Develop unique selling propositions by leveraging competitive pricing and green branding. • Secure long-term trade partnerships and multilateral agreements to diversify market reach.

IV. Investment and Public Finance

In Jordan, public funding and investment are essential to the implementation of green hydrogen initiatives. Large capital expenditures in workforce development, technology, and infrastructure are needed to do this. Subsidies, grants, and tax incentives are examples of public finance tools that are crucial for reducing initial financial risks and encouraging private sector involvement. Furthermore, establishing global alliances and loans can guarantee long-term financial viability and fill funding shortages. Green hydrogen mobilization will be made possible by transparent legislation, strategic budget planning, and effective governance.

Outlined below are the results of our risk assessment for investment and public finance:

Risk	Impact	Mitigation
High investment cost and fluctuations in interest rates. Probability Impact Period of Influence **Short-term**	High capital costs for establishing hydrogen plant infrastructure could deter private sector participation and cause project delays. Fluctuating interest rates increase financial uncertainty, further deterring investments. Early-stage operational costs could strain government budgets and discourage long-term investments.	• Offer financial incentives and low-interest funding through partnerships. • Implement risk-sharing mechanisms like guarantees and co-financing. • Develop a national PPP framework for effective investment distribution.
Limited access to private investments. Probability Impact Period of Influence **Short-term**	Uncertainty in the hydrogen market and high upfront risks may discourage private investors from funding hydrogen projects.	• Establish a dedicated green hydrogen fund with public and private contributions. • Provide tax incentives for investors. • Create an enabling regulatory framework that reduces risks for private sector involvement.
Delayed infrastructure development. Probability Impact Period of Influence **Mid-term**	Slow implementation of infrastructure (e.g., ports, pipelines, storage) could create bottlenecks in hydrogen export operations and reduce market competitiveness.	• Develop a detailed infrastructure roadmap with clear timelines; prioritize funding for critical infrastructure; collaborate with international stakeholders to leverage technical expertise and funding.
Short-term public expenditure outpacing revenue. Probability Impact Period of Influence **Short-term**	Public expenditure on infrastructure and subsidies may exceed initial revenues from hydrogen exports, creating fiscal pressure.	• Develop a long-term budget plan with phased funding allocations; ensure diversification of revenue streams (e.g., domestic taxes, export duties, and international carbon markets) to support public expenditures.

4.3 Social Aspect

I. Access to Energy and Resources

This pillar tackles the availability, affordability, and equity of energy resources required for the production, distribution, and consumption of hydrogen, particularly when it comes to addressing social challenges related to energy access.

Green hydrogen produced using renewable energy sources (such as wind or solar power) holds the potential to serve as a clean energy alternative for industries, transportation, and power generation. However, its production and distribution can create social concerns and opportunities related to energy access by local communities; this affects both Jordanians and regional and local workers at hydrogen facilities.

Outlined below are the results of our risk assessment for access to energy and resources:

Risk	Impact	Mitigation
Oriented local reallocation risks. Probability Impact Period of Influence **Long-term**	High competition among the Aqaba community in terms of land, the local market and job vacancies in the area, leading to greater damage to energy and water resources.	• Projected population growth should align with the country's economic plan, particularly in Aqaba. • Conduct focused impact assessments to identify the project's effects on local communities and implement customized support initiatives for affected groups. • Incorporate urban planning and project planning to prevent resource strain and conflicts. • Perform strategic energy demand studies to ensure that energy generation is in alignment with the community's needs. • Adopt sustainable water management and conservation practices to alleviate resource strain.
Conflicts over land use. Probability Impact Period of Influence **Short-term**	Renewable energy projects may displace traditional land uses, including grazing and agriculture, leading to opposition from local populations.	• Improve community engagement by ensuring transparent communication and consistent consultation regarding the benefits and impacts of the project. • Offer equitable compensation or alternative livelihoods to displaced land users. • Investigate alternative project locations in other governorates, such as Mafraq, to reduce land use conflicts in Aqaba. • Prior to selecting a site, conduct comprehensive land use feasibility studies.
Lack of community awareness & engagement. Probability Impact Period of Influence **Short-term**	Lack of local awareness and engagement in green hydrogen access to resources may lead to local resistance causing project delays.	• Develop a stakeholder engagement plan tailored to hydrogen projects. • Engage local influencers and community leaders to promote awareness. • Use adequate communications protocols. • Employ workers from surrounding communities.

Risk	Impact	Mitigation
Limited access for disadvantaged groups. Probability Impact Period of Influence **Long-term**	The increased demand for energy and water resources due to hydrogen production could significantly impact access to these resources for poor and vulnerable communities, potentially worsening their quality of life.	• Incorporate the demands of surrounding communities and disadvantaged groups in renewable energy and water capacity solutions devised for hydrogen projects. • Develop social investment programs to encourage collaboration between investors and the government to support the local community, and in particular disadvantaged groups in the targeted areas.

II. Jobs and Skills

This pillar relates to the workforce involved in the production, distribution, and exporting of hydrogen. As the hydrogen sector expands, it has the potential to create new job opportunities while also demanding specialized skills to support the transition toward cleaner, sustainable energy solutions.

