

HySupply Progress to date - Australian Developments

Hysupply Special Session, Fourth Energy Future Conference

UNSW Sydney, 18-20 October 2021

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School of Electrical Engineering and Telecommunications

Collaboration on Energy and Environmental Markets (CEEM)

ARC Industry Transformation Training Centre for the Global Hydrogen Economy (GlobH2E)



Australian Government

Department of Foreign Affairs and Trade



Australian Government

Department of Industry, Science,
Energy and Resources



Baringa
Brighter together



UNSW
SYDNEY

HySupply Partnership



BDI

Bundesverband der
Deutschen Industrie e.V.



acatech

DEUTSCHE AKADEMIE DER
TECHNIKWISSENSCHAFTEN

Key Partners



Baringa
Brighter together

Lead and
Administrating
Organization

Joint Feasibility Study of Renewable Hydrogen

German-Australian Hydrogen Supply Chain

Module 1: Production

Renewable energy



Hydrogen



Module 4: End use

Steel industry



Refineries



Chemical industry



Business cases



AUSTRALIA

Technology export

GERMANY



Module 2: Transport

Export



Import



Hydrogen based energy carriers

Module 3: Recovery

Recovery and distribution

Source: BDI/acatech

Australian Consortium



Deloitte.



ARENA



L A V O



Hydrogen Energy Research Centre
UNSW Sydney



Deutsch-Australische
Industrie- und Handelskammer
German-Australian Chamber
of Industry and Commerce



Note: We seek and welcome new consortium members across Australia's emerging green hydrogen value chain. Please feel free to contact either Dr Rahman Daiyan (r.daiyan@unsw.edu.au) or Associate Professor Iain MacGill (i.macgill@unsw.edu.au) to explore this further.

Assessing the State-of-Play



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

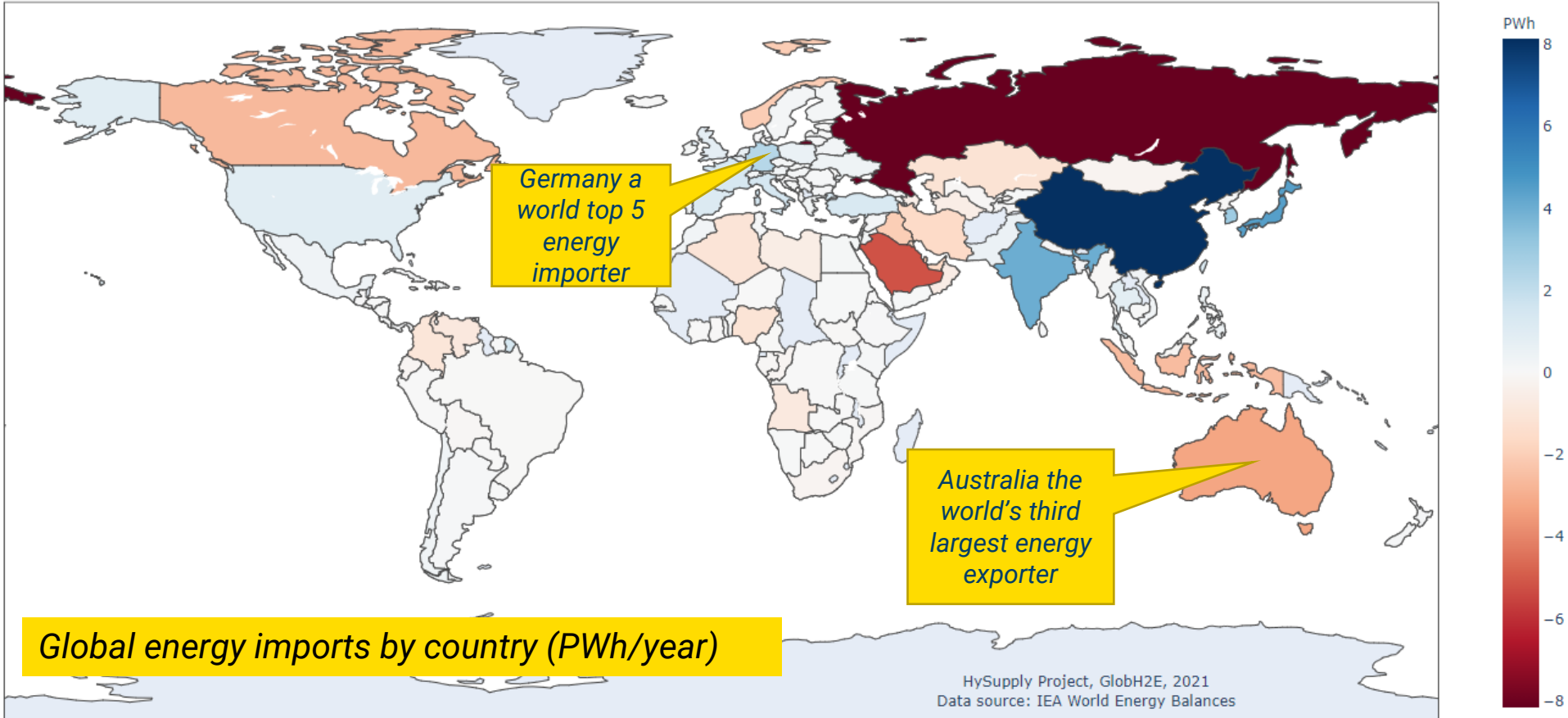
Working paper for consultation
September 2021

