

Enabling Renewable Hydrogen Export: Certifications and Beyond

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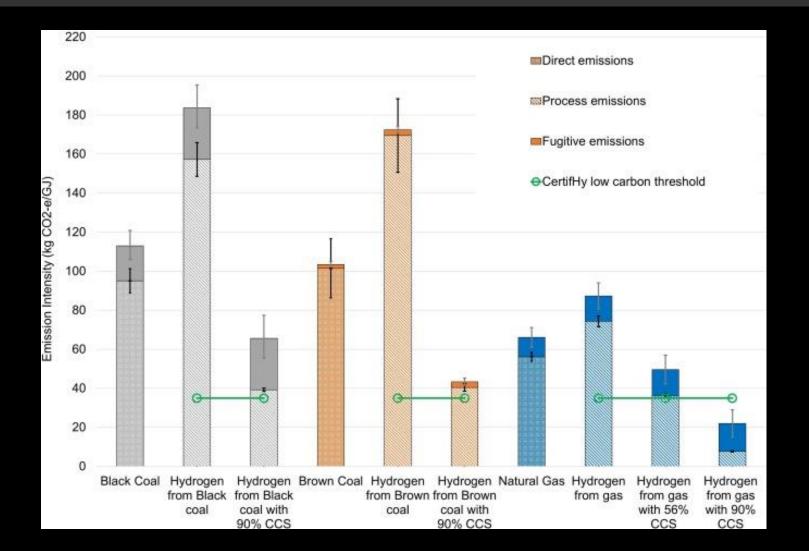
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Renewable hydrogen as a game changer for the net zero transition

• With blue hydrogen where carbon capture rates are low, there is a risk of lock-in of scaled high-emissions fossil fuel production.

• if capture rates are high, there is a risk of stranded assets as hydrogen production with CCS may lose its competitive edge over green hydrogen

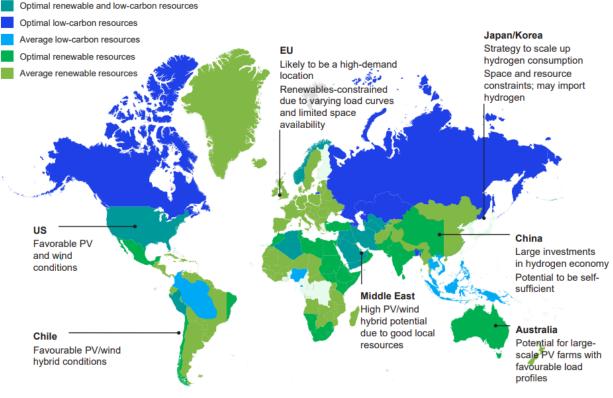


Source: Longden, Thomas, et al. "'<u>Clean' hydrogen?–Comparing the emissions and costs of fossil fuel versus renewable electricity</u> <u>based hydrogen</u>." *Applied Energy* 306 (2022): 118145.



Australia as Renewable Hydrogen Powerhouse

Best source of low-carbon hydrogen in different regions



SOURCE: IEA; McKinsey

Demand centres, e.g. EU, North-east Asia, are often constrained for resources, and may not be able to self-supply hydrogen.

Countries with complementary load profiles of wind and PV can produce renewable hydrogen at very low prices.

Regions like China and the US are both demand centres and have favourable RES.

-GERMANY HYDROGEN ACCORD INITIATIVE ESEARCH PILOTS, TRIALS AND DEMOS

Innounced that it will play a key role in the developmen drogen Innovation and Technology Incubator known

Australian Hydrogen Export Market to Germany

The Case for an Australian Hydrogen Export Market to Germany: State of Play Version 1.0

Working paper for consultation September 2021



Multi-criteria Analysis of Off-takers Preference Configuration

Table 15: Base Case, Energy Export Focused and Decarbonisation Focused Multi-criteria Analysis for the Hydrogen Export Value Chain.

(Here LH, is liquefied hydrogen, NH, is ammonia, CH, is methane, CH, OH is methanol, LOHCs are liquid organic hydrogen carriers with di-methyl ether, DME, used as the example).

		Eva	luation	Rand				Energy Export Focused MCA						Decarbonisation Focused MCA									
Criterion	Evaluation band					Score					Score						Score						
	LH ₂	NHa	СН	сн,он	LOHCs	Weighting	LHg	NHa	СН	СН ₃ ОН	LOHCs	Weighting	LH ₂	NHa	CH4	сн,он	LOHCs	Weighting	LH	NHa	СН	сн _а он	LOHCs
Commercial Metrics																							
Technology Readiness	3	5	5	4	3	15.00	45	75	75	60	45	15.00	45	75	75	60	45	10.00	30	50	50	40	30
Capital Cost for Carrier Implementation in terms of energy exported p.a. (A\$ kWh ⁻¹ yr ⁻¹)	2	2	5	2	1	15.00	30	30	75	30	15	5.00	10	10	25	10	5	5.00	10	10	25	10	5
Operating Cost for Carrier Production in terms of energy exported p.a. (A\$ kWh ⁻¹ yr ⁻¹)	2	4	5	4	1	15.00	30	60	75	60	15	5.00	10	20	25	20	5	5.00	10	20	25	20	5
Hydrogen Export Metrics																							
Hydrogen Storage Density	5	3	4	2	1	5.00	25	15	20	10	5	15.00	75	45	60	30	15	5.00	25	15	20	10	5
Hydrogen Conversion Efficiency	5	3	4	5	4	5.00	25	15	20	25	20	5.00	25	15	20	25	20	5.00	25	15	20	25	20
Energy Export Metrics																							
Gravimetric Energy Density (MJ kg-1)	5	2	5	2	4	5.00	25	10	25	10	20	15.00	75	30	75	30	60	5.00	25	10	25	10	20
Volumetric Energy Density (MJ L ⁻¹)	1	2	5	4	5	5.00	5	10	25	20	25	15.00	15	30	75	60	75	5.00	5	10	25	20	25
Transportation Metrics																							
Transportation Cost (A\$ kg ⁻¹)	5	4	з	5	5	10.00	50	40	30	50	50	5.00	5	20	15	25	25	5.00	5	20	15	25	25
Carrier Yield Loss During Transportation (%)	1	5	4	5	5	10.00	10	50	40	50	50	15.00	15	75	60	75	75	5.00	5	25	20	25	25
Decarbonisation Metrics					·																		
Decarbonisation Benefit	5	5	1	1	5	15.00	75	75	15	15	75	5.00	25	25	5	5	25	50.00	250	250	50	50	250
						Total	320	380	400	330	320	Total	300	345	435	340	350	Total	390	425	275	235	410

Choice of carriers is subject to off-takers' preference.

Internal infrastructure in the EU would substantially influence such preference.

Note: The values in the tables are based on preliminary analysis of the values provided in the cited literature and is subject to change in the detailed analysis. The capital and operating costs represented include the cost of hydrogen generation from electrolysis, its conversion to the carrier, on loading to ship for export, and officialing at receiving port. The costs are then levelised based on the energy content of each hydrogen carrier (in kWh). The analysis is detailed in Appendix C (Table C1-C2).

R. Daiyan, I. MacGill, R. Amal, S. Kara, K.F. Aguey-Zinsou, M.H. Khan, K. Polepalle, W. Rayward-Smith. (2021). <u>The Case for an Australian</u> Hydrogen Export Market to Germany: State of Play Version 1.0.



Potential barrier for exporters

- There are diversified infrastructure demands for different carriers, and it is not enough to consider pipelines only
- The reconversion cost can be high

Conversion to Carrier Some key Opportunities / Challenges Renewable Energy Supply High energy density Easy reconversion to gas H₂ Wide range of direct H₂ applications from fuel to feedstock Energy and capital intensive liquification, storage + shipping Liquid Hydrogen (LH₂) Continuing 'boil off' Electrolyze Well established, internationally traded, industry feedstock Gaseous Easy to store and ship Direct use options - e.g. engines 'Green' requires carbon neutral C source (biomass, direct air capture) Challenging reconversion to gas H₂ Pipelines Very well established, internationally Storage traded, industry feedstock Vessels/Tanks Relatively easy to store and ship Rail Direct use fuel options under development - e.g. engines Some safety challenges Ammonia Challenging reconversion to gas H Tube Trailers Can be a direct 'green' substitute for Underground Intermediate H₂ Transport natural gas across its many diverse Storage applications - energy, feedstock Major existing global shipping and Intermediate H₂ Storage storage infrastructure 'Green' requires carbon neutral C source (biomass, direct air capture) Various possible 'carriers with particular characteristics Some LOHCs have modest existing feedstock uses - e.g. toluene Moderate energy density Significant conversion and reconversion energy losses and costs LOHCs

R. Daiyan, I. MacGill, R. Amal, S. Kara, K.F. Aguey-Zinsou, M.H. Khan, K. Polepalle, W. Rayward-Smith. (2021). <u>The Case for an Australian Hydrogen Export Market to Germany: State of Play Version</u> <u>1.0.</u>

Figure B: Opportunities and challenges for different hydrogen carriers considered.



- Certifications to provide credible information
- Track embedded emissions when blending hydrogen in the natural gas pipeline
- Enhance compatibility to avoid regulatory competition
 - Carbon accounting boundaries
 - Certify actual emissions vs set thresholds



Approaches to certifying Australia-Germany Green Hydrogen Supply Chains:

informing discussion Produced for the German-Australian HySupply Project



In case you are interested:

- Aisbett, Emma, Wenting Cheng, Iain MacGill, and Lee White. (2022). <u>Approaches to certifying Australia-Germany Green Hydrogen</u> <u>Supply Chains: informing discussion</u>
- Cheng, Wenting, and Sora Lee. "<u>How Green Are the National Hydrogen Strategies</u>?". Sustainability 14, no. 3 (2022): 1930.
- Neill, Lily O', Fiona J. Beck, Karrina Nolan, and Wenting Cheng. "<u>Renewable Hydrogen Will Be Produced on Land Traditionally</u> <u>Owned by First Nations People: Will Its Owners Benefit</u>?". Australian Environment Review 36, no. 6 (2022): 149-58.
- White, Lee V, Reza Fazeli, Wenting Cheng, Emma Aisbett, Fiona J Beck, Kenneth GH Baldwin, Penelope Howarth, and Lily O'Neill.
 "<u>Towards Emissions Certification Systems for International Trade in Hydrogen</u>: The Policy Challenge of Defining Boundaries for Emissions Accounting." Energy 215 (2021): 119139.