Development pathways to establishing a hydrogen Hub in Mejillones, Chile

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Summary

Hydrogen is expected to play a key role in a climate-neutral energy system, acting as a feedstock, fuel and energy carrier. Both Chile and the Netherlands have set ambitious goals for scaling up the production and implementation of renewable hydrogen in their respective National Hydrogen Strategies. The Netherlands is anticipated to be a key destination market for green hydrogen, with Chile positioned as a strategic market partner. Since 2021, the Netherlands and Chile have collaborated to establish a hydrogen corridor. Within many activities, the Port of Rotterdam recently renewed its Memorandum of Understanding (MoU) with the Chilean government to develop a master plan for the port of Mejillones, one of the main hydrogen hubs in the near future. Despite the efforts to scale up hydrogen production in the region, there are delays in the realization of projects in the Mejillones area.

This study, aimed at identifying the key socio-economic and environmental challenges and opportunities for developing a Hydrogen Hub in the Mejillones area, employed the comprehensive PESTLE framework. This framework, covering Political, Economic, Social, Technological, Legal, and Environmental factors, was instrumental in our analysis. The study also identified the main stakeholders and analyzed how these factors and stakeholders influence the potential development of the Hydrogen Hub. Most of the analysis was based on open interviews with relevant stakeholders and a structural literature review.

The main stakeholders involved in potentially enabling a hydrogen hub in Mejillones are divided between Chile and Dutch parties. For both countries, the main identified enabling stakeholders that can play a pivotal role are listed below in Table 1.1.

Table 1.1: Potential relevant stakeholder to enable a hydrgogen hub in Mejillones.

Stakeholder type	Chile	The Netherlands
Government	• Ministry of Environment • Ministry of Transport • National Agency for Innovation and Development (ANID) • Regional Government of Antofagasta • SEREMI	• Ministry of Economic Affairs and Climate Policy • Netherlands Enterprise Agency (RVO)
Industry	• Mining companies (e.g.,BHP, Antofagasta Minerals, Codelco) • Energy companies (e.g.,Colbún, Enel Generación Chile) • Port operators (e.g.,CPM, Puerto Angamos) • Hydrogen producers (e.g., Linde, Air Liquide) • Transportation companies (e.g., DHL, Maersk)	• Port of Rotterdam/ Amsterdam • Gasunie • Shell • Vopak • Chemical and refining hubs.
Academia / knoewldege institues	• Universidad de Antofagasta • Universidad Católica del Norte	• TNO • New Energy Coalition

Civil society	• Environmental groups • Community organizations • Indigenous communities	
Funding Institutions	• CORFO • Invest Chile	• RVO • TKI
Financial Institutions	• World Bank • Inter-American Development Bank • Private investors • FMO (Dutch entrepreneurial development bank) • Invest International	

From the PESTLE factors, the ones recognized with high influence on final investment decision to enable a hydrogen hub in Mejillones are shown in Table 1.2.

Table 1.2: High relevance PESTLE factor for final investment decision.

Factor type	Factor	Description
Political	Government Policy Stability	The consistency and longevity of government policies supporting renewable energy and hydrogen development in Chile, including incentives, subsidies, and regulatory frameworks, significantly influence the decision-making process as these are key to sustaining investments in the long term.
Political	Regulatory Environment	The clarity, consistency, and efficiency of regulatory processes related to project approvals, environmental permits, and land rights can affect the timeline and cost of project development, thus influencing the FID decision for hydrogen hubs in Mejillones.
Economic	Price of Green Hydrogen - Market vs Demand	The cost competitiveness of renewable energy sources plus infrastructure investment, the availability and adequacy of infrastructure, including transportation networks, utilities, and port facilities such as solar and wind, which are essential for hydrogen production, is a critical factor influencing the final investment decision.
Economic	Investment Opportunities and Competitive Landscape	The availability of investment opportunities, including access to financing, grants, subsidies, and other financial incentives, can significantly impact the final investment decision. Favorable investment conditions attract capital and support project realization.
Societal	Community Acceptance and Engagement	The level of acceptance and engagement from local communities in Mejillones is a critical societal factor influencing the final investment decision. Positive community relations, addressing concerns, and fostering meaningful dialogue can mitigate social risks and enhance the project.
Technical	Technology Readiness and Scalability	The readiness and scalability of hydrogen production, storage, and distribution technologies are critical technical factors influencing the final investment decision. Mature and scalable technologies reduce implementation risks and enhance project feasibility.

Technical	Infrastructure Requirements	The adequacy and availability of infrastructure, including transportation networks, utilities, and port facilities, are medium-level technical factors affecting the final investment decision. Access to necessary infrastructure reduces project risks and lowers operational costs for hydrogen hub development in Mejillones.
Environmental	Carbon Emissions Reduction	A critical environmental factor is the potential for carbon emissions reduction through the deployment of hydrogen hubs in Mejillones. Green hydrogen production from renewable sources can significantly contribute to mitigating climate change and meeting the country's sustainability targets. However, clear accounting methods for CO2 emissions are required
Environmental	Water Usage and Conservation	The environmental impact of water usage in hydrogen production processes remains high, considering the desalinization and handling of the subproducts. Assessing water availability, implementing efficient water management practices, and minimizing water consumption within the process are important considerations.
Legal	Regulatory Framework	The clarity, stability, and adequacy of the regulatory framework governing hydrogen hub development in Mejillones are high-level legal factors influencing the final investment decision. Clear regulatory guidelines, permitting processes, and compliance requirements provide certainty and reduce regulatory risks for investors.
Legal	Land Rights and Permitting	The clarity, stability, and adequacy of the regulatory framework governing hydrogen hub development in Mejillones are high-level legal factors influencing the FID decision. Clear regulatory guidelines, permitting processes, and compliance requirements provide certainty and reduce regulatory risks for investors.

In conclusion, the development of a hydrogen hub in Mejillones relies on addressing key challenges related to the factors mentioned above. Both Chile and the Netherlands share a vision for green hydrogen production, and key priorities should focus on:

- Infrastructure Expansion: Collaboration among stakeholders is essential for a robust infrastructure to support scaling up, innovation, and future demands.
- Sustainability and Social Impact: Emphasizing poverty reduction, job creation, and community engagement is crucial for social acceptance, alongside environmental considerations like reducing greenhouse gas emissions and minimizing ecological impact.
- Technology and Knowledge Transfer: Partnerships between research institutions, industries, and governments are vital for technological advancements, human capital development, and securing funding.
- Comprehensive Master Plan: A strategy plan with clear KPIs, defined roles, collaboration agreements, and investment commitments is necessary for effective coordination, accountability, and progress. In this study, we suggest a general strategy plan (in the conclusions section) over a ten-year horizon to materialize and future-proof Mejillones as a hydrogen hub with the main characteristics listed below. However, note that for Mejillones, several of these steps are already ongoing.

1. Initial Phase (Year 1-2): Foundation and Planning
   - Master Plan Development
   - Coordination and KPIs
   - Share best practices from Dutch green hydrogen projects
   - Feasibility Studies and Risk Assessments
2. Development Phase (Year 3-5): Infrastructure and Capacity Building
   - Infrastructure Development
   - Training Programs and Knowledge Exchange
   - Public-Private Partnerships
3. Expansion Phase (Year 6-10): Market Development and Regulatory Alignment
   - Market Development
   - Regulatory Framework
   - Innovation and R&D
4. Operational Phase (Post Year 10): Sustained Operations and Continuous Improvement
   - Ongoing Operations
   - Technological Advancements
   - Innovative Storage solutions
   - Modular Storage Solutions
   - Community and Environmental Focus

Contents

1 Introduction

Hydrogen is expected to play a key role in a climate-neutral energy system, acting as a feedstock, fuel and energy carrier. Both Chile and the Netherlands have set ambitious goals for scaling-up the production and implementation of renewable hydrogen in their respective National Hydrogen Strategies. Chile has been recognized internationally as a future hotspot for the production, use and export of renewable hydrogen (Jaradat et al., 2024). With its abundant wind and solar resources, it could produce renewable hydrogen at very low cost (<1.50 USD/kg) (Matthias et al., 2022). Chile plans to use hydrogen to decarbonize the local industry and transport sector and become a key exporter to other markets (Ferrada et al., 2023).

