ARTICLE

Green H_2 as new growth pocket for desalination - Once it takes off at scale

What the likely growth in demand for green hydrogen could mean for the desalination market

Roland Berger

PREFACE

The energy transition continues apace, transforming industries around the globe. Energy companies are increasingly aware of what the transformation means for them. For example, according to IRENA, if we are to meet our goal of limiting global warming to well below 2 °C compared to pre-industrial levels, demand for green hydrogen will need to grow to as much as 500 mtpa by 2050. This would have a substantial knock-on effect on other industries.

In this study we look at the potential opportunity that the likely growth of green hydrogen presents for desalination companies. Specifically, we calculate that the green hydrogen industry could require 250,000-500,000 m^3 per day of desalination capacity by 2030, potentially rising to ten to 20 million m^3 per day by 2050.

What is driving this forecast growth in water demand for green hydrogen, and why do we believe that desalination could be part of the answer? Where will the major centers of production for green hydrogen be located, and hence the need for desalination arise? And what should desalination players be doing now to prepare themselves for this likely increase in demand? We look at the truth behind the figures and examine what this new opportunity could mean for market players.

Contents

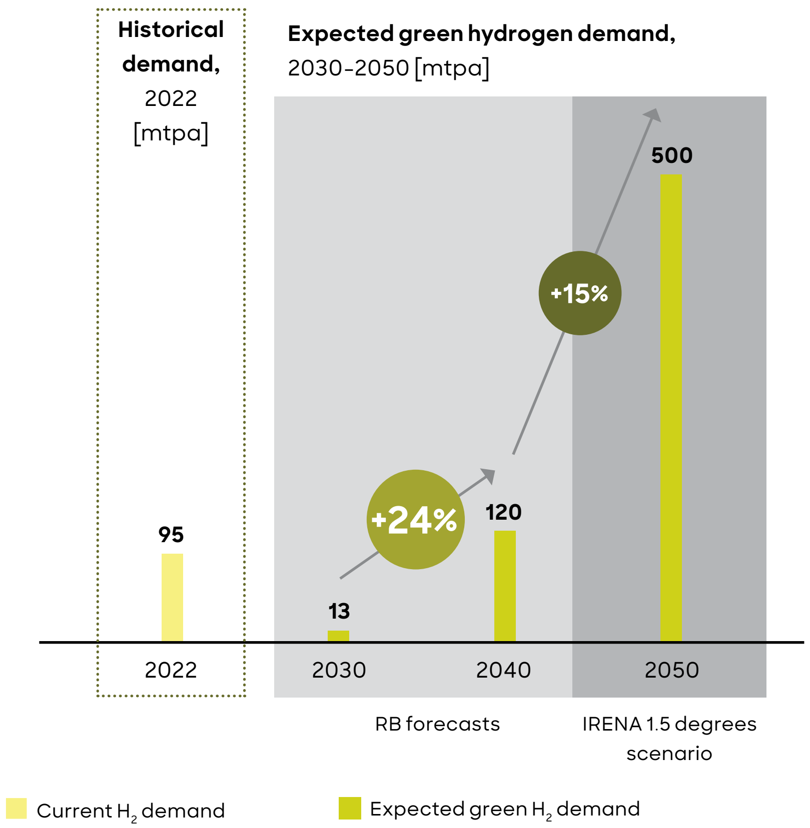
1 Green hydrogen and the global energy transition

Hydrogen is currently used in a wide range of applications across a variety of sectors, including oil refining and ammonia production. However, most of the hydrogen consumed by these sectors today is gray hydrogen – hydrogen derived from natural gas, the production of which causes greenhouse gas (GHG) emissions.

A clean alternative is to produce hydrogen via electrolysis of water using renewable electricity (solar, wind, hydro, and so on). Green hydrogen, as it is known, will likely be a major enabler of the energy transition, as hydrogen is a versatile molecule that has unique characteristics such as attractive energy storage properties.

Thanks to green hydrogen's unique role in enabling decarbonization, demand is expected to expand significantly over the coming decades. Market interest in recent years has been significant, although on-the-ground project development remains sluggish. Roland Berger predicts that green hydrogen production will reach around 13 million tons per annum (mtpa) by 2030 and will really take off towards 2040, potentially rising to 120 mtpa. This strong market growth will be necessary in order to meet the world's longer-term climate ambitions: The International Renewable Energy Agency (IRENA) describes a 1.5 °C scenario in its 2023 World Energy Transition Outlook, estimating the required green hydrogen production by 2050 to be around 500 mtpa. This level of green hydrogen production will help enable the decarbonization of hard-to-abate sectors such as steel production, oil refining and transportation.

A Expected global demand for green hydrogen, 2030-50 [mtpa]



Source: IRENA, Roland Berger hydrogen market model

Of course, for the production of green hydrogen to be competitive, renewable electricity must be available at low cost. Countries that enjoy excellent solar or wind resources are therefore likely to be future hotspots for the supply of green hydrogen – nations such as Saudi Arabia, Chile, Australia, the United Arab Emirates, Spain and Morocco – assuming that current challenges related to long-distance transportation of hydrogen can be overcome. Europe, the USA and China are also expected to be major producers of green hydrogen, but mostly for domestic consumption.

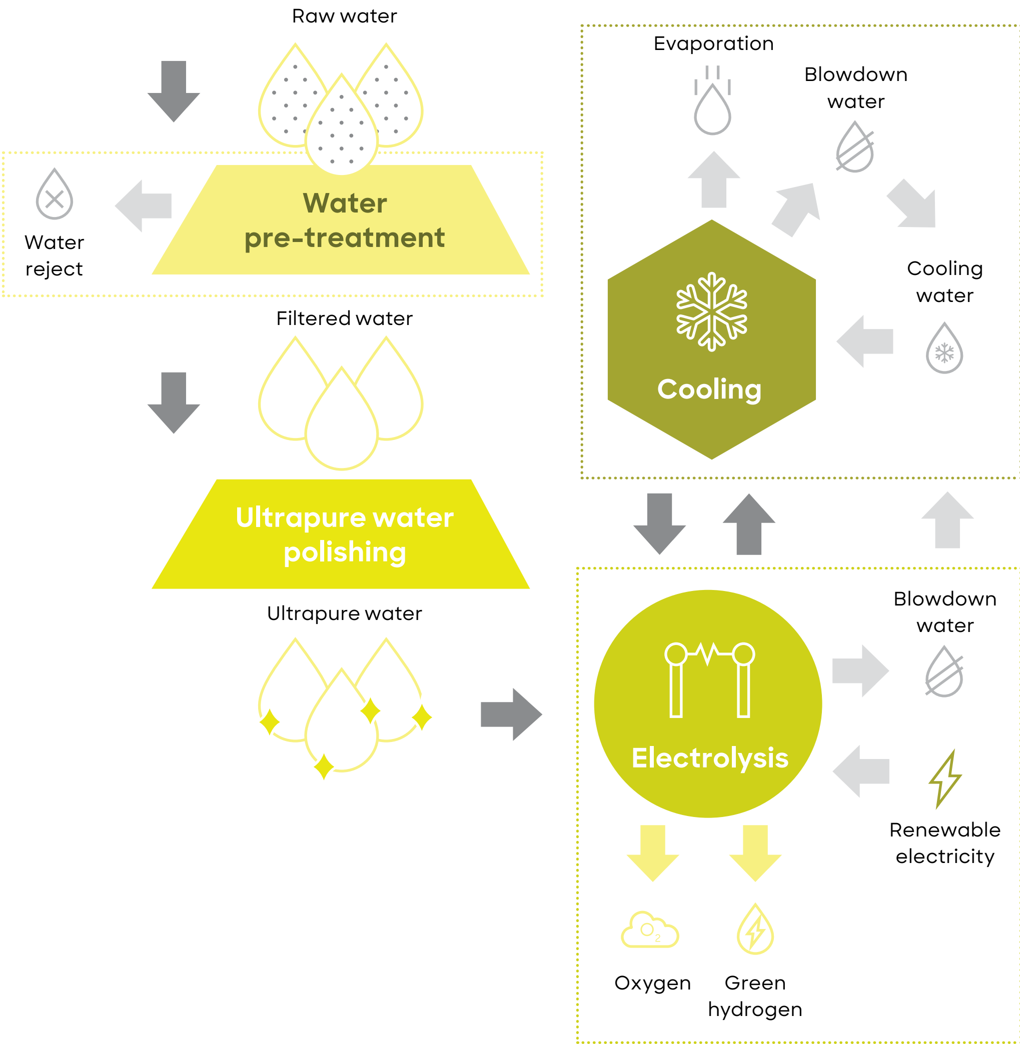
Today's discussions around green hydrogen are mostly driven by the energy sector, with the focus primarily on securing the required renewable electricity and offtake of the produced hydrogen. The other key input required for producing green hydrogen is water. We calculate that green hydrogen production could require up to 130 million m^3 of ultrapure water by 2030 and five billion m^3 by 2050, of which we believe a significant share will be supplied by seawater desalination. This translates into 250,000-500,000 m^3 per day of desalination capacity by 2030, rising to ten to 20 million m^3 per day by 2050. While these water needs, especially through 2030, are minimal compared to water consumption from other industrial sectors and only modest compared to the overall size and growth of the desalination market, they represent a potential new pocket of growth for desalination players – a new market segment with specific requirements and dynamics that market players need to understand, especially as we move into the 2040s and '50s. It is to this topic that we turn in the following chapters.

2 The need for water

Green hydrogen is produced through the electrolysis of water, a process in which water molecules are split into hydrogen and oxygen by an electrical current. In fact, water is required in the production process for green hydrogen in two capacities:

- **As process water:** Ultrapure water (with very low conductivity and organic load) is used as process water for the electrolyzer, where the H_2O molecules are split into hydrogen and oxygen. In theory, nine liters of water are required to produce one kilogram of hydrogen, although in practice around ten liters are needed due to losses in the electrolyzer
- **As cooling water:** Electrolyzers also produce waste heat and therefore need to be cooled. This cooling can be water-based, in which case cooling water is required, or it can be air-based, in which case no cooling water is required

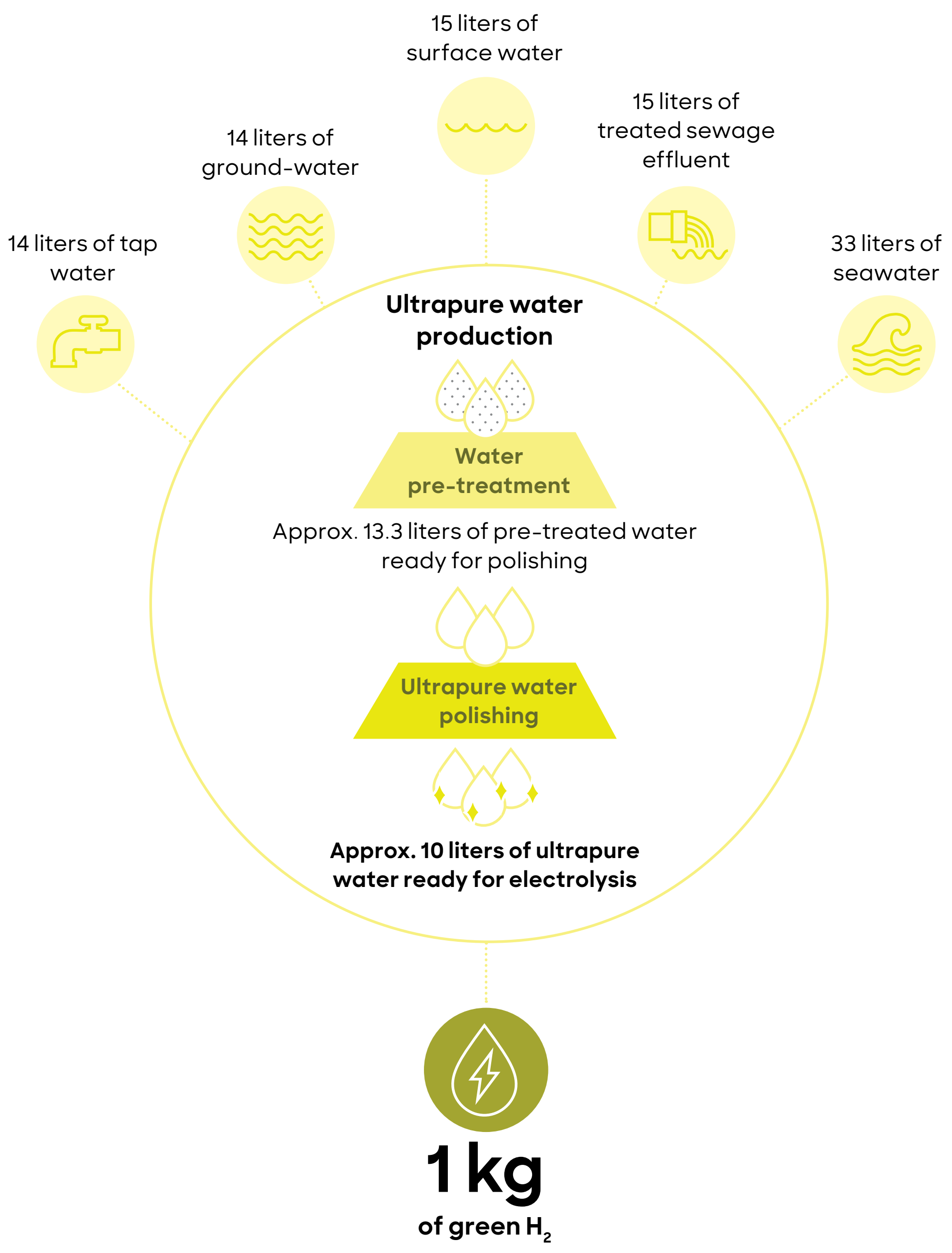
B The green hydrogen production process



Source: Roland Berger

In this study we focus on the need for process water in the green hydrogen production process. Because ultrapure water is required for the electrolysis process, green hydrogen production units will typically have a water treatment installation attached to them to filter and polish the incoming water supply, turning it into ultrapure water. This incoming water can be tap water, groundwater, surface water (water from rivers and lakes), treated sewage effluent or seawater. The lower the purity of the water supply, the greater the amount of water needed for the same output of ultrapure water. To produce the ten liters of ultrapure water required to produce one kilogram of green hydrogen, between 14 and 33 liters of incoming water is needed, depending on the source.

C **Approximate amounts of water needed to produce 1 kg of green hydrogen, by type of water**



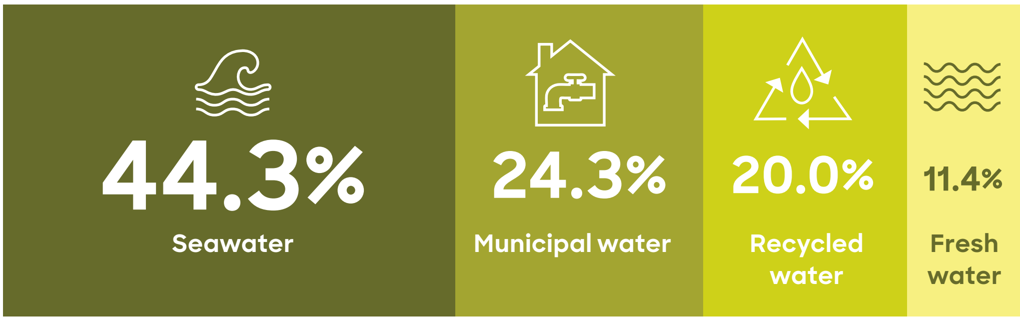
Source: Roland Berger

3 A new growth pocket for desalination?

Where will the water for the major expansion of green hydrogen production in the coming decades come from? While green hydrogen's water needs are minor compared to society's overall water footprint, we believe that freshwater is unlikely to be the source. Factors such as population growth, socio-economic development and changing consumer behavior are pushing up global demand for freshwater, while climate change and water pollution are limiting its supply. Water is also critical for society to sustain itself, so any new industrial applications requiring water potentially face a public backlash, warranted or unwarranted. For that reason it seems improbable that industry will use valuable freshwater as process water in green hydrogen projects.

Recent announcements of green hydrogen projects appear to confirm this. Just under half of the announced green hydrogen projects that have declared their water source will rely on desalination of seawater. That proportion is likely to grow over time.

D Declared[1] water sources of announced green hydrogen projects [%]



1) Only 9% of announced green hydrogen projects have so far declared their source of water

Source: GWI

The two non-conventional sources of water available for green hydrogen production are treated sewage effluent and seawater. The use of treated sewage effluent is more water-efficient than seawater. Moreover, co-locating wastewater treatment with green hydrogen production allows for synergies with the use of the by-product oxygen for aeration (a standard purification step in the treatment of wastewater) and the use of waste heat from the electrolyzer for drying the sewage sludge. However, green hydrogen production units that rely on treated sewage effluent must be located close to wastewater treatment plants and their size is limited by the availability of treated sewage effluent.

While less treated sewage effluent is required than seawater for the same output of green hydrogen, seawater in fact has four clear advantages over other water sources:

1. **Physical proximity:** It is expected that green hydrogen production will be concentrated in regions with abundant low-cost sources of renewable electricity (countries in the Gulf Cooperation Council, Australia, Chile and parts of Africa), then exported as hydrogen or its derivatives to regions with high demand (Europe, Japan and South Korea). Hydrogen production in exporting regions is therefore likely to be concentrated around ports, which naturally have direct access to seawater
2. **No impact on local water resources:** Currently announced green hydrogen production projects include many smaller projects that will not have a noticeable impact on conventional water sources. However, projects are expected to grow in size over the coming decades and could impact local resources. In addition, using seawater would be less likely to attract public scrutiny, although it will be important to ensure that desalination brine is handled properly

3. **Negligible impact on costs:** The process water required for green hydrogen production represents only a fraction of the cost of the hydrogen produced, even if desalination is required. Accordingly, project developers are likely to choose the most reliable, risk-free source of process water, which will often be desalinated seawater
4. **Not affected by water scarcity:** Water demand is growing and supply is decreasing, driven in part by climate change. As this trend continues, green hydrogen production's reliance on conventional water resources will come under increasing scrutiny and government regulators are likely to promote the use of alternative water resources, such as desalinated seawater

CALCULATING FUTURE DEMAND

Based on expected growth in demand for green hydrogen, we calculate that demand for ultrapure water to be supplied to electrolyzers could amount to around 130 million m^3 by 2030 and five billion m^3 by 2050. Assuming approximately 75 percent conversion efficiency of the ultrapure water polishing step, a total of around 175 million m^3 of filtered water could be required by 2030 and 6.6 billion m^3 by 2050 as input for the polishing step of the ultrapure water treatment.

Depending on the source of water used as input for the water pre-treatment process, total water demand could therefore amount to 200-400 million m^3 by 2030 and between seven and 16 billion m^3 a year by 2050. It should be noted that this only represents a fraction of total freshwater withdrawal (currently around 4,000 billion m^3 a year), so the water needs of green hydrogen production are unlikely to have a noticeable impact on water resources.

Assuming that between half and all of green hydrogen is produced using desalinated seawater and a typical desalination plant operates 8,000 hours a year, we calculate that **total demand for desalination capacity to supply process water to green hydrogen projects could be 250,000-500,000 m^3 per day by 2030, rising to ten to 20 million m^3 per day by 2050.**

Before 2030, hydrogen production is unlikely to have a noticeable impact on the dynamics of the desalination market. The estimated 250,000-500,000 m^3 per day of required desalination capacity compares to tens or even hundreds of thousands of m^3 per day for a typical desalination plant for municipal applications. But after 2030, and especially in a world that doubles down on its climate ambitions, hydrogen production could become a more significant driver of incremental growth in the desalination market, contributing to investment decisions in desalination capacity.

In regions with high levels of water scarcity, demand for desalination for green hydrogen will often go hand-in-hand with demand for desalination for drinking water, other industrial uses and in some cases even agriculture. We therefore do not expect to see dedicated desalination plants serving hydrogen production facilities: Even a multi-Gigawatt electrolyzer installation would only require desalination capacity in the order of 10,000-100,000 m^3 per day, which could be produced by a mid-size plant[1]. Rather, we see green hydrogen becoming one of several factors driving investments in desalination capacity.

The growth of green hydrogen production thus opens up a new pocket of growth for players in the desalination market. In the final section of this report, we turn to the implications for those in a position to capture that potential, businesses that are either active in the market or looking to enter it, and their relationship with other stakeholders.

1 For comparison, the world's largest desalination plant, located in Ras Al Khair in Saudi Arabia, has a capacity of over 1,000,000 m^3 per day.

4

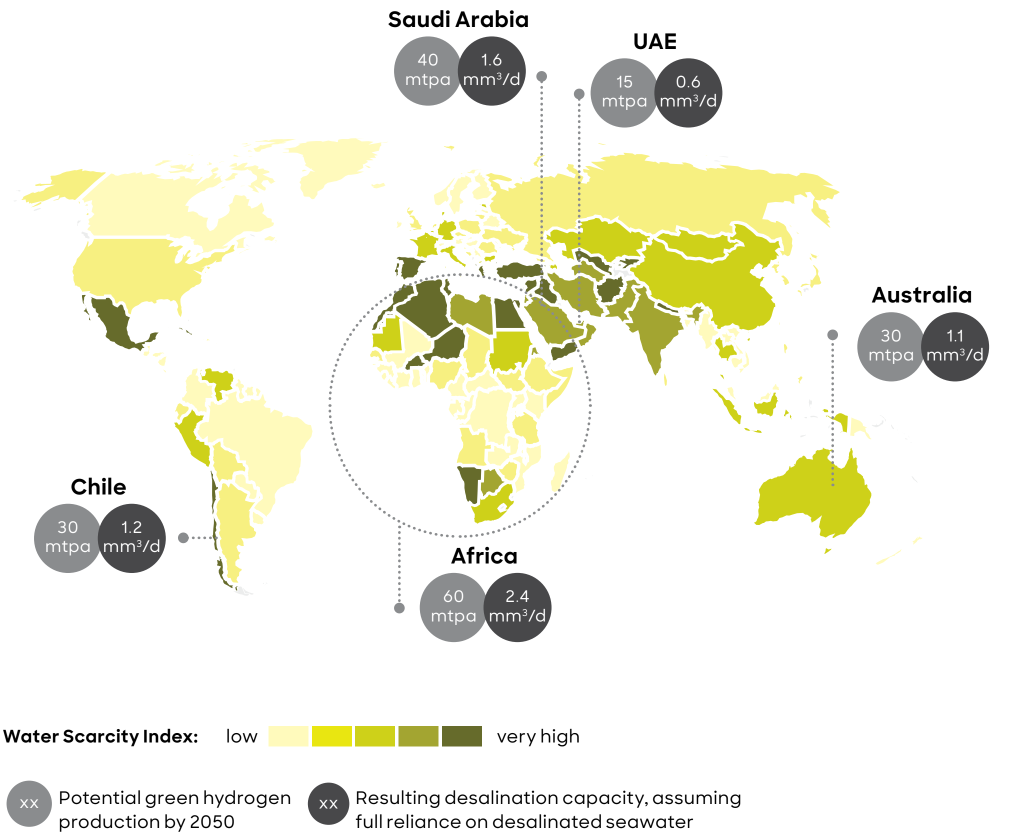
Capturing the potential

In 2022, around 21,000 desalination plants were operating worldwide, with a total production capacity of more than 100 million m^3 of desalinated water a day[2]. The desalination market is already growing strongly due to the need to provide a reliable source of water to an increasingly drought-stricken world. The extra desalination demand that could arise from green hydrogen production, while modest compared to the overall size and growth of the market, represents an additional pocket of growth that market players can tap into, especially in the decades after 2030.

As mentioned in Chapter 3, there is good reason to believe that if we can overcome the current challenges of long-distance transportation of hydrogen, a significant share of the new desalination capacity required for green hydrogen production will be located in the countries in the Gulf Cooperation Council, Australia, Chile and parts of Africa. These regions have best-in-class renewable electricity resources but often face a high level of water scarcity. Figure 5 indicates the potential size of green hydrogen production in selected regions in 2050 and the resulting desalination capacity required.

2 See: IFRI - The Geopolitics of Seawater Desalination (2022); Jones et al. (2018)

E Projected green hydrogen production and desalination capacity requirements, selected regions, 2050



Source: Green hydrogen production figures: for UAE, National Hydrogen Strategy; for Saudi Arabia, Deloitte 2023 Global Green Hydrogen Outlook; for Africa, AGHA 2022 Africa's Green Hydrogen Potential; for Australia, BloombergNEF's latest New Energy Outlook on Australia (covering only exported green hydrogen); for Chile, Chilean 2020 National Green Hydrogen Strategy

IMPLICATIONS FOR MARKET PLAYERS

Desalination players will need to expertly navigate the emerging green hydrogen ecosystem. What should they be doing to prepare themselves for the coming expansion of the market?

First and foremost, desalination players must position themselves with regard to **green hydrogen consortia**. Recent green hydrogen projects have typically been developed by consortia made up of different types of companies, including renewable energy players, chemical players and hydrogen off-takers or traders. Desalination companies need to identify the winning consortia and position themselves as their solution providers of choice. To do so, they need an end-to-end offering covering all requirements with regard to water, both desalination and polishing. The quality of the process water supplied to the electrolyzer has a significant impact on its performance and durability, as impurities can permanently damage the electrodes. For this reason, consortia will be paying close attention to the reputation and reliability of the water supplier.

Second, desalination companies must be careful to work closely with **local governments and regulators**. While desalination is commonplace in regions such as the Middle East, it is not yet widely practiced in some of the countries where we expect to see a boom in the production of green hydrogen. In these countries, desalination players will need to convince policymakers, local governments and regulators to allow the introduction of seawater desalination plants and provide financial support where appropriate.

One topic of particular importance is the **management of brine**, a by-product of the desalination process. Currently, this brine is generally discharged back into the sea, but companies should investigate methods that limit or even avoid this entirely and instead capture the valuable elements present in the brine.

Another key topic is the use of **renewable energy** to power desalination plants – potentially a key success factor in winning over both hydrogen consortia and regulators. Several players, especially in Middle Eastern countries such as Saudi Arabia and the United Arab Emirates, already have in-depth experience with both desalination and renewable electricity, and these players will be particularly well positioned to provide the desalination plants for upcoming green hydrogen products around the world.

Finally, desalination players must understand the growth dynamics of demand for water, particularly in regions and for specific applications where desalination could be a relevant source, and integrate them into their investment considerations.

At Roland Berger we provide consulting services in both the hydrogen and desalination industries, with an eye towards their expected growth beyond 2030. Our expertise covers all areas of the hydrogen and water markets, including market dynamics, sector strategies, regulations and user needs. Through our extensive work in the hydrogen sector we have developed a network of development consortia, allowing us to effectively connect key players in the market. Additionally, we possess in-depth knowledge of the technologies used in hydrogen production, desalination and ultrapure water treatment, equipping us to support our clients effectively in this evolving industry.

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