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Is hydrogen the next "clean coal"?

The rush to develop Australia's hydrogen industry is based on export opportunities, especially to Japan and Korea, which have been vastly overstated by comparison with Japanese and Korean targets. Developing hydrogen with coal and gas risks locking in increased emissions, given the track record of carbon capture and storage. Australia should focus on hydrogen produced with renewable energy.

Discussion paper

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Summary

Hydrogen power has been heralded as a game changer in the global transition to low-carbon energy. Hydrogen produces zero emissions when combusted and can be used as an energy carrier in electricity, transport and industry.

Currently, subtantial amounts of hydrogen is produced globally for use as an input into industrial processes, using gas and coal as a feedstock. This is very greenhouse gas intensive, currently emitting as much as the UK and Indonesia combined. However hydrogen can be produced with zero emissions through electrolysis, powered by renewable. Fossil hydrogen could also be combined with carbon capture and storage (CCS) to reduce its emissions.

Countries like Japan and South Korea have plans and targets for greater direct consumption of hydrogen, as well as manufacture of hydrogen vehicles and energy systems. In Australia, political, scientific and business leaders have urged immediate action to capitalise on the increasing demand by establishing itself as a major hydrogen exporter. Of particular focus are potential hydrogen exports to Japan as part of a close bilateral relationship, extending or even replacing current Australian coal and gas exports.

Numerous recent reports and government plans for developing Australia's hydrogen industry all use rhetoric of economic potential, optimism and urgency in claiming 'the race is on' to capture a share of the emerging hydrogen market. This includes a major report from CSIRO, Australia's National Hydrogen Strategy, the Chief Scientist's advice to COAG, the joint ministerial statement on hydrogen, and state government policy documents.

All of these documents base their claims about demand and associated economic benefits on a single report published by ACIL Allen. This report provides projections of import demand in key markets like Japan and Korea that vastly exceed targets in official government strategies.

For Japan the ACIL Allen hydrogen import projections for 2030 are up to 11 times Japan's official target. Even the low demand projection is two and half times the official target. The projections for South Korea are similarly high by comparison with government plans. Both countries see imports playing a much smaller role to 2030.

Combining the Japanese procurememnt cost and volume targets, we see hydrogen exports are worth 0.5% of Australia's current exports to Japan, smaller than cheese and curd, wheat, barley or animal feed and even smaller than machines, vehicles and computers, more widely thought of as imports from Japan to Australia.

ACIL Allen's discrepancy with government policies is surprising, given that the basis of increased demand is said to be policy in importing countries. In fact, ACIL Allen's projections

assume highly ambitious climate policy, with effective carbon prices of US$125–US$140 per tonne CO2 in 2040. This is acknowledeged by none of the documents citing ACIL Allen's projections.

A clearer view of timeframes and assumptions gives Australia more time to carefully plan and develop a sustainable hydrogen industry.

Fast-tracking substantial hydrogen development is likely to favour fossil based hydrogen, given currently this is the cheaper way to produce it. However, renewable powered electrolysis is widely projected to be competitive in the coming decade. Regulation and funding could help Australia play a leading role in this development.

Australian goverments are supporting both renewable and fossil based hydrogen projects. Half of the Commonwealth government's funding has gone to one coal gasification project in the La Trobe Valley, co-funded by the Victorian Government. By contrast the South Australian Government is focusing exlusively on renewable-powered hydrogen.

Notwithstanding the existing hydrogen industry's extensive emissions, some argue fossil hydrogen can be low emission (although not zero emission) through carbon capture and storage (CCS). Promises of CCS risk instead promoting unabated fossil fuel use and emissions, just as they have in debates about 'clean coal'.

CCS continues to be a costly and concerning failure in Australia and across the world, falling far behind nearly every target set for it. Australia's flagship CCS project at Gorgon LNG was obliged to sequester carbon from 2016, only started ramping up in August 2019, to levels that remain uncertain, and yet has faced no penalties. It enjoys Commonwealth government subsidy and complete indemnity from carbon leakage liabilities. Gorgon's CCS failures have been responsible for half the increase in Australia's annual CO2 emissions.

Without strong and credible carbon pricing or other regulation, a fossil-based hydrogen export industry will almost certaintly result in increased Australian emissions. Japan's main incentives are energy security and lower domestic emissions. It would in effect be would in effect be exporting emissions to Australia. Moreover, the differences in the technology, geography and infrastructure required for different production methods make it likely that fossil hydrogen production and associated emissions will be "locked in" for use even after hydrogen production using renewable energy becomes cost competitive.

Hydrogen could play a major role in decarbonising Australia's and the world's energy systems and presents a substantial zero-carbon economic opportunity for Australia. However this would be put at risk by a short-term rush into fossil hydrogen, on the basis of inflated demand projections and yet futher promises of CCS.

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Introduction

The introduction of hydrogen to the energy and transportation sectors, as both an energy carrier and an energy source, could play a major role in reducing emissions and slowing the increase of global temperatures. Hydrogen fuel emits no carbon dioxide at time of use and can be produced using renewable energy sources.

Many hydrogen development projects are already underway across the world.

The hydrogen debate in Australia is fuelled mainly by the export opportunities to Japan, and to a lesser extent, South Korea.

In 2017 Japan announced their intention to shift towards a “hydrogen economy” and import hydrogen on a large scale to meet their domestic needs.

Australia is well positioned to become a major supplier of Japan’s hydrogen due to its strong bilateral trading relationship, geographic proximity, and abundance of natural resources.

The Australian government is currently supporting the development of fossil fuel hydrogen projects. These projects are highly polluting unless combined with carbon capture and storage (CCS). Yet promises and predictions about CCS have a long history of being proven false.

The push into fossil hydrogen is based on the urgency of establishing a hydrogen supply chain to Japan to capture market share. However the basis for this claim is not supported by official Japanese targets.

The role of hydrogen in the global energy mix

AUSTRALIA-JAPAN BILATERAL ENERGY RELATIONSHIP

The strong bilateral relationship between Japan and Australia is currently underpinned by coal and liquified natural gas (LNG) exports. Japan is Australia's second-largest export market, with coal and LNG two of Australia's major merchandise exports to Japan.[1]

Despite this, both Japan and Australia are signatories to the Paris Agreement which aims to hold global warming to below 2°C. The two countries have put forth similarly low targets under the Agreement, with Australia aiming for a 26 to 28 percent reduction from 2005 levels by 2030, and Japan aiming for a 25.4 percent reduction from 2005 levels by 2030.[2] Both targets are insufficient under the goals of the Paris Agreement.[3]

Both Japan and Australia are large emitters of greenhouse gas, in part due to their reliance on coal-generated electricity. Japan has the 5th highest emissions and Australia has the 14th, although per capita Australia's emissions are more than twice as large. Australia has the highest per capita emissions in the OECD.[4]

70% percent of Australia's electricity comes from coal, with just 22% percent from renewable energy sources such as hydropower, wind and solar.[5] Australia is also the largest exporter of coal in the world. Around a quarter of this is imported by Japan, the largest coal importer of Australian coal, and most of this is thermal coal.[6]

Japan's energy mix is dominated by coal, oil, and natural gas, totalling 75% of electricity generation in 2018.[7] After the Fukushima power plant disaster in 2011 and the subsequent closure of all nuclear power plants, coal and gas generation increased while energy

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[1] DFAT (2017) Australia-Japan bilateral relationship. https://dfat.gov.au/geo/japan/Pages/australia-japan-bilateral-relationship.aspx#overview

[2] Carbon Brief (2015) *Paris 2015: Tracking country climate pledges.* https://www.carbonbrief.org/paris-2015-tracking-country-climate-pledges

[3] Climate Action Tracker (2019) *Countries.* https://climateactiontracker.org/countries/

[4] Swann (2019) *High Carbon from a Land Down Under* https://www.tai.org.au/sites/default/files/P667%20High%20Carbon%20from%20a%20Land%20Down%20Under%20%5BWEB%5D_0.pdf

[5] Open NEM (2019) *Energy NEM 1Y: October 2018-October 2019.* https://opennem.org.au/energy/nem

[6] Office of the Chief Economist (2019) https://publications.industry.gov.au/publications/resourcesandenergyquarterlyseptember2019/index.html

[7] BP (2019) *Statistical Review of World Energy* https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

efficiency measures saw demand fall. In recent years there has been a significant increase in renewable energy and some nuclear power stations have come back online.

The global energy landscape is changing drastically, fuelled by climate change, air pollution and technological developments. Many countries are now seeking low-carbon alternatives to fossil fuels. Japan and Australia are both increasing their renewable energy production. Both countries are also looking to hydrogen.

A NEW MARKET FOR HYDROGEN?

Hydrogen is viewed by many as playing a key role in reducing dependence on fossil fuels. It emits zero carbon when combusted, and can be produced with renewable energy. It can be stored and transported, used as a transport fuel, used to generate electricity and mixed into existing gas supply.