The Netherlands is one of these expected top destination markets. The Netherlands and Chile have been working together already since 2021 to create a hydrogen corridor generated from renewable energy in Chile and distribute it efficiently throughout Europe from the Dutch ports. The Port of Rotterdam renewed its MoU with the government of Chile in January 2023 to develop a master plan for the port of Mejillones. In order to strengthen the governmental cooperation between both countries as well as economic, scientific and technological exchanges, the Minister of Energy of the Republic of Chile, Mr. Diego Gonzalo Pardow Lorenzo and the Minister for Climate and Energy Policy of the Netherlands, Mr. Rob Jetten, established in 2023 an Agenda for Strategic Cooperation on Green Hydrogen for the period 2023-2025 (The Ministry of Energy of the Republic of Chile & Ministry of Economic Affairs of The Netherlands, 2023). Several activities envisioned in the Agenda involve the development of a hydrogen hub in Mejillones in the northern part of Chile.

Chile's northern region has already developed competitive solar generation and desalinization plants, a vibrant mining sector, and multiple private operators (Scholvin, 2023). This environment is promising for the development of a renewable hydrogen ecosystem that will allow the implementation of local and export of renewable hydrogen derivatives for decarbonization purposes. Hydrogen exports could start with ammonia, for which ships are currently close to being available, and later include liquid hydrogen once technically safety and cost issues are resolved (Machaj et al., 2022). This region already has multiple pilot projects in various phases, and several stakeholders are involved. However, it appears that a lack of coordination among all regional active actors and market hesitance leads to uncertainties in local communities, regional actors and Dutch stakeholders interested in investing in large-scale developments.

In addition, social and environmental risks need to be assessed and addressed in a timely fashion to develop this region consistently as one of the most sustainable and important domestic hydrogen hubs. Realizing this potential requires boosting coordination among national and international stakeholders, reducing market hesitance by providing a clear and stable regulatory environment, and effectively managing social and environmental risks. By doing so, this region can ensure sustainable development, gain the trust and support of all stakeholders, and attract the necessary investments to become a key player in the hydrogen economy.

2 Purpose

This study aims to identify the main socio-economic and environmental challenges and opportunities to develop a Hydrogen Hub in the Mejillones area. In addition, it focuses on identifying key enabling local and international (under a Dutch perspective) stakeholders for such a hydrogen hub. To that end, TNO developed a stepwise approach, which is described in the following section. This study is commissioned by the Ministry of Economic Affairs and Climate Policy (Ministerie van Economische Zaken en Klimaat, EZK) of The Netherlands. The Ministry of Economic Affairs and Climate Policy is a key governmental body responsible for shaping and implementing the country's economic and climate policies. Its overarching goal is to foster sustainable economic growth while simultaneously addressing the challenges posed by climate change.

2.1 Connection to Dutch and European markets

The Netherlands and Europe will largely depend on green hydrogen imports to meet climate change-related targets, mainly for the industry and transport sectors. This trend has become more evident as recent studies have highlighted that producing green hydrogen in the Netherlands is significantly more expensive than assumed until recently, led by high investment costs and rising electricity grid tariff; with a levelized cost of hydrogen between 12-14 €/kg H2 (Eblé & Weeda, 2024). The Dutch industry consumes approximately 180 PJ of hydrogen annually (from natural gas and industrial waste gas), making it the second-largest user in the EU after Germany (Dutch National Hydrogen Programme (NWP), 2022). In addition, the updated Renewable Energy Directive (RED-III) has introduced binding targets for Renewable Fuels of Non-Biological Origin (RFNBOs) in industry and the mobility sector.

Chile aims to produce up to 25 million tons of green hydrogen annually by 2050 (outlined in the Chilean National Green Hydrogen Strategy) for its internal demand and imports (The Ministry of Energy of the Republic of Chile, 2020); this is approximately 3000 PJ. Thus, Chile stands out as a major strategic partner for the Netherlands and the EU when it comes to hydrogen-related value chains. However, achieving such ambitious numbers at competitive costs for systemic change will require rapid scale-up and cooperation between Dutch and Chilean public and private parties.

2.2 Methods

The study focuses exclusively on Mejillones and its immediate surroundings without extending to other regions or countries. It will analyze key Chilean and Dutch stakeholder groups, maintaining confidentiality by not focusing on individuals or specific organizations. Various hydrogen production technologies will be considered, excluding speculative or experimental ones beyond current feasibility. Existing regulatory frameworks in Chile will be reviewed, but detailed legal analyses of specific regulations or compliance requirements will not be provided. Stakeholder engagement in Mejillones will be emphasized without addressing broader societal acceptance issues. General infrastructure requirements will be outlined, but detailed site-specific assessments, such as land surveys or engineering studies, will not be conducted.

A comprehensive stakeholder group map relevant to the Mejillones region is carried out through desk research, which also considered previous networking/contacts between TNO and Chile hydrogen-related stakeholders. The stakeholder mapping prioritizes key decision-makers related to establishing a Hydrogen Hub in the Mejillones area, including government agencies, industry players, local communities, and international partners. Additionally, different perspectives on the Mejillones Region are described to understand the stakeholders' positions better. Stakeholder positions are reviewed through desk research, position papers, websites, and other sources, and the main storylines are identified. These perspectives are selected based on their relevance in the green hydrogen value chain and stakeholders are mapped following a pragmatic classification that leads to the greatest possible recognizability among the parties involved in this sector. A structural review is also conducted to map ongoing (feasibility) projects and activities in the region relevant to hydrogen production and infrastructure development, along with the parties involved (up to 2030).

Stepwise approach:

1. Stakeholder Mapping: Develop a comprehensive stakeholder map that identifies key actors involved in decision-making related to the establishment of a Hydrogen Hub in the Mejillones area, including government agencies, industry players, local communities, and international partners.
2. Project Mapping: Conduct a mapping of ongoing (feasibility) projects and activities in the region, along with the parties involved, with a focus on initiatives relevant to hydrogen production and infrastructure development, extending until 2030.
3. PESTEL Analysis: Perform a PESTEL analysis to identify the most relevant political, economic, socio-cultural, technological, environmental, and legal factors influencing the development of hydrogen projects in Mejillones. Highlight key challenges and business opportunities to accelerate projects towards Financial Investment Decision (FID).
4. Presentation Preparation: Prepare a presentation of the study results for the World Hydrogen Summit 2024 in Rotterdam, showcasing insights from stakeholder mapping, project mapping, and PESTEL analysis. Another event with Chilean counterparts should also be organized online to disseminate the findings and engage with relevant stakeholders in Chile.
5. Strategy and Action Plan: Outline a comprehensive strategy and action plan for stakeholder engagement around Hydrogen Hubs in Mejillones. This includes identifying engagement goals, target stakeholders, communication channels, and activities to foster collaboration, address concerns, and promote alignment toward common objectives.

2.3 Political, Economic, Sociological, Technological, Legal and Environmental (PESTEL) analysis

A PESTEL analysis is conducted to identify the barriers and incentives influencing the development of renewable hydrogen production projects in the Mejillones region. This analysis identifies the most relevant political, economic, socio-cultural, technological, environmental, and legal factors affecting hydrogen project development in Mejillones, highlighting key challenges and business opportunities that potentially affect the FID. For the PESTEL analysis, several stakeholders are interviewed to provide relevant underlying information. Open interviews based on a pre-shared guideline are conducted, allowing

interviewees to discuss a range of prepared questions relevant to PESTEL topics. The interviews are confidential. Literature regarding the topic is also reviewed to provide additional context for the interviews. Each PESTEL factor is examined through literature obtained from interviews, key stakeholder websites, and keyword searches focused on stakeholder activities and key technologies. This process is carried out to corroborate the interview findings. Note that the PESTLE analysis is largely the main focus of the report.

2.4 Strategy and Action Plan

Based on the previous steps, a strategy and action plan (targeting stakeholder engagement) are suggested, including relevant parameters such as engagement goals, target stakeholders, communication channels, and activities to foster collaboration, address concerns, and promote alignment toward common objectives. Additionally, the strategy and action plan discuss the following perspectives:

- Potential risks and challenges associated with developing and deploying renewable hydrogen projects and value chains in Mejillones. Implement risk mitigation strategies to address these challenges, ensuring smooth project development and operational efficiency.
- Cross-sectoral collaboration and innovation ecosystems to accelerate renewable hydrogen projects and value chains in Mejillones. Foster synergies between industries, research institutions, and government agencies to drive innovation and project realization.
- Bilateral collaborations and partnerships between stakeholders in Mejillones and the Netherlands are needed to foster innovation, investment, and knowledge exchange in the renewable hydrogen sector.

3 Results and Discussion

3.1 Stakeholder Mapping

Table 3.1: Stakeholder Mapping Chile.

