ENERGY PARTNERSHIP
CHILE-ALEMANIA

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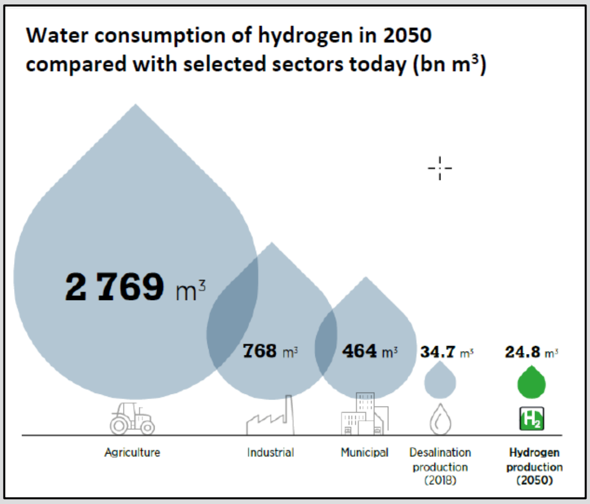
Water and Energy Synergy: Desalination, Treatment, and Sustainable Hydrogen

For Germany, the import of green hydrogen and its derivatives will play a pivotal role in achieving the goal of carbon neutrality by 2045. Given Chile's vast renewable energy resources, the country has significant potential to support Germany in reaching its targets by becoming a major supplier of renewable molecules. However, the electrolysis process requires a substantial amount of treated water, making a responsible approach to water treatment essential to ensure availability for both local populations and the emerging hydrogen industry. Sustainable water management, including desalination and reuse of wastewater, will be crucial to ensure local acceptance and comply with environmental regulations.

Water Consumption Power-to-X

The value chain of a Power-to-X facility can be broadly divided into four parts: power generation, water supply, electrolysis, and PtX synthesis. Due to the composition of water, which is about 90% oxygen, approximately nine kilograms of water are required to produce one kilogram of hydrogen, depending on the type of electrolysis used. Considering an electrolyzer efficiency between 80% and 95%, this amount increases to 9.5–11 liters of water per kilogram of hydrogen. Additional water is also required for cooling: a 1 MW PEM electrolyzer producing 18.2 kg of H_2 per hour consumes 400 liters of cooling water per hour, which equates to 22 liters of cooling water per kilogram of hydrogen. Furthermore, the process of achieving the necessary water quality also consumes water, adding up to a total of approximately 35 liters of desalinated or distilled water per kilogram of hydrogen produced. It is possible to improve water efficiency, but this would require a significant amount of energy. So, considering energy efficiency and the low costs of water, water efficiency losses are therefore accepted.

Nevertheless, the water consumption of the hydrogen production predicted for 2050 is just a fraction in comparison with other sectors today, like agriculture or industry as shown in graph 1. To put it into perspective for Chile: the demand for water by the hydrogen industry would only be 15% of the projected water demand by the mining industry, for example.



Graph 1 Source: IRENA, The Geopolitics of the Energy Transformation: The Hydrogen Factor, 01/2022, p.9.

Desalination and Waste Water Treatment

The quality of water injected into the electrolyzer is crucial for proper operation. In fact, the water requires a secondary treatment before being introduced into the electrolyzer. Since 2018, global desalination capacity has grown by approximately 25% and is projected to increase by an additional 20% by 2028. The Latin American market held a 5% share in 2023 and is anticipated to grow at a rate of around 10% in the coming years (see graph 2). Currently, 13,000 desalination plants worldwide operate using reverse osmosis technology, accounting for 69% of all desalination facilities. Among these, 34% source water from the sea.

