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Australia's Opportunity: Synergies between Hydrogen Export and Domestic Energy Transition in Australia

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In November 2019, the Australian federal government launched its National Hydrogen Strategy[1] which aims to position Australia as a major player in the global hydrogen market by 2030. This is an economic opportunity ripe for international collaboration, such as through the recent Joint Declaration between German and Australian governments to further the research in this field.[2] The production of renewable (green) hydrogen shows potential for significant cost reduction,[3] and combined with Australia's renewable and mineral resources renders it an attractive proposition for supplying green energy and energy-intensive products to the global market. The bilateral scenario working group of the Australian-German Energy Transition Hub analysed the potential impact of hydrogen exports on energy systems in Australia as part of a multi-model scenario analysis. The scenario analysis[4] is based on four energy-economic models which examine a range of carbon abatement scenarios for Australia, ranging from a "Status Quo" scenario (which only considers the existing energy policy) to an ambitious "200% Renewables" scenario where not only is domestic demand met with renewables, but an additional 100% is generated to supply electrolysis for large-scale green hydrogen exports. The "200% Renewables" scenario highlights a visionary goal for Australia to become a global leader in both climate mitigation and the export of zero-carbon energy.

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1 COAG Energy Council, Australia's National Hydrogen Strategy. 2019.

2 Department of Foreign Affairs and Trade. Joint Declaration of Intent on an Australian-German Supply Chain Feasibility Study of Hydrogen produced from Renewables. 28 August [cited 2020 28 August]; Available from: www.dfat.gov.au/international-relations/themes/climate-change/joint-declaration-intent-australian-german-supply-chain-feasibility-study-hydrogen-produced-renewables

3 Longden, T., et al., Green hydrogen production costs in Australia: implications of renewable energy and electrolyser costs. CCEP Working Paper 20-07 Crawford School of Public Policy, The Australian National University. , 2020(August).

4 Ueckerdt, F., et al., Australia's power advantage: Energy transition and hydrogen export scenarios, Insights from the Australian-German Energy Transition Hub. 2019(September).

The 200% Renewables scenario

The 200% Renewables scenario addresses opportunities from an emerging green hydrogen export industry on the pathway to carbon neutrality for all energy sectors (not only electricity) by 2050. The scenario assumes an almost full electrification of demand of transport, building heat, and industrial processes, leading to a doubling of electricity demand from the National Electricity Market (NEM). The cost-optimal transition pathway leads to a 100% renewable system (covering the existing electricity demand and newly electrified sectors) by 2050. We add another 100% renewable electricity generation for export purposes in the form of green hydrogen and energy-intensive metals, taking advantage of Australia's enormous renewable electricity potential (see Figure 1). Our hydrogen export assumptions are in line with ACIL Allen's High Export Scenario,[5] a study commissioned by the Australian Renewable Energy Agency. Together, this constitutes the 200% Renewables scenario which goes far beyond today's electricity demand – more than four times of current electricity consumption from the National Electricity Market (NEM).

In the 200% Renewables scenario, we aim to explore how a major hydrogen industry might roll out in Australia, especially considering the optimal locations for prospective hydrogen production facilities.

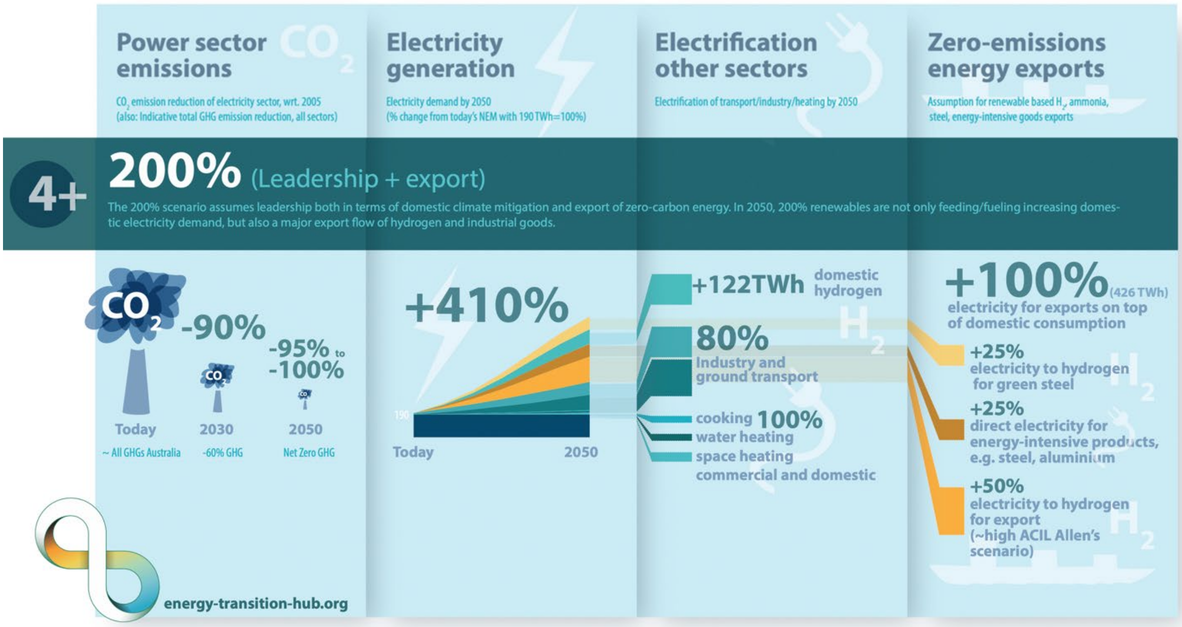

Figure 1 the 200% Renewables scenario

The average cost of electricity supply may be reduced with flexible hydrogen production

Modelling results demonstrate that there are beneficial synergies between hydrogen export and Australia's domestic energy transition. The scenario with large-scale grid-connected hydrogen exports (the 200% Renewables scenario) sees a 30% reduction in the average cost of electricity supply in the mid- to long-term compared to the 100% Renewables scenario.

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5 ACIL Allen Consulting, Opportunities for Australia From Hydrogen Exports, ACIL Allen Consulting for ARENA. 2018(August).

This is due to the flexible operation of hydrogen production, which reduces the balancing costs, required storage capacity, transmission reinforcement and renewable energy curtailment.

Modelling results also show Australia's vast wind and solar resources will be a main pillar of decarbonisation on the pathway to net-zero emissions. New wind and increasingly solar power plants are the cheapest new source of electricity, and electricity from coal is phased out either when the plant reaches the end of life, or earlier if they become uneconomic. Variable renewables are balanced with several flexibility options including electrolysis, while the scenarios show that gas is unlikely to be a transition fuel towards net-zero emissions by 2050 with no new gas-fired capacity being built.

Beyond 200% renewables

We further demonstrate that the average cost of electricity supply may be reduced further if we continue to increase the amount of hydrogen exports beyond the 200% Renewables scenario. With an aim to replace Australia's current LNG exports with energy equivalent in hydrogen, a further 300% and 400% Renewables scenarios are evaluated in Figure 2. This would mean that Australia could potentially become an even greater hydrogen exporter as hydrogen could be offered at an even lower price to resource-limited nations such as Germany to simultaneously help them to decarbonise their economies.

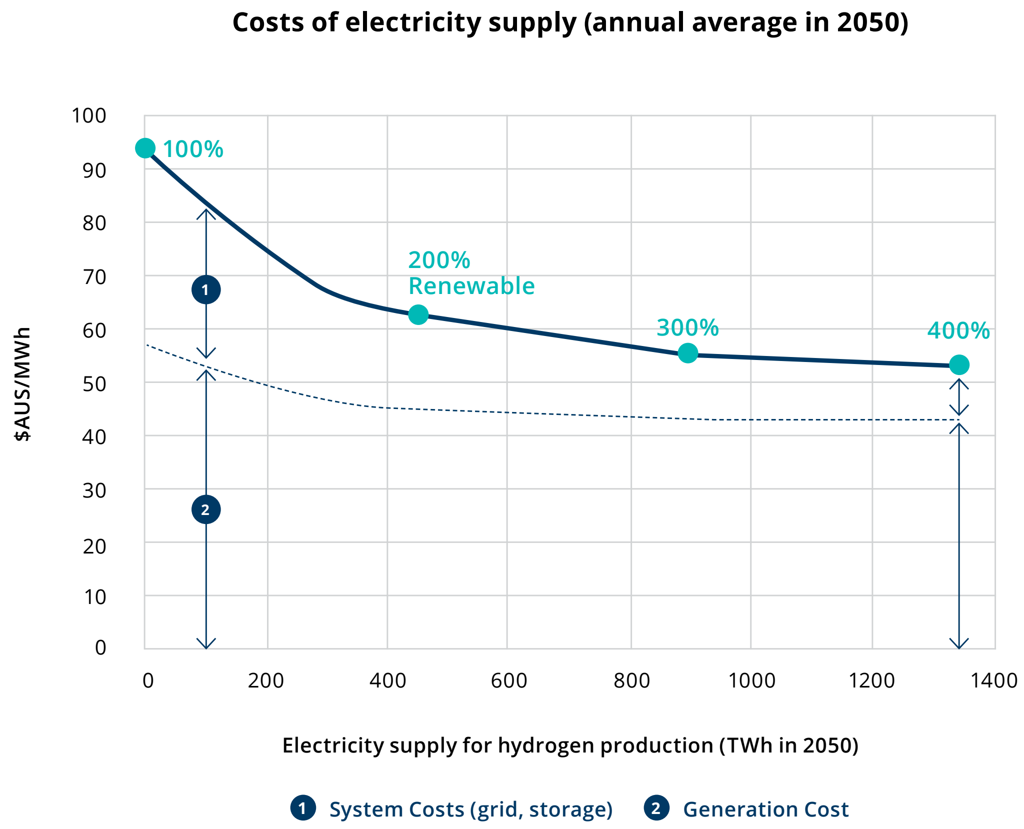

Figure 2 Average 2050 costs of supply per unit of electricity demand (domestic and export) as a function of hydrogen production from the MUREIL model. Going beyond 200 per cent renewables further decreases the system cost element and overall costs of electricity supply.

Two possible hydrogen futures

Two systematically different locations for electrolysis and resulting hydrogen hubs could emerge in Australia, with very different implications for the domestic energy transition and the value to the domestic economy from a large hydrogen export industry. First, huge electrolysers could be placed at the best renewable sites, e.g. in the Pilbara, building off-grid hydrogen islands. Alternatively, electrolysis could be integrated into the electricity grid, so that they can provide flexibility to balance increasing renewable electricity shares.

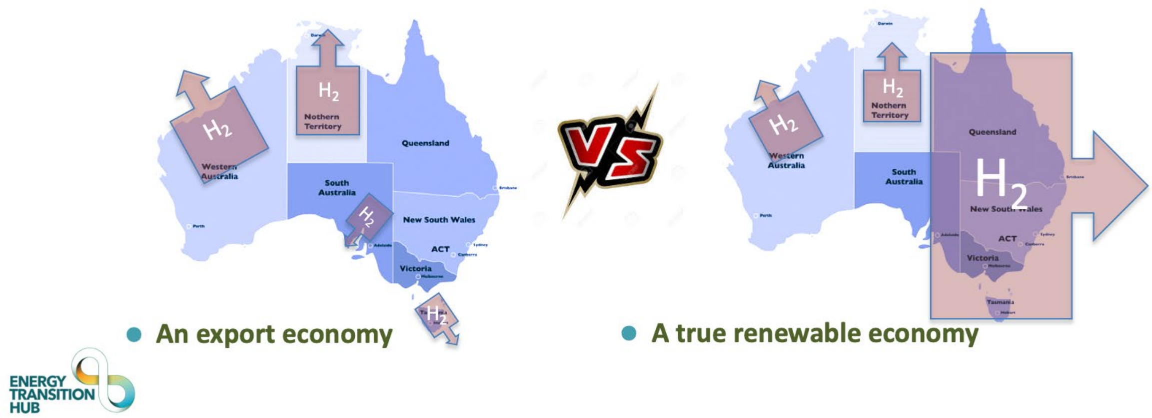

Figure 3 two possible hydrogen futures for Australia

Our analysis shows the choice of an optimal location for future hydrogen production strongly depends on:[6]

- the degree of renewable shares in electricity generation
- specific electrolyser capital costs (and conversion efficiencies)
- hydrogen production (export) volumes

Modelling indicates that if the cost of electrolysis stays relatively high and the renewable shares of Australia's electricity system are growing only slowly, the short-term hydrogen production costs could be minimised at locations with the best wind and solar resources. This result holds most strongly when electrolyser costs are high (around $3000/kW as assumed in Australia's Hydrogen Roadmap[7]). Under these circumstances, capacity factors need to be maximised by combining the highest and most complementary solar and wind resources, or hydro power. In these early years, ideal electrolyser locations tend to be in the Pilbara, South Australia, Tasmania, northern Queensland, and the central Northern Territory (if surface water may be used). This finding is consistent with early investments in large-scale green hydrogen export projects in Australia. The 15 GW Asian Renewable Energy Hub in the Pilbara proposes to deploy around 3 GW for domestic consumption, leaving around 12 GW for the large-scale production of green hydrogen for domestic and export markets.[8]

6 Burdon, R., et al., Innovation and export opportunities of the energy transition Insights from the Australian-German Energy Transition Hub. 2019.

7 Bruce, S., et al., National Hydrogen Roadmap - Pathways to an economically sustainable hydrogen industry in Australia. 2019.

8 The Asian Renewable Energy Hub. 2017 [cited 2020 15 July]; Available from: https://asianrehub.com/

Alternatively, if, as is widely predicted,[9] the cost of electrolysis drops with economies of scale and we see rapid electrification of sectors including transport, commercial and industry – then hydrogen production and its use become dispersed across the NEM. Under these circumstances, and despite the much lower utilisation rate, electrolysis could provide electricity system benefits that reduce domestic electricity prices. Hydrogen electrolysis reduces curtailment and the need for electricity storage and transmission investment. This outcome delivers benefits to the whole economy. In this case, the cost reductions (due to an integrated and optimised operation of electrolysers in a renewable-heavy NEM) outweigh the impact of better renewable resources at remote and isolated locations. It is also more likely that electrolysers will be located in dispersed locations around the NEM when electrolyser costs are assumed to fall over time (to AUD800/kW). It also increases the chance that Australia could potentially become an even greater hydrogen exporter as hydrogen could be offered at an even lower price when hydrogen production is further increased, as illustrated in Figure 2.

The location of electrolysers is likely to have major implications for the use of hydrogen in the domestic Australian market. It may be more likely that hydrogen will be produced primarily for export markets if production facilities are located in remote locations, as illustrated on the left of Figure 3. Conversely, if ambition increases and costs decline sufficiently – it opens up a new chapter for Australia to embrace a true renewable economy and be a major energy and product exporter,[10] as illustrated on the right of Figure 3. If hydrogen production is located close to potential sources of domestic demand (such as existing gas networks), it renders it more likely to support greater use within the domestic economy as well.

A long-term system-wide perspective is critical

A long-term system-wide perspective is critical for the design of energy policies that can secure wider energy system benefits.[11] The scenario analysis suggests that it is unclear if large-scale hydrogen exports will be produced from grid-connected electrolysers, particularly in the early years, without policy intervention. Nevertheless, this remains an important strategic factor and presents a long-term opportunity to achieve improvements in energy system efficiencies and cost savings, by planning and building shared infrastructure for a new hydrogen industry. The consideration of path dependencies regarding the short-term economic gains of individual projects and their wider long-term system benefits will allow the Australian Federal and State governments to determine appropriate policies and pathways towards carbon neutrality and a hydrogen economy.

Government support is required

If Australia was to build a giga-watt-scale hydrogen export industry, it appears likely that the industry would require significant government support through subsidies, grants and tax incentives to help drive adaptation and decrease technology capital expenditure. However, this stimulus would enable Australia to take a leading role in the global renewable hydrogen economy by creating hydrogen within the National Electricity Market. Although requiring some subsidy in the short-term, it would also create significant long-term sustainable economic benefits while simultaneously reducing energy costs within its domestic market.

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9 IRENA, Hydrogen From Renewable Power: Technology outlook for the energy transition. 2018. p. 1-52.

10 Hamilton, S., et al. Enough ambition (and hydrogen) could get Australia to 200% renewable energy. 2019 [cited 2020 August 24]; Available from: https://theconversation.com/enough-ambition-and-hydrogen-could-get-australia-to-200-renewable-energy-127117

11 Hamilton, S., et al., Energy Transition Hub submission on the Technology Investment Roadmap Discussion Paper. 2020.

About the Authors

Changlong Wang

Changlong has just submitted his PhD thesis (on "Modelling Australia's transition to a low carbon electricity system with optimised transmission networks and renewable energy exports") in September 2020 at the University of Melbourne. In his PhD, Changlong developed a large-scale multi-decadal capacity expansion model that can simultaneously optimise the electricity generation, transmission, and storage systems for an orderly energy transition. The model has also been used to explore export opportunities (in terms of hydrogen, renewable electricity via HVDC cables and green steel) for Australia in a carbon-constrained world.

Changlong is a researcher at the Australian-German Energy Transition Hub and has been working in a bilateral scenario modelling group of 15 researchers to investigate the impact of large-scale hydrogen industry on the Australian energy system. Chang is also one of the two Australian experts, who represent Australia in a new IEA, Hydrogen Implement Agreement, Task 41: "Analysis and Modelling of Hydrogen Technologies". His work involves developing knowledge of modelling Hydrogen in the value chain.

Changlong is a recipient of the Melbourne International Engagement Award, CSIRO Office of the Chief Executive postgraduate award, Australian Institute of Energy's postgraduate award and a top-up scholarship from the National ICT Australia (now known as Data61).

Dr Roger Dargaville

Dr Roger Dargaville is an expert in the field of energy and climate systems and has deep understanding of the workings of a broad range of energy technologies and the policy challenges of the transition to a low carbon energy future. His research foci are large-scale optimised high penetration renewable electricity networks, novel energy storage technologies, and role of climate and weather extremes on the energy system. He has extensive experience working with industry having several close partnerships with major energy and engineering companies. Roger has an international view of climate and energy issues, having worked for organisations such as the International Energy Agency, UNESCO and the American National Center for Atmospheric Research.

Roger is currently a Senior Lecturer in the Resources Engineering group in Civil Engineering at Monash and the lead of the Renewable Energy stream. He is developing and coordinating the delivery of an undergraduate degree in renewable energy, incorporating wind, solar, hydro, geothermal, bioenergy and power system units. He has also recently undertaken the role of Deputy Director of the Monash Energy Institute, leading the Resources theme, is the current Vice-President of the Australian Meteorological and Oceanographic Society, and is the convenor of the 2020 Asia-Pacific Solar Research Conference, being held in Melbourne (and virtually) later this year.

Dr Falko Ueckerdt

Falko Ueckerdt is a senior scientist at the Potsdam Institute for Climate Impact Research (PIK) and leads the team National Energy Transitions. He leads or works in national and international research projects with researchers from all over the world, including China, USA, India, Europe and Australia. Dr Ueckerdt is part of two IEA advisory groups, on system integration of variable renewables and on projected costs of generation. He was/is a contributing author to the Special Report on Renewable Energy Sources and Climate Change Mitigation of the IPCC (2011) and the Sixth Assessment Report (current).

In the past, Falko Ueckerdt was a postdoctoral research scholar at the Hanley Sustainability Institute of the University of Dayton, Ohio (2016), worked in energy planning for the International Renewable Energy Agency (2014/2015) and in e-mobility for the Boston Consulting Group (2009). Falko Ueckerdt studied physics at the Humboldt University Berlin and did his PhD at PIK (on renewable system integration) supervised by Ottmar Edenhofer, Bob Brecha and Gunnar Luderer.

Falko Ueckerdt has a background in physics and economics and conducts research and policy advice in the field of climate change mitigation and energy system transformation, particularly on wind and solar power integration, sector coupling, electrification, hydrogen and efuels.

* The Hub scenario working group consists of 15 researchers from six Hub partner institutes using four models: REMIND, REMix, OpenCEM and MUREIL.

About the Periscope Series

'Periscope' is the Occasional Analysis Paper/Brief series of the Konrad Adenauer Foundation's Regional Programme Australia and the Pacific. Just like the real-world sighting instrument, Periscope is meant as a lens to broaden our insights - taking in views from different angles. This way, it seeks to bring together perspectives from Germany, Europe, Australia, New Zealand and the Pacific region to augment our understanding of contemporary issues and help address the pressing problems of our time. The Periscope Series covers topics from the area of foreign and security policy, cybersecurity, terrorism/ counter-terrorism, energy policy, rule of law, socio-economic matters and development policy. It comprises both **longer Analysis Papers**– in the form of single-author (and co-authored) contributions or edited volumes with multiple authors - and **shorter Analysis Briefs**.

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