Chile	
Government	• Ministry of Energy • Ministry of Environment • Ministry of Transport • National Agency for Innovation and Development (ANID) • Regional Government of Antofagasta • SEREMI
Industry	• Mining companies (e.g.,BHP, Antofagasta Minerals, Codelco) • Energy companies (e.g.,Colbún, Enel Generación Chile) • Port operators (e.g.,CPM, Puerto Angamos) • Hydrogen producers (e.g., Linde, Air Liquide) • Transportation companies (e.g., DHL, Maersk)
Academia	• Universidad de Antofagasta • Universidad Católica del Norte
Civil Society	• Environmental groups • Community organizations • Indigenous communities
Funding Institutions	• CORFO • Invest Chile
Financial Institutions	• World Bank • Inter-American Development Bank • Private investors

Table 3.2: Stakeholder Mapping Netherlands.

Netherlands	
Government	• Ministry of Economic Affairs and Climate Policy • Netherlands Enterprise Agency (RVO)
Industry	• Port of Rotterdam/ Amsterdam • Gasunie • Shell • Vopak • Chemical, refinery, etc.
Knowledge Institutions	• TNO • New Energy Coalition
Funding Institutions	• RVO • TKI, etc

Netherlands	
Financial Institutions	• World Bank • Inter-American Development Bank • Private investors • FMO (Dutch entrepreneurial development bank) • Invest International

3.2 Current Status of Projects in Mejillones Region

Based on the (H2 Chile, 2024) at the national level, there are 64 projects announced in various stages of development, with an announced nominal power capacity of 26.4 GW of electrolysis[1]. Approximately 47% of the projects are oriented towards domestic demand, around 28% towards export, while the remaining portion has not been specified yet. The distribution of the projects is as follows:

- Northern Zone: 26
- Central Zone: 14
- Southern Zone: 22
- Location information not available: 2

Note that there is no update on the nominal power, but an update on the number of projects on a map basis has been presented in April 2024 (as seen in the map legend). Therefore, the most recent map with a total of 73 projects is presented in Figure 3.1.

[1] Data is updated on December 2023. Figures based on publicly announced information, so it is expected that the nominal power of electrolysis will be higher.

Figure 3.1: Hydrogen-related projects updated up to April/June 20204 (H2 Chile, 2024), the region focused in this study is highlighted in red

3.3 Consortia MAE – Project Example

After three years of technical and environmental studies, as well as extensive community engagement, the company MAE will soon submit the Environmental Impact Study (EIA) for its Volta project to the Environmental Impact Assessment System. The project will be located in the Antofagasta Region, in the municipality of Mejillones. Volta is poised to be a pioneering project in the green hydrogen and ammonia industry in Chile and the region.

Key Highlights:

- The total investment is estimated at US$ 2.5 billion, generating around 1,700 jobs during the construction phase and approximately 500 direct and indirect jobs during full operation.
- Construction of a green hydrogen plant for the production of green ammonia, with an estimated capacity of approximately 600,000 tons per year, divided into two stages of 300,000 tons per year each. The project includes considerations for a solar plant to power the chemical plant and connecting to the grid to increase operational efficiency. The goal is to reach the Final Investment Decision (FID) by the end of 2025, with production starting by the end of 2027.
- Initial shipments of green ammonia are expected by 2027, targeting both local and international markets.
- The green ammonia plant, at full capacity, is projected to reduce over 1 million tons per year of CO_2 emissions, equivalent to the pollution of more than 200,000 internal combustion engine vehicles in one year.
- Additionally, the Volta project includes the construction of a 600 MW photovoltaic park for renewable energy supply. Water supply will come from existing desalination plants

with environmental approvals, and wastewater from Mejillones will be used, contributing to cleaning its bay. This is a solution that creates an added value to the community and

- The project development involves an investment of over US$ 2.5 billion, with an approximate generation of 1,700 jobs during the construction phase and around 500 direct and indirect jobs during full operation.
- The Volta project upholds high technical and environmental standards, focusing on resource efficiency and the incorporation of circular economy principles. Early community engagement has been prioritized, including a process of early citizen participation prior to the environmental assessment of the project.
- MAE emphasizes the importance of the Volta project for the development of the green hydrogen and ammonia industry in Chile, positioning Mejillones as a key production center in the country and the region. The submission of the EIA is a significant milestone towards making this industry a reality and supporting the transition to a low-carbon economy in Mejillones, the Antofagasta Region, and the country.

3.4 PESTEL Analysis

The development of a green hydrogen industry in Mejillones presents both opportunities and challenges for the local community, investors, and policymakers. To navigate this complex landscape effectively, we present the results of the PESTEL assessment with the factors that FID for projects.

3.4.1 Political Factors

Factor	Description	FID Decision Influence
Government Policy Stability	The consistency and longevity of government policies supporting renewable energy and hydrogen development in Chile, including incentives, subsidies, and regulatory frameworks, significantly influence the decision-making process for as these are key to sustain the investments in the long term.	High
Political Support and Commitment	Direct support and commitment from political leaders and government officials at local, regional, and national levels can support investor confidence and provide assurance of ongoing political backing for hydrogen projects in Mejillones.	Medium
Inter-governmental Agreements	Bilateral or multilateral agreements between Chile and other countries, particularly those related to trade, investment, and technology transfer in the hydrogen sector, can impact the FID decision by opening up avenues for international collaboration and market access.	Medium
Regulatory Environment	The clarity, consistency, and efficiency of regulatory processes related to project approvals, environmental permits, and land rights can affect the timeline and cost of project development, thus influencing the FID decision for hydrogen hubs in Mejillones	High
Political Instability or Uncertainty	Political instability, including changes in government leadership, policy reversals, or unpredictable regulatory environments, may introduce uncertainties and risks that could lower investor confidence and potentially delay or deter the FID. However, these are always going to be present and therefore risk management needs to be accountable.	Low

3.4.2 Economic Factors

Factor	Description	FID Decision Influence
Price of Green Hydrogen – Market vs Demand	The cost competitiveness of renewable energy sources plus infrastructure investment, the availability and adequacy of infrastructure, including transportation networks, utilities, and port facilities such as solar and wind, which are essential for hydrogen production, is a critical factor influencing the FID decision.	High
Investment Opportunities and competitive landscape	The availability of investment opportunities, including access to financing, grants, subsidies, and other financial incentives, can significantly impact the FID decision Favorable investment conditions attract capital and support project realization.	High
Market Demand and Pricing	Anticipated demand for hydrogen and its derivatives, along with pricing dynamics (1.5 USD/kg?), play a medium-level role in the FID decision. Understanding market trends, potential customers, and pricing mechanisms is crucial for assessing project profitability and revenue generation	Medium
Operating Costs	While operating costs, including equipment, labor, maintenance, and utilities, are essential considerations, they typically have a lower impact on the FID decision compared to renewable energy costs and investment opportunities. However, optimizing operating expenses is still important for project economics.	Low
Economic Stability	The overall economic stability of Chile and global economic conditions, including factors such as inflation rates, currency fluctuations, and GDP growth, can influence investor confidence and risk perceptions but generally have a lower direct impact compared to the factors described above.	Low

3.4.3 Societal Factors

Factor	Description	FID Decision Influence
Community Acceptance and Engagement	The level of acceptance and engagement from local communities in Mejillones is a critical societal factor influencing the FID decision. Positive community relations, addressing concerns, and fostering meaningful dialogue can mitigate social risks and enhance project feasibility.	High
Job Creation and Economic Development	The potential for job creation and economic development resulting from hydrogen hub projects in Mejillones is a significant societal factor. Providing employment opportunities, supporting local businesses, and contributing to socio-economic prosperity are important considerations for stakeholders and decision-makers.	Medium
Health and Safety	Ensuring the health and safety of workers, residents, and the broader community in Mejillones is a medium-level societal factor affecting the FID decision. Implementing robust safety measures, environmental safeguards, and emergency response protocols are essential to address societal concerns and maintain public trust.	Medium

Factor	Description	FID Decision Influence
Cultural Heritage Preservation	Although important, the preservation of cultural heritage and indigenous rights in Mejillones typically has a lower direct impact on the FID decision compared to community acceptance and economic factors. However, respecting cultural heritage and indigenous rights is essential for building trust and maintaining positive relationships with local stakeholders.	Low
Education and Awareness	The level of education and awareness about hydrogen technology and its potential benefits among the local population in Mejillones is a societal factor that can influence the FID decision indirectly. Investing in educational initiatives and raising awareness about the importance of hydrogen projects can foster support and engagement from the community	Low