Pending



Current global energy trade

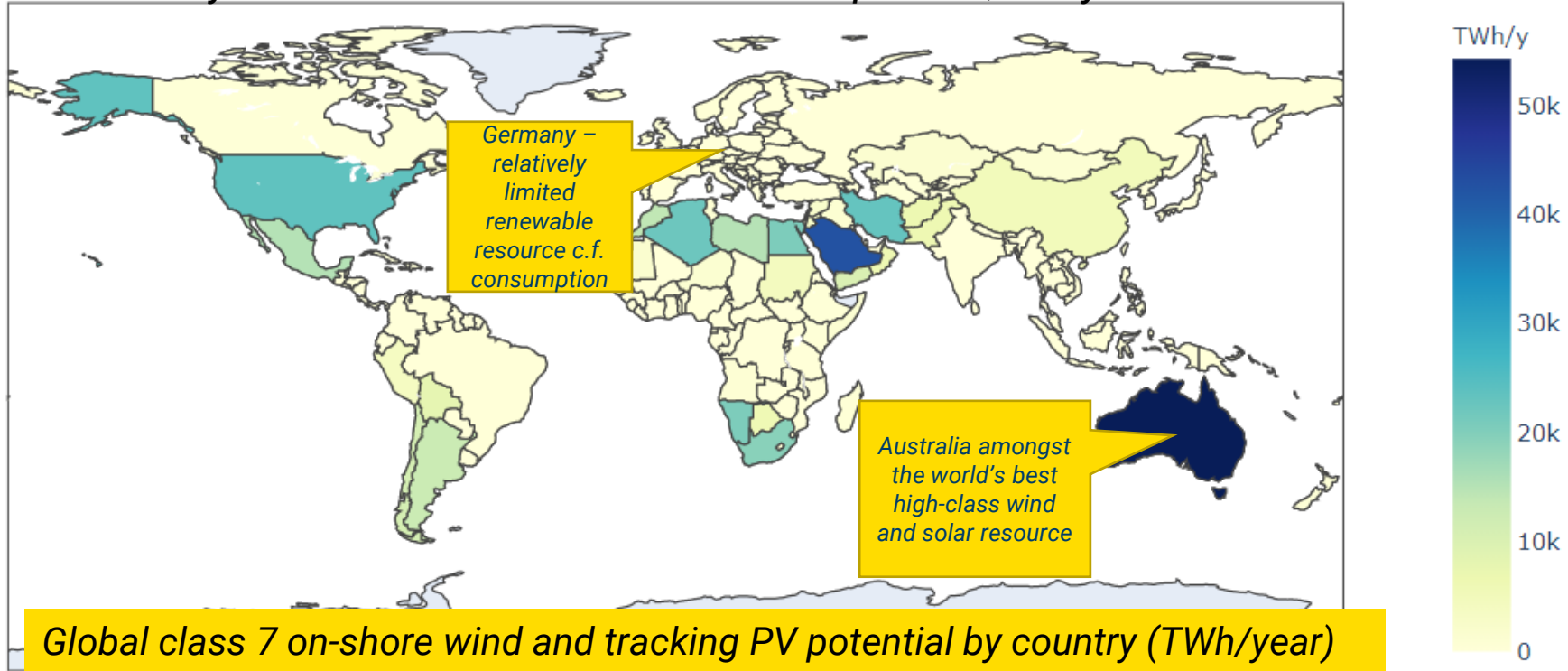
Largely an outcome of the availability of easily extracted low-cost fossil fuels



A mostly renewable world more self reliant

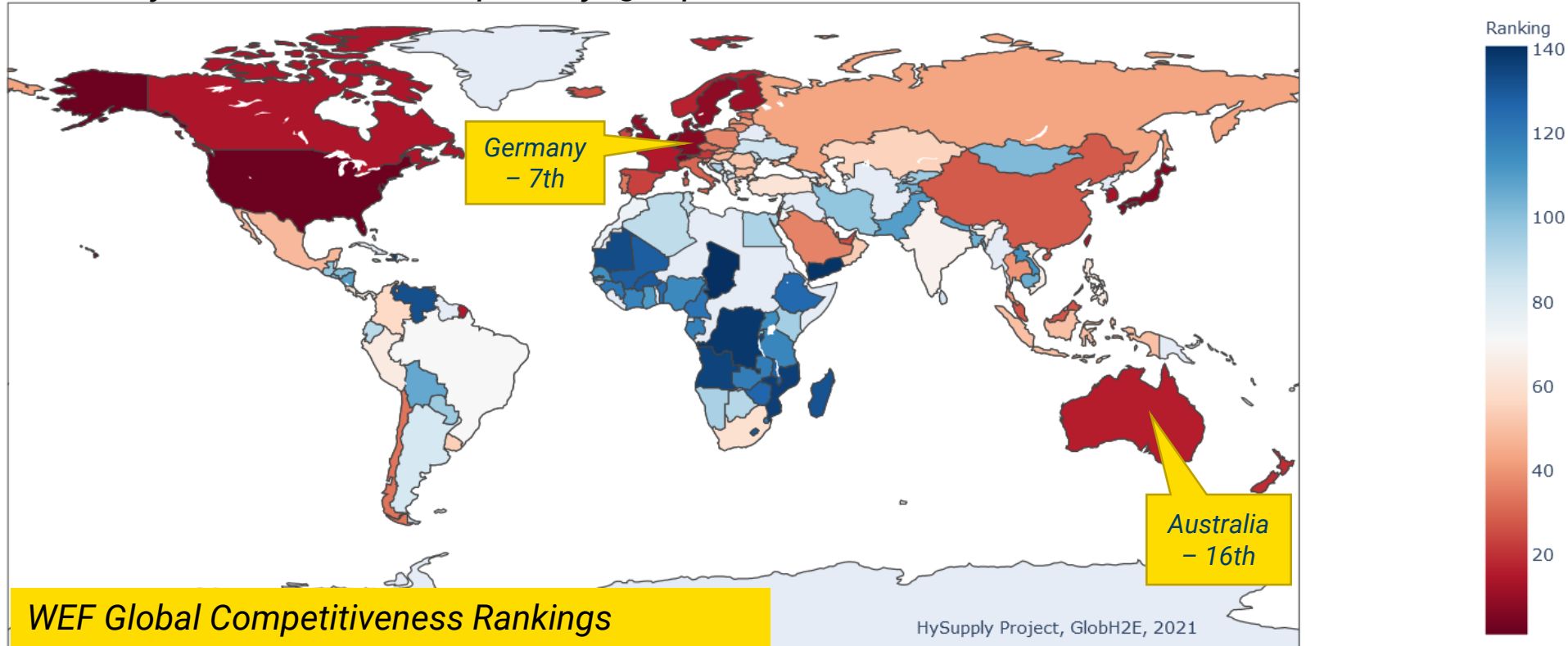
... however, various countries still seem likely to require energy imports including Germany and some others in Europe, Japan, Korea

Potentially new renewables 'electrostate' exporters, likely some old ones



Trade relationships generally multi-faceted

Delivered price is key, but not the only consideration - existing trade relationships, stability, demonstrated capability, geopolitical considerations....



Significant government support – *although competition is growing*

Western Australia

- **2020 Renewable Energy Investment:** **A\$2.0 billion** invested last year to grow capacity by 0.4 GW.
- **WA System Plan:** Target established to convert WA's energy supply capacity to 70% renewables by 2040.
- **WA Renewable Hydrogen Strategy and Roadmap:** The state has established long-term goals to develop a hydrogen industry. Key short-term goals (2022) include development of a renewable hydrogen export project and inject H₂ in gas grid.
- **WA Renewable Hydrogen Fund:** **A\$5 million** was provided for hydrogen project feasibility studies. The state government also invested **A\$22 million** in 2020 to develop a 1.5 GW renewable energy and hydrogen hub.

