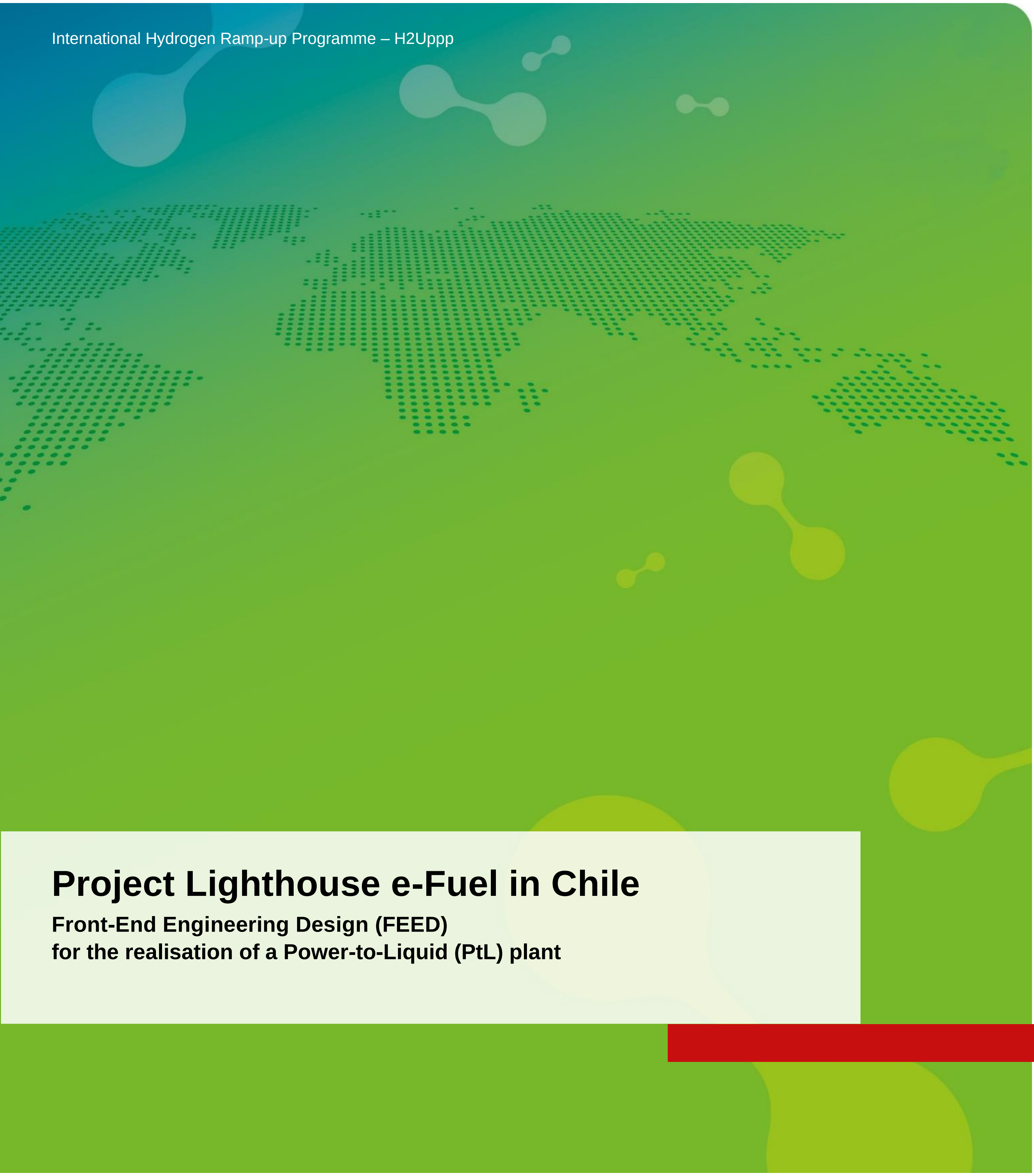

Project Lighthouse e-Fuel in Chile

Front-End Engineering Design (FEED)
for the realisation of a Power-to-Liquid (PtL) plant

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

INERATEC

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

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The International Hydrogen Promotion Program (H2Uppp) of the Federal Ministry for Economic Affairs and Climate Protection (BMWK) of Germany promotes projects and the development of the green hydrogen market in certain developing and emerging countries as part of the National Hydrogen Strategy.

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Santiago, May 2024

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List of Terms and Definitions

The following terms are used in this report:

Term	Definition
Agricultural and Livestock Service (SAG)	The Agricultural and Livestock Service (Servicio Agrícola y Ganadero or SAG) is a governmental agency in Chile responsible for the regulation, oversight, and promotion of agriculture, livestock, forestry, and food safety within the country.
Biogenic CO_2	Refers to carbon dioxide (CO_2) that is released into the atmosphere from natural biological processes, such as decomposition of organic matter or combustion of biomass.
Block Flow Diagram (BFD)	A Block Flow Diagram (BFD) is a simplified drawing or schematic representation that illustrates the overall process flow of a chemical plant or industrial facility.
Coordinador Eléctrico Nacional (CEN)	Coordinador Eléctrico Nacional (CEN) is an entity in charge of coordinating and supervising the operation of the electrical system in Chile. Its main responsibility is to guarantee the safety, reliability and efficiency of the electricity supply throughout the country.
Comisión Nacional de Energía (CNE)	The National Energy Commissionis a government agency responsible for the development, regulation, and oversight of the energy sector in Chile. Its main objective is to promote the sustainable development of the energy sector, ensuring the efficient and reliable supply of energy while respecting environmental concerns and promoting competitiveness within the industry.
Communal Regulatory Plan (PRC)	The Communal Regulatory Plan (PRC) is a land-use planning instrument used in Chile to regulate and guide urban development within a specific municipality or commune (comuna). It is a legally binding document that outlines the zoning regulations, development policies, and guidelines for land use and construction within the jurisdiction of the commune.
e-Fuels	Refers "electrofuels" or "synthetic fuels," are liquid or gaseous fuels produced through the use of renewable electricity and captured CO_2. They are created through processes such as PtL or GtL technologies.
Environmental Impact Study (EIA)	A regulatory process governed by the Environmental Framework Law (Law No. 19,300) and its subsequent regulations. EIA in Chile is conducted is conducted to determine the existence of significant impacts on any of the environmental components (soil, water, air, human environment) linked to the parts, works, and actions of the project at each of its stages.
Environmental Impact Statement (DIA)	Document required for certain types of projects as part of the environmental impact process regulated by the Environmental Framework Law (Law No. 19,300) and its associated regulations. The Environmental Impact Statement (DIA), which allows demonstrating the absence of significant impacts linked to the project in its parts, works, and actions at each of its stages.
FEED	FEED stands for Front-End Engineering Design. It is a crucial phase in the development of engineering projects, particularly in industries such as oil and gas, petrochemicals, power generation, and infrastructure.
Free Customer	Means a consumer having the freedom of choice in selecting a supplier. This term is often used in deregulated or competitive markets where consumers have the autonomy to select their utilities, or other products based on factors such as price, quality, and customer service (e.g. electricity market).
Gas-to-Liquid (GtL)	A technology that converts natural gas or other gaseous hydrocarbons into liquid hydrocarbon fuels or other valuable liquid products.
Green Hydrogen	Hydrogen produced by electrolysis with electricity from renewable energy sources.
Hard-to-Abate Sectors	Refers to industries or areas of the economy that present significant challenges in reducing their greenhouse gas emissions to meet climate targets. These sectors typically rely heavily on fossil fuels and emit large amounts of CO_2 as a result of their processes, making it difficult to transition to low-carbon alternatives.
Industrial CO_2	Refers to carbon dioxide (CO_2) emissions that result from various industrial processes and activities. These emissions can come from a wide range of sources across different sectors of the economy, including manufacturing, energy production, transportation, and agriculture.
Marine Diesel Oil (MDO)	Marine Diesel Oil (MDO) is a type of fuel used in marine diesel engines, primarily for powering ships and vessels. It is a distillate fuel derived from crude oil through a refining process. MDO typically has a lower viscosity and lower sulfur content compared to heavy fuel oil (HFO), another common type of marine fuel.
Offtaker	Company that purchases the product (e.g. hydrogen) based on an off-take agreement.
Power-to-Liquid (PtL)	A technology that converts electrical power into liquid fuels, typically through a multi-step process involving electrolysis of water to produce hydrogen, and subsequent chemical reactions to synthesize liquid hydrocarbon fuels such as synthetic diesel, synthetic gasoline or jetfuel.

Resolución de Calificación Ambiental (RCA)	Resolutive document that approves or rejects the project under evaluation and integrates the most relevant elements of the DIA or EIA, depending on the case. The RCA is issued by the Environmental Assessment Service (Servicio de Evaluación Ambiental or SEA).
Renewable Energy	Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed, such as sunlight, wind, rain, tides, waves, and geothermal heat. The utilization of renewable energy contributes to reducing greenhouse gas emissions, mitigating climate change, enhancing energy security, and fostering economic development.
Sistema Eléctrico de Aysén (SEA)	SEA is an electricity generation, transmission and distribution system located in the Aysén Region, in the extreme south of Chile. This region, known for its natural beauty and relative geographic isolation, faces unique challenges in energy provision due to its mountainous and sparsely populated topography.
Environmental Impact Assessment System (SEIA)	System used to asses the potential environmental impacts of specific projects before their implementation. The SEIA is a environmental management instrument applied by the Environmental Assessment Service (SEA) to determine the magnitude of impacts on different environmental components and to define actions for their mitigation.
Sistema Eléctrico de Magallanes (SEM)	The electricity generation, transmission and distribution system that supplies the Magallanes and Chilean Antarctic Region, located in the extreme south of Chile. This region, known for its extreme climate, mountainous geography and geographic isolation, presents unique challenges in terms of energy provision.
Superintendencia de Electricidad y Combustibles (SEC)	The Superintendency of Electricity and Fuels is a regulatory agency in Chile responsible for overseeing and regulating the electricity, fuels, and natural gas sectors within the country. It operates under the Ministry of Energy and serves as the primary authority for ensuring the safety, reliability, and efficiency of energy supply and distribution.
Sustainable Aviation Fuels (SAF)	Sustainable Aviation Fuels (SAF) are types of aviation fuels that are produced from renewable resources and have lower lifecycle carbon emissions compared to traditional fossil fuels like jet fuel derived from crude oil. These fuels are designed to reduce the environmental impact of aviation, particularly its contribution to greenhouse gas emissions and climate change. SAFs can be produced from various feedstocks such as biomass (like waste oils, agricultural residues, and algae), municipal solid waste, or renewable electricity (through processes like electrolysis to produce hydrogen, which is then converted into synthetic aviation fuels).
Syngas	Syngas, short for "synthesis gas," is a mixture primarily composed of hydrogen (H2) and carbon monoxide (CO), often produced through the gasification of carbon-containing materials such as coal, biomass, or natural gas. It can also be generated through certain chemical processes like steam reforming of hydrocarbons. Syngas is a versatile intermediate product that serves as a precursor for the production of various other chemicals and fuels

Executive summary

This report presents the main results of the project entitled "Project Lighthouse e-Fuel in Chile: Front-End Engineering Design (FEED) for the realisation of a Power-to-Liquid (PtL) plant", developed by INERATEC in collaboration with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH within the framework of the H2Uppp Program. This public-private partnership (PPP) project involves the development of a series of studies aimed at elaborating an innovative and replicable proposal. INERATEC has put a Front-End Engineering Design (FEED) Study into practice to evaluate the technical and commercial feasibility for the installation of a Power-to-Liquid plant allowing a production capacity of 50,000 t/a synthetic fuel in Chile.

The following report encapsulates the comprehensive findings and insights from an in-depth study conducted within the H2Uppp *Project Lighthouse e-Fuel in Chile*. This study aims at analysing the potential and constraints of establishing an e-Fuel production plant. This project has been initiated relying on a growing interest and demand for sustainable fuels in Chile.

This report delves into the multifaceted aspects of a Power-to-Liquid (PtL) project for the production of CO_2 neutral synthetic fuels, exploring its technological advancements, environmental implications, economic viability, and potential for fostering energy independence in Chile. With a focus on both the successes achieved and the challenges encountered, this report serves as a critical evaluation of the PPP project, offering valuable perspectives for stakeholders, policymakers, and industry professionals invested in the sustainable energy landscape of Chile and beyond.

As an integral component of the study, a thorough examination of potential feedstocks, including CO_2, green H_2, and renewable electricity was conducted. The selection of feedstocks plays a pivotal role in determining the sustainability, scalability, and economic feasibility of PtL projects. The availability of mandatory feedstocks plays a determining role in identifying optimal locations for e-Fuel production. Thus, various factors such as feedstock availability, electrical market dynamics, green hydrogen projects and water sources were evaluated to determine the viability of different sites all along the country. The main results of this assessment led to a mapping of 10 high-potential sites.

At the heart of the PPP Project lies INERATEC PtL plant, serving as the cornerstone of innovation and sustainable energy production. The PtL plant's significance within the project is underscored by its comprehensive facility plot plan, meticulously designed to optimize operational efficiency and resource utilization. Detailed insights into the facility's layout provide a holistic understanding of its infrastructure, from feedstock intake to product distribution. A block flow diagram elucidates the intricate processes involved in e-Fuel synthesis, offering a systematic overview of each unit operation within the PtL plant. This visual representation delineates the conversion pathways from feedstock to end-product, elucidating the synergies between various process streams and highlighting opportunities for optimization and integration.

Moreover, the PPP Project emphasizes the importance of local production and assembly, fostering economic growth and technological advancement within Chile. INERATEC commitment to localized manufacturing not only enhances job creation and skills development but also promotes knowledge transfer and technology diffusion, catalyzing the emergence of a vibrant ecosystem of suppliers and service providers.

In parallel, the permitting process for the PtL plant is outlined, delineating the regulatory framework governing project development. Key agencies involved in the permitting process are identified, along with the stages of project development, from initial feasibility studies to operational authorization. By navigating the regulatory landscape with diligence and transparency, the PPP Project endeavors to ensure compliance with environmental standards and community engagement requirements, fostering trust and collaboration among stakeholders.

Furthermore, an exhaustive economic analysis was undertaken to gauge the feasibility of e-Fuel production within the Chilean market, serving as a critical component of the PtL Project's strategic planning. The analysis encompassed a comprehensive assessment of production costs, and market dynamics, aimed at elucidating the economic viability of e-Fuel production amidst prevailing market conditions. Strategies to decrease production costs were rigorously explored, leveraging technological innovations, process optimization, and economies of scale. By scrutinizing each cost component, from feedstock procurement to product distribution, the analysis identified opportunities for cost reduction and efficiency enhancement, thereby bolstering the competitiveness of e-Fuels vis-à-vis traditional liquid fuels.

Furthermore, the potential customer base for e-Fuels was delineated based on volumes of liquid fuels distributed and technical requirements. Through market segmentation and customer profiling, target sectors and industries were identified, ranging from transportation and logistics to aviation and maritime. By aligning e-Fuel specifications with the technical requirements of end-users, such as engine compatibility and fuel performance standards, the analysis sought to unlock market opportunities and drive demand for sustainable alternatives to conventional fuels. Moreover, strategic partnerships and collaborative initiatives were explored to stimulate market uptake and foster industry buy-in. By engaging with key stakeholders, including government agencies, industry associations, and fuel distributors, the PPP Project aims to catalyze the transition towards e-Fuel adoption, positioning Chile as a frontrunner in sustainable energy innovation.

1 Introduction

On behalf of the BMWK, the "International Hydrogen Ramp-Up Programme" (H2Uppp), implemented by the German International Cooperation Agency (GIZ), supports the expansion and development of green hydrogen (GH2) markets and its derivatives, referred to as PtX products, in certain developing and emerging countries. Chile is one of the partner countries of H2Uppp and has the potential to become a global player in green hydrogen production, domestic use, and export, due to its high potential for renewable energy. In this context, the evolution of the green hydrogen market, both in Chile and globally, is becoming increasingly dynamic. Emerging and developing countries need specific support to identify economic pathways for production and use, project opportunities along the value chain, develop business models, as well as improve their regulatory framework for GH2 and PtX products.

The present report offers the main results of the project called "Project Lighthouse e-Fuel in Chile: Front-End Engineering Design (FEED) for the realisation of a Power-to-Liquid (PtL) plant", developed between June 1, 2023, and March 31, 2024, by INERATEC in collaboration with GIZ under the H2Uppp program.

INERATEC, a leading German company in the development and commercialization of Power-to-X and Gas-to-X processes, specializes in producing carbon-neutral synthetic e-Fuels and e-Chemicals. This includes manufacturing sustainable aviation fuel (e-SAF), marine diesel (MDO), and various chemical products such as e-Waxes, e-Methanol, and e-Naphtha. These products directly replace conventional fossil fuels and are compatible with existing infrastructure.

Following the description of the project, it's important to understand the broader context in which it operates. Decarbonization represents a multidimensional challenge that requires the implementation of various strategies and technologies. Among these, renewable energy generation, energy efficiency, electrification of transportation and heating, carbon capture, as well as the development of synthetic fuels, also called e-Fuels, from renewable sources stand out.

In the specific case of Chile, which is distinguished by its potential for the development of renewable energies, it has been determined that e-Fuels emerge as a promising option for defossilizing transportation and contributing to the reduction of greenhouse gas emissions. Furthermore, part of the measures aimed at achieving carbon neutrality is the National Green Hydrogen Strategy, published by the Ministry of Energy in 2020. This approach focuses on the development and use of Green Hydrogen as an alternative to gradually eliminate fossil fuel consumption in the country.

In this context, establishing an e-Fuel production plant in Chile, undergoing the so-called Power-to-Liquid[1] (PtL) processing route, can serve several strategic objectives, both for the country and for the investors involved, such as:

- **Energy Diversification***:* Chile heavily relies on imported fossil fuels for its energy needs. By establishing e-Fuel production plants, Chile can diversify its energy sources, reducing dependency on imports and enhancing energy security.
- **Renewable Energy Integration***:* Chile possesses abundant renewable energy resources, particularly solar and wind. An e-Fuel production plant can utilize potential renewable electricity during periods of high generation, thereby helping to balance the grid and integrate more renewable energy into the system.
- **Decarbonization***:* Power-to-Liquid (PtL) technology offers a pathway for decarbonizing hard-to-abate sectors such as transportation and industry. By producing e-Fuels from renewable electricity and CO_2 captured from the atmosphere, biogenic or industrial processes, Chile can reduce its carbon footprint and contribute to global efforts to combat climate change.
- **Economic Development***:* Establishing an e-Fuel plant can stimulate economic growth by creating jobs, attracting investment, and fostering innovation in the renewable energy and clean technology sectors. It can also serve as a catalyst for the development of a domestic supply chain for renewable energy equipment and materials.

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[1] Power-to-Liquids (PtL) is a production pathway for liquid hydrocarbons based on electric energy, water and CO_2 as resources.

- **Export Opportunities***:* Chile's strategic location and abundant renewable energy resources position it well to become a regional hub for e-Fuel production. Synthetic fuels produced in Chile could be exported, helping to meet their energy needs while generating revenue for Chilean companies.
- **Technology Leadership***:* By investing in PtL technology and infrastructure, Chile can position itself as a leader in the global transition to a low-carbon economy. This could attract partnerships, research collaborations, and further investment in clean energy projects within the country.
- **Energy Independence***:* Producing liquid fuels domestically reduces reliance on volatile international energy markets and enhances Chile's energy independence. This can be particularly important in times of geopolitical instability or disruptions to global supply chains.
- **Environmental Purpose***:* In addition to reducing greenhouse gas emissions, producing e-Fuels can help mitigate other environmental impacts associated with traditional fossil fuel extraction and combustion, such as air and water pollution.

2 The PPP project

2.1 PPP background

At the end of 2020, the Chilean Government through the Ministry of Energy launched Chile's Green Hydrogen Strategy, focusing on the development and use of green hydrogen to phase-out all fossil fuels consumed by the country by 2050. This strategy is one of the keys to reach net zero in accordance with the energy plans of the Chilean Government.
In the short term, one of the main objectives of this strategy is to promote the local demand of green hydrogen and derivatives in Chile. This will help to ramp-up the domestic hydrogen market, as well as to prepare the base conditions and specialized local capacities needed for the development of the large export projects planned for 2030.

The effort to limit global warming calls for decarbonization and new technologies in many sectors. While some industry sectors can be easily electrified with renewable power, other sectors like the mining, maritime, aviation and heavy- duty transport sectors are facing big challenges when it comes to reduce their CO_2 emissions and de-fossilize their fleets. For these applications, so-called electrofuels (e-Fuels), produced from renewable electricity and unavoidable CO_2, may be a promising option, especially in countries with high wind and solar energy potentials, such as Chile. In the present project idea, the prospects of electrofuels in Chile will be investigated.

2.2 Private sector partner in the PPP collaboration: INERATEC

INERATEC is the leading company for the development and commercialization of Power-to-X and Gas-to-X processes for the production of carbon-neutral and climate-friendly synthetic e-Fuels and e-Chemicals, such as drop-in ready sustainable aviation fuel (e-SAF), marine diesel (MDO), and other chemical products, such as e-Waxes, e-Methanol and e-Naphtha. The fuels are directly replacing the fossil crude oil products and are compliant with the existing infrastructure.

Established in 2016 and building upon more than two decades of research and excellence in the field of chemical and process engineering, INERATEC has developed and commercialized a standardized and modular synthesis technology that is capable of recycling the greenhouse gas CO_2 and uses green hydrogen generated from renewable electricity to produce so-called e-Crude and e-Waxes for the chemical industry. The synthesis units are equipped with INERATEC's patent-protected micro-structured chemical reactor technology that strongly intensifies the chemical process resulting in superior performance.

The key benefits are:

- **Modularity and compactness:** INERATEC synthesis units are equipped with the most compact and most efficient chemical reactor technology in the world. The all-metallic chemical reactors are manufactured from micro-structured metal plates, resulting in standardized reactors suitable for serial production. The chemical reactors serve as a synthesis platform and can be used for Fischer-Tropsch synthesis, Methanol synthesis, RWGS synthesis and methanation. Due to process intensification the process is characterized by unique compactness (80x more compact than with conventional chemical reactors).
- **Highest efficiency:** Micro-structuring enables a tremendous increase of heat and mass transfer for demanding chemical reactions and in turn results in a 2x more efficient process based on exergetic efficiency compared to conventional technology.
- **Load flexibility:** As a result from compact reaction volumes and process intensification, INERATEC'ssynthesis modules are load-flexible, and making them ideally suitable for the operation with fluctuating renewable energy supply. Additionally, the units are characterized by very short start-up and shut-down times, making them safe to operate.
- **Scalability:** The synthesis units are standardized and scaled-up via numbering-up, and ready to be mass-produced, while scaling in a way similar to photovoltaic (PV) modules, battery cells, and electrolysers. In parallel, the chemical reactors are scaled-up, increasing the capacity of each module. INERATEC has already reached the multi-megawatt scale and is aiming for Gigawatt capacities by 2030. Scale-up via modularization will also decrease project and investment risk, resulting in faster FID.

- **Lowest e-Fuels production costs:** The modular approach allows for a serial production of reactors and synthesis units, ready to be shipped and installed, significantly shortening planning and construction processes. At the same time standardization and mass production results in CapEx reduction compared to conventional technology.

Additionally, INERATEC aims at achieving OpEx reduction by implementing the modules in global sweet spots (e.g. Chile), with ideal access to low-cost renewable electricity and feedstock availability. With this approach, INERATEC is supplying the synthesis modules along the availability of green hydrogen and CO_2, matching the available upstream technology, i.e. electrolysers, carbon capturing units and gasification units. The INERATEC process is agnostic to the feedstock, providing a wide range of process options, always aiming for the lowest e-Fuels production costs.

2.3 Scope and objectives of the PPP project

In order to assess the potential and possible constraints of an e-Fuel production plant in Chile, INERATEC has put a Front-End Engineering Design (FEED) Study into practice to evaluate the technical and commercial feasibility for a Power-to-Liquid plant allowing a production capacity of 50,000 t/a synthetic fuels, using approximately 23,000 t/a green H_2 and recycling up to 170,000 t/a CO_2.

This study will enable understanding Chile's position regarding the production of synthetic fuels. Considering that Chile consumes over 14 million tons of fuel annually (Table 15) and that, in 2020, 26% of its energy matrix consisted of crude oil[2], analyzing the feasibility of synthetic fuel production would assist Chile in achieving its decarbonization goals and also move it towards greater energy independence. It is within this context that the objectives of this project are established: Within this context, the objectives of this project are established, with the following specific objectives aimed at being achieved by the FEED study:

- Identify and analyse different locations in Chile for establishing e-Fuel plants.
- Develop and optimize the design of the PtL plant to best fit the local requirements regarding technical and feasibility.
- Investigate the environment of local stakeholders to build a sustainable value chain for e-Fuels in Chile.
- Assess the economic plant efficiency and exploitation potential.

Furthermore, the study benefits the public and private sector by promoting and making visible the sustainable pathway for the development of e-Fuel projects in Chile by:

- Defining and explaining the basic principles, components, and processes of a PtL plant based on green hydrogen and unavoidable CO_2 sources.
- Delivering the Block Flow Diagram (BFD) as a blueprint for other PtL plants.
- Identifying synergies and possible local stakeholders for the supply of the required feedstock: water, renewable electricity, unavoidable CO_2, fuel upgrading; as well as relevant stakeholders like authorities delivering permit, possible offtakers, local procurement, certification bodies, among others. This would be extremely helpful for other project developers interested to enter this promising market in the future, giving them the opportunity to seek cooperation opportunities with the different stakeholders identified.
- Showing the enabling conditions for the development of a PtL production plant, both in terms of technical requirements as well as in terms of economic parameters, e.g., business cases to attract potential investors, market research, CAPEX and OPEX estimations.

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[2] Available at: Informe Balance Nacional de Energía 2020 (energia.gob.cl).

2.4 Methodological approach

By following a systematic and rigorous methodological approach, INERATEC effectively evaluated the technical and economic feasibility of establishing e-Fuel production plants in Chile that contribute to the transition towards a sustainable and carbon-neutral energy future. Resulting from a public call for proposals launched by INERATEC to identify and select local engineering companies to support the implementation of the study, the choice fell on the Chilean engineering company, Gamma Ingenieros S.A.S.[3], who has been granted to perform the sweet-spot-analysis at local level.

Performing a sweet spots analysis involves identifying areas where various factors align favorably, often resulting in optimal outcomes or opportunities. Following factors have been assessed:

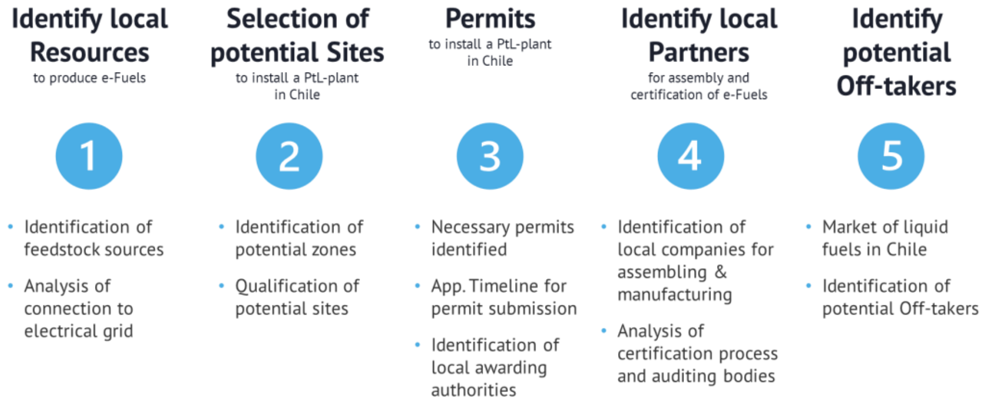

Figure 1. Factors identified within the sweet spots analysis.

Through a synthesis of desktop research and interviews with relevant companies, this analysis endeavors to offer a comprehensive overview of the mandatory prerequisites for establishing e-Fuel production. By doing so, it aims to furnish stakeholders across the value chain with valuable insights to inform their strategic decisions. Specifically, one-to-one interviews have been conducted with public (e.g. Superintendency of Electricity and Fuels (SEC), Vuelo Limpio, etc.) and private organisations (e.g. pulp & paper industry, cement, water distribution, etc.) underscoring a multi-stakeholder approach, fostering synergy and collective action towards the common goal of advancing sustainbaile energy solutions in Chile.

3 Sweet spots analysis

When profiling potential sites for the establishment of e-Fuel production plants, several criteria need to be carefully considered to ensure the success and sustainability of the project. For example, zoning regulations and land use restrictions may affect the suitability of potential sites for e-Fuel production plants. Sites should be located in areas zoned for industrial use and compliant with local land use regulations. Consideration should also be given to factors such as land availability, land acquisition costs, and compatibility with surrounding land uses. Furthermore, the availability and proximity to the primary feedstock sources are crucial. Suitable feedstock for e-Fuels production include captured carbon dioxide, renewable electricity, renewable hydrogen, syngas or a combination thereof. Sites located near abundant and sustainable sources of feedstock can reduce transportation costs and logistical challenges. Also adequate infrastructure and utilities are essential for the operation of e-Fuel production plants. Sites should have access to water for process requirements, cooling purposes, but also for producing the necessary hydrogen as feedstock. Availability of electricity and other utilities is also important; e.g. proximity to dedicated substations for accessing the grid. Additionally, proximity to transportation networks, such as roads, railways, and ports, facilitates the transportation of feedstock and finished products.

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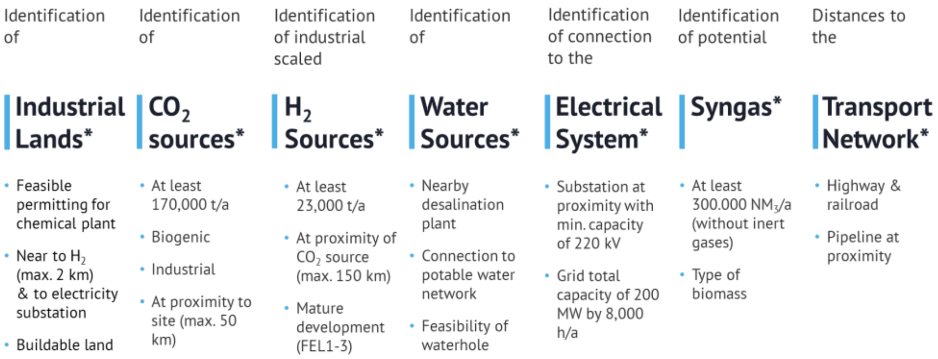
[3] Information available at: https://gammaingenieros.com/

In the following figure, mandatory criteria are presented which are relevant for profiling and qualifying potential sites.



Identification of	Identification of	Identification of industrial scaled	Identification of	Identification of connection to the	Identification of potential	Distances to the
Industrial Lands*	**CO_2 sources***	**H_2 Sources***	**Water Sources***	**Electrical System***	**Syngas***	**Transport Network***
• Feasible permitting for chemical plant • Near to H_2 (max. 2 km) & to electricity substation • Buildable land	• At least 170,000 t/a • Biogenic • Industrial • At proximity to site (max. 50 km)	• At least 23,000 t/a • At proximity of CO_2 source (max. 150 km) • Mature development (FEL1-3)	• Nearby desalination plant • Connection to potable water network • Feasibility of waterhole	• Substation at proximity with min. capacity of 220 kV • Grid total capacity of 200 MW by 8,000 h/a	• At least 300.000 NM_3/a (without inert gases) • Type of biomass	• Highway & railroad • Pipeline at proximity

Figure 2. Mandatory criteria for site profiling.

3.1 Identification of available feedstocks

3.1.1 Feedstock requirements for PtL/GtL plant by INERATEC

INERATEC aims at realising Power-to-Liquid (PtL) and/or Gas-to-Liquid (GtL) plants to produce approximately 50.000 tons of e-Fuels per year. The power-to-liquid (PtL) process is a method of producing synthetic fuels involving:

1. **Electrolysis:** Renewable electricity, such as solar or wind power, is used to split water (H_2O) into hydrogen (H_2) and oxygen (O_2) through electrolysis. This step requires an electrolyzer, which can be powered by renewable energy sources.
2. **Syngas Production:** The hydrogen produced from electrolysis is combined with carbon dioxide (CO_2) from different sources to produce syngas (a mixture of hydrogen and carbon monoxide) via the water-gas shift reaction. CO_2 can be captured from industrial processes, direct air capture, or even from biogenic sources.
3. **Fischer-Tropsch Synthesis:** The syngas is then fed into a Fischer-Tropsch reactor, where it undergoes catalytic reactions to produce liquid hydrocarbons. These hydrocarbons can range from light to heavy fractions, resembling conventional fuels such as gasoline, diesel, or jet fuel.

If we consider **continuous production for approximately 8,000 hours/a and production outputs from 50.000 t/a**, the **PtL plant** will require **170.000 tons of CO_2** per year, **23.000 tons of H_2** per year, **300 million liters of water** per year and **approximately 214 MW renewable power** (considering the H_2 production)[4].

Another way to produce e-Fuels is to undergo the so-called **Gas-to-Liquid (GtL) process** which involves the conversion of natural gas or syngas into liquid hydrocarbons through the Fischer-Tropsch synthesis. Syngas can be produced from various sources, including natural gas, coal, biomass, or even renewable electricity. The most common method involves the gasification of carbonaceous materials, such as coal or biomass, followed by the water-gas shift reaction to adjust the ratio of hydrogen to carbon monoxide. INERATEC mainly focuses on biogenic sources as syngas sources guaranteeing effective GHG emissions against fossil coal or natural gas. Using syngas as a feedstock for e-Fuel production is a promising approach in the quest for sustainable energy solutions.

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[4] If INERATEC buys H_2 from a third party, the plant would require approximately only 30 MW of renewable power, since the hydrogen does not need to be produced on site.

Syngas, which is a mixture of carbon monoxide (CO) and hydrogen (H_2), can be obtained from various sources such as biomass, natural gas, or coal through processes like gasification. The advantage of using syngas as a feedstock for e-fuel production lies in its versatility and potential for carbon neutrality. By utilizing renewable sources for syngas production, such as biomass or renewable electricity for electrolysis, the resulting e-fuels can have a significantly lower carbon footprint compared to traditional fossil fuels.

At the current stage, there are any production of syngas in operation yet in Chile. However, the country's abundant renewable energy resources and biomass sources, primarily concentrated in regions like BíoBío, lay the foundation for unlocking the potential of syngas production. Syngas can be produced through various methods such as biomass gasification or by using renewable electricity to electrolyze water and produce hydrogen, which can then be combined with carbon dioxide to produce syngas. Given Chile's commitment to renewable energy and efforts to reduce carbon emissions, there may be high potential in exploring syngas production as a precursor to e-Fuel production or for other industrial applications. Additionally, syngas can also be used as a feedstock for chemical synthesis, providing opportunities for diversification of the country's industrial base. However, the development of syngas production infrastructure in Chile would likely depend on factors such as technological advancements, policy support, and investment incentives. As renewable energy technologies continue to advance and become more cost-competitive, it is possible that syngas production could become a viable option for Chile in the future.

3.1.2 Sources of CO_2

The production of e-Fuels through a PtL process requires CO_2 as feedstock, which can be obtained from a point source (industrial, biogenic) or directly from the air. According to INERATEC's requirements, the scope of this study is limited to the identification of point sources of CO_2.

Point sources of CO_2 can be classified into 2 different categories:

1. **Industrial Sources:** These include emissions from industries such as cement production, steel manufacturing, mining, refining, chemical production, and power generation from fossil fuels. These industries often release significant amounts of CO_2 as a byproduct of their processes, particularly those involving the combustion of fossil fuels or the calcination of limestone (as in cement production).
2. **Biogenic Sources:** Biogenic CO_2 emissions stem from natural processes or human activities involving biological materials. Examples include fermentation processes in breweries or bioethanol production, biomass combustion for heating or power generation, and decomposition of organic matter in landfills. While these sources emit CO_2, the carbon released was originally absorbed from the atmosphere during the growth of the biological material, making biogenic emissions part of the natural carbon cycle.

To identify CO_2 sources, data from the latest available report from the Emissions and Pollutant Transfer Register (RETC)[5] of the Ministry of the Environment (MMA) were considered, relying on data of 2021 and published in 2022. This register is a public database designed to capture, systematize, and analyze information about potentially harmful pollutants to health.

As seen in Figure 3, the following chart presents the total CO_2 emissions to be considered by INERATEC per region.

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[5] Information available at: Ministry of Environment (MMA), "Consolidated Report on Emissions and Transfers of Pollutants" (ICETC-RETC), 2022.

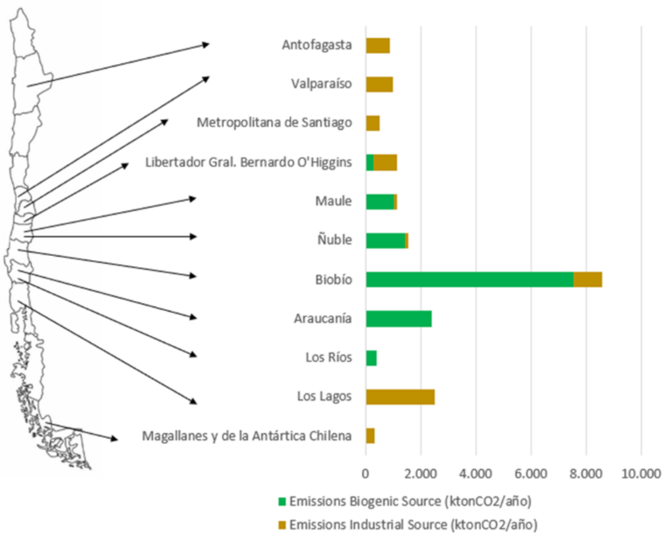

Figure 3. Total emissions of CO_2 per region and per type of source.

It shows that the Biobío region has the highest emissions, around 8.6 million tons per year, followed by the regions Los Lagos and Araucanía with 2.5 and 2.4 million tons of CO_2 per year, respectively.

On the other hand, the industry with the highest CO_2 emissions is the pulp and paper industry, specifically the companies Celulosa Arauco and CMPC (both cellulose's companies), accounting for nearly 50 % of the potential emissions to be considered by INERATEC. The rest is emitted by manufacturing industries, biomass-based thermoelectric power plants, mining, etc.

Finally, from the total potential CO_2 emissions to be considered by INERATEC, 13.1 million tons per year are considered biogenic sources (64 % of total), with black liquor being the primary source, followed by biomass accounting for 36 % and 28 % of the total potential CO2 emissions, respectively.

Carbon capture systems in Chile

At this time, most industries in Chile do not have CO_2 capture systems installed, except for breweries, which obtain CO_2 from the fermentation process and use it directly in their products (they inject the CO_2 into the beers). Additionally, conversations with Air Products and Linde Chile indicate that there are only two companies disposing of CO_2 capture systems in Chile: The first one is integrated in the ENAP Hualpén refinery (Biobío), using tail gas technology, owned by Air Products, while the second system is installed in the ENAP Concón refinery, which is obtained from the hydrogen production process.

3.1.3 Sources of green H_2

Currently, in Chile, there are more than **59 projects or initiatives** associated with green hydrogen and PtX production that have been announced by various companies in the previous years[6]. Specifically, **25** of these projects have reported that their electrolysis capacity will be **less than 3 MW**, while **34** of them are projected to have **at least 3 MW** and even higher capacity. The following table shows the number of projects by capacity range:

Capacity Range	Amount	Total Capacity (MW)
0 to 3 MW	25	26
3 to 50 MW	9	148
50 to 200 MW	3	355
200 to 500 MW	1	300
500 to 1000 MW	6	4,356
> 1000 MW	15	36,550
Total	59	41,735

Table 1. Amount of project per capacity range.

Considering only the projects that could potentially produce at least 23.000 tons of H_2 per year, which is the amount of H_2 that is needed for a 50.000 t/a production of synthetic fuel, only 22 projects can be considered. Amongst the 22 projects, **13 projects** are in the **Antofagasta region** with approximately 19.6 GW of capacity, and **9** are in the **Magallanes region** with approximately 21.6 GW of capacity. It can be observed that the large H_2 production projects are mainly located in **the northern desert region** due to the **solar radiation** and **in the southern part** of the country due to the **wind capacity**.

As stated in the following figure, 4 projects have been chosen from the pool of 22 potential projects due to their advanced stage of development, enabling production to commence as early as 2026.

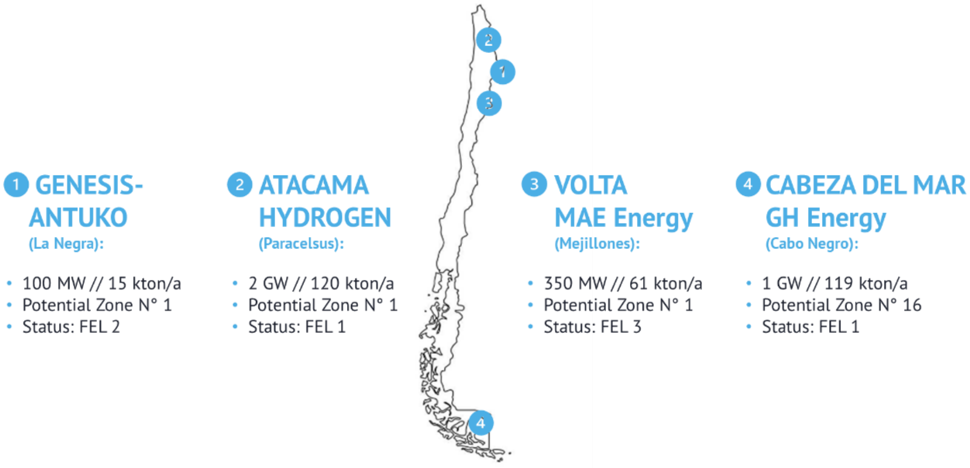

Figure 4. Main relevant H2 projects for a 50.000 t/a e-Fuel production.

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[6] Information gathered through interviews with representatives of hydrogen associations (e.g. H2 Chile, GEHMA), GIZ (4e Chile Program), market intelligence portal (B2B) and from company websites.

3.1.4 Renewable electricity in Chile

In Chile, the installed potential capacity for electricity generation is approximately 33.8 GW, of which around 20.5 GW are renewable project facilities. This information was obtained from the National Energy Commission (CNE) and the National Electric Coordinator (CEN). The following figure show the installed capacity of renewable power plants broken down by source type and by region (from north to south).

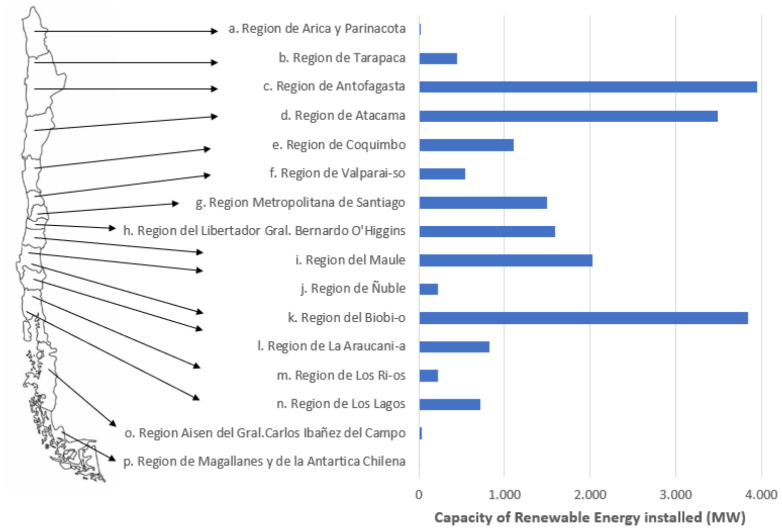

Figure 5. Installed renewable energy capacity in Chile per region.

Out of the total installed renewable capacity in Chile, nearly 50% is generated by 5 major power generation companies:

	Company	Capacity
1	ENEL	5,988 MW
2	COLBÚN	1,786 MW
3	ENGIE	260 MW
4	ACCIONA ENERGY	540 MW
5	AES GENER	537 MW

Table 2. Renewable energy companies.

3.1.4.1 Electrical systems in Chile

In Chile, the Sistema Eléctrico Nacional (SEN) constitutes a vast interconnected electrical grid stretching from the Arica and Parinacota Region to Chiloé Island (Los Lagos Region). Spanning over 3,100 kilometers of the national territory from north to south, it encompasses more than 35,000 kilometers of power lines. Additionally, there are two medium-sized systems: the Sistema Eléctrico de Aysén (SEA), serving the Aysén Region, and the Sistema Eléctrico de Magallanes (SEM), catering to the Magallanes Region. Oversight of all electrical systems in Chile falls under the purview of the Coordinador Eléctrico Nacional (CEN), responsible for the daily scheduling of all power generation plants

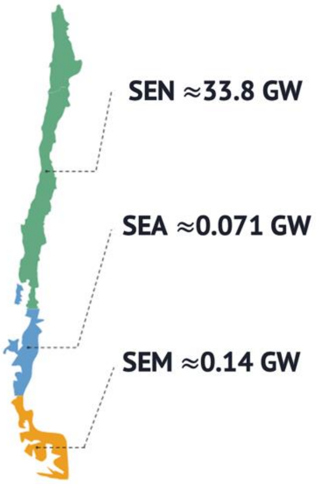

Figure 6. Electrical systems in Chile.

3.1.4.2 Renewable energy projects in construction

As of August 2023, data from the CNE[7] indicates that Chile has 5.3 GW of renewable power plants under construction, distributed across 82 installations. Among these, solar photovoltaic parks lead the way with a capacity of 3.1 GW, followed by wind parks and small hydroelectric (run-of-river) plants with capacities of 1.8 GW and 0.4 GW, respectively.

Technology	MW
Photovoltaic	3.093
Wind	1.794
Small hydroelectric	386
Total	5.273

Table 3. Renewable energy project in construction per technology.

On the other hand, 44 % of these projects are located in the Antofagasta region, followed by the Atacama region with 17 %, precisely in the northern regions of Chile where there is a greater availability of solar power. Finally, the following table shows the top 5 owners of these projects under construction, with Colbún, ENEL, and Engie who already have a significant installed renewable capacity and continue to build new projects.

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[7] Information available at: Nacional Energy Commission (CNE), "Projects declared under construction", 2023, [On line] <https://www.cne.cl/tarificacion/electrica/declaracion-en-construccion/>

Company	MW
COLBÚN	816
ENEL	601
CEME	480
ENGIE	342
COPIAPÓ SOLAR	293
Others	2.741
Total	**5.273**

Table 4 Renewable energy project capacity in construction, per owner.

3.1.5 Electrical market in Chile

The electric offer in Chile consists of **three sectors** which provide electrical energy to the various points of the country. First, there is the **(1) generation sector**, which is responsible for producing the electricity. The next is the **(2) transmission sector**, which is responsible for transmitting the energy, at **high voltage levels**, to all points of the electric system. Finally, there is the **(3) distribution sector**, which is responsible for distributing energy **at lower voltage levels** than those of transmission, from a certain point in the electric system to mostly regulated consumers (low consumption customers). The physical interconnection of the components of each of these sectors is the electric system.

3.1.5.1 Electrical transmission in Chile

The transmission segment in Chile is a natural monopoly due to the significant economies of scale involved in its development, and it operates as a public service. Consequently, it is heavily regulated. Additionally, it is a capital-intensive activity, and given the extended economic lifetime of transmission infrastructure (typically 30 to 50 years), there must be an elevated level of certainty regarding the recovery of invested capital. This activity conducted by private entities and the National Energy Commission (CNE) determines the required infrastructure in the system each year, which is then subject to competitive bidding.

In 2016, the Transmission Law in Chile (Law 29.396) was modified. This law defined and modified various aspects, including new transmission systems (national, zonal, dedicated, and development poles, among others), expansion works, remuneration mechanisms, and the scope of open access, meaning that owners cannot deny the use of the transmission system. Instead, it is the responsibility of the National Coordinator of the Electric System (CEN) to determine the technical capacity of the system. If there is no technical capacity, the CEN must inform the CNE of the need to include more infrastructure in the expansion plan (every 4 years). If a project needs to be completed in a shorter period, the new law includes Article 102, which states that new works can be introduced when the need and urgency for them are justified (this justification must also come from the CEN).

Another crucial point is that the location factor for transmission remuneration was eliminated in Chile. Therefore, in terms of tariffs, where the project connects to the system may not be relevant, there could be some difference in prices due to electrical grid congestion issues. However, the 2016 amendment to the law obliges users to connect only at substations, meaning that direct connection to the power grid via “tap-offs” is no longer allowed (exceptions exist for dedicated transmission lines, like projects disconnected from the grid, model used for large-scale hydrogen production projects.). This means that INERATEC will have to connect to a substation near the location where the PtL plant will be situated to supply electrical power to the plant.

N.B: There is no uniform connection fee. Everything will depend on the type of project, capacity, number of lines, etc. On the other hand, it’s necessary to take into account some costs for technical studies that the National Electric Coordinator (CEN) must conduct prior to the connection.

3.1.5.2 Estimation of the total cost of electricity supply

A free customer in Chile (customers with a power capacity greater than 5,000 kW) will be required to pay the following components for electricity costs:

a. Electricity Price according to the Power Purchase Agreement (PPA) contract.
b. Power Price (Electrical Capacity).
c. Transmission Price or grid cost (national, zonal, and dedicated if applicable).
d. Other costs (complementary service (SSCC), over cost, stabilized price, public service, etc.).

N.B: All these costs depend on the consumed energy, except for the power price, which is the only charge dependent on the installed plant power.

Power Purchase Agreement (PPA)

A renewable Power Purchase Agreement (PPA) is a contract for the sale and purchase of electric power, typically long-term, between an electricity generation company and the end customer (usually it is intended for industries). In this arrangement, both parties assume reciprocal obligations. To facilitate this, INERATEC will need to enter a contract with a renewable generator, with sufficient projects to ensure that withdrawals of electric power meet the final customer's demand, are offset by injections of generated renewable electric power (creating an internal renewable energy balance). For contracting purposes, a free customer has the flexibility to define its own contracting strategy. Among the contracting strategies are direct negotiation, one-to-one processes, or the development of a public or private bidding process.

According to energy market information, some of the clauses being negotiated in new PPAs include:

a. **Supply Blocks:** What is sought in free contracts is to establish an annual energy supply, which is usually divided into energy blocks, whether these are based on specific time periods or not. This is in accordance with the conditions set by the customer in their supply bidding processes.
b. **Energy Price:** Typically, in these types of contracts, a price is established in USD/MWh. This value is fixed at the beginning of the supply and is later indexed by the US Consumer Price Index (CPI) on an annual, semi-annual, or monthly basis. However, there are negotiations where the price is indexed to other market variables such as the Chilean Consumer Price Index (IPC-Chile), the price of coal, or marginal costs of a particular electric S/E.
c. **Power Price:** This type of charge is paid for withdrawals from the system, where a Pass-Through arrangement is established.
d. **Transfer of Other Costs:** Associated with the energy supply contract, there are various costs that are specific to the sector, many of which are difficult for end customers to understand and manage. In this regard, the transfer of costs in a Pass-Through arrangement is naturally accepted for some costs, such as Tolls, Ancillary Services, and System Surcharges.
e. **Auto-generation:** Considering the current reality regarding environmental and social responsibility aspects demanded by society from companies, customers require the establishment of a condition that allows them, during the contract period, to implement energy efficiency and/or self-generation projects.
f. **Exit Clauses and Early Termination:** Considering the length of contracts, the uncertainty of the long term, and the potential catastrophic contingencies a customer may face, it is necessary to include conditions that facilitate the early termination of the contract before its expiration. This should anticipate fair compensations to protect the supplier and maintain an economic balance in the signed contract. A highly requested tool is the use of compensation tables, for example, with respect to the remaining months until the end of the contract.
g. **Green Energy Certification:** Many customers belong to international groups or trade their products abroad, a situation that requires compliance with standards and regulations regarding the traceability of their products and the environmental impact derived from their processes.

Power price

The power price is the only electrical charge that depends on the installed power of the plant and not on the consumed energy. Currently, this value is close to 12 USD/kW-month (stand: January 2024)[8]. For billing purposes and the calculation of the power price for the 12 months of a year, the installed power is calculated as the **average of the 52 maximum demands during peak hours (18:00 to 23:00 hrs.)** between the months of April to September of the previous year.

For example:

- Average of the 52 maximum demands in 2023 = 10 MW.
- Power price for the next 12 months (2024) = 10 MW*12 USD/kW-month = 120.000 USD/month.

In other words, if during these peak periods between the months of April to September, INERATEC operates its PtL plant at partial load, the total cost for power for the next 12 months of the following year will be reduced proportionally to the load at which it operates. This allows for operating at higher loads during other time periods.

N.B.: There is no type of volume discount in the Chilean market. The only competitive advantage is the ability to negotiate directly with a generator the price of energy (PPA), so the greater the consumption, the greater the bargaining power.

Grid and other costs

On the other hand, the payment for the use of networks (national, zonal, and dedicated transmission) is regulated, as provided in Article 115 of the General Electricity Services Law (LGSE). Additionally, the tariffs associated with the provision of Complementary Services (SSCC)[9] are also defined in the LGSE, in Article 72-7. Both tariffs are charged to free and regulated customers in Chile through a Single Charge, expressed in CLP/kWh. The following table shows a projection of transmission rates and complementary services, in addition to other supply charges up to the year 2030.

Description	Unit	2023	2024	2025	2026	2027	2028	2029	2030
National/Zonal Transmission	US$/MWh	14,0	14,5	16,5	17,0	21,0	23,0	23,0	23,0
Dedicated Transmission	US$/MWh	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0
MT overcosts	US$/MWh	5,0	6,0	6,0	6,5	6,5	6,5	6,5	6,5
SSCC	US$/MWh	0,5	0,5	3,5	3,5	3,5	3,5	3,5	3,5
Green tax compensations	US$/MWh	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Stabilized price	US$/MWh	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Others (Line Item)	US$/MWh	0,0	0,0	0,5	0,5	0,5	0,5	0,5	0,5
Public Service (SSPP)	US$/MWh	1,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0
Total other charges	**US$/MWh**	**23,5**	**26,0**	**31,5**	**32,5**	**36,5**	**38,5**	**38,5**	**38,5**

Table 5. Projection of other supply charges.

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[8] Information available at: https://www.statista.com/statistics/1373368/monthly-industrial-electricity-price-chile/

[9] SSCC are at least frequency control, voltage control and service recovery plan.

As mentioned earlier, all these transmission costs and other charges depend on the consumed energy. However, the price of zonal transmission also depends on the energy withdrawal point of the system (according to the zone where the project is located) and the voltage level (the table above shows only an average of them), where charges are lower in the central and northern regions of the country and increase in the southern regions. For example, according to the Res. Ex. N°206, CNE publishes a report on transmission system usage charges in Chile every 6 months. The following tables show the zonal transmission charges in different areas of Chile for 2 voltage levels (110 kV and 66 kV):

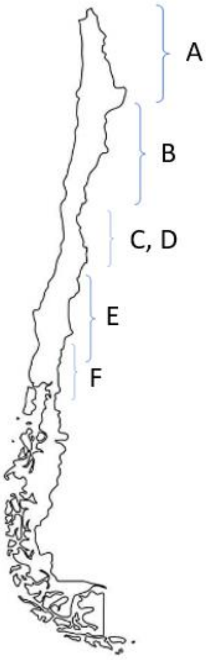

Table 6. Transmission zonal charges for 110 kV.

Tx Zonal System	Region of Chile	Charge (USD/MWh)
A	Arica to Antofagasta	5,57
B	Antofagasta to Coquimbo	4,82
C	Valparaíso	0,00
D	RM	3,12
E	O'higgins to Araucanía	4,64
F	Los Ríos & Los Lagos	3,70
		3,64

Table 7. Transmission zonal charges for 66 kV.

Tx Zonal System	Region of Chile	Charge (USD/MWh)
A	Arica to Antofagasta	6,69
B	Antofagasta to Coquimbo	6,63
C	Valparaíso	0,00
D	RM	3,12
E	O'higgins to Araucanía	11,39
F	Los Ríos & Los Lagos	14,46
		7,05

N.B: In Chile, the Complementary Services market (SSCC) is currently not fully active, which means that this critical activity is not yet being compensated. However, in compliance with technical regulations, all major customers connected to the transmission system, such as INERATEC, are required to implement a Complementary Service known as the Automatic Load Disconnection Scheme (EDAC, for its Spanish acronym). This scheme enables frequency control by allowing for partial or total interruption of their supply. It is anticipated that within a period of two years, the SSCC market in Chile will become fully operational, and consequently, this essential service will be compensated accordingly.

Given the information provided, the following figure illustrates a projection of total electricity supply costs up to the year 2030, delineated by distinct cost components. The price per unit of power has been estimated considering a typical load factor of 65%[10].

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[10] Load factor is the average load divided by the maximum load in a specific time period.

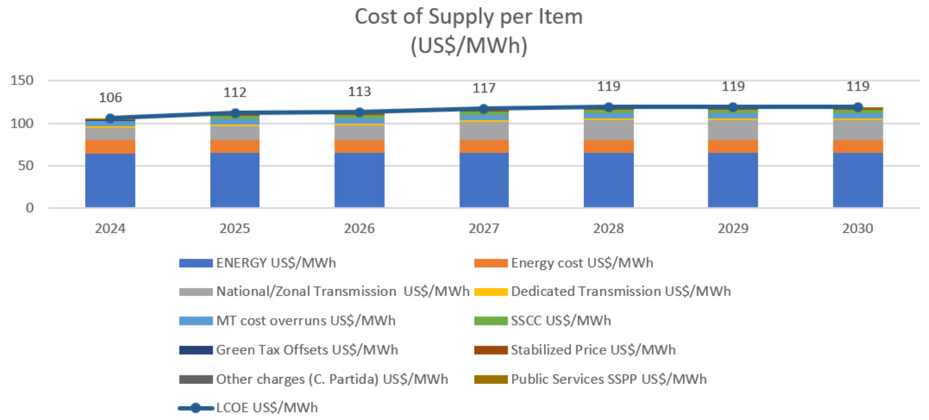


Figure 7. Projection of total electricity supply costs until the year 2030.

It is considered that with even more renewable energy projects, the electricity prices in Chile may remain stable as well as the supply costs, hovering around $119 USD/MWh. This stability is due to increasing system costs, which offset the potential price reduction. These system costs are primarily driven by the need for complementary services essential to maintain operational security, especially with the introduction of more variable renewable generation. Moreover, transmission costs are on the rise due to new demand requirements in Chile, prompting the need for additional investments in infrastructure. These costs are distributed among customers proportionally based on their withdrawals to meet each demand.

Electricity market price (CMg)

The pricing structure for the Power Purchase Agreement (PPA) comprises the Marginal Cost of generation (CMg) along with a fixed fee. Therefore, it is insightful to examine the fluctuation of CMg throughout the day, as this variation offers the opportunity to design a PPA with dynamic pricing options over the course of the day.

The following figure shows the main substations or energy withdrawal points of the National Electric System (CEN), and subsequently, the average hourly Marginal Costs (CMg) for each of them are presented during:

- Scenario A: The last month (October 2023).
- Scenario B: The last 6 month (May 2023 to October 2023).
- Scenario C: The last 12 month (November 2022 to October 2023).

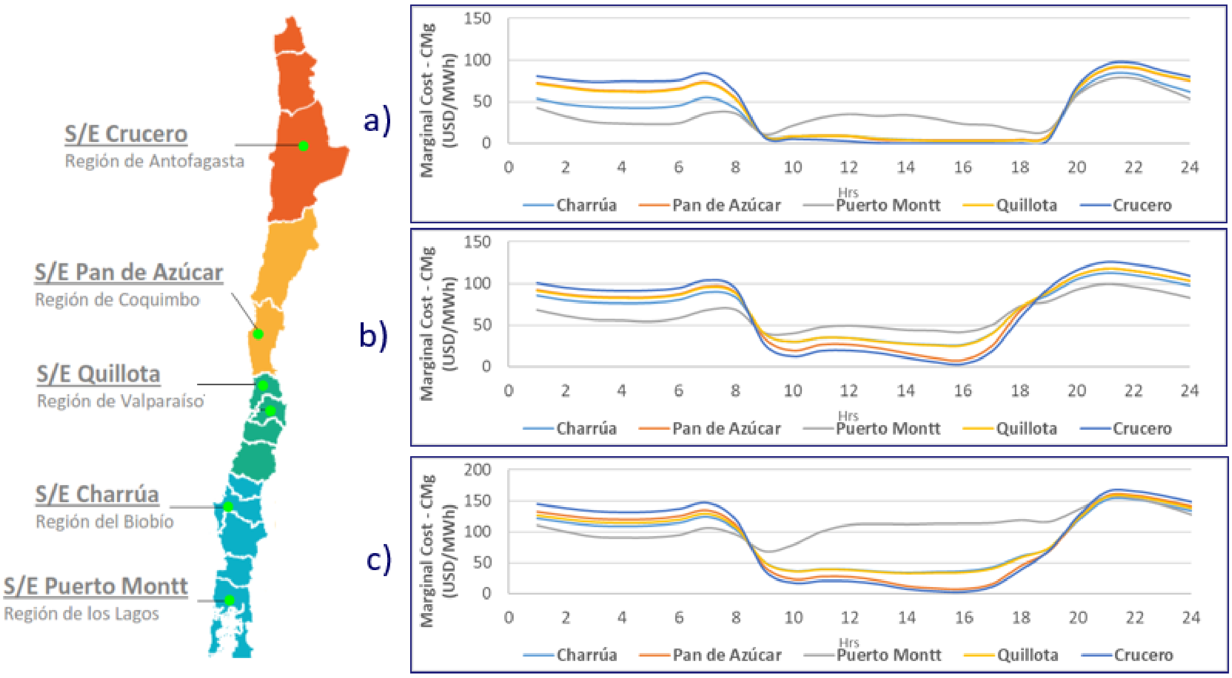


Figure 8. CMg of the main substations (S/E) in Chile.

Analysis of the provided graph reveals significant fluctuations in the Energy Marginal Costs (CMg) of the system, driven by day-night seasonality. Notably, during daytime hours, CMg tends to be lower compared to evening hours, largely influenced by the presence of variable renewable energy generation projects. For instance, over the course of the entire last year (November 2022 to October 2023), the average CMg for all energy withdrawal points stands at approximately $48.34 USD/MWh between 9:01 and 19:00 hours. In contrast, between 19:01 and 9:00, this value escalates to $127.96 USD/MWh.

S/E	09:01 to 19:00	19:01 to 9:00
Charrúa	43.64	123.44
Pan de Azúcar	27.68	131.89
Puerto Montt	105.43	115.06
Quillota	42.94	128.04
Crucero	21.99	141.38
Average	**48.34**	**127.96**

Table 8. Average marginal costs for the last 12 months in USD/MWh.

In an ideal scenario, full coupling of the entire National Electric System (SEN) is desired. However, in Chile, certain transmission challenges persist in specific areas, hindering the efficient transport of energy from large generation sources to consumption points. For instance, the Puerto Montt area regularly encounters transmission constraints, resulting in inadequate capacity to transmit substantial energy volumes from the north to the south. Consequently, during periods of high demand, such as daytime hours, leveraging variable renewable energy generation from the north at a low cost may not be feasible. Instead, meeting demand necessitates resorting to conventional generation methods like diesel engines, incurring significant costs.

This trend is evident in the provided table, where the average CMg over the past year in Puerto Montt exceeds $100 USD/MWh during the hours from 09:01 to 19:00, while in other areas, the average stands at only $34.06 USD/MWh.

3.1.6 Sources of water

Chile's industrial water sources comprise sanitation companies nationwide, surface and groundwater reservoirs, and predominantly, seawater desalination plants situated in the northern region of the country.

3.1.6.1 Seawater desalination plants

Based on information obtained from the Chilean Desalination Association (ACADES) and the market intelligence portal (B2B Media), Chile currently operates **29 desalination plants**. Among these, **24 units boast capacities** exceeding 10 liters per second (300 million liters per year), aligning with the requirements of INERATEC's plants. Notably, 20 of these plants serve the mining and energy generation sectors, while the remaining 4 are under the ownership of sanitation companies. Furthermore, over 80% of these plants are located in the northern region of the country. The accompanying figure provides a regional breakdown of desalination plants and their total capacities.

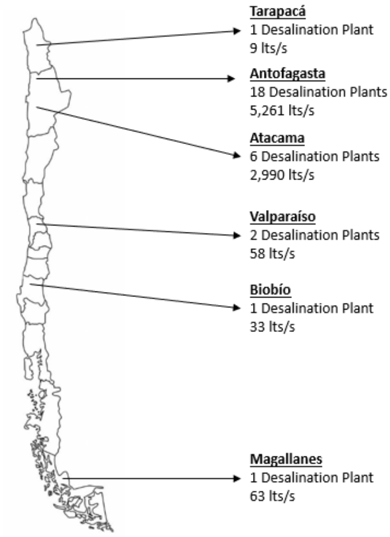


Figure 9. Desalination plants per region and capacity.

As previously mentioned, 20 of these plants are owned by mining and power generation companies, with each plant dedicated to a single entity. Consequently, access to these water sources is contingent upon the current utilization of these plants by their respective companies. In practice, accessing these water sources may pose challenges.

Below is a comprehensive breakdown of the 24 aforementioned desalination plants, highlighting that those affiliated with mining exhibit the highest desalinated water flow rates.

Name	Owner	Sector	Region	City	Capacity (L/s)
Escondida ESW Ampliación	BHP	Minery	Antofagasta	Antofagasta	2.500
Escondida Puerto Coloso	BHP	Minery	Antofagasta	Antofagasta	525
Antucoya	Minera Antucolla	Minery	Antofagasta	María Elena	48
Sierra Gorda	Sierra Gorda Sociedad Contractual Minera	Minery	Antofagasta	Sierra Gorda	63
Distrito Centinela	Minera Centinela S.A.	Minery	Antogafasta	Sierra Gorda – Mejillones	50
Planta Desaladora Michilla	Haldeman Mining Company	Sanitary	Antofagasta	Sierra Gorda	75
Planta Desaladora Norte (Ex La Chimba)	Aguas de Antofagasta S.A.	Sanitary	Antofagasta	Antofagasta	680
Central Termoeléctrica Angamos	AES Gener S.A.	Thermoelectric	Antofagasta	Mejillones	60
Minera Spence Growth Option	Minera Spence S.A.	Minery	Antofagasta	Mejillones	1.000
Tocopilla	Aguas de Antofagasta S.A.	Sanitary	Antofagasta	Tocopilla	100
Tocopilla	Norgener/AES Andes	Thermoelectric	Antofagasta	Tocopilla	25
CTT Tocopilla	Engie	Thermoelectric	Antofagasta	Tocopilla	22
Mejillones	Gasatacama	Thermoelectric	Antofagasta	Mejillones	30
Mejillones	EE Cochrane/AES Chile	Thermoelectric	Antofagasta	Mejillones	56
Minera Mantoverde	Mantos Copper S.A.	Minery	Atacama	Chañaral	120
Cerro Negro Norte	CAP S.A.	Minery	Atacama	Caldera	600
Minera Candelaria	Sociedad Contractual Minera Candelaria	Minery	Atacama	Caldera	500
Candelaria 2030 - Continuidad Operacional	Sociedad Contractual Minera Candelaria	Minery	Atacama	Caldera	500
Planta Desalinizadora Provincias de Copiapó y Chañaral	Empresa Concesionaria de Servicios Sanitarios S.A	Sanitary	Atacama	Caldera	1.200
Huasco	Gualcolda Energía	Thermoelectric	Atacama	Huasco	70
Unidad 3 Ventanas	AES Chile	Thermoelectric	Valparaíso	Puchuncaví	28
Unidad 4 Ventanas	AES Chile	Thermoelectric	Valparaíso	Puchuncaví	30
CT Santa María	Colbún	Thermoelectric	Biobío	Coronel	33
Cabo Negro	Methanex	Industrial	Magallanes	Punta Arenas	83

Table 9. Desalination plants – Capacity > 10 lts/s (≈ 300 MMlts/y).

3.1.6.2 Surface water (rivers) and sanitary companies

The central and southern regions of Chile enjoy abundant water resources, boasting over 1,250 rivers spread across 101 hydrographic basins, alongside numerous lakes. However, regional analysis reveals prevailing conditions of water scarcity from the Metropolitan Region northward. Despite the richness of resources, the northern and central regions of the country have grappled with a decade-long drought. Many industries in Chile rely on water from surface bodies like rivers for various consumption purposes. Notably, each of the country's regions is served by at least one sanitary company.

N.B.: During our analysis of this water supply, we considered its certification and social acceptance. However, it is important to note that the utilization of river water is generally frowned upon, particularly in Chile, where significant social conflicts surround this issue. Although we examined the availability of this resource, its actual use was never seriously contemplated.

3.1.7 Syngas in Chile

In Chile, there is currently no production or supply of syngas or any comparable gas. Major gas suppliers in Chile, including Linde Chile and Air Products, have confirmed this. Consequently, the following chapter will focus on identifying Chilean producers of suitable biomass for syngas production.

3.1.7.1 Syngas production out of biomass

Syngas comprises primarily hydrogen (H2) and carbon monoxide (CO), along with inert gases such as nitrogen (N2) and carbon dioxide (CO2). Its exact composition varies depending on factors like the primary feedstock and the production process employed. For the Fischer-Tropsch (FT) process conducted by INERATEC, the optimal ratio is H2:CO = 2:1, with a maximum of 50% inert gases. Thus, the focus lies on generating H_2 and CO, which can be achieved either separately (indirect syngas production) or combined in one process (direct syngas production). Biomass gasification is a well-established and mature technology for syngas production. According to literature, fluidized bed and entrained flow gasifiers are the most suitable technologies for producing syngas for synthetic fuel. Several industries can be considered as potential syngas producers:

- Corn industry: **1.56 kg** of syngas per 1 kg of corn stover.
- Pulp industry: **1.69 kg** of syngas per 1 kg of wood waste.
- Wheat industry: **1.56 kg** of syngas per 1 kg of wheat stover.

The table below presents the estimated annual production potential of syngas in Chile, taking into account the industries mentioned earlier..

Industry	Process	By-product and residue	Technology	Total annual production of by-product or residue (ton/year)	Total annual syngas potential (tons/year)
Wood, Pulp & paper industry	Direct	Wood waste	Gasification of biomass	2,585,000	4,368,650
Corn Industry	Direct	Corn straw	Gasification of biomass	418	652
Wheat Industry	Direct	Wheat straw	Gasification of biomass	2,003	3,125

Table 10. Total annual syngas potential production in Chile.

Based on the obtained results, the following observations were made:

- There is a significant potential for syngas production from wood waste, estimated at over 4 million tons per year. This will be further elaborated in the subsequent subsection.
- The corn and wheat industries in Chile are relatively small, with an approximate syngas production potential of only 3,700 tons per year. Moreover, these industries are dispersed over more than 1,000 kilometers across different regions of Chile, and both products are seasonal, being harvested only during the summer months (December to February). As a result, they are not considered viable options for syngas production.

3.1.7.2 Producers of wood waste biomass

Chile stands as a significant producer and exporter of forest products, boasting over 2 million hectares of plantations, predominantly of Radiata Pine and Eucalyptus. In 2022, the country processed over 40 million cubic meters (MMm3) of solid wood without bark (SSC in Spanish). These resources primarily fuel the production of cellulose, sawn timber, wood chips, boards, veneers, and poles. Of this output, 28.3 MMm3 originated from Pine, 11.9 MMm3 from Eucalyptus, and a mere 133,000 m3 from native woods. Throughout the production process, approximately 4.7 MMm3/year (equivalent to roughly 2.6 million tons/year) of waste or by-products are generated, primarily comprising sawdust, bark, chips, shavings, and trimmings. A significant portion of these by-products is commercialized, while the remainder is utilized for internal consumption.

Data from the Forestry Institute of Chile (INFOR) reveals the presence of over 1,000 sawmills and chipboard plants in Chile, with the majority contributing to this waste stream. For the purpose of this study, we focus on plants generating more than 100,000 tons of wood waste per year, as detailed breakdowns of waste production per company are not available, only their respective ranges.

Company / Plant	Region	Commune
Aserraderos Loncoche S.A.	Araucanía	Loncoche
CMPC Maderas SPA (Planta Bucalemu)	Biobío	Los Ángeles
CMPC Maderas SPA (Planta Mulchén)	Biobío	Mulchén
CMPC Maderas SPA (Planta Nacimiento)	Biobío	Nacimiento
Foraction Chili S.A.	Biobío	Curanilahue
Maderas Arauco S.A. (Planta Cholguán)	Ñuble	Yungay
Maderas Arauco S.A. (Planta El Colorado)	Biobío	Curanilahue
Maderas Arauco S.A. (Planta Horcones I)	Biobío	Arauco
Maderas Arauco S.A. (Planta Horcones II)	Biobío	Arauco
Maderas Arauco S.A. (Planta Nueva Aldea)	Ñuble	Nueva Aldea
Maderas Arauco S.A. (Planta Valdivia)	Los Ríos	Mariquina
Maderas Arauco S.A. (Planta Viñales)	Maule	Constitución
Mauricio Muñoz y Cia. Ltda.	Maule	Constitución
Procesadora de Maderas Los Ángeles S.A.	Biobío	Los Ángeles
Fulghum Fibres Chile S.A. (Planta PAC)	Biobío	Coronel
Fulghum Fibres Chile S.A. (Planta CRN)	Biobío	Coronel

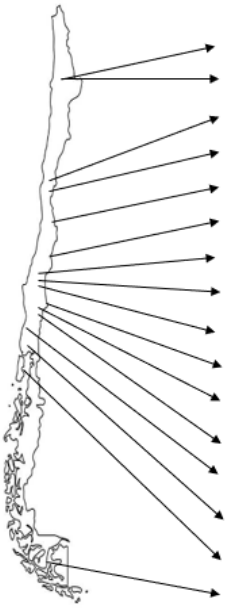
Table 11. Companies/Plants that produce more than 100,000 tons per year of forest residues.

It is noteworthy that over 60 % of the plants are situated in the Biobío Region. Among these, 10 are owned by CMPC and Arauco. Additionally, Fulghum Fibres, a company operating 2 plants in Coronel, Biobío Region, sells their waste materials to sector companies for energy generation.

3.2 Potential sites for e-Fuel production

3.2.1 Selection zones to install a PtL plant

Considering the specifications outlined for INERATEC's PtL plants in section 3.1, as well as the identification of CO_2 sources, potential H_2 projects, sources of water, and electrical infrastructure in Chile, a preliminary selection process has led to the identification of **16 potential zones** for establishing PtL plants. Each of these selected sites adheres to the criterion that all required resources should be within a maximum radius of 60 kilometers. The following illustration shows the approximate location of each of these potential sites.



Name
Potential Zone N°1 - Antofagasta
Potential Zone N°2 - El Loa
Potential Zone N°3 - Valparaíso & Tiltil (RM)
Potential Zone N°4 - Rancagua
Potential Zone N°5 - Maule
Potential Zone N°6 - Ñuble
Potential Zone N°7 - Laja, Cabrero & Diguillín
Potential Zone N°10 - Talcahuano & Hualpén
Potential Zone N°9 - Coronel & SPDLP
Potential Zone N°8 - Arauco
Potential Zone N°11 - Nacimiento, Minico & Mulchen
Potential Zone N°12 - Lautaro
Potential Zone N°13 - Valdivia
Potential Zone N°14 - Puerto Montt
Potential Zone N°15 - Castro Chiloé
Potential Zone N°16 - Cabro Negro (MAG)

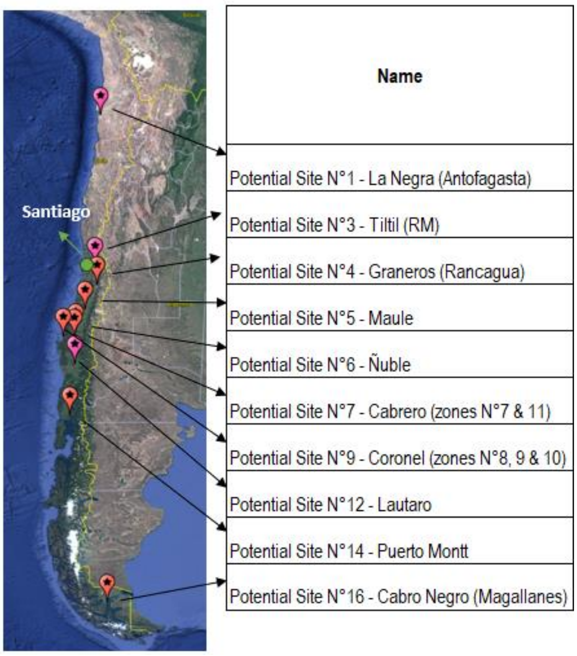
Figure 10. Approximate located of potential zone to install PtL plant.

Drawing upon a thorough analysis of the potential zones in line with the mandatory requirements for establishing a PtL plant, the following conclusions were drawn:

- The **potential zone N°2** has **3 sources of CO_2 with less than 170.000 ton/year (in total).** Thus, it was eliminated because too small volume of CO_2 emitted.
- A similar situation exists in **zone N°15**, which has just **1 source of CO_2**. Additionally, Chiloé is an island and a zone usually subjected to **low transmission capacity** (just 1 line).
- Unfortunately, there is **not available industrial land** for **potential site N°13**. However, there is only one source of CO_2 in the sector, and the transmission system is weak in that area.
- Some neighboring zones can be joined to form a single zone as long as the distances of the CO_2 sources permit it.

For example: 1. Potential zones N°7 and N°11 are in an area around 100 km and they are joined; 2. a similar situation exists in zones N°8, N°9 and N°10.

In regard to these reasons, the list of 16 potential zones was trimmed down to **10 potential sites.**



Name
Potential Site N°1 - La Negra (Antofagasta)
Potential Site N°3 - Tiltil (RM)
Potential Site N°4 - Graneros (Rancagua)
Potential Site N°5 - Maule
Potential Site N°6 - Ñuble
Potential Site N°7 - Cabrero (zones N°7 & 11)
Potential Site N°9 - Coronel (zones N°8, 9 & 10)
Potential Site N°12 - Lautaro
Potential Site N°14 - Puerto Montt
Potential Site N°16 - Cabro Negro (Magallanes)

Figure 11. Approximate location of selected potential sites to install PtL plant.

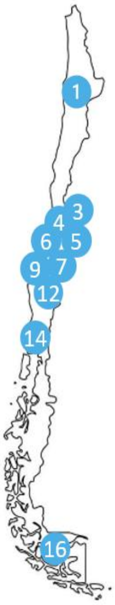
As previously mentioned, in each potential zone, efforts were made to identify available industrial land situated as close as possible to electrical lines for grid connection and sources of CO_2. It is important to note that there is a limited availability of industrial lands with adequate space for installing the INERATEC's PtL plant. Furthermore, it is imperative to ensure that the selected site is suitable for constructing a plant of this nature. In this regard, it is worth noting that in 2022, the Ministry of Housing and Urban Development (MINVU) issued Circular ORD. No. 0504 from the Division of Urban Development (DDU 470), outlining the applicable land use regulations for buildings, facilities, and networks associated with H_2 generation or related projects. Essentially, these projects are categorized as energy infrastructure land use if located within the area covered by the Communal Regulatory Plan (PRC). However, if situated in a rural area outside the PRC, approval is required from the General Directorate of Municipal Works, a favorable report from the MINVU SEREMI, and approval from the Agricultural and Livestock Service (SAG).

The workflow conducted for each potential site can be summarized as follows:

1. **Search for industrial lands suitable** for constructing the PtL Plant, including the addition of XY coordinates for related locations/sites.
2. **Identification of CO_2 sources** in each area, specifying the company name, plant name, economic activity, fuel used, source classification: Industrial or biogenic, total CO_2 emissions, exact distance (by highway) and region and commune.
3. Determination of the solution to **connect the project to the Electrical System**, specifying the Substation name (S/E), capacity (kV) and exact distance.
4. **Identification of a water source**, such as nearby desalination plants, connection to the potable water network of the sanitation company, presence or feasibility of a waterhole, among other options, specifying the name, capacity (lts/s) and distance (if applicable).
5. **Identification of industrial-scale H_2 projects** specifying the name, capacity (MW), estimated production (kton/year), location and exact distance.
6. **Identification of potential syngas sources**, specifying the company name, plant name, exact distance (by highway), region and commune.
7. Assessment of **distance to highways and railroads** for each potential site.

3.2.2 Selection of qualified sites

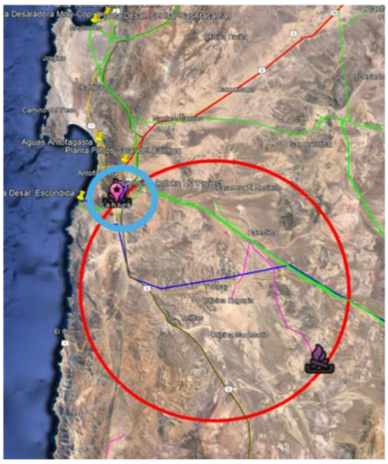
The following table shows an iverview of the 10 high-potential sites gathering all mandatory requirements for a 50.000 t/a e-Fuel production plant.



Name	Industrial CO_2 > 170.000 t/a	Biogenic CO_2 > 170.000 t/a	Potential Sources of syngas	Water	Electricity	H_2
Potential Site N°1 - La Negra (Antofagasta)	☑			☑	☑	☑
Potential Site N°3 - Tiltil (RM)	☑			☑	☑	
Potential Site N°4 - Graneros (Rancagua)	☑	☑		☑	☑	
Potential Site N°5 - Maule	☑	☑	☑	☑	☑	
Potential Site N°6 - Ñuble	☑	☑	☑	☑	☑	
Potential Site N°7 - Cabrero (zones N°7 & 11)	☑	☑	☑	☑	☑	
Potential Site N°9 - Coronel (zones N°8, 9 & 10)	☑	☑	☑	☑	☑	
Potential Site N°12 - Lautaro	☑	☑	☑	☑	☑	
Potential Site N°14 - Puerto Montt	☑			☑	☑	
Potential Site N°16 - Cabro Negro (Magallanes)	☑			☑		☑

Table 12. Overview of 10 high-potential sites for e-Fuel plant realisation.

In the following images presented in this section, each site is presented showing all details, ranging from its geographical location to its infrastructural features and feedstock availability. This comprehensive overview aims to provide readers with a thorough understanding of each site's significance within its respective environment, offering insights into each site's characteristics for a better qualification:



Site N° 1 – LA NEGRA

Industrial Land	**38,000 m²**
Distance by railroad	**0.8 km**
Distance by Highway	**0 km (Ruta 5)**

Electrical connection to substation

Tension	**220 kV**
Distance	**0.8 km**
Estimated year	**2025**

H_2 sources

Name	**Antuko-Genesis (La Negra)**
Capacity	**100 MW**
Production	**15 kton/year**
Distance by highway	**1.8 km**

Principal water source

Type	**Feasibility of waterhole** **Desalination plant Coloso**

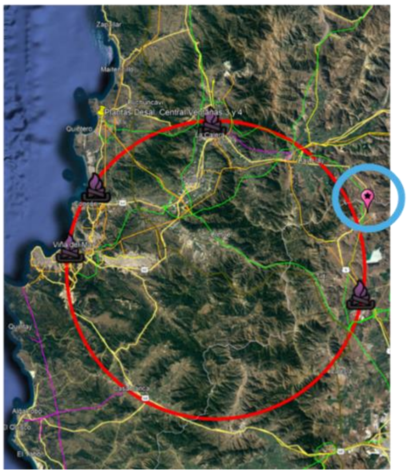
CO_2 sources

Planta Cemento Antofagasta

Emissions	**167,295 t/a**
Distance to highway	**0.3 km**

Faena el penon

Emissions	**600,139 t/a**
Distance by highway	**136 km**



Site N° 3 – TILTIL (RM)

Industrial Land	**75,000 m²**
Distance to railroad	**0.5 km**
Distance to Highway	**0.4 km**

Electrical connection to substation

Tension	**220 kV**
Distance	**1.6 km**
Estimated year	**2026-2027**

H_2 sources

None

Principal water source

Type	**Feasibility of waterhole**

CO_2 sources

Planta Cerro Blanco	500,000 t/a, 28.8 km
Cemento Melòn Planta	144,221 t/a, 48.8 km
Planta Co Generadora	178,669 t/a, 85.4 km
Refineria ENAP	294,729 t/a, 85.4 km
Elaboradora de Cobre	259,516 t/a, 105.5 km

Site N° 4 – RANCAGUA

Industrial Land	**77,000 m²**
Distance to railroad	**1.2 km**
Distance to Highway	**0 km**

Electrical connection to substation

Tension	**66 kV**
Distance	**1.0 km**
Estimated year	**2026-2027**

H_2 sources

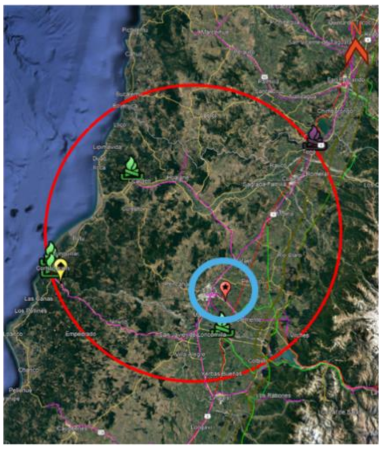
None

Principal water source

Type	**Feasibility of waterhole**

CO_2 sources

Energia Pacifico S.A.	293,325 t/a, 9.4 km
Comafri S.A.	117,754 t/a, 14.21 km
Codelco Divisionel	728,456 t/a, 72 km



Site N° 5 – MAULE

Industrial Land	**50,000 m²**
Distance to Highway	**0 km**

Electrical connection to substation

Tension	**110 kV**
Distance	**5.1 km**
Estimated year	**2026-2027**

Biomass producer

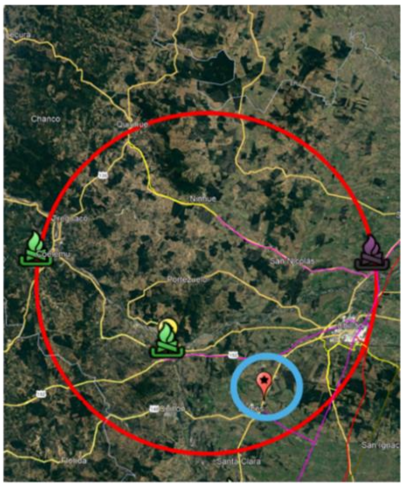
Mauricio Muñóz y Cia. Ltda.	**109km**

Principal water source

Type	**Feasibility of waterhole**

CO_2 sources

Energias Industiales S.A.	388,623 t/a, 38.77 km
Bío Bío Cementos SA Planta	104,741 t/a, 89.2 km
Planta Licancel	105,775 t/a, 103 km
Aserraderos Arauco S.A. Planta Viñales (1)	411,978 t/a, 112 km
Planta constitucion	125,135 t/a, 117 km



Site N° 6 – ÑUBLE

Industrial Land	**44,700 m²**
Distance by railroad	**0.9 km**
Distance by Highway	**0 km**

Electrical connection to substation

Tension	**66 kV**
Distance	**2.5 km**
Estimated year	**2026-2027**

H_2 sources

None

Biomass producer

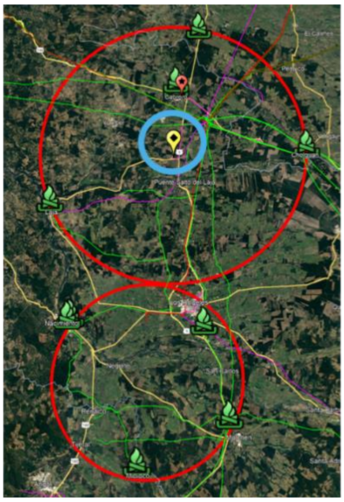
Maderas Arauco S. A.	
Distance by highway	**31 km**

Principal water source

Type	**Sanitary distribution network**

CO_2 sources

ORAFTI CHILE S. A.	338,340 t/a, 21.9km
Nueva Aldea	538,867 t/a, 31.2 km
Iansagro Planta Ñuble	121,208 t/a, 33.2 km
Energia Leon S.A.	122,742 t/a, 70.2 km



Site N° 7 – CABRERO

Industrial Land	**83,550 m²**
Distance by railroad	**0 km**
Distance by Highway	**1.3 km**

Electrical connection to substation

Tension	**66 kV**
Distance	**1.0 km**
Estimated year	**2026-2027**

H_2 sources

None

Biomass producer

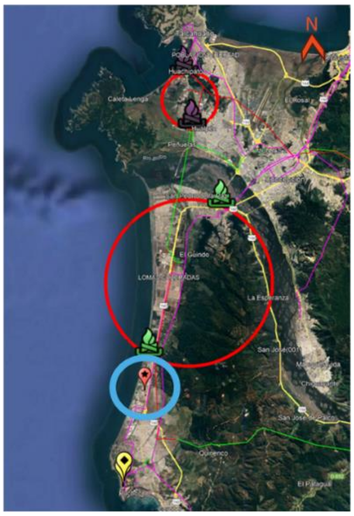
CMPC Maderas S.P.A.	
Distance by highway	**19 km**

Principal water source

Type	**Sanitary distribution network**

CO_2 sources

Neomas S.P.A.	255,512 t/a, 1.5 km
Central Termoelectrica	115,801 t/a, 2.2 km
Orafti Chile S.A.	338,340 t/a, 15.5 km
Planta Trupán/Cholguan	403,049 t/a, 32.3 km
CMPC Cellulosa Planta	1,562,965 t/a, 54.2 km
Planta Remanofactura	107,940 t/a, 57.2 km
Aserradero Mulchen	148,753 t/a, 53.9 km



Site N° 9 – CORONEL

Industrial Land	**22,730 m²**
Distance by railroad	**0.1 km**
Distance by Highway	**0.2 km**

Electrical connection to substation

Tension	**66 kV**
Distance	**1.0 km**
Estimated year	**2026**

Principal water source

Type	**Sanitary distribution network**

Biomass producer

Fulghum Fibres Chile S.A. (Planta PAC)	**8.1 km**
Fulghum Fibres Chile S.A. (Planta CRN)	**8.1 km**
Maderas Arauco S.A. (Planta Horcones I/II)	**41.9 km**
Maderas Arauco S.A. (Planta El Colorado)	**68.4 km**
Foraction Chili S.A.	**82.2 km**

CO_2 sources

Eléctrica Nueva Energia S.A	150,403 t/a, 3.1 km
Unipapel	125,289 t/a, 16.8 km
Cogeneradora Petropower	423,873 t/a, 25.9 km
Rafineria Enap	286,312 t/a, 25.9 km
Compañia Siderúgica Huach	350,882 t/a, 30.1 km
Planta Arauco	991,993 t/a, 41.1 km

Site N° 12 – LAUTARO

Industrial Land	**22,800 m²**
Distance by railroad	**0.4 km**
Distance by Highway	**0.7 km**

Electrical connection to substation

Tension	**66 kV**
Distance	**3.2 km**
Estimated year	**2025**

Principal water source

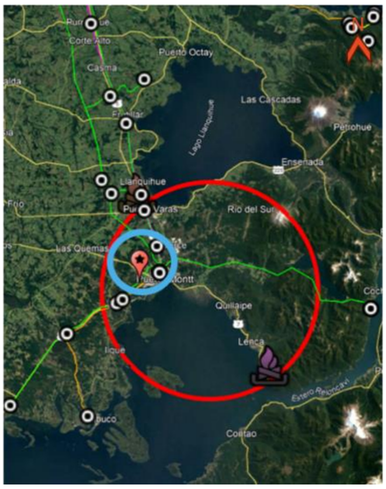
Type	**Sanitary distribution network**

Biomass producer

Aserraderos	**108.1 km**
Maderas Arauco S:A. (Planta Valdivia)	**135.2 km**

CO_2 sources

Eagon Lautaro S.A.	125,225 t/a, 3.3 km
Central Lautaro	320,000 t/a, 6.4 km



Site N° 14 – PUERTO MONTT

Industrial Land	**25,000 m²**
Distance by Highway	**0.6 km**

Electrical connection to substation

Tension	**110 kV**
Distance	**3.2 km**
Estimated year	**2025**

Principal water source

Type	**Rural sanitary water network**

CO_2 sources

Galvanizadora del sur	846,934 t/a, 23.5 km
Caleta Milagro 101936	1,532,194 t/a, 52.3 km

Site N° 16 – CABO NEGRO (MAG)

Industrial Land	**> 170 ha available**
Distance by highway	**0.7 km**

Electrical connection to substation

None

Principal water source

Type	**Feasibility of waterhole**

H_2 sources

Name	**Cabeza del Mar**
Capacity	**1,000 MW**
Production	**> 100 kton/a**
Distance by highway	**20 km**

CO_2 sources

Methanex Chile S.A.	
Emissions	**217,676 t/a**

3.3 Conclusions from sites analysis

Based on the previous analysis, the following conclusions can be drawn:

- All potential sites are situated in areas where PtL plant construction would comply with municipality regulations. However, 2 sites (Potential Site No. 12 and Potential Site No. 14) are located outside the municipal regulatory plan, necessitating prior approval from the MINVU SEREMI and the SAG.
- Each of the selected final sites boasts CO_2 sources emitting at least 170 kton/year.
- 7 potential sites (Potential Sites No. 4, 5, 6, 7, 9, and 12) not only have CO_2 sources totaling more than 170,000 tons per year but also feature biogenic sources. This is significant for INERATEC's fuel export to Europe, as it ensures compliance with EU regulations. The bulk of CO_2 emissions from these sites originates from pulp and paper companies and biomass-based power plants.
- 4 sites possess potential sources of syngas, generating wood residues exceeding 100,000 tons per year.
- With the exception of Potential Site No. 16 in Magallanes, all potential sites have nearby electrical infrastructure suitable for PtL plant connection. Feasible connection alternatives were identified for each site, considering time and associated costs. Although connection feasibility exists for all sites, Potential Site No. 1 stands out as the most optimal choice. Here, a new substation with sufficient capacity for project connection will be constructed just 800 meters away, scheduled for completion by 2025. All potential sites can provide water sources for the PtL project. Options include waterholes (or feasibility for their construction), connection to the distribution sanitary network, or utilization of desalination plants installed by private entities for mining or thermal power plants.
- Lastly, only 2 potential sites have nearby hydrogen projects, located in the Antofagasta and Magallanes regions (Potential Site No. 1 and Potential Site No. 16).

4 INERATEC ‘s Power-to-Liquid plant

4.1 Facility plot plan

The facility plot plan for INERATEC’s Power-to-Liquid (PtL) plant provides a comprehensive overview of the site's layout and infrastructure. Designed to showcase the cutting-edge technology and efficient operation of the plant, this visualization provides stakeholders with a detailed understanding of its design and functionality. It encompasses various elements essential for the e-Fuel production, including processing units, storage facilities, utilities, and administrative buildings. Key features include the PtL synthesis, electrolysis, Hydrocracking, isomerisation and distillation columns within the processing area, as well as the allocation of space for feedstock storage, product storage tanks, and ancillary equipment. Additionally, the plan incorporates access roads, parking areas, and additional spaces to ensure functionality and accessibility. It is important to note that PtL plant designs can vary significantly depending on factors such as site-specific conditions, engineering developments, and the availability of electrolyzers on-site. The specific configuration and sizing of equipment may vary depending on factors such as the capacity of the plant, the desired output fuels, the efficiency of the conversion processes, and the availability of resources. For example, the size and number of electrolyzers may vary based on the availability of renewable electricity and water resources at the site.

Figure 12. 3D Visualisation of 50.000 t/a e-Fuel plant.

4.2 Block Flow Diagram (BFD)

The Block Flow Diagram (BFD) for INERATEC's PtL plant provides a simplified yet comprehensive representation of the key processes involved in converting feedstock into synthetic fuels. It outlines the flow of materials and streams through various stages of production, highlighting major equipment and unit operations along the way.

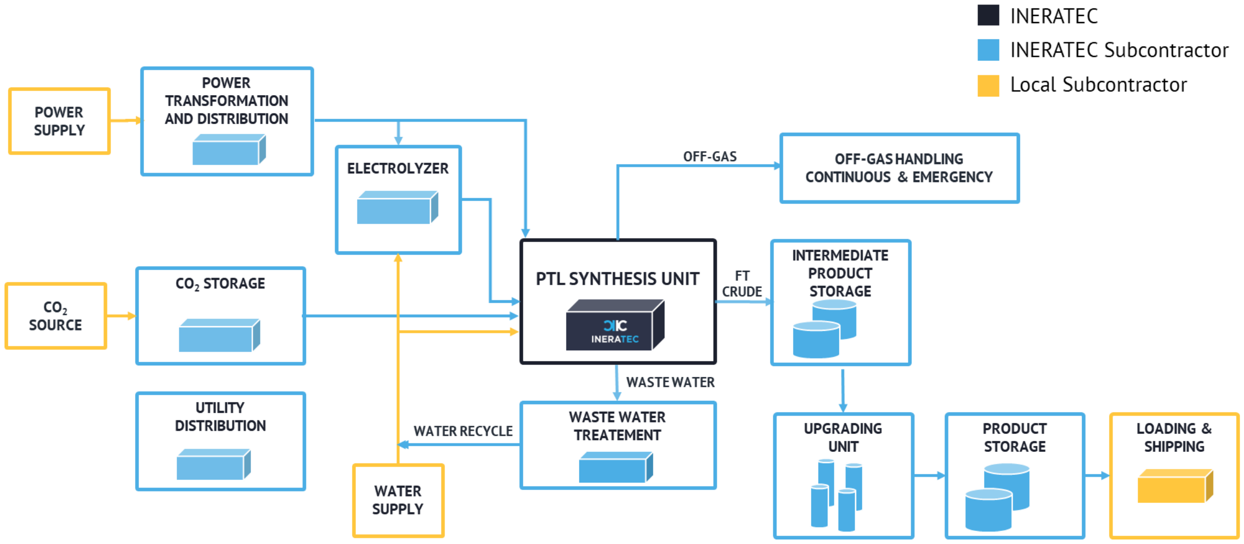


Figure 13. Block flow diagram of PtL plant.

At the outset, the diagram illustrates the sequential steps involved in converting electrical power into liquid hydrocarbon fuels. Here is an overview of the main components typically included in a PtL BFD:

1. **Feedstock Preparation:**
    - Water Electrolysis: Electrical power is used to split water molecules (H_2O) into hydrogen (H_2) and oxygen (O_2) through electrolysis.
    - Carbon Capture: Carbon dioxide (CO_2) is captured from industrial or biogenic sources or directly from the atmosphere using carbon capture and utilization (CCU) technologies.
2. **Reverse Water-Gas Shift (RWGS) reactor integrated into the synthesis module:** CO_2 and H_2 are reacted in the presence of a catalyst to produce carbon monoxide (CO) and water (H2O) through the reverse water-gas shift reaction.
3. **Fischer-Tropsch (FT) reactor integrated into the synthesis module:** CO produced in the RWGS reactor, along with additional H_2, is fed into the Fischer-Tropsch reactor. The FT synthesis converts CO and H_2 into long-chain hydrocarbons (synthetic fuels) over a catalyst.
4. **Product Separation and Refining:** The synthesized hydrocarbons, along with water and unreacted gases, are separated using distillation or other separation techniques.
5. **Refining:** The separated products undergo refining processes to improve purity and quality.
6. **Product Storage and Distribution:** The refined liquid hydrocarbon fuels are stored in tanks ready for distribution to end-users, such as transportation or industrial sectors.

7. **Utilities:**
    - Steam Generation: Steam is generated for various process heating requirements.
    - Cooling: Cooling water is used to remove heat from reactors and equipment.
    - Electricity: Electrical power is supplied to the electrolysis units and other process equipment.

4.3 Opportunities for local production and assembly

As depicted in the above BFD, INERATEC envisages collaborating with local production and assembly companies to facilitate the implementation of the PtL plant. These collaborations are essential for several aspects of the PtL plant construction and operation, including:

- **Equipment Fabrication:** Local production companies can manufacture various components and equipment required for the PtL plant, such as separators, heat exchangers, and storage tanks. By leveraging local manufacturing capabilities, INERATEC aims at ensuring timely delivery of high-quality equipment while minimizing transportation costs and lead times.
- **Assembly and Installation:** Local assembly companies can assist in the assembly and installation of process units and equipment at the PtL plant site. This includes mechanical assembly, piping installation, electrical wiring, and instrumentation setup. Collaborating with local contractors ensures efficient installation processes and compliance with local regulations and standards.
- **Maintenance and Support:** Partnering with local companies for maintenance and support services is crucial for ensuring the long-term reliability and performance of the PtL plant. Local service providers can offer on-site maintenance, troubleshooting, and repair services, minimizing downtime and ensuring optimal plant operation.
- **Knowledge Transfer and Skills Development**: Collaboration with local production and assembly companies provides an opportunity for knowledge transfer and skills development within the local workforce. INERATEC can share technical expertise and best practices with local employees, contributing to the growth of local capabilities in the renewable energy and manufacturing sectors.

4.4 Permitting process

The permitting process in Chile has been thoroughly assessed to ensure compliance with regulatory requirements and facilitate the smooth implementation of PtL plants. Some key aspects to consider:

- **Regulatory Compliance:** Prior to initiating any project, it is essential to understand and adhere to the relevant regulatory framework established by local, regional, and national authorities. This includes environmental regulations, land use laws, safety standards, and any other applicable regulations governing the specific industry or project type.
- **Environmental Impact Assessment:** Many projects in Chile require an Environmental Impact Assessment to evaluate the existence of significant environmental impacts and propose mitigation measures. The assesmentprocess involves submitting a comprehensive study detailing the project's potential environmental effects, conducting public consultations, and obtaining approval from the relevant environmental authorities.

- **Permit Applications:** Depending on the nature of the project, various permits and authorizations may be required from government agencies at different levels. These permits may include land use permits, construction permits, water rights permits, air emissions permits, and others. Each permit application typically involves submitting detailed project plans, environmental assessments, and other relevant documentation for review and approval.
- **Public Consultation:** Public participation is often a mandatory part of the permitting process in Chile, particularly for projects with potential environmental or social impacts. Public consultation processes provide an opportunity for stakeholders, including local communities, NGOs, and other interested parties, to express their views, raise concerns, and provide input on proposed projects.
- **Government Coordination:** Coordination among various government agencies is essential to streamline the permitting process and ensure timely approvals. Close collaboration between project developers and government authorities helps identify potential issues early in the process and facilitates effective resolution.
- **Legal Compliance:** Throughout the permitting process, strict adherence to legal requirements and regulations is paramount. Failure to comply with regulatory obligations can result in delays, fines, or even project suspension or cancellation.

4.4.1 Agencies involved in granting permits

Following agencies are to be consulted during the permitting process:

4.4.1.1 Municipality

The municipality intervenes on the following occasions:

A. The permitting authority evaluates and issues the construction permit based on the following criteria:
  (i) Ensuring that the selected site aligns with the designated area for industrial activities outlined in the Commune's Regulatory Plan.
  (ii) Verifying that the architectural design complies with relevant legislation, specifically the General Ordinance of Urbanism and Constructions, to ensure adherence to legal and regulatory standards.
B. It oversees construction activities, ensuring compliance with the issued construction permit, national construction regulations, and standards. This includes verifying adherence to building construction standards certification, as well as the installation of dedicated facilities for electricity, drinking water, sewage, and fuel permits.

4.4.1.2 Environmental Assessment Service (SEA)

It verifies and approves the environmental impact study of the plant, encompassing assessments of emissions' effects on the environment, distance from neighboring areas, traffic density in the vicinity, impacts on flora and fauna, transmission of noise, vibrations, lighting, among other aspects. This process includes community consultation to ensure stakeholders' input and concerns are addressed.

To facilitate the preparation of the environmental impact study, the SEA has prepared specific guidelines for the submission of projects:

- Asessment Criteria in the SEIA: Introduction to green hydrogen projects.
- SEIA Asessment Criteria: Integrated description of green hydrogen generation projects in the SEIA.

4.4.1.3 Superintendency of Electricity and Fuels (SEC)

The SEC ensures compliance with regulations and standards governing electrical and fuel installations, as well as the structural integrity of associated civil works. This verification involves assessing structural and seismic calculations conducted by specialists. Indirect verification is achieved through certification of installations by qualified third-party certification bodies such as SGS, TÜV, Bureau Veritas, etc.

To streamline the application process for approval of hydrogen projects, the Ministry of Energy has developed comprehensive guidelines titled "*Supporting Guidelines for Application for Approval of Special Hydrogen Projects*". These guidelines provide detailed instructions for preparing and submitting H_2 projects, facilitating efficient and standardized application procedures.

4.4.1.4 National Energy Commission (CNE) and National Electric Coordinator (CEN)

The CNE serves as a technical entity tasked with analyzing prices, tariffs, and technical standards within the energy sector. Companies involved in energy production, generation, transportation, and distribution are required to adhere to the regulations set forth by the CNE. In contrast, the CEN operates as an autonomous, technical, and independent organization responsible for coordinating the operation of the National Electric System (SEN). Its primary objective is to maintain the reliability of electrical supply while ensuring safety and affordability, along with facilitating open access to transmission systems. When a project owner seeks to connect their project to the electrical grid, they must initiate the process by requesting access from the CEN. Subsequently, the CEN conducts the necessary studies to ensure a seamless connection and seeks the most optimal solution. Concurrently, the CNE plays a role in overseeing the annual transmission planning processes, particularly if new infrastructure is necessary for the connection.

4.4.2 Specific documents to be submitted

Below is a comprehensive list of documents that must be prepared and submitted to obtain the necessary permits for the installation of a PtL plant in Chile.

N°	Required permits	Documents to be submitted and content [Organization]
1	**Prior Information Certificate**	**Request for Prior Information [Municipality]**
		* Certificate of ownership of the property
		* Location plan of property
2	**Environmental approval of the project (RCA)**	**Environmental Assesment [Environmental Evaluation Services]**
		* Description of the project or activity
		* Baseline description
		* Basis for the need to carry out an EIA
		* Environmental impact prediction and assessment
		* Measures to minimize adverse effects
		*Sectoral environmental permits
		* Monitoring plan for relevant environmental variables
		* Plan for compliance with applicable environmental legislation
3	**Water supply**	**Sanitary water network:** Feasibility Request [to **Water Distribution Company**]
		Waterhole: * Purchase water right [General Directorate of Water (DGA)]
4	**Building permit**	**Folder with Building Permit Application (1) [Municipality]**
		* Architectural drawings, calculation memories and Tech. specifications.
		* Structural drawings, calculation memories and technical specifications.
		* Drinking water and sewerage feasibility certificate (2)
		* Plans, calculation memories and Tech. specifications of Sanitary, Electrical and Gas Installations.
5	**Plant Operating Permit**	**Application to Superintendency of Electricity and Fuels, SEC.**
		***** Content according to the Guidelines for Presenting Hydrogen Projects.)
		- Introduction of the project (presentation, legal background), etc.
		- Description of the project (location, general process diagram, reference documents, reference to other related projects).
		- Standards applicable to the project (comparative analysis report of the project in terms of safety parameters of the declared technical standards). The CNE includes an annex with the matrix.
		- Project design (requirement, design basis, main equipment, calculation memories).
		- Facility security (risk assessment study, risk mitigation matrix, classification of irrigation zones, description of facility security systems, calculation of classified areas).
		- Quality (compliance assessment).
		***** Certification of the plant by a 3rd Party Certification Body.
6	**Official registration Annex Facilities**	**Applications for registration and approval of annexed facilities.**
		* Applications for registration of Electricity and Gas Plant Installations **[SEC]**
		* Application for approval of Water and Sewerage Plant Facilities
7	**Municipal Construction Reception**	**Application for Municipal Acceptance [Municipality]**
		* Folder with "As-built" Drawings
		* Environmental approval
		* Official registrations of Sanitary, Electrical and Gas Installations.

Table 13. Preliminary list of documents and permits to be submitted to install a PtL plant.

In the previous table, a column has been added with references to the project timeline, which will be further described in subsection 4.4.4.

4.4.3 Stages for the development of the project

In the subsequent section, the 4 primary stages involved in the permitting process for the development of a PtL plant project are detailed. These stages encompass the acquisition of the permits aforementioned, along with other requisite activities inherent to and indispensable for the advancement of such projects.

4.4.3.1 Stage 1 – Previous ***a***ctivities

This phase encapsulates all preceding activities that need to be undertalen. A pivotal step within this phase is initiating the development of the Environmental Impact Study (EIA) or Environmental Impact Statement (DIA), as deemed applicable. Commencing the preparation of the EIA or DIA necessitates the prior completion of fundamental engineering tasks and preliminary endeavors, including feasibility studies, land acquisition, among others.

Environmental study

Projects or activities with the potential to cause environmental impact at any stage must adhere to the Environmental Impact Assessment System (SEIA), as stipulated in Article 3 of the Environmental Impact Assessment System Regulation. For INERATEC's project, the initial grounds for SEIA application are outlined as follows (RSEIA article references provided):

- (k.1) Industrial facilities with installed power exceeding 2,000 kVA.
- (ñ.1) Production of toxic substances (e.g., methanol or others) exceeding 10,000 kg/day or with a storage capacity of 30,000 kg or more.
- (ñ.3) Production of flammable substances (e.g., methanol, diesel, gasoline, and potentially others) exceeding 80,000 kg/day or with a storage capacity of 80,000 kg or more.

Upon fulfilling at least one of these criteria, the project necessitates environmental assessment. Subsequently, when it is determined that the project falls under SEIA, the methodology for submission (EIA or DIA) of the document presented by the proponent for environmental assessment will depends on whether the project present some of the effects, characteristics, and circumstances mentioned in Article 11 of Law 19,300 of General Principñes of the Environment. The. EIA entails more comprehensive content than DIA and consequently requires lengthier preparation and processing periods. A significant characteristic of EIA is the mandatory inclusion of citizen participation, a feature not obligatory for the majority of DIA submissions.

Article 11° of Law 19,300 of General Principñes of the Environment stipulates that projects falling under SEIA must prepare an Environmental Impact Study (EIA), instead of a DIA, if they manifest or generate one or more of the following effects, characteristics, or circumstances:

a. Risk to public health due to the quantity and quality of effluents, emissions, or waste.
b. Significant adverse impacts on the quantity and quality of renewable natural resources, encompassing soil, water, and air.
c. Resettlement of human communities or significant alteration of the lifestyles and customs of human groups.
d. Proximity to or location within populations, protected areas, priority conservation sites, protected wetlands, glaciers, and areas vital for astronomical observation for scientific research, susceptible to potential environmental impact, as well as the environmental significance of the territory where it is intended to be situated.
e. Substantial alteration, in terms of magnitude or duration, of the landscape or tourism value of an area; and
f. Impact on monuments, sites of anthropological, archaeological, historical value, and cultural heritage in general.

Given that some of these criteria undoubtedly classify the study for an EIA, the aforementioned project will likely require evaluation through an Environmental Impact Studies (EIA).

EIAs encompass a more extensive range of content compared to DIAs, resulting in lengthier preparation and processing times. Notably, EIAs include mandatory public participation, a feature generally absent in most DIAs.

Conversely, Sectoral Environmental Permits, governed by Title VII of the RSEIA, are authorizations or declarations issued by State Administration Bodies (OAE) concerning projects or activities undergoing SEIA scrutiny to ensure environmental safeguarding.

Application for connection to the electrical system

From the project's inception, it is both feasible and advisable to initiate the interconnection process with the National Electric System (SEN) concurrently. Upon defining the project's location, a connection request is submitted to the National Electric Coordinator. This can be accomplished either through an Open Access Request (SAC) for national or zonal transmission infrastructure involvement or via a Request for Use of Available Technical Capacity (SUCTD) for dedicated infrastructure. As detailed in subsection 3.2, all sites possess the capability to connect to national or zonal transmission infrastructure, ensuring open access. The CEN is tasked with identifying the optimal connection alternative to the electrical system. Given the absence of idle capacity in the current system, expansions or new infrastructure installations are requisite, necessitating management through a planning process undertaken jointly by the CEN and the CNE.

Commencing the connection process early expedites the project's integration into the electrical system, as planning and constructing new transmission infrastructure typically entail lead times spanning approximately 18 to 30 months.

Notably, Potential Site N°1 holds a notable advantage: an expansion plan (Decree 4/2019) encompasses new infrastructure (substation) just 800 meters from the industrial site. This substation, slated for expansion, currently possesses sufficient capacity. Construction is already underway, with operational readiness expected by 2025.

4.4.3.2 Stage 2 – Environmental Assesment

The environmental evaluation process for project implementation will involve the development of sequential preliminary stages, each with an estimated time depending on the complexity of the process. Initially, there is a stage of information preparation, involving baseline studies on the affected environmental components, assessing their condition both with and without de project. This study can last from one year, covering all four seasons, with the aim of identifyng the most adverse scenarios. Subsequently, document preparation can take at least three months depending on its complexity and must include all information requested by the environmental service, with the minimum content defined in the Article 18 of the RSEIA (D.S 40 M.M.A.). Once the evaluation begins, the EIA is submitted to the SEA. Review timelines for obtainning the RCA vary, with a minimum estimated time ranging from a year an a half to two years, considering processes such as citizen participation, rectification reports, clarifications, consolidated reports, obtaining the resolution, and subsequent publication in the officcial gazette. This timelime may be extended if new intermediate processes requested by the environmental institution are added. Finally, once the RCA is obtained, the project can start its execution with the construction phase.

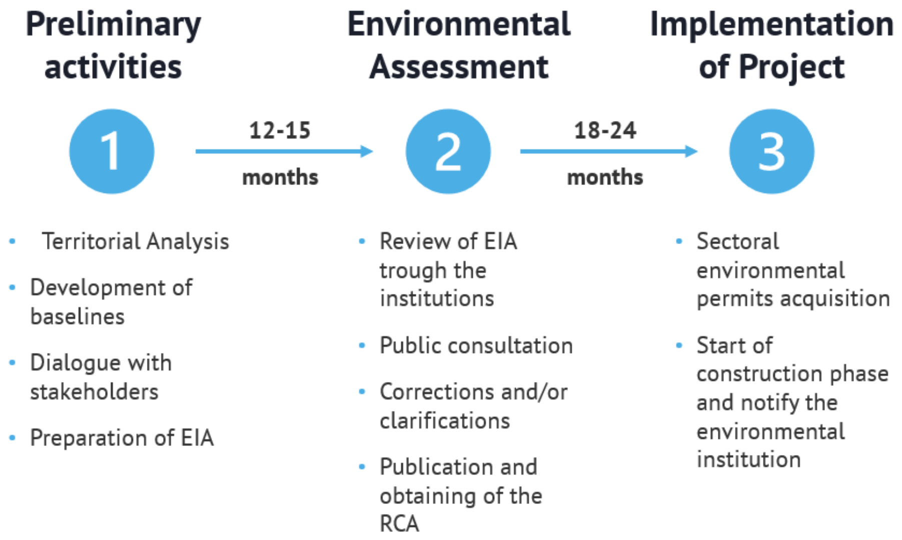


Figure 14. Estimated timeline for a project submitted to the SEA through an EIA

4.4.3.3 Stage 3 – Plant construction

Upon obtaining the Environmental Qualification Resolution (RCA) for the project, the company can initiate construction of the PtL plant, along with the necessary transmission line for electrical system connection. To commence, the company must request construction permits from the Municipality, furnishing comprehensive project details encompassing both technical aspects and the acquired environmental permit. This entails arrangements for all utilities, including electrical connections, water, sewerage services, and more. The timeline for this phase hinges on the company's progress, with an estimated duration of approximately 1 year.

Plant certification and third-party certification

Throughout the project stage, its construction must be certified by a third-party organization. Additionally, it is necessary to initiate the processing of the project authorization permit with the SEC for its subsequent operation. In this regard, the SEC published a *Support Guide for the Authorization Request of Special Hydrogen Projects* in 2021, which is applicable to PtL plants. The guide outlines all the information that the project owner must provide to obtain the respective operating authorization.

It is recommended to initiate the processing of this permit parallelly to the environmental assessment, i.e., as early as possible, once the project's basic engineering is available with the design details of each component.

As a summary, SEC requires the following information:

a. Project introduction: Letter of presentation and legal background of the project owner.
b. Project description: Location, diagram, and reference documents.
c. Applicable regulations to the project: A comparative analysis report must be prepared on the project's compliance with safety requirements of technical standards.
d. Project design: Design bases, main equipment design, plans, and calculation reports.
e. Safety in installations: Risk assessment study, risk mitigation measures, classification of risk zones, description of security systems, etc.
f. Quality: Conformity assessment.

4.4.3.4 Stage 4 – Final activities and operational start

Before the project can commence its operations, the electrical and fuel installations must undergo acceptance and registration by the SEC. Additionally, the project must undergo the acceptance process by the municipality. These final activities are typically allocated only a couple of months for completion.

5 Economic Analysis towards market ramp-up of e-Fuels

5.1 Relevant criteria for production of e-Fuels

The economic assessment of PtL plants involves evaluating various factors to determine the viability and profitability of such facilities. Here is an outline of key aspects typically considered:

- **Capital Costs (CAPEX):** This includes the initial investment required to build the PtL plant, including infrastructure, equipment, and technology. These costs can vary significantly depending on the scale and complexity of the plant.
- **Operating Costs (OPEX):** These encompass ongoing expenses such as energy consumption, raw material procurement, labor, maintenance, and any other operational expenses.
- **Feedstock Costs:** PtL plants typically require feedstocks such as renewable electricity and carbon dioxide (CO_2) or water. Evaluating the availability, cost, and sustainability of these feedstocks is crucial.
- **Revenue Streams:** PtL plants produce synthetic fuels and chemicals, which can be sold on the market. Assessing potential revenue streams from the sale of these products is essential.
- **Market Demand and Prices:** Understanding the demand for synthetic fuels or chemicals and their market prices is crucial for assessing the economic viability of PtL plants.
- **Policy and Regulatory Environment:** Government policies, incentives, and regulations can significantly impact the economic feasibility of PtL plants. This includes subsidies, carbon pricing mechanisms, renewable energy targets, and environmental regulations.
- **Risk Assessment:** Assessing risks associated with PtL projects, such as market volatility, regulatory changes, technological risks, and project execution risks, is essential for determining the overall economic feasibility.

Overall, the economic assessment of PtL plants requires a comprehensive analysis of various factors to determine their feasibility, profitability, and potential contribution to the energy transition and sustainable development goals.

5.2 How to decrease production costs of e-Fuels?

To be economically efficient, PtL facilities require inexpensive renewable electricity and high full load hours. However, decreasing the production costs of e-Fuels is crucial for enhancing their competitiveness and promoting their widespread adoption. Here are several factors that can contribute to reducing production costs:

- **Improving Energy Efficiency:** Enhancing the efficiency of PtL conversion processes can significantly reduce energy consumption, a major cost component. This can be achieved through technological advancements, optimization of process parameters, and minimizing energy losses during production.
- **Utilizing Low-Cost Renewable Energy:** Accessing low-cost renewable electricity sources, such as solar or wind power, can substantially reduce the primary input cost for PtL production.It's important that the energy be inexpensive and available for many hours; otherwise, if it's cheap for only a short period, it wouldn't be useful. Locating PtL plants in regions with abundant and inexpensive renewable energy resources can be advantageous.

- **Optimizing Feedstock Selection:** Selecting feedstocks that are readily available, cost-effective, and sustainable can lower production costs. For example, using captured CO_2 from industrial processes and utilizing waste or low-cost biomass as carbon sources can reduce feedstock expenses.
- **Economies of Scale:** Scaling up PtL production facilities can lead to economies of scale, reducing capital costs per unit of output. Large-scale production facilities benefit from improved production efficiency, lower unit costs for equipment and materials, and better negotiation power with suppliers.
- **Technological Innovation and Process Optimization:** Continuously advancing PtL technologies and optimizing production processes can lead to cost reductions. Research and development efforts focused on improving catalysts, reactor designs, and process integration can enhance efficiency and reduce production costs over time.
- **Recycling and Waste Minimization:** Implementing strategies to recycle and reuse process by-products and waste streams can minimize material costs and disposal expenses. Additionally, reducing waste generation through process optimization contributes to cost savings.
- **Streamlining Supply Chains:** Optimizing supply chains for raw materials, equipment, and services can reduce procurement costs and minimize transportation expenses. Establishing strategic partnerships with suppliers and leveraging regional resources can improve supply chain efficiency.
- **Policy Support and Incentives:** Government policies, subsidies, and incentives aimed at promoting renewable energy, decarbonization, and sustainable fuels can help offset production costs. Supportive policies may include tax incentives, grants, loan programs, and carbon pricing mechanisms.
- **Reducing Operating Expenses:** Implementing efficient operation and maintenance practices, utilizing automation and digitalization technologies, and minimizing labor costs can contribute to overall cost reduction.
- **Risk Management and Financing Strategies:** Mitigating financial risks associated with PtL projects and securing favorable financing terms can lower the cost of capital and reduce project expenses. Exploring innovative financing mechanisms, such as project finance, public-private partnerships, or green bonds, can help attract investment and reduce financing costs.

By addressing these factors comprehensively, stakeholders can contribute to the adoption and use of e-Fuels, making them more competitive alternatives to conventional fossil fuels and accelerating the transition to a sustainable energy future.

As depicted in the table below, the decreasing price trend for e-Fuel over time is contingent upon the evolution of the following parameters:

Parameter	2023	2027	2030	2035
Electrolysis Efficiency	60%	60%	65%	65%
FT Efficiency	60%	65%	70%	77%
Electricity Price (EUR/MWh)	120	60	20	20
CO_2 (EUR/t)	100	80	60	10
Electrolysis EUR/kW	2000	1500	1000	750
Synthesis EUR/kW	5700	3000	2000	750
Upgrading EUR/kW	2500	1500	750	750

Table 14. Parameter influencing e-Fuel price[11].

Relying on the table above, the graph below illustrates assumptions concerning the price trajectory of e-Fuels, influenced by various factors such as optimized production costs through lower electricity prices, reduced CO_2 expenses, enhanced efficiency leading to decreased capital expenditure (CAPEX) for electrolysis and PtL synthesis, as well as decreased CAPEX for upgrading units. Hence, by implementing these cost optimization strategies, a consistent decrease in price over time can be assured.

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[11] According to: Frontier Economics, *The Future Cost of Electricity-Based Synthetic Fuels,* 2018.

N.B.: The estimated costs for technology may vary depending on the technology providers. Different suppliers might offer the same technology at different prices due to variations in their manufacturing processes, material costs, and other operational factors. Stakeholders should consider obtaining quotes from multiple providers to ensure competitive pricing and optimal technology selection for the project

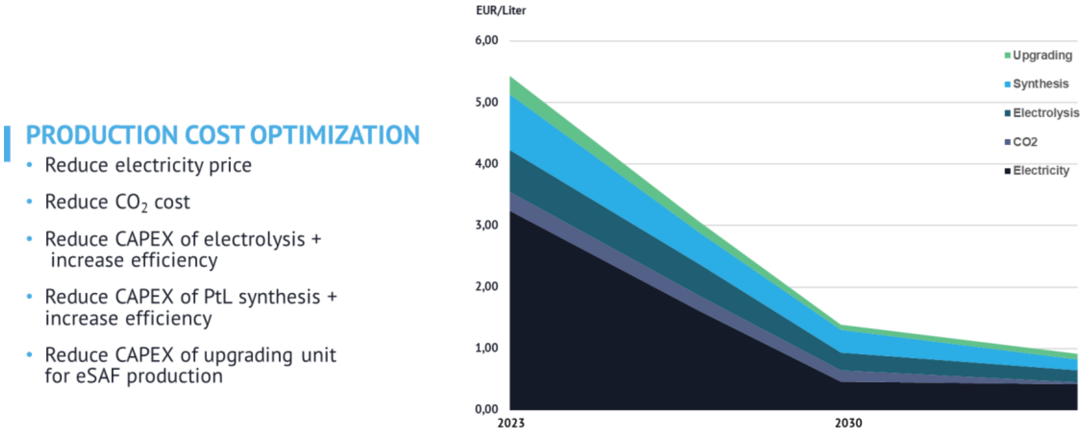

Figure 15. Cost assumptions for production of e-Fuels.

5.3 Assessing the Chilean market for eFuels

5.3.1 Volumes of liquids fuels distributed in Chile

5.3.1.1 Total fossil fuel volumes distributed

The distribution of liquid fuels is primarily handled by distributor companies, with ENAP stepping in for specific circumstances. The table below outlines the total sales volumes, measured in thousands of tons (kton), for each fuel type during the year 2022. The principal fuels volumes correspond to diesel, gasolines and Jet Fuels.

Company	Jet fuels	AVGAS 100	Diesel A and B1	Gasoline 93-97	Marine diesel
Fuel Distributors	1,024	4	8,839	4,075	-
ENAP	2	-	86	4	38
Total country	**1,026**	**4**	**8,925**	**4,079**	**38**

Table 15. Total fuels sold in Chile 2022 (kton/year).

Fuel distribution companies supply these products to various sectors, including service stations, mining and industrial clients, trucking companies, railroads, and airlines. Sales to airlines are conducted through dedicated installations located at national airports across Chile.

5.3.1.2 Distributor sales of principal fuels

The table below presents the distribution volumes of the top three fuel distributors, which collectively account for 94% of the market share.

Company	Jet fuels	Diesel A1 and B1	Gasoline 93-97
Copec S.A. (60% market) (1)	614	5,300	2,445
Enex S.A. (21% market) (1)	214	1,848	847
Esmax SpA (13% market) (1)	133	1,149	530
Others (6%) (2)	65	627	257
Total country	**1,026**	**8,925**	**4,079**

(1) Market share from annual report of companies.
(2) It includes Enap and others small distributors.

Table 16. Distributor sales of principal fuels (kton/year)

5.3.1.3 Estimate of the Jet Fuels consumptions per Airline

Jet fuel volumes for each airline are considered private information. Therefore, the jet fuel consumption per airline was estimated based on the assumption that it is proportional to the passenger-kilometers travelled by each airline. The estimated volumes are detailed in Table 17.

Air Operators	Passengers-km (millions) (1)	Percentage %	Jet fuels consumption (kton/year)
Latam Airlines	14.959	50	511
Sky Airline	4.575	15	156
JetSmart	2.904	10	99
Other internationals operators	7.611	25	260
Total country	**30.049**		**1,026**

(1) Statistics from Junta de Aeronáutica Civil (JAC) of Chile.

Table 17. Jet Fuels consumptions estimate per airline 2022.

Chilean airlines collectively account for 75% of the total jet fuel consumption. Notably, Chile's Latam Airline alone represents 50% of the country's total consumption. Official statistics from SEC reveal that in 2022, the Santiago airport contributed 85% to the overall jet fuel consumption in Chile.

5.3.2 Supply of fuels for Chile

The primary distributors directly import diesel through their maritime facilities, primarily located in northern and central Chile. However, most other liquid fuels are produced and supplied to distributors by ENAP.

5.3.2.1 Transportation of liquid fuels

The transportation of liquid fuels typically involves tanker trucks, which transport fuels from coastal refineries and maritime fuel plants owned by distributors. However, in central Chile, pipelines are utilized for transportation.

For the Santiago airport (AMB Airport), jet fuel is transported from the coast through two consecutive pipelines owned by Sonacol, a company jointly owned by the distributor companies with a minor shareholding by ENAP. The jet fuel installations at the airport are owned and operated by SIAV, a company owned by the three primary fuel distributors.

5.3.2.2 Competition between distributors

The liquid fuels market witnesses intense competition among distributors. On average, the total cost of fuel, including disembarkation, storage, transportation to customers, losses, client installations, administrative expenses, and a net margin for distributors, amounts to approximately 5% of the final price. This calculation excludes value-added tax and additional taxes specific to gasoline and diesel used for automobiles and trucks. Notably, these additional taxes are not levied on industrial, mining, or airline activities.

Major customers periodically tender their fuel consumptions among distributors, while international airlines directly tender their annual consumptions from their central international offices.

5.3.3 Technical requirements

The technical specifications for fuels are outlined in the Chilean standards for liquid fuels, including DS 60/2011, NCh64 Of1995, NCh62 Of2000, and NCh1937 Of2000 for gasoline, diesel, and aviation jet fuel. The Jet Fuel Chilean Standard is derived from ASTM D 1655.

5.4 Main potential customers identified

The analysis of potential customers for e-Fuels involves several key considerations:

- **End-user Segmentation:** Identify various sectors that could benefit from eFuels, including transportation, aviation, industrial, and marine.
- **Technical Requirements:** Understand the specific technical requirements for eFuels in each sector, ensuring compatibility with existing infrastructure and machinery.
- **Volume Demands:** Assess the volume demands of each customer segment to determine market potential and scalability of eFuel production.
- **Price Sensitivity:** Evaluate the price sensitivity of potential customers to determine the competitiveness of eFuels compared to traditional fossil fuels.
- **Regulatory Landscape:** Consider regulatory frameworks and incentives that may influence customer adoption of eFuels, such as emissions regulations or carbon pricing mechanisms.
- **Market Dynamics:** Analyze market dynamics, including competition from traditional fuel suppliers and other alternative fuel options, to identify potential barriers and opportunities for eFuels.

The following table shows a first mapping of potential customers for e-Fuels in Chile.

Company	Economic activity	Fuel	Consumption (m3/year)	Consumption (ton/year)
Codelco Div. Chuquicamata	Mining	Diesel B1	301,691	253,420
Codelco Div. Radomiro Tomic	Mining	Diesel B1	113,062	94,972
Codelco Div. Ministro Hales	Mining	Diesel B1	47,221	39,666
Minera Centinela	Mining	Diesel B1	116,651	97,987
Compañía Minera Zaldívar	Mining	Diesel B1	39,930	33,541
Minera Antucoya	Mining	Diesel B1	25,857	21,720
Compañía Minera Lomas Bayas	Mining	Diesel B1	40,984	34,427
FCAB	Railroad	Diesel A1	14,000	11,760
Fepasa	Railroad	Diesel A1	12,000	10,080
Ferronor	Railroad	Diesel A1	9,000	7,560
Transap	Railroad	Diesel A1	3,500	2,940
Transportes Nazar	Transportation (Trucks)	Diesel A1	36,000	30,240
Transportes Ilzauspe	Transportation (Trucks)	Diesel A1	13,000	10,920
Latam Airlines	Airline	Jet Fuel	639,000	511,200
Sky Airlines	Airline	Jet fuel	195,000	156,000
JetSmart Airlines	Airline	Jet Fuel	124,000	99,200
Total Fuel Consumption			**1,730,896**	**1,415,633**

Table 18. Summary of the potential customers identified.

N.B.: Diesel B1 exhibits slightly heavier properties compared to diesel A1. Specifically, its maximum kinematic viscosity is higher at 5.5 cSt, compared to 4.1 cSt for diesel A1. Additionally, the maximum sulfur content in diesel B1 is also elevated at 0.3%, whereas diesel A1 maintains a lower sulfur content at 0.15%. Originally, the A1 grade was formulated to mitigate sulfur emissions in specific regions. However, it is now available throughout Chile, despite its initial regional focus.

6 Conclusions

The findings from the FEED study conducted to evaluate the technical and economic feasibility of establishing an e-Fuel production facility in Chile have provided valuable insights into the country's landscape and operational dynamics. It is evident that there is significant interest in e-Fuels within Chile, supported by a high market demand and promising market traction. The study has highlighted the immense potential for the e-Fuel business in Chile, indicating a compelling opportunity for investment and development in this sector. With a clear indication of market interest and potential, further exploration and strategic planning are warranted to capitalize on this high-potential market opportunity.

In addition to the study findings, insights derived from a World Café session held during the final event of the PPP project on March 5th, 2024, in Santiago de Chile, have enriched our understanding of the e-Fuel landscape. Participants deliberated on diverse questions pertinent to the e-Fuel domain, offering nuanced considerations and recommendations for Chile's trajectory in this sector. Discussions revolved around identifying key measures, encompassing policies, infrastructure enhancement, and production strategies, deemed essential for catalyzing the development of e-Fuels within Chile. Moreover, participants critically assessed the primary barriers impeding e-Fuel advancement, including regulatory hurdles, technological limitations, and market dynamics. Additionally, challenges confronting e-Fuels, such as scalability, cost competitiveness, and supply chain complexities, were scrutinized to foster a comprehensive understanding of the sector's intricacies.

Furthermore, deliberations delved into the prospect of bolstering sustainability initiatives through the imposition of increased CO_2 taxes or analogous mechanisms. Evaluating the potential impact on incentivizing sustainable and alternative fuel markets, participants engaged in thoughtful discourse, weighing the implications and feasibility of such policy interventions within Chile's economic and environmental landscape.

In summary, a **range of challenges** has been identified and effectively addressed in our pursuit of advancing e-Fuels. These challenges encompassed various facets, including navigating the **regulatory framework** governing production and fuel usage, addressing **price competitiveness** concerns such as willingness to pay and unrealistic parity prices, streamlining **permitting processes** plagued by lengthy timelines, obtaining **necessary certifications**, securing **financing**, establishing enabling **infrastructure** encompassing energy and transportation logistics, tackling the technological and cost barriers associated with **CO_2 capture**, and addressing the crucial aspects of **human capital development and social acceptance**.

In response to these challenges, **several recommendations and measures** have been proposed to further propel the e-Fuel industry forward. These include **implementing targeted taxes and/or subsidies** to incentivize the transition from fossil fuels, **enhancing control mechanisms**, and **promoting the adoption of e-Fuels**. Additionally, a robust **CO_2 capture policy** is recommended to encourage the **establishment of a carbon market** and increase **initiatives aimed at recruiting talent in this domain**. Furthermore, efforts to encourage the use of e-Fuels should capitalize on the relative ease of technological adoption and incentivize local utilization, thus bolstering the momentum towards a sustainable energy future.

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The International Hydrogen Ramp-up Programme (H2Uppp) of the German Federal Ministry for EconomicAffairs and Climate Action (BMWK) promotes projects and market development for green hydrogen in selected developing and emerging countries as part of the National Hydrogen Strategy.