3.4.4 Technical Factors

Factor	Description	FID Decision Influence
Technology Readiness and Scalability	The readiness and scalability of hydrogen production, storage, and distribution technologies are critical technical factors influencing the FID decision. Mature and scalable technologies reduce implementation risks and enhance project feasibility.	High
Infrastructure Requirements	The adequacy and availability of infrastructure, including transportation networks, utilities, and port facilities, are medium-level technical factors affecting the FID decision. Access to necessary infrastructure reduces project risks and lowers operational costs for hydrogen hub development in Mejillones.	High
Supply Chain Integration	The integration of hydrogen supply chains, including sourcing raw materials, manufacturing components, and logistics coordination, is a medium-level technical factor. Efficient supply chain management ensures reliable and cost-effective operations for hydrogen hub projects.	Medium
Technology Innovation and R&D	While important, technology innovation and ongoing research and development (R&D) initiatives have a lower direct impact compared to technology readiness and infrastructure requirements. However, investing in innovation and R&D can enhance the long-term competitiveness and sustainability of hydrogen hub projects	Low
Operational Efficiency and Maintenance	The operational efficiency and maintenance requirements of hydrogen production, storage, and distribution facilities are technical factors that have a relatively lower impact on the FID decision. However, optimizing operational processes and maintenance practices can improve project economics and reliability over the project lifecycle.	Low

3.4.5 Environmental Factors

Factor	Description	FID Decision Influence
Carbon Emissions Reduction	The potential for carbon emissions reduction through the deployment of hydrogen hubs in Mejillones is a critical environmental factor. Green hydrogen production from renewable sources can significantly contribute to mitigating climate change and meeting sustainability targets established by the country. However, clear accounting methods for CO2 emissions are required	High
Water Usage and Conservation	The environmental impact of water usage in hydrogen production processes remain high considering the desalinization and handling the subproducts. Assessing water availability, implementing efficient water management practices, and minimizing water consumption within the process are important considerations.	High
Land Use and Biodiversity Conservation	The impact of land use and habitat disruption on biodiversity conservation is a medium-level environmental factor. Responsible land use planning, habitat preservation, and ecological restoration efforts are essential for minimizing environmental impacts and maintaining biodiversity.	Medium
Waste Management and Pollution Control	While important, waste management and pollution control have a lower direct impact on the FID decision compared to carbon emissions reduction and water usage. Implementing effective waste management strategies and pollution control measures ensures minimal environmental impact from hydrogen hub operations.	Low
Ecological Footprint Assessment	Conducting ecological footprint assessments to evaluate the overall environmental impact is a technical factor that typically has a lower direct impact on the FID decision. However, assessing and mitigating ecological impacts are important for ensuring environmental sustainability and regulatory compliance.	Low

3.4.6 Legal Factors

Factor	Description	FID Decision Influence
Regulatory Framework	The clarity, stability, and adequacy of the regulatory framework governing hydrogen hub development in Mejillones are high-level legal factors influencing the FID decision. Clear regulatory guidelines, permitting processes, and compliance requirements provide certainty and reduce regulatory risks for investors.	High
Land Rights and Permitting	Securing land rights and obtaining necessary permits for infrastructure development are medium-level legal factors affecting the FID decision. Streamlined permitting processes and efficient land acquisition procedures facilitate project implementation and reduce delays.	High
Contractual Agreements	Establishing clear contractual agreements between project stakeholders, including suppliers, investors, and government entities, is a medium-level legal factor. Well-defined contracts mitigate legal risks, ensure accountability, and protect the interests of all parties involved.	Medium

Factor	Description	FID Decision Influence
Taxation and Incentives	While taxation policies and incentives play a role in project economics, they generally have a lower direct impact on the FID decision compared to regulatory framework and contractual agreements. Nonetheless, favorable tax incentives can enhance the attractiveness of hydrogen hub projects to investors.	Low
Dispute Resolution Mechanisms	Implementing effective dispute resolution mechanisms, such as arbitration or mediation procedures, is a legal factor that has a relatively lower direct impact on the FID decision. However, having robust mechanisms in place for resolving conflicts can mitigate legal uncertainties and promote investor confidence in Mejillones	Low

4 Understanding Stakeholders: Chile and The Netherlands

4.1 Municipality of Mejillones

Vision

The Municipality of Mejillones envisions itself as a leading hub for sustainable energy innovation, capitalizing on its strategic location to drive the development of the Green Hydrogen industry. By 2030, Mejillones aims to become a benchmark for sustainable industrial practices, harmonizing economic growth with environmental stewardship and social inclusion.

Key Interests

Mejillones aims to collaborate with national and international partners, establish a supportive policy framework, and attract investments to position itself at the forefront of the green hydrogen economy, contributing significantly to Chile's renewable energy goals.

Needs

Need for Informed Decision-Making: There is a general concern about decision-making based on perceptions rather than concrete evidence and facts. Emphasizing the importance of informed and participatory processes to understand the implications of regulatory decisions on local development and sustainability.

Concerns

- Inhabitants are concerned about the development of these projects and how this will affect their lives, and how this will impact their own economic, social and cultural development. Furthermore, community shall participate in the formulation, implementation and evaluation of national and regional development plans and programmes which may affect them directly.

- Restriction on Growth: The proposed regulatory plan designates a significant portion of the Mejillones bay as an "inoffensive zone," where existing companies can operate but cannot expand. This limitation could hinder the growth of businesses in the area and prevent the arrival of new industries. Hydrogen designations remain unclear (explosive vs dangerous).

- Clarifying Risk Perceptions: It's crucial to differentiate between hazardous activities related to energy infrastructure and productive processes, which are often misunderstood as synonymous with pollution. According to legislation distinguishes between dangerous activities, which involve handling risky substances, and contaminating activities. Proper understanding and classification by health authorities

and urban planning laws are essential for informed decision-making and support by the local community.

- Divergent Opinions: There is a divided opinion among municipal councilors and the mayor regarding the plan, ranging from halting industrial expansion to transitioning to a tourism-focused approach. This divergence complicates decision-making and could impact the region's future development and the need for additional job opportunities. The proposal will be voted on in November, after the municipal election and before the new authorities take office.

- Disconnect with National Goals: The potential approval of the regulatory plan could contradict national goals related to decarbonization by limiting projects like green hydrogen production. This inconsistency highlights the need for alignment between local planning decisions and broader environmental and economic objectives.

- Harmonizing Infrastructure Planning: The plan fails to account for important infrastructure projects like desalination plants, which are crucial for water supply but are categorized as "nuisance" in the proposed zoning. This oversight could hinder essential infrastructure developments in the region.

4.2 Demand Side - Chilean Industry

Vision

The Chilean industry wants to position itself as a leader in promoting and adopting green hydrogen as a fundamental energy resource in modern industry. They recognize its versatility, efficiency, and sustainability as pillars for successful energy transformation.

Key Interests

- Diverse Investor Landscape: Various types of investors and countries are actively pursuing investments in the green hydrogen industry. These investors are also the primary importers of green fuels.
- Interest from Industrialized Nations: Industrialized nations, lacking sufficient landmass for large-scale green hydrogen projects to meet their own demands, are investing in projects abroad to ensure a sustainable fuel supply and decarbonize their industries.
- There is regular contact with international stakeholders, including the Port of Rotterdam, indicating interest and potential collaboration in the future. The project's shareholders, primarily based in Houston, are experienced in energy transition and related industries, further supporting the project's viability and strategic direction.

Needs

- The local market in Chile is seen to have potential but more likely around 2030, so initial focus is on exports. Chile's stable political environment and existing regulatory framework are advantageous, but the new industry needs support for specific infrastructure, such as ammonia pipelines.
- Ammonia is targeted as a primary hydrogen carrier due to its transport efficiency. The project is designed to produce ammonia directly from hydrogen, without storing large volumes of hydrogen. The plan includes securing environmental permits, advancing engineering, and signing long-term contracts for resources like port facilities and water by the end of 2025.

- Permitting remains a main issue. Environmental permits take a lot of documentation, and the lead time is very long and uncertain due to internal bureaucracy. This also depends on the value chain for a particular project.

