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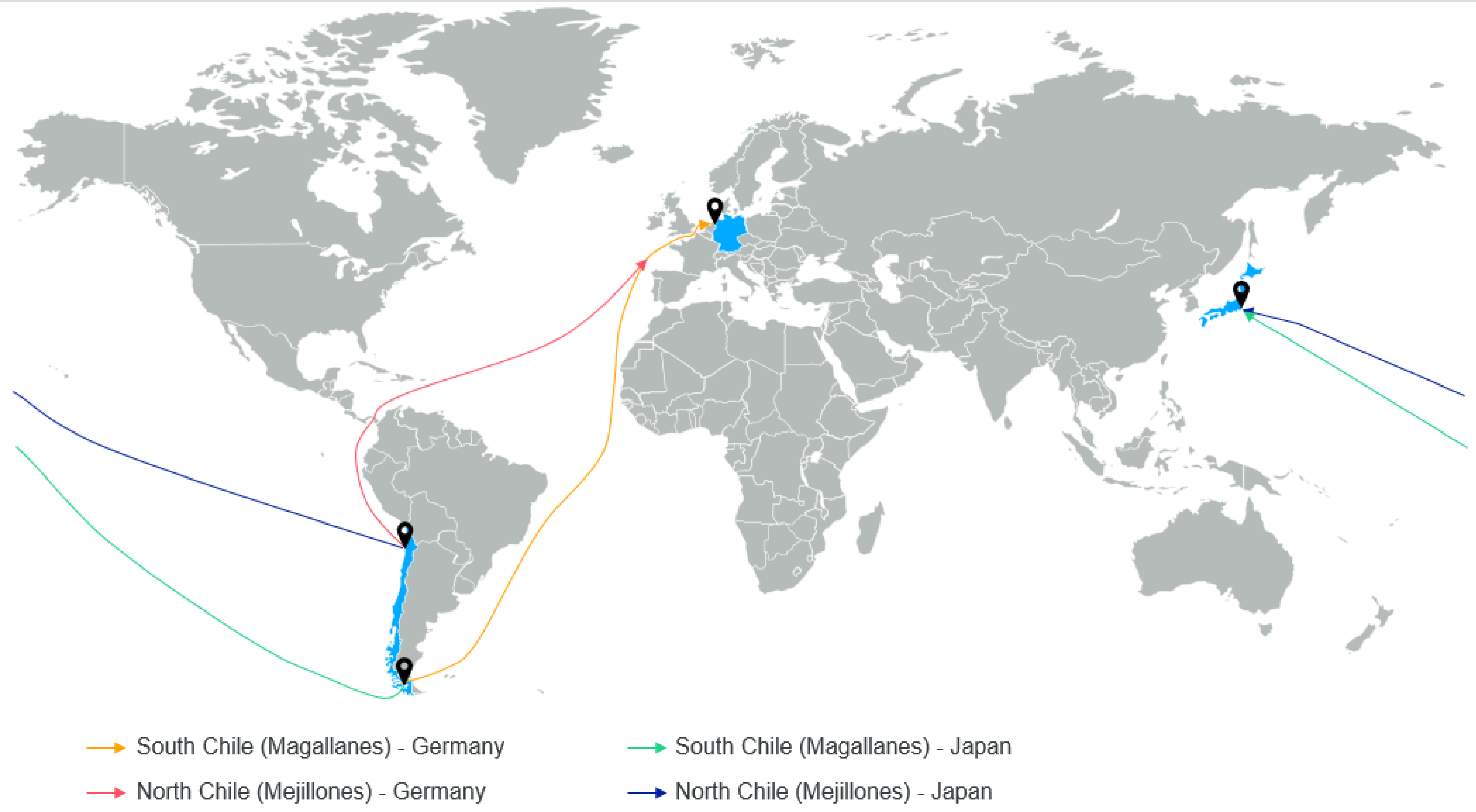
Conditions and Opportunities of Green Hydrogen Trade from Chile to Germany and Japan



Abstract

The study "Conditions and Opportunities of Green Hydrogen Trade from Chile to Germany and Japan" provides technical, logistical, and economical information about the potential for trading green hydrogen and its carriers methanol and ammonia between **Chile and Germany and Japan**. In line with Germany's general interest to strengthen international green hydrogen markets, and to reduce prices through learning effects and large-scale approaches, the study pushes the boundaries on the body of **knowledge of green hydrogen exportation**. The work developed a detailed analysis of producing hydrogen in the **most promising zones of Chile**; the **Atacama Desert** (Antofagasta Region/ high solar potentials) and **Patagonia** (Magallanes Region/ high wind potentials), identifying opportunities for transporting it as **ammonia, methanol, and liquid hydrogen**, considering the complete **export value chain including shipping routes and local infrastructure needs,** in the time horizon of **2025, 2030 and 2040.**

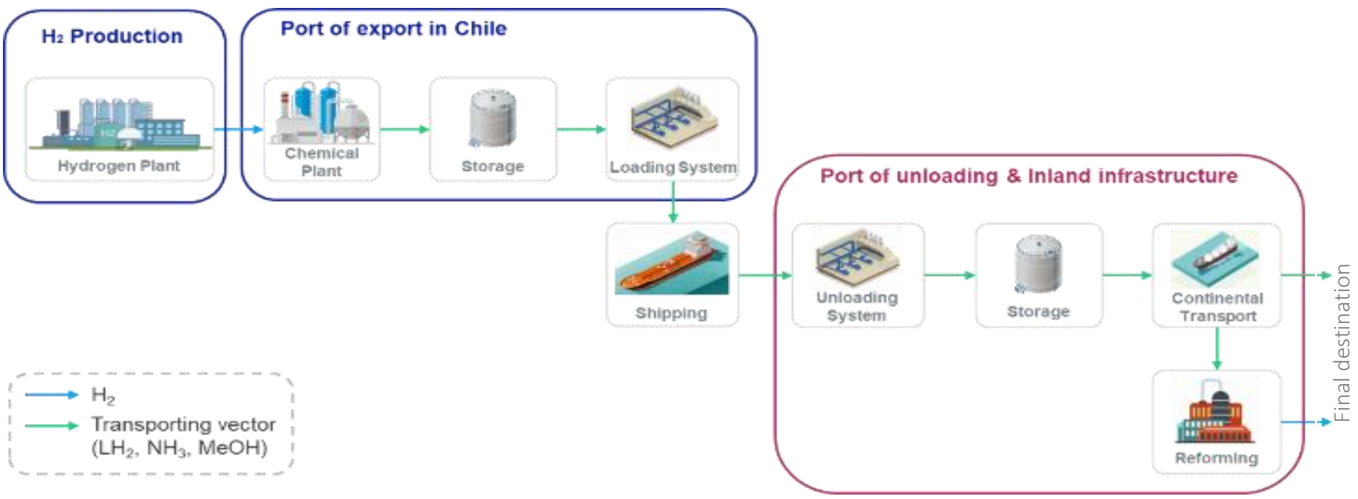
This study concludes that **Chile is ideally positioned to become an important player in the global energy transition, exporting green energy using hydrogen carriers. Significant investment is necessary to provide the adequate export infrastructure** to be competitive and play a leading role in this new market.

To achieve the international hydrogen cost (LCOH) targets, zones with high potential of producing green hydrogen (like Chile) should set ambitious targets and analyze complex factors that will help to decrease the value chain costs. Such **constrains can include transmission lines congestions and bottlenecks, stability issues, impact in the utility system cost, management of curtailment, detailed energy cost structure, land and water availability and permits**, and variable renewable profile among others.

Five different scenarios are accounted in terms of the amount of carrier to be traded: all the hydrogen production capacity in the north of Chile goes to Germany (1) or Japan (2); all the hydrogen production capacity in the south of Chile goes to Germany (3) or Japan (4); the hydrogen production capacity in the north and south is split between Germany and Japan (5). However, since the distance between the north and Japan is the shortest compared to the south, it can be assumed that the north supply the demand from Japan, leaving the remaining capacity to fulfill part of Germany's demand and the south produces hydrogen solely for Germany.

Although different types of carriers are analyzed in this study, their respective demands were set based on the green hydrogen production capacity of Chile. To calculate realistic costs of the exportation value chains, assumptions were made on the CAPEX, OPEX and efficiency of every part of the value chain. For the export value chain all values come from public sources and international studies. For the hydrogen production plants in Chile and the cost of renewables, the study recognizes different projections, considering optimistic and pessimistic scenarios when it comes to the future costs of grid and island-system electricity. Irrespective of Chile's excellent location conditions for cheap renewable electricity, these projections have a significant effect on the price of green H_2. The influence of CO_2 prices and other climate policy measures were not discussed.

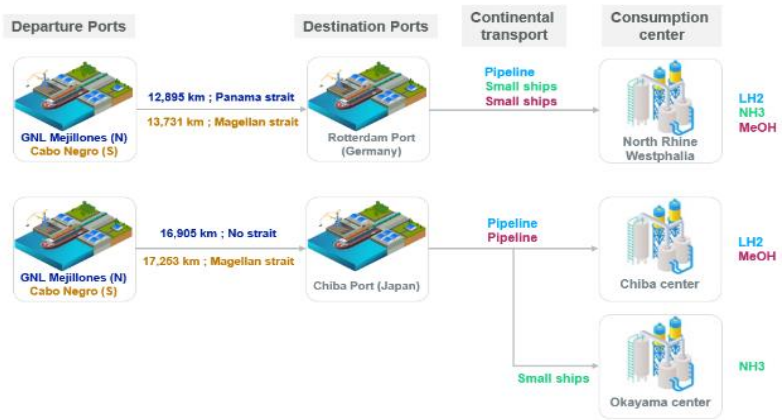
The study was carried out by Engie Impact/Tractebel on behalf of the Ministry of Energy and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in the framework of the Energy Partnership Chile-Alemania, which is supported by the German Federal Ministry for Economic Affairs and Energy (BMWi).



Key Messages

A) Production Costs & Shipping

Shipping costs only constitute a fraction of the total costs (LCOH) of the export value chain to Germany/Europe or Japan/Asia. Chilean Hydrogen can be competitive despite the distance from consumption centres. The cheap production costs for green Hydrogen make Chile competitive with other producers closer to demand centers. In the case of H2 export through methanol, from the North of Chile to Germany, the shipping cost constitutes less than 5% of the total costs of the export value chain by 2025; while in the case of H2 export through ammonia, constitutes less than 6% for the same year. Exporting to Germany /EU is a bit cheaper than exporting to Japan.



If ships, that export the hydrogen/carriers are used to transport chemicals on their way back from Germany to Chile, the shipping cost can almost be cut to half. This would have the biggest influence for the liquid hydrogen value chain, where the total LCOH can drop 4 to 8 percent. For ammonia this lowers to 2 to 3 percent and for methanol the influence is only 0.7 to 1.1 percent of the total LCOH. In 2018, 15.76 percent of the total Chilean chemical imports came from Germany, importing 360 billion USD of chemicals[1], so there is a potential market.

The methanol value chain can provide the lowest end costs in the destination markets by 2025[2] for delivering hydrogen as an end-product. Green ammonia should become more competitive by 2030. The biggest advantage of using methanol as hydrogen carrier compared to ammonia is the high overall efficiency of the value chain. Transporting liquid hydrogen still faces technical and price challenges, but its transport costs will be cut in half in the next decade and by even more until 2040.

B) Infrastructure & Export

For this study two Chilean ports were selected, one in the north and one in the south. However, other production sites and ports in the center of Chile are also realistic. Excellent solar resource availability in the north and excellent wind energy potential in the south mean that cost-competitive green Hydrogen can be produced locally, thus reducing transportation costs.

North: The GNL Mejillones S.A terminal has the required infrastructure for Liquid gas handling (LNG): unloading dock, LNG tanks for storage, regasification plant and loading/unloading truck infrastructure. Part of these existing facilities can be leveraged to reduce the overall value chain cost. Puerto Angamos, which is also located in Mejillones, has four available docks that trade different type of goods. Chilean company ENAEX uses one of these ports to import ammonia.

South: The Cabo Negro terminal has the required infrastructure to trade propane, butane, diesel and petrol. It is located next to the Magellan Strait, with the possibility to export hydrogen through the Pacific and/or Atlantic Ocean(s) and located next to METHANEX, a methanol production plant having methanol storage and terminalling facilities that might be utilized.

Center: Among others, the port GNL Quintero in the central Valparaíso region can alternatively developed in the future.

To meet the exportation levels presented in the study, capital investment in Chileans infrastructure of 80-100 MUSD is necessary at

[1] World Bank, 2016 "Chile Chemicals Imports". Available: https://wits.worldbank.org/CountryProfile/en/Country/CHL/Year/2016/TradeFlow/Import/Partner/All/Product/28-38_Chemicals.

[2] excluding costs for CO2 capture

both the ports of Mejillones and Cabo Negro. Being able to use existing port infrastructure both in Chile and Europe/Japan can lower the final hydrogen cost by ±1%.

Considering renewables construction, hydrogen production plants, liquefaction/ methanol or ammonia synthesis plants, and port infrastructure, total investments in Hydrogen infrastructure of around 3bn USD until 2025 and around 20bn USD until 2040 are estimated to be necessary.

In Europe, Rotterdam was chosen as port of destination, and in Japan Chiba. In April 2021, Chile signed an MoU with the Port of Rotterdam. The selected consumption center for hydrogen in Germany is North Rhine-Westphalia. To deliver hydrogen to this region, both the port of Rotterdam in the Netherlands and the cooperation ports of Zeebrugge and Antwerp are the best candidates. In Japan, the port of Chiba also counts with necessary infrastructure (LNG, LPG, crude oil, and chemicals).

Additionally, the port of Hamburg is projecting pipeline infrastructure to deliver hydrogen (or a carrier) to the Elbe region. The region around the port is an interesting cluster for the future hydrogen economy, to produce basic materials like steel, aluminum, and copper and to use green hydrogen as a storage solution/fuel.

C) Chile & the H_2 Market

In the future shipping industry, cheap hydrogen carriers and new green hydrogen propulsion technology are expected to be utilized. Special internal combustion engines powered by green ammonia o green methanol are expected to allow carbon-neutral ship transport in the future. Thus, **Chile has the chance become additionally, a global "green fuel bunkering hub"** in a completely new market, if it builds the necessary export and storage infrastructure.

As the GIZ study "Cuantificación del encadenamiento laboral para el desarrollo del hidrógeno en Chile bajo un escenario de exportación" points out, the development of an export industry of hydrogen and its derivatives in Chile has the potential to generate 38 thousand, 172 thousand and 570 thousand jobs for the years 2030, 2040 and 2050 respectively, considering for the export of green H2 products the same assumptions of this study and data from announced projects so far, and a scenario of demand for hydrogen and its derivatives as a CO_2-free maritime fuel. This creates enormous possibilities for **economic growth.**

According to a conservative scenario, Chile could, for example, provide half of the demand of green H2 and its derivates of an industrialized country like Germany in the future. Between the north and the south, at least 0.21, 1.05 and 2.1 Mtons/yr of hydrogen could be exported by 2025, 2030 and 2040 respectively[3]. Other studies have even higher estimations. Germany and Japan have ambitious demand targets for hydrogen in their roadmaps and strategy reports, 4.8 Mton/yr and 10.8 Mton/yr by 2040 respectively.

These new developments will support Chile's ambition to be among the top 3 producers of green hydrogen in the future, as stipulated in the Chilean National Green Hydrogen Strategy.

[3] Estimated from internal studies based on amounts of for projected exporting projects.

IMPRINT

The study was carried out by Tractebel/Engie Impact on behalf of the Energy Partnership Chile-Alemania.

Leading partners are the German Ministry for Economy and Energy (BMWi) and the Chilean Ministry for Energy (ME), together with numerous affiliated institutions. The GIZ, executive body of the partnership, can look back to more than ten years of successful cooperation with the Chilean Ministry of Energy (ME).

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