SUBNATIONAL CLIMATE FUND

Market Study on Green Hydrogen in Chile

Final report- November 2023

Global investments accelerating
local action for a sustainable future

Acknowledgements

Authors: This report was written by ImplementaSur

This report has been financed by the Subnational Climate Fund (SCF), which features a dedicated, grant funded facility for Technical Assistance (TA) that provides technical support to stakeholders in identifying and strengthening investment proposals for the fund.

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Executive summary

The following report was developed by ImplementaSur with the objective of creating an analysis of the current challenges and barriers of green hydrogen (GH2) in the Chilean market, as well as its potential to achieve Chile's national climate ambitions. This report will provide robust information for a potential future engagement of Catalytic Finance in the Chilean GH2 industry.

The report evidenced the competitiveness of Chile in a globalized GH2 market, along with the importance of this commodity in achieving carbon neutrality. On the one hand, Chile's total GHG emissions are mainly related to the Energy sector (51.34%), which includes Transport sub-sector (70% of the Energy sector's), and within its NDC, GH2 is considered to help mitigate 21% of Chile's emissions in 2050.

Among the sectors where GH2 is more competitive are **mining industry**, due to its ambitious climate goals, high demand potential, an suitable location for GH2 production (most mining operations are located in the north of Chile); **export projects** (ammonia and synthetic fuel) specially for ammonia since it does not have a feedstock challenge (such as CO2 capture), and possess synergies with the fertilizers sector; and **industry sector**, specifically for heat applications and steel.

Based on interviews with stakeholders and developers of GH2 projects, insights from the market were collected regarding barriers and challenges from the sector. The main insights identified related to supply sector were: regulation, permitting, supply chain, and environmental challenges. From the demand sector, export market challenges were the main challenges identified.

A cost analysis was also performed identifying the variables that weighted the most in the cost structure of a GH2 production project. Electrolyzer and renewable energy infrastructure cost was the most relevant variable to define LCOH. Additionally, if the cost of electrolyzer decreases 52% over the next 7 years, and 73% for 2050 (in line with IEA projections), the model suggest that Chile would achieve its goal to provide GH2 at a price lower than 1.5 USD/tonH2 by 2030, and at a price lower than 1 USD/tonH2 by 2050 in the north and south regions using solar and wind sources respectively.

Funding programs were also assessed considering the different instruments that have been put in place in the sector for GH2 acceleration, and other instruments soon to be announced. Since Chile is no longer an ODA country, accessing to international financial instruments for GH2 development is very limited, and concessional resources from the Government to reduce LCOH are also very conservative.

Finally, some recommendations to monitor and identify investment opportunities for Chile related with GH2 are provided. The main recommendations are:

1. **Focus the scoping efforts in the north of Chile**: Even if there are two big GH2 valleys in Chile (north and south), the northern region is more cost competitive in the long run, and has less environmental and permit challenges.
2. **Engage with utility providers**: Large scale projects will consider utility companies to lead the renewable energy infrastructure development of the project. They will be a good focal point for project scouting.
3. **Engage with mining industries**: On a secondary level of priority, monitoring and engaging with mining companies could help to identify long-term investment opportunities with a high climate impact, not the only for GH2 projects, but also for large-scale electromobility investment opportunities.
4. **Monitor alternative opportunities related with GH2 development**: scouting of the development of enabling and shared infrastructure related with GH2, such as ports, gas pipelines, and desalinization infrastructure.
5. **Engage with the local GH2 environment**: engaging with focal points such as InvestChile, Corfo, Asociación H2V de Chile, and Fundación Chile would help to generate networks and identify new investment opportunities.

BMWK: German Federal Ministry for Economic Affairs and Climate Action

CAEX: Heavy mining truck

CAPEX: Capital expenditure

CCS : Carbon capture and storage

CO2: Carbon dioxide

CORFO: Chilean economic development agency

DIA: Environmental Assessment Declaration

ENAP: National Petroleum Company

EOI: Expressions of Interest

GH2: Green hydrogen

GHG: GreenHouse Gas

GW: Gigawatts

IDB: Inter-American Development Bank

IEA: According to the International Energy Agency

IRA: Inflation Reduction Act

LCOE: Levelized Cost of Energy

LCOH: Levelized Cost of Hydrogen

NCRE: Non conventional renewable energies

NDC : Nationally Determined Contribution

OEM: Original equipment manufacturer

OPEX: Operating expenses

OPEX: Operational expenditures

PPA: Power Purchase Agreement

RCA: Environmental Resolution

SEIA: Environmental Impact Assessment System

1 Introduction

Green hydrogen has become a topic of growing interest in the transition to a low-carbon and sustainable economy. It is produced from renewable energy such as wind, solar, hydroelectric, or biomass, through a process of water electrolysis that does not generate greenhouse gas emissions. Due to its versatility and ability to significantly reduce carbon emissions in hard-to-abate sectors, such as heavy industry and transportation, green hydrogen has become a key pillar in achieving decarbonization and climate neutrality goals.

However, despite its promising potential, the widespread deployment and adoption of green hydrogen faces several challenges that are important to analyze in detail. Some of the main challenges include:

- **Costs**: Despite the advantages of producing green hydrogen from renewable sources, the initial production costs, and the lack of economies of scale can hinder its competitiveness compared to other traditional energy sources and fuels.
- **Infrastructure**: The production, transportation, and storage of green hydrogen require specific infrastructure that is not fully developed in many places or requires associativity (for example for ports). This includes expanding existing electrolysis plants, hydrogen transportation systems, and safe/efficient storage solutions.
- **Regulatory framework and policies**: The development of green hydrogen is strongly influenced by the regulatory framework and government policies. It is important to have coherent short, medium, and long-term planning for the sector, as well as enabling rules for the project's development and operation.
- **Funding**: Fundraising is another significant challenge for the widespread deployment and adoption of green hydrogen. Obtaining the necessary financial resources to carry out these initiatives can be a complex task. Establishing incentives and support mechanisms that encourage investment and adoption of green hydrogen is important.

Following are some motivations to provide an in-depth analysis of the Chilean potential to participate in a globalized GH2 market and its favorable conditions to become an exponent of it.

1.1 What is green hydrogen?

Hydrogen, the most abundant chemical element in nature, has experienced a significant increase in its global demand as an energy source and fuel in recent decades. According to the International Energy Agency (IEA), this demand has tripled since 1975, reaching a volume of approximately 70 million tons per year in 2018. The growing awareness of the adverse effects of fossil fuels on the environment and climate change has driven the exploration of more sustainable alternatives, and in this context, **Renewable Hydrogen** (RH2) has emerged as a promising energy substitution. RH2 will include hydrogen that was produced through a low carbon emission source[1], and currently, there are several definitions to describe the source of this fuel. The following are the most commonly accepted and used definitions for hydrogen production:

- **Gray Hydrogen**: This form of hydrogen is obtained from natural gas through the steam methane reforming process, but it produces significant carbon dioxide emissions. Although it is the most widespread production technique, its negative environmental impact makes it the least sustainable.
- **Green Hydrogen (GH2)**: is based on the process of water electrolysis, a chemical process in which water is broken down into its fundamental components: hydrogen and oxygen. In this technique, an electric current is

[1] Usually compared to Gray Hydrogen which is based in fossil fuels and has a high carbon emission factor.

passed through water, causing the molecules of water to break down into their basic elements. What distinguishes green hydrogen from other forms of hydrogen is the energy source used for the electrolysis. In the case of green hydrogen, the electricity used is exclusively obtained from renewable sources such as solar energy, wind energy, or low emission sources.

- **Blue Hydrogen**: Similar to gray hydrogen, it is obtained from natural gas, but in this case, resulting carbon emissions are captured and stored using carbon capture and storage technologies (CCUS). Although it represents an improvement over gray hydrogen, it still depends on non-renewable energy sources and its emission factor is higher than GH2.

Green hydrogen offers various advantages, however, it faces significant challenges, such as the need to improve the efficiency of electrolysis processes, invest in renewable energy infrastructure, and reduce costs to achieve competitiveness with other energy sources. Despite these challenges, green hydrogen is seen as a key element in the transition toward a cleaner and more sustainable economy.

1.2 GH2's role to achieve carbon neutrality

In 2020, Chile's total GHG emissions were estimated at 105,552 kt CO2e, of which 51.34% corresponded to the Energy sector (includes Transport sub-sector), being this the largest sector in terms of emissions in the country. This is due to Chile's sustained energy consumption, which includes coal and natural gas for electricity generation (Energy Industry subcategory), as well as consumption of liquid fuels for land transport, mainly diesel and gasoline (Transport subcategory), accounting 70% of the energy sector's emissions (Ministerio del Medio Ambiente, n.d.). Figure 1-1 shows the sub-sectors related with potential GH2 applications.

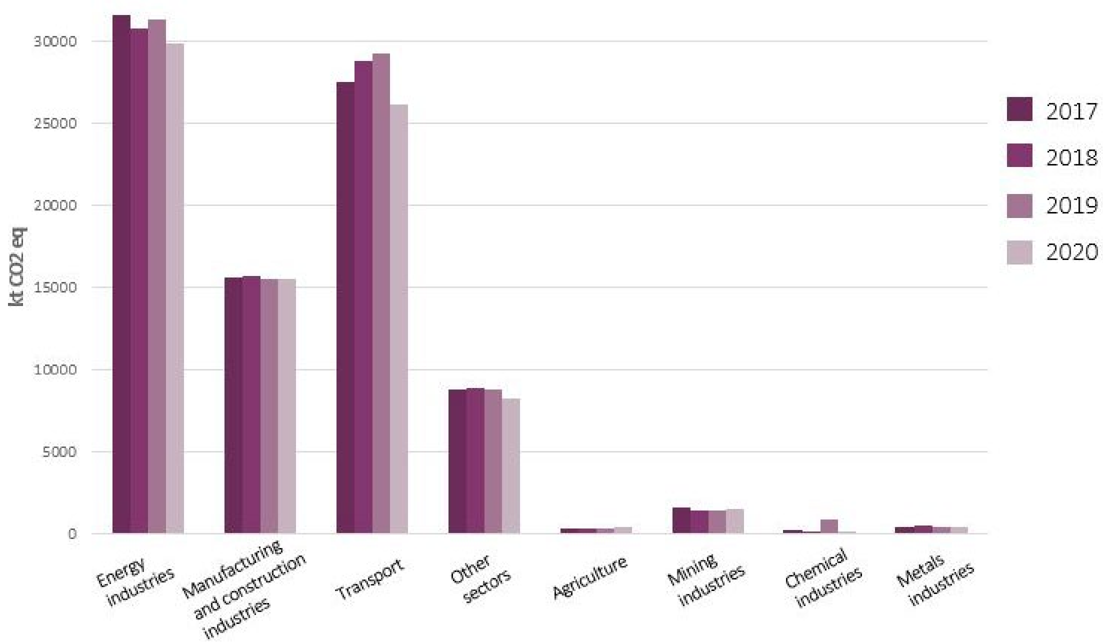


Figure 1-1: GHG emissions in sub-sectors with potential for GH2 mitigation, 2017- 2020
Source: own elaboration based on (Ministerio del Medio Ambiente, n.d).

The Energy sector, with GHG emissions of around 30,000 ktCO2eq per year, is the sub-sector with the highest emission reduction potential. Some trend for decrease of GHG emissions in 2020 is due to the SARS CoV-2 pandemic, which significantly affected the industry and transport sectors.

In the current Chilean context, green hydrogen and its applications play an important role in achieving Chile's NDCs goals. It is estimated that GH2 contribution to reach the country's NDCs by 2050 is equivalent to 21%, specifically in those sectors that are difficult to mitigate such as mining, metallurgical, chemical and agriculture industries (World Bank, 2023). Figure 1-2 presents the emission reduction trajectory of 2050 carbon neutrality scenario.

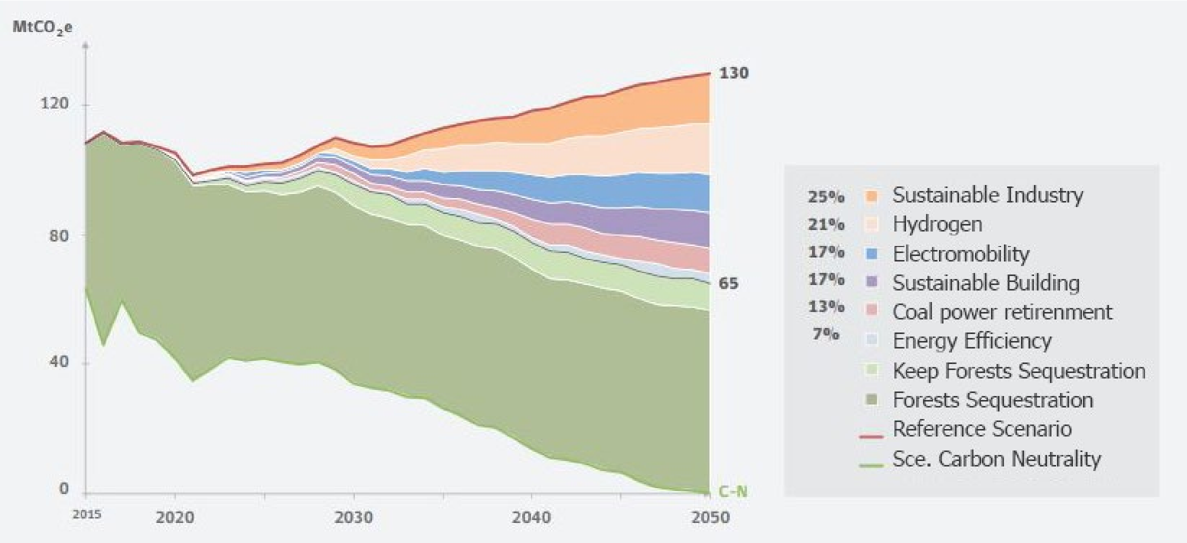


Figure 1-2: Emissions pathway of the carbon neutrality scenario towards 2050.
Source: (Ministerio de Energía, 2019)

This pathway considers three mitigation measures involving the use of GH2; the replacement of diesel in domestic road freight transport; the replacement of diesel engines in mining and industry equivalent to 20% of final energy consumption in this area; and the replacement of gas for residential and commercial uses (Ministerio de Energía, 2019).

Furthermore, the demand and mitigation potential of different category of projects is presented in the following Figure 1-3[2] (Comité Solar e Innovación Energética , 2020).

[2] The estimation was made based on available bibliographic information, and experience from hydrogen demand for each project.