In 2017, Japan became the first country to publish a Basic Hydrogen Strategy, detailing its plans for the future supply and consumption of hydrogen.[8] Many countries have since followed suit. Currently, there are several major developments underway in Europe trialling the production of hydrogen using renewable energy and its use in pre-existing gas grids.[9]

There are also a number of ongoing hydrogen projects in Australia, most notably in the Latrobe Valley in Victoria. Here, hydrogen production from brown coal is being tested in a partnership with Japan's Kawasaki Heavy Industries.[10] The project is the first of its kind in the world and is designed to cement Australia's role as a major hydrogen exporter, and more broadly to strengthen the bilateral relationship with Japan.

Prior to the federal election in May 2019 the Labor opposition announced their National Hydrogen Plan. Currently the Council of Australian Governments (COAG) Energy Council is consulting over a national hydrogen plan. There has been significant public interest in prospects for an Australian hydrogen industry.

Presently, demand for hydrogen is based on its use in refining and chemical production. However, as an energy carrier, its potential applications are far-reaching. Cleaner and more efficient than internal combustion engines, and able to fuel electric vehicles faster than batteries, some suggest hydrogen-powered vehicles will be key to decarbonising the transport sector.

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[8] Japanese Ministry of Economy Trade and Industry (2017) *Basic Hydrogen Strategy*, https://www.meti.go.jp/english/press/2017/1226_003.html

[9] Fukui (2019) *Hydrogen: Tracking Clean Energy Progress* https://www.iea.org/tcep/energyintegration/hydrogen/

[10] Lazzaro (2018) *World-first coal to hydrogen plant trial launched in Victoria*, ABC, 12 April. https://www.abc.net.au/news/2018-04-12/coal-to-hydrogen-trial-for-latrobe-valley/9643570

With large amounts of public and private investment going into hydrogen fuel cell vehicles and refuelling stations, some automotive executives estimate fuel cell vehicles will account for 23 percent of total automobile sales by 2040.[11] Others have been more sceptical about hydrogen for cars. There are however a wide range of transport applications, including fuel cell buses and trains.

Additionally, Japan's deployment of residential fuel cells, nicknamed "Ene-Farm", demonstrates the use of hydrogen in heating and powering homes.[12] Other potential applications of hydrogen include storing excess renewable energy, powering remote areas without access to the electricity grids, providing backup power for data centres and fuelling space travel.

HYDROGEN PRODUCTION METHODS

While hydrogen is making headlines under exciting descriptions such as "zero-emission fuel" and "green energy carrier", its environmental impact differs dramatically depending upon the method by which it was produced.

Hydrogen emits zero carbon at the time of *consumption* in fuel cells, where the by-products are mostly water vapour and small amounts of nitrogen oxides.

However, hydrogen is not necessarily zero carbon during *production*. There are a range of methods available for producing hydrogen (outlined in more detail in Appendix A). Some use fossil fuels as a feedstock. These methods produce greenhouse gas emissions.

Currently, the leading extraction methods are coal gasification and steam methane reforming (SMR). These are significantly cheaper per unit of output than electrolysis from renewable energy sources.

The Latrobe Valley project plans to use brown coal to produce hydrogen through coal gasification. Hydrogen made via this method is known as "brown hydrogen". This method of producing hydrogen is highly inefficient and polluting. The pilot project in the Latrobe Valley estimates that it will produce over thirty times more carbon dioxide than hydrogen in weight.[13]

The most common method of extraction is the process of steam methane reforming. In contrast to brown hydrogen sourced from coal, this method utilises 'natural gas' or methane. The gas industry is now marketing this as "blue hydrogen".

[11] Bragg (2019) *Automotive industry enters 'perfect storm' of change and uncertainty*, Sydney: KPMG.
[12] Japan LP Gas Association (n.d.) *Home-use Fuel Cell*. http://www.j-lpgas.gr.jp/en/appliances/
[13] HESC (2019) *FAQs* https://hydrogenenergysupplychain.com/faqs/

Emissions from methane are lower than emissions associated with hydrogen production from coal. The Energy Transition Hub estimates emissions of 54 kilograms of carbon dioxide per gigajoule of hydrogen using SMR, compared to 107 kilograms per gigajoule using coal gasification.[14] The amount of carbon dioxide by-product from blue hydrogen is significant, despite being lower than those from brown hydrogen.

Electrolysis is currently more expensive than the previous two methods of hydrogen production but produces truly zero-carbon hydrogen known as "green hydrogen". In this process, oxygen is the only by-product of production (see Appendix A).

Currently this is a higher cost method of producing hydrogen than through coal gasification and SMR. However, technology costs are falling rapidly, both for electrolysis and for renewable energy, and the combination is being explored for future large scale deployment.[15] Recent analysis by Bloomberg New Energy Finance projected green hydrogen costs to fall by 80% by 2030.[16]

Connecting electrolysis to renewable sources such as wind farms and solar plants would allow for low price, excess energy to be stored as hydrogen, which could in turn reduce volatility in renewable energy supply.

Hydrogen has the potential to be a key part of global climate change mitigation. However, misguided action today could have severe adverse consequences.

[14] Palmer (2018) *Australia's Hydrogen Future*. https://www.energy-transition-hub.org/resource/australias-hydrogen-future-research-report

[15] Mazengarb (2019) *Renewable hydrogen getting cheaper, Australia could lead global market* https://reneweconomy.com.au/renewable-hydrogen-getting-cheaper-australia-could-lead-global-market-95168/

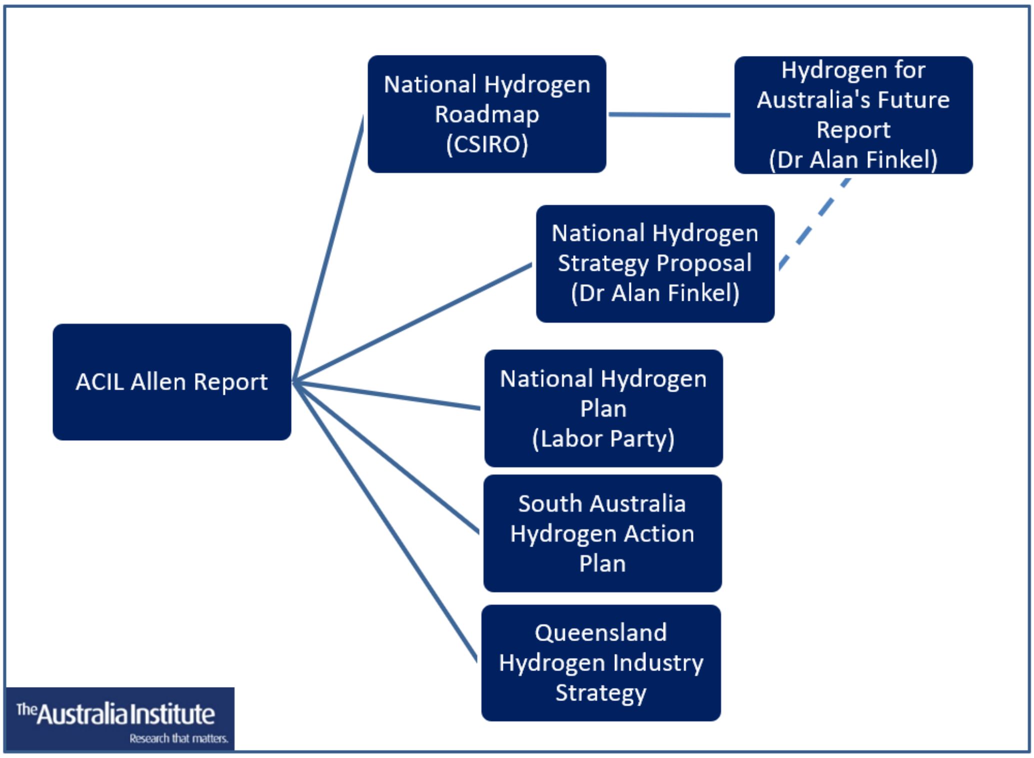
[16] Mathis and Thornhill (2019) *Hydrogen's Plunging Price Boosts Role as Climate Solution* https://www.bloomberg.com/news/articles/2019-08-21/cost-of-hydrogen-from-renewables-to-plummet-next-decade-bnef

Australia’s hydrogen rhetoric

Hydrogen has captured significant attention in recent Australian energy policy debates. The language used to describe Australia’s future hydrogen industry is overwhelmingly optimistic, particularly regarding Australia’s place in the global hydrogen market.

This section traces the rapid development of this rhetoric about the economic opportunity of hydrogen exports through reports over the last year (see Figure 1). Economic claims in these reports can can be traced back to just one source: a report by ACIL Allen consulting.