Concerns

- In the case of MAE, legal frameworks in Chile are generally sufficient, but changes must be carefully managed to avoid setbacks. The project requires various approvals and off-take contracts to proceed to the next phase by the end of 2025, with production starting as planned.
- The international mandates are very aggressive compared to the national ones. There is a huge demand for green hydrogen in order to mitigate climate change.
- Cost and Incentives: The traditional industry may be hesitant to transition to green ammonia or hydrogen due to higher costs and the need for incentives. Positive incentives such as grants and support, as well as negative incentives like carbon footprint charges, may be necessary to encourage adoption.
- Shared Infrastructure: Leveraging existing infrastructure and enabling it for broader use are seen as critical for sustainability but the issue remains in how fast this infrastructure needs to be replaced. Demand of electrolyzers and the type remains very challenge. It is expected to is to have local manufacturing in the Chile in the future supported by international suppliers.
- Inhabitants are concerned about the development of these projects and how this will affect their lives, and how this will impact their own economic, social and cultural development. Furthermore, the community shall participate in the formulation, implementation and evaluation of national and regional development plans and programmes which may affect them directly.

4.3 Industrial Association Mejillones

Vision

The purpose of the Association is to work collectively to contribute to the sustainable development of industry, the community, and the country. The AIM coordinates different stakeholders to align their objectives and develop projects related to green hydrogen that position the commune of Mejillones as a virtuous development hub for the country, an open bay toward the future in terms of tourism promotion and quality of life support.

Key Interests

- Community Engagement and Consultation: Ensuring active and meaningful engagement with local communities throughout the project development process is crucial to address their concerns and ensure equitable distribution of benefits.
- Employment and Skills Development: While green hydrogen projects can create new jobs, it is important to ensure that local communities have access to training and skills development opportunities to qualify for these new positions.

Needs

Main need: Foreign companies, delegations, or investors should consider this question as part of their action plan: What do you give in return to the local communities, and how do you ensure the legacy of these projects is preserved? The arrival of foreign companies, delegations, and investors in Mejillones presents both opportunities and challenges for the local communities. While the green hydrogen industry can bring economic growth and

technological advancements, it is crucial to ensure that these developments benefit the community in a tangible and sustainable way. This means moving beyond simple financial transactions and considering how foreign stakeholders can actively contribute to the long-term well-being and prosperity of the region.

Concerns

- Potential Social Disruptions: The influx of migrant workers during the construction and operation phases of the projects could strain local infrastructure and resources, leading to potential social disruption.
- Potential Negative Impacts on Traditional Livelihoods: Mejillones is traditionally a mining industry region, if green hydrogen projects come to the region, it is crucial to ensure that workers and communities dependent on these industries have alternative livelihood options and receive adequate support and understanding on the impact during the transition.
- Long-Term Engagement: The impact of foreign involvement should extend beyond the immediate project development phase. It is essential for companies, delegations, and investors to maintain a long-term commitment to the community, even after project completion by demonstrating a genuine and enduring interest in the well-being of the community, foreign stakeholders can solidify their legacy and contribute to a more prosperous and sustainable future for the region.

4.4 Ports – Complejo Portuario de Mejillones (CPM) – Chile

Companies Interviewed: Complejo Portuario de Mejillones (CPM)

Vision

Overall, CPM's is strategic committed to actively contributing to the green hydrogen revolution in the Mejillones region. Their focus on infrastructure development, collaboration with project developers, and recognition of the strategic importance of the industry suggest they will play a crucial role in facilitating the export of clean energy solutions and supporting the region's transition towards a sustainable future.

Key Interests

- Focus on Green Ammonia Exports: CPM sees green ammonia as its primary export focus due to its ease of transportation and storage compared to hydrogen. This aligns with the broader industry trend as many potential exporters are considering ammonia and methanol derivatives for similar reasons.
- Infrastructure Development: CPM is committed to providing the necessary infrastructure for the storage and export of green ammonia. They are currently updating their port master plan and exploring options like building a new liquid bulk terminal or adapting existing infrastructure.
- Collaboration with Project Developers: CPM acknowledges the numerous green hydrogen projects in the Antofagasta region and seeks collaboration with project developers to provide efficient export channels. MAE's US$2.5bn Volta project is a prominent example, for which CPM will likely offer logistical support.
- Strategic Importance: CPM recognizes the strategic importance of green hydrogen for the region's economic and industrial development, particularly as a hub for the mining

industry. They aim to position Mejillones as a key gateway for exporting clean energy solutions.
- Leverage Existing Expertise: As a subsidiary of Codelco, CPM benefits from strong ties to the mining industry and extensive experience in managing complex port operations. They plan to leverage this expertise to support the efficient development of the green hydrogen ecosystem. At Mejillones port, grain terminal concessionaire TGN is completing an expansion project, work that involves building new mooring facilities for the dispatch of mineral concentrates.

Needs

- Infrastructure Expansion and Adaptation: The ports in Mejillones need to invest in expanding and modifying their infrastructure to accommodate the specific handling, storage, and export requirements of green hydrogen and its derivatives like ammonia and methanol. This includes building new terminals, adapting existing facilities, and acquiring specialized equipment.

Concerns

- Competition and Market Volatility: Ports in Mejillones will face competition from other ports globally vying to become green hydrogen export hubs. Securing competitive advantages, off takers, diversifying markets, and building strong partnerships will be crucial for success in a volatile market.
- Social and Economic Impacts on Port Communities: The influx of workers and potential changes in port operations may impact local communities. Addressing concerns about job displacement, ensuring equitable distribution of benefits, and engaging in open dialogue with stakeholders will be crucial.

4.5 Ports – Port of Rotterdam – The Netherlands

Vision

The Port of Rotterdam aims to transform into a fully decarbonized port and industrial complex by 2050, achieving a net-zero carbon footprint. This vision includes both the port's operations and the broader industrial ecosystem, acknowledging their combined environmental impact. The target year of 2050 reflects the substantial scale, complexity, and costs involved in achieving such an ambitious change.

Key Interests

- Scale of Transformation: Decarbonizing this port, which handles 13% of European energy consumption, necessitates massive and coordinated changes across numerous facets: energy sources and consumption within the port, infrastructure upgrades for green energy integration (like hydrogen), operational practices within industrial facilities associated with the port, transportation modes used within the port and industrial complex, etc.
- Port of Rotterdam as a key stakeholder, contributing its knowledge, matchmaking capabilities, potential investments in local ports in collaborating countries, and influencing government policy.
- Technological Development & Adoption Rate of Green Solutions: Achieving this ambitious vision hinges largely on advancements in green technologies - such as hydrogen - and their widespread application in various domains within and around the port's operation. The success and pace of the Port will depend on how rapidly these solutions become

commercially viable, scalable, and widely accessible, as the vision's timeline requires significant progress within 30 years. This includes not just technical feasibility but achieving affordability and compatibility with existing infrastructure/processes in the industrial complex.
- Integration and Collaboration: Realizing decarbonization at this scale is hardly an endeavor solely within the Port's own control. Extensive cooperation across diverse stakeholders is essential.

Needs

- Urgency for hydrogen market kickoff, despite ongoing development. Delays to hydrogen's full-scale adoption threaten progress towards its 2050 ambitions.
- Several factors make Chile appealing, including favorable wind conditions, economic stability, established governmental involvement, and the presence of multiple, well-developed projects. Mejillones as a hub in need, benefitting from its pre-existing port and industrial zone coupled with its potential for shared infrastructure. Potential concerns include a lack of central leadership and clear governmental vision for infrastructure support.
- Public-private partnership is vital. However, private sectors cannot cover all infrastructure expenses. Government involvement is required, not with direct, large-scale investments, but rather through strategic financial mechanisms like subsidies focused on green hydrogen producers.
- Importance of detailed follow-up plans – Masterplan, going past existing proposals and into actionable details on government roles and investments.
- Collaboration framework: How government(s) can work most effectively (e.g., dedicated agency; existing infrastructure bodies with new mandates)?

Concerns

- Identifying Suitable Off takers: The Port of Rotterdam can help connect Mejillones projects with potential European offtakes who meet RED II and III regulatory requirements. This requires understanding specific offtake needs and facilitating agreements between producers and buyers.
- Bridging the Gap: Financial support mechanisms for off takers, particularly during early stages, can bridge the gap in the current business case for hydrogen until the market matures. Such incentives can help attract initial investors and stimulate demand, ultimately supporting project viability.
- Local Offtake Development: Encouraging local demand through government incentives and subsidies can create a viable initial market, allowing producers to scale up for future exports. This approach also reduces dependence on solely international off taker partnerships.
- Investment Uncertainty and Timing: The initial substantial investment required for shared infrastructure development falls upon the Chilean government. This creates uncertainty for private investors who may be hesitant to commit until they see a concrete plan and guaranteed returns. Therefore, finding a balance between public pre-investment and attracting private participation is crucial.
- Leadership and Coordination: Currently, there is a lack of centralized leadership and coordination for shared infrastructure development in Mejillones. This leads to fragmented planning, potential duplication of efforts, and inefficiencies.
- Optimizing Infrastructure Design and Utilization: The design and utilization of shared infrastructure needs careful consideration to ensure maximum efficiency and cost-effectiveness. This includes factors like location, capacity, flexibility to accommodate future growth, and potential synergies between existing and planned facilities.