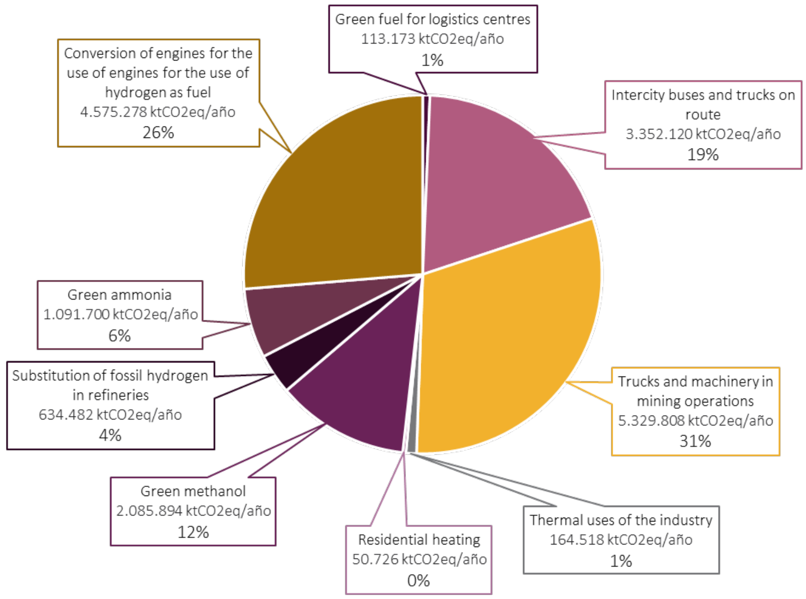


Figure 1-3: Estimate of the GH2 emissions mitigation potential in the Chilean market
Source: own elaboration based on (Comité Solar e Innovación Energética, 2020)

The potential mitigation of carbon emissions from GH2 is more relevant for trucks and machinery in mining operations, and green ammonia, used to produce fertilisers in agriculture.

1.3 Why green hydrogen in Chile?

Chile is currently embarking on an ambitious journey to become the world's leading producer of green hydrogen and its derivatives, while striving to ensure that its production is highly competitive in terms of costs. This strategic premise is not a mere aspiration, but a clearly defined direction guided by various governmental policies and guidelines. Among these, the National Hydrogen Strategy stands out, aiming to achieve a cost of $1.5 USD/kg of hydrogen by the year 2030[3].

Chile's uniqueness and competitive advantage in establishing a thriving hydrogen industry largely stem from its abundance of renewable energy generation resources, having one of the best renewable resources in the world, with solar in the north (Arica y Parinacota, Tarapacá, Atacama and Antofagasta regions) and wind in the south (Magallanes Region). The country boasts an exceptional potential estimated at 2.1 terawatts (TW) from solar, wind, and hydropower sources (Ministerio de Energía, 2021a). This wealth of renewable natural resources serves as a fundamental foundation for the sustainable and efficient development of green hydrogen production.

A crucial element enhancing confidence in Chile's energy sector investment is its stable business environment. The nation has demonstrated an inclination toward open trade and a welcoming attitude towards foreign investment, creating an environment conducive to innovation and collaboration in the energy field. An example of this appealing dynamic is the fact that Chile has maintained its position as a leader in Bloomberg's Climatescope ranking for the second time in three years, considered the top country for investing in renewable energies among the world's

[3] 1.5 USD/kg of hydrogen has been taken as the benchmark for hydrogen cost compared to today's fossil-based commodity.

emerging markets (BloombergNEF, 2022). This reflects Chile's ongoing commitment to sustainability and its ability to attract clean energy investments.

This approach's demonstration can be seen in the growth of the unconventional renewable energy segment. In terms of installed capacity, this segment takes the first spot, followed by thermal generation (which includes coal, natural gas, and diesel). Highlighting the 14.8 GW already installed, 7.2 GW under construction, and 12.9 GW undergoing evaluation by the Environmental Assessment System (Ministerio de Energía, 2023). Furthermore, in terms of exports, it is projected that Chile could generate exports totaling around $30 billion annually by the year 2050 (World Bank, 2023).

In summary, Chile is assuming a central role in the global green hydrogen revolution. Leveraging its natural resources and proactive governmental direction, the country is on the path not only to becoming a leader in green hydrogen and its derivatives production but also to establishing a benchmark in terms of cost competitiveness (IRENA, 2022). The National Green Hydrogen Strategy foresees that GH2 produced in the Atacama Desert and the Magallanes Region will have the lowest levelized production cost in the world by 2030. These initiatives not only benefit the country economically but also significantly contribute to the global fight against climate change and the transition to a more sustainable energy future.

2 Green Hydrogen in Chile: Policies and Regulation

The energy transition is one of the Government’s priorities. To achieve this objective, it has incorporated policies and regulations to promote the development of this technology based on international standards, which in turn contribute to the reduction of obstacles and barriers to investment.

2.1 Regulatory framework, strategies and policies on green hydrogen and its derivatives.

The hierarchical structure of regulations in Chile follows a descending order of importance. From top to bottom, we find the National Constitution, laws approved by the National Congress, decrees and regulations issued by various government bodies and ministries, resolutions and administrative provisions issued by administrative and regulatory authorities, and strategies and action plans. For more information on this topic, refer to Annex 8.1.

A review of the main regulatory instruments involved in the hydrogen sector is included in the table below. For more information, refer to Annex 8.2.

Table 2-1: Description of the main regulatory framework regarding GH2 in Chile

Type of regulation	Name	Description
Ordinary Laws	**Law 21.305 - Energy Efficiency Law** (Ley de Eficiencia Energética)	This law defines hydrogen as a fuel and gives the Ministry of Energy the competencies to include developing and regulating green hydrogen and hydrogen derivatives within its activities and tasks.
	Law 21.455 - Climate Change Framework (Ley Marco de Cambio Climático)	This document sets specific targets in the areas of energy, mining, and transport that include the development of green hydrogen.
	Law 21.505 – Promotion for energy storage and electromobility	This law establishes definitions aiming at minimizing the systemic costs for GH2 producers when withdrawing electricity from the system.
Strategies	**National Electromobility Strategy** (Estrategia Nacional de Electromovilidad)	This strategy promotes the development of pilot projects for green hydrogen vehicles in freight and passenger transport, logistics operations, intercity buses, and mining machinery.

Type of regulation	Name	Description
	Long Term Energy Strategy (Planificación Energética de Largo Plazo)	Its preliminary report includes the generation and use of green hydrogen as one of the technologies to achieve carbon neutrality by 2050
	National Green Hydrogen Strategy (Estrategia Nacional de Hidrógeno Verde)	This strategy proposes funding to leverage green hydrogen projects in their start-up phase, develop public-private coordination to boost the industry, and generate regulation and standards that encourage investment and facilitate operating authorizations.
Action Plans	**Green Hydrogen Action Plan 2023- 2030** (Plan de Acción de Hidrógeno Verde 2023- 2030)	The plan seeks to review the current regulation on green hydrogen, financial facilities for the different stages of development, the inclusion of this type of project in the Environmental Impact Assessment System (SEIA), capacity strengthening of local governments on the subject, and a national plan to promote the production of green hydrogen in fiscal territory.
Others	**Chile's National Determined Contribution** (NDC)	It sets out as measures for carbon neutrality in 2050 that 71% of freight transport, 12% of motorized uses in industry and mining, and 7% of thermal use in households and 2% in industry should use hydrogen.

Source: own elaboration

2.2 Green hydrogen certification

The certification of green hydrogen has become an essential point for both buyers and consumers, as it not only guarantees the origin and quality of the product, but also contributes to the fulfillment of climate objectives, fosters competitiveness in global markets, and promotes the adaptation of more sustainable practices in the production and use of green hydrogen.

Currently, there is no specific certification method to quantify GH2 emission reduction or sustainable attribute. However, adopting international certification schemes has been closely monitored by the Government and industry, such as CertifHy or The Green Hydrogen Standard. For more information on the schemes, refer to Annex 8.3.

It is clear that one of the biggest challenges of green hydrogen certification is the need to reach an international consensus on quality standards and certification procedures. For this, the adoption of an existing scheme would be beneficial for Chile to secure its participation in an international market.

Additional initiatives for GH2 reduction emission certification are The Hydrogen for Net Zero Initiative, which in collaboration with South Pole, are working in providing a standardized methodology for hydrogen projects, as no certified methodology has been developed for this technology to date.

3 Review of the Chilean market

3.1 The market for hydrogen in Chile before GH2

Currently in Chile, the process of hydrogen production is largely in the hands of specialized companies engaged in the production of industrial gases. These companies play a fundamental role in meeting the domestic demand for hydrogen, which is used in a variety of applications across different industries in the country.

One of the most significant sectors in which hydrogen plays a crucial role is the fuel and refining industry. Hydrogen is employed in essential processes such as hydroprocessing, hydrocracking, and desulfurization. These procedures are critical for refining fuels and ensuring they meet quality standards and environmental regulations. In Chile there are 2 refineries that uses hydrogen as a feedstock, Refinería Bio-Bío and Refinería Aconcagua, both owned by the National Petroleum Company (ENAP).

Furthermore, in the food industry, hydrogen has an important role in the production of oils and margarines. Its use in these processes contributes to the production of high-quality processed foods that meet market needs.

In the glass industry, hydrogen also plays a vital role. It is used to protect the molten tin bath in the float glass process, which is essential for producing flat and high-quality glass. Additionally, it is used for surface polishing and edge burning in glass products, enhancing their final finish. In Chile, Vidrios Lirquén, owned by Indura S.A., is the only one performing these operations.

Another crucial use of hydrogen is in power generation. In this context, it is employed as a coolant in generators. Hydrogen's efficient heat transfer capability makes it a valuable option for maintaining generator temperatures under control, which is essential for the safe and efficient operation of power generation plants.

On the production side, there are only two companies that produces GH2 through electrolysis, Linde Gas Chile S.A., Hidrógenos Bio Bio S.A., Indura, and Methanex:

- Linde Gas Chile S.A.: hydrogen produced through steam methane reforming (SMR)[4] and built for the Aconcagua refinery.
- Hidrógenos del Biobío S.A.: hydrogen produced through steam methane reforming (SMR)[5] and built for the Bio Bio refinery.
- Indura (Grupo AIR PRODUCTS): hydrogen produced through electrolysis (without renewable energy sources) for glass application and retail.
- Methanex: does not produce hydrogen but methanol, and it can be considered a competition for GH2.

It is important to mention that Chile does not have natural gas resources, so grey hydrogen is not competitive as other countries with low natural gas costs, so GH2 will not compete with grey hydrogen applications unless there are previous agreements for grey hydrogen provision (as for example at refineries and glass industries).

3.2 Project developments for GH2 supply

Due to the attractive renewable energy potential present in several of the country's regions, many projects have been brought forward for the implementation of production plants for green hydrogen or related biproducts for a variety

[4] SMR is the traditional process for grey hydrogen production based on natural gas.

[5] SMR is the traditional process for grey hydrogen production based on natural gas.

of applications that seek to reduce GHG emissions. Most projects are in the early stages of development, carrying out pre-feasibility and feasibility studies for their pilot and complete phase stages. The projects currently announced have complex societal structures, where each investor is expert in one part of the product's value chain, and help de-risk that fraction.

In particular, the funding call led by CORFO[6], have brought forth great attention for future project developers. The projects presented in that call were comparable in size with currently available worldwide green hydrogen production projects, positioning the country as the first of the South American region in green hydrogen development[7].

Among the recent challenges faced by the initiatives selected by CORFO are: the pause of the Faro del Sur project, which retired its environmental impact study, declaring that the evaluation exceeded the habitual standards; and the Quintero Bay project lack of demand, which compromises the profitability of the project, and may jeopardize its implementation (Reporte Minero, 2022). More information related to the projects awarded to CORFO's call can be found in Annex 8.4.

In addition to these projects, there is a long list of projects under development related to green hydrogen production. These projects are mainly announcements of development from different utilities, and some of them are in more advanced phase of development. Table 8-2:5 shows current projects and their specifications in greater detail.

In the following figure, the geographical layout of all projects announced with total investment by region is shown. It is worth noting that the projects shown correspond to those for the year 2021 and that, to date, several other projects have been announced.

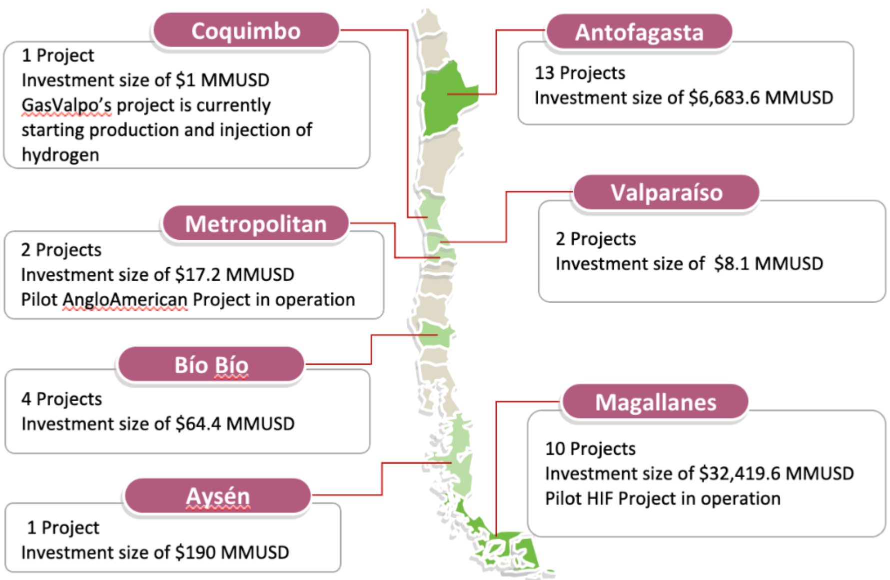


Figure 3-1: Map of hydrogen projects and investment
Source: own elaboration based on (CORFO, 2021a) (Switzerland Global Enterprise, 2022)

[6] Corfo is the Chilean Government agency under the Ministry of Economy, Development and Tourism in charge of supporting entrepreneurship, innovation and competitiveness in the country. For more information visit https://www.corfo.cl/sites/cpp/homecorfo
[7] These projects have to still face several challenges like passing environmental impact evaluations and finding markets with enough demand for the sale of green hydrogen related products.

As can be observed, most announced projects are being developed in the regions of Antofagasta (17% of the projects) and Magallanes (82% of the projects). This is due to the high quality and abundance of renewable energy sources, particularly solar and wind energy respectively.

Every project previously mapped was categorized by their announced target market and its development stage. It is important to note that these do not represent the effective number of projects, only their declared applications. For example, one project may have 4 sectors in mind for their business model, which does not mean that there are 4 projects, only 4 sectors for the application of said project.

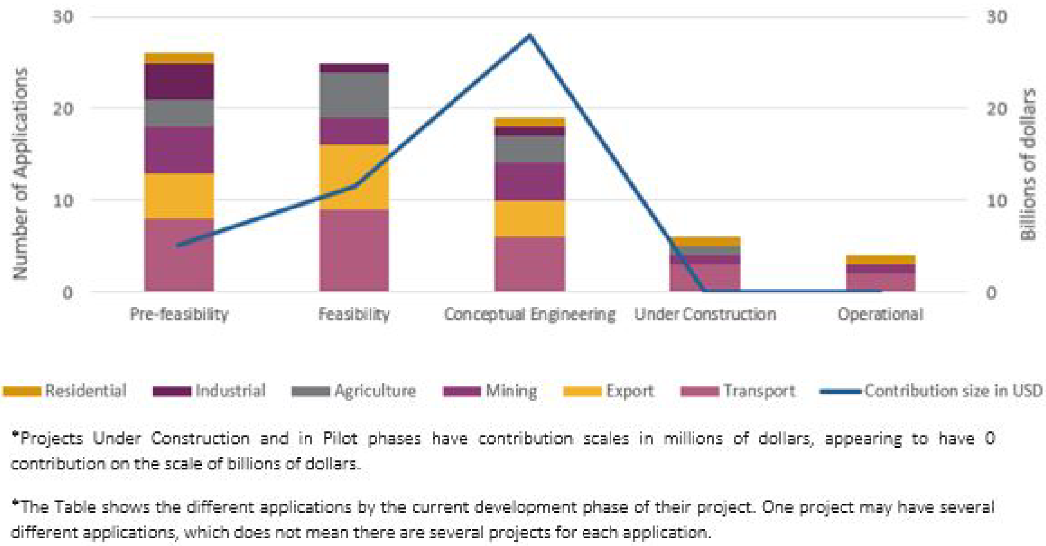


Figure 3-2: Number of Announced Projects and Investment size by Development Stage
Source: own elaboration based on (CORFO, 2021a) (Switzerland Global Enterprise, 2022)

By listing the previously mentioned projects over their announced sectors for hydrogen use, we can see the most relevant sectors for current GH2 development are: **Transport, Export, Mining**, and **Agriculture**. Additionally, the results show that the greatest number of projects are currently in their **pre-feasibility** stage.