Figure 1. Reference to ACIL Allen’s projected demand for hydrogen



Source: reports as described in text

ACIL Allen Report

In August 2018, ACIL Allen Consulting published *Opportunities for Australia from Hydrogen Exports* (ACIL Allen report). This report was commissioned by the Australian Renewable Energy Agency (ARENA).[17]

[17] ACIL Allen Consulting for ARENA (2018) *Opportunities for Australia from Hydrogen Exports*. https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf

The ACIL Allen report projects future global demand for hydrogen and outlines how Australia could best position itself to be a world leader in hydrogen exports.

Specifically, it predicts Japan and Korea to be the two major importers of Australian hydrogen due to large projected demand, their lack of domestic resources to meet projected demand and geographic suitability for transporting liquid hydrogen from Australia.

CSIRO Report

In August 2018 the Commonwealth Scientific and Industrial Research Organisation (CSIRO) published *The National Hydrogen Roadmap* (CSIRO report).[18]

The CSIRO report examines the potential applications of hydrogen in Australia's economy and provides a framework for the development of the industry.

It emphasises Japan and South Korea's increasing demand for hydrogen as a major opportunity for Australia. It cites the ACIL Allen report and a report published in December 2017 by the International Energy Agency, *Global Trends and Outlook for Hydrogen* (IEA report).

Hydrogen for Australia's Future Report

In August 2018 the Hydrogen Strategy Group published *Hydrogen for Australia's Future*, as a briefing paper for the COAG Energy Council.[19]

The Hydrogen Strategy Group is chaired by Australia's current Chief Scientist Alan Finkel.

The report identifies the opportunity for Australia's domestic economy to reap the benefits of a hydrogen export market. It includes energy exports as one of three main drivers of the hydrogen industry. As keys to the future of Australia's hydrogen exports it cites Japan's current reliance on foreign energy sources and the strong Australia-Japan bilateral trading relationship.

The report claims that Australia has two major advantages as a low-emission hydrogen supplier: an abundance of natural resources to produce renewable hydrogen, and offshore sites suitable for producing hydrogen using carbon capture and storage (CCS).

The report cites the ACIL Allen report, the CSIRO Report, and the IEA report.

National Hydrogen Strategy Proposal

In December 2018 Chief Scientist Alan Finkel published *Proposal for a National Hydrogen*

[18] CSIRO (2018) *National Hydrogen Roadmap*, https://www.csiro.au/en/Do-business/Futures/Reports/Hydrogen-Roadmap

[19] Hydrogen Strategy Group (2018) *Hydrogen for Australia's Future*, Commonwealth of Australia. https://www.chiefscientist.gov.au/wp-content/uploads/HydrogenCOAGWhitePaper_WEB.pdf

Strategy (National Hydrogen Strategy Proposal).[20] It was prepared by following the COAG Energy Council response to the earlier briefing note.

The Proposal cites the future hydrogen demand numbers in the ACIL Allen reports, and names Japan, South Korea, and China as key markets.

The December COAG meeting established a Hydrogen Working Group chaired by the Chief Scientist. One of the six work streams of the Working Group is dedicated to hydrogen exports and will consider a national hydrogen strategy.

Additionally, in December the COAG Energy Ministers issued a "Joint Ministerial Statement: Hydrogen", as recommended in the Proposal. The statement outlines a vision to "make Australia a major player in a global hydrogen industry by 2030".[21]

Labor's National Hydrogen Plan

In January 2019, before the federal election, the Australian Labor Party (ALP) published their *National Hydrogen Plan* (Labor plan).[22] The Labor plan estimates the size of Australia's hydrogen market using figures on Japan's import demand from the ACIL Allen report.

The plan included an investment of $1 billion into research and development for clean hydrogen technology, whilst also supporting commercialisation in Gladstone due to existing liquefied natural gas (LNG) infrastructure.

South Australia's Hydrogen Action PlanIn September 2019, the Government of South Australia released *South Australia's Hydrogen Action Plan* (South Australia Plan).[23] The Plan outlines how South Australian can benefit from emerging global market for hydrogen, referring to ACIL Allen's projections for Australian hydrogen exports.

Queensland Hydrogen Industry StrategyIn May 2019, The Queensland Government released the Queensland Hydrogen Industry Strategy (The Queensland Strategy).[24] The Queensland Strategy outlines how Queensland can position itself as a large hydrogen trading partner

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[20] Finkel (2018) *Proposal for a national hydrogen strategy,* Commonwealth of Australia. http://www.coagenergycouncil.gov.au/publications/establishment-hydrogen-working-group-coag-energy-council

[21] COAG Energy Council (2018) *Joint Ministerial Statement: Hydrogen*. http://www.coagenergycouncil.gov.au/publications/establishment-hydrogen-working-group-coag-energy-council

[22] Australian Labor Party (2019) *Labor's Plan For Hydrogen*. https://web.archive.org/web/20190518084758/https://www.alp.org.au/policies/labors-plan-for-hydrogen/

[23] Government of South Australia (2019) *South Australia's Hydrogen Action Plan.* http://www.renewablessa.sa.gov.au/content/uploads/2019/09/south-australias-hydrogen-action-plan-online.pdf

[24] Queensland Government (2019) *Queensland Hydrogen Industry Strategy.* https://www.dsdmip.qld.gov.au/resources/strategy/queensland-hydrogen-strategy.pdf

internationally. In a foreword the Premier writes: "This emerging industry will have enormous economic benefits for Australia, worth an estimated $1.7 billion in exports annually by 2030."[25] While no reference is given here, this figure comes from ACIL Allen.

OPTIMISM, URGENCY AND EXPORT POTENTIAL

The documents outlined above have several common characteristics.

First, they all reference statistics from the ACIL Allen report for projected global demand for hydrogen, and the total scale and value of hydrogen production for export (see Figure 1).

Second, despite mentions of the benefits of implementing hydrogen in Australia's domestic energy mix, the focus is on developing a hydrogen export industry.

Thirdly, they all identify Japan as the key market for hydrogen exports. Reasons for this focus include geographical proximity, strong trade relationship, Japan's lack of natural resources and well-established hydrogen strategy.

Finally, all of the above documents convey an urgency to develop hydrogen technology and infrastructure as quickly as possible. Capitalising on growing foreign demand early, capturing market share and cementing Australia's place as a global leader in the hydrogen industry requires early and fast action.

According to the National Hydrogen Strategy proposal, hydrogen is

> emerging as a major economic prospect for Australia, but there is a limited window of time to capitalise on this opportunity.[26]

The Joint Ministerial Statement sets a target year of 2030 to establish Australia in the global hydrogen market.[27]

The optimistic and urgent claims about hydrogen have been picked up in political debates. Across the political divide, Australian politicians have been eager to spruik Australia's hydrogen export potential.

Angus Taylor, Australia's Energy Minister, has voiced excitement about Australia's hydrogen export opportunities, stating

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[25] Ibid. p.3

[26] Finkel (2018) *Proposal for a national hydrogen strategy,* Commonwealth of Australia, p 1. http://www.coagenergycouncil.gov.au/publications/establishment-hydrogen-working-group-coag-energy-council

[27] COAG Energy Council (2018) *Joint Ministerial Statement: Hydrogen*. http://www.coagenergycouncil.gov.au/publications/establishment-hydrogen-working-group-coag-energy-council

> Australia has the potential to be world leader in hydrogen because of our abundant energy resources and proximity to emerging export markets in North Asia.[28]

Richard Di Natale, leader of the Australian Greens, has highlighted the opportunities for Australia from Japan and South Korea's growing hydrogen demand

> Some of our biggest coal export markets like japan and South Korea have made it clear that they want to transition to alternative fuels like clean hydrogen. And that's where Australia's future lies …
>
> What you're seeing in countries like South Korea, Japan, other developed economies, is a rapid transition - and we've got a great opportunity to create jobs, to create investment, build a hydrogen economy, and make sure that those jobs are there for our kids and our grandkids**.**[29]

Much of the interest in hydrogen for Australia relates specifically to renewable hydrogen. The ACIL Allen report, among others, cite Australia's abundant renewable energy resources and infrastructure as reasons why Australia is "well-positioned to become a significant exporter of low or zero emissions energy".[30] Similarly, Fiona J. Beck of the Australian National University's Energy Change Institute believes that Australia has the potential to be a world leader in green hydrogen exports, stating

> There is a sense that the rest of the world is encouraging Australia to make this work. Australia has a real opportunity to become a renewable hydrogen superpower: we need to make sure we take full advantage of it.[31]

At the same time, enthusiasm from Australia's political and scientific leaders is also being urged on by the gas and coal industries. The Minerals Council of Australia, which represents Australia's coal industry, enthusiastically backed the Federal Opposition's National Hydrogen Strategy, stating

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[28] Coorey (2019) *Oh what a feeling! Toyota receives $3.1m for hydrogen plant,* https://www.afr.com/politics/federal/oh-what-a-feeling-toyota-receives-3-1m-for-hydrogen-plant-20190319-p515cs