Northern Territory

- **2020 Renewable Energy Investment:** **A\$100 million** invested last year to grow capacity by 64 MW.
- **State Renewable Energy Funding:** The state is financing development of large-scale batteries for renewable energy storage, has made grants available for household solar systems and made 'Sun Cable' project a key priority.
- **Renewable Energy Target:** NT has a target for 50% renewables supply in electricity grid by 2030 and to reach net zero by 2050.
- **NT Renewable Hydrogen Strategy:** The state has developed its hydrogen strategy to become a global hub for hydrogen research, production and technology manufacturing.
- **Renewable Hydrogen Project:** The state government is supporting the "Aqua Aere" demonstration project to generate hydrogen using water from air and grid supplied

Queensland

- **2020 Renewable Energy Investment:** **A\$3.4 billion** invested last year to grow capacity by 1.9 GW. (3rd highest amongst other states)
- **Renewable Energy Corridors:** **A\$145 million** committed to develop renewable energy zones in the north, central and south-western part of the state.
- **Renewable Energy Fund:** **A\$500 million** in additional funding committed as part of the Covid-19 Recovery Plan to support commercial energy projects and to develop infrastructure.
- **Queensland Renewable Energy Target:** The state has a target to become 50% renewable powered by 2030 and to attain net zero by 2050.
- **Queensland Hydrogen Industry Strategy:** The state government has committed **A\$19 million** to support the emerging hydrogen economy.
- **Queensland Hydrogen Hubs:** QLD government has recently backed the development of a hydrogen hub in Townsville.

South Australia

- **2020 Renewable Energy Investment:** **A\$2.4 billion** invested last year to grow capacity by 1.4 GW.
- **Renewable Energy Target:** Target established to convert SA's grid to 500% renewables to become net energy exporter to the Australia National Energy Market.
- **SA's Hydrogen Action Plan:** Action plan developed to establish SA as a key renewable hydrogen strategy. State has provided **A\$17 million** in grants and **A\$25 million** in loans to hydrogen projects.
- **South Australia Hydrogen Export Hub:** The state has announced plans to develop 3 renewable hydrogen hubs with a combined capacity of 2.6 GWs.
- **Australia's largest electrolyser:** The state is home to Australia's largest operational electrolyser of 1.25 MW capacity. The SA government provided **A\$4.9 million** in grant funding for the project.

Tasmania

- **2020 Renewable Energy Status:** The state has the highest share of renewable electricity in power generation (~99%).
- **Tasmanian Renewable Energy Target:** Achieving 200% of current energy demand with renewable electricity supply by 2040 and become a net exporter.
- **Tasmanian Renewable Hydrogen Action Plan:** **A\$50 million** package committed to develop a green hydrogen economy, start H₂ export by 2025 and become a global export hub by 2030.

Victoria

- **2020 Renewable Energy Investment:** **A\$5.0 billion** invested last year to grow capacity by 2.9 GW. (2nd highest amongst other states)
- **Victorian Renewable Hydrogen Industry Development Plan:** **A\$6.2 million** committed to accelerate pilot projects, **A\$10 million** committed for Victorian H₂ hub and **A\$1 million** available in grants.
- **Victorian 2020 Budget Commitments:** **A\$1.6 billion** committed for development of renewable energy hubs and auction 600 MWs of new solar and wind capacity.
- **Victoria Emissions target:** The state has a target to become net zero by 2050.
- **Hydrogen Energy Supply Chain Project:** The state is host to the world's first H₂ supply pilot. The project was provided with **A\$50 million** in funding by the state government.

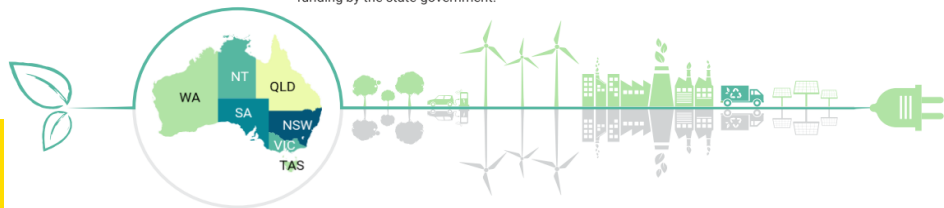
NSW

- **2020 Renewable Energy Investment:** **A\$5.6 billion** invested last year to grow capacity by 3.6 GW. (Highest amongst other states)
- **NSW Electricity Infrastructure Roadmap:** The state expects investment of **A\$32 billion** by 2030 to increase its renewable capacity by 12 GW. Hydrogen is expected to be a key growth driver.
- **NSW Net Zero Plan Stage 1:** Stage 1 of NSW Climate Change Policy - **A\$2 billion** committed in partnership with the Commonwealth for low emission technology including H₂.
- **NSW Climate Change Policy Framework:** State target of achieving net zero by 2050.
- **NSW Hydrogen Strategy:** Under development.
- **NSW Hydrogen Hubs:** **A\$70 million** committed to Hunter and Illawarra H₂ Hub as part of a greater **A\$750 million** Net Zero Industry and Innovation Program.



Federal

- **National Hydrogen Roadmap (2018) & National Hydrogen Strategy (2019).**
- **CEFC Advancing Hydrogen Fund:** **A\$300 million.**
- **Low Emission Technology Roadmap (2010):** **A\$1.9 billion** committed for five priority low emissions technologies, including hydrogen.
- **ARENA:** **A\$103 million** committed to develop electrolyser projects.
- **National Energy Resource Australia:** seed funding provided to develop 13 Hydrogen clusters.
- **Environmental Pledge:** reduce Australia's emissions by 26% to 28% below 2005 level by 2030.
- **Federal Funding for H₂ Hubs:** **A\$314 million** in funding for developing regional H₂ Hubs and carrying out 10 feasibility studies.
- **German-Australia Hydrogen Innovation and Technology Incubator:** **A\$50 million** commitment.
- **Hydrogen Ready Power Generators:** **A\$24.9 million** in funding to enable hydrogen capable gas power generators.



Australia well placed as an H2 energy exporter



Global leader in energy exports



Australia – A potential giant hydrogen exporter



Ranked 14th in ease of doing business



1/3rd of AS1 trillion in FDI for energy and mineral export projects (2020)



