Hydro Tasmania

Tasmania's 'green hydrogen' opportunity

Tasmania's unique advantage as a 'green hydrogen' development zone

November 2019

Foreword

Hydrogen is gaining unprecedented global attention as a key enabler of a clean, secure and affordable energy future.

This report identifies the unique attributes Tasmania has to become an early Australian participant in hydrogen production, including analysis of relative economics.

Tasmania's existing electricity system is primarily based on hydropower, with contributions from wind energy, residential solar, gas generation and interconnection with Victoria. The Tasmanian hydropower system consists of 30 power stations, each with different hydrological characteristics. The hydropower system is able to operate flexibly with wind and other variable renewables to provide reliable, clean energy to support the production of hydrogen at high capacity factor. We believe this will be a key element in supporting the growth of a competitive 'green' hydrogen industry in Tasmania, to support both overseas and local markets, as the world transitions to low-carbon energy sources.

A Tasmanian hydrogen industry and the Battery of the Nation initiative would work together to provide value through economic, technology and employment growth opportunities for the Tasmanian community, in addition to supporting the transition to a national and global clean energy future.

Steve Davy

Hydro Tasmania Chief Executive Officer

November 2019

Contents

Hydro Tasmania document control			
Title	Tasmania’s Green Hydrogen Opportunity		Version:1.0
		Document owner:	Tony Field
		Date created:	8 November 2019
Approver:	Steve Davy, CEO	Date approved:	8 November 2019
		Date effective:	12 November 2019

1.0 Executive Summary

Tasmania is well positioned to meet the emerging international demand for hydrogen produced from clean energy sources. This White Paper outlines a unique set of advantages Tasmania offers in 'green hydrogen' production.

Japan and other markets have flagged the intention to import substantial quantities of hydrogen produced from clean sources to meet emission reduction targets. While hydrogen can be produced using fossil fuels with carbon capture and storage (CCS), industry sources have expressed a preference for the 'green hydrogen', produced from renewable energy.

The following advantages create a strong opportunity to pursue a competitive green hydrogen industry.

- **Low cost.** Green hydrogen can be produced in Tasmania for approximately 10-15% less than other Australian power grids needing to offset emissions and 20%-30% less than from dedicated off-grid renewables[1] due to the higher capacity factor available.
- **Low risk.** International partners can rely on hydrogen supply from Tasmania due to a high level of energy security. Tasmania is also very stable in terms of geopolitical and other major risks.
- **100% renewable integrated system.** Tasmania is predicted to be the first state in Australia to be self-sufficient in renewable power generation – on target for 2022. This will provide strong credentials for the provision of green hydrogen from an integrated power system, without the need for carbon offsets.
- **Potential for high electrolyser utilisation.** Wind and solar energy backed by hydropower could provide a reliable supply of renewable energy at all times of the day.
- **Excellent infrastructure.** Tasmania has accessible and expandable existing port infrastructure, strong transmission infrastructure, significant and reliable access to fresh water, and an established industrial precinct with development sites. Tasmania, as with other Australian development locations, is comparatively close to Japan and Korea both of whom are actively developing opportunities and partnerships to deliver clean hydrogen.
- **Options for expansion of supply.** Expansion of Tasmania's renewable energy generation through development of further interconnection and the *Battery of the Nation* project will provide more options for supply.
- **Tasmanian brand.** Tasmania's 'clean, green' brand is likely to add value to green hydrogen produced in the state.

Tasmania is uniquely placed to offer an excellent environment for green hydrogen production with competitively-priced renewable energy from high capacity factor wind supported by hydropower supply. A large-scale, cost-competitive green hydrogen production industry could be developed in Tasmania over the coming decade. There is an opportunity to leverage this market leading position to form long-term strategic partnerships.

[1] Hydro Tasmania analysis (see Assumptions Book Section 5.0)

2.0 Background

Tasmania has a successful history of industrial development fuelled by low cost renewable electricity developments. We are entering a new era through *Battery of the Nation*, placing Tasmania in a competitive positon for attracting new industry to fuel economic growth for the state. 'Green hydrogen' (hydrogen produced by renewable energy) production is one such emerging industry where Tasmania is likely to have a competitive advantage, particularly in the near term.

The global market potential for hydrogen export is massive. ACIL Allen have predicted export potential for Australia at around 1.3 million tonnes by 2040[2]. To put this in context, a 1000 MW production facility in Tasmania would represent just 10% of this volume – and yet it would more than double Tasmania's current major industrial electricity demand.

Hydrogen production has the potential to support further large scale investment in new renewables as well as direct employment. If Tasmania is able to gain an early position in hydrogen it opens the prospect of also creating industries around related technology and developing local expertise, producing substantial benefits for the Tasmanian economy.

2.1 Why is capacity factor important to achieve cost competitive hydrogen production?

At a high level, the cost of production for hydrogen is influenced by:

a) Cost of electricity ($/MWh),
b) Process (electrolyser) efficiency (MWh/kg),
c) Capital cost of hydrogen plant ($),and
d) Operating costs ($/year).

The capital cost of the hydrogen plant is a major part of total cost of production. Higher capacity factor (i.e. utilisation) makes better use of the investment by allowing the fixed costs of plant to be spread across more hours of operation, resulting in a lower cost per kilogram of hydrogen.

2.2 Can "green" hydrogen be produced from grids with a high emissions intensity factor?

The relevance of the emissions intensity of the grid to the production of green hydrogen will depend on the final outcome of an internationally accepted 'guarantee of origin' standard. It is considered very unlikely that emissions free attributes will be transferred simply through power purchase agreements from producers of (variable) renewable energy, noting that to achieve economic plant utilisation it will be necessary to procure firming which will need to be sourced from predominantly fossil fuels in most regions. In order to achieve green certification for hydrogen, purchase of carbon offset or carbon credits to cover the emissions intensity from the grid may be required. This will add additional cost to the production of hydrogen or ammonia to achieve the 'green' status from a power

[2] https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf Table 4.9

system with emissions. For example, Australian Carbon Credit Units (ACCUs) are trading at around $15-16[3] per tonne in October 2019. Emissions intensity factors[4] vary between regions with an average across the NEM of around 0.725 t CO2/MWh

2.3 Can hydrogen be produced by off grid wind and solar?

While it is technically possible to produce hydrogen using off grid wind and solar, it is unlikely to be economically viable, particularly in the short-term.

Electrolysers can operate over a wide range of power input down to around 10%. However, in a commercial operation there is always a level of baseload power required to support the balance of plant. This adds cost to provide some kind of storage to manage the baseload supply to the balance of plant. However, much more importantly, wind and solar are the most readily available and cost-effective renewable energy, but they will deliver lower capacity factor energy (25 – 50%). This will seriously impact the cost-effectiveness of the solution[5]. Operating at low capacity factors means that the fixed costs of plant need to be spread across fewer hours of operation, resulting in a higher cost per kilogram of hydrogen than can be achieved through a grid connection.

In the long term, as the cost of electrolysers fall, the economics of operating at lower capacity factors will improve. This will enable hydrogen production to provide important grid support services with more production aligned to periods of excess renewable generation. Hydrogen production could become an important part of the solution to achieve high renewables penetration in the power system, however, in the foreseeable future operating at high capacity factor is important to reduce the cost of production.

[3] https://tfsgreen.com.au/australian-environmental-markets/carbon-markets/
[4] https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Settlements-and-payments/Settlements/Carbon-Dioxide-Equivalent-Intensity-Index
[5] This conclusion is also supported in the Hydrogen Economy evaluation by Jacobs analysis: https://www.jacobs.com/hydrogen-economy

3.0 Tasmania's unique 'green' hydrogen production advantage

3.1 Tasmania has the potential to produce hydrogen at large scale from renewable energy

Tasmania has large scale new renewable resource development potential

- *8700+ MW (including 260 MW under construction) of potential new wind development potential in addition to 300 MW existing, all with world class wind resource driven by the Roaring 40s weather pattern*
- *2400 MW of current hydro generation with scope for 3400 MW of pumped hydro capacity – expandable within the existing hydro system[6].*

The progression of significant new Tasmanian wind development proposals, currently in the planning stage, will make Tasmania a net exporter of renewable energy. This could mean that Tasmanian hydrogen and ammonia would be considered 'green' without the need to procure additional carbon offset credits. Accreditation of green hydrogen could be provided through the existing National Greenhouse and Energy Reporting (NGER) or through the National Carbon Offset Standard.

3.2 Tasmania can provide high capacity renewable energy

While solar PV and wind are now the cheapest sources of new electricity, the relatively low capacity factor (25% to 50%) has a significant impact on the economics of green hydrogen production.

Tasmania is unique in Australia in that it has an existing hydro generation system that is capable of providing renewable firming to new low cost wind generation in a region that will become a net exporter of renewable energy. This provides a major advantage to the economics of green hydrogen production as it is will be possible to produce in Tasmania from grid supply at high plant utilisation.

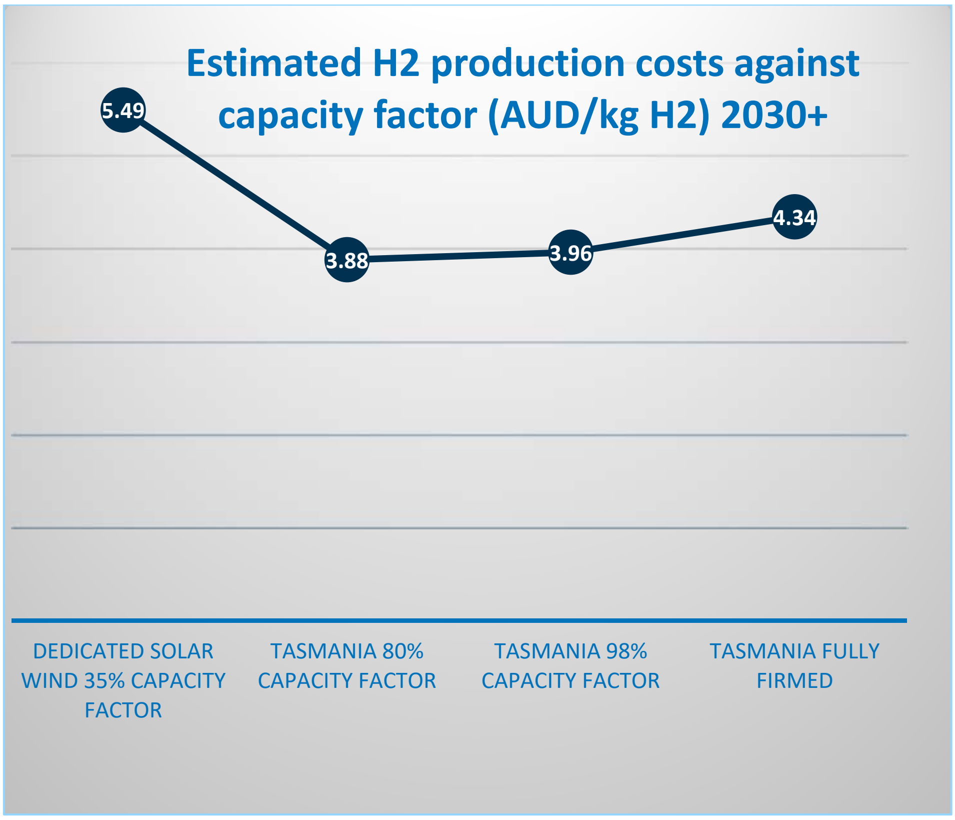
A much higher capacity, achieved through hydropower firming, allows the fixed costs of plant to be spread across more hours of operation, resulting in a lower cost per kilogram of hydrogen.

[6] https://www.hydro.com.au/clean-energy/battery-of-the-nation/pumped-hydro

3.3 Tasmania can produce low cost hydrogen

Tasmania has a range of options that could be used to support hydrogen production. Notable benefits can be derived from using energy directly from the grid to achieve high capacity factors. The following graph shows a cost calculation using the full set of assumptions in Section 5.0.

Based on this analysis, the lowest cost of production is likely to be achieved between 80% and 90% capacity factor. At higher capacity factors electricity is being consumed at high price periods which affects the total cost of electricity and results in increased production costs.



Analysis by Hydro Tasmania based on the attached Assumptions Book

3.4 Tasmania has a 'ready-made' large-scale hydrogen production hub

Tasmania is well placed in terms of infrastructure to initiate large-scale hydrogen production. The Bell Bay Advanced Manufacturing Zone in northern Tasmania has all the key attributes for green hydrogen production including:

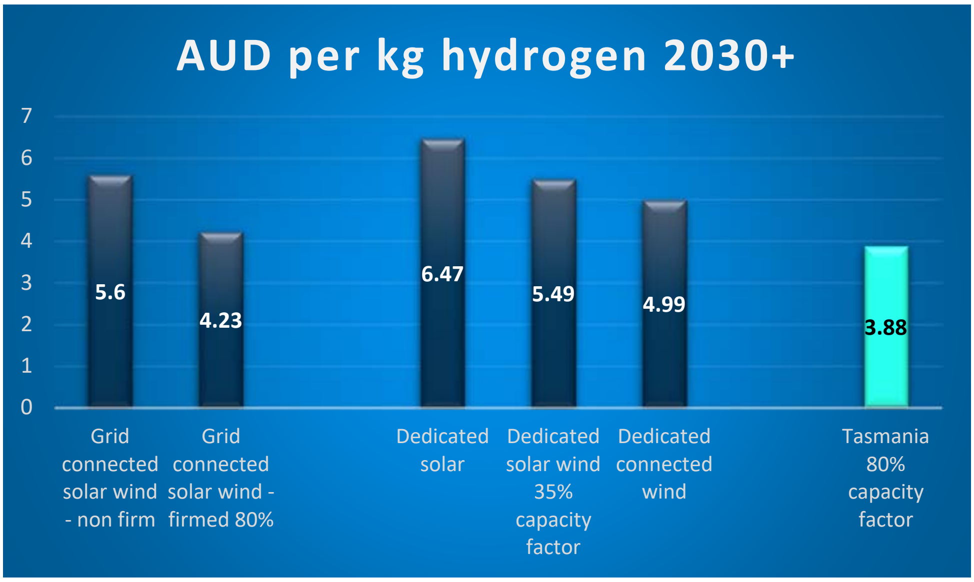
- Existing strong transmission connection built for major industry;
- Deep all-weather port with scope for expansion;
- Access to fresh water;
- Established industrial precinct with development sites available; and
- Social mandate for new low impact industry

Many other locations will need to factor in the cost of desalination. The requirement for desalination may add up to around 2% of operation and maintenance cost (excluding energy). Social licence for use of fresh water is unlikely to be an issue in Tasmania in the volumes contemplated.

3.5 Comparing the future cost of production across the NEM

The following graph identifies that green hydrogen could be produced from the grid in Tasmania at around 10-15% less than other Australian power grids (at average emissions intensity) and 20%-30% less than from dedicated off-grid renewables. Japan has set a 2030 price target of 30 yen per normal cubic metre (about AUD 5 per kg) and this provides a useful benchmark. Considering transportation supply chain costs, it is estimated that hydrogen would need to be produced at around AUD 3.10 per kg in Australia to meet this target.[7] This is only preliminary analysis and should be considered indicative. There may be options to find further efficiencies.

It is also important to note that it is acknowledged that it will take time to achieve this price and while the industry matures higher costs are expected.



Analysis by Hydro Tasmania based on the attached assumptions book

3.6 Tasmania is a low risk option for international partners

Affordable, reliable and secure energy is one of the key foundations of a successful modern economy. Importing energy from an international partner is a decision that needs to be made carefully – particularly with respect to full consideration of risk. Geopolitically and economically Tasmania, as with the rest of Australia, would be considered stable and low risk. This is a very attractive proposition for such a critical foundation of a national economy. Tasmania doesn't necessarily have a significant advantage over other Australian states in this regard – but may have an advantage over other countries.

[7] based on currency conversion 0.014AUD/Yen - 9 Oct 2019

4.0 Conclusions

While still a maturing industry, hydrogen is likely to have substantial advantages for energy transport and fuel replacement. This means that hydrogen presents a significant long-term opportunity for energy-rich countries – particularly countries that can cost-effectively produce large amounts of renewable energy from high value resources. Australia has large-scale opportunities to develop a strong hydrogen production industry to support both export and domestic demand.

There are few locations in the world that have the unique attributes of Tasmania for the production of green hydrogen at scale. The unique attribute of being able to support hydrogen production from renewable energy at high capacity factor enabled by hydropower firming is likely to give Tasmania a sustainable production cost advantage compared to other regions. Tasmania's clean, green, brand would also provide value to this proposition.

The analysis indicates that green hydrogen can be produced in Tasmania for approximately 10-15% less than other Australian power grids needing to offset emissions and 20%-30% less than from dedicated off-grid renewables due to the higher capacity factor available.

Meeting Japan's 2030 cost target will be challenging – yet with cost and supply chain improvements it may be within range for Tasmania. This is potentially achievable through a combination of further reduction in wind costs, improved transport process efficiency, technology cost reduction, improvements in electrolyser efficiencies, improved technology for extraction of hydrogen at destination or direct end use of hydrogen derivatives such as ammonia, liquid organic hydrogen carriers (LOHC) or methanol.

There is a near-term opportunity to develop relationships that can grow into long-term partnerships. Large-scale demonstration facilities will be required and Tasmania presents a highly attractive opportunity. Short-term there is a cost advantage for green hydrogen and also the potential to scale up to support a much larger industry.

5.0 Assumptions Book

Assumption	Value	Source
a) **Delivered Cost of electricity ($/MWh),**		Based on projected energy prices for new entrant solar and wind off grid and on grid with and without firming. Tasmanian and rest of NEM long term contract price convergence assumed. Tasmanian energy price for different capacity factor based on long term projected price duration curves Hydro Tasmania internal assumptions.
b) **WACC (Weighted Average Cost of Capital) real**	8%	International Energy Agency (IEA) IEA G20 Hydrogen report, 2019. Assumptions.
c) **Cost of water ($/ML),**	$850/ML limited quality water Taswater Water consumption 20 l/kg H2 Cost covered within O&M allowance	Poatina or South Esk $22.25/ML plus infrastructure. - https://www.hydro.com.au/water/water-prices Or $850/ML limited quality water https://www.taswater.com.au/Your-Account/Water-and-Sewerage-Charges Consumption 20 l/kg H2 Allows for 9l of water to produce 1 kg hydrogen plus 11 l/kg for closed circuit cooling systems plus losses in demineralisation) If a standard Taswater limited quality tariff was applied it would be $850/Ml pa plus around $20,000 pa connection being around $110,000 pa for a 100 MW electrolyser - this would be a high estimate – assume included within O&M (< 2.5% of O&M allowance)
d) **System efficiency (MWh/kg) ,**	45kWh/kg 2031 +	https://www.iea.org/hydrogen2019/ page 45 outlines ranges 56%-60% % today (55 kWh/kg) 2025 68% (48 kWh/kg) 2030 For PEM. SOEC rises to 77%-90% long term Jacobs used 55 kWh/kg in 2025 and 45 kWh/kg in 2041

e)	**Operating costs ($/year),**	4% of capex plus 40% of replacement cost over 25 years	https://arena.gov.au/assets/2016/05/Assessment-of-the-cost-of-hydrogen-from-PV.pdf
f)	**System capital expenditure ($), and,**	$1.8m/MW 2025 $1.2m/MW 2030 **>100 MW scale**	IRENA indicate 700Euro/kW in 2025 (AUD 1.1m/MW) IEA say USD 1.8m/MW 2019 (AUD 2.7m)* IEA say USD 1.5m/MW 2030 (AUD 2.2m) including balance of plant https://webstore.iea.org/the-future-of-hydrogen Jacobs say AUD 1.4m/MW 2020 declining to $0.75m/MW in 2040 ref https://www.jacobs.com/hydrogen-economy There is a wide range between these numbers. The following has been adopted as a reasonable estimate including balance of plant for PEM electrolysers $1.8m/MW and $1.2m/MW for 2025 and 2030 respectively have been assumed Cost per MW is significantly influenced also by installation size
g)	**Utilisation factor (%).**	Tasmania analysed up to 98% capacity factor Co-located wind solar 35% **Wind 40%** **Solar 28%**	Combined solar/wind used 35% - National Hydrogen Roadmap CSIRO https://www.csiro.au/en/Do-business/Futures/Reports/Hydrogen-Roadmap - Table 3 https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf Off grid solar 28% Off grid wind 40% average https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf Table 4.2
h)	**Transport costs - shipping**	$0.03/tkm – ammonia $0.09/tkm – liquid hydrogen	Distance Bell Bay to Osaka 10,060 km Ammonia transport $0.29/kg Liquid hydrogen transport $0.9/kg https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf

i)	**Est additional cost landed in Japan**	$1.9/kg in 2030 – with ammonia or LOHC as medium	$1.90/kg adopted. This includes capital and operational costs associated with conversion, loading, shipping, unloading and extraction.
j)	**Japan Target 2030**	AUD $5.00/kg	2030 = 30Y/nm3 ref Japan basic hydrogen strategy https://www.meti.go.jp/english/press/2017/pdf/1226_003a.pdf AUD Yen conversion 0.014AUD/Yen (9 Oct 2019)
k)	**Price for carbon offsets**	$10.9/MWh NEM emissions intensity factor* 0.725 T CO_2/MWh	Australian Carbon Credit Unit (ACCU) - recently trading between $15 to $16 per ton CO2 http://www.cleanenergyregulator.gov.au/Infohub/Markets/buying-accus/australian-carbon-credit-unit-market-updates/statement-of-opportunities-in-the-accu-market-%E2%80%93-march-2019 *https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Settlements-and-payments/Settlements/Carbon-Dioxide-Equivalent-Intensity-Index Emissions intensity varies significantly by state. After Tasmania the offset cost would be least in SA but differences in electricity pricing must also be considered. All state emissions intensities are likely to fall in coming years but cost of offsetting is likely to still be substantial. Offset equivalent 0.725 T CO_2/MWh*$15 = $10.9/MWh

NOTE: RET EITE exemption assumption - Exemption assumed for RET liability under Emissions-Intensive Trade-exposed industry scheme for all export hydrogen production Australia (The Renewable Energy Target (RET) scheme includes an exemption mechanism targeted to emissions-intensive trade-exposed (EITE) activities. The intention of the RET EITE exemption scheme is that electricity used in carrying on an EITE activity is exempt from costs associated with the RET. As part of the package of reforms to the RET legislation in 2015, the Parliament increased the rate of exemption for EITE activities to 100 per cent in respect of electricity used in undertaking an EITE activity).