HOW CAN I OPTIMISE WATER REQUIREMENTS FOR MY GREEN HYDROGEN PROJECT?

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ABSTRACT

Green hydrogen will help store, transport, and utilise renewable energy and is seen as key in terms of assisting Australia and the world moves towards a net zero carbon economy. Water is integral for hydrogen production so it will be important to source sustainably and accurately estimate requirements. Australia is also seen as a significant future exporter of hydrogen. However, high water use has an impact on community acceptability, as well as an environmental impact. Based on several renewable hydrogen projects undertaken around Australia, this investigation identified key factors which drive water requirements. These include location, climatic conditions, electrolyser efficiency, cooling strategy, raw water source, water recovery and brine / waste management. This paper summarises the water requirements for various green hydrogen project concepts, based on the factors identified, which will help optimise water use.

INTRODUCTION

Renewable hydrogen (or “green hydrogen”) is considered vital to assist Australia’s and the world’s drive 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 the global hydrogen demand by 2050 will be over 580 million tonnes per annum (Mt/a) with two thirds of this via renewable green hydrogen (IRENA, 2021). It is expected that the hydrogen export for Australia will be 1 Mt/a by 2030 through export of hydrogen to China, Germany, Japan, South Korea etc (ACIL Consulting for ARENA, 2018). This may increase to 45 Mt/a by 2050 and become a $90 billion industry for Australia (Murray, 2021). Assuming good quality surface water with minimal cooling requirements, the raw water requirement may be as low as 14-15 L per kg of hydrogen (with 9.0 L of pure water required per kg of hydrogen). This would result in a total requirement of almost 700 GL/year of good quality raw water. These numbers will increase significantly if low quality water or sea water were to be utilised.

Therefore, given the shear 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

A detailed investigation was subsequently undertaken where eight case studies were developed to capture several realistic variations of the above factors and to determine the water requirements for each. The relative water requirements were then summarised (on a L/kg hydrogen basis), along with the capacity of key infrastructure to provide an indication of water-related project costs and complexity.

HIGHLIGHTS

- Factors affecting renewable hydrogen water requirements were identified.
- Comparison of available water concepts were developed for different technologies.
- Quantification of methods to reduce water and waste while producing green hydrogen were undertaken.
- Cooling methodology and raw water quality are the main factors affecting water requirements.
- Electrolyser properties, such as lifetime reduction of efficiency and cooling circuit temperature, are very important and often overlooked

METHODOLOGY

The methodology employed to undertake this investigation covered:

1. Identification of key factors which directly affect water requirements.
2. Options for each factor were identified and options with fatal flaws or low likelihood of implementation were excluded. The options identified and short-listed are shown in Table 1.

3. Concepts were developed which included likely combinations of factors which enabled comparison water requirements. The concepts investigated are summarised in Table 2.
4. Flow diagrams were developed for each concept and simulations were undertaken to develop mass and energy balances with their respective water requirements.

RESULTS

The concepts developed using the methodology above enabled ready comparison of key factors likely to be used in future hydrogen plants. The following summarises the developed concepts (see Table 2):

- Small (300MW) electrolysers were coupled with inland locations due to likely reduced infrastructure (i.e. power, water and export locations), whilst large (1GW) electrolysers were placed at the coast.
- Inland water quality is considered to be surface water quality (TDS ~500 mg/L) and coastal water quality was typical sea water (TDS of ~35,000 mg/L)
- Current electrolyser efficiency is typically 70% whilst future technology improvements may result in 90% efficiency. This provided a proxy to investigate the lifetime decline of electrolyser efficiency (up to 15%).
- Both evaporative and air cooling were investigated inland and at the coast, whilst once-through cooling was appled at the coast only (similar to Eraring and Torrens power stations).
- Reverse osmosis is the core desalination utilised however a highly novel water production technology was also included to evaluate it's potential beneifts i.e. Air Water Generation (AWG).
- Inland options employ zero liquid discharge (ZLD) as evaporation ponds have significant footprint and environmental concerns. Disposal of brine to the sea was the only viable approach for coastal options.

The water requirements and water infrastructure capacities were then developed for each concept and are summarised in Table 3 and Table 4. The following summarises the 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 the 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 the evaporative cooling at inland locations requires small yet very expensive ZLD equipment.
- The AWG could potentially provide significant benefits in terms of not requiring a surface or sea water source of water and producing very little waste. 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. typically >100 kWh/m^3 of treated water compared to <3-4 kWh/m^3 treated water for most RO systems). Although there are opportunities to use waste heat to drive part of the process.

CONCLUSION

Given renewable hydrogen is seen as critical to the pathway to net zero, it will play a large role in Australia as an export industry. Renewable hydrogen will require significant volumes of water to meet current expectations and sustainable sources need to be sought after, in particular for a dry continent such as Australia. Therefore, it is important to understand the factors that could reduce water requirements for hydrogen production. It has been found, through this investigation and based on real projects, that the cooling strategy, raw water quality and electrolyser efficiency have the greatest impact. The greatest reduction in water use is through the use of air cooling. Air cooling however requires more energy and has higher capital costs compared to evaporative cooling and is not possible on hot days (i.e. many locations in Australia) without electrolyser derating or augmentation (e.g. with chillers or evaporative cooling). While these have an economic impact on hydrogen development, they are currently dwarfed by electrolyser capital cost and power consumption (although this may change with electrolyser developments in the medium term).

High water use has an impact on social licence, as well as an 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.

REFERENCES

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Table 1: Options Development Table (removed options are crossed out)

Location	Size	Renewable H2 Tech	Cooling	Raw Water Source	Treatment technology	Brine Tech	Brine / Waste Disposal
Inland	Small	PEM (current Eff)	Evaporative	Seawater	RO	None	~~None~~
Coastal	Large (1 GW)	PEM (90% Eff)	Air	~~Brackish~~	~~Thermal Power Driven~~	~~Solar Evaporation Ponds~~	Ocean disposal
		~~SOEC~~	~~Chillers~~	Surface water	~~Thermal Heat Recovery~~	Thermal ZLD – Power Driven	~~Brine Injection~~
		~~Solar thermal~~	Sea Water Once Through	Air	AWG power driven	~~Thermal ZLD – Heat Recovery~~	~~Evaporation Pond / Tailings Dam~~
		~~Alkaline~~	Sea Water Evaporative	~~Bore~~	~~AWG heat recovery~~	~~Encapsulation~~	Landfill
		~~Others~~	Others e.g. bore	~~Recycled water~~	~~Others~~	~~Others~~	~~Others~~

Table 2: Concepts Table

Option	Location / Water Source	Electrolyser Size (MW)	Renewable H2 Tech	Cooling	Water Tech	Brine Tech	Brine Disposal
1	Inland Surface Water	300	PEM - current efficiency	Evaporative	RO	ZLD	Landfill
2	Inland Surface Water	300	90% efficiency electrolyser	Evaporative	RO	ZLD	Landfill
3	Inland Surface Water	300	PEM - current efficiency	Air	RO	ZLD	Landfill
4	Inland Surface Water	300	PEM - current efficiency	Air	AWG	None	None
5	Coastal Seawater	1,000	PEM - current efficiency	Air	RO	None	Sea
6	Coastal Seawater	1,000	SOEC - 90% efficiency	Air	RO	None	Sea
7	Coastal Seawater	1,000	PEM - current efficiency	Evaporative	RO	None	Sea
8	Coastal Seawater	1,000	PEM - current efficiency	SW Once Through	RO	None	Sea

Table 3: Water requirements for each concept

	Concept	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	Inland Typ. Eff. Evap.	37	12	25	2.5%	Blowdown WTP used for water recovery
2	Inland High Eff. Evap.	22	12	9	2.6%	Blowdown WTP used for water recovery
3	Inland Typ. Eff. Air	12	12	N/A	9.5%	No Blowdown WTP
4	Inland Typ. Eff. Air AWG	11	11	N/A	N/A	AWG therefore no RO waste
5	Coast Typ. Eff. Air	26	26	N/A	59%	No Blowdown WTP
6	Coast High Eff. Air	26	26	N/A	59%	No Blowdown WTP
7	Coast Typ. Eff. Evap.	85	27	58	53%	Blowdown recycled into Main WTP
8	Coast Typ. Eff Once Thr.	1480	26	1454	1.0%	RO concentrate diluted by cooling water

Table 4: Water infrastructure capacity for each concept

	Concept	Intake / Feed Capacity (ML/d)	Outfall Capacity (ML/d)	RO Plant Feed Capacity (ML/d)	Demin Plant Feed Capacity (ML/d)	Water Recovery Plant Capacity (ML/d)	Zero Liquid Discharge Plant Capacity (ML/d)
1	Inland Typ. Eff. Evap.	4.7	N/A	1.5	1.3	0.6	0.12
2	Inland High Eff. Evap.	3.4	N/A	1.8	1.6	0.5	0.09
3	Inland Typ. Eff. Air	1.6	N/A	1.5	1.3	0.2	0.04
4	Inland Typ. Eff. Air AWG	1.4	N/A	1.3	1.3	0.1	N/A
5	Coast Typ. Eff. Air	11	0.0	11	4.5	N/A	N/A
6	Coast High Eff. Air	14	0.0	14	5.5	N/A	N/A
7	Coast Typ. Eff. Evap.	36	11	35	4.5	N/A	N/A
8	Coast Typ. Eff Once Thr.	630	620	11	4.5	N/A	N/A