15 Active Free Trade Agreements with leading economies



6th on the Renewable Energy Country Index

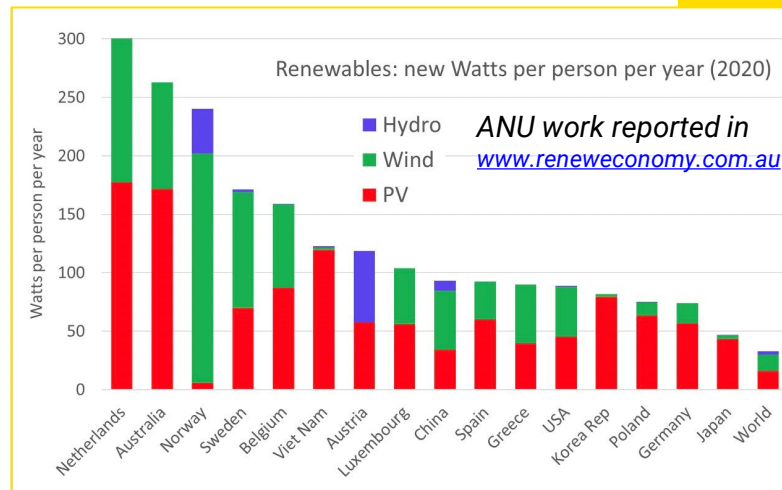


Government commitment to low carbon energy

Vast natural resources and rapidly growing renewable energy sector



Study	Renewable Exporter	Renewable Importer
Harvard Belfer Centre (2020) ³¹	Australia , Morocco, Western Sahara, Norway, United States, Canada, Mexico	North Western Europe, Korea, Japan, Southeast Asian Countries
Hydrogen Council (2021) ¹⁴	Australia , China, India, Saudi Arabia, South Africa, Iran, Turkey, Norway, Spain, Portugal, US, Chile	All Southeast Asian Countries, Russia, North-western and central European States.
Wood Mackenzie (2019) ³²	Australia	Japan and Germany
ACIL Allen (2018) ³³	Australia , Middle East, North African countries, and United States.	China, Japan, Korea, Singapore
ERIA (2018) ³⁴	United States, North African Countries, Middle East	China, Singapore, Korea, and Japan
IEA (2018) ¹⁰	United States, Australia , Africa, Middle East, Chile	Japan, Europe
IRENA (2021) ²⁷	Brazil, Norway, Australia , Chile, Sub Sahara, Middle East	Europe, China, Southeast Asia
Carbon Tracker (2021) ³⁵	Namibia, Botswana, Ethiopia and most of South America, Northern Africa, Middle East, Australia	Singapore, Belgium, Germany, Netherlands, South Korea, Taiwan, Switzerland, Japan, Poland, Italy
HySupply analysis	Australia , Middle East, Northern Africa, Western South America, United States	Europe.



State-of-play report - general approach



The backbone of this green hydrogen export value-chain is the sourcing of low-cost renewable energy. Preliminary modelling was completed to map out the capacity factor and average renewable energy generation potential for each state in Australia.



The preliminary electricity model was used to calculate an estimated levelised cost of hydrogen for each state. This modelling provides a high-level overview of how location and renewable generation source, underpins the economics of hydrogen production in Australia. Parameters affecting production costs were explored.



A preliminary investigation was performed to determine the most viable medium for hydrogen storage and transportation. The key hydrogen carriers that were investigated in this analysis include: ammonia, methanol, methane, liquified hydrogen and liquid organic hydrogen carriers (LOHCs). These carriers were selected as they provide varying degrees of benefit to store and transport hydrogen. A multi-criteria analysis (MCA) was used to compare the hydrogen carriers across broad range of socio-economic criteria, to provide a perspective to stakeholders on which options are the most viable.



Preliminary modelling based on literature was performed to provide an indicative guide for the shipping costs for each of implementation scenario. The foundational analysis from this chapter will form the basis for a more detailed value-chain model downstream.

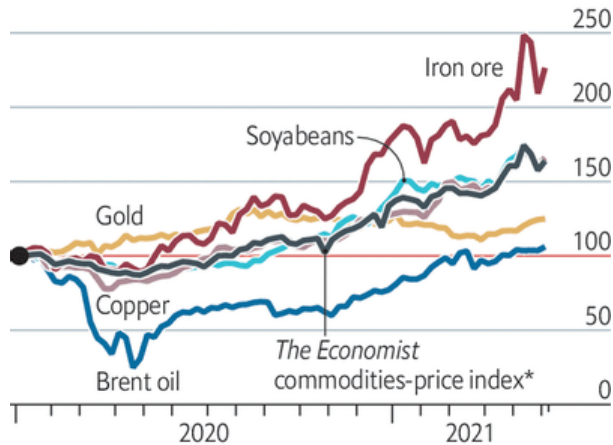


The findings from the MCA were used to create three potential implementation scenarios for this export value chain. The scenarios expand on the key learnings and provide a current status of costs across the value chain, to present a few implementation scenarios considering Australia and Germany's key technological, commercial and infrastructure capabilities and demands.

Becoming modesty required for all assessments

Hot commodities

Commodity prices, January 1st 2020=100



Sources: Bloomberg; Refinitiv Datastream; The Economist *\$ terms

The Economist

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Getting to zero

The first big energy shock of the green era

There are grave problems with the transition to clean energy power

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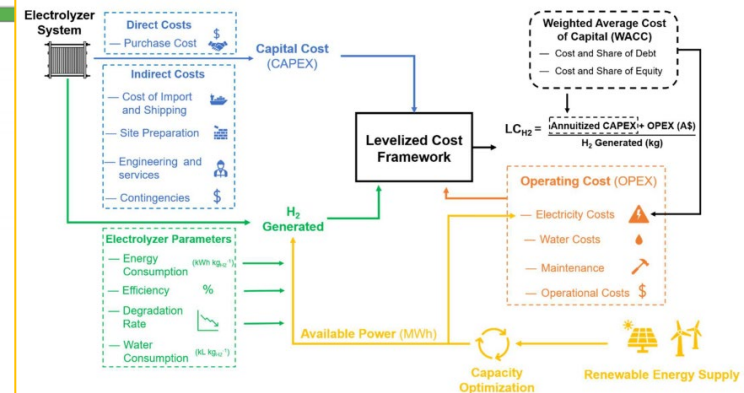
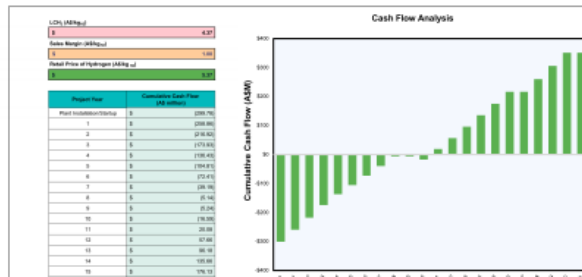
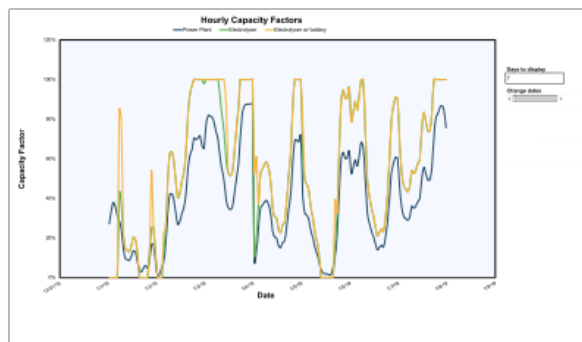
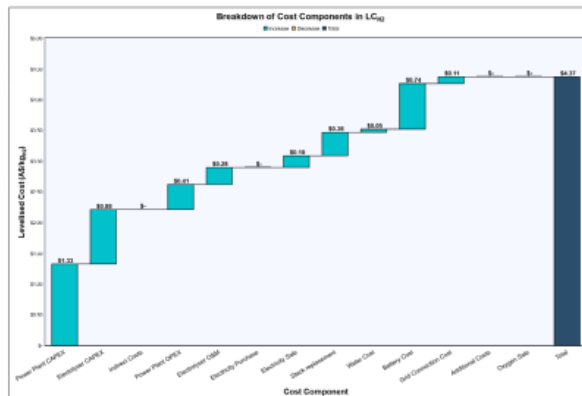
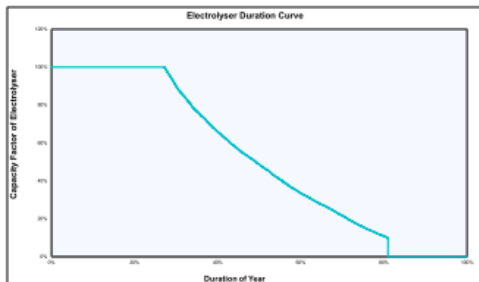
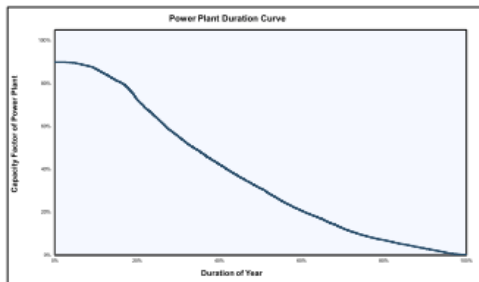
Making sense of the chaos in commodity markets