4.6 Demand-side Industry – The Netherlands

Vision

For energy-intensive process industries, complying with climate transition targets means a transition towards sustainable processes. This involves both an energy transition and a resource transition. In both transitions, they need to mind their competitiveness and limit long-term investment risks.

View in Green Hydrogen

- As a feedstock and an energy carrier, green hydrogen will deliver an important contribution to a circular and decarbonized industry.
- For most parts of industry, the 'color' of hydrogen doesn't matter; a stable, low-cost supply is much more important. For industries with a need for very pure hydrogen, green hydrogen is preferred.
- Hydrogen as a carrier and raw material does not have to be produced locally; like for other fuels and resources, the market is global. Other manufacturing should stay.

Key Interests

- International competitiveness - attractive investment climate
- Investment security in relation to the availability and costs of energy carriers.
- Continued license to operate.
- The status of the industry in Europe, based on concrete actions for decarbonization and not only relying on imports.

Needs

- Sufficient, predictable and secure supplies of (carbon neutral) energy and resources
- Cost-effective decarbonization options also considering current infrastructure and diverse feedstocks.
- Availability of sufficient and diverse infrastructure for decarbonization: electricity, hydrogen, CO_2, heat.

Concerns

- Regulations creating an internationally unlevel playing field, resulting in declining competitiveness.
- High costs of decarbonization, high costs in hydrogen price are not competitive.
- Future variation in (renewable) energy supply and prices.
- Uncertainty about future carbon prices.
- Connection fees and timely access to infrastructure.
- Slow, undecided and fickle policy decisions pose a barrier to timely investment decisions.
- Uncertainty about the future availability of infrastructure for and relative costs of different decarbonization options (direct electrification, hydrogen, CCS)
- The costs, reliability and availability of flexible production technologies
- Existing installations and the need for ammonia crackers and new equipment.
- Reasonable costs of retrofitting and shared infrastructure.

4.7 Dutch Policy Makers

Ministry of Economic Affairs & Climate Policy (EZK)

Vision

Responsible for shaping climate and energy policies, the ministry oversees various aspects within the Climate Agreement, particularly focusing on electricity and industry. It plays a pivotal role in formulating policies concerning the energy system, covering areas such as offshore wind, gas production, hydrogen, and CCS (Carbon Capture and Storage). The ministry also coordinates the Program Energy System, aiming to drive forward the energy transition using technology-neutral tools and incentives.
Maintaining a close partnership with Chile, a Letter of Intent was established to facilitate knowledge exchange, particularly regarding hydrogen strategies, marking one of the earliest collaborations in this field.

In early 2023, a strategic agenda was established, outlining specific actions, including initiatives related to the import and export of derivatives. Among these actions is the development of infrastructure and ports, with ongoing projects in Magallanes, Gasuine, and PoR. The focus is on translating the knowledge gained from these projects into exportable expertise, enhancing opportunities for the Netherlands in the global market.

View in Green Hydrogen

Hydrogen stands as a crucial energy carrier pivotal for facilitating the transition and integration of energy systems. Recognizing its significance, government support in the initial stages is essential to jumpstart the (low carbon) hydrogen market. To this end, a National Hydrogen Programme for 2022-2025 is presently under development, aiming to provide the necessary framework and support for hydrogen-related initiatives.

Key Interests

- Continued cooperation in the ARRA region, particularly focusing on the Hamburg port, aims to enhance trade and economic prosperity in the area, facilitating smoother transit of goods and boosting regional development.
- Trilateral projects with neighboring countries, especially considering financial challenges, seek to foster collaboration and resource-sharing to overcome economic obstacles collectively, promoting mutual growth and stability.
- A clean, affordable, and reliable energy system signifies a commitment to sustainability and cost-effectiveness, ensuring access to energy while minimizing environmental impact, thus contributing to a greener future.
- Achievement of policy goals and meeting (international) obligations.
- The politically acceptable weighting of different stakeholder interests.
- Public and stakeholder support for policies.
- Interest in developing Import routes via long-term contracts with Germany
- Foster infrastructure projects with the EU in large scales.
- Diversification of sources are a priority and are geographically agnostic. i.e. EU, Middle east, Canada, USA, LATAM.

Needs

- Clear connections to existing studies and knowledge to promote a consistent, common knowledge base. promoting alignment and coherence in understanding to advance research and implementation strategies effectively.

- Contribution of system integration and specific technologies to policy goals, e.g., preventing, mitigating and reducing environmental and ecological impacts and positive contributions to ecological development.
- Insights into perceived policy/regulations barriers to system integration, preferred locations and framework conditions for the green hydrogen hubs.
- Explore green hydrogen derivatives to facilitate growth in the hydrogen market, analyzing opportunities for innovation and economic growth while promoting sustainability and environmental responsibility.
- Establish the blending limits for hydrogen considering industrial requirements and end-users.
- Advocate for standardization in hydrogen carriers to enhance interoperability, safety, and efficiency within the hydrogen sector, promoting consistency and reliability in transport and storage solutions for hydrogen-based technologies.

Concerns

- Establishing a robust supply value chain is crucial for financing these projects, ensuring smooth funding processes and investment mechanisms to support the development and implementation of sustainable initiatives effectively.
- Prioritize sustainable development in the region, considering just transition elements (JTE) and emphasizing social acceptance by incorporating and valuing local perspectives and needs to foster community engagement and support.
- While green hydrogen is widely acceptable in the Netherlands, challenges exist regarding ammonia, particularly related to safety and transportation issues, posing potential hurdles that need to be addressed for successful integration and adoption.
- Assess the Technology Readiness Level (TRL) status of ammonia crackers and focus on upscaling initiatives to effectively feed green hydrogen into the grid, aiming to advance technology development and deployment for efficient utilization of green hydrogen as an energy source.

5 Strategic Pillars for Bilateral Collaboration between Chile and the Netherlands

Topic of Collaboration	Potential Ideas	Potential Instruments
Knowledge and Technology Transfer	• Collaboration on research and development projects. • Knowledge exchange programs for students and researchers • Supporting development of green hydrogen derivatives: Partnering with Chilean companies to explore new applications for green ammonia and methanol. • Chile - Low Carbon - Team Europe Initiative - The Team Europe Proposal activities include Enabling environment through: Regulatory and policy development support, Specialized human capital for GH2 production, Assessment of GH2 value chain and suppliers support program, Green H2 production and application projects, GH2 technological development and production. Green H2 I+D through: Technical assistance	Example of funding Mechanisms: Fuel Cell and Hydrogen Joint Undertaking (FCH JU), Team Europe Initiatives, RVO Develop2Build, Horizon Europe CL5, K2K, EIB. I+D+I development fund in GH2 production and applications National funding programs via RVO, CORFO, etc. for R&D and Industry. Training programs, knowledge exchange initiatives, and technical assistance can enhance the capabilities for both countries creating opportunities for employment, entrepreneurship, and professional growth within the local community.
Financial Support and Investment	• Grants, loans, subsidies, and access to international climate finance mechanisms. • Public-private partnerships (PPPs) and joint ventures. - Green hydrogen investment funds. Refer to above instruments.	• Bilateral agreements between the Netherlands and Chile, such as Bilateral Investment Treaties (BITs), coupled with the utilization of de-risking tools, can serve to foster greater Dutch investment in Chile's increasing hydrogen economy. Invest Chile, Invest International, PPP funds, etc. • Green Hydrogen Purchase Agreements (GHPA): Contractual agreements between producers and buyers, specifying the volume, price, and delivery terms for green hydrogen.

		• Take-or-Pay Contracts: Buyers commit to purchasing a minimum amount of green hydrogen, regardless of their actual needs, providing producers with guaranteed revenue. • Price Stabilization Mechanisms: Tools like price collars or price floors can mitigate price volatility and ensure stable returns for producers.
Infrastructure Development	• Collaboration with Mejillones Port and other infrastructure stakeholders. • Expertise in port infrastructure management and logistics. • Development of pipelines, storage facilities, and export terminals.	European Investment Bank's Green Loan Program: Provides financing for sustainable infrastructure projects, including green hydrogen production and transportation. EU's Connecting Europe Facility (CEF): Supports the development of trans-European transport infrastructure, including potential hydrogen pipelines. Global Infrastructure Facility (GIF): Offers advisory services and risk mitigation tools to facilitate private investment in infrastructure projects. Climate Investment Funds (CIF): Provides financing for climate mitigation and adaptation projects, including green hydrogen infrastructure.
Market Development and Offtake Agreements	• Promoting Chilean green hydrogen to international markets. • Negotiation and signing of offtake agreements with European buyers. • Establishing a green hydrogen trading platform	• Online Marketplaces and Platforms: Develop online marketplaces or platforms specifically for green hydrogen trading, facilitating easier connections between suppliers and buyers. • Standardized Contracts and Terms: Develop standardized contracts and terms for green hydrogen offtake agreements to streamline negotiations and reduce transaction costs. • Legal and Financial Expertise: Provide legal and financial expertise to assist Chilean producers in negotiating and signing offtake agreements with European buyers. • Risk Mitigation Instruments: Explore risk mitigation instruments such as insurance or price stabilization mechanisms to reduce the financial risks associated with long-term offtake agreements.

Policy and Regulatory Framework	• Collaborative efforts to establish a supportive regulatory environment. Plus, knowledge exchange and dialogue between policymakers. • Support harmonization of standards and certifications. • Legal and Financial Expertise: Assist Chilean producers in negotiations to ensure price stabilization mechanisms to reduce financial risks.	• Harmonizing regulatory frameworks and policies related to hydrogen production, transportation, and usage can foster a conducive environment for collaboration. • Standardization provides a foundation of trust and consensus on which companies and countries can cooperate to foster a just energy transition (JET). For example, the new ISO/TS 19870 (unveiled COP28 2023) as a foundation for harmonization, safety, interoperability and sustainability across the hydrogen value chain. • Both countries can work together to develop supportive policies, such carbon pricing mechanisms (CBAM) and incentives for hydrogen adoption. Dialogue can ensure alignment and coherence in regulatory approaches, facilitating cross-border collaboration. Establish Equator Principles: A framework for financial institutions to assess and manage environmental and social risks in project financing.
Community Engagement and Social Responsibility	• Develop comprehensive CSR programs that go beyond compliance with legal requirements and actively contribute to the well-being of local communities. Integrate social responsibility considerations into all aspects of business operations, including environmental sustainability, labor practices, and community engagement. • Report regularly on CSR performance to stakeholders, demonstrating the company's commitment to making a positive impact on the community.	• Scholarship opportunities for Chilean students in Dutch universities. Establish dedicated committees with representatives from the local community, project developers, and relevant authorities to ensure open communication and collaboration. • Prioritize local hiring and procurement in Mejillones to create employment opportunities and stimulate the local economy. • Investing in community development projects that address local needs and priorities, such as education, healthcare, and infrastructure improvements. • Regularly evaluate the effectiveness of community engagement strategies and adapt them as needed to address emerging concerns or opportunities. • Donate equipment, materials, or expertise to local schools, hospitals, or other community organizations. • Provide technical assistance and training to local businesses and individuals to enhance their skills and capacity.

Environmental Sustainability	• Implementation of best practices for renewable energy integration and sustainable land use. • Research and development of innovative technologies for carbon capture and storage.	Besides National programs, here are other instruments: Green Climate Fund (GCF): Provides financial support for developing countries to mitigate and adapt to climate change, including projects that promote green hydrogen production. Global Environment Facility (GEF): Supports projects that conserve biodiversity and promote sustainable development, including those that advance the green hydrogen sector. Clean Technology Fund (CTF): Finances clean energy projects in developing countries, including those that support the deployment of green hydrogen technologies.
Promotion and Advocacy	• Organize trade missions and business forums to connect Chilean green hydrogen producers with potential buyers in Europe and other markets. • Matchmaking Services: Establish matchmaking services to connect Chilean producers with suitable buyers based on their specific needs and requirements.	• Trade Missions and Business Forums: Connect Chilean green hydrogen producers with potential buyers. • Matchmaking Services: Facilitate connections between suppliers and buyers. • Standardized Contracts and Terms: Streamline negotiations and reduce transaction costs. • Risk Mitigation Instruments: Insurance or price stabilization mechanisms to reduce financial risks.

6 Conclusions

The development of a hydrogen hub in Mejillones will be extensively determined by overcoming the complex challenges between economic factors, such as investment costs and market readiness, and social aspects, including community acceptance and job creation. Both countries share a common vision of green hydrogen production, and thus, several aspects need to be prioritized through national or international strategy plans with its investment capabilities:

- Infrastructure expansion through enhanced collaboration: The successful implementation of any project is deeply rooted in robust infrastructure expansion and adequate collaboration among all stakeholders. Infrastructure expansion provides the backbone, enabling projects to scale, innovate, and respond efficiently to future needs. It ensures that the physical and digital foundations can support increased demands and complexities.
- Emphasis on sustainability and social impact: Just transition elements (JTE) such as reducing poverty and creating decent work and quality jobs are crucial, especially for a country with a history of socio-economic conflicts related to extractives industries for international markets. Social acceptance needs to be at the top of the agenda by incorporating local values and constant community engagement. In addition, environmental considerations across the value chain are required not only from a potential reduction in greenhouse gas emissions perspective (generally, the only indicator considered in international standards) but also the overall ecological footprint in aspects such as water use and resource scarcity.
- Technology and knowledge transfer: Collaborative relationships between research institutions, industries, and governments are crucial. These partnerships enable access to resources, expertise, and knowledge exchange to ensure that technological advancements are effectively implemented. Furthermore, investing in human capital through education and training programs helps build the necessary skills and expertise required to develop the Mejillones area into a hydrogen hub. Securing adequate funding from public or private sources (e.g., grants or capital investment) is vital to derive a competitive hydrogen hub ready for the (inter)national markets and commercialization.
- A master plan with clear KPIs, defined roles, collaboration agreements, and investment capabilities from national and international stakeholders is needed from an independent coordination perspective. The latter is key to ensuring accountability and oversight for different project aspects, maintaining momentum, and addressing issues promptly.

1. PESTEL Barriers and Incentives Optimization:

The analysis of PESTEL factors has highlighted several barriers and incentives influencing green hydrogen production projects in Mejillones. Leveraging political support and regulatory frameworks to incentivize renewable energy projects can mitigate political and legal barriers. Economic incentives such as subsidies and tax breaks can attract investment and reduce financial barriers. Social factors, including public awareness and acceptance, can be addressed through community engagement and long-term and supportive social initiatives. Technological advancements and shared infrastructure development are critical for overcoming technological barriers. Finally, environmental sustainability should remain a

central focus, with measures in place to minimize ecological impact and promote green hydrogen production methods.

2. Risk Mitigation Strategies:
The development and deployment of renewable hydrogen projects in Mejillones comes with inherent risks and challenges. These include technological uncertainties, market volatility, regulatory hurdles, and financial constraints. To address these challenges, robust risk mitigation strategies must be implemented during the realization of several projects. This involves conducting thorough feasibility studies and risk assessments to identify potential pitfalls and develop contingency plans. Diversifying funding sources and securing long-term contracts can mitigate financial risks, while engaging with regulatory authorities and stakeholders from both countries can help navigate regulatory complexities. Embracing innovation and adaptive management practices can also enhance resilience and agility in the face of uncertainty for FID at the end.

3. Leveraging Cross-Sectoral Collaboration and Innovation Ecosystems:
Cross-sectoral collaboration and innovation ecosystems play a pivotal role in accelerating renewable hydrogen projects in Mejillones. By fostering synergies between industries, research institutions, and government agencies, innovative solutions can be developed to overcome common challenges. Collaborative research and development initiatives can drive technological innovation, while knowledge sharing, and capacity building initiatives can enhance expertise and skills. Public-private partnerships (PPP) can facilitate resource pooling and risk sharing, enabling more efficient project execution. By leveraging existing networks and fostering a culture of collaboration, Mejillones can unlock new opportunities and drive sustainable growth in the renewable hydrogen sector.

4. Bilateral Collaborations and Partnerships with the Netherlands:
Bilateral collaborations and partnerships between stakeholders in Mejillones and the Netherlands present significant opportunities for mutual benefit in the green hydrogen sector. Leveraging the Netherlands expertise in renewable energy technologies and its supportive policy environment can accelerate innovation and investment in Mejillones. Knowledge exchange initiatives and joint research projects can facilitate the transfer of best practices and cutting-edge technologies. Furthermore, partnerships between businesses, research institutions, and government agencies can help establish sustainable supply chains and enhance market access for green hydrogen products.