[29] Di Natale (2019) *Adani battle a 'long way from over': Greens leader Richard Di Natale,* from 7:19. https://www.abc.net.au/radionational/programs/breakfast/adani-battle-a-long-way-from-over:-greens-richard-di-natale/11204918

[30] ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p 1. https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf

[31] Energy Change Institute (2019) *Hydrogen can transition Australia into a zero-carbon energy export superpower*, http://energy.anu.edu.au/news-events/hydrogen-can-transition-australia-zero-carbon-energy-export-superpower

> Australia and other major advanced economies such as Japan are already making large investments in this energy source. Given Australia's significant coal resources, our country is well-placed to become a global producer of hydrogen in the future.[32]

Woodside Petroleum promote their interest in 'blue hydrogen' from gas:

> hydrogen is future energy, here today … [it is] already being produced from our LNG exports in some of our destination markets[33]

The Hydrogen Energy Supply Chain (HESC) consortium, aim to develop brown hydrogen from coal in the La Trobe Valley. The goal is to develop a commercial-scale hydrogen supply chain that encompasses production, transportation and storage, with a goal of delivering liquefied hydrogen to Japan. The consortium says

> Japan is seeking to work with other countries, primarily Australia, to explore ways to produce and import the commodity. Australia could be the first country to create a thriving hydrogen export industry with huge local economic benefits.[34]

There is no shortage of enthusiasm about the economic opportunities of exporting hydrogen to Japan.

[32] Minerals Council of Australia (2019) *Media release: Using Australian coal to power hydrogen's future.* https://minerals.org.au/sites/default/files/190122%20Using%20Australian%20coal%20to%20power%20hydrogen%27s%20future_1.pdf

[33] Ibid.

[34] HESC (2019) *FAQs* https://hydrogenenergysupplychain.com/faqs/

Future hydrogen demand

JAPAN

ACIL Allen estimates

Japanese hydrogen demand is widely seen as key to establishing Australia's industry. The sense of urgency about meeting Japanese demand mostly stems from the projections in ACIL Allen's report (see Table 1, below).

Table 1: ACIL Allen projected value-add of Australian hydrogen production for export

	Value-add		
	2025	2030	2040
Economic footprint	A$m	A$m	A$m
Low H_2 demand scenario	92	806	1,972
Medium H_2 demand scenario	473	1,672	4,287
High H_2 demand scenario	1,196	3,625	10,095
Employment footprint	**FTE**	**FTE**	**FTE**
Low H_2 demand scenario	164	1,439	3,519
Medium H_2 demand scenario	788	2,787	7,142
High H_2 demand scenario	1,898	5,754	16,024

Source: ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p 53

ACIL Allen first estimates the scale of demand in different countries under different scenarios, then estimates the scale of import demand, then estimates Australia's share of that export market. The economic value of the hydrogen export market for Australia is estimated

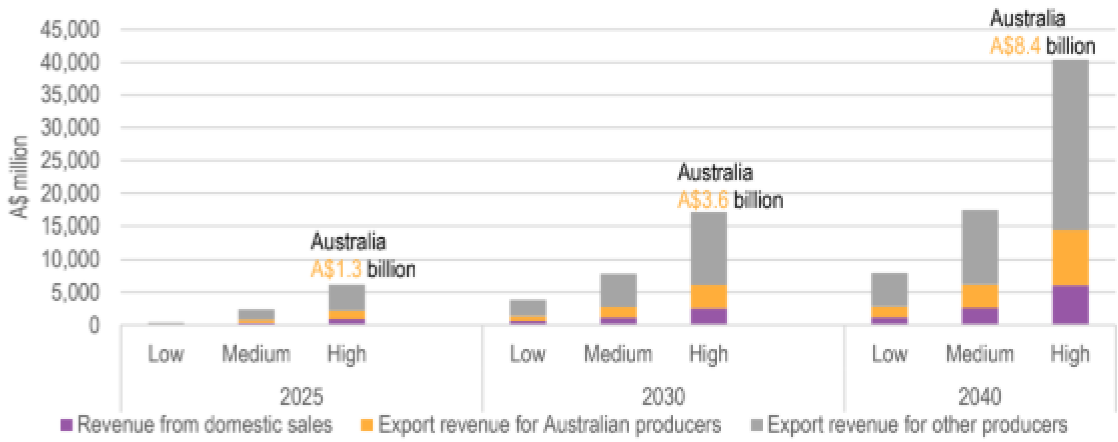
- in a low-demand scenario, at $806 million value-added and 1439 jobs;
- in a medium-demand scenario, at $1.67 billion value-added and 2787 jobs;
- in a high-demand scenario, at $3.62 billion value-added and 5754 jobs.[35]

These projections are based upon ACIL Allen's projected hydrogen demand in several export markets. Japan is emphasised as a key player. Along with estimates for other countries, ACIL Allen's estimates of Japanese import demand form the basis of the economic analysis in the report, and consequently, the claims made by Australia's political and scientific leaders.

[35] ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p 53. https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf

ACIL Allen estimate that by 2030, under a high demand scenario the total value of hydrogen demand in Japan will be over $15 billion, with potential for $3.6 billion in export revenue for Australia (see yellow in middle section of Figure 2).[36]

Figure 2: ACIL Allen estimated value of Japan hydrogen demand, by source and scenario



Source: ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p 43

As can be seen, domestic sales in Japan (purple) are project to make up a small part of Japan's overall demand. Australia (yellow) provides a significant but minority share of the total imports – 21% of total demand, or 25% of imports.

ACIL Allen's estimates of Japanese import demand are many time greater than Japan's official targets.

Japan's official targets

The Japanese Ministry of Economy, Trade and Industry (METI) published the *Basic Hydrogen Strategy* in 2017, outlining Japan's hydrogen plans and revising the Japanese Government's *2014 Strategic Roadmap for Hydrogen and Fuel Cells*.[37] The *Basic Hydrogen Strategy* provides an 'action plan' for a hydrogen-based economy.

The strategy states

> Japan will develop commercial-scale supply chains by around 2030 to procure 300,000 tons of hydrogen annually.[38]

[36] Ibid.

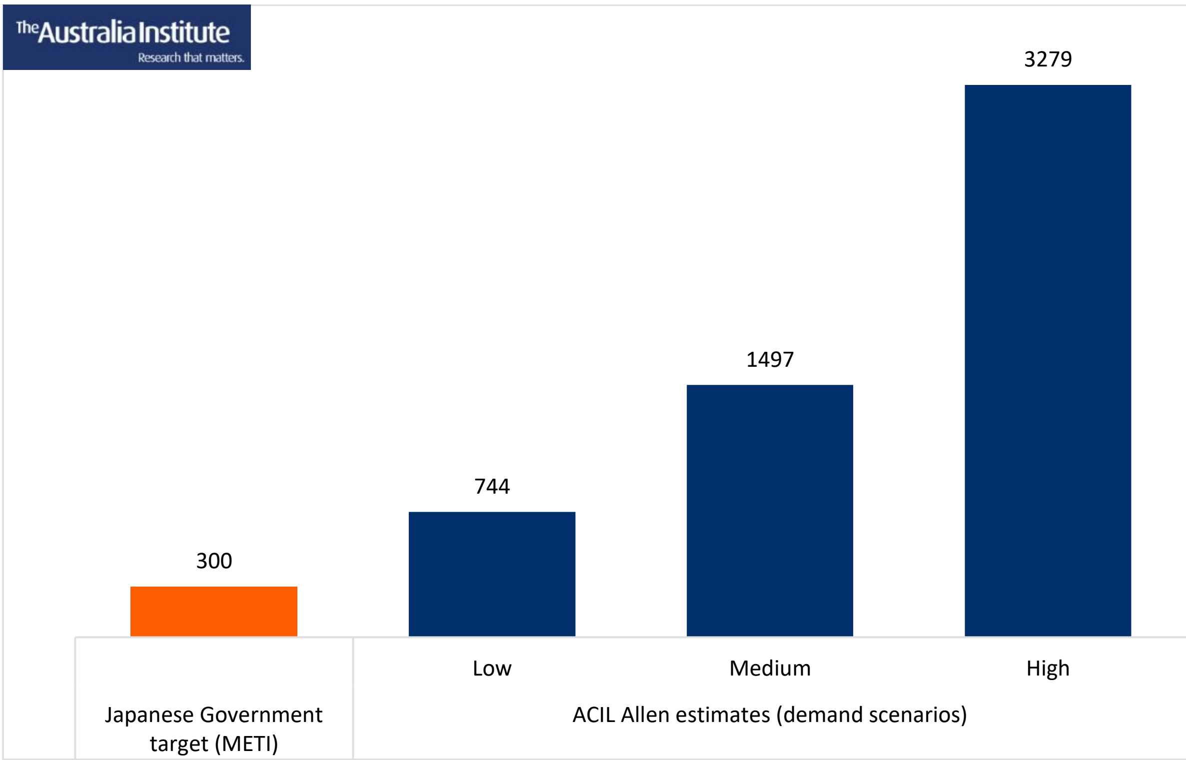
[37] Ministry of Economy Trade and Industry (2014) *Strategic Roadmap for Hydrogen and Fuel Cells.* https://www.meti.go.jp/english/press/2014/0624_04.html

[38] Ministry of Economy Trade and Industry (2017) *Basic Hydrogen Strategy*. https://www.meti.go.jp/english/press/2017/1226_003.html

This 300,000 tonne target is reiterated in METI's 2^{nd} *Strategic Roadmap for Hydrogen and Fuel Cells*, published in March 2019.[39]

This is far smaller than even ACIL Allen's lower demand estimate. ACIL Allen estimates Japan's total demand in 2030 at between 875,000 tonnes (low demand scenario) and 3,858,000 million tonnes (high demand scenario).[40] ACIL Allen estimates "more than 85 per cent of hydrogen demand in Japan will be supplied by imports".[41] On this basis, we can derive ACIL Allen estimates of Japanese import demand (see Figure 3).