3.3 Key sectors for domestic GH2 demand

The National Hydrogen Strategy lays the ground floor for the country's ambitions for GH2, declaring it as part of the country's energy transition, seeking to replace fossil fuel consumption in the mining, transportation, and agricultural sectors through different products and projects that are expected to increase their demand as shown in Figure 3-3 (Gobierno de Chile, 2020a).

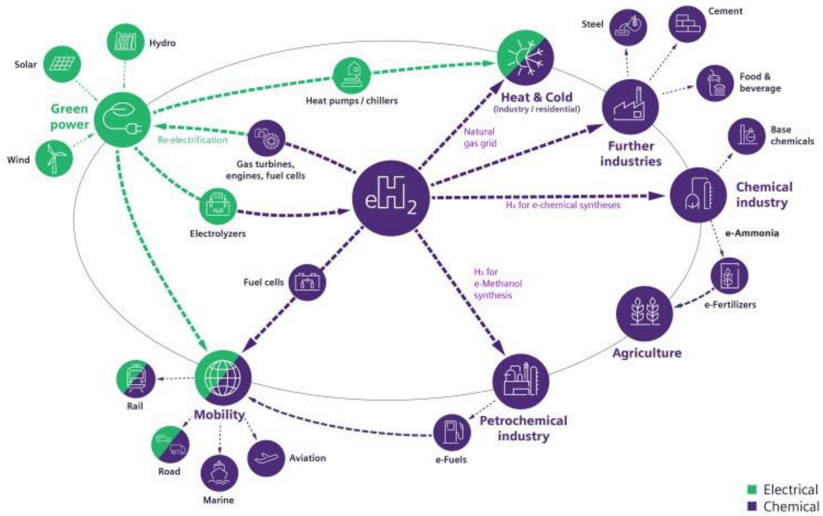


Figure 3-3: Green hydrogen applications
Source: (Siemens Energy, 2021)

Each application would face its own challenges, and should be assessed based on its **potential demand**, the **readiness level** of the technology, if it **competes with other low-carbon technologies**, **cost effectiveness**, and **feedstocks restrictions**. The main applications based on the Green Hydrogen Strategy, and the recent announcement of project developed can be wrapped up in the following table. Table 3-1 provides 10 applications of GH2, selected according to recent project development trends and the Government priority areas for GH2 development. For each application, a description is provided along with its weaknesses and strengths based on technology development, cost challenges, feedstock requirements and mitigation potential of the application.

Application	Description	Strengths	Weaknesses	Market size[8] (ton GH2)
Hauling trucks for mining	In Chile, the main economic activity is mining, and emissions from mining trucks fueled with diesel are responsible for 40% of the industry's emissions. Trucks and machinery in mining operations have a market potential of 600,000 tons of H2 in Chile. Hydrogen applications in mining haul trucks will compete with batteries or catenaries applications, which are being studied and deployed in other countries.	Big urgency for the mining sector, and high abatement potential. This industry is mainly concentrated in the Atacama Desert, a zone with the highest solar radiation worldwide. Corfo has developed a technological program seeking to create a technological consortium to adapt and develop technological solutions for the transformation of the conventional diesel-based operation of trucks in mining operations.	Very low Technology Readiness for Hauling Trucks and Refueling Stations (high compression levels are required). There are some pilots implemented, but no solution provider from OEM provides the solution with guarantees and aftersales services (such as maintenance, or others). Additionally, GH2 solutions compete with electricity-based solutions, which are a more suitable solution for the short term (such as batteries or catenaries).	594,755
Long-distance transportation	This application considers using GH2 for transportation in buses or trucks[9]. This can be applied using fuel cells to produce electricity and power an electric engine, or it can be used directly in a combustion process to produce movement at an internal combustion engine (ICE), releasing water as a by-product.	High maturity on technology (most applications have a commercial providers), but prices are still high in comparison to electric or fossil fuel technologies. GH2 solutions should be a suitable solution for heavy-duty applications.	Economy of scale for competitive GH2 trucks or buses has not been reached, and infrastructure to run a hydrogen-based transportation system is needed (refueling stations). These solutions will compete directly with battery solutions, which is the main low carbon solution for several transportation sectors (such as lightweight vehicles, or public transportation). In Chile, at least for public transportation, high penetration of battery-based electric buses is being used.	381,518
Ammonia production	Ammonia is the most-produced synthetic chemical in the world. Ammonia can be used as an energy carrier (export), as a fertilizer, and for the production of explosives.	Chile is an importer of fertilizers, so there is a market available. High Technology Readiness (Haber-Bosch process for ammonia production is completely deployed and developed). Since it is a common chemical, storage, utilization and production is already regulated in Chile. Several companies have announced ammonia projects in the north and south of Chile. The target markets are for export and explosives production, such as the Austrian Energy and the Enaex & Engie projects.	Production of green fertilizers (refined product from ammonia) faces the same barriers as methanol applications, which needs the incorporation of CCS systems for the production of urea and other fertilizers.	83,933
Methanol production	Methanol is a versatile compound in the chemical industry, used to produce formaldehyde, acetic acid, and can be used as fuel, or to produce derived synthetic fuels. Also, can be used as an energy carrier for export.	Very versatile, and there is an existing market already. High Technology Readiness. There is experience in Chile producing methanol (Methanex in the south), and a pilot project to produce it from renewable sources (HIF).	Low-carbon methanol is very expensive compared to its current commodity price (it could cost 5 times the current spot price). Carbon Capture & Usage (CCU) technologies are needed for its production. Unavoidable sources[10] are very difficult to find in Chile, and cost for CCU technology is very high (low TRL).	296,849
Synthetic fuel production	Liquid fuels that differ from conventional fuels (diesel, gasoline, kerosene) in both the production process and the replacement of crude oil as a raw material source. These fuels have similar properties and composition to conventional petroleum-based fuels, so they can directly replace fosil-base fuels in common combustion engines. Also can be used as an energy carrier for export.	Can be distributed via the existing infrastructure as well as facilitate their market introduction. There is a high demand and an existing market for these products.	High cost compared to their fosil-fuel option. Carbon Capture & Usage (CCU) technologies are needed for its production. Unavoidable sources are very difficult to find in Chile, and cost for CCU technology is very high (low TRL).	Not identified

[8] Reference according to (Comité Solar e Innovación Energética , 2020)
[9] Train applications are not being dicussed since in Chile train developments are not being considered for transportation expansión.
[10] Sources considered as unavoidable are: Energy generation, cement, food industry, wood industry, and paper and cellulose industry (GIZ, Análisis de la captura de carbono para la producción de combustibles sintéticos en Chile, 2021).

Application	Description	Strengths	Weaknesses	Market size[8] (ton GH2)
Cement	Hydrogen could be used in furnaces replacing fossil fuels, thus avoiding CO2 emissions.	There is an industry in the country and potential demand for GH2 in this application.	Low Technology Readiness for GH2 burner in cement furnaces. There are concerns regarding the fuel replacement being secure and not compromising the final product (test and research is needed). High costs compared to baseline.	Not identified
Refineries	Hydrogen is used in refineries to decrease the sulfur content of the crude oil and fuels. The process, known as hydrocracking, breaks the heavy molecules into lighter components such as gasoline and diesel.	There is an existing demand and application for the product in Chile[11].	Demand for GH2 for this application is low. Also abatement potential is the lowest among the selected applications.	51,057
Stationary applications (electricity generation)	Stationary applications are those in which heat or electricity is generated in a specific location for primary power. Using fuel cells or dual applications (hydrogen and diesel combustion for example) are some examples of this application.	Diesel engines for backup electricity generation are overly installed in the country, and there is an opportunity to replace that diesel using a fraction of GH2. Curtailment of renewable energy is a common situation in the north of Chile, which could be stored as GH2 and injected back to the grid using fuel cells.	For dual generation with diesel, Technology Readiness is low and no company offers reliable conversion services. For fuel cell applications, service is expensive and not competitive, and overall efficiency is low. Currently this market is being taken by BESS systems.	329,313
Natural gas blending	Blending of GH2 into natural gas pipelines and applications is feasible. In this case, emissions are avoided through natural gas replacement.	There is an existing demand and infrastructure for GH2 usage. But the demand volume is low. There are operating projects for natural gas blending in Chile.	In occupying existing gas networks, the difficulty of possible cracks and leaks is presented. For blending with low concentrations in volume (10-15%), the solution does not present major risks.	Not identified
Forklifts	The use of forklift has been quite widespread, especially for retail operations. New technologies based on natural gas, batteries and GH2 are solutions for low carbon emission technologies.	High TRL, price competitive and there are applications in the world, and the announcement of a project in Chile led by Walmart. Additionally, in comparison with battery operated models, using H2 fuel cells allows a constant energy output without the need to charge the batteries (Linde, n.d.). Studies also show a lower total cost of ownership (TCO) for fuel cells than electric batteries and diesel internal combustion by 2050 (Rout, Li, Dupont, & Wadud, 2022).	These solutions will compete directly with battery solutions, but GH2 has proven to be a better option for this application.	12,838

Table 3-1: Description of the main applications regarding GH2 in Chile
Source: own elaboration

According to the previous table, the applications with the highest mitigation potential (in case GH2 is adopted entirely) are mining, long-distance applications, and stationary applications. Unfortunately, those 3 sectors compete directly with electrification as an alternative low-carbon solution.

In conclusion, there is not a market consensus in terms of which application will be an early adopter of GH2. Still, suitable sectors for utility scale project implementation (mainly considering its market volume and investment opportunity) are:

- **Mining:** due to its high climate ambition, high demand potential, and suitable location for GH2 production (most mining operations are located in the north of Chile, having a great solar power potential).
- **Export** (ammonia and synthetic fuel projects)**:** specifically for ammonia since it does not have a feedstock challenge (such as CO2 capturing for synthetic fuels production). Ammonia also has synergies with the fertilizers sector, making it a typology suitable for utility scale investment. Location near to ports would be

[11] There are 2 companies in Chile that have a hydrogen production plant for refineries. The first one is Linde Gas, a German company, that provides to the Aconcagua refinery, owned by the National Petroleum Company, ENAP. The second company is Hidrógeno Biobío S.A. (CHBB), owner of a high purity hydrogen production plant, intended exclusively to supply the Biobío Refinery of ENAP.

required, and so shared infrastructure (such as ports conditioned for ammonia exportation, or desalinated water).

- **Industry**: specifically for heat applications (were GH2 could be mixed with other fuels), and steel (where there is an initiative running from the only integrated steel plant, Siderurgica Huachipato).

Regarding export applications, enabling and shared infrastructure will be required. This infrastructure will depend on the carrier that will be selected for that specific port (which could be liquified GH2, methanol, ammonia or liquid organic hydrogen carriers). For this purpose, renovation or construction of pipelines, storage tanks, and conversion facilities will be needed. Infrastructure for the aforementioned carriers is highly developed, and no technological risk is identified (Peggy Shu-Ling Chen, et al., 2022).

In this regard, investment opportunities are concentrated in:

- **San Antonio port** is identified as one of the 20 early GH2 ports worldwide (Peggy Shu-Ling Chen, et al., 2022). Additionally, there are ongoing GH2 initiatives in the facility for early adoption of this fuel[12].
- **Mejillones port** is located in the Antofagasta region, a GH2 hub in Chile, and is one of the main ports in the north of Chile. Several GH2 projects have been announced close to the port, and there are initiatives also to accelerate its adaptation for GH2 exportation (such as an MoU signed with the port of Rotterdam[13]).
- **Magallanes region** is seen as a GH2 hub, and several mega-projects have been announced, among them the HIF project which will export synthetic fuels to Europe. The region has access to the coast, there are several ports operating, and a high opportunity for reconditioning. A new port was announced for the HNH GH2 project[14], and ENAP, the National Petroleum Company, owner of 3 ports in the region, is also evaluating investing in their reconditioning[15].

Other niche announcements (such as forklift applications) would be relevant for engaging in an early market, but the number of projects in those sectors will be limited to special cases in which the business model is competitive.

Now considering the reduction emission potential for these sectors, a mitigation potential analysis is provided. When exporting ammonia, it can be estimated that a Haber-Bosh facility that produces 30,000 metric tons of NH3 annually, with a total investment of 145 million USD will help mitigate roughly 73,600 metric tons of CO2 per year (Comité Solar e Innovación Energética , 2020). Therefore, the plant's ability to reduce emissions is approximately 508 metric tons of CO2 per million USD invested.

For industrial applications, substituting hydrogen for fossil fuels in furnaces can effectively decrease carbon emissions. To implement this initiative in a 20MW furnace, an investment of 80 million USD would be necessary (considering GH2 provision and modification of burners). By doing so, it is projected that approximately 32,200 tons of CO2 can be reduced annually (Comité Solar e Innovación Energética , 2020). This equals a potential mitigation of approximately 403 tons of CO2 for every million USD invested.

In a project of converting 30 hauling trucks in a mining operation, a total investment of US$363 million would be needed. A project this size is expected to mitigate approximately 106,600 tons of CO2 per year (Comité Solar e

[12] More information in: Port of San Antonio to develop green hydrogen plant for its operations
[13] More information in: Acuerdan potenciar la bahía de Mejillones para la industria del hidrógeno verde
[14] More information in: Empresa HNH Energy de Hidrógeno Verde construirá un megapuerto para exportación en Magallanes
[15] More information in: Chilena Enap podría adaptar puerto de Magallanes para apoyar economía del hidrógeno

Innovación Energética , 2020), which implies a mitigation potential of roughly 294 tons of CO_2 for every million USD invested.

Based on the cases presented, it can be inferred that the export industry holds the most significant potential for mitigation. Nevertheless, it is crucial to note that the specific projects analyzed in each sector will determine the extent of this potential. Technological advancements have led to the emergence of various green hydrogen initiatives, particularly in exports, mining, and industry, with promising potential for mitigation. This, in turn, encourages investment in such projects.

3.4 Insights from key producers of green hydrogen in Chile

As a part of this study's development, comprehensive interviews were conducted with a wide range of key stakeholders across the industry, academia, and investment sectors (for the list of stakeholders interviewed see Annex 9.11). These in-depth conversations provided a valuable and holistic insight into the landscape of green hydrogen, addressing essential matters such as the current market situation, existing regulations, permitting processes, and the supply chain in relation to projects associated with this technology.

Following, there are some of the key findings discussed and grouped by topic of interest. The information provided was complemented with external information and the consultant's experience.

3.4.1 Risks and uncertainties related to GH2 offer

- **Regulation and Permitting**

The interviews underscored the importance of having a clear and predictable regulatory framework to foster investment and the development of green hydrogen projects. Current regulatory challenges revolve around the multitude of permits required for project implementation, which in some cases, it can exceed over 90 permits, and extend the process up to 7 years (measurements for environmental variables, prefeasibility studies, submission of environmental and sectorial studies, and approval of environmental permissions).

These projects, depending on their complexity and characteristics, must be submitted under the Environmental Impact Assessment System (SEIA), which would concede its Environmental Resolution (RCA). In the process, the SEIA could delay the approval of the project if the minimum requirements are not met (this requirement could change over the time, or geographically). It could take between 1 to 3 years for the approval of an Environmental Assessment Study-EIA. Depending on the size and configuration of a project, these terms may vary. For example, Haru Oni obtained an RCA for its pilot project in a 6-month period after the presentation of its Environmental Assessment Declaration-DIA. Another benchmark is that obtaining a marine permit requires a baseline sampling of at least two years before its presentation to the SEIA (IADB, 2022).

In spite of these challenges, the Government is addressing these issues through the creation of a specialized permitting agency, the establishment of deadlines for processing, and the assessment of implementing expedited procedures.

- **Supply Chain**

Interviewees highlighted the critical importance of ensuring a constant and reliable supply of essential equipment for green hydrogen production, including electrolyzers. There is growing concern about the shortage risk of the provision of electrolyzers for the short and medium term due to the high demand.

At the end of 2021, the installed capacity of electrolyzers globally reached 0.5 GW (International Energy Agency, 2022). This figure is insufficient to meet the projected green hydrogen production targets, so several experts have conducted numerous studies and projections to quantify the needed installed capacity to produce green hydrogen (See Annex 8.7). It is concluded that the development in the electrolyzer production industry would be sufficient to meet the estimated demand. In addition, no electrolyzer supplier is established in Chile, so maintenance or other services linked to the OEM are difficulted.

According to the IEA, a capacity of 134 to 240 GW of electrolysis capacity would be needed by the year 2030, where the current construction rate is approximately 8 GW per year, representing a great challenge for OEM. Still, by the year 2025, it is expected that the production capacity of electrolyzers will triple, reaching 20 GW per year (Wappler, et al., 2022) and it is projected to increase eightfold by 2030, reaching 60 GW per year. A similar analysis of the manufacturer's projections was conducted by EY (See Annex 8.8) (EY Parthenon, 2023). This substantial development in the electrolyzer production industry would be sufficient to meet the estimated demand. Additional to this, it is worth mentioning that no electrolyzer manufacturer is established in Chile, so maintenance or other services linked to the OEM are difficulted.

In this line, the CORFO Green Hydrogen Committee, in collaboration with InvestChile[16] and multiple public and private actors, led a call to develop electrolyzer manufacturing projects in Chile (Pizzoleo, 2023). Nine Expressions of Interest (EOI) to carry out electrolyzer manufacturing projects in the country were received. Six of these EOI propose the installation of electrolyzer manufacturing plants with an annual capacity ranging from 0.5GW to 1GW, with estimated investments ranging from USD 50 to 100 million.

Companies from Spain, Belgium, Italy, the United States and China responded to the process, allowing information to be gathered regarding the enabling conditions that would be necessary to make the investments feasible in the country. All of this is framed with the purpose of promoting a production in Chile with participation of the local industry. Further research on this topic shows that the main suppliers of electrolyzers are the following ones for each type of electrolyzer[17].

Table 3-2:1 World's leading manufacturers of electrolyzers

Company	Country	Alkaline Electrolyzer	PEM Electrolyzer
McPhy	France	✓	
Air Liquide	France		✓
Siemens Energy	Germany		✓
Cummins	United States	✓	
ITM Power	England		✓
Nel Hydrogen	Norway	✓	✓
Sunfire	Germany	✓	
Teledyne Energy Systems	United States	✓	
TianJin Mainland Hydrogen Equipment Co. Ltd.	China	✓	
Plug Power	United States		✓
Elogen	France		✓
Asahi Kasei	Japan	✓	
H-TEC Systems	Germany		✓

[16] Chilean public agency that promotes foreign investment in the country. For more information visit https://www.investchile.gob.cl/es/
[17] More information regarding electrolizers producers can be found in the Anexes.

Company	Country	Alkaline Electrolyzer	PEM Electrolyzer
Green Hydrogen Systems	Italy	✓	✓
ThyssenKrupp	Germany	✓	

Source: (CIC energiGUNE, 2022)

- **Environmental Challenges**

Among the environmental challenges addressed in the interviews, concerns arose regarding the impact on bird migration routes, especially in wind power projects in the Magallanes region where there are migration routes for protected species. This is not only a problem for GH2 projects but specifically for wind generation projects, where the environmental entity has become more extract over the years, hindering the environmental resolutions obtaining of these projects. This has translated into difficulties for large-scale projects in obtaining their environmental approval (such as the Faro del Sur project, from Enel and HIF), and other projects under development.

Regarding water usage and the current drought situation in the central and northern regions of Chile, it was mentioned that the sector is not concerned of this topic since water from desalination processes is being considered for most of the projects. This is a possibility for shared infrastructure development, where desalinization plants could be used by more than one company, or it could be used to provide drinkable water for cities and communities. As an insight, currently 20 desalinization plants are in operation sourcing 3 m3/s mainly to the mining sector, and another 17 have been announced for the present decade to supply 12 m3/s or 50% of the water demand by 2030.

On the other hand, the water footprint of GH2 production is not identified as a problem since even if water consumption is intense, it is not comparable with other industries. As for example, if all of the heavy-duty mining fleet (hauling truck) were running 100% on hydrogen, demanding 600 kt of GH2, this would require a flow of 0,3 m3/s of water, equivalent to 1% of the mining water demand by 2030.

The electrolysis process requires a low amount of water consumption, but at the same time high quality water supply, as specified in Chapter 3.4. That's why purer sources of water are more appropriate to generate GH2 than more polluted ones, such as wastewater, where treatment will be required before use (International Energy Agency, 2016).

In terms of the alternative sources of a low-carbon hydrogen, we can explain the following:

- Generating hydrogen from biogas does not capture any competitive opportunity for Chile, which are their renewable resources. Currently, biomass is seen as an opportunity for electricity generation, and could be used for H2 generation on smaller scale, so it is not seen as an opportunity for the country. Moreover, an economic study concludes that there are no viable-sized plants capable of producing hydrogen at the target price of USD 3/kg or less (Swartbooi, Kapanji-Kakoma, & Musyoka, 2022). As a result, this option is not currently competitive in the hydrogen market.
- New alternative sources of "natural H2" can become a promising supply of low carbon hydrogen. However, on one hand these are still in a very immature stage of development, which implies significant uncertainties for investment. On the other hand, natural hydrogen deposits have only been discovered in Africa (Prinzhofer, Tahara, & Boubacar, 2018). In Chile, at the moment, research regarding H2 production by using geothermal energy has been made, but no H2 natural deposits have been found.

As a bottom line, Chile is seen as a good GH2 competitor for its renewable potential, so other H2 sources are unlikely to give Chile an advantage in a domestic or international market.

3.4.2 Risks and uncertainties relating to demand

- **Export Market Challenges**

As seen in the current GH2 portfolio in Chile, the most mature and attractive projects are the ones related to and export market. This is due to the scale of the demand and a more mature off-taker willing to transition from traditional energy sources to cleaner ones.

During the interviews, an emerging concern regards the swift progress of other countries in relation to GH2 production, pushed mainly through fiscal advantages implemented from their governments. One example is the Inflation Reduction Act (IRA), which provides USD $3 in tax credits per kilogram of green hydrogen produced, creating unbalanced market conditions favoring green hydrogen production in other countries.

A common topic in all interviews is the importance of financial incentives from the state to make the green hydrogen industry feasible. A reduction in the land cost or a deduction in loan rates were given as examples. Right now, the only evidence of incentives in the market is Law 21.505 (described in the Regulatory Framework Chapter) which would reduce systemic costs for GH2 production assets.

4 Cost analysis and breakdown of producing green hydrogen.

In this section of the report, a thorough assessment of the costs involved in the production of green hydrogen across different time frames and geographical regions within Chile will be performed. This analysis will focus on identifying how variations in costs, particularly those related to vital components of the process (such as the electrolyzer), can impact the feasibility and overall economics of the project and an analysis of the mitigation potential for the sectors of interest suggested in this report.

A Levelized Cost of Hydrogen (LCOH) will be analyzed. This methodology estimates the minimum average cost per kilogram of hydrogen over the project's lifespan. The evaluation will consider geographical factors, generation configuration used, and cost projections of the main infrastructure used for the process (mainly electricity generation and electrolyzer CAPEX). This will provide a comprehensive understanding of the costs involved in the project, and the competitivity of the GH2 produced in Chile for current and future markets.

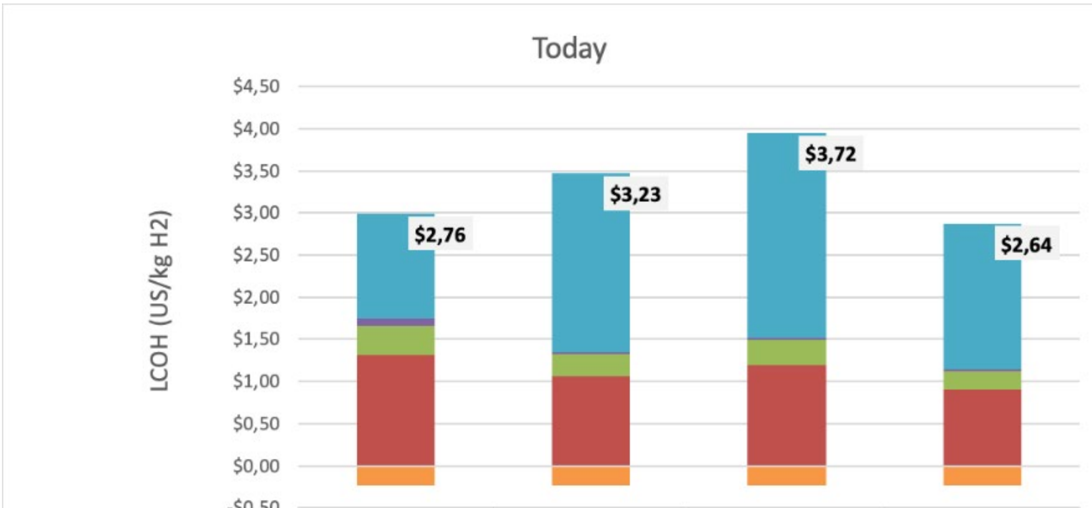
The main assumptions are:

- **Geographical Location**: The model is configured to incorporate production costs based on geographical location, defined as North, Central, South, and Patagonia. The model will incorporate different capacity factors for renewable resources associated with these regions.
- **Electric Generation Technology**: The model considers the optimal mix of solar and wind configuration to supply 1 MW of electrolyzer depending on the capacity factor of the region.
- **GH2 Production Configuration**: The model assumes that GH2 is produced in the same location as where the electricity is generated. This assumption is considered since consuming electricity from the grid makes the projects not competitive since systemic costs are relevant in comparison to electricity price (transport, distribution, public services, etc).

- **Equipment and Electrolyzers**: The model has been designed to consider the costs associated with the equipment required for green hydrogen production. In particular, it focuses on the cost and operation of electrolyzers and renewable technology. Factors such as initial acquisition costs, operation and maintenance costs throughout the project's lifespan, as well as replacement and technological upgrade costs over time, are considered.

The price of the electrolyzer considered was 1025 USD/kg for "today's" scenario, 440 USD/kg for 2030 scenario, and 269 USD/kg for the long term (International Energy Agency, 2022). For the cost of water, a value of 1,4 USD/m^3 was assumed (GIZ, 2018), and for the north of Chile an overcost of 5 USD/m^3 was assumed. These values are very conservatives in comparison with the national reality, and there is evidence of water cost from desalinated water under 1 USD/m^3 for several operations in Chile[18].

In the following figures, the cost breakdown of the LCOH is shown. In this cost structure, prices for oxygen sales, electricity supply, water supply, OPEX, CAPEX are considered for each region for the "today" scenario. According to this cost structure, the energy technology represents the highest share for LCOH, followed by the electrolyzer's CAPEX.



	North	Central	South	Pat. Chile
Oxigen sales	-0,23	-0,23	-0,23	-0,23
Electricity supply	1,25	2,11	2,43	1,73
Water supply	0,08	0,02	0,02	0,02
OPEX electrolyzer	0,34	0,27	0,30	0,22
CAPEX electrolyzer	1,32	1,06	1,19	0,90
LCOH production (US/kgH2)	2,76	3,23	3,72	2,64

Figure 4-1: Breakdown of LCOH costs for today.
Source: own elaboration.

Sensitivity analysis shows that the most relevant components of production costs for GH2 are electrolyzer capacity factor (CF Ez), cost of electricity, and electrolyzer's investment cost (CAPEX Ez).

[18] For more information: La desalación toma fuerza en el norte, aunque aún es costosa para la RM

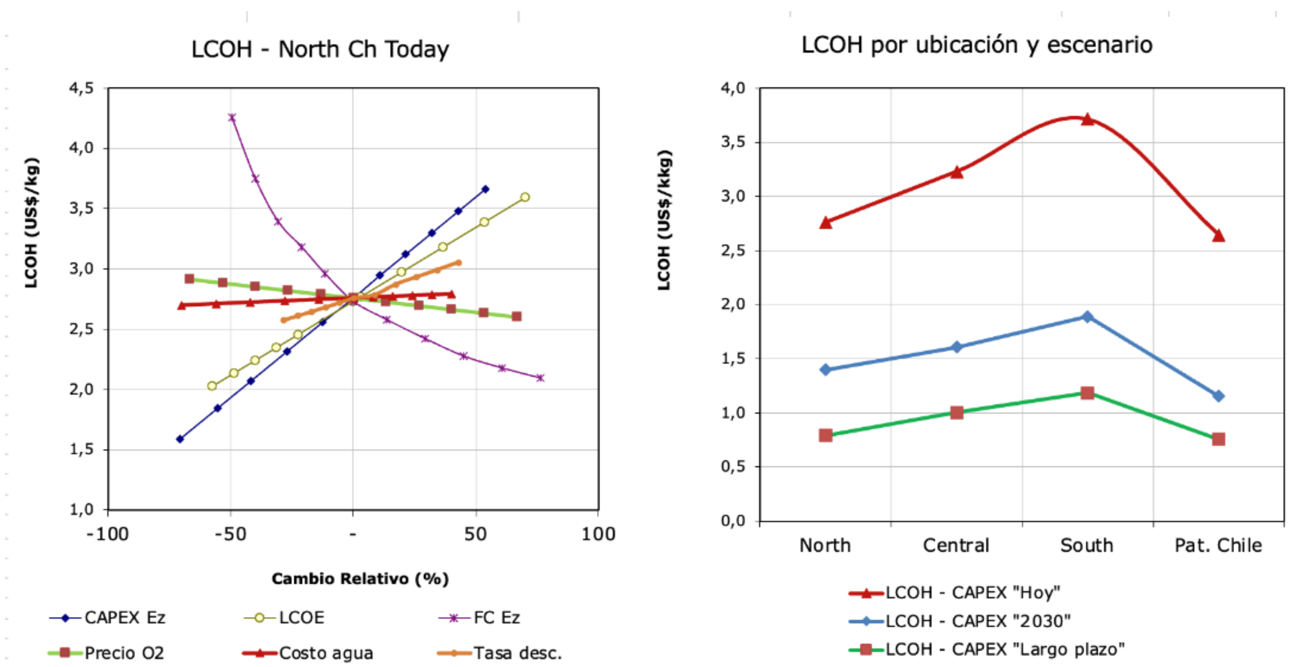


Figure 4-2: GH2 production scenarios.
Source: own elaboration.

Furthermore, the LCOH projections for each geographical location suggest that the lowest LCOH costs are found in the northern zone and Chilean Patagonia, which is coherent with the investment decision making of early GH2 developers.

From the graphs presented, it is essential to highlight that for 2030, green hydrogen production prices in the northern zone and Chilean Patagonia are below 1.5 USD/kg, so the goal of the National Hydrogen Strategy would be reached for those regions of the country, and would achieve parity with grey hydrogen (considered to be 1.5 USD/kgH2). The central and southern zones are not far from that goal, so the country would become a good prospect for producing green hydrogen in the long term.

GH2 could also be compared to other commodity prices such as methanol and ammonia. In that case the analysis must incorporate the process of converting GH2 into these products. On the one hand, the current spot market price for methanol fluctuates between 227 and 500 USD/tonsMeOH, and it is estimated that for 2030 green methanol will cost 520 USD/tonsMeOH. On the other hand, the current spot price of ammonia fluctuates between 216 and 406 USD/tonsNH2, and it is expected that it will reach 475 USD/tonsNH3 in 2030. It is important to mention that both green commodities' current costs are close to 4-5 times the price of their spot market benchmark.

Annex 8.7 presents a table of the LCOE in the selected regions of Chile. As mentioned in the sensibility analysis, the cost of electricity is one of the main variables for setting LCOH. For today's scenario, combined LCOE's dispersion ranges from 23,50 USD/MWh (in the north) to 43,54 USD/MWh (in the south). These prices are coherent to the electricity market context according to recent public tender processes[19] and the consultant experience. In these cases, LCOH fluctuates between 2,76 USD/kgH2 (in the north) and 3,72 USD/kgH2 (for the south). Hence, a realistic cost for GH2 production in Chile should vary between that cost window.

[19] The average price offered in the last public electricity tender processes was 37,4 USD/MWh for 2022-1, and 23,78 USD/MWh for 2021-1, which fluctuated between 13,32 USD/MWh and 35 USD/MWh.

Now, for the final cost of GH2 delivered, storage and transport costs should also be considered. These costs will depend on the demand and case study, so for this exercise, only general guidelines can be provided. For transportation, GH2 could be transported through liquified GH2, compressed GH2, and converted as other energy vectors such as ammonia or liquid organic hydrogen carriers (LOHCs). According to the International Energy Agency (IEA), transportation over 1,500 km should be done by pipelines, and currently for distances under 300 km, compressed or liquified GH2 in trailer trucks is the best option (IEA, 2019).

The cost of dedicated truck transport is dependent on the amount of hydrogen transported and the kilometers of transport distance. It is possible to assume a cost of transportation equal to 0.12-0.13 USD/kg H2 for every 100 kilometers traveled in the case of liquified GH2 and ammonia, and 0.6 USD/kg H2 for every 100 kilometers traveled in the case of compressed green hydrogen (both at low and high pressure) (Gallardo et al, 2021). It should be noted that Chile is a very narrow country, and the maximum width is 360 kilometers. In that case, assuming 200 km transport from GH2 production site to an export port, cost of transport should be close to 0.26 USD/kg H2.

From that information, it is concluded that at today's cost of technology, green hydrogen sourced by solar in the north has the lowest levelized production costs, which are expected to be maintained throughout the years. However, GH2 sourced by the wind in Chilean Patagonia is expected to also have a similar low production cost in the long term. As for the central and southern regions, hybrid hydrogen production using combined wind and solar would be less competitive than dedicated solar or wind production in the regions already mentioned. Additionally, if the cost of electrolyzer is reduced over the years, the model suggest that Chile would achieve its goal to provide GH2 at a price lower than 1.5 USD/tonH2 by 2030, and at a price lower than 1 USD/tonH2 by 2050.

5 Funding Programs available for Green Hydrogen Projects in Chile

Funding programs play a key role in addressing the opportunities and challenges in the green hydrogen market. They not only open the door to accessing the capital needed for the development of critical areas such as research, infrastructure, and production capacity, but also play a crucial role in mitigating the financial risks inherent in this industry. In particular, by addressing upfront investment and the adoption of emerging technologies, funding programs help to reduce the financial burden and increase the economic viability of the industry.

5.1 Context of financing programs in Chile

Given the country's conditions, Chile has great potential to develop the green hydrogen industry in its territory. Therefore, various financial programs have been implemented nationally and internationally focused on designing and implementing pilot projects that generate transformational change and incentivize the country's green hydrogen industry.

Within this context, in 2018 Fundación Chile[20] launched the **CLIN Fund**, a private investment fund with a ten-year life horizon. This fund is focused on solving sustainability and productivity challenges in fields such as energy, water, mining, smart cities, big data, and Internet of Things (IoT), among others (Fundación Chile, 2018). Although the CLIN Fund was not designed specifically for the green hydrogen market, its focus on sustainability and innovation makes it a natural candidate to support projects that encourage the production and adoption of this clean and renewable energy source.

Following, in 2021, the first call to national and international companies interested in financing green hydrogen projects in Chile was performed. The **Green Hydrogen Fund from CORFO** had 50 MM USD to be assigned as grants, with a co-financing of 30 MM USD maximum per project to support new green hydrogen facilities in the country. Some of its requirements were that the project entails installing a nominal power of electrolyzers greater than or equal to 10 MW, that it will use 100% renewable energy, and that its operation occurs by December 2025 (CORFO, 2021b).

Complementary to CORFO's initiative, the Energy Sustainability Agency (Agencia de Sostenibilidad Energética, ASE) created in the same year the **Green Hydrogen Accelerator Program** (Programa Aceleradora de Hidrógeno Verde – AH2V), linked to the National Hydrogen Strategy (Estrategia Nacional de Hidrogeno). AH2V aimed to foster initiatives that would use GH2 as a feedstock and distributed 300 kUSD for the calls. These centered around three sectors; Logistics and Transportation; Industry; and Others. Among these sectors are considered electricity generation, use of engines, peak or backup turbines, and other small-scale applications that consume hydrogen and can be implemented in the short term.

During the 2021 call, the Program received 27 applications, of which ten projects were selected during Stage I of diagnosis phase and design support (technical, economic, and regulatory workspaces). Subsequently, in Stage II, two projects were selected to receive support in their implementation. During this version of the program, valuable lessons were learned, such as the high LCOH observed for these projects (Agencia de Sostenibilidad Energética, 2023).

With the knowledge acquired, the 2023 call sought to develop and implement projects with less than 500 kW of installed capacity of electrolyzers, focusing on local consumption with a degree of progress between pre-feasibility and feasibility. This call considered two stages with different technical bases. The first stage, associated with the co-

[20] Fundación Chile is a public and private organization seeking to boost transformation toward sustainable development in Chile, achieving alliances with more than 160 institutions in 25 countries throughout the years (Fundación Chile, n.d.)

financing of basic engineering, is already closed and the projects have been awarded, while the application for the second stage, based on co-financing for implementation, is not yet available.

Following the previous initiatives, H2Global Stiftung created the **H2Global** Instrument, which seeks to support existing efforts to comply with the GEI carbon neutrality goals of Germany and the European Union defined in the Paris Agreement, promoting the production and use of green hydrogen and its derivatives (PtX) globally. This is achieved through a market approach to overcome existing market failures such as lack of investment in production capacity and lack of availability of neutral energy sources (The H2Global instrument, n.d.).

Unlike the funds mentioned above, H2Global is not a financial instrument as such, but rather a mechanism that seeks to mitigate risks by managing long-term contracts for the supply and short-term contracts for the demand of green hydrogen from Germany with companies internationally (*Contract for Differences*). Therefore, this mechanism will apply to Chile if it is a country with competitive prices in the industry (The H2Global instrument, n.d.). The first tender was available from December 2022 to February 2023, and it was possible thanks to the input from the German Federal Ministry for Economic Affairs and Climate Action (BMWK) of 900 MM EUR (Jones, Dietz-Polte, & Thomson, 2022).

Lastly, in June 2023, the **Program to Support the Development of the Green Hydrogen Industry** in Chile was launched, whose general objective is to contribute to the development of the green hydrogen industry and its derivatives to help the decarbonization of the national economy, as well as the supply and demand of its products (Gobierno de Chile, 2023b). This arises from a loan made by the Inter-American Development Bank (IDB) to the Republic of Chile, for a total of 400 MMUSD where CORFO assumes the responsibility as executing agency.

As a summary, the following figure presents the different funds, programs, and financing instruments that have been implemented or will be implemented in the field of green hydrogen and that are or potentially can apply to Chile.

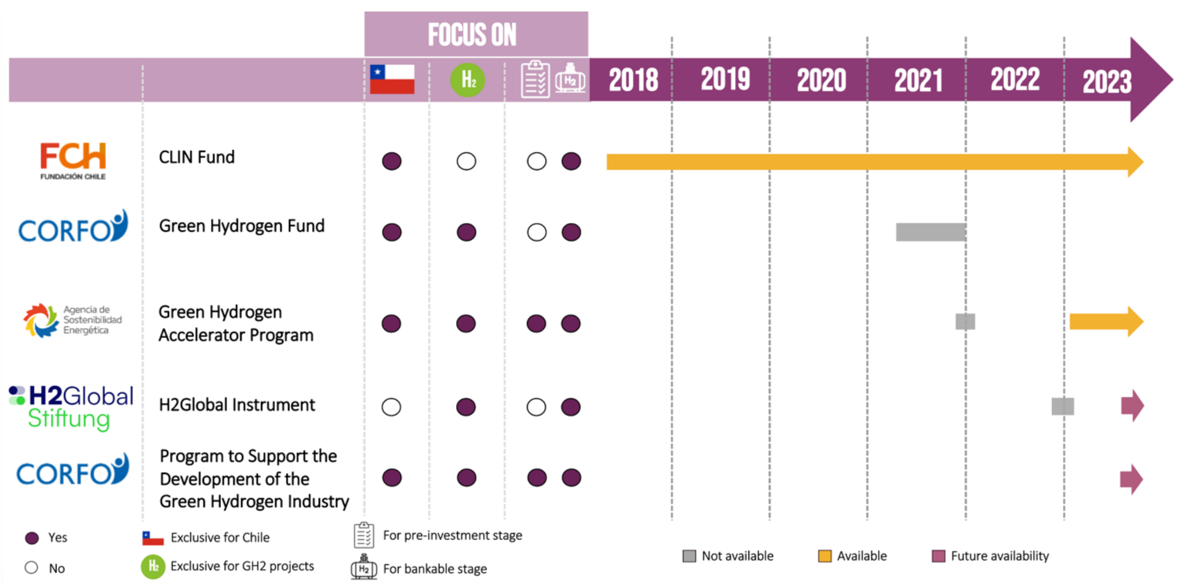


Figure 5-1: Context of green hydrogen project financing applicable to Chile. Source: own elaboration.

On the one hand, Chile is no longer eligible for donations (non-ODA country), so accessing to international financial instruments for GH2 development is very limited. However, the potential to develop this industry attracts new expectations for international collaboration. One of the most recent is the government of Chile signing a memorandum of understanding with the Japan Bank for International Cooperation to promote cooperation in sectors that use hydrogen and ammonia as a fuel source (CORFO, 2023). In addition, there are contributions from the IDB, World Bank, BMWK and EU to strengthen the Green Hydrogen Fund from CORFO Facility, which aims to develop local demand and generate production capacities by granting an amount of USD $1,000MM that so far has no further specification of its financing mechanisms.

Currently, financing sources are still very narrow, and no specific industry or application has stepped ahead for massive deployment. For this reason, tracking the industry's evolution would be necessary for the following years. Furthermore, it is worth mentioning that Chile has not been keen for grant assignments for technology deployment (something seen in the solar energy industry development). Still, for reducing LCOH, the Green Hydrogen Action Plan 2023- 2030 mentions implementing Tax Credit incentives for low cost GH2 production (Gobierno de Chile, 2023c). This Plan is still in the public consultation stage, but it demonstrates the Government's interest in developing this industry in the country.

6 Recommendations

Even if Chile has a great prospect for GH2 in comparison with other countries for participating in a global market, currently there is no consensus of which application would be the front runner to participate in the market. Even if there are several GH2 projects announced, the applications and industries are very diverse. To assess the opportunity for each application, some good criteria to consider are: potential demand, readiness level of the technology, competition with other low-carbon technologies, cost effectiveness, and feedstocks restrictions. These are good indicators to characterize a sector and understand if it's suitable for a short-term or a long-term engagement.

According to the previous criteria, it is recommended to track the development of the **mining industry**, new **export** project announcements (such as ammonia and synthetic fuel), and heat demand in the **industry** sector. To monitor and identify investment opportunities in the market, the following actions are proposed.

1. Focus the scoping efforts in the north of Chile

Even if there are two big GH2 valleys in Chile, one in the north (specifically the Antofagasta Region) and the second one in the south (Magallanes Region), GH2 projects in the south have faced several environmental and permit difficulties. The region has also several intrinsic challenges, such as land ownership (mainly property of privates), fauna (bird migration routes), and enabling infrastructures (lack of roads, ports and desalinization construction experience).

In comparison, the northern region is more experienced in developing infrastructure projects. The territory is mainly administrated by the National Assets Ministry (Ministerio de Bienes Nacionales), and in the long term, it should be even more competitive from a cost perspective than the south.

For these reasons, prioritizing projects in the north could help reduce investment risks and secure a well driven project development.

2. Engage with utility providers

Large scale projects with investment over 50 MMUSD will be mainly triggered by the export sector. For these projects, utility companies with presence in Chile will lead the renewable energy infrastructure development of the project, and in some cases, even the GH2 production process. Utility companies have participated in most of the large-scale projects announced, and they are foreseeing GH2 development projects due to the synergies with their core business[21].

This configuration has been evidenced in the recent project announcements, where these type configurations help to de-risk part of the value chain production of projects. The big four utility companies in Chile are: Enel (Italian), AES Andes (American), Engie (French), and Colbún (Chilean). Nevertheless, other utility companies with less market share are also scoping for GH2 projects in the country, such as AME (developer of the HIF project), EDF, and Statkraft.

3. Engage with mining industries

On a secondary level of priority, monitoring and engaging with mining companies could help to identify long-term investment opportunities with a high climate impact. As mentioned before, GH2 is not the only option to

[21] Synergies such as storage capacity to mitigate risks of curtailment, or providing energy vectors additional to electricity.

decarbonize 40% of the mining industry's emissions but is a good alternative in the long-term. Monitoring the evolution of these technologies could unlock GH2 or electromobility investment opportunities on a large scale with high impact.

The main mining companies in Chile are: BHP (Australia), Ango American (England), Codelco (Chilean State Company), and AMSA (Chile). All of these have declared willingness to incorporate GH2 into their operations to achieve their climate goals. Anglo American is the only one that has a pilot project and has installed a GH2 refueling station inside their operations.

4. Monitor alternative opportunities related with GH2 development

One of the main challenges of GH2 project deployment is the development of enabling and shared infrastructure that is required for production and commercialization of GH2. Ports, gas pipelines, and desalinization infrastructure will be needed. This represents a challenge for anyone who wishes to produce GH2, but it is also an opportunity to invest in other part of the value chain.

In Magallanes, a new port has been already announced from Austria Energy. In the north, due to drought and water scarcity, desalinization investment opportunities will occur. Additionally, in order to blend higher amounts of GH2 in natural gas pipelines, several equipment and material will require its replacement to avoid material damage. For this reason, also engaging with natural gas distributors or O&G companies (ENAP) would help to identify investment opportunities for the short-term.

5. Engage with the local GH2 environment

Collaboration and associativity have been key for the development of an early GH2 market. Several governmental and private actors have created discussion instances to debate on the sector's challenges and how to overcome them. Workshops and working groups have helped to channel these discussions and establish goals to foster the market.

Hence, engaging with focal points such as InvestChile, Corfo, Asociación H2V de Chile, and Fundación Chile would help to generate networks and identify new investment opportunities. The prior would also contribute to crafting effective solutions to manage relevant risk for the development of projects.

7 About the Subnational Climate Fund:

The Subnational Climate Fund (SCF) is a global blended finance initiative that aims to invest in and scale mid-sized (5 – 75 M $USD) subnational infrastructure projects in the fields of sustainable energy, waste and sanitation, regenerative agriculture and nature-based solutions in developing countries.

The SCF finances projects with a blend of concessional and conventional capital, along with Technical Assistance grants that help mitigate risk and ensure financial and environmental goals are achieved.

For further information about the SCF, visit: www.subnational.finance

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9 Annexes

9.1 The hierarchy of norms and regulations in Chile.

The hierarchical structure of regulations in Chile follows a descending order of importance. At the top, we find the National Constitution[22], which establishes the fundamental principles and basic rights of citizens. The Constitution provides the framework within which subsequent laws and regulations are developed and applied.

Directly beneath the Constitution, we encounter laws that are approved by the National Congress[23]. These laws can encompass a diverse range of topics, spanning from civil law to labor and environmental law. Laws concretize the principles established in the Constitution and offer a more detailed guide for the application of specific policies and regulations.

Next, we have decrees and regulations, which are issued by various government bodies and ministries. These documents outline the technical and procedural aspects for implementing laws. They possess a more specific character and can cover anything from safety requirements in the industry to administrative procedures.

At a lower level in the hierarchy, we find resolutions and administrative provisions issued by administrative and regulatory authorities. These regulations address specific and concrete matters within a defined area. They can range from quality standards in products to guidelines for the submission of legal documents.

Figure 8-1: Hierarchical structure of regulations in Chile
Source: Own elaboration

[22] During 2023, a constitutional process is underway, in which three designated bodies are to draft a proposal for a new Constitution to be submitted to a plebiscite in December of the same year.
[23] Constitutional body of popular representation formed by the Chamber of Deputies and the Senate. Its main functions are legislative and oversight of government acts, in accordance with the provisions of the Political Constitution of the Republic (Cámara de Diputadas y Diputados, n.d.).

It is essential to highlight that there are clear distinctions among laws, strategies, and action plans. These last two elements are instruments used in the management and implementation of public policies and the government's political commitments that establish guidelines for the future at the national level.

Strategies are planned, high-level approaches that the government adopts to achieve long-term objectives. These strategies often involve key decisions about how to allocate resources, how to address challenges, and how to seize opportunities. They are a fundamental guide that influences future decisions and actions, and usually they don’t include sanctions for not achieving an objective.

Action Plans are more detailed and specific measures derived from a strategy. These plans break down the concrete actions that need to be taken to implement the strategy and achieve the established goals. Action plans often include deadlines, responsibilities, and allocated resources. They are frequently designed to be flexible and adapt to changes in the environment or circumstances.

9.2 In-depth review of Regulatory framework, strategies, and policies on green hydrogen

- **Law 21.305 - Energy Efficiency Law** (Ley de Eficiencia Energética)

This law states that the Ministry of Energy must draw up a National Energy Efficiency Plan every five years (Ley 21305, 2021). This plan must propose goals and lines of action to achieve energy efficiency at the residential, productive and city levels, as well as in education, building and transport.

Additionally, this law seeks to promote energy management by establishing the obligation for large companies to report their energy consumption and energy intensity, and to implement Energy Management Systems (SGE by its acronym in Spanish).

This law defines hydrogen as a fuel and gives the Ministry of Energy the competences to include the development and regulation of green hydrogen and hydrogen derivatives within its activities and tasks. In addition, this law provides tax benefits in the calculation of depreciation to electric or hybrid vehicles with external electric charging, as well as others classified as zero emissions by resolution of the Ministry of Energy, in the ten years following the entry into force of the law.

- **Law 21.455 - Climate Change Framework** (Ley Marco de Cambio Climático)

This law, published in 2022, aims to move towards a carbon neutrality scenario by 2050. It also seeks to adapt to climate change, reducing vulnerability and increasing resilience to its adverse effects, as well as to comply with Chile's international commitments in this area (Ley No 21455, 2022).

Its instruments include the Long-Term Climate Strategy, which defines the general guidelines that Chile will follow over the next 30 years to address climate change. This document sets specific targets in the areas of energy, mining and transport that include the development of green hydrogen (Gobierno de Chile, 2021). For example, it defines as a goal to reach 15% of zero-emission fuels such as green hydrogen and its derivatives in non-electric final energy uses by 2030, and 70% by 2050. It is also established that by 2030 a program to transition into clean technologies in public transport with pilot experiences in electromobility and green hydrogen should be in place.

- **Law 21.505 – Promotion for energy storage and electromobility**

This law defines modifications to the General Law of Electrical Services of 2006, of the Ministry of Economy, Development and Reconstruction. The amendments mainly include energy storage systems within the electricity regulation framework (not included until that moment) (Ley No 21505, 2022).

Additionally, it establishes within its definitions the "generation-consumption assets" which is intended for infrastructure destined to the production of hydrogen with renewable electricity generation in a single facility (i.e. renewable plant with an electrolyzer in the facility). The motivation of this modification is that before the Law, a project with this configuration would have to incur in systemic costs for the electricity that is simultaneously generated and consumed for GH2 production. Systemic costs could add-up over 30 USD/MWh in electricity costs for the project, so this modification would help these facilities reducing their electricity costs. This concept entails a significant advantage in terms of minimizing the systemic costs for GH2 producers when withdrawing electricity from the system.

- **National Electromobility Strategy** (Estrategia Nacional de Electromovilidad)

This strategy aims to establish strategic axes, measures and specific goals that allow for the accelerated and sustainable development of electric transport in Chile. Among the main goals of the strategy are that by 2035, 100% of new additions to urban public transport will be zero emissions, and 100% of sales of light and medium vehicles will be zero emissions. In addition, the total sales of machinery of more than 560 kW of power should be zero emissions by 2035 and those of more than 19 kW from 2040 onwards (Ministerio de Energía, 2021b).

The Ministry of Energy is committed in this strategy to promote the development of pilot projects for green hydrogen vehicles in freight and passenger transport, logistics operations, intercity buses, and mining machinery. It also indicates its commitment to work on enabling regulation.

- **Long Term Energy Strategy** (Planificación Energética de Largo Plazo)

The General Law of Electricity Services establishes in its Article 83 that the Ministry of Energy must develop every five years a long-term energy planning process considering the scenarios of energy generation and consumption expansion (Ministerio de Energía, 2022).

These long-term energy scenarios show the alternative paths of demand and development of the energy matrix and allow planning the necessary infrastructure to achieve the country's goals and commitments to carbon neutrality and the retirement of coal-fired power plants.

Its preliminary report includes the generation and use of green hydrogen as one of the technologies to achieve carbon neutrality by 2050. It also indicates compliance of the national GH2 strategy as part of the accelerated transition scenario projected by the Ministry of Energy (Ministerio de Energía, 2022).

- **National Green Hydrogen Strategy** (Estrategia Nacional de Hidrógeno Verde)

This strategy was published in 2020 and is divided into three stages. The first is to incentivize production and promote domestic demand for green hydrogen by 2025. The second stage between 2025 and 2030 aims to enter strongly into international markets with the production and export of green ammonia. The third stage seeks that after 2030, global decarbonization initiatives will promote new technologies, so the export market will scale up and diversify, and Chile will be able to take advantage of the industry's development (Ministerio de Energía, 2020).

The ambition of this strategy includes the country becoming the world's leading producer of green hydrogen by electrolysis by 2030, and the cheapest available at less than USD 1.5 per kg.

Among the actions proposed in this strategy is to provide funding to leverage green hydrogen projects in their start-up phase, develop public-private coordination to boost the industry, and generate regulation and standards that encourage investment and facilitate operating authorizations. It is also proposed to articulate with the private sector to increase capacities and competencies in the hydrogen value chain and create a roadmap for innovation in this industry.

- **Green Hydrogen Action Plan 2023- 2030** (Plan de Acción de Hidrógeno Verde 2023- 2030)

The Green Hydrogen Action Plan 2023- 2030 is an initiative undertaken by the government, through the Ministry of Energy, which seeks to establish a roadmap to boost this industry by reconciling economic development with respect for the environment, regions and communities (Gobierno de Chile, 2023a).

The process of developing the plan includes participatory spaces with citizens, an advisory council and a strategic committee, which will address the challenges and needs for the advancement of this industry along three main lines of action: Investment and Institutionality; Sustainability and Local Value; and Infrastructure and Territory.

In July 2023, the members of the strategic committee and the first measures to drive this action plan forward were presented. The measures include a review of the current regulation on green hydrogen, financial facilities for the different stages of development, the inclusion of this type of project in the Environmental Impact Assessment System (SEIA), capacity strengthening of local governments on the subject, and a national plan to promote the production of green hydrogen in fiscal territory.

- **Chile's National Determined Contribution** (NDC)

Nationally Determined Contributions are commitments made by countries to enhance their actions against climate change, in mitigation and adaptation, depending on each national context and existing capacities. This is done by countries that are part of the United Nations Framework Convention on Climate Change (UNFCCC) to comply with the Paris Agreement to keep the global average temperature increase below 2°C and to make efforts to limit the increase to 1.5°C above pre-industrial levels (UNFCC, n.d.)

Chile submitted its NDC to the Agreement in 2015 and updated it in April 2020. In November 2022 the country made a strengthening of its commitments through an annex to the 2020 version in response to the international call for increased ambition. In this document, Chile commits to a GHG emissions budget of no more than 1,100 Mt CO_2e between 2020 and 2030, with peak emissions in 2025, and to reach a GHG emissions level of 95 Mt CO_2e by 2030.

Regarding the development of green hydrogen, this NDC indicates the relevance of this fuel in order to meet the carbon neutrality target by 2050. It specifically sets out as measures for carbon neutrality in 2050 that 71% of freight transport, 12% of motorized uses in industry and mining, and 7% of thermal use in households and 2% in industry should use hydrogen.

- **Other laws under discussion that could impact GH2 sector**

There are other policies to promote the development of GH2 in Chile that are under discussion and has not been approved yet. For example, in 2021, a bill was presented to promote the production and use of GH2, through the development of domestic applications. One proposal was to foster GH2 blending in the natural gas distribution networks, triggering a local demand, and at the same time reducing emissions through the usage of existing gas infrastructure. However, this project is currently on hold in the Chamber of Deputies since 2021.

- **Additional policy guidelines**

In 2021 the Ministry of Energy published two guides for special hydrogen projects. The first guide is a collaboration with the Superintendence of Electricity and Fuels (SEC) and its objective is to help those companies interested in implementing hydrogen projects. This document provides guidelines to facilitate the processing of special installation authorizations for projects within the green hydrogen value chain based in international normative in the absence of industry-specific regulation (Ministerio de Energía, 2021c).

The second guide is a collaboration with the Ministry of Mining to facilitate the procedures and authorizations for mining companies to develop hydrogen pilot projects. This guide provides a framework for action before the mining safety supervisory body (SERNAGEOMIN) so that mining companies can develop projects for the safe production, storage, transport or use of this fuel at their sites. It also allows standardizing the evaluation criteria applicable to these projects while the definitive regulation is being processed (SERNAGEOMIN, 2021).

9.3 Certificates

The certification of green hydrogen has become an essential point for both buyers and consumers, as it not only guarantees the origin and quality of the product, but also contributes to the fulfillment of climate objectives, fosters competitiveness in global markets, and promotes the adaptation of more sustainable practices in the production and use of green hydrogen.

Currently, there is no specific certification method to quantify GH2 emission reduction or sustainable attribute. In this context, the Government is seeking to secure a GH2 certification scheme for the green molecules produced in the country that is compatible with both international markets, and the existing Chilean Measurement, Reporting, and Verification (MRV) system (Hinicio-LBST, 2021a). Along the same lines, Chile has established strategic agreements with other States and ports worldwide (such as Germany, Singapore, the Port of Rotterdam and the Port of Hamburg), whose objectives include promoting collaboration in the development of international certification systems (Martí, 2022).

The current Government's strategy is to adopt an existing certification scheme for hydrogen and other hydrogen-derived "green" products. This is because market and regulatory signals from potential export markets indicate that adopting an internationally recognized scheme is the safest approach to ensure long-term sustainability criteria in other markets. One of the most recognized schemes is CertifHy, which has positioned itself as one of the most advanced in the world and is serving as a potential model for this unified global scheme (Hinicio-LBST, 2021a). However, there are other options, which are presented in Figure 2-2.

	Low Carbon Fuel Standard	CertifHy	TÜV SÜD	Australia
Year of establishment	2011	2019	2011	planned for the next years
Public or private	Public/ governmental	private	private	Public/ governmental
Geographic scope	California, USA	Focus on European Economic Area; to be extended internationally	Focus on Germany; but applicable internationally	Australia (for international trade of hydrogen)
Objective	Compliance with legal requirements	Consumer disclosure; to be extended to compliance with legal requirements in EU	Consumer disclosure (voluntary certification)	Support international trade
Governance	California Air Resources Board	Stakeholder Platform	TÜV SÜD	Not specified yet
Verification	Third-party verification for fuel pathways, otherwise: carried out by CARB	Certification bodies (third party; so far only TÜV SÜD recognized by CertifHy)	Carried out by TÜV SÜD or other certification bodies, who have a valid accreditation for certifications of products	Not specified yet
Quantification of emissions through	CI standard	Guarantee of Origin scheme for Green & Low Carbon Hydrogen	Green Hydrogen standard	Distinction of three types of emission scopes

Figure 8-2: Existing hydrogen certification systems with international recognition. Source: (Hinicio-LBS, 2021b).

Each of these schemes cover different areas and use different thresholds, which means that the definition of green hydrogen is not standardized and the final product has different environmental attributes depending on the associated certification scheme. However, the schemes seek to set acceptable low-carbon energy technologies to be used for GH2 production, establish social, regulatory, and environmental conditions that safeguard a low-impact project, show how the emissions associated with these products will be quantified and set a common taxonomy for a product.

Specifically, Certifhy is a Guarantees of Origin (GO) scheme that seeks to demonstrate that the hydrogen is green or low carbon, providing information on attributes such as: the primary energy source for production, information on the plant that produced the hydrogen (location, technology used, start date of operation) and the greenhouse gas intensity of the hydrogen (Ángel & Márquez, 2022).

For CertifHy, GHG emissions in the hydrogen production process must not exceed 36.4 g of CO2 per MJ of H2. Hydrogen that meets this maximum emissions threshold is then classified into two labels, depending on the energy source used:

- **Green hydrogen**, which come from renewable energies defined by the RED II Directive.
- **Low-carbon hydrogen**, which is hydrogen produced by non-renewable energy sources (e.g. nuclear or fossil sources with CCS).

As in the case of CertifHy, most schemes focus on two main attributes: the renewable nature of the energy source used, and the CO2 emissions released during its production. However, discussions have begun to include other sustainability attributes such as water consumption, protection of natural biospheres or potential social impacts (Hinicio-LBST, 2021a).

Based on the above, the Green Hydrogen Organization has recently released The Green Hydrogen Standard. A new certification scheme that is much stricter with respect to the criteria and requirements that a green hydrogen project must meet in order to acquire its certification. In this scheme, green hydrogen is defined as hydrogen produced by electrolysis, with nearly 100% of its energy coming from renewable sources (maximum 5% from other sources). In terms of emissions intensity, a maximum threshold of 1kg of Co2 per kg of H2 is established, which corresponds to approximately 8.33 g of CO2 per MJ of H2, a value considerably lower than that established by CertifHy (Green Hydrogen Organisation , 2022) .

In addition, The Green Hydrogen Standard requires the assessment of social, environmental and governance consequences of hydrogen production. In this way the development opportunities and impacts of hydrogen production will be carefully considered within the framework of the Sustainable Development Goals.

Will all of the above, it is clear that one of the biggest challenges of green hydrogen certification is the need to reach an international consensus on quality standards and certification procedures. For this, the adoption of an existing scheme would be beneficial for Chile to secure its participation in an international market.

9.4 Projects subsidized through the CORFO funding call

Initiative	Business model assumptions	Company	Project name	Region	Contribution size in USD
Construction of a pilot plant for green hydrogen production	Production of 3200 tons/year of hydrogen	ENGIE S.A.	Hyex-Producción de Hidrógeno Verde	Antofagasta	$9,533,668
Production of e-methanol from renewable energy	Production of 60000 tons/year of e-methanol	Air Liquide Chile S.A.	Amer E-Methanol	Antofagasta	$11,786,582

Initiative	Business model assumptions	Company	Project name	Region	Contribution size in USD
Construction of a pilot plant for green hydrogen production	Production of 1550 tons/year of hydrogen	CAP S.A.	Planta piloto de producción de hidrógeno verde para la descarbonización de la industria siderúrgica nacional	Bío Bío	$3,631,174
Green hydrogen production with wind energy	Production of 25000 tons/year of hydrogen with energy from a wind farm	Enel Green Power Chile S.A.	Faro del Sur	Magallanes	$16,896,848
Construction of the first large-scale green hydrogen production plant	Initial production of 500 tons/year of hydrogen set to increase as demand for hydrogen grows	GNL Quintero S.A.	Quintero Bay H2 Hub	Valparaíso	$5,727,099
Replacement of a portion of grey hydrogen production	Production of 3000 tons/year of hydrogen to replace grey hydrogen production from nearby petroleum refinery plant	Linde GMBH	HyPro Aconcagua	Valparaíso	$2,424,629

Table 8-1: Projects with CORFO grants
Source: (CORFO, 2021a) (ACERA, 2022)

9.5 GH2 project portfolio

Initiative	Business model assumptions	Company	Project name and Development Stage	Application sector	Region	Contribution size in USD
Construction of a plant for green ammonia production	Production of 130,000 tons/year of green hydrogen for production of 750,000 tons/year of green ammonia	FreePower and Ghenergy	H2V Cabeza del Mar Project – Conceptual Engineering stage	Transport Export Mining Agriculture	Magallanes	$2,850,000,000
Construction of a plant for large-scale green ammonia production from favorable wind energy conditions	Production of 30,200 tons/year of green hydrogen for production of 172,000 tons/year of green ammonia	-	TANGO Project – Feasibility stage	Transport Export Mining Agriculture	Antofagasta	-
Construction of a plant for large-scale green ammonia production from favorable wind energy conditions	Production of 250 kTpa of green hydrogen for production of 1,250 kTpa of green ammonia	TEG	Gente Grande – Feasibility stage	Transport Export Mining Agriculture	Magallanes	-
Construction of a plant for green ammonia production from favorable wind energy conditions	Production of 120,000 tons/year of green hydrogen for production of 700,000 tons/year of green ammonia	Consorcio Eolico	Pionero Project – Feasibility stage	Transport Export Agriculture	Magallanes	$4,500,000,000
Decarbonization of the San Pedro mine by developing a hydrogen center	-	Centro Nacional de Pilotaje de Tecnologías para la Minería y MSP	San Pedro Mining Project – Conceptual Engineering stage	Transport Mining	Metropolitan	$1,330,000
Construction of the first giga-scale green ammonia project	Production of 800,000 tons/year of green hydrogen for production of 4,400,000 tons/year of green ammonia	Total Eren	H2 Magallanes – Conceptual engineering stage	Transport Export Mining Agriculture	Magallanes	$20,000,000,000
Production of green hydrogen from Cerro Dominador's concentrated solar power and PV complex	Production of 950 tons/year of green hydrogen	Cerro Dominador	H2 CSP+PV Project – Pre-feasibility stage	Transport Mining Industrial	Antofagasta	$6,000,000
Production, storage, and distribution of green hydrogen and oxygen for energy generation and industrial heat	Production of 6,200 tons/year of green hydrogen and 50,000 tons/year of oxygen	Antuko	H2 Genesis Project – Pre-feasibility stage	Export Mining Industrial	Antofagasta	$80,000,000
Production of green hydrogen for supplying the Chilean domestic market and for export	Production of 8,500 tons/year of green hydrogen in Scenario 1 and production of 170,000 tons/year of	Statkraft	Pauna Greener Future – Pre-feasibility stage	Transport Export Mining Agriculture	Antofagasta	$1,040,000 in Scenario 1 and $1,540,000 in Scenario 2

Initiative	Business model assumptions	Company	Project name and Development Stage	Application sector	Region	Contribution size in USD
	green ammonia in Scenario 2					
Deployment of a pilot to power a green hydrogen fuel-celled forklift	Consumption of 2 kg/day for powering a 5 kW fuel cell forklift	AngloAmerican	Hydrogen Generation Unit – Pilot operation stage	Transport Mining	Metropolitan	$890,000
Supply of non-intermittent electricity from renewable sources using green hydrogen, fuel cells, and energy storage	Production of 900 tons/year of green hydrogen from 36 MW of wind energy installed capacity in conjunction with 12 MW of Fuel cells to deliver stable supply	HDF	Renewable Kosten Aike Project – Conceptual engineering stage	residential	Aysen	$190,000,000
Generation of green hydrogen from strong winds and available solar radiation	Production of 300 kg/day of green hydrogen from installed capacity of 10.5 MW of wind energy and 9 MW of solar energy	Tikuna	Zorzal Project – Under construction	Transport Mining Agriculture	Bío Bío	$30,000,000
Construction of a green hydrogen pilot plant and the use in applications within the university campus to create and transfer capabilities	Production of 0.8 tons/year	UCSC	UCSC Projects – Under construction	Transport Residential	Bío Bío	$800,000
Retrofitting of existing battery powered forklifts with green hydrogen powered fuel cells	Production 10.8 kg/hour for retrofitting 259 forklifts	Walmart Chile	Hydrogen Forklifts Project – Under construction	Transport	Metropolitan	$15,000,000
Production of green ammonia from wind energy potential	Production of 63,000 tons/year of green hydrogen for production of 350,000 tons/year of green ammonia	RWE	Vientos Magallánicos – Prefeasibility stage	Transport Export Mining Agriculture	Magallanes	$1,800,000
Production of green hydrogen for injection into natural gas distribution network	Injection of 5% green hydrogen content into gas network, later scaled to 20% volume	GasValpo	H2GN Project - Operational	Residential	Coquimbo	$1,000,000
Decarbonization of the mining sector by replacing diesel consumption by way of hydrogen fuel cells and batteries	Replacement of 3,000 litters/day of diesel consumption per truck	ENGIE and Mining3	Hydra Project – Pre-feasibility stage	Transport Mining	Antofagasta	$40,000,000

Initiative	Business model assumptions	Company	Project name and Development Stage	Application sector	Region	Contribution size in USD
Production of green ammonia for export with wind energy	Production of 85,000 tons/year of green hydrogen for production of 500,000 tons/year of green ammonia	Sociedad de Inversiones Albatros Ltda.	Llaquedona Green Hydrogen – Conceptual engineering stage	Transport Export	Magallanes	$2,000,000,000
Development of an ecosystem of zero-emission transport of mine workers from cities to mine sites	Production of 48 tons/year of green hydrogen and operation of 1-3 electric buses. Phase 2 will scale up to 20 buses and Phase 3 will scale to 50 electric buses under production	AirLiquide and Atamostec	H2 Solar Project – Pre-feasibility stage	Transport	Antofagasta	$10,000,000
Promotion of green hydrogen as a solution for increasing energy independence and supporting local development	Production of 102,000 tons/year of green hydrogen for production of 250,000 tons/year of green ammonia, in conjunction of 140,200 tons/year of agricultural products	TCI Gecomp	Hoasis Project – Pre-feasibility stage	Transport Export Agriculture Industrial	Antofagasta	$5,000,000,000
Incorporation of green hydrogen and renewable energy into existing fossil fuel generation systems in isolated areas		Cummins Chile	San Pedro de Atacama Project – Pre-feasibility stage	Residential	Antofagasta	$10,000,000
Construction of a large-scale facility for green hydrogen and ammonia production	Production of 170,000 tons/year of green hydrogen for the production of 1,000,000 tons/year of	CWP Global	H1 Magallanes – Feasibility stage	Transport Export Agriculture	Magallanes	
Reduction of CO2 emissions from steel production processes by incorporating green hydrogen in the value chain	Production of 1,550 tons/year of green hydrogen for reduction of coke consumption in blast furnaces and direct reduction of iron ore and green steel production	Siderurgica Huachipato	Green Steel Project – Feasibility stage	Industrial	Bío Bío	$30,000,000
Construction of a large-scale facility for green ammonia production	Production of 1,300,000 tons/year of green hydrogen for production of 250,000 tons/year of green ammonia	Anker Clean Hydrogen and Mainstream Renewable Power	Faraday Project – Feasibility stage	Transport Export	-	$5,400,000,000
Construction of a large-scale electrolysis facility	Production of 110 kton/year of green hydrogen for production of 600	Humboldt Hidrogeno Verde	Atacama Hydrogen Hub – Pre-feasibility stage	Transport Export	Antofagasta	$5,000,000

Initiative	Business model assumptions	Company	Project name and Development Stage	Application sector	Region	Contribution size in USD
	kton/year of green ammonia. Later scaled to 550 ktons/year of green hydrogen					
Production of green ammonia on a large scale for export	Production of 150,000 tons/year of hydrogen for the production of 850,000 tons/year of green ammonia	AustriaEnergy	HNH Energy Project – Conceptual engineering stage	Transport Export Mining Agriculture	Magallanes	$3,000,000,000
Construction of an industrial-scale plant for producing synthetic fuels for export	Production of synthetic methanol to convert into 131 m^3/year of eGasoline for Pilot and later scaled to 70,000 m^3/year in Phase 1	HIF	HIF Project – Pilot Project operational	Transport	Magallanes	$51,000,000 for Pilot and $755,000,000 for Phase 1
Construction of a plant for large scale green ammonia production	Production of 50,000 t/year of hydrogen to produce 250,000 tons/year of green ammonia	AES Andes	Green Ammonia AES Andes – Feasibility stage	Transport Export	Antofagasta	$1,500,000,000
Construction of a pilot plant for green hydrogen production	Production of 365 tons/year of hydrogen in first phase of the project and two charging stations for hydrogen vehicles	AES Andes	Adelaida – Feasibility stage	Transport	Antofagasta	$10,000,000

Table 8-2:9 1 Portfolio of GH2 projects
Source: (Switzerland Global Enterprise, 2022)

9.6 H2Global instrument funding mechanism

Figure 8-3: Schematic of the H2Global instrument funding mechanism - general.
Source: (H2Global-Stiftung, n.d.)

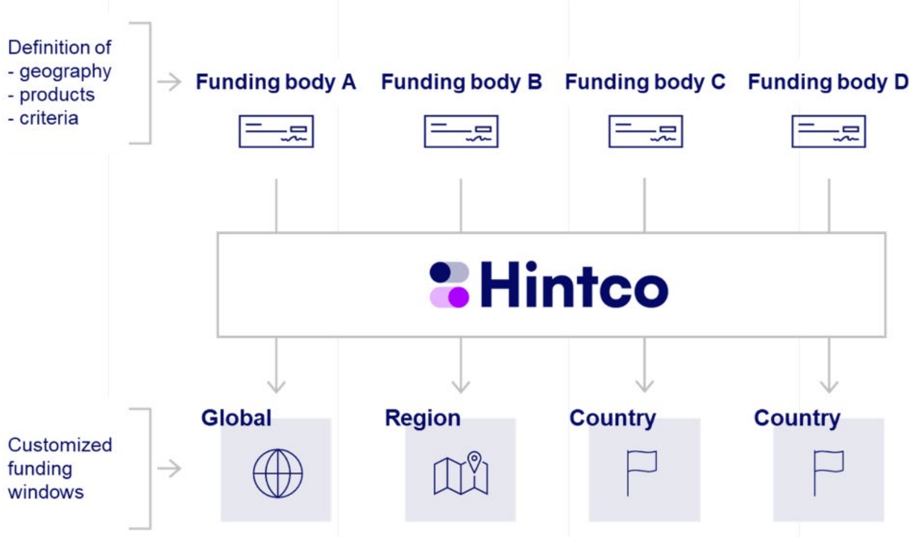

Figure 8-4: Schematic of the H2Global instrument funding mechanism - specific.
Source: (H2Global-Stiftung, n.d.)

9.7 Capacity factors and levelized cost of electricity (LCOE) in selected Chilean regions

Concept	North	Central	South	Pat. Chile
Solar capacity factor	*38.1%*	*28.8%*	*23.9%*	*17.4%*
LCOE solar "Today" (US$/MWh)	23.50	31.00	37.48	51.40
LCOE solar "2030" (US$/MWh)	18.81	24.82	30.01	41.14
LCOE solar "Long Term" (US$/MWh)	12.83	16.92	20.46	28.06
Wind capacity factor	*37.2%*	*37.9%*	*34.2%*	*51.8%*
LCOE wind "Today" (US$/MWh)	46.17	45.38	50.25	33.16
LCOE wind "2030" (US$/MWh)	27.20	26.74	29.60	19.54
LCOE wind "Long Term" (US$/MWh)	22.44	22.06	24.42	16.12
LCOE combined "Today" (US$/MWh)	23.50	38.09	43.46	33.16
LCOE combined "2030" (US$/MWh)	18.81	25.76	29.82	19.54
LCOE combined "Long Term" (US$/MWh)	12.83	19.46	22.32	16.12

Table 89-32: Capacity factors and levelized cost of electricity (LCOE) in selected regions
Source: own elaboration

9.8 Projections of the main electrolyzer manufacturers with regard to production capacity

Manufacturers	Headquarters	Technology	Capacity (MW)		
			Current	Expansion plans	Growth
ITM Power	UK	PEM	1,000	5,000 (by 2024)	5x
McPhy	France	PEM, Alkaline	100	1,300 (by 2024)	13x
Nel	Norway	PEM, Alkaline	500	10,000 (by 2025)	20x
John Cockerill	Belgium	Alkaline	350	8,000 (by 2025)	22x
Plug Power	US	PEM	75	3,000 (by 2025)	40x
Thyssenkrupp	Germany	Alkaline	1,000	5,000 (by 2030)	5x
Sunfire	Germany	Alkaline, Solid oxide	40	500 (by 2023)^	12x
Siemens Energy	Germany	PEM	125	1,000 (by 2030)	8x
Cummins	US	PEM, Alkaline, Solid oxide	38	3,500 (by 2025)	92x
Topsoe	Denmark	Solid oxide	75	5,000 (by 2030)	66x
Ohmium	US	PEM	500	2,000 (by 2022)	4x
Enapter	Italy	AEM	30	300 (by 2023)	10x
Bloomenergy	US	Solid oxide	500	1,000 (by 2023)	2x
Green Hydrogen Systems	Denmark	Alkaline	75	400 (by 2023)	5x
Hydrogen Pro	Norway	Alkaline	100	1,000 (by 2030)	10x
Elogen	France	PEM	160	1,000 (by 2025)	6x
Other manufacturers		PEM, Alkaline, Solid oxide	1,000E	12,000E (by 2030)	
Total			**5,600**	**37,000 (by 2025)**	**6x**
				60,000 (next 10 years)	**10x**

Figure 89-53: Projections of the main electrolyzer manufacturers with regard to production capacity Source: (EY Parthenon, 2023).

9.9 Specific regulation on Environmental, Health and Safety

Green hydrogen is considered a dangerous substance and is categorized along other flammable gases under NCh382.Of98:2021. Given the physiochemical properties of green hydrogen, certain standards must be met to address the risks to the operators, machinery, and installation that involve synthetic fuels. The main risks needed to account for are flammability, treatment of small molecule chemicals, material interactions, suffocation, and storage risks.

The following policies have norms which could regulate the use of hydrogen on its different applications, however it is important to note that some policies only establish norms for sectors where hydrogen would play a future role, requiring further adjustments regarding hydrogen to be put in place.

Ruling Entity	Description	Document type, number, and year issued	Sector
Ministry of economy	Creates the "green hydrogen industry development committee" and establishes rules that will regulate its operation; and approves its regulations. The entity's responsibilities include supporting the national green hydrogen strategy, managing government-driven initiatives for the green hydrogen industry, promoting research and innovation, facilitating education and training, designing incentives, monitoring outcomes, and handling inquiries related to green hydrogen development.	Resolution 60:2022	
Ministry of health	Establishes the norms that regulate basic security conditions in which dangerous substances must be stored in order to avoid risking the health and safety of the public. It mentions specifically the norms of hydrogen storage and lists the complete measures regarding the safety distances and maximum capacities for storage, among other measures. However, this norm does not have effect for gas and liquid fuels used for energy purposes, which sets the need for further regulation regarding green hydrogen.	Decree-43:2016 - Regulations for the storage of dangerous substances	Storage
	Sets the regulation for basic sanitary and environmental	Decree-594:2018 - Regulation for basic	Production

Ruling Entity	Description	Document type, number, and year issued	Sector
	workplace conditions. It includes implicitly norms regarding hydrogen by setting measures for the handling of flammable substances and fire prevention methods, but it has no specifications regarding the prevention of explosions.	sanitary and environmental conditions at workplaces	
	Establishes the listing of substances which constitute as a health hazard. It establishes hydrogen as a dangerous substance in its compressed and liquid form.	Exempt Resolution 408:2016	
Ministry of transport and telecommunications	Establishes the conditions, norms, and procedures applicable for the transport of cargo, through streets and roads, containing dangerous substances. This would regulate all transportation of hydrogen that would be carried out through roads, with the only other method for land transport being pipes.	Decree-298:2002	
	Establishes the operational regulation of dangerous cargo in port premises. It refers mainly to administrative matters, like product classifications and indications on which can be delivered in the port area. It has no indications for the transfer of flammable gases, and it transfers regulation power to the international code for the maritime transport of dangerous goods in packaged form (IMDG).	Resolution 96:1997 - Regulations for the transport of hazardous cargo on roads and highways	Export
	Sets the dimensional and functional requirements for vehicles that offer services for public urban transport. This would set the general norms for vehicles like buses used for public transport that would make use of hydrogen. However, hydrogen is rarely	Decree-122:2022 -	Transport

Ruling Entity	Description	Document type, number, and year issued	Sector
	mentioned and would need further regulation to be added.		
Ministry of work and social welfare	Sets rules for employers to develop and update safety and hygiene standards for workers, along with corresponding risk warnings and capacitation. There is no specific mention for hydrogen, but it would require employers to set the necessary safety and hygiene standards for its handling or use.	Decree-40:1995 - Regulation on occupational risk prevention	
Ministry of energy	Establishes the norms for mining safety. It has no mentions of hydrogen, but it would involve its use indirectly as it sets safety conditions for mining establishments. This norm permits the use of liquid petroleum gas and compressed natural gas as fuel for underground machinery, which could later be extended for the use of hydrogen.	Decree-132:2004 - Mining Safety Regulations	
Ministry of planning and housing	Classifies the infrastructure for hydrogen production as "energy infrastructure".	DDU 470:2022 - Land use applicable to buildings, facilities and networks associated with hydrogen generation.	
National Policy Institute	Classifies hydrogen as a dangerous substance along other flammable gases.	NCh382.Of98:2003	
	Sets distinctions for risk identification regarding the transport of dangerous substances.	NCh2190.Of:2003	
	Risk prevention by the regulation of security markings for material risk identification.	NCh1411/4.Of78:2000	
	A sheet of security data for chemical products	NCh2245.Of:2015	

Table 8-4 Systematization of sectoral regulations for the Environment, Health and Safety
Source: Own elaboration with data from (GIZ, 2020)

Most of the norms observed either have no specific considerations for hydrogen or have need for further details regarding safety conditions. Several aspects like ventilation, explosion prevention measures, high pressure equipment, cryogenic equipment, and norms regarding handling and delivery of green hydrogen are currently missing in current policies. Current regulation only slightly covers storage and distribution for hydrogen, but several revisions or new policies are urgently needed to cover the regulation barriers in production, storage, distribution, and consumption of hydrogen (GIZ, 2020).

9.10 Description of funding programs available

The following describes the funds currently available, or that will become available in the short term. The following categories are considered for their description:

- Name of instrument/fund and Management agency: name of the instrument/fund studied.
- Type of instrument: whether its credit improvement, insurance, concessional financing,
- bilateral policies, income support policies, political contributions, or others.
- General objective: Main purpose of the instrument/fund.
- Targeted development stage: if it's in an early, bankable, funded, or mature stage.
- Scope of the fund: area of focus of the instrument/fund and its delivery guidelines.
- Requirements and coverage: obligatory aspects asked by the instrument/fund and its scope.
- Deadlines/application periods: timeline given by the instrument/fund.
- Link to green hydrogen: relation to green hydrogen to justify its usage.
- Additional characteristics: important information not mentioned in the points above.

As for the amounts presented, the main currency used is the USD so that these amounts can be compared more easily[24].

Table 9-1: Description of CLIN Fund.

Name of instrument	CLIN Fund.
Management agency	ChileGlobal Venture of Fundación Chile.
Type of instrument	Venture Capital.
Targeted development stage	Early stage.
General objective of the fund	The fund is focused on solving sustainability and productivity challenges in the energy, water, mining, Smart Cities, big data, and Internet of Things (IoT) sectors. To this end, it seeks to leverage resources from companies and direct them to the significant challenges of these sectors. The Fund started in 2018 with $18 MM USD of venture capital and has an expected duration of 10 years. By 2023, it will have 20 MM USD contributed by five limited partners and leveraged by CORFO.
Scope of the fund	The Fund seeks to support innovative, high-impact Latin American ventures with the potential for scaling up the development of new technologies and with the potential to participate in international markets (with a focus on business-to-business, or B2B).
Requirements and coverage	The CLIN Fund seeks to invest in 20-25 early-stage companies with innovative technologies and scaling potential, providing between 0.5MM USD and 1MM USD. The CLIN II Fund seeks to invest in a smaller number of early-stage companies with innovative technologies and scaling potential, providing between USD 1MM and USD 1.5MM.
Deadlines/application periods	Open-ended fund, which does not have a specific deadline

[24] Para aquellos montos que se presentan en otra moneda, se utilizó la tasa de cambio observada el 31 de julio del 2023 en Bloomberg, siendo para USD a CLP 838,94 CLP/USD (o 0,0012 USD/CLP), y para EUR a USD 1,0998 USD/EUR (https://www.bloomberg.com/quote/USDCLP:CUR y https://www.bloomberg.com/quote/EURUSD:CUR, respectivamente).

Link to green hydrogen	This Fund will be able to support green hydrogen ventures as long as they are innovative and have a high impact.
Additional characteristics	No information available.

Source: own elaboration based on (Chile Global Ventures, n.d.) (Fundación Chile, 2018)

- H2Global Stiftung

Table 9-2: Description of the financial instrument of the H2Global instrument.

Name of instrument	H2Global instrument
Management agency	H2Global Stiftung
Type of instrument	Long-term contracts for supply and short-term contracts for demand.
Targeted development stage	Bankable stage.
General objective of the instrument	This mechanism seeks to support existing efforts to meet Germany's and the European Union's GHG carbon neutrality targets defined in the Paris Agreement. Specifically, it states that the transition depends on the use of GH2 and its derivatives (ammonia, methanol and sustainable aviation fuel, or Power-to-X (ptX)).
Scope of the instrument	Not limited for Chile only. For the purchase and sale of PtX products, the price is determined by bidding, where the lowest supply price and the highest demand price, respectively, are chosen. For the operation of this mechanism, the participation of the Hydrogen Intermediary Company GmbH (HINT.CO, intermediary) is required, who will enter into long-term purchase contracts on the supply side, and short-term sales contracts on the demand side. Similar to contracts for difference (CfD), in this case, the difference between the bid and ask prices is compensated by subsidies from a public or philanthropic actor. Figure X in Annex shows a schematic of the H2Global instrument funding mechanism. In this way, HINT.CO provides the necessary investment security to enable large-scale investments.
Requirements and coverage	The financing windows are individually designed, which provides greater flexibility and dynamism. However, some specific parameters of interest are: • The products to be promoted (ammonium, methanol, others). • Geographical application of the instrument. • Product requirements and sustainability criteria for the different stages (production, transport, and marketing). The Annex 8.6 shows another H2Global instrument funding mechanism schematic.
Deadlines/application periods	Recruitment and sales calls are handled by HINTCO and are not deadlines set.
Link to green hydrogen	The instrument is focused on procurement of green hydrogen derivatives.
Additional characteristics	No information.

Source: own elaboration based on https://www.h2global-stiftung.com/project/h2g-mechanism (H2Global-Stiftung, n.d.)

Table 9-3: Description of the financial instruments of the "Program to Support the Development of the Green Hydrogen Industry in Chile".

Name of Fund	Program to Support the Development of the Green Hydrogen Industry in Chile
Management agency	CORFO

Type of instrument	(1) Grants, and (2) Loans and guarantees.
Targeted development stage	(1) Early stage, and (2) Bankable stage.
General objective of the Fund	The general objective of the Program is to contribute to the development of the Green Hydrogen industry and its derivatives in Chile and, in this way, contribute to the decarbonization of the national economy. The Program contemplates a total amount of $400 MM USD divided into $50 MM USD for subsidies and $350 MM USD for loans and guarantees.
Scope of the Fund	(1) Grants Seeks to support actions to maximize the positive impact of new investments in the GH2 sector in Chile and thus contribute to the decarbonization of the country's economy. It will support the provision of public goods and the mitigation of market failures that are identified, affecting the development of this sector. Consider the following types of grants: 1. Grants to increase local demand ($8.4 MM USD): focused on technological institutions that provide services to companies to finance project portfolios that require technological innovation to demand GH2. 2. Capacity Building Grants ($4 MM USD): focused on funding capacity-building courses relevant to the GH2 industry. 3. Subsidies for providing public inputs ($9.3 MM USD): focused on generating public inputs such as technical standards, safety protocols, and public-public and public-private collaboration. 4. Grants to promote innovation ($13.4 MM USD): focused on increasing public and private innovation by financing research and innovation projects in goods and services. 5. Grants to promote entrepreneurship (USD 8.5 million): seeks to support and contribute to developing local links in the GH2 chain. (2) Loans and guarantees It will support the purchase and installation of electrolyzer plants for GH2 production and will be limited to support only investments in green hydrogen production projects.
Requirements and coverage	(1) Grants Subsidies to increase local demand: up to 70% of the cost for up to $4 MM USD. They are focused on institutions incorporated in Chile that demonstrate technical capabilities. Capacity building grants: maximum amount per grantee of USD 3,000. With eligible national or regional projects, grantees may be Chilean or foreign residents who can cover at least 10% of the cost of the course. Subsidies for the provision of public inputs: up to 85% of the development cost of the public input with a maximum of USD 240,000. It considers that the project must have a principal, a beneficiary entity, and a set of beneficiaries served. Subsidies to promote innovation: coverage between 40% and 80% of project costs, with a maximum of US$240,000 and US$480,000. It is

	focused on companies incorporated in Chile with innovation projects that include collaborating entities (such as research and development centers). Grants to promote entrepreneurship: up to 75% of the project cost, with a maximum amount between USD 18,000 and USD 70,000 per venture. Natural and legal persons incorporated in Chile as a company or entities to promote entrepreneurship may be beneficiaries. (2) Loans and guarantees No information, pending the development of the Program's Operating Regulations, which should occur within this year.
Deadlines/application periods	(1) Grants No information, pending the development of the Program's Operating Regulations, which should occur within this year. (2) Loans and guarantees (3) No information, pending the development of the Program's Operating Regulations, which should occur within this year.
Link to green hydrogen	The instrument is focused on green hydrogen projects.
Additional characteristics	The delivery of these instruments will value that the projects to be financed include gender actions within the proposal to promote women's incorporation in this industry.

Source: own elaboration based on IDB, 2023.

9.11 Stakeholders interviewed

Below we include a list of the stakeholders interviewed for the development of this study.

- Enrique Espinoza from Asociación Chilena de Hidrógeno (H2 Chile) – (enrique.espinoza@h2chile.com)
- Gabriel Casaburi from IDB – (GABRIELCA@iadb.org)
- Pablo Hojman from MAE – (phojman@mae-energy.com)
- Jennyfer Salazar from TCI GECOMP – (jennifer.salazar@tci-gecomp.com)
- Francisco Belmar from Angloamerican – (francisco.belmar@angloamerican.com)
- Gina Gonthier from ENAP – (ggonthier@enap.cl)