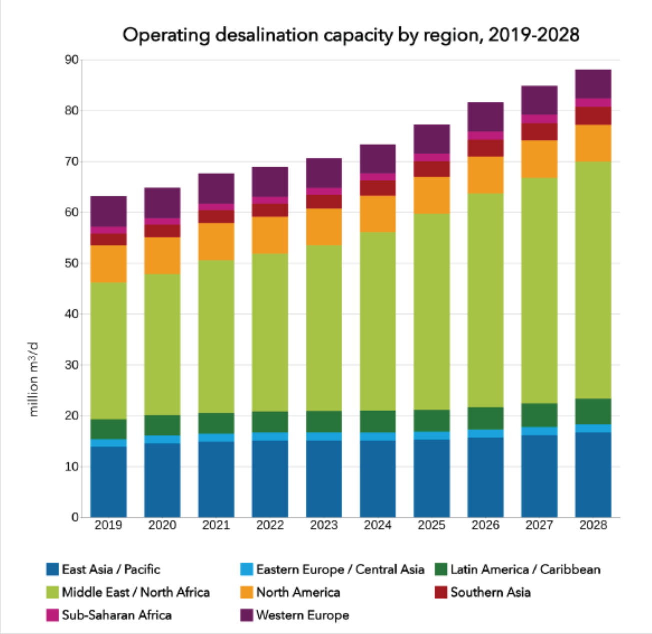
Chile has 22 desalination plants with a production capacity exceeding 20 liters per second, generating 8 m³ of desalinated water per second. Nationally, the mining sector consumes 81% of this desalinated water. In terms of regional output, the Antofagasta Region leads with 79% of national production at over 6 m³/s, whereas the Magallanes and Chilean Antarctic Region contribute less than 1%, at 0.063 m³/s.

Desalination plant efficiency varies; for ocean water processed through reverse osmosis, the recovery coefficient is 0.42. So, to get to the 35 liters of desalinated water needed to produce 1 kg of hydrogen 83 liters of ocean water are required. In contrast, with wastewater, the recovery coefficient is 0.65, reducing the water requirement per kilogram of hydrogen by 29 liters, to 54 liters. Currently, only 6% of wastewater in Chile is reused.

By 2030, Chile aims to produce 3 million tons of green hydrogen, demanding about 107 million cubic meters of treated water. To meet this requirement, 255 million cubic meters of seawater would need desalination, or alternatively, 166 million cubic meters of wastewater could be reused. In regions like Antofagasta, wastewater reuse could cover 143% of the water needed for green hydrogen, while in the Magallanes Region, it would meet only 9% of demand.

Economically, there is a strong correlation between the cost of energy and the cost of desalinated water, making the energy source the primary driver for reducing overall costs. In Chile, there are primarily three options for energy deployment: 1) Grid connection with a high percentage of renewable energy; 2) Direct renewable energy supply with grid backup, allowing the desalination plant to operate at partial load and benefit from off-peak energy discounts; or 3) Autonomous renewable energy, with or without energy storage, for intermittent operation. In Germany, studies are being conducted to explore another option: using only direct renewable energy sources and shutting down the desalination plant when these sources are unavailable.

Additionally, it is important to note that 70% of the total energy consumed in the desalination process goes into the reverse osmosis stage, highlighting the critical role of



Graph 2 Desalination capacities in operation and forecasts by region, 2019 - 2028, Source Global Water Intelligence GWI

this process step. To reduce costs and improve environmental sustainability, ongoing research focuses on optimizing reverse osmosis. This includes the development of chlorine-resistant membranes, which will make biofouling pretreatment more effective and cost-efficient. Other innovative approaches being investigated include increasing membrane permeability while maintaining a high salt rejection rate, developing membranes for higher pressure ratios and recovery rates, optimizing energy recovery by components, and improving energy conversion, pressure exchangers, and pressure intensifiers. Efforts are also being made to enhance the efficiency of pumps and converters.

In conclusion, with the growing demand for water driven by the expanding hydrogen industry, Chile has an opportunity to diversify its water sources by increasing wastewater reuse and enhancing desalination plant efficiency. These efforts would not only lessen environmental impacts but also contribute to creating local value.

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