Figure 3: Estimates of Japan's Hydrogen Import Demand for 2030 (kilotonnes)



Source: total demand and import share, ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p. 43, p. 104; METI (2017) *Basic Hydrogen Strategy*

The target is eleven times smaller than ACIL Allen's high demand scenario for Japan, and two-fiths the size in ACIL Allen's lowest demand scenario.

Discrepancy

ACIL Allen themselves acknowledge there is a discrepancy, but do not discuss or explain it. They note that "in some cases, ACIL Allen's modelling leads to projections that are higher

[39] Japanese METI (2019) *2nd Strategic Roadmap for Hydrogen and Fuel Cells*.

[40] ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p 43, (p 27 as marked). https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf

[41] Ibid. p. 104 (C-5 as marked)

than current government targets for future hydrogen demand".[42] Similarly, in a footnote, ACIL Allen note

> some [of] the projections for hydrogen demand in Japan under the scenarios are well above the current estimates outlined in the Japanese METI's Strategic Roadmap for Hydrogen and Fuel Cells. This merely represents an alternative view of what the future demand for hydrogen might be under different circumstances*.* They shouldnot be interpreted as a commenton the accuracyof any official figures for hydrogen demand*.*[43]

In fact, not some but all of the projections for hydrogen demand in Japan are about the official Japanese targets.

ACIL Allen state "Japan intends to import 900,000 tons of hydrogen by 2030",[44] citing a report by the IEA, but that report itself has no reference for the claim, which is contradicted by Japanese government documents.[45]

Setting out the modelling inputs, ACIL Allen gives a general disclaimer:

> It is important to note this report does not provide forecasts of potential hydrogen demand. Rather the hydrogen demand scenarios are designed to provide alternative views of what the future opportunities for hydrogen exports might be under different circumstances.[46]

ACIL Allen does not explain why these "alternative views" result in such "different scenarios" to the Japanese government targets.

This is surprising, given that Japanese policy intent is supposed to be as the basis for increased Japanese demand.

The section on modelling assumptions makes clear that hydrogen demand scenarios all include substantial new climate policy. The scenarios are based on the IEA's 'Sustainable Development Scenario' (SDS) and include "implicit carbon price ranges [of] between US$43–US$63/tonne CO2 in 2025 and US$125–US$140/tonne CO2 in 2040."[47] A footnote says "The existence of a carbon price in an importing country will be an important factor in the

[42] Ibid, p 10.
[43] Ibid, p iii.
[44] Ibid, p 78 (A-6 as marked)
[45] IEA (2017) Global Trends And Outlook For Hydrogen, p 15, http://ieahydrogen.org/pdfs/Global-Outlook-and-Trends-for-Hydrogen_Dec2017_WEB.aspx
[46] ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p ii.
[47] Ibid, p 20.

demand for low carbon hydrogen".[48] ACIL Allen did not run scenarios with lower carbon prices or less stringent policy.

Neither Japan nor Australia have a significant carbon price or other comparable policy.

None of the subsequent reports acknowledge the scale of Japanese carbon policy assumed by ACIL Allen. Many do not mention carbon pricing at all.

Japan's targeted hydrogen import market

ACIL Allen's estimate of Japanese hydrogen demand by 2030 is up to 11 times larger than official figures from the Japanese government. This has led to a vastly overstated value of hydrogen demand when compared to calculations based on the Japanese government demand figures.

The *Basic Hydrogen Strategy* and the *2^nd^ Strategic Roadmap* outline both a mass target of 300,000 tonnes by 2030, and a cost target of 30 yen per normal cubic metre (Nm^3) in 2030.[49]

It is somewhat unclear if the *Strategy* targets supply costs or wholesale prices, appearing at times to equate these, while at other times distinguishing them. However, assuming the eventual market for hydrogen operates with some degree of efficiency, prices will approach marginal costs needed to meet supply.

Combining the mass and cost target allows an estimation of the targeted cost of meeting Japan's hydrogen imports. These calculations are set out in full in Appendix B.

The Japanese government is targeting hydrogen imports in 2030 with a value of around A$1.3 billion.

Of course, Australia will not be supplying all of Japan's hydrogen needs. ACIL Allen estimate Australia would provide 21% of Japan's hydrogen demand.[50]

Applying the same market share to Japan's official targets, this would equate to an Australian export industry of around $273 million per year in 2030.

To put this in context, in 2018, Australian exports to Japan were worth $56.2 billion.[51]

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[48] Footnote 89, p 20.

[49] Ibid.

[50] ACIL Allen Consulting for ARENA (2018) *Opportunities for Australia from Hydrogen Exports*, p 41. https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf

[51] DFAT (2019) *Trade statistical pivot tables, Country and commodity pivot table 2006 to 2018,* https://dfat.gov.au/about-us/publications/Pages/trade-statistical-pivot-tables.aspx

Australia's share of the Japanese targets in 2030 is worth 0.5% of the value of total 2018 exports to Japan.

The value of Australia's share of the 2030 Japanese target hydrogen import value ($273m) is less than the value Australia's 2018 exports to Japan of

- cheese and curd ($497m),
- wheat ($350m), barley ($268m) and animal feed ($305m),
- and even machines, vehicles and computers ($313m), more widely thought of as imports from Japan to Australia.

Again, the official target is far smaller than ACIL Allen's estimates of the value of Japanese hydrogen demand for Australia in 2030. As noted above, this reaches $3.6 billion in the high demand scenario.[52]

SOUTH KOREA

The ACIL Allen estimates for demand from South Korea also far exceed national targets.

The South Korean government announced the *Hydrogen Economy Plan* in January 2019, outlining the country's plans for transitioning to hydrogen and fuel cells.[53]

The Plan targets total hydrogen supply in 2030 of 1.94 million tonnes per year, at a target price of 4,000 won/kg.

50% is targetted from domestic hydrogen production from fossil fuels, with the remaining 50% from a combination of hydrogen by-products from other industrial processes, domestic production from renewable energy sources, and overseas production.[54] By placing overseas production last in this list, the document suggests the government intends to minimise imports.

By comparison, ACIL Allen's report projects Korea's total demand in 2030 would be 0.37-1.56 million tonnes (low to high demand scenario).[55] However, ACIL Allen sees 85% of this being met by imports, compared with less than 50% in the South Korean Plan.