Based on the strategic pillars described in section 6 of this document, a proposed Strategic Action Plan (SAP) is shown as follows:

Strategy Action Plan

To materialize the supply chains for green hydrogen, the following stages need to be addressed, with Dutch stakeholders leveraging their expertise to support each phase:

1. Initial Phase (Year 1-2): Foundation and Planning

a. Master Plan Development: Considering the Green Hydrogen Action Plan proposed by the Ministry of Energy in Chile (The Ministry of Energy of the Republic of Chile, 2020) and the Strategic Cooperation on Green Hydrogen 2023-2025 between the Ministry of Energy of both countries is key to create a detailed master plan for infrastructure development and collaboration, incorporating input from both Chilean and Dutch stakeholders. One of these initiatives have been started between the Port of Rotterdam and the government of Chile; and the recent Trade Missions sponsored by the Ministry of Foreign Affairs and RVO

programs such as PIB (Partners in Business). The Netherlands is at the forefront of the global transition to sustainable energy, particularly in the development of green hydrogen value chains. The country's expertise spans across various stages of the hydrogen value chain, from production and storage to distribution and end-use applications.

b. Coordination and KPIs: To oversee the coordination of such a plan, it is important to establish an independent coordination body to ensure the implementation with clear KPIs is conducted. The Netherlands has established independent coordination bodies that oversee the implementation of complex energy projects throughout the country. These bodies ensure that projects stay on track, within budget, and meet their key performance indicators (KPIs).

c. Share best practices from Dutch green hydrogen projects: The Netherlands has a wealth of knowledge and best practices from previous green hydrogen project. Besides best practices, sustainability is a key focus in Dutch project planning and coordination. Projects are designed to minimize environmental impact, promote circular economy principles, and ensure long-term viability.

d. Feasibility Studies and Risk Assessments: Conduct comprehensive feasibility studies and risk assessments to identify potential challenges and opportunities for the key green hydrogen supply value chains by identifying them and assigning the priority considering the current market, production value and infrastructure to be developed or expanded.

2. Development Phase (Year 3-5): Infrastructure and Capacity Building

a. Infrastructure Development: Start building the necessary infrastructure, such as production facilities, pipelines, storage units, and export terminals. The Netherlands has experience in developing and managing extensive natural gas infrastructure, which is being repurposed for hydrogen. The country is developing a national hydrogen backbone that includes pipelines, storage facilities, and refueling stations. In addition, there are already other initiatives in place such as the Port of Rotterdam, are transforming into green hydrogen hubs. These ports will have the infrastructure needed to handle large-scale hydrogen import, export, and distribution, making them critical nodes in the global hydrogen supply chain.

b. Training Programs and Knowledge Exchange: Dutch institutions and companies are heavily involved in R&D to improve the efficiency and reduce the costs of green hydrogen production. This includes innovations in catalyst development, system integration, and scaling up production processes. It is important the co-creation and Implementation of training programs and knowledge exchange initiatives to build local capacities such as pilot and demonstration projects to test and validate new technologies and processes in real-world conditions, paving the way for large-scale implementation.

c. Public-Private Partnerships (PPPs): Leverage Dutch investment funds and PPP experience to secure financial resources. The Netherlands has a robust ecosystem of public-private partnerships that drive the commercialization of green hydrogen technologies. Initiatives such as the H2Gateway and the Hydrogen Valley in the Northern Netherlands bring together government, industry, and academia.

3. Expansion Phase (Year 6-10): Market Development and Regulatory Alignment

a. Market Development: Promote Chilean green hydrogen to international markets and negotiate offtake agreements. With strong connections to European and global markets, Dutch companies play a pivotal role in the green hydrogen supply chain. The Netherlands'

strategic location and trade relationships enable efficient distribution of hydrogen products across Europe and beyond.

b. Regulatory Framework: Work towards harmonizing regulatory frameworks and standards for green hydrogen. The Dutch government has established a comprehensive hydrogen strategy that includes regulatory frameworks, subsidies, and incentives to support the hydrogen economy. This policy environment fosters innovation and investment in the hydrogen sector. Besides this, the country is developing international standards and certification schemes for green hydrogen, ensuring product quality and facilitating global trade.

c. Innovation and R&D: The Netherlands has advanced knowledge in electrolysis technologies, particularly Proton Exchange Membrane (PEM) and Solid Oxide Electrolyzers (SOE), which are crucial for producing green hydrogen using renewable energy sources. Dutch industries are continuing scaling up and integrating green hydrogen into various applications, including steel production, chemical manufacturing, and refining, contributing to decarbonization efforts.

4. Operational Phase (Post Year 10): Sustained Operations and Continuous Improvement

a. Ongoing Operations: To ensure the long-term success and sustainability of the green hydrogen hub in Mejillones, Chile, it is essential to focus on the continuous maintenance and optimization of the supply chain. To ensure seamless coordination between different segments of the supply chain, including production facilities, storage units, pipelines, and export terminals. This requires effective communication and collaboration among all stakeholders. In addition, the Implementation of advanced monitoring systems using data analytics to identify bottlenecks, inefficiencies, and areas for improvement to track the performance of each component in the supply chain, including production, storage, and distribution.

b. Technological Advancements: In the upcoming years, the use of Deploy automated systems for monitoring and controlling production processes using AI for predictive maintenance of electrolysis equipment and other production infrastructure, minimizing downtime and reducing operational costs will be more than needed and collaboration between producers, suppliers and off takers will be needed. This includes automated adjustments in response to fluctuations in renewable energy supply, ensuring consistent hydrogen output.

c. Innovative Storage solutions: Advanced Compression Techniques considering advanced high-pressure storage systems that can safely and efficiently store hydrogen at pressures of 700 bar or more will be needed, optimizing space and reducing storage costs. In addition, Smart Compression Systems and liquid Hydrogen Storage which offers a higher energy density and reduces storage volume. Besides, the implementation of automated thermal management systems to maintain the necessary cryogenic temperatures, improving safety and efficiency.

d. Modular Storage Solutions: Develop modular storage units that can be easily scaled and transported, facilitating flexible and scalable storage solutions for both domestic use and international export.

e. Community and Environmental Focus: Ensure continued community engagement and adherence to environmental sustainability practices. This includes Dutch expertise in circular economy for hydrogen, where by-products and waste are minimized. This holistic approach

ensures that hydrogen production and use are environmentally sustainable, while emphasizing community engagement and social responsibility in hydrogen projects, ensuring that local communities benefit from economic and environmental gains.

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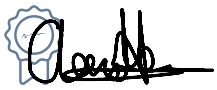
Signature

TNO Energy & Materials Transition Utrecht, 29 August 2024



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on 2024-08-29 13:10:02

Clare Harvey
Deputy Research manager

Alix Reichenecker
Project Manager

Appendix A
Stakeholder Interviews

As part of this stakeholder analysis, relevant interviews with Stakeholders were conducted.

Organization	Stakeholder Group	Country
CPM – Complejo Portuario de Mejillones	Port	Chile
Yara	Demand Industry	Netherlands
Port of Rotterdam	Port	Netherlands
Eanex	Demand Industry	Chile
MAE	Demand Industry	Chile
Universidad Católica de Chile	Academy	Chile
Gasunie	Demand Industry	Netherlands
Asociación Industrial de Mejillones	Association	Chile
Municipalidad de Mejillones	Local Government	Chile
Ministry of Economic Affairs and Climate EZK	Local Goverment	Netherlands
PIB Former Partners	Association	Netherlands

Appendix B
Stakeholder Key Questions

The questions below were selected from a list of PESTEL questions and were asked to stakeholders, considering their relevance and the stakeholders' ability to address them freely:

- What is the current status of H2 projects? Milestones?
- What are your main concerns regarding the execution of the H2 projects in the region?
- What is your vision in the future?
- How is coordination and collaboration with other government and local entities addressed when establishing a hydrogen hub?
- What are the long-term perspectives and strategies of the Ministry of Energy regarding the development of hydrogen infrastructure?
- What potential barriers or concerns (+/-) do you foresee in adopting hydrogen technology in your operations?
- Future Exports: How can technological collaboration facilitate the efficient production, storage, and transportation of hydrogen from Chile to the Netherlands?
- Future Exports: Are there technological standards and compatibility concerns that need to be addressed to ensure a smooth integration of Chilean hydrogen into the Dutch energy infrastructure?
- How does the local political landscape and government support align with the development of a hydrogen hub in Mejillones?
- Are there any local policies or regulations that either support or hinder the execution of a hydrogen project in the city?
- How can the mayor work with national government initiatives to ensure political backing for the hydrogen hub project?

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