The 2000s were about the supercycle. The 2020s are about supermayhem



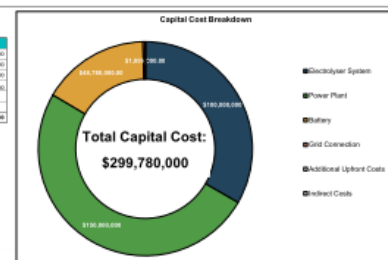
Justin Met

Summary of Key Inputs		
Location	New England	
Configuration	Grid Connected Wind Generation with Electrolyser and Battery with Storage Head to Grid	
Electrolyser Type	PEM	
Electrolyser Capacity (MW)	100	
Power Plant Capacity (MW)	100	
Battery Capacity (MWh)	40	
Summary of Results		
Power Plant Capacity Factor	30%	
Flow Electrolyser is at its Maximum Capacity (% of 1750t/yr)	20%	
Flow Time Electrolyser is Operating (% of 4750 t/yr)	24%	
Electrolyser Capacity Factor Achieved	50%	
Storage Consumed by Electrolyser (MWh/yr)	403,070	
Storage Energy Not Utilised by Electrolyser (MWh/yr)	42,870	
Hydrogen Output (t/yr)	4,377	
LC _{H2} (\$/kg)	4.17	
Level Price of Hydrogen (\$/kg) (Price set F&E)	\$101,596,746.00	
Net Profit (\$M)	107%	
Return on Investment (%)	107%	
Payback Period (years)	5.48	



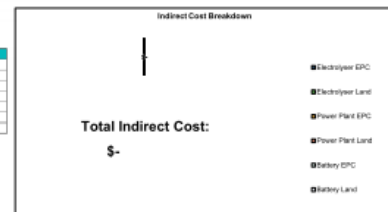
Capital Cost Breakdown

Component	Value (\$M)
Electrolyser System	150,000,000
Power Plant	150,000,000
Battery	40,300,000
Grid Connection	2,000,000
Additional Upfront Costs	0
Indirect Costs	0
Total Capital Investment	\$299,780,000



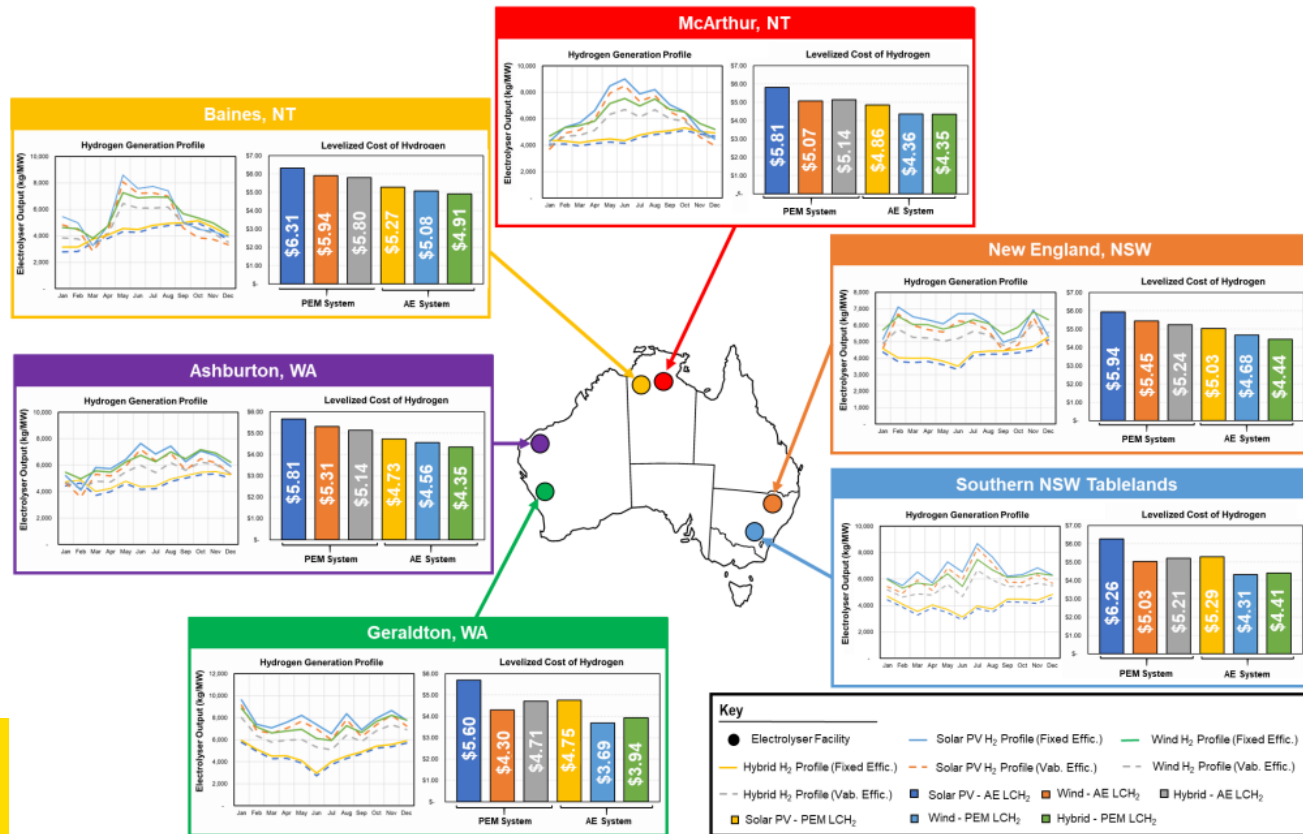
Indirect Cost Breakdown

Component	Value (\$M)
Electrolyser EPC	0
Electrolyser Land	0
Power Plant EPC	0
Power Plant Land	0
Battery EPC	0
Battery Land	0
Total Capital Investment	0



State of Play report findings, and associated open-source value-chain models

Hourly resolution renewables + electrolyser modelling required to properly assess processes, conversion systems, buffer storage needs and firmed energy requirements



Green H₂ production costs

Location matters

Cost reductions needed

- Renewables costs down, CF up
- Electrolysers costs down, efficiency up
- Improved integration (CF optimisation) for both off-grid and NEM / SWIS / DKIS projects
- Low cost (de-risked) finance

Proponent	Target/projection /Scenario	Price range/kg _{H₂}	Adjusted to A\$/kg _{H₂}	Price year	References
Australian Government	Stretch target		A\$2	Not indicated	Low Emissions Technology Roadmap, 2020 ⁸⁷
Hydrogen Council	Projection	US \$1.40 – 2.30 (US\$1.40 in optimal locations)	A\$1.89 – 3.11	2030	Hydrogen insights, 2021 ¹²
EU	Target	Euro 1.1 – 2.4	A\$1.77 – 3.87	2030	Hydrogen strategy, 2020 ¹²⁰
IEA	Net Zero Emissions scenario	US \$1.50 – 3.50	A\$2.03 – 4.73	2030	Net Zero by 2050, 2021 ¹⁹
IRENA	Scenarios	US \$1.40 – 2	A\$1.89 – 2.70	2030	Low RE cost scenarios in Green Hydrogen cost reduction, 2020 ²²
IEA	Renewables connected scenario	US \$2 – 4	A\$2.70 – 5.40	2030	Future of Hydrogen, 2019 ¹⁰
IRENA	Projection	US \$1.80 – 3.30	A\$2.60 – 4.78	2030	Hydrogen: A Renewable Energy Perspective, 2019 ¹¹⁶
Bloomberg	Projections	US \$1.20 – 2.7	A\$1.62 – 3.65	2030	BNEF: Hydrogen Economy Outlook, 2020 ¹³

Designing Optimal Integrated Electricity Supply Configurations for Renewable Hydrogen Generation in Australia

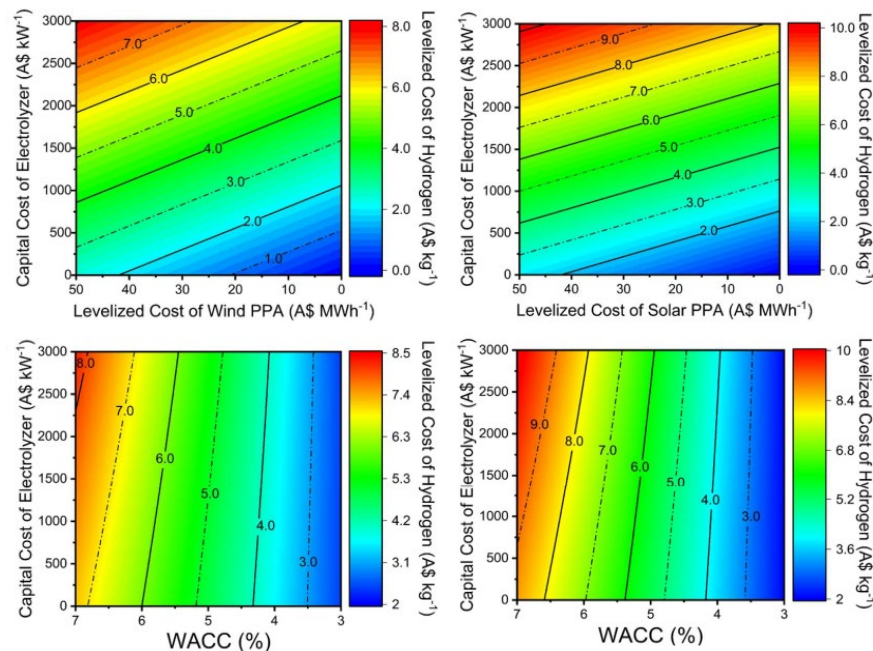
Muhammad Haider Ali Khan^a, Rahman Daiyan^{a*}, Zhaojun Han^a, Martin Hablutzl^b, Nawshad Haque^c, Rose Amal^a, Iain MacGill^{a,d}

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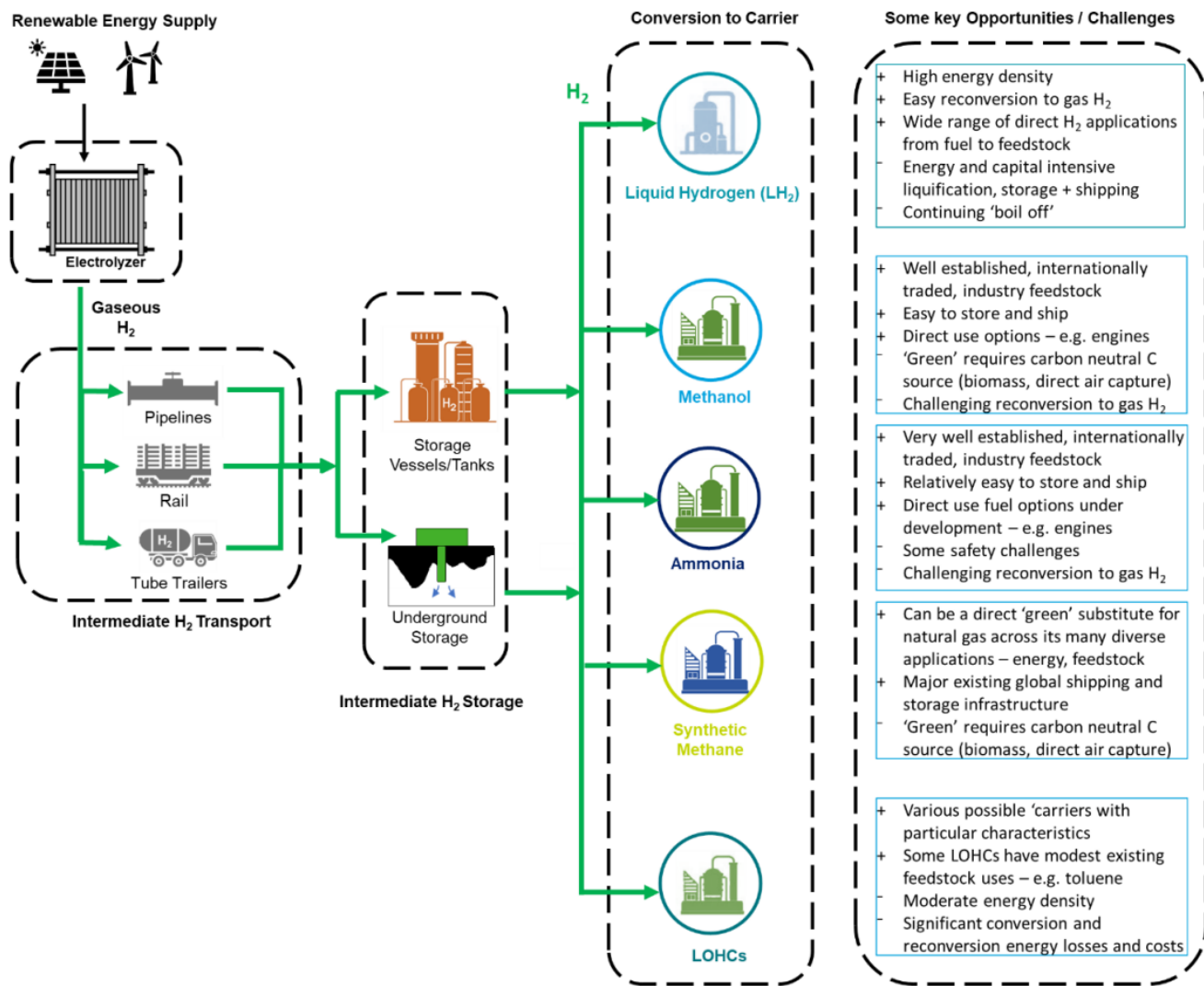
^b Siemens Limited, Melbourne, VIC 3153, Australia