Assuming around 20% of Korea's targeted demand is met with imports, then Korea's imports will be 388,000 tonnes in 2030. This is a little higher than total imports in ACIL

[52] ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p 43. https://arena.gov.au/assets/2018/08/opportunities-for-australia-from-hydrogen-exports.pdf

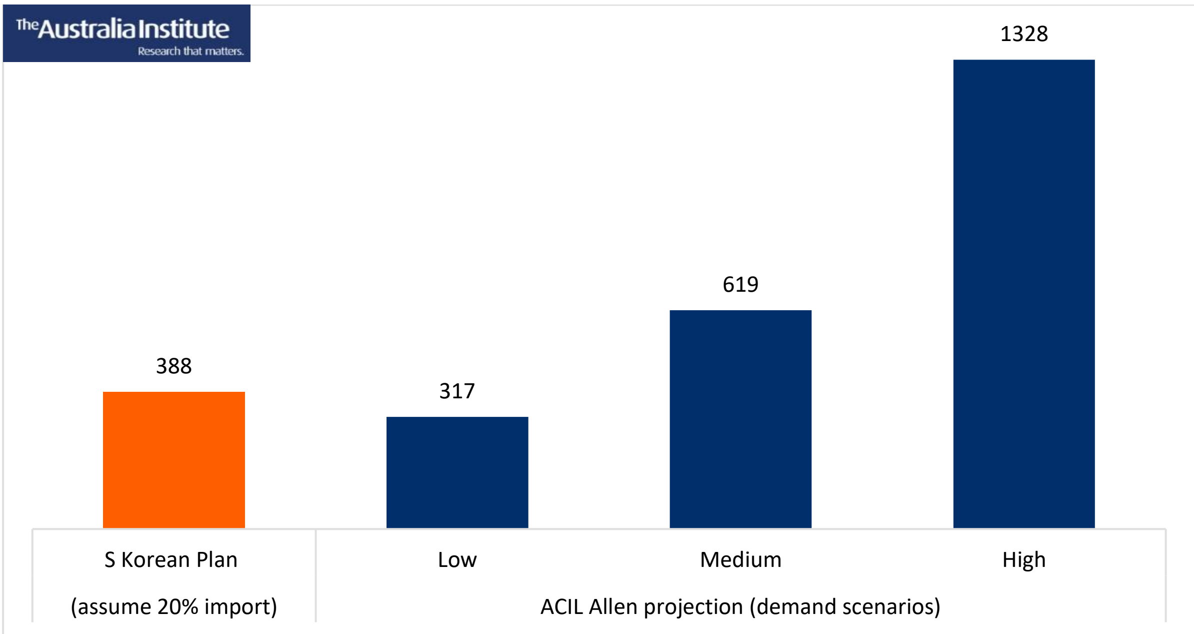
[53] Korean Ministry of Trade, Industry and Energy (2019) *Hydrogen economy plan*, p 13, www.motie.go.kr/motie/ne/presse/press2/bbs/bbsView.do?bbs_seq_n=161262&bbs_cd_n=81

[54] Ibid.

[55] ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p 43.

Allen's low demand scenario, but lower than in the medium or high demand scenarios, as shown in Figure 4 below.

Figure 4: Estimates of Japan's Hydrogen Import Demand for 2030 (kilotonnes)



Source: total demand and import share, ACIL Allen (2018) *Opportunities for Australia from Hydrogen Exports*, p 43, p 59, Korean Ministry of Trade, Industry & Energy (2019) *Hydrogen economy plan*, p 13,

Not all of these imports will come from Australia. The ACIL Allen report projects South Korea would import 11% of its demand from Australia, or 13% of imports.

This can be combined with the target price to estimate targeted import value (assuming 20% of demand met with imports, calculations in Appendix B).

Based on these calclations, the 2030 target value of South Korea hydrogen imports is $1.8 billion. A 13% Australian share of these imports of this is $234 million.

The South Korean Plan also only accounts for hydrogen from imports from 2030 onwards. Their 2018 analysis and 2022 projections only include hydrogen supply from domestic sources.

It is likely that Australia's hydrogen will constitute an even smaller portion of Korea's total hydrogen supply than Japan's.

‘The race is on’?

Claims ‘the race is on’ to capture a share of the emerging hydrogen export market are based on projections of import demand in key markets like Japan and Korea that vastly exceed targets in official government strategies. The official documents see demand rising more substantially beyond 2030.

A clearer view of this timeframe gives Australia more time to carefully plan and develop a sustainable hydrogen industry. It also makes clear which interests are served by an exaggerated demand for hydrogen in Japan and South Korea. The urgency provides a justification for investing in the development of a fossil fuel based hydrogen industry.

COSTS

Producing hydrogen using coal gasification or steam methane reforming methods is substantially lower than the cost of producing hydrogen through electrolysis. A short term rush is therefore most likely to pursue fossil fuel hydrogen.

The implications for greenhouse gas emissions are clear. As noted by the International energy Agency (IEA):

> **Hydrogen is almost entirely supplied from natural gas and coal today.** Hydrogen is already with us at industrial scale all around the world, but its production is responsible for annual CO2 emissions equivalent to those of Indonesia and the United Kingdom combined.[56]

However, it is widely expected that the cost of electrolysis with renewables will continue to fall and become increasingly competive over the decade, given appropriate policy support. The IEA notes

> **Producing hydrogen from low-carbon energy is costly at the moment.** IEA analysis finds that the cost of producing hydrogen from renewable electricity could fall 30% by 2030 as a result of declining costs of renewables and the scaling up of hydrogen production.[57]

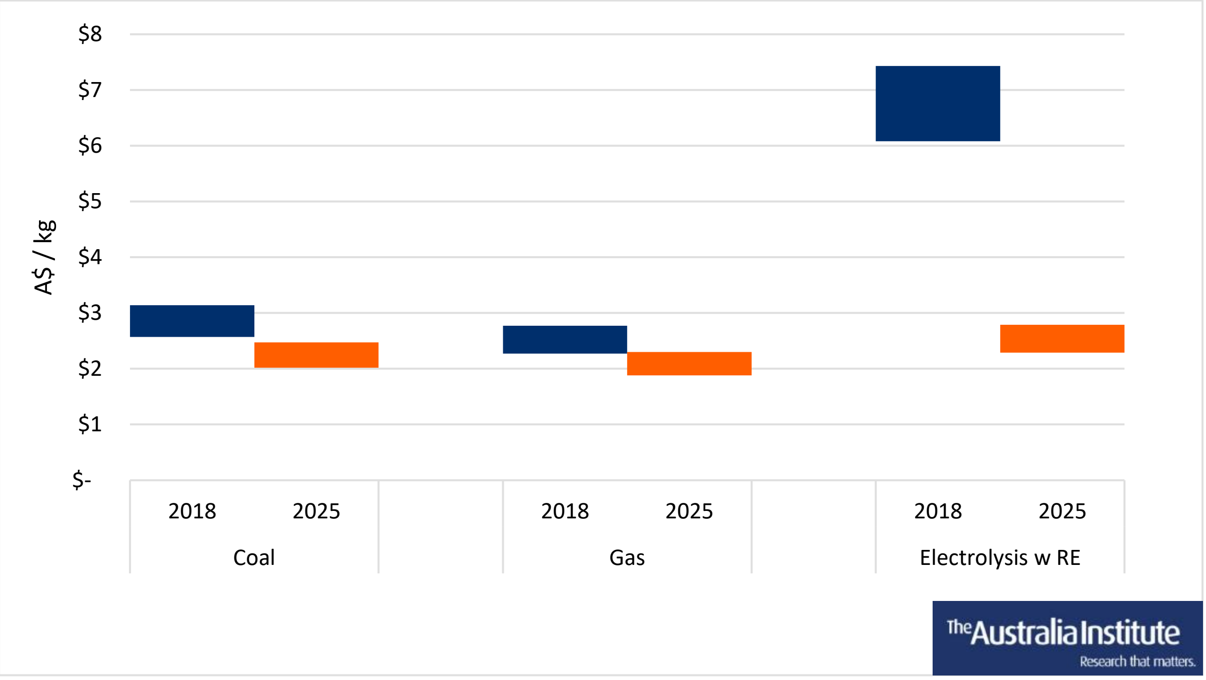
Analysis by Bloomberg New Energy Finance (BNEF) sees this as conservative, with potential for electrolysis with renewable energy to more than halve in cost by 2030. BNEF conclude

[56] IEA (2019) *The Future of Hydrogen* , p. 14
https://webstore.iea.org/download/direct/2803?fileName=The_Future_of_Hydrogen.pdf
[57] Ibid

Between now and 2030, demand would slowly grow from being basically non-existent today. Once costs come down after 2030, that demand would take off over the next couple decades[58]

The CSIRO *National Hydrogen Roadmap* estimates of the cost ranges in 2018 for different ways to produce hydrogen, in Australia, as well as 'best case' cost ranges for 2025. Note this is a estimate of potential cost reductions based on specific research, development and deployment (RD&D) interventions. CSIRO estimates that by 2025, with targeted investment into RD&D, electrolysis costs will be almost on par with coal gasification and steam methane reforming (see Figure 5).[59] The analysis does not extend further.

Figure 5. CSIRO: Levelised cost of hydrogen (LCOH) from coal, SMR and electrolysis



Source: CSIRO (2018) *National Hydrogen Roadmap*, from appendix. Electrolysis costs are Polymer Electrolyte Membrane (PEM), coal is black coal gasification with CCS, gas is steam methane reforming with CCS.

Note the CSIRO costs for fossil hydrogen include carbon capture and storage (CCS). The modelling includes a range of CCS costs of $7-$40/tCO2, based on a 2015 study by the CO2CRC.[60]

[58] BNEF (2019) *Hydrogen's Plunging Price Boosts Role as Climate Solution*, https://www.bloomberg.com/news/articles/2019-08-21/cost-of-hydrogen-from-renewables-to-plummet-next-decade-bnef

[59] Ibid.

[60] It is unclear where in the CO2CRC report the CSIRO cost assumptions are drawn from.