Jobs and skills encompass various dimensions that impact the workforce, communities and industries involved in the transition to a hydrogen economy. While hydrogen projects hold the potential to create new jobs, the social risks associated with this transition must be carefully managed to avoid exacerbating existing social inequalities and economic disruptions.

Outlined below are the results of our risk assessment on jobs and skills:

Risk	Impact	Mitigation
Skill gaps in the local workforce. Probability Impact Period of Influence **Mid-term**	Lack of technical skills (e.g., electrolysis,) could hinder local employment and increase reliance on foreign expertise.	• Partner with local vocational institutions to design specialized green hydrogen and renewable energy training programs. • Collaborate with international experts to train local workers. • Develop long-term apprenticeship and mentorship programs in collaboration with major hydrogen companies. • Encourage local businesses to offer on-the-job training programs for green hydrogen technologies.
Unemployment in specific sectors. Probability Impact Period of Influence **Long-term**	The transition to renewable energy may impact jobs relying on fossil fuel production, extraction, supply and transportation, leading to the unemployment of workers in the sector.	• Offer reskilling programs. • Provide financial incentives and compensation for transitioning workers. • Create customized job placement initiatives to connect transitioning workers with new opportunities in the green hydrogen value chain. • Implement awareness campaigns to emphasize the potential for career advancement in the field of renewable energy.

Risk	Impact	Mitigation
Lack of co-ordination among stakeholders. Probability Impact Period of Influence **Short-term**	A lack of alignment between the government, private sector, and academia could disrupt workforce development efforts.	• Establish a multi-stakeholder task force for workforce alignment. • Define clear roles and responsibilities for stakeholders. • Review the available job seekers and trainees' database at ASEZA and select the relevant competency available for the required type of job. • Establish collaborative forums or workshops to promote communication and ensure alignment among stakeholders.

III. Human Rights and Labour Standards

This pillar focuses on the rights and well-being of workers, local communities, and affected populations, which must be respected throughout the lifecycle of the hydrogen projects. This includes ensuring that the production, distribution, and trade of hydrogen adhere to internationally recognized human rights standards and labor practices.

Outlined below are the results of our risk assessment for human rights and labor standards:

Risk	Impact	Mitigation
Disregard for labor rights. Probability Impact Period of Influence **Mid-term**	Disregard for workers' rights may hinder hydrogen production capacity and lead to non-compliance with relevant standards.	• Investors should develop anti-discrimination policies that guarantee equal treatment in relation to hiring, wages, and working conditions. • Ensure that management and employees receive consistent training and updates in order to comply with International Labor Organization (ILO) standards. • Conduct inspections of labor practices and status. • Oblige all third-party organizations, including suppliers and subcontractors, to sign a code of ethics and code of conduct, and conduct regular compliance monitoring. • Establish a confidential grievance mechanism for employees to report violations.
Poor diversity and inclusion. Probability Impact Period of Influence **Mid-term**	Non-equal employment and beneficiaries for diverse social groups; gender and age may lead to misalignment with international standards for exporting markets and local community dissatisfaction satisfactory.	• Enhance diversity hiring initiatives by establishing quantifiable objectives to attract and retain underrepresented groups, such as women and young people. • Implement awareness and sensitivity training programs to encourage inclusion at all levels of the workforce. • Guarantee that all social groups receive equitable distributions of project benefits, such as employment and training. • Ensure transparency and accountability by regularly monitoring diversity metrics and publicly reporting on progress.

IV. Health and Safety

This pillar tackles impacts on the well-being of workers, local communities, and the broader public that may arise due to the inherent risks associated with the production, storage, transport, and use of hydrogen as an energy source.

Given that hydrogen is a dangerous gas, complex infrastructure is needed for its production and distribution. Ensuring strong health and safety protocols is crucial for preventing accidents, protecting workers, and minimizing risks to public health.

Outlined below are the results of our risk assessment for health and safety:

Risk	Impact	Mitigation
Lack of local safety awareness. Probability Impact Period of Influence **Mid-term**	Nearby communities unaware of safety protocols may face increased risks during accidents.	• Conduct public awareness campaigns focusing on hydrogen safety and emergency protocols. • Provide accessible safety information and training on emergency protocols.
Hydrogen flammability and explosiveness. Probability Impact Period of Influence **Mid-term**	High flammability range and potential for detonation in confined hydrogen storage spaces may cause extensive damage to infrastructure and endanger human lives.	• Enforce technical health and safety regulations. • Provide regular safety training and promote the use of safety measures like person Personal Protective Equipment (PPE). • Implement and monitor efficacy of fire-fighting system. • Conduct emergency drills in collaboration with civil defense and local safety authorities. • Create automated alerts for real-time hydrogen leak detection systems.
Exposure to ammonia and toxic chemicals. Probability Impact Period of Influence **Mid-term**	Ammonia and chemical leaks may damage workers' and nearby residents' respiratory systems and cause chronic health diseases.	• Apply safety monitoring systems for chemical leaks. • Train workers in emergency response and provide respiratory protection equipment. • Ensure proper storage and handling protocols for hydrogen and ammonia products. • Conduct regular audits of safety protocols and revise them for alignment with best practices.

Risk	Impact	Mitigation
Risk of natural hazards (flooding and rockfalls). Probability Impact Period of Influence **Long-term**	Hydrogen projects may encounter flooding and rockfalls in the suggested hub location at the southern boundaries of Aqaba, causing damage to hydrogen facilities and exposing workers to physical injures and drowning risks.	• Conduct geological and flood risk assessments. • Design hydrogen facilities with infrastructure resistant to flooding and rockfalls. • Build protective barriers and nets in rockfall-prone areas. • Engage with local authorities and geological specialists for continuous hazard surveillance and early warning systems.
Threat to habitats and biodiversity. Probability Impact Period of Influence **Short-term**	Construction and operation of hydrogen facilities in the suggested area may disrupt habitats, causing extinction risks.	• Conduct detailed environmental impact assessments (EIAs). • Develop habitat restoration programs, including reforestation or relocation of affected species. • Regularly monitor biodiversity impacts. • Collaborate with regional conservation entities to mitigate habitat disturbance and advance ecological sustainability.

4.4 Governance Aspect

I. Policy Commitment and Coherence

This aspect addresses how well governments, regulators, and companies ensure that the policies driving the transition to hydrogen energy are clear, consistent, enforceable, and coordinated across different levels of government and sectors.

It focuses on how these policies align with broader national and international energy goals, climate targets, and sustainability objectives, while also considering relevant governance frameworks in the hydrogen value chain.

Outlined below are the results of our risk assessment for policy commitment and coherence:

Risk	Impact	Mitigation
Fragmented regulatory strategies and policies. Probability Impact Period of Influence **Short-term**	• Inefficient compliance processes and increased operational costs for hydrogen producers. • The potential for market access and investment opportunities may be restricted by the absence of coordination between national and international standards. • Undermined public confidence in the safety of hydrogen technologies.	• Encourage collaboration among governments, regulatory bodies, industry stakeholders, and international organizations to develop a cohesive regulatory strategy. • Implement regular reviews and updates of the regulatory framework, policies and laws related to hydrogen activities in Jordan; energy law, gas law, hydrogen policy and strategy. • Amend the Environment Law to include regulations related to hydrogen gas, such as environmental impact assessments.

Risk	Impact	Mitigation
Turnover in governmental leadership. Probability Impact Period of Influence **Long-term**	• Shifts in priorities and policy directions. • Introduction of different interpretations of existing policies. • Complications in coordination and cooperation among various stakeholders.	• Building cross-party and cross-sectoral consensus. • Develop clear, long-term strategy documents or roadmaps for hydrogen that outline goals, timelines, and expected outcomes. • Regular engagement and communication in the handing over processes between governments.
International treaties discrepancies. Probability Impact Period of Influence **Mid-term**	Diverging green hydrogen visions and strategies between importing and exporting countries can create significant alignment challenges for investors. These challenges may hinder the efficient development and commercialization of hydrogen technologies, slowing down the growth of the industry.	• Engage neighboring countries to agree on resource utilization, particularly as regards water for desalination. • Develop common regulations for hydrogen production across key exporting and importing countries. • Consider bilateral agreements to enhance export incentives for investors.
Disparate regulatory frameworks. Probability Impact Period of Influence **Mid-term**	Inequalities by which some businesses might face stricter requirements than others. This variability in regulatory standards can influence competition and investment decisions.	• Maintain alignment with national priorities. • Design and implement effective sensitivity analysis towards having robust informed decision making. • Use adaptive technological solutions to streamline compliance across multiple frameworks. • Harmonize the efforts in facing risks and balance the benefits gained between government and the investors, where the flexibility in the development of legislations and laws is a key factor to success.
Lack of adaptive institutional mechanisms. Probability Impact Period of Influence **Short-term**	Difficulties in maintaining the incorporation of amendments and /or updates to regulations, which requires progressive induction and capacity building, and may lead to the delay or misuse of these amendments in a way adversely affects investors.	• Establish robust internal communications mechanisms to promptly disseminate updates to regulations. • Establish centralized consultations and structured capacity building initiatives. • Establish structured capacity-building initiatives for government agencies, industry leaders, and regulators. • Incorporate technological solutions for immediate adaptation.

II. Stability and Rule of Law

This pillar tackles the political, legal, and institutional stability of the country or region and the strength and predictability of its legal and regulatory systems. It focuses on whether a country or region has a stable political environment and a reliable legal framework that can support the long-term development of hydrogen technologies, investments, and markets.

Outlined below are the results of our risk assessment on stability and rule of law:

Risk	Impact	Mitigation
Political instability. Probability Impact Period of Influence **Long-term**	• Political instability significantly impacts hydrogen project implementation and EU export potential. • Frequent policy changes or hold-on(s) due to unstable political situations hinder consistent long-term regulations. • Shifting priorities from donors may reduce or redirect the financial support mechanisms.	• Build an effective risk and crisis management framework to incorporate contingency measures within national strategies and policies. • Enhance local investment and reduce dependence on donor support by strengthening public-private partnerships (PPPs).
Disparities in business models and studies outputs. Probability Impact Period of Influence **Mid-term**	Impacted government decision-making on suitable regulatory approaches due to vague technical requirements and limitations.	• Immediately form a community of practitioners for all involved consultancy organizations to integrate their studies and research outputs in a common framework.
Ambiguity of government regulations. Probability Impact Period of Influence **Short-term**	Referencing many sets of regulations from different organizations may damage investor confidence and lead to delays to project implementation.	• Develop a unified regulatory framework that is tailored to hydrogen projects, thereby guaranteeing consistency among all stakeholders. • Regulate adequate grievance mechanisms customized to hydrogen projects. • Develop a digital platform that will centralize and simplify all regulatory references for hydrogen activities.

III. Transparency and Participation

This pillar is associated with the openness, clarity, and inclusivity of decision-making processes related to hydrogen initiatives. It addresses whether stakeholders—such as investors, local communities, governments, and civil society—are adequately informed and involved in decisions that affect the development, regulation, and trade of hydrogen.

It focuses on the accountability, information-sharing, and opportunities for public participation in the policy, regulatory, and business processes that shape the hydrogen economy.

Outlined below are the results of our risk assessment on transparency and participation:

Risk	Impact	Mitigation
Ineffective communication with investors. Probability Impact Period of Influence **Short-term**	• Investors' ability to provide reliable feasibility studies before signing investment agreements may be impacted. • The time needed to launch the implementation of hydrogen projects may increase.	• Maintain the conduction of regular roundtable discussions with investors to share updates, communicate decisions directly, and gather feedback for potential adjustments. • Align policies and decision-making with common understanding shared with investors.
Lack of a shared vision among committee members. Probability Impact Period of Influence **Short-term**	A lack of idea-sharing and limited channels of communication may result in fragmented decision-making, inefficiencies, and failure to achieve strategic objectives.	• Facilitate the exchange of strategic plans between organizations to promote harmonization and synergy, helping to avoid the adverse impacts of independently developed regulations. • Continue conducting regular inter-committee workshops to ensure aligned decision-making.
Limited participation in decision-making. Probability Impact Period of Influence **Short-term**	Misunderstandings, misinterpretation, and conflict.	• Extend participation in formalized committees to include academia, economists, and related subject matter experts. • Extend the participation to include MODEE, to define possibilities for digitization across ministries.

IV. Standards and Certification

This pillar tackles the establishment, enforcement, and recognition of consistent standards and certification processes for hydrogen products, technologies, and operations.

It focuses on the need for well-defined and widely-accepted standards and certification systems to ensure the quality, safety, reasonable environmental impact, and sustainability of hydrogen-related activities across the value chain—from production to trading and usage.

Outlined below are the results of our risk assessment on standards and certification:

Risk	Impact	Mitigation
Challenges in establishing regulatory guidelines. Probability Impact Period of Influence **Short-term**	Lack of uniformity in engineering requirements for design, testing, construction, operation, and safety can undermine public trust and political support for hydrogen projects.	• Develop clear, consistent, and transparent regulatory frameworks incorporating experts' consultation. • Design regulations with flexibility to adapt to rapid technological advancements. • Ensure global compatibility by harmonizing local regulations and benchmarking international standards. • Consistently revise regulatory guidelines to adapt to the latest innovations and best practices.
Non- compliance with ESG requirements. Probability Impact Period of Influence **Short-term**	Investments that fail to meet ESG criteria could face public opposition, reputational risks, or funding rejections from financial institutions.	• Integrate robust ESG compliance requirements into all public and private funding agreements. • Conduct thorough environmental and social impact assessments (ESIAs) for all projects.
Challenges in obtaining the necessary certifications. Probability Impact Period of Influence **Mid-term**	The complexity and stringent requirements for obtaining certification in hydrogen production could create significant barriers to market entry and exclusion from trade agreements.	• Engage with industry experts to provide guidance on compliance, ensuring that producers are fully aware of the standards, safety protocols, and testing procedures required for certification.
Gaps in available competencies. Probability Impact Period of Influence **Mid-term**	Difficulties in hiring staff with the required competencies, which may be costly and take a significant amount of time compared to the rapid advancements in the hydrogen market.	• Encourage educational and training institutions, as well as universities, to offer specialized studies in hydrogen development and production. This would help enhance the capacity building required for the field, ensuring a skilled workforce aligned with industry needs.

5. Effective Implementation of Risk Matrices

I. Validation through Stakeholder Consultation

This section outlines a structured validation process designed to integrate stakeholder feedback and expertise, ensuring that the risk matrices for green hydrogen development are effectively implemented, continually refined, and aligned with Jordan's national and regional development objectives. This validation process is crucial for the long-term success and sustainability of the project, as it facilitates collaboration, accountability, and adaptive management.

Outlined below are comprehensive steps for validation and implementation:

1. Verification of Risk Definitions:

Relevant stakeholders, comprising representatives from the public sector, business enterprises, research institutes, and foreign partners, shall evaluate the identified risks. Their inputs shall assist in:

- ***Validating Relevance:*** Confirming that the identified risks are aligned with Jordan's socio-economic, political, and environmental landscape, considering factors like national energy policies, economic priorities, and environmental concerns.
- ***Identifying Overlooked Risks:*** Drawing attention to new and emerging risks that may have been overlooked, such as those arising from global trends, technological advances, or local socio-political shifts. For instance, risks associated with climate change impacts, supply chain disruptions, or geopolitical tensions.
- ***Improving Risk Clarity:*** Enhancing the precision and specificity of risk descriptions to ensure they are clear, actionable, and measurable. This will involve refining the language used to describe risks and ensuring that the matrix provides a sound basis for decision-making.

2. Comprehensive Impact Analysis:

Stakeholders shall collaborate to conduct an in-depth analysis of the potential impacts of each identified risk. This will include the following dimensions:

- ***Economic Impacts:*** Assessing how risks may affect fiscal sustainability, investment flows, project financing, and the overall economic viability of hydrogen projects. For example, an unforeseen technological failure could hinder investment opportunities.
- ***Environmental Impacts:*** Evaluating the consequences for natural resources, ecosystems, and progress towards emission reduction targets.
- ***Social Impacts:*** Analyzing risks in terms of their potential effects on equity, accessibility, and the social acceptance of hydrogen projects. Stakeholders may identify risks related to local community opposition, unequal access to green hydrogen technologies, or workforce displacement.

- ***Governance Impacts:*** Identifying governance-related risks at the state of time, such as regulatory gaps, institutional constraints, or the lack of effective policy frameworks. For instance, delays in regulatory approvals could significantly hinder the timely execution of hydrogen projects.

This comprehensive assessment will deepen stakeholders’ understanding of each risk's severity and help prioritize mitigation strategies, ensuring that potential consequences are thoroughly accounted for.

2. Validation of Mitigation Measures:

Proposed mitigation measures will be evaluated and modified based on stakeholder feedback to ensure:

- ***Feasibility***: Ensuring that proposed mitigation measures are realistic, achievable, and aligned with available resources, technologies, and capabilities. Stakeholders shall assess whether the proposed measures can be effectively implemented within the existing institutional and financial frameworks.
- ***Efficacy:*** Evaluating the effectiveness of mitigation strategies in addressing the root causes of identified risks. Measures shall aim to reduce the likelihood of risks or minimize their impact if they occur.
- ***Adaptability:*** Verifying the flexibility of mitigation measures to accommodate evolving circumstances, such as advances in technology, market dynamics, or shifts in policy. Strategies shall be designed to adapt to the future landscape of green hydrogen development.
- ***Action Phases:*** The mitigation measures shall be classified into immediate (0–5 years), medium-term (6–15 years), and long-term (16–30 years) actions to allow for phased implementation, with urgent issues addressed first and long-term challenges planned for future resolution.

3. Risk Classification by Operational Domain:

To ensure the effective implementation of mitigation measures, risks shall be categorized according to their significance within specific operational domains of Jordan's green hydrogen ecosystem. This approach will streamline the allocation of resources and efforts:

- ***Water Desalination:*** Address risks related to water scarcity and the effective use of desalination technology to support hydrogen production in arid regions. Stakeholders shall assess the potential for technological advancements in desalination that could mitigate risks associated with water shortages.
- ***Renewable Energy (Wind and Solar):*** Classify risks such as land resource availability, intermittency of renewable energy, and the expansion of renewable energy infrastructure. Stakeholders may suggest solutions like hybrid energy supply systems or energy storage to manage intermittency.
- ***Hydrogen Production:*** Categorize technological and operational risks in hydrogen production, such as inefficiencies or scaling challenges in electrolysis technology or other production methods. Stakeholders shall explore innovative solutions to improve production efficiency.

- ***Ammonia Production:*** Identifying risks related to the infrastructure and logistics of ammonia production and export. Stakeholders may propose risk-reduction measures such as improved transportation infrastructure or the development of localized production facilities.

5. Allocation of Roles and Responsibilities:

A clear allocation of roles and responsibilities shall be established to guide the implementation of mitigation strategies:

- ***Governmental Institutions:*** Responsible for policy development, ensuring regulatory compliance, and overseeing the execution of mitigation measures. They shall also play a central role in coordinating inter-agency efforts and international treaties, enforcing regulations and communicating progress effectively with stakeholders.
- ***Private Sector:*** Key players in investment and infrastructure development from the private sector shall drive technological innovation and scale hydrogen projects, ensuring they are financially viable and aligned with market needs.
- ***Academic and Research Institutions:*** These entities shall lead research and development efforts to overcome technical challenges, support capacity building, and foster innovation in the hydrogen sector.
- ***International Institutions:*** Responsible for providing technical expertise, financial support, and facilitating the transfer of advanced technologies. International organizations can also aid in knowledge-sharing and capacity-building to strengthen the local hydrogen ecosystem.

6. Definition of Implementation Durations:

Each mitigation plan shall assign specific implementation timelines to ensure prioritized actions are carried out in a structured manner:

- ***Short-Term (0–10 years***): Focus on critical issues such as regulatory alignment, infrastructure readiness, and stakeholder engagement to lay the groundwork for the green hydrogen sector.
- ***Mid-Term (11–20 years):*** Strengthen policy frameworks, enhance technological capabilities, and expand stakeholder participation to scale up hydrogen production and usage.
- ***Long-Term (21–30 years):*** Ensure long-term sustainability, scalability, and conformity with international standards, with a focus on maintaining resilience in the face of evolving risks.

7. Stakeholder Feedback and Iterative Evaluation:

To ensure ongoing relevance and responsiveness, a continuous feedback mechanism shall be implemented as follows:

- ***Regular Workshops and Forums:*** Stakeholders shall convene to share updates on the status of risk mitigation efforts, emerging risks, and lessons learned from international experiences in their periodically-conducted round tables.

- ***Dynamic Risk Matrix Updates:*** As new risks emerge or mitigation strategies evolve, the risk matrix shall be adjusted to reflect current realities. This iterative process ensures that the framework remains adaptable and relevant.
- ***Global Benchmarking:*** Successful international green hydrogen projects will inform and inspire local policies, ensuring the project benefits from best practices and international standards as well as the adaptation of adequate measures to mitigate the risks occurred as per their experience with these types of projects.

8. **Alignment with National and Regional Strategies:**

To ensure the effective integration of risk management into broader development objectives, the following considerations should be taken into account:

- ***National Strategy Alignment:*** The risk matrices shall align with Jordan's national energy, environmental and economic development vision, ensuring consistency with the country's renewable energy, sustainability, and economic development plans.
- ***Regional Cooperation:*** Regional collaboration with neighboring countries will be fostered to exchange best practices, share knowledge, and address cross-border risks such as market competition, trade barriers, and resource-sharing.

9. **Capacity Development and Resource Acquisition:**

A comprehensive strategy for capacity building shall be developed to ensure stakeholders have the skills and resources to manage risks effectively. This will include:

- ***Training Programs:*** Capacity building initiatives for stakeholders to enhance their understanding of risk management, particularly in the context of green hydrogen development.
- ***Resource Mobilization:*** Identifying funding sources from government, private sector, and international partners to support risk mitigation efforts and ensure the availability of financial resources for implementation.

10. **Clear Reporting and Communication:**

Effective communication is essential for stakeholder engagement and public support and should be addressed as follows:

- ***Progress Reports:*** Regularly published reports will track the progress of risk mitigation efforts, offering transparency and accountability.
- ***Public Awareness:*** Transparent communication strategies will be employed to engage the public, increase awareness, and gain societal support for green hydrogen initiatives, ensuring that the broader community remains informed and involved.

II. Risk Matrices as a Tool for Progress Tracking

The following expanded framework outlines a refined approach for monitoring and assessing the progress in minimizing identified risks within the green hydrogen development sector. This methodology leverages risk matrices as a key tool for progress tracking and continuous improvement, ensuring that mitigation efforts are dynamic, systematic, and aligned with broader environmental, economic, social, and governance (EESG) objectives.

1. **Identify and Prioritize Risks**
   The Hydrogen Committee must employ a comprehensive, multi-dimensional approach to identify and prioritize risks, ensuring they are rigorously assessed based on:

   - ***Severity:*** How critical the risk is to the project's success (e.g., could it cause a complete project failure or just delay progress).
   - ***Probability:*** The likelihood of the risk materializing, whether high, moderate, or low.
   - ***Temporal Impact:*** The timeframe over which the risk could affect the project (short-term, medium-term, long-term).
   - ***Strategic Alignment:*** Risks should be assessed in alignment with national energy policies, environmental goals, and global hydrogen market trends. By using a scoring system that incorporates these dimensions, the committee can prioritize risks effectively, creating a clear, actionable hierarchy of focus areas.

2. **Establish Performance Indicators**
   For each identified risk, the committee must define SMART (Specific, Measurable, Achievable, Relevant, Time-Bound) performance indicators. These metrics are essential for:

   - ***Effectiveness of Mitigation Actions:*** Metrics must clearly indicate whether risk mitigation strategies are successfully reducing the likelihood and/or impact of risks.
   - ***Continuous Tracking:*** Performance indicators should be granular enough to allow for continuous monitoring, providing early warnings if mitigation strategies are reducing in efficacy.
   - ***EESG Integration:*** Each metric should align with the EESG dimensions (Environmental, Economic, Social, Governance) to ensure that mitigation efforts not only address technical or financial risks but also align with broader sustainability objectives.

3. **Establish a Risk Tracking System**
   The creation of a dynamic, real-time risk tracking system is crucial. This system must be:

   - ***User-Friendly:*** Accessible to all stakeholders, from government agencies to project managers and contractors, ensuring seamless updates and communication.
   - ***Categorization by EESG Dimensions:*** Risks should be categorized and tracked according to EESG factors (e.g., environmental risks like carbon emissions, social risks like community acceptance, economic risks like market volatility).

- ***Visualization:*** The system should incorporate visual dashboards, heat maps, or trend lines to track the progress of risk mitigation efforts. This makes it easier to identify bottlenecks or areas where additional focus is required.
- ***Interactivity:*** The system should allow for real-time updates and offer drill-down capabilities to explore specific risks in greater detail.

4. **Assess Mitigation Execution**

   Once mitigation strategies are implemented, it is essential to have clear criteria for evaluating:

   - ***Execution Status:*** Whether the mitigation actions have been fully executed, partially implemented, postponed, or not executed at all.
   - ***Root Cause Analysis for Deviations:*** In cases of deviations, a thorough analysis should be conducted to understand the root cause, whether it is resource limitations, lack of coordination, or unforeseen external factors.
   - ***Actionable Insights:*** These assessments should provide actionable insights, prompting necessary adjustments to the mitigation strategies to ensure alignment with the project's risk management goals.
   - ***Escalation Process:*** For high-priority risks, an escalation process should be in place to ensure timely attention and resolution.

5. **Implement Systematic Evaluation Procedures**

   To ensure the long-term relevance and effectiveness of the risk matrices, biannual evaluations should be conducted. These evaluations will:

   - ***Review Effectiveness:*** Assess the success of mitigation strategies by comparing actual outcomes against the established performance indicators.
   - ***Detect Emerging Risks:*** Analyze emerging trends, new risks, and external factors that might impact the project (e.g., regulatory changes, technological innovations, or market shifts).
   - ***Recalibration:*** If necessary, recalibrate the risk matrices, updating priorities and mitigation strategies to align with evolving circumstances.

6. **Integrate Emerging Risks**

   The risk tracking framework must remain flexible and adaptive to integrate new risks as they arise. Emerging risks could stem from:

   - ***Technological Advances:*** New technologies may introduce unforeseen risks or create new opportunities.
   - ***Regulatory Changes:*** Shifts in energy policy, environmental regulations, or trade agreements can introduce risks that were previously unanticipated.
   - ***Market Dynamics:*** Changes in the hydrogen market, such as price fluctuations or competition, can create new financial or logistical risks. By continuously monitoring the external landscape and integrating newly-identified risks, the risk matrix can remain comprehensive and forward-looking.

7. **Create Interactive Dashboards**

   Developing interactive dashboards is key to improving transparency and communication. These dashboards should:

   - ***Visualize Progress:*** Display risk mitigation progress in clear, accessible formats (e.g., graphs, pie charts, color-coded indicators).
   - ***Track Key Metrics:*** Highlight key performance indicators for each risk, such as on-time execution rates or cost-effectiveness of mitigation actions.
   - ***Identify Bottlenecks:*** Use the dashboard to pinpoint areas where mitigation efforts are lagging and require additional focus or resources.
   - ***Stakeholder Engagement:*** Dashboards should be tailored for different audiences (e.g., project teams, investors, regulatory bodies) and should provide them with the relevant level of detail for decision-making.

8. **Augment Reporting and Communication**

   Establish comprehensive reporting systems to ensure transparent and frequent communication with relevant stakeholders. Reports should:

   - ***Highlight Key Accomplishments:*** Provide a clear narrative on significant milestones achieved in regards to risk mitigation.
   - ***Address Obstacles:*** Transparently communicate any challenges or barriers faced during the mitigation process, along with plans to overcome them.
   - ***Recommend Adjustments:*** Suggest modifications to the risk mitigation strategies based on new insights, emerging risks, or changes in project scope.
   - ***Tailored Reports:*** Reports should be customized for various stakeholders, such as government agencies, investors, or the public, focusing on their specific areas of interest.

9. **Continuous Feedback and Stakeholder Involvement**

   To ensure the success of the risk management framework, it is essential to establish continuous feedback loops with stakeholders. This involves:

   - ***Regular Consultations:*** Engage stakeholders (e.g., local communities, environmental organizations, industry experts) to validate the risk matrices, ensuring they reflect real-world conditions and concerns.
   - ***Optimize Tracking Mechanisms:*** Use feedback to refine performance indicators, improve tracking systems, and ensure alignment with national and international goals.
   - ***Adaptive Risk Management:*** Stakeholder feedback should drive iterative improvements, fostering a more agile and responsive risk management framework. Their insights can highlight deficiencies or provide new perspectives on emerging challenges.

6. Recommendations

The following suggestions, which adhere to the EESG Framework, have been tailored to address the opportunities and risks observed during our risk assessment for green hydrogen development in Aqaba. With an emphasis on creating a strong and long-lasting green hydrogen ecosystem, these suggestions take into account Jordan's socioeconomic, environmental, and governance contexts.

General Recommendations:

1. Results and outcomes from all studies related to hydrogen development should be combined in the upcoming phases.
2. The economic development plan should be aligned with hydrogen-related decision-making processes, ensuring collaboration between the Ministry of Investment and the Ministry of Energy.
3. A conducive environment for investment should be created in Jordan, reducing the risks of losing investors to more competitive markets in the region.
4. Effective communication should be maintained with stakeholders, including investors and local communities, and stakeholders should be provided with regular progress updates throughout the journey.

Environmental Recommendations

1. Ensure sustainable water sourcing without affecting the share for the Jordanian people through the establishment of desalination plants.
2. Conduct research and development in advanced electrolysis technologies to improve efficiency, reduce water consumption and lower hydrogen water footprint.
3. Abide by the concept of additionality to produce hydrogen, ensuring that the renewable electricity used is new to the system and avoids utilizing fossil sources.
4. Build understanding of local legal and regulatory frameworks and international standards governing land acquisition, especially as relates to the available lands around the Aqaba Port and other nearby plots that may have constraints or other commitments.
5. Use brine management technologies that reduce concentrated brine and chemical discharge affecting marine ecosystems.
6. Conduct wildlife surveys to understand bird migration, breeding and feeding dynamics to adequately optimize wind turbine designs.
7. Ensure that project designs adopt the most suitable techniques to limit usage of critical materials/metals
8. Ensure circularity is continued at the end of solar panels and turbines' lifecycle.
9. Conduct research and development on hydrogen storage and transportation technologies, leak detection technologies, and emergency response protocols for the avoidance of hydrogen leakages and release.
10. Increase efforts to accelerate the green hydrogen production sector, thereby helping Jordan achieve its Nationally Determined Contributions and meet its commitments under the Paris Climate Agreement.

11. Undertake regular revision and update of the objectives and actions of the National Green Hydrogen Strategy in parallel with the continuous evolution of this new sector.
12. Update and adopt new regulations and health and safety standards related to green hydrogen production (including emergency preparedness and response) and guidelines meeting international regulations.
13. Establish (under MEMR) a committee formed from private and governmental sector stakeholders, as well as policymakers and research entities, that can assess the environmental impacts of utilizing green hydrogen in Jordan and advising the government on such matters.

Economic Recommendations

1. Strengthen Domestic and Foreign Investment.
2. Develop public-private partnerships (PPPs) to allocate financial risks among private and public stakeholders.
3. Encourage local and international investors by establishing government-supported financing mechanisms, such as green hydrogen investment funds or soft loans.
4. Provide tariff exemptions and tax incentives for the import of hydrogen-related equipment and renewable energy in order to mitigate initial project expenses.
5. Improve competitiveness in export markets.
6. Capitalize on Aqaba's strategic location and close proximity to European and Middle Eastern markets to establish Jordan as a regional hub for green hydrogen export.
7. Establish long-term hydrogen export agreements to guarantee economic predictability and stabilize revenue streams.
8. Optimize resource costs and infrastructure.
9. Develop a phased strategy to mitigate the financial burdens of domestic and industrial users by addressing the conversion costs of existing fossil fuel-based equipment to green hydrogen.
10. Invest in shared infrastructure, such as centralized hydrogen storage and transportation facilities, to mitigate logistical expenses.

Social Recommendations

1. Encourage the development of the local workforce.
2. Create vocational training programs to upskill competencies specifically designed for green hydrogen technologies, with an emphasis on the development of a skilled local workforce that includes engineers, technicians, and other professionals.
3. Collaborate with nearby universities and training institutes to develop customized courses on the production, storage, and logistics of hydrogen.
4. Enhance stakeholder engagement and utilize the communication tools addressed through social engagement committees and public publishing channels aiming to involve the community at every step.
5. Organize consistent consultation forums with private sector stakeholders, government entities, and local communities to guarantee that all inputs and concerns are incorporated into the project plans.

6. Share the advantages and prospects of green hydrogen projects with the communities that are impacted in a transparent manner to cultivate acceptance and establish trust.
7. Mitigate social impacts of infrastructure projects through providing adequate financial and psychological support in the affected areas.
8. Establish resettlement and compensation policies for communities that have been impacted by the allocation of land for green hydrogen facilities.
9. Prioritize community-driven benefit-sharing mechanisms to guarantee social inclusion.

Governance Recommendations

1. Finalize and strengthen regulatory frameworks.
2. Accelerate the completion of Jordan's national hydrogen strategy to establish a definitive framework for green hydrogen advancement.
3. Revise regulatory frameworks to tackle emerging hydrogen-specific issues, encompassing safety protocols, storage specifications, and export certifications.
4. Consolidate governance for hydrogen advancement.
5. Undertake continuous enhancement of the National and Technical Hydrogen Steering Committees to supervise green hydrogen initiatives, ensuring coordination among ministries, agencies, and private stakeholders.
6. Establish a singular point of contact for developers and investors to enhance communication and expedite project approvals.
7. Enhance international collaboration and plan for treaties with neighboring countries in the region.
8. Engage with regional leaders in hydrogen development (e.g., UAE, Saudi Arabia, Oman) to establish a collective knowledge repository, standardized regulations, and collaborative infrastructure initiatives.
9. Collaborate with global entities such as PtX Hub and international financial institutions (e.g., the World Bank) to implement best practices and obtain funding.
10. Adopt dynamic risk monitoring and adaptation.
11. Consistently revise the risk matrix to account for evolving challenges and new opportunities in green hydrogen development.
12. Establish a monitoring and evaluation framework to assess project performance and policy execution, facilitating prompt adjustments.

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ESSG Framework for Green Hydrogen Development in Jordan

According to PtX hub

The transition to a low carbon energy future presents opportunities for Jordan and the MENA region. Developing a green hydrogen economy using the region's renewable energy potential offers economic diversification, job creation, and sustainable growth, but must be approached with justice, responsibility, and long term national and local interest.

There is interest in green hydrogen exports and potential for Jordan in regional value chains. However, if projects develop as resource extraction ventures for export, national value addition, local community benefit, and the domestic energy transition may be marginalized.

The hydrogen economy should be a partnership of equals, not an enclave of extraction. It must create local jobs, promote technology and knowledge transfer, involve civil society, and support growth in local communities with focus on youth employment and long-term national benefit.

This report provides an analytical foundation to assess environmental, economic, social, and governance opportunities and risks of green hydrogen projects in Jordan, supporting stakeholders in guiding a hydrogen economy that is viable, equitable, responsible, and aligned with the national interest.

Further information on this topic can be found here:
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