How can we optimise water supply for green hydrogen?

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Introduction

Renewable hydrogen (or green hydrogen) is considered vital to assist in the transition towards a net zero carbon economy. Renewable hydrogen refers to hydrogen that is produced from renewable energy and generally uses water as the feedstock for hydrogen.

It is estimated that Australia will export 45 Mt/a by 2050 (Murray, 2021) with a key export location being Singapore. On this basis, and assuming optimistic water requirements (i.e. low levels at 15 L raw water per kg H2 for good quality water and dry cooling), this would result in a total requirement of almost 700 GL/year i.e. water for almost 10 million people. This number would increase for lower quality water and warmer climates.

Many of the proposed hydrogen projects and hubs around Australia are based in water scarce locations (Figures 1 and 2). Proponents need to appropriately consider the water supply challenge as a integraland complex aspect of project development.

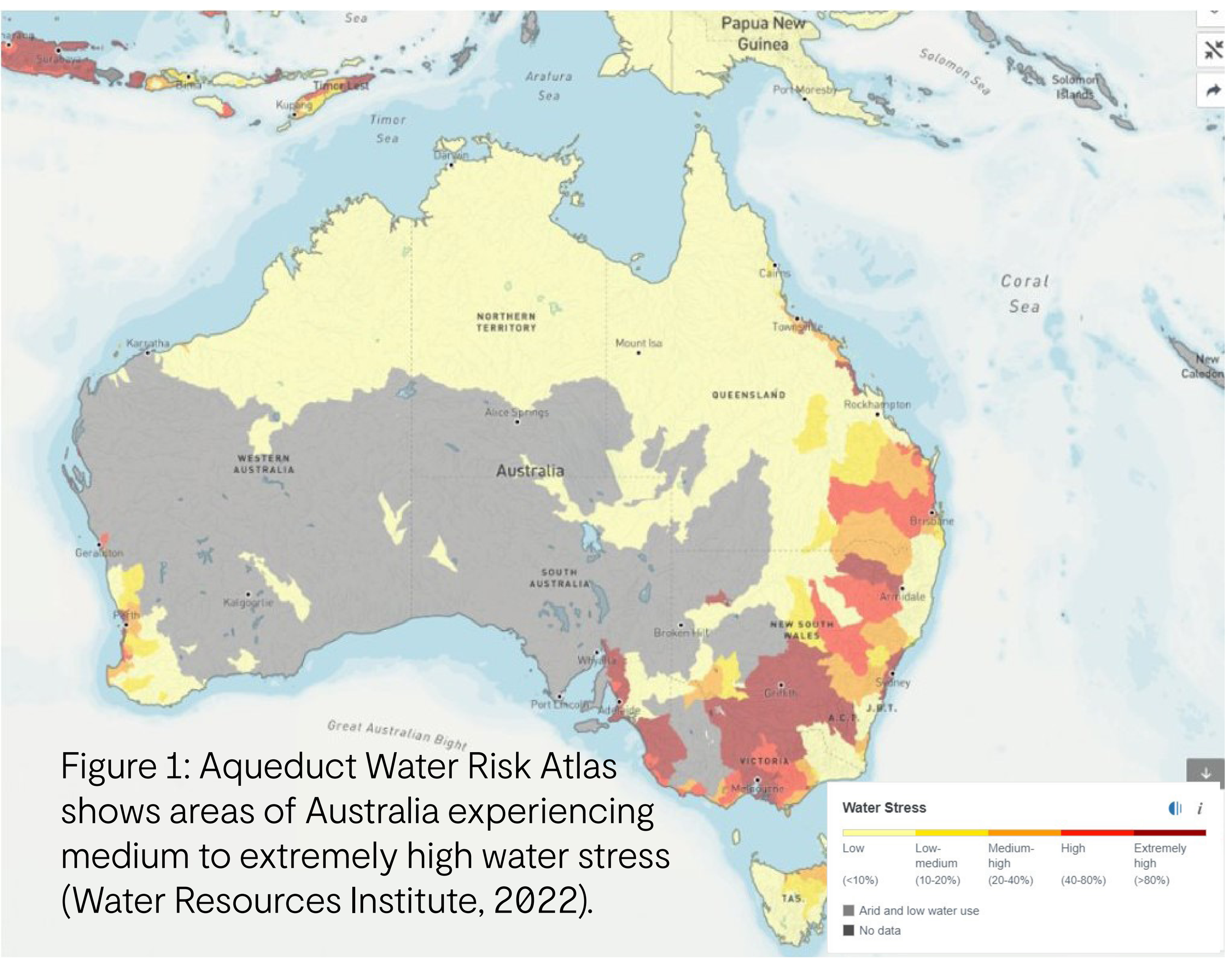

Figure 1: Aqueduct Water Risk Atlas shows areas of Australia experiencing medium to extremely high water stress (Water Resources Institute, 2022).

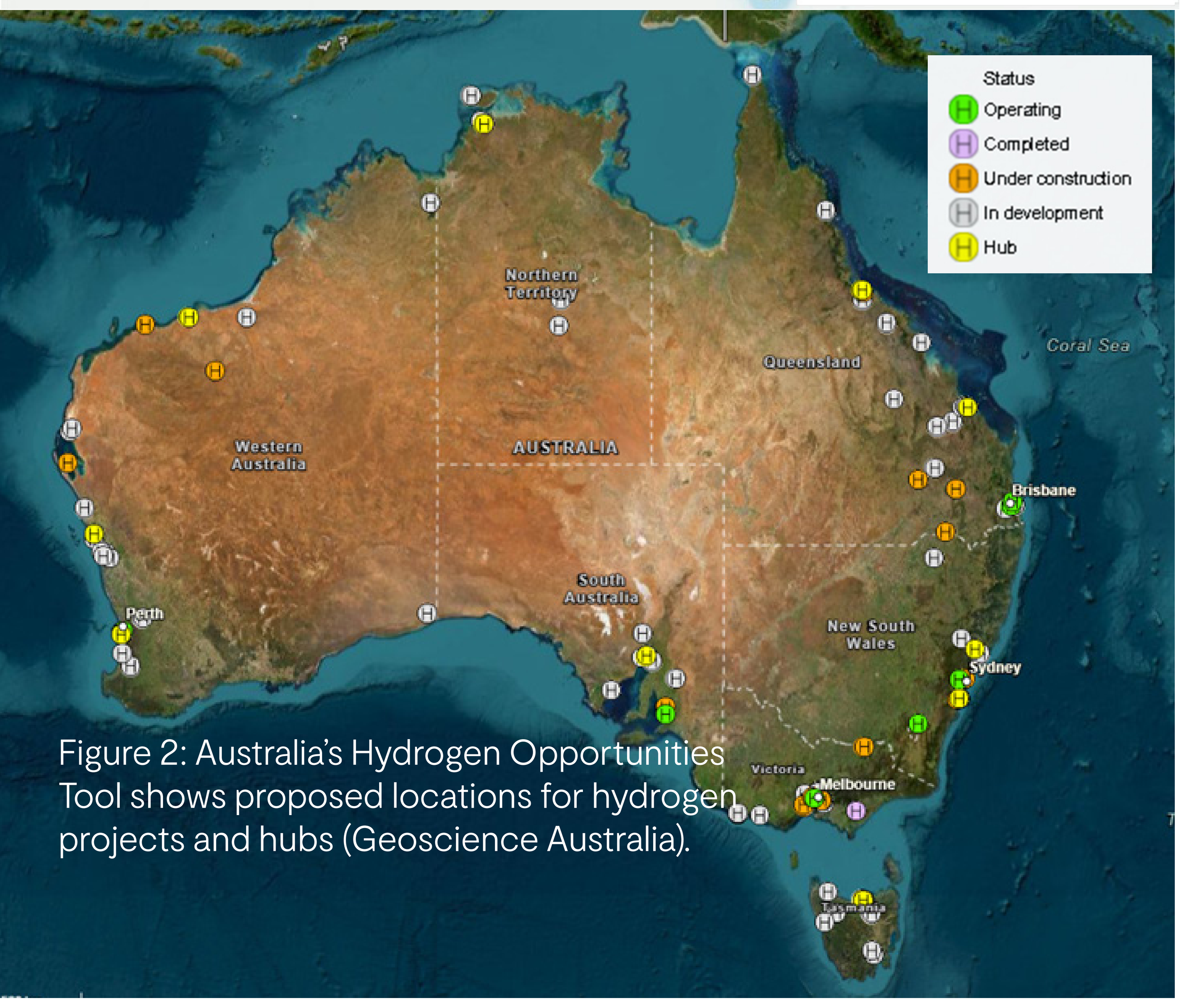

Figure 2: Australia's Hydrogen Opportunities Tool shows proposed locations for hydrogen projects and hubs (Geoscience Australia).

Considerations

Given the sheer potential scale of the hydrogen industry, it is important to understand the factors that affect water requirements. These may include project location, climatic conditions, raw water source and quality, project size, electrolyser efficiency, cooling strategy, desalination technology, water recovery and recycling methods, brine/waste management opportunities and constraints.

This research presents the results of a detailed investigation into how various project factors affect water requirements and waste production.

Water demands

Hydrogen production (electrolyser):

- Demineralised water required is approximately 10-12 L per kg of hydrogen produced

Cooling:

- Many types available
- 0.5 to 20 times hydrogen electrolysis water demand
- Electrolyser cooling demand increases over time
- Feed water quality ranges from sea water to demineralised water
- Cooling demand doubles with most H_2 carrier forms

Types	Quantity required	Water quality required	CAPEX / OPEX	Energy	Typical Application
Once through cooling	Very high	Surface or Sea Water	Low	Low	Older large scale
Evaporative cooling	High	Surface / sometimes Sea Water	Medium	Low	Older large scale / recent small scale
Air cooling including adiabatic	Medium / Very high intermittent	Demin, town water	Medium	Medium	Recent small/ large scale
Air cooling	Very low	Demin, town water	Medium – High	Medium	Recent small/ large scale
Chillers / refrigeration	Very low	Demin, town water	High	High	Recent small/ large scale
Waste heat utilisation	Very low	Demin, town water	Medium – High	Low	Not common

Table 1: Cooling strategies and their respective water quality and quantity requirements.

Waste streams

All process areas produce various by-products/waste, in particular, water treatment and often cooling. Factors affecting raw water requirement and waste stream production include:

- Raw water quality (especially salinity)
- Cooling (type/climate)
- Hydrogen carrier type
- Level of water/waste recycling

To optimise water and hydrogen costs and risks, consider water and hydrogen processes together. Figure 3 demonstrates an integrated approach for an inland location with many aspects adopted from the power industry.

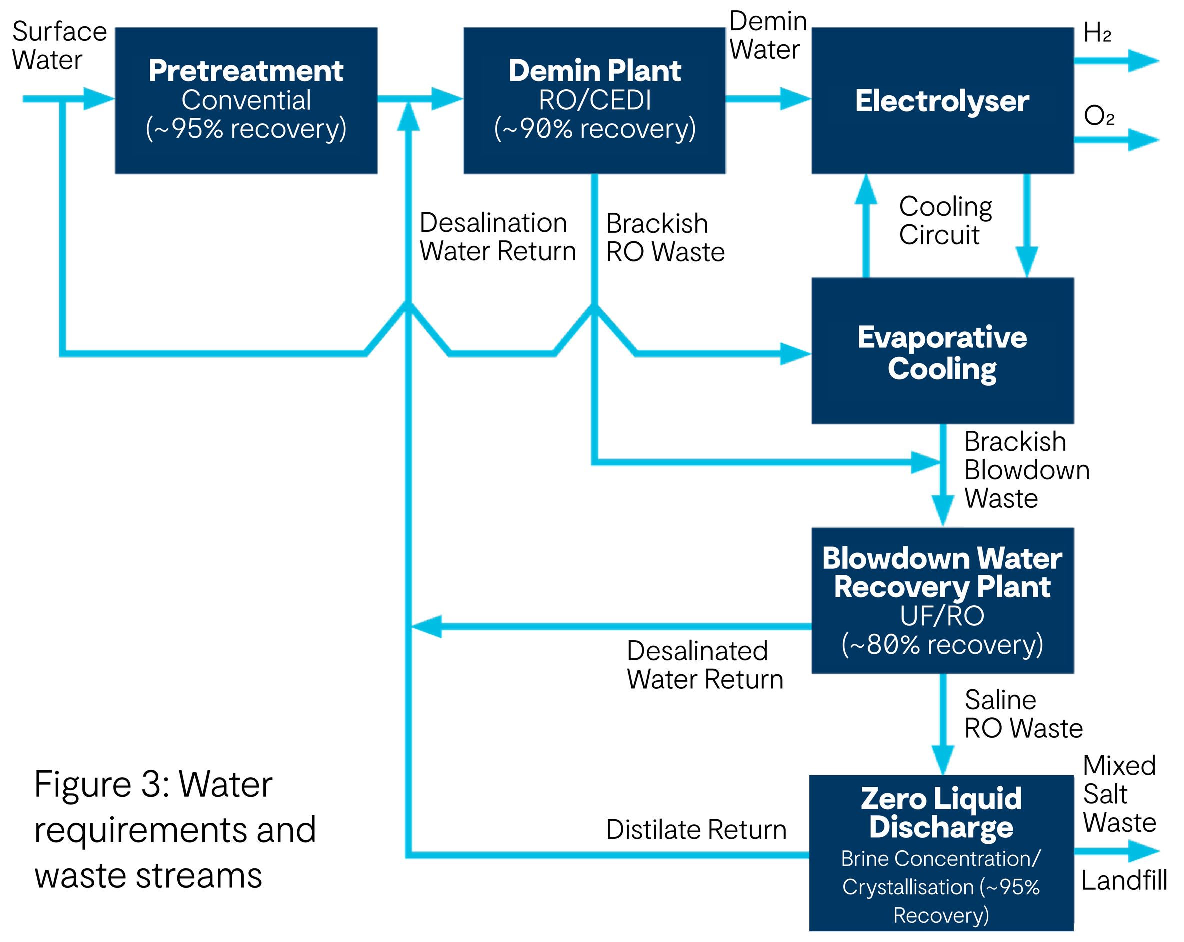

Figure 3: Water requirements and waste streams

Methodology

The methodology we used to undertake this investigation included:

1. Identifying key factors which directly affect water requirements.
2. Identifying options for each factor (Table 2). Options with fatal flaws or low likelihood of implementation were excluded.
3. Developing concepts which included likely combinations of factors to enable comparison water requirements (Table 2).
4. Developing flow diagrams for each concept and undertaking simulations to develop mass and energy balances with their respective water requirements.

Options

Understanding the key factors which directly affect water requirements can help identify which options are suitable for future hydrogen projects.

Table 2: Concepts demonstrating requirements for each option.

Option	Electrolyser Size (MW)	Renewable H2 Tech	Cooling	Water Tech	Brine Tech	Brine Disposal	Total raw water demand (L/kg H2)	Raw water demand for demin (L/kg H2)	Raw water demand for cooling (L/kg H2)	RO concentrate production (% of raw water volume)	Comments
1	300	PEM - current efficiency	Evaporative	RO	ZLD	Landfill	37	12	25	2.5%	Blowdown WTP used for water recovery
2	300	90% efficiency electrolyser	Evaporative	RO	ZLD	Landfill	22	12	9	2.6%	Blowdown WTP used for water recovery
3	300	PEM - current efficiency	Air	RO	ZLD	Landfill	12	12	N/A	9.5%	No blowdown WTP
4	300	PEM - current efficiency	Air	AWG	None	None	11	11	N/A	N/A	AWG therefore no RO waste
5	1,000	PEM - current efficiency	Air	RO	None	Sea	26	26	N/A	59%	No blowdown WTP
6	1,000	SOEC - 90% efficiency	Air	RO	None	Sea	27	27	N/A	59%	No blowdown WTP
7	1,000	PEM - current efficiency	Evaporative	RO	None	Sea	53	27	27	53%	Blowdown recycled into main WTP
8	1,000	PEM - current efficiency	SW Once Through	RO	None	Sea	1480	26	1454	1.0%	RO concentrate diluted by cooling water

Key findings

The largest direct impact on water requirements, as anticipated, is the cooling strategy employed, with air having the lowest requirement, followed by evaporative cooling and then by once through cooling.

The next largest impact is the raw water quality where more saline water results in higher raw water requirements, more capital and energy intensive treatment, lower recoveries and higher production of waste (i.e. brine). The latter is addressed at the coast via sea outfall, although it is important that environmental impacts and community concerns need to be considered and addressed.

The efficiency of an electrolyser has a large impact in terms of cooling water requirements where a decrease in efficiency from 90% to 70% can effectively triple the cooling requirements.

The use of evaporative cooling at inland locations requires small yet very expensive ZLD equipment.

The AWG could potentially provide significant benefits. However, AWG is highly novel, has not been proven at larger scales (i.e., 1-2 ML/d) and uses significant amounts of energy (i.e 25 times more energy than seawater RO). Although there are opportunities to use waste heat to drive part of the process.

Challenges and opportunities

Challenge / Opportunity	Description
Location siting	– Proximity to various water sources, hydrogen export location, feed stock methane, energy sources – Cooling considerations
Cooling water requirements	– Air versus water cooled dependent on local climate and interplays with siting – Sea water once through cooling versus sea water cooling tower – Adiabatic cooling requirements at hot inland locations (requires very high water usage)
Feed water availability and chemistry	– Feed water availability (i.e. even in high rainfall areas, all available water may already be allocation for drinking water, agriculture or environmental flows) – Feed water quality and quality uncertainty (e.g. untested groundwater) – Many available sources but are challenging to treat (e.g. brackish groundwater, brackish water from estuaries) – Regulations related to water access and the end-uses
Brine management strategy	– Many readily accessible water streams require desalination – Desalination produces a considerable waste stream that is challenging to treat, manage and dispose.
Recycling of waste streams from water treatment and hydrogen production waste streams	– At water constrained locations there are drivers to maximise plant recovery via waste stream recycling – Waste stream recycling can be challenging due to quality, lack of information available on HPU waste streams etc
Waste heat recovery	– Waste heat may be used for desalination (e.g. membrane distillation) and/or assist cooling processes

Conclusion

Given renewable hydrogen is seen as critical to the pathway to net zero, it will play a large role in Australia's export industry. Renewable hydrogen will require significant volumes of water to meet current expectations and sustainable sources need to be sought after, especially for a dry continent such as Australia. Therefore, it is important to understand the factors that could reduce water requirements for hydrogen production.

While all projects have common and scenario-specific challenges and opportunities, high water use has an impact on social licence, as well as environmental impact. The challenge will be to find sites that are amenable to the hydrogen industry, community and the environment and to consider all the relevant factors when choosing a raw water source, cooling philosophy and water/brine treatment flowsheet.

GHD has a readily available tool that can incorporate process simulation for project-specific technical issues, including water quality and water treatment technology. Get in touch with the team to learn more.