^c CSIRO Energy, Private Bag 10, Clayton Victoria 3169, Australia

^d Collaboration on Energy and Environmental Markets, The University of New South Wales, Sydney, NSW 2052, Australia

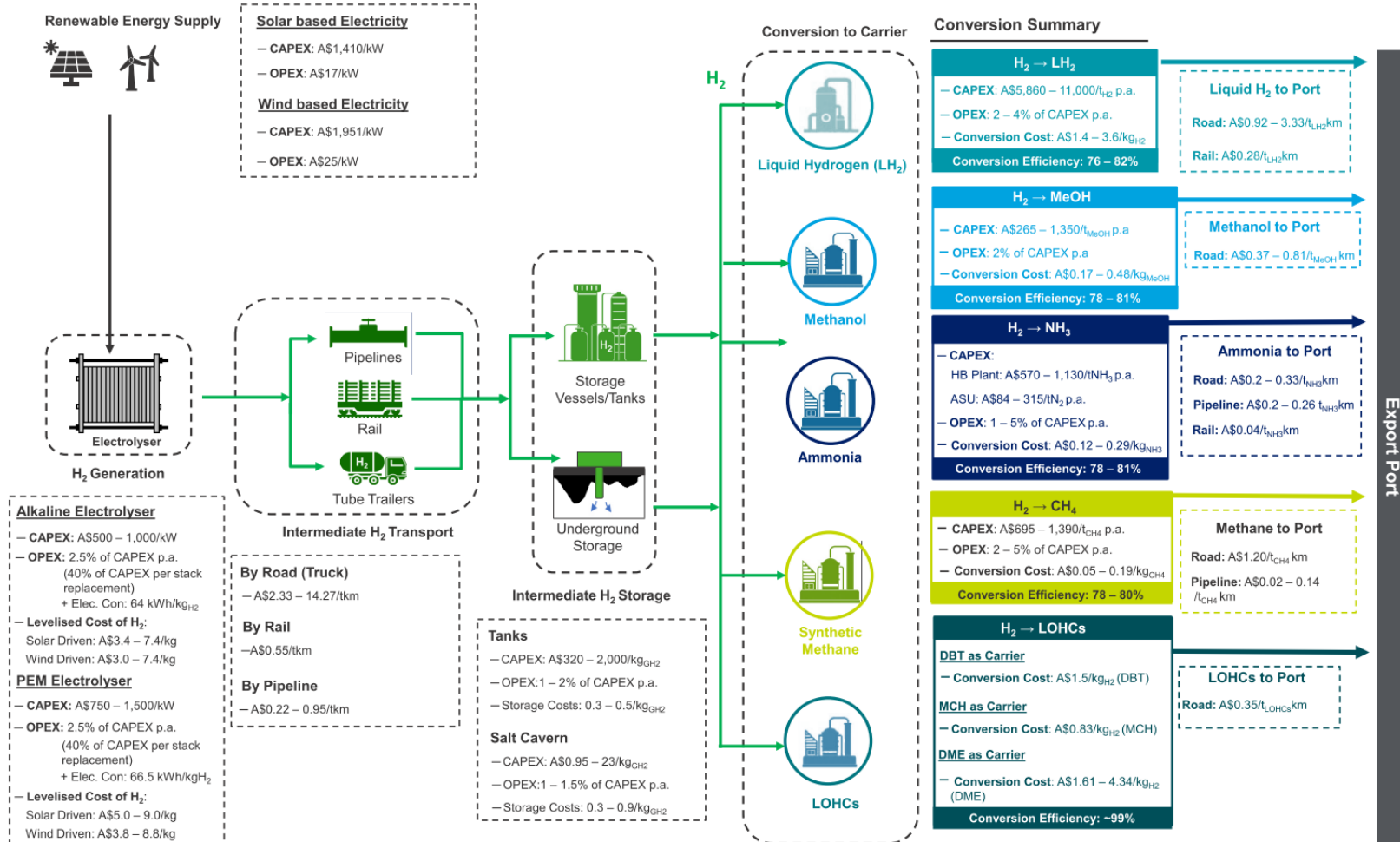


Consider multiple possible pathways



Preliminary modelling: open-source models

coming



Shipping hydrogen

- *Advantages for hydrogen production near point of use*
- *Pipelines the lowest cost, albeit less flexible, option for distances up to thousands of km, subject to route constraints*
- *However, shipping delivers 80% of global trade, flexible, low cost.... and needs clean fuels*

Figure 23: LNG Shipping Density Map for 2019¹⁷²

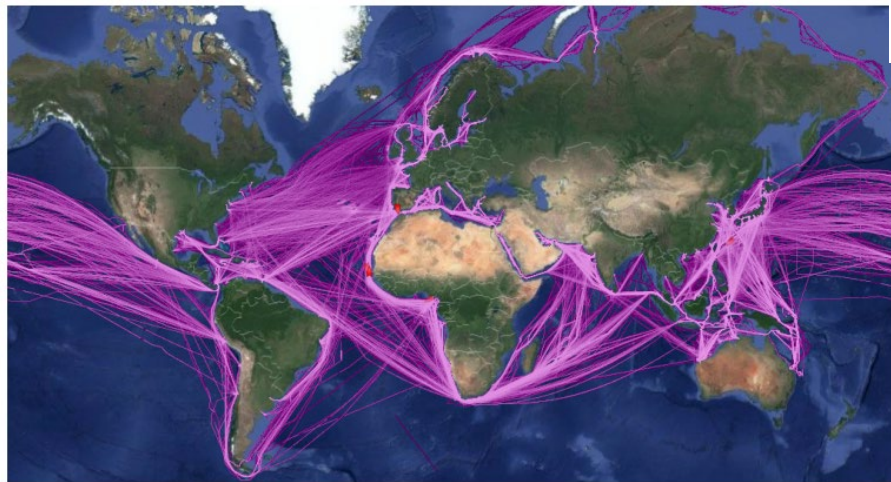
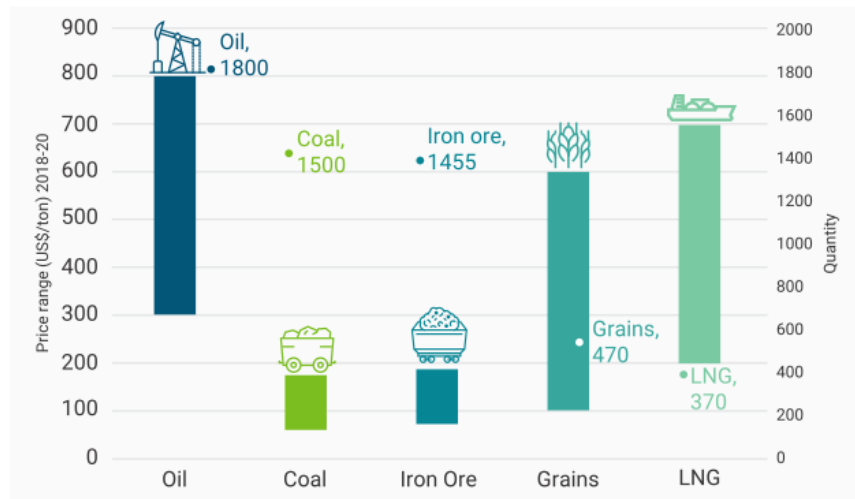
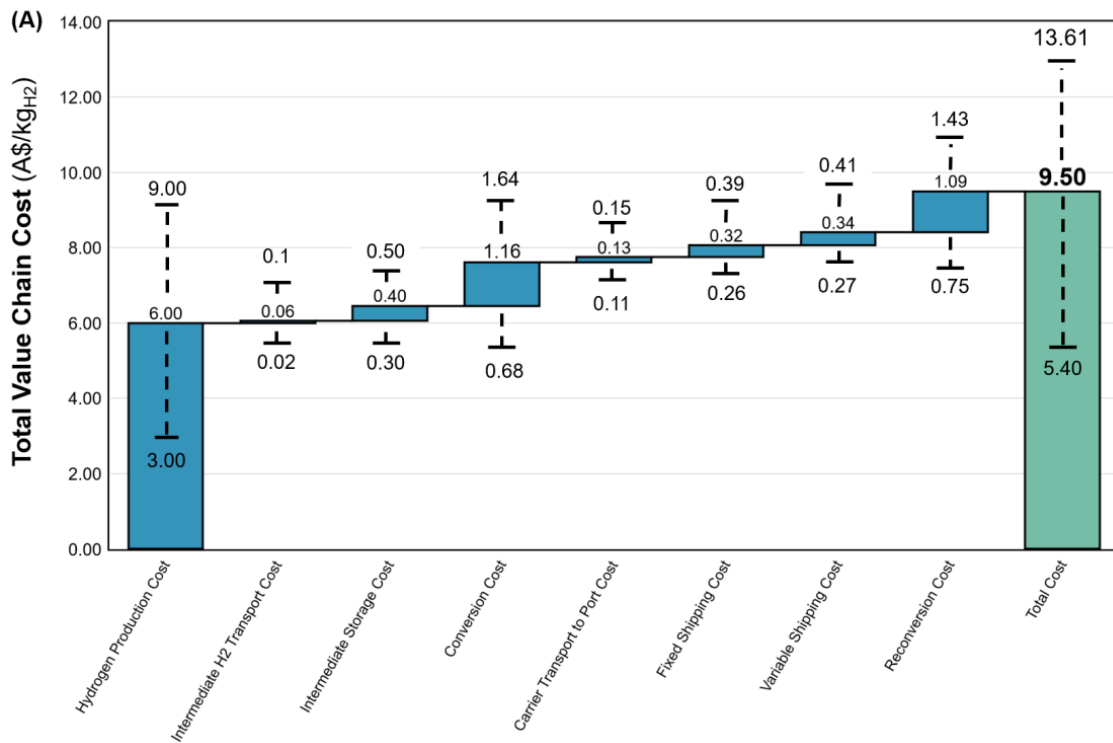


Figure 5: Shipped tonnage and average price ranges for some key traded commodities.

Note that the price indications are spot price ranges over 2018-2020 and shipped tonnages from 2019. For hydrogen trade, prices of around US\$1.50 – 2.50/kg would translate to ~US\$1,500-2,500/ton, representing a relatively high value commodity while traded volumes in various 2050 scenarios would likely be well below the shipped tonnage of some existing commodities.



Preliminary findings (open-source tool coming)



HySupply Australia Preliminary roadmapping Process

The roadmapping process will feature three key stages: planning, consultation and synthesis

Preliminary Roadmapping Process

Planning

Knowledge Base Development

Leverage the learnings from the COAG National Hydrogen Strategy (NHS), CSIRO National Hydrogen Roadmap (NHR) and HySupply State of Play (SoP)

Stakeholder Identification

The hydrogen/ hydrogen-derivatives value-chain was mapped out, to identify the key stakeholders to draw insights from

Consultation

Stakeholder Consultation

Up to 50 stakeholders will be consulted for the Preliminary Unilateral Roadmapping phase. These stakeholders will be consulted to **draw out the key implementation, technology, export, social license, policy, regulatory and workforce** related barriers and opportunities for Australia.

Consultation Findings

The key insights from the consultations will be translated into a 'stakeholder findings pack'.

Synthesis

Preliminary Unilateral Roadmapping Summary Paper

- **Builds on the actions** from the NHS, NHR and SoP
- Highlights the **key barriers and opportunities for Australia** in developing a hydrogen/ hydrogen-derivatives export value chain.
- Provides a **framework** for realising these export opportunities for Australia in the form of potential **short-, medium- and long-term** next steps.

Next steps for HySupply

Release of State of Play report for consultation

Rolling release of open source models

Preliminary roadmapping with Deloitte

Much to be optimistic about... but much more to be done



GlobH2E

Questions, comments, suggestions all welcome

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