CSIRO state CCS faces major challenges from capital risk, long-term liability and RD&D requirements. Despite this, they state “once operating” the cost of CCS “is not a material driver of cost given that the CO2 capture component is an embedded part of hydrogen production.”[61]

CCS has a long history of over-promise and under-delivery, as discussed below. Yet even on these assumptions, CSIRO finds green hydrogen could be competitive by 2025.

GOVERNMENT SUPPORT

Some governments and agencies have supported renewable hydrogen projects, while some are supporting fossil hydrogen projects. In the absence of credible limits on emissions, or stringent regulatory requirements, promoting hydrogen exports risks promoting fossil hydrogen without CCS, increasing Australian emissions.

The Commonwealth Government states it has provided over $100 million to hydrogen projects. Around half of this was for the Hydrogen Energy Supply Chain (HESC) brown hydrogen project in the Latrobe Valley, receiving $50 million the Commonwealth and another $50 million from the Victorian government.

Led by Japan’s Kawasaki Heavy Industries, the HESC trial will turn 160 tonnes of brown coal into 3 tonnes of hydrogen through coal gasification, which will then beliquified and shipped to Japan in 2020.[62] If the project is successful, the consortia propose to build a commercial facility at the Loy Yang power station in the Latrobe Valley for exporting hydrogen, albeit not until the 2030s. The pilot does not include CCS. The consortia and Victorian government say this is intended for later developments.

Other Commonwealth funding to hydroden includes $22 million from the Australian Renewable Energy Agency (ARENA) for 16 hydrogen projects, all of which are based on green hydrogen..[63]

Before the 2019 election, the Labor Opposition’s *Hydrogen Plan* proposed redirecting some RD&D funding to renewable-powered electrolysis. It also proposed new financial and regulatory support for hydrogen infrastructure, which could support fossil hydrogen.[64]

CO2CRC (2015) *Australian Power Generation Technology Report* https://web.archive.org/web/20160329012730/http://www.co2crc.com.au/dls/Reports/LCOE_Report_final_web.pdf

[61] Ibid. p56

[62] Hydrogen Energy Supply Chain (2019) *Latrobe Valley.* https://hydrogenenergysupplychain.com/latrobe-valley/

[63] ARENA (2019) *Hydrogen* https://arena.gov.au/renewable-energy/hydrogen/

[64] Australian Labor Party (2019) *Labor's Plan For Hydrogen*. https://web.archive.org/web/20190518084758/https://www.alp.org.au/policies/labors-plan-for-hydrogen/

The Queensland Government has a $15 million Hydrogen Industry Development Fund. Surrounding documentation emphasises the Fund's support to renewable hydrogen, however the Fund is open to "hydrogen from non-renewable sources".[65] The terms of reference say non-renewable hydrogen projects must contribute to meeting the state's emissions reduction and renewable energ targets; it is unclear how this will apply in project selection.

The Queensland government publicly supports the Gladstone Energy and Ammonia project.[66] This $1 billion project includes a coal gasification plant among other facilities to produce ammonia, synthetic natural gas and electrical power from 1.5 million tonnes of coal per year.[67] While the aim of the project is not to produce hydrogen for export, it utilises technology that may be used for this purpose. More broadly, it is indicative of willingness to continue expand fossil fuel industries, despite international commitments and expectations, and rising emissions.

The South Australian Government *Action Plan* focuses explicitly and exclusively on hydrogen generated from renewable energy. The government has provided a range of grants and loans to RD&D projects across the green hydrogen supply chain, including the

- Port Lincoln Hydrogen and Ammonia Supply Chain Demonstrator,
- the Neoen Hydrogen Superhub at Crystal Brook Energy Park and
- the University of South Australia's Renewable Energy Testbed.[68]

Australia has the resource and skill capacity to become a major exporter of hydrogen in the future using only renewable energy sources. However, the current direction of Australia's hydrogen industry development and the lack of federal climate policy allows coal and natural gas to position to establish themselves as key players in the hydrogen economy.

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[65] Queensland Government (2019) *Hydrogen Industry Development Fund* https://www.dsdmip.qld.gov.au/resources/guideline/hydrogen-fund-applicant-guidelines.pdf

[66] Queensland Government (2019) *$1 billion Gladstone Energy and Ammonia project one step closer*. 5 March. http://statements.qld.gov.au/Statement/2019/3/5/1-billion-gladstone-energy-and-ammonia-project-one-step-closer

[67] Queensland Government (2019) *Gladstone Energy and Ammonia project.* http://www.dsdmip.qld.gov.au/assessments-and-approvals/gladstone-energy-and-ammonia-project.html

[68] Government of South Australia (2019) *South Australia's Hydrogen Action Plan.* http://www.renewablessa.sa.gov.au/content/uploads/2019/09/south-australias-hydrogen-action-plan-online.pdf

Problems with fossil-first

A rush to develop a hydrogen export industry is likely to promote hydrogen from fossil fuels. This poses a number of economic and environmental risks.

THE DISMAL TRACK RECORD OF CCS

Carbon capture and storage (CCS) is used to justify carbon dioxide-emitting hydrogen production methods. CCS refers to a range of technologies used to capture carbon dioxide emissions from a facility, transport them to a storage location and store them securely, traditionally underground.[69]

It is claimed that CCS will enable hydrogen produced from coal and natural gas to be "low-emission". Importantly, it will not be zero emissions.

There is a long history in Australia and globally of fossil fuel affiliates promoting CCS. The Minerals Council of Australia (MCA) claims that CCS is "the most viable technology to reduce emissions from the existing fossil fuel power generation fleet", which is needed to to provide energy that has "24/7 availability with reduced emissions and is affordable, safe, secure and reliable" and."[70]

However, CCS projects have failed to live up to promises, both domestically and globally.

Global CCS deployment has failed by a very large margin to meet nearly all institutional targets set for it. This includes targets set by IEA in its core scenarios, by the Global CCS Institute, by the International Energy Council, by the Council of the European Union and the Intergovernmental Panel on Climate Change.[71]

CCS technology in Australia has failed to meet targets set in 2009 by the Australian Coal Association's (now a part of the MCA). ACA claimed full-scale CCS projects running by 2015. The South West Hub project and the CarbonNet project, funded under the government-funded CCS Flagships program, had an initial target year of 2015, but are unlikely to be completed by the second target year of 2020.[72]

[69] Carbon Capture and Storage Association (2019) *What is CCS?* http://www.ccsassociation.org/what-is-ccs/

[70] Minerals Council of Australia (2018) *Clean Energy Finance Corporation Amendment Bill 2017*.

[71] Browne (2018) *Sunk costs: Carbon capture and storage will miss every target set for it*, http://www.tai.org.au/content/sunk-costs-carbon-capture-and-storage-will-miss-every-target-set-it

[72] Puyvelde (2016) *What about Carbon Capture and Storage?* https://www.energynetworks.com.au/news/energy-insider/what-about-carbon-capture-and-storage#_ftn1

Chevron's Gorgon CCS project in Western Australia is an example of the ramifications of relying on flawed CCS technology. The project houses the only large-scale CCS facility in Australia.[73] Despite Chevron's estimate in 2015, that CCS technology would store between 5.5 and 7.8 million tonnes of carbon dioxide in the first two years of production, CCS only became operational in August 2018, and there is still no sign of how much it is sequestering or when it will meet its target.[74]

Despite the WA Government's approval for Gorgon requiring 80% of emissions to be stored, penalties have not been imposed for Gorgon's failure to sequester emissions during the first two years of operation.[75] Gorgon also faces no penalties under the federal 'safeguard mechanism', as their emissions limit is set based on the assumption that CCS does not work. In addition, the Commonwealth has indemnified the WA government against the long term risk of the CCS failing.[76]

The Gorgon project was the single largest source of Australia's emissions in the year to March 2018. Its failure to operate accounted for more than half of Australia's total greenhouse gas emissions for that year.[77]

The dismal track record of CCS is particularly alarming considering the amount of public money spent on developing CCS infrastructure. The Australian government has granted over $3.5 billion in funding CCS projects, with $1.3 billion distributed, and little to show for the investment.[78]

The support for CCS technology has, however, achieved another goal. It has promoted the political possibility of "clean coal", or more broadly, the possibility that the booming fossil fuel industry in Australia could be compatible with a carbon-constrained future. Indeed, Australian coal exports have remained strong over the last few years and natural gas exports have expanded greatly.

The absence of a successful, large-scale CCS facility in Australia casts doubt on the claim that CCS is the answer to a low-emission future hydrogen industry. However, there is no mention of this in Australia's pro-hydrogen literature.

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[73] Global CCS Institute (2019) *Facilities Database,* https://www.globalccsinstitute.com/resources/ccs-image-library/

[74] Milne (2017) *Carbon hiccup for Chevron with 5 million-tonne greenhouse gas problem at Gorgon LNG plant*. https://thewest.com.au/business/oil-gas/carbon-hiccup-for-chevron-with-5-million-tonne-greenhouse-gas-problem-at-gorgon-lng-plant-ng-b88694565z

[75] Ibid.

[76] Clean Energy Regulator (2019) *Safeguard baselines table*. http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/Safeguard-baselines-table#Safeguard-baselines-table

[77] Swann (2018) *Gorgon-tuan Problem*, http://www.tai.org.au/content/gorgon-tuan-problem

[78] Browne and Swann (2017) *Money for nothing,* http://www.tai.org.au/content/money-nothing

CSIRO *National Hydrogen Roadmap* states "capture of CO_2, typically the most expensive CCS component, is embedded in the hydrogen extraction and purification process".[79] While it uses 'mature' cost figures for CCS, it also notes the need to "successfully demonstrate" CCS with fossil hydrogen at scale.[80] The report fails to note the broader policy and technology failures of CCS to date, including the large scale of existing global fossil hydrogen production without CCS.

In two short paragraphs the report says CCS needs "policy and regulation", including "a legislative requirement or long term pricing signal would be needed to incentivise investment" and a "regulatory framework for CCS" to "support the long term liability associated with storage of CO_2".[81] These are preconditions for CCS as such and they remain lacking, despite decades of promises and fossil fuel industry advocacy. Indeed, those urging CCS in political debates rarely acknowledge the policy frameworks required. The treatement in the CSIRO *Roadmap* itself is cursory. Ironically, it refers to Gorgon LNG as a positive example of CCS, but does not refer to the failures at the facility, nor the lack of penalties, nor the government indemnity.

Approvals and funding for fossil hydrogen are likely to be more effective in increasing fossil fuel consumption and Australia's emissions than deploying the CCS on which the support was premised.

In short, 'clean' fossil hydrogen is at great risk of becoming the new 'clean coal'.

CLEAN CONSUMPTION, DIRTY PRODUCTION

Another justification being used to promote Australia's hydrogen industry is the promise of transitioning to green hydrogen once the costs of production are comparable to fossil fuel hydrogen. This is in turn supported by the idea that Australia's key importers are interested in low-emission hydrogen, provide an incentive for Australia to move towards zero or low emissions hydrogen production.

As Australia's key future import market, Japan's interest in "clean" hydrogen is repeatedly emphasised. The *Hydrogen for Australia's Future* paper states Japan has

[79] CSIRO (2018) *National Hydrogen Roadmap*, p. 20, https://www.csiro.au/en/Do-business/Futures/Reports/Hydrogen-Roadmap

[80] Ibid p. 82

[81] Ibid p. 24

> identified imported hydrogen as a zero-emission fuel that can be used in power generation, mobility, heating and industrial processes… [Japan will] import hydrogen from low-emission sources at the right price.[82]

Western Australia's Regional Development Minister said

> many of our traditional gas markets – Japan, Korea – have adopted strategies that put hydrogen and ultimately renewable hydrogen at the core of their energy future.[83]

Dr Daniel Roberts from the CSIRO Hydrogen Energy Systems Future Science Platform says

> for the first time, we've got a real strong global pull for imported, low-carbon hydrogen. Japan has got this central to their energy strategy.[84]

However, Japan's interest in hydrogen lies in its potential role in securing and diversifying energy supply while reducing *domestic* emissions. The focus on hydrogen as a zero-emission fuel relates to the domestic economy, as a way to reduce emissions in the power generation, transportation, and industrial sectors.[85]

Japan's *Basic Hydrogen Strategy* notes "CCS and renewable energy technologies can be used to make hydrogen a completely-CO2-free energy source," and says these are "promising approaches… under which Japan will develop international integrated hydrogen supply chains".[86] Yet there is no goal or target year at which imports be 'completely-CO2-free'. Indeed the preceeding Japanese 2014 *Roadmap*, which forms the basis of the *Strategy* document includes aims for "a CO2-free hydrogen supply system on a total basis" only at "Phase 3… by around 2040".[87] In the 2019 2nd *Action Plan* the target of "hydrogen supply cost 30/Nm3 around 2030" is directly linked to "the success of Japan–Australia Brown Coal-to -Hydrogen project", while under "Hydrogen Utilization" there is a goal of "Utilizing CO2-free hydrogen in the future".[88]

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[82] Hydrogen Strategy Group (2018) *Hydrogen for Australia's Future*, p 9, https://www.chiefscientist.gov.au/wp-content/uploads/HydrogenCOAGWhitePaper_WEB.pdf

[83] Sonali (2018) *Rocket fuel: Australia targets hydrogen as next big energy export,* https://www.cnbc.com/2018/11/13/reuters-america-rocket-fuel-australia-targets-hydrogen-as-next-big-energy-export.html

[84] Mazengarb (2019) *Renewable hydrogen getting cheaper, Australian could lead global market,* https://reneweconomy.com.au/renewable-hydrogen-getting-cheaper-australia-could-lead-global-market-95168/

[85] Japanese METI (2017) *Basic Hydrogen Strategy,* https://www.meti.go.jp/english/press/2017/1226_003.html

[86] Ibid

[87] Cited in Ibid, p. 6

[88] Japanese METI (2019) *The Strategic Road Map for Hydrogen and Fuel Cells* p.3, p.4. https://www.meti.go.jp/english/press/2019/pdf/0312_002a.pdf

LOCKING-IN HIGH EMISSIONS

Another argument for fossil hydrogen is that establishing the industry on this basis will assist with a later transition to renewable-fueled electrolysis.

However, such an approach risks “lock in” of high carbon infrastructure that would promote high-emitting production measures and undermine the green hydrogen opportunity.

Hydrogen made from fossil fuel methods and electrolysis utilise different chemical processes, requiring different physical infrastructure.

Transportation infrastructure might be shared between the different hydrogen production methods, however, production would likely be stationed in different areas, depending on the type of production measures used.

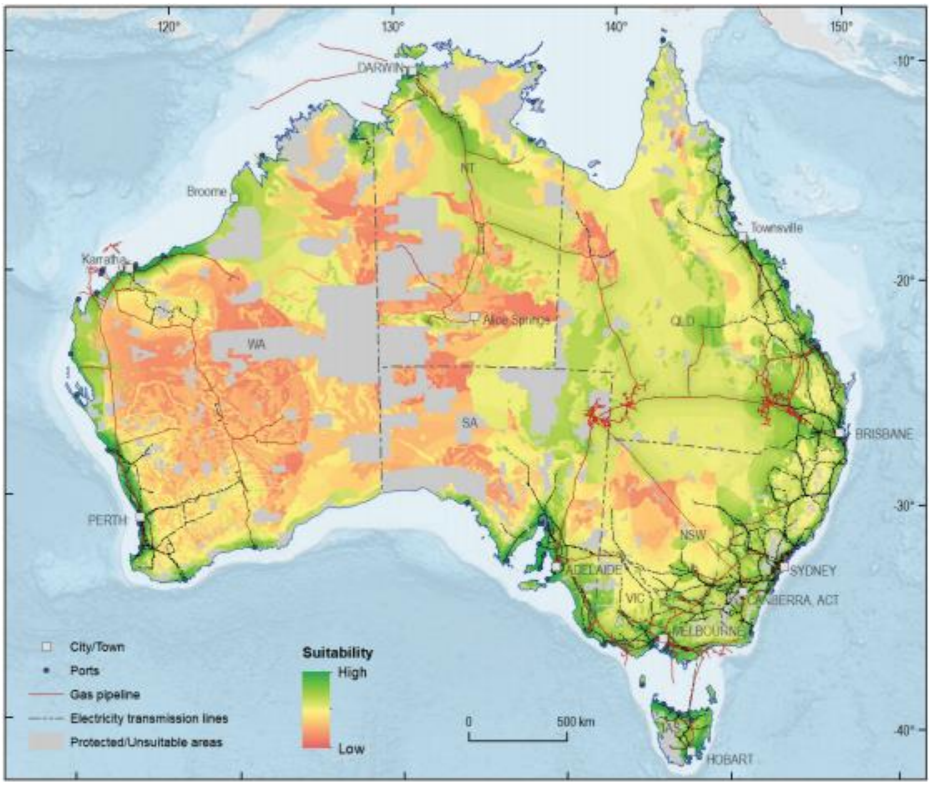
Geoscience Australia finds that areas suitable for future hydrogen production differs substantially based on whether the hydrogen is derived from electrolysis with renewables, or fossil fuels coupled with CCS.[89] For green hydrogen, an area’s suitability for hydrogen production is determined by renewable energy potential and the availability of water, while fossil hydrogen relies on proximity to the fossil fuel resources, water and carbon storage sites. This is shown in Figure 6 and 7 below.

Figure 6 shows potential green hydrogen production using both inland and coastal water supplies. Highly suitable areas are mostly located on the coast due to proximity to seