TECHNICAL COOPERATION FOR GREEN HYDROGEN PRODUCTION, STORAGE, TRANSPORTATION AND USE

I N I T I A T I V E

CHILE – EUROPEAN UNION
BILATERAL FUND
FOR DEVELOPMENT IN TRANSITION

CONTENT

BACKGROUND

This document aims to share the results of the implementation of the **"Technical Cooperation for Green Hydrogen Production, Storage, Transportation and Use"** initiative, financed by the Chile – European Union Bilateral Fund for Development in Transition. This is a joint initiative between the European Commission's Directorate-General for International Partnerships (INTPA) and the Chilean International Cooperation Agency for Development (AGCID).

This technical cooperation initiative was implemented by the Ministry of Energy of Chile and the Chilean Economic Development Agency (CORFO) and led to the development of the "**Call for Proposals for Co-financing Pre-investment Studies for Green Hydrogen Production, Storage, Transportation and/or Use"**, in which seven companies participated and its results are presented in this document.

ACKNOWLEDGEMENTS

This project was made possible thanks to the work and dedication of the teams at the **Ministry of Energy of Chile and the Chilean Economic Development Agency (CORFO).** The support of the **Delegation of the European Union to Chile,** with whom AGCID has worked in partnership on the implementation of the Fund and its projects, has also been instrumental.

Finally, we would like to thank the Spanish companies **Calvera, Ariema, Iberdrola and the Spanish National Hydrogen Centre** for their willingness to share their valuable knowledge and experience related to the transport, storage, supply and production of green hydrogen and its derivatives. Their contribution was fundamental to enriching the knowledge of the Chilean professionals and representatives of the companies that participated in the mission to Madrid in May 2022. Furthermore, we would like to thank the staff of the Chilean Mission to the European Union for their cooperation in ensuring the successful participation of the project members in the European Development Days event.

OPENING REMARKS

The European Union and Chile share a conviction that, now more than ever, it is crucial to address the challenges of climate change and the energy transition, particularly in light of the growing energy crisis in Europe and the rest of the world as a result of Russia's war on Ukraine.

In our efforts to adapt to the challenges of cooperation with countries, such as Chile, that have achieved income levels that make them ineligible for Official Development Assistance (ODA), we have promoted the concept of "Development in Transition", working with our partners in the region, such as ECLAC, the OECD and Chile.

Development in Transition involves understanding development as a multi-dimensional process, and we look to address these complex processes in an open and collaborative manner.

One result of our collaborative efforts has been the Bilateral Fund for Development in Transition. Co-funded by the EU and Chile through AGCID, this fund provides an innovative tool to address issues of common interest and generate new areas of cooperation.

The Fund has carried out several actions, including the "Technical Cooperation for Green Hydrogen Production, Storage, Transportation and Use" initiative, which provided a total of seven companies with co-financing to develop pre-investment studies for green hydrogen projects in four regions of Chile. The green hydrogen industry is a sector that holds enormous transformative potential for both Chile and region, and thanks to this initiative, these pioneering projects have received the support needed to advance to further stages.

This work falls within the framework of the Team Europe Initiative (TEI) on Green Hydrogen (GH2) development in Chile, in coordination with the EU, its member countries, cooperation agencies, and other private and public actors.

In the EU, we are convinced that joint cooperation in this area is crucial if we are to progress towards carbon-neutrality, a goal we share with Chile, and which will allow us to achieve a balance between sustainable development and the protection of the environment.

León de la Torre Krais
Ambassador of the European Union to Chile

Chile, akin to numerous nations within the Latin America and Caribbean region, is classified as a developing country. In pursuit of advancing this status, the Chilean International Cooperation Agency for Development (AGCID) has made significant strides in establishing and disseminating the notion of "Development in Transition." This initiative has been successful in fostering a constructive dialogue within the region and has garnered substantial international and multilateral support, exemplified by endorsements from prominent organizations such as ECLAC, the European Commission and its member countries, and the OECD Development Centre.

Development in Transition is an analytical framework that takes into account the multidimensional nature of development needs in order to implement the 2030 Agenda and its Sustainable Development Goals (SDGs). Furthermore, it approaches the development process not as one that seeks to achieve a distinct upward trend, but as a continuous process that looks to overcome the structural gaps and pitfalls of middle- and high-income countries.

In terms of transforming Development in Transition into development for action, for many years, AGCID has promoted “development partnerships” with all of its partners. In this sense, we would like to highlight and express our appreciation for the creation and financing of the Facility for Development in Transition to the EU, with which we have jointly designed, structured and co-financed the Bilateral Fund for Development in Transition, an innovative cooperation instrument between the European Union and Chile that focuses on strengthening the alliances between both parties as well as supporting Chile’s progress towards sustainable development, beyond income measurement criteria.

Within the framework of this bi-regional partnership and in coordination with the Ministry of Energy of Chile and the Chilean Economic Development Agency (CORFO), AGCID has implemented the initiative “Technical Cooperation for Green Hydrogen Production, Storage, Transportation and Use”, the results of which are presented on the following pages.

This joint effort by Chile and the European Union, which involved both public and private actors, has resulted in seven pre-investment studies that seek to advance the green hydrogen industry in Chile. It has also strengthened capacities in the country through the sharing experiences and knowledge.

Chile remains committed to advancing along these lines of cooperation, actively promoting and implementing innovative initiatives that address global challenges and contribute to the pursuit of equitable and sustainable development for our nation and the wider region.

Enrique O’Farrill-Julien
Executive Director,
Chilean International Cooperation Agency for Development (AGCID)

With its enormous renewable energy sources, Chile is positioned to become a leader in the production of green hydrogen (GH2) and a central figure in the global energy transition.

The government is committed to accelerating the development of the local energy industry. We want Chile to not only be recognised as a leader in GH2 production and an exporter of knowledge and innovation, but also as a country that brings together technology transfer actions and contributes to generating added value in the region.

The GH2 industry has the potential to play a significant role in the shift towards a new development model for the country, one that focuses on sustainability, on strengthening the development of added value and, above all, on national industry, transforming a large part of the country's production chain. GH2 could, for example, contribute to low emissions mining, provide more sustainable tourism, improve freight transport, and help create solutions for communities that currently lack energy storage and stand-alone power systems. In addition, it could be used in heating systems and the production of derivatives, such as ammonia and methanol.

The private sector has been quick to respond to the opportunities Chile has to offer. There are more than 15 production projects in the pipeline, six of which have received a total of USD 50 million in development funds from CORFO. These six projects add up to almost 400 MW of electrolysis capacity and an annual production of around 45,000 tonnes per year.

This year, we will draw up lines of action to accelerate the transformation in local consumption through various demand-side programmes and define a road map to put the existing strategy into practice.

In addition, we will strengthen our collaboration with other countries, which is a crucial step to fostering the areas in which we want hydrogen to have an impact on national welfare. One example of our collaborative work is the Technical Cooperation initiative for GH2 production, storage, transport and use projects, an effort which is financed by the Chile – European Union Bilateral Fund and implemented by CORFO, AGCID and the Ministry of Energy.

Such partnerships will continue to be essential for sharing lessons learned and promoting the early development of the industry. In this way, we hope to transition toward a new energy matrix and a sustainable development model that benefits everyone and generates a greater appreciation of what we can do locally.

Diego Pardow
Minister of Energy

President Boric's government sees green hydrogen (GH2) as an instrument that will allow us to achieve Chile's mission of decarbonising the country by 2050, transforming our energy matrix and creating opportunities for the development of a new industry, that could transform local high energy demand industries and be a competitive and sustainable offer to international zero emissions fuel and chemicals markets.

It will involve challenges, such as engaging in more sophisticated activities, local manufacturing, providing specialised services, and developing innovations to facilitate the process.

How we progress will depend on multiple state actors, the commitment of the productive sector and the early participation of communities and civil society. The key lies in coordinating the public sector and working with its private counterpart. This, in turn, requires that we communicate the importance of this new industry, the availability of public resources to invest in it, and the commitment of the government to solve priority issues.

It is along these lines that we have created the CORFO Committee to oversee the promotion of the GH2 industry in Chile. It is led by the Ministry of Energy, with the participation of ten other ministries, and will address issues such as development and land management, the environment, regulations, investment and financing, knowledge building and technology transfer, logistics, international relations, and the production of associated goods and services. The committee also provides a space to dialogue with investors, communities, regional governments, and other key stakeholders.

At CORFO, we understand that GH2 presents both challenges and opportunities for decarbonising our local energy demand. It requires the transformation of our energy capacity to produce green hydrogen and thus meet domestic demand; a restructuring of our traditional Chilean sector to be able to use this clean energy; and exports, where we have competitive advantages. CORFO is interested in generating local value through the energy transformation of local industries that incorporate green hydrogen and the production of parts and pieces along the value chain, such as electrolysers.

This builds on the momentum of a strategy that has identified the potential for 25 GW of electrolysis capacity by 2030. How much of this opportunity we can capture will depend not only on promoting these investment and technological development efforts, but also on our ability to move forward and ensure the sustainability of the industry, both environmentally and socially, particularly in the regions positioned to become the largest GH2 production hubs in the country.

CORFO's work over the past several years leads us to conclude that Chile would have one of the largest production hubs of green hydrogen for the world by 2025. But it is a journey that has only just begun.

José Miguel Benavente
Executive Vice President, CORFO

DEVELOPING GREEN HYDROGEN IN CHILE

Chile is making strong progress in its efforts against climate change and has committed to becoming a carbon neutral country by 2050, as established in the country's recently enacted Framework Law on Climate Change. Green hydrogen plays a central role in meeting this goal, with the potential to account for a 24 per cent reduction in carbon emissions in the energy sector by 2050, transforming the way in which energy is produced and consumed, and paving the way for decarbonisation solutions and applications that are more cost-effective and feasible compared with other energy carriers.

The country's renewable energy potential is internationally recognised both in terms of quantity and quality of resources. Chile's renewable sources consist mainly of solar energy in the northern regions of the country, such as the Atacama Desert, and its large wind energy potential in the south and Patagonia. The International Energy Agency estimates that Chile could achieve a green hydrogen production cost of less than USD 1.50 per kilogram by 2030 (IEA, 2019).

Chile approved its National Green Hydrogen Strategy in 2020. It aims to attract USD 5 billion in investment by 2025 and achieve a target of 25 GW of electrolysers by 2030. There are several challenges involved, including social and environmental challenges, which the country is determined to address.

Chile is also highly receptive to foreign investment and is the most competitive country in Latin America. Historically, it has topped several international rankings of competitiveness and ease of doing business. Likewise, Chile has proven to have a highly competitive market in the energy sector. It was ranked the second most attractive country for investment in the sector among 107 emerging economies, and eleventh worldwide, when developed countries were included in the ranking (Climatescope, 2021).

Many companies have made public their green hydrogen projects and initiatives throughout the country and the Chile Hydrogen Association (H2Chile) now has more than 130 members, an indication of a lively private ecosystem that is looking to develop projects and grow this market rapidly.

In the public sector, it is worth noting that in 2021 CORFO opened the first call for financing of industrial-scale projects in Chile. Today there are six projects throughout the country with an aggregate electrolyser capacity of 388 MW and investments of USD 1 billion, all progressing towards the goal of beginning production by December 2025.

ABOUT THE CHILE – EUROPEAN UNION BILATERAL FUND FOR DEVELOPMENT IN TRANSITION

The Chile – European Union Bilateral Fund for Development in Transition is a joint initiative of the Chilean International Cooperation Agency for Development (AGCID) and the Directorate-General for International Partnerships (INTPA, formerly DEVCO), in coordination with the Delegation of the European Union to Chile and developed within the framework of the Regional Facility for Development in Transition.

The overall objective is to foster and support Chile's transition process towards sustainable and inclusive development through the promotion of the renewable energy sector and, in particular, green hydrogen. To this end, a forum for strategic dialogue has been established to help generate new forms of cooperation between the partners; for the selection and implementation of innovative demonstration actions that align with the strategic priorities of the cooperation between Chile and the EU; and to systematize the management and development of the new agenda for Development in Transition, incorporating best practices and experiences.

In support of the efforts of the Chilean State to develop a new clean energy industry in the country, the Ministry of Energy of Chile and the Chilean Economic Development Agency (CORFO) have proposed and financed the "Technical Cooperation for Green Hydrogen Production, Storage, Transportation and Use" initiative.

OBJECTIVES:

1.– To provide technical support to innovative demonstration projects that mobilise a demand market for green hydrogen in Chile.

2.– To generate feasible technical-economic assessments of green hydrogen projects in Chile that accelerate the development of demonstration initiatives for the use and/or production of green hydrogen.

3.– To generate the conditions that enhance partnerships of companies throughout the entire green hydrogen production value chain.

4.– To generate the information and knowledge to reduce the uncertainties related to this new industry

THE CALL FOR

CO-FINANCING OF PRE-INVESTMENT STUDIES FOR GREEN HYDROGEN PROJECTS

Within the framework of the technical cooperation for the promotion of green hydrogen projects, a call for applications was opened on 11 May 2021 with a view to **"co-financing the pre-investment studies for green hydrogen production, storage, transport and/or use projects".**

The call was closed on 26 July 2021, with 11 companies having presented applications. Following an evaluation by the technical committee, seven projects were awarded co-financing to carry out pre-investment studies during 2022 of green hydrogen production, storage, transportation and/or use projects in four regions of the country: Antofagasta (3), Coquimbo (1), Aysén (1) and Magallanes (2).

AWARDED COMPANIES AND PROJECTS:

ANTOFAGASTA REGION

- Antuko Comercialización SPA
- Empresa Eléctrica Pilmaiquén S.A.
- Cerro Dominador CSP S.A.

COQUIMBO REGION

- CVE Energía Renovable Chile SPA

AYSÉN REGION

- MOWI Chile S.A.

MAGALLANES REGION

- RWE Renewables Chile SPA
- Inversiones y Desarrollos Energéticos Free Power SPA

An overview of each of the projects and the principal findings of the studies produced with the support of the fund can be found on the pages that follow. This information is expected to contribute to the investment decision making process, thus accelerating the development of the green hydrogen industry and, with it, advancing towards the country's decarbonisation goals.

PROJECTS

1.- GENESIS PROJECT

Company name and description: Antuko Comercialización SPA

Antuko Comercialización SPA develops projects involving green hydrogen and battery energy storage systems (BESS). The company also provides comprehensive solutions for investors, developers and financiers of energy projects. Its business areas include energy trading, economic load dispatch and asset management, M&A corporate finance, quantitative consulting, energy price forecasting and market intelligence.

Consulting firm that conducted the study: Tractebel Engineering S.A.

Project description:

The project is located in La Negra industrial district of the Antofagasta Region. It focuses on the production, storage and distribution of green hydrogen using electrolysis. The project foresees three stages of scalability, beginning with an installed electrolysis capacity of 20 MW, scaling up to an additional 40 MW in the third year of operation, and another additional 40 MW in the fourth year of operation, until reaching an installed capacity of 100 MW (20, 60, and 100 MW).

The aim is to leverage the large amount of renewable energy available in the Antofagasta Region in order to provide decarbonisation solutions for certain processes in hard-to-abate industries where electrification has its limitations. Thus, its primary objective is to supply hydrogen to the domestic market. There have been several conversations with offtakers from different industries, such as mining, cement, steelworks, mobility, and others.

The study is currently at the pre-feasibility stage and is expected to begin feasibility studies in the coming months. Next steps include signing agreements with offtakers, developing the Environmental Impact Statement (EIS), advancing with feasibility and identifying possible co-developers and/or purchasers.

Gaps identified:

As with any project of this type, several potential risks have been identified, mainly of a technical-economic and/or regulatory nature. In this sense, aligning private objectives with the National Strategy will be crucial.

Opportunities identified:

By 2030, Chile's LCOE will be very competitive in comparison with other countries, allowing it to produce highly competitive green hydrogen. There has been a lot of uncertainty in the global energy market in recent months due to several factors, such as the war in Ukraine. Chile has the opportunity to be a leader in decarbonising its matrix and, at the same time, achieve self-sufficiency by 2030. Being able to use green hydrogen to decarbonise industries that have historically been large polluters would allow Chile to position itself as a leader in new "green" markets, such as green copper. The Antofagasta Region has enormous potential for green hydrogen consumption because of its high density of industries that cannot be electrified.

Applications:

Industrial heat
Feedstock
Reducing agent
Mobility

Main findings of the study:

- Highly competitive marginal costs.
- Potential for multiple applications in a relatively small setting. Access to infrastructure.
- Competitive LCOH.
- Potential to trade 02.

TECHNICAL DESCRIPTION	
Electrolyser power [MW]	100MW
Hydrogen production [tonnes/year]	15,000 tonnes/year
Derivatives productions (hydrogen, ammonia, methanol, other) [tonnes/year] or [m3/year]	Only hydrogen gas and oxygen will be produced.
Electricity supply [MW solar/MW wind/grid/PPA]	Renewable PPAs
Water supply and consumption required [l/year or m3/year]	40 m3/h (annual consumption will depend on the load factor of the equipment). Estimated at 140,000–332,000 m3/year
Amount of CO2 equivalent avoided [tonnes CO2/year]	Avoided ~ 120,000 tonnes/year
Amount of investment [USD]	USD 160-212 MM
Expected year of entry into the SEIA	2022
Expected year of entry into operation	First phase 2025

2.- PAUNA GREENER FUTURE PROJECT

Company name and description: Empresa Eléctrica Pilmaiquén S.A., a STATKRAFT company dedicated to renewable energy generation.

Consulting firm that conducted the study: HINICIO

Project description:

Located in the Antofagasta Region, this project involves the design, construction and operation of a green ammonia plant for export to Europe. It is currently exploring target markets, potential offtakers and eventual trading partners, as well as meeting with possible suppliers of key project equipment in order to refine its CAPEX and OPEX. At the same time, the project is also seeking quotes for the engineering so that it can be submitted to SEIA for environmental assessment.

It is currently at the conceptual engineering stage and the pre-feasibility is very encouraging, with preliminary results that are tremendously competitive at the global level.

Gaps identified:

One of the gaps identified is the lack of an offtaker, which directly impacts the investment decision. In response, the company is exploring alternatives for offtakers both in Chile and abroad.

Applications:

Green ammonia for energy replacement

Target market: Rotterdam.

Main findings of the study:

The technology is sufficiently mature to develop a project of this nature. However, there are gaps to resolve if attractive LCOAs that compete with other energy sources are to be achieved, including: the availability of buyers, the supply of equipment within reasonable timeframes, and more competitive pricing of said equipment. This is a world-class and very competitively priced project.

TECHNICAL DESCRIPTION	
Electrolyser power [MW]	447 MW
Hydrogen production [tonnes/year]	29,000 tonnes/year
Derivatives productions (hydrogen, ammonia, methanol, other) [tonnes/year] or [m3/year]	162,000 tonnes/year
Electricity supply [MW solar/MW wind/grid/PPA]	562 MW solar + 10 MW grid
Water supply and consumption required [l/year or m3/year]	530 m3/h peak
Amount of CO2 equivalent avoided [tonne CO2/year]	192.208
Amount of investment [USD]	USD 560 MM
Expected year of entry into the SEIA	2023
Expected year of entry into operation	Q4 2027

Statkraft

3.- PROJECT FOR THE PRODUCTION OF GREEN HYDROGEN BY ELECTROLYSIS AND ENERGY CARRIERS (AMMONIA, SYNTHETIC DIESEL, AND OTHERS), USING ELECTRICITY FROM TWO SOLAR TECHNOLOGIES IN COMBINATION: PHOTOVOLTAIC (PV) AND CONCENTRATED SOLAR POWER (CSP)

Company name and description: Grupo Cerro

Grupo Cerro, which is wholly-owned by investments funds managed by EIG Global Energy Partners, operates a solar complex producing 100 MW PV and 110 MW CSP in the Atacama Desert, and also has a portfolio of 110 MW of small and medium-sized run-of-river hydroelectric power plants in the O'Higgins, Maule, Biobío and Araucanía regions.

The Cerro Dominador Solar Complex produces low-cost, 100 per cent renewable energy 24 hours a day, seven days a week, using an innovative 17.5-hour thermal storage system. This makes the technology highly manageable and dispatchable, supplying stable and predictable electricity 24 hours a day and allowing it to respond to all periods of energy demand.

Grupo Cerro's portfolio of future projects includes CSP (up to 690 MW) and PV (up to 600 MW), as well as more than 40 MW of run-of-river hydroelectric power plants.

Consulting firm that conducted the study: CEA-Liten

Project description:

Located in the district of María Elena, Province of Tocopilla, Antofagasta Region, this initiative aims to build a plant that will supply 2,600 kg/day of green hydrogen (949 tonnes of H2/year) using a 6MWe electrolyser. The production of energy carriers or synthetic fuels through additional industrial processes will be assessed at a later date.

The H2 investment project is currently at the conceptual pre-feasibility stage. Detailed engineering studies are expected to be carried out during 2023 so that, by the end of the year and through an international tender, the suppliers in charge of the construction of the proposed H2 production plant can be selected and the corresponding EPC contracts can be signed, with the expectation to begin works in the second half of 2024 and a COD of end of 2025.

Gaps identified:

Without the approval and development of more SOEL technology pilot projects that will allow SOEL technology to mature, the CAPEX for SOEL technology may remain high in 2024 compared with alkaline technologies and PEM.

Opportunities identified:

High temperature SOEL electrolyser technology is the most promising technology for the future. Although this technology is not yet mature, investment in pilot projects that look to increase experience and make improvements in the technology could lead to hydrogen production at the lowest possible cost, bearing in mind its high efficiency (90 per cent, higher than other current alkaline and PEM production technologies, which have an efficiency of approximately 70 per cent).

Furthermore, SOEL electrolyser technology makes direct use of part of the heat from the CSP plant, which results in greater efficiency and an even more competitive cost in the future.

Should there be no demand for the H2 at a certain time, there is also the possibility of producing electricity again by using the H2 produced by the electrolyser, thanks to a fuel cell. This is the power-to-power chain, which in the long term could be an energy storage alternative that complements variable renewable energy production.

Applications:

The project looks to install an electrolyser and storage system for hydrogen production at the Cerro Dominador Complex.

Target market:

The target market for the hydrogen will be the domestic market, the clean fuels market, given its high potential to replace the use of fossil fuels in machinery and trucks in fuel-intensive industries, such as transport and mining, as well as the use of LPG and natural gas at the commercial level. Considering that a truck with a 32 kg tank of H2 can travel a distance of 400 km, and that the average distance travelled by a single truck in one year is approximately 40,000 km, the electrolyser could fuel 300 trucks.

Main findings of the study:

The pilot has focused on the production of hydrogen for mixing with other fuels. Taking into account that H2 is the starting point for any other H2 carrier, other derivatives could be produced at a later stage, depending on demand.

The valorisation of surplus electricity is also important, considering the potential transmission bottlenecks. The company looks to establish a pilot in 2025. For this, a 6 MWe alkaline electrolyser could meet the requirements. However, it is the high-temperature SOEL electrolyser technology that is the most promising in the near future.

TECHNICAL DESCRIPTION	
Electrolyser power [MW]	6 MWe
Hydrogen production [tonnes/year]	949 tonnes H2/year
Electricity supply [MW solar/MW wind/grid/PPA]	110 MW CSP Cerro Dominador + 100 MW PV Cerro Dominador
Water supply and consumption required [l/year or m3/year]	8,540 m3/year
Amount of CO2 equivalent avoided [tonne CO2/year]	5,600 tonnes CO2/year
Amount of investment [€]	€ 10.75 MM
Expected year of entry into the SEIA	Second half of 2023
Expected year of entry into operation	2025

GRUPO cerro

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4.- H2V CVE CHILE PROJECT

Company name and description: CVE Chile

CVE is an independent renewable energy producer that is active in the PV solar, biogas and hydroelectric power markets. It is headquartered in France and has operations in Chile, the United States and Africa. CVE's market vision is based on decentralised production and direct energy sales. It looks to find sustainable solutions to the energy and environmental needs of companies and communities. CVE has operated in Chile since 2017, where its business is focused on photovoltaic generation in the PMGD sector (a Spanish acronym for Small Means of Distributed Generation). It is developing, building and operating photovoltaic plants throughout the country.

Consulting firm that conducted the study: CEA-Liten

Project description:

This initiative involves a project under development in the Coquimbo Region. It consists of the technical-economic analysis of an investment project for the valorisation of green hydrogen produced via electrolysis at a small photovoltaic plant for distributed generation (PMGD) in Chile, evaluating different modes of production and end uses.

The objective is to build a water electrolysis plant powered by an existing PMGD photovoltaic plant, thus enhancing the value of CVE's assets, either by producing green hydrogen (GH2) via surpluses from generation, or using a plant that is entirely dedicated to GH2 production. The implementation of the project seeks to increase the profitability of CVE's assets by adding GH2, either for own use or for commercialisation.

The project proposes a business alternative to be able to invest in a demonstration pilot that could be replicated at all CVE Chile and CVE Group plants that have surpluses or are subject to curtailments or dumping, and also as a new form of operation, with plants that are wholly dedicated to distributed hydrogen generation.

The study analyses a 10MWdc PV solar plant, looking at eight different hydrogen production scenarios in which the photovoltaic generation conditions vary, with a focus on four different hydrogen applications: mobility, industry, power-to-power, and ammonia.

The results obtained at the conclusion of the study provide grounds for new business strategies at CVE Chile, with a focus on the distributed generation of green hydrogen. The study has delivered the technical-economic results required to move ahead with the development stage of CVE Chile's first hydrogen pilot project. The project is expected to be developed in the near future and the corresponding permit processes will begin.

Gaps identified:

When generating electricity with fuel cells, overall system efficiency must be improved. For it to be scaled up in a cost-effective manner, there needs to be a better identification of the hydrogen demand for the different applications.

Opportunities identified:

By considering PMGD plants that are located in close proximity to potential consumers, the need for hydrogen transport is eliminated and thus the final cost is lowered.

Applications:

The project considers applications in mobility, industry and power generation. In terms of mobility, the aim is to generate hydrogen to supply petrol stations, to replace diesel trucks for hydrogen-powered trucks. Industrial applications consider using 10 to 100 per cent hydrogen mixtures as a replacement fuel in heat processes. And, in terms of power generation, the project studies energy storage in the form of hydrogen for power production by means of fuel cells.

Target market:

The target market is the domestic energy market, mainly distributed energy generation, either in the form of electricity or hydrogen. Initially, CVE Chile will focus on its PMGD plants under development and on individual projects with other interested companies.

Main findings of the study:

In the different scenarios, there are configurations that make for cost-effective business models under specific conditions and scales, with the estimated demand for hydrogen being key in each application. Ammonia and power generation with fuel cells are ruled out at the PMGD scale.

The project has the potential to be replicated at all PMGD plants in Chile, where there is about 1 GW in solar PV PMGD plants, which would allow the distributed energy sector to not only supply power but also hydrogen, as a second product.

TECHNICAL DESCRIPTION	
Electrolyser power [MW]	The study looks at different capacities of electrolysers of up to 10 MW for the various
Hydrogen production [tonnes/year]	Different production levels are obtained in the different scenarios, ranging from 4.5 to 200 tonnes/year.
Derivatives productions (hydrogen, ammonia, methanol, other) [tonnes/year] or [m3/year]	The study rules out ammonia production as a business for CVE Chile.
Electricity supply [MW solar/MW wind/grid/PPA]	A 10 MW solar plant is considered under different generation scenarios.
Water supply and consumption required [l/year or m3/year]	From 40 to 400 m3 of water, depending on the scenario.
Amount of CO2 equivalent avoided [tonne CO2/year]	Estimates of between 4,500 and 9,000 tonnes of C02/year avoided.
Amount of investment [USD]	Figures with solar plant investment of up to USD 10 MM
Expected year of entry into the SEIA	2023
Expected year of entry into operation	2026

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5.- PRE-FEASIBILITY STUDY AND PREPARATION OF A ROADMAP FOR A GREEN HYDROGEN PROJECT AT AYSÉN FJORD FISH FARMS (PFA)

Company name and description: Mowi Chile

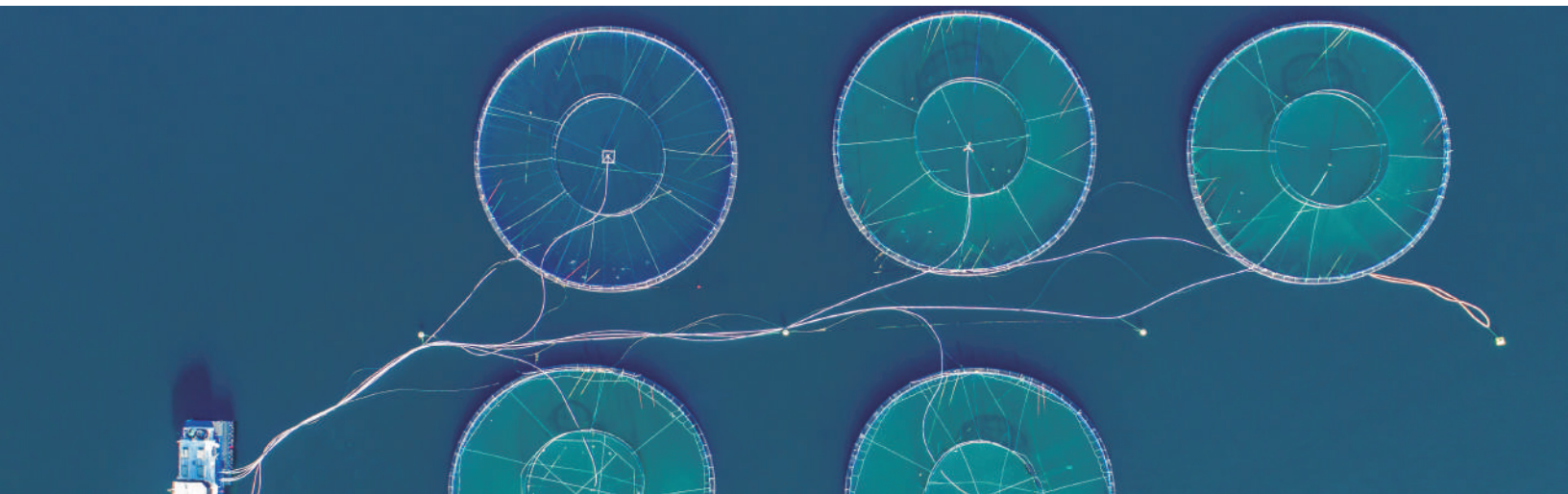
Mowi Chile is a salmon production company. As a group, Mowi is the world's largest producer of Atlantic salmon and, as a global company, sustainability is one of its main priorities and it is committed to the principles of the United Nations Sustainable Development Goals. It is concerned by climate change and has placed much emphasis on reducing its carbon footprint. Against this backdrop, Mowi is exploring the very interesting possibility of generating green hydrogen (GH2) that can be used in its production processes, thus reducing its use of fossil fuels.

Consulting firm that conducted the study: INVENT Universidad Austral de Chile.

Project description:

This initiative is located in the Aysén Region and consists of a pre-feasibility study that would allow Mowi Chile to implement a pilot GH2 generation plant at Aysén Fjord Fish Farms (PFA, for its acronym in Spanish). This would allow it to begin a decarbonisation process at the freshwater smolt production stage and at the saltwater growth stage, processes which are directly linked to PFA and the farming centres, respectively.

The pilot plant makes use of a pre-existing 2 MW run-of-river hydroelectric power plant at PFA as the renewable energy source for GH2 generation. The GH2 is stored by means of electrolysers installed at PFA and later transported to the farming centres in bottle racks. At the farming centres, the GH2 is used, by way of a fuel cell system, to provide electricity for services and thus minimize the use of the diesel oil currently being consumed. Mowi Chile is considering how it can scale this GH2 Pilot Plant project to cover its other productive areas. It has taken into consideration the development of a consistent long term road map that includes short- and medium-term goals; this would allow for scalability while achieving Mowi Chile's KPIs. The essential prerequisite is to transform PFA into the energy operations centre from which Mowi Chile can begin the process of achieving decarbonisation by 2050. Generating and using GH2 will allow the company to reduce the carbon footprint of the salmon production process.



The pre-feasibility study took into account the following activities:

- An estimate of potential GH2 production based on the existing hydroelectric power generation at PFA. In order to size the GH2 Pilot Plant, surplus hydropower generation and electricity demand were calculated for both PFA and for the pontoons at the farming centres. Other local energy sources were analysed and the project plan was developed based on an estimate of greenhouse gas emissions and pollutants in order to quantify the impact of developing the GH2 Pilot Plant.

- An analysis of GH2 storage / transport from PFA to the pontoons at the farming centres, with a view to streamlining the associated maritime transport logistics processes that PFA currently handles. The maritime transportation system was characterised and an analysis carried out of the potential for using GH2 in the transportation system, under different forms of storage.

- An analysis of GH2 as an energy source for the pontoons of the farming centres; they are diesel-dependent and currently do not have an energy option that would allow for their decarbonisation. Fuel cell integration was analysed, which would enable generation and thus reduce the current use of diesel oil-fuelled generators. Using GH2 in the generator sets was considered as an option.

- The design of an economic model and an assessment of the GH2 Pilot Plant using the surplus generation from the existing hydroelectric power plant at PFA. The assessment took into consideration the current operation of PFA in terms of energy, which allows for a comparison of different options for the GH2 Pilot Plant.

- The preparation of a road map for the implementation of the GH2 Pilot Plant.

The project is currently leveraging grants in order to move forward with implementation. The project has a pre-feasibility study and Mowi Chile continues to receive the support of INVENT UACh, who are coordinating Mowi's application for the instruments available from organisations such as CORFO, so that at least the first stage of the Pilot Plant can be developed. The application takes into account the need to marinize the storage and transport system, since it will operate in a marine environment. The premise is to be able to optimise and maintain the useful life of the Pilot Plant.

In parallel, and to strengthen its applications for available competitive funding, Mowi is seeking to formalise partnerships with companies that supply the equipment needed for developing the GH2 Pilot Plant.

Implementing this project will provide Mowi Chile with a road map to 2050 and, at the same time, enable the development of other renewable electricity generation options that will allow GH2 production to be scaled and reach more of Mowi Chile’s farming centres.

Applications:

GH2 generation will replace the diesel oil currently used for the pontoons at the farming centres in the Aysén Region. The GH2 will be consumed by fuel cells for emission- and pollutant-free power generation. The O2 generated during GH2 production will be captured and used as an input in the smolt production process at PFA; the project results revealed the potential for replacing the existing O2 generation plant.

Gaps identified:

Grants will be necessary for further development of the Pilot Plant as the costs of generation, storage and use equipment remain high and availability is low. The logistics of supply and the availability of NCRE projects for electricity generation must also be resolved in order to scale up the Pilot Plant. Nevertheless, in terms of environmental impact, the production and use of GH2 would bridge the gap in reducing greenhouse gas emissions and pollutants, something which is very difficult to achieve in this industry due to the distances and areas in which both the PFA and the farming centres are located.

Opportunities identified:

By carrying out an analysis of other renewable sources of generation, we were able to identify the potential to generate power internally at PFA and replace the current consumption of diesel oil for back-up. The potential is so great that it would allow the GH2 Pilot Project to be scaled up rapidly. This is an important opportunity to be able to meet the 2050 sustainability goals and continue to contribute to improving the environmental impact of the production processes. In addition, the benefits of using GH2 could contribute to the surrounding communities and solve their energy gaps.

Target market:

Current operations at the freshwater smolt production stage and the saltwater growth stage at PFA and the farming centres, respectively. The salmon production carbon footprint will be reduced, and thus the target market is the end consumer.

Main findings of the study:

A feasibility analysis of the first GH2 Pilot Plant for the salmon industry has been completed thanks to the joint work of Mowi Chile and INVENT UACh, and with the partial financing granted by the Chile – European Union Bilateral Fund for Development in Transition. The feasibility analysis included: the assessment of GH2 as an alternative energy supply for Mowi Chile's operations; the study of the salmon farming processes and a characterisation of their energy consumption; the calculation of renewable resources in the vicinity of PFA; the design of GH2 production plants; renewable energy-based generation; and the transport and use of GH2 at Mowi Chile's operations, both at PFA and at three farming centres.

TECHNICAL DESCRIPTION OF THE PROJECT:	
Electrolyser power [MW]	0,43 MW
Hydrogen production [tonnes/year]	96 kg/day
Derivatives productions (hydrogen, ammonia, methanol, other) [tonnes/year] or [m3/year]	768 kg/day of O2
Electricity supply [MW solar/MW wind/grid/PPA]	2 MW hydroelectric power plant
Water supply and consumption required [l/year or m3/year]	13 L/kg H2
Amount of CO2 equivalent avoided [tonne CO2/year]	136 tonnes CO2/year
Amount of investment [USD]	CAPEX of USD 1.25 million
Expected year of entry into the SEIA	2023
Expected year of entry into operation	2024

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INNOVATIVE ENERGY TECHNOLOGIES

6.- VIENTOS MAGALLÁNICOS: RENEWABLE HYDROGEN FOR A SUSTAINABLE CHEMICAL INDUSTRY

Company name and description: RWE Renewables Chile

One of Europe's leading companies, RWE is an energy company that was founded in Germany in 1898 and has its headquarters in Essen. It has vast experience throughout the entirety of the energy chain and approximately 20,000 employees in its different markets and subsidiaries. It has a presence at each link of the energy value chain and divides its operations into four main branches: RWE Renewables, RWE Supply & Trading, RWE Generation and RWE Power.

RWE Renewables is one of the world's leading renewable energy companies, with 3,500 employees and a presence in 20 countries. It focuses on the development, construction and operation of renewable energy projects, onshore and offshore wind energy, PV solar, and storage. Currently, it has an installed capacity of approximately 10 GW. Its goal is to achieve carbon neutrality by 2040 and, as part of this effort, at the end of 2021, it announced it would invest 50 billion euros to increase its current installed capacity of renewable energy to 50 GW in 2030, including green hydrogen.

Consulting firm that conducted the study: Hinicio

Project description:

The project is located in the municipality of Río Verde, in the Magallanes and Chilean Antarctica Region. The aim is to sustainably integrate the region's wind energy potential, via a plant that will produce green hydrogen and renewable ammonia for export to European markets. At this time, the pre-feasibility study has been completed and the next step is to carry out the feasibility study, which will provide more precise cost estimations and a more advanced engineering design. In parallel, the plan is to move forward with studies measuring wind resources in the area as well as environmental studies, community surveys and outreach, in order to be able to move forward with a technically, socially, and environmentally robust project.

Gaps identified:

Developing the infrastructure necessary to transport and export ammonia derivatives in the Magallanes Region presents substantial challenges. In fact, a comparison of Chile with other countries that have similar advantages in green hydrogen production shows that this is one of the main gaps the country must overcome. On the other hand, given this is a new industry, it is crucial to work in a forward-looking manner, to provide training and build networks with the study centres that will provide the technicians and professionals that will be needed. It is also important to have the required technology and equipment for projects of this magnitude, both for the wind farm and electrolysers, batteries, etc.

It is also important to prepare the city, towns and communities for the arrival of so much equipment and personnel.

Opportunities identified:

GH2 production is an enormous opportunity for Chile since it will generate social development in the region, attract investments, create jobs and each project will contribute to the area. It also provides an important opportunity to decentralise the country and leverage the Magallanes Region as a centre for developing professionals and technicians.

The project itself will contribute to achieving the carbon-neutrality targets of Chile, of other countries, and of industries that, today, are highly polluting. At the same time, it will create new opportunities for other projects in other areas of the country, thanks to the installed capacities that will be generated.

In particular, it will create sustainable jobs and the project will be important at the global level, taking advantage of the opportunities presented by Europe and, specifically, Germany for GH2 development.

Applications:

The project involves the construction of a wind farm to feed the electrolysis process for green hydrogen production. Given the absence of an electrical grid that can absorb periods of low wind generation, the design includes a battery system, making the product 100 per cent renewable. For ammonia production, the Haber-Bosch process will be used for synthesis. The ammonia will then be stored and exported for international markets.

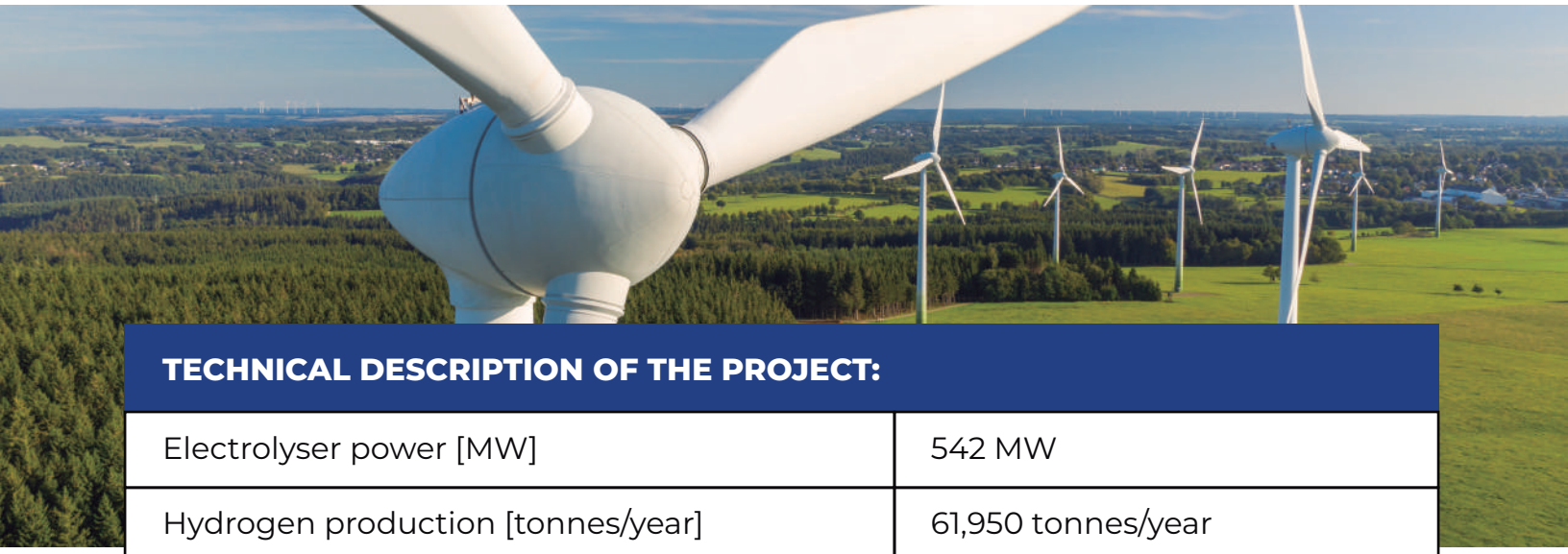
Target market:

The target is the current and future ammonia market in Europe, focusing on Germany and its neighbouring countries. According to the FCH Observatory platform, approximately 8.7 million tonnes of grey hydrogen are consumed by the industrial sector (8 per cent to 10 per cent of the global market), of which about 33 per cent is dedicated exclusively to ammonia production, equivalent to 14.6 million tonnes of ammonia per year. This project looks to export zero-emission ammonia to Europe via the ports of Hamburg and Rotterdam, with the aim of reusing existing infrastructure for the further processing of ammonia into fertilisers.

Main findings of the study:

The study determined that the construction and operation of a plant producing green hydrogen and derivatives based on wind energy in the Magallanes Region is technically feasible. The CAPEX of the entire project is close to USD 2 billion,

with the wind farm accounting for the largest component of the cost (approximately 35 per cent), followed by the electrolyser and hydrogen storage. Finally, the study concluded that a back-up energy source must be incorporated due to the fragility of the Magallanes' electrical system. The back-up could consist of fuel-based generation or a battery system, but RWE chose batteries as the alternative because it is looking for a project that is completely renewable.



TECHNICAL DESCRIPTION OF THE PROJECT:	
Electrolyser power [MW]	542 MW
Hydrogen production [tonnes/year]	61,950 tonnes/year
Derivatives productions (hydrogen, ammonia, methanol, other) [tonnes/year] or [m3/year]	350,000 tonnes/year of green ammonia
Electricity supply [MW solar/MW wind/grid/PPA]	726 MW installed capacity of wind farm
Water supply and consumption required [l/year or m3/year]	687,645 m3/year
Amount of CO2 equivalent avoided [tonne CO2/year]	Approx. 560,000 tonnes CO2/year
Amount of investment [USD]	USD 2.099 MM
Expected year of entry into the SEIA	2025
Expected year of entry into operation	2030

RWE Hinicio

7.- H2V CABEZA DEL MAR PROJECT

Company name and description: FreePower SpA and GH Energy

FreePower SpA's mission is to develop large-scale non-conventional renewable energy (NCRE) projects and custom energy solutions that allow for the widespread use of sustainable energies, both in Chile and in South America. FreePower focuses on developing solar, wind, green hydrogen and electrical transmission projects with a team of electrical, environmental, civil and mechanical engineers.

GH Energy aims to assist in the decarbonisation of the planet, using a technology that guarantees a better quality of life for all in the long term. In addition, it aims to modify the power matrix, making it more sustainable. GH Energy's team includes lawyers, engineers and land managers.

Consulting firm that conducted the study: Wood Ingeniería y Consultoría Chile Ltda.

Project description:

The project is located 40 km north of the city of Punta Arenas in the Magallanes and Chilean Antarctica Region, at an industrial facility that includes a wind farm and a water electrolysis plant earmarked for the production of green hydrogen that will directly feed a chemical plant for ammonia synthesis through the Haber-Bosch process. The project will encompass a 9,000-ha area. The energy required for the process is generated by a wind farm. The chemical plant is designed to produce a total of 1,600 tonnes of ammonia per day. The wind farm has a generating capacity of approximately 900–1,000 MW and consists of wind turbines with a capacity of 6–7 MW each, interconnected by a power transmission grid, which feeds directly into the production plant.

The hydrogen plant uses water electrolysis with highly efficient alkaline cells that can be operated in a range of between 20 per cent and 100 per cent of their nominal capacity. The production of hydrogen gas feeds directly into the ammonia production process by means of compressors. The water needed for the process will be obtained using a seawater desalination plant, with reverse osmosis membranes. The high-quality water required by the electrolysers is obtained by passing the desalinated water through a demineralisation process that uses electro deionisation.

The nitrogen plant uses a liquid air distillation process to produce nitrogen gas, which then is passed through compressors to the ammonia production reactor.

The ammonia plant produces ammonia through the Haber-Bosch artificial nitrogen fixation process, which is the most commonly used process for ammonia production worldwide. The capacity of the plant is 2,000 tonnes per day of anhydrous ammonia, which will be condensed and stored at atmospheric pressure at low temperature. The product will then be transported via ships, filled from storage ponds via an onshore pipeline connected to a system of loading buoys.

The support services required by the project include the supply of compressed air, drinking water, sewage treatment, maintenance and operation buildings, as well as access roads to the wind farm for construction and maintenance.

The chemical plant will be built on an approximately 36-hectare site.

The life cycle of the project is 30 years and is currently at the feasibility stage, given that the pre-feasibility engineering for the project has already been evaluated and returned positive results.

Gaps identified:

One of the main gaps lies in the operation, reliability and stability of the internal electrical system; in other words, in keeping the production plant in operation, given that due to its location and size, the project would operate as an island (there is no connection to an electrical grid). To this end, it is expected that other technologies will be integrated to provide reliability and electrical stability. Different environmental impacts have also been identified, but these can be mitigated and offset through the use of a correct and adequate baseline for the entire project, in accordance with the guidelines of the Environment Assessment Service (SEA).

Opportunities identified:

The ammonia-related industry (the end product of the project) is already remarkable today and will soon be given a further boost, since it will also be used as a means of transporting green hydrogen. The location of the project, near the Strait of Magellan, gives it an additional commercial advantage due to the installation of its own port or a service contract for another port, thus facilitating the export of the ammonia to other continents such as Asia or Europe, as well as to areas within the country.

Applications:

- Maritime transport (use as fuel/ammonia)
- Chemical industry (ammonia as fertiliser)
- Electricity generation

Target market:

The first target market will be sales for combustion and power generation uses, for which it will be transported as liquid ammonia, which reduces transport costs and dispersion losses from storage tanks.

A possible future market is the use of ammonia as a fuel for ships. This would significantly reduce oil pollution in the shipping industry.

The fertilizer industry is another important market, where anhydrous ammonia is widely used, making it another relevant market.

Main findings of the study:

It is feasible to produce green ammonia using the winds in the southern zone of the country as an energy source. The technologies selected for the process (hydrogen generation by electrolysis, nitrogen separation, and ammonia synthesis) are evolving rapidly. Advances such as better performance, lower electricity consumption, smaller space requirements and better catalysts allow us to anticipate that there will be positive and substantive changes over the next five to ten years, which will result in more efficient equipment with lower consumption and, thus, a reduction in investment and operating costs

TECHNICAL DESCRIPTION	
Electrolyser power [MW]	700 MW
Hydrogen production [tonnes/year]	80,000 tonnes/year
Derivatives productions (hydrogen, ammonia, methanol, other) [tonnes/year] or [m3/year]	450,000 tonnes/year of ammonia
Electricity supply [MW solar/MW wind/grid/PPA]	944 MW wind
Water supply and consumption required [l/year or m3/year]	Water will be supplied by a desalination plant. Required water consumption is 7,000,000 m3/year, which will be used both for the production of green hydrogen (demineralised water) and for the cooling systems (industrial water). The cooling systems have the largest requirements, using 85 per cent of the water; green hydrogen production will use 15 per cent.
Amount of CO2 equivalent avoided [tonne CO2/year]	960,000 tonnes CO2 equivalent/year
Amount of investment [USD]	USD 3,157,000
Expected year of entry into the SEIA	2024
Expected year of entry into operation	2030

MISSION TO SHARE PRE-INVESTMENT STUDIES, FOR TRAINING IN GREEN HYDROGEN, AND OTHER MATTERS

Between 17 and 23 May 2022, a Technological Mission was carried out to Spain to provide the companies awarded in the call with an opportunity to participate in activities where they could disseminate the results of their pre-investment studies and network with potential investors.

Chilean public officials also participated in the mission so that, together with representatives of the awarded companies, they could attend the 2022 European Hydrogen Energy Conference (EHEC). As part of the activity, the companies presented their pre-investment projects at a side event titled “Green Hydrogen Business Opportunities in Chile”. The mission also included a visit to Spanish plants involved in green hydrogen production, transport and research, such as Calvera, ARIEMA, IBERDROLA and the National Hydrogen Centre.

Thanks to the mission, participants were able to access up-to-date information about the main global developments in the green hydrogen industry, the technical challenges with respect to its transport and other relevant issues related to business exchanges. They also had the opportunity to make a site visit to Europe’s largest operating GH2 plant.

EUROPEAN DEVELOPMENT DAYS EVENT (EDD)

On the 21 and 22 June 2022, representatives of the Ministry of Energy and the Chilean International Cooperation Agency for Development (AGCID), in collaboration with the Embassy of Chile in Brussels, participated in the European Development Days event. This is the main European forum for international cooperation and it brings together different key actors to share ideas and experiences, build new partnerships and foster innovative solutions to the most pressing sustainable development challenges.

At the event, Executive Director of AGCID Enrique O’Farrill-Julien presented an analysis of the Development in Transition strategy and the fruitful cooperation relationship which Chile maintains with the European Union. Camilo Avilés, an expert in new energies at the Ministry of Energy, then discussed the National Green Hydrogen Strategy and presented the results of the project financed by the Chile – European Union Bilateral Fund for Development in Transition.

The project also had a stand at the event to communicate the cooperation partnership between Chile and the European Union and their joint agenda focused on developing renewable energies and, in particular, green hydrogen.

GLOSSARY OF TERMS

- AGCID – Chilean International Cooperation Agency for Development (Agencia Chilena de Cooperación Internacional para el Desarrollo)
- CORFO – Chilean Economic Development Agency (Corporación de Fomento de la Producción)
- ECLAC – Economic Commission for Latin America and the Caribbean
- EDD – European Development Days
- EHEC – European Hydrogen Energy ConferenceEU – European Union
- IEA – International Energy Agency
- INTPA – Directorate-General for International Partnerships
- OECD – Organisation for Economic Co-operation and Development
- PMGD – Spanish acronym for Small Means of Distributed Generation
- PPA - Power Purchase Agreement
- SDGs – Sustainable Development Goals
- SOEC – Solid oxide electrolyser cell

INITIATIVE

"TECHNICAL COOPERATION FOR GREEN HYDROGEN PRODUCTION, STORAGE, TRANSPORTATION AND USE PROJECTS"

CHILE – EUROPEAN UNION
BILATERAL FUND
FOR DEVELOPMENT IN TRANSITION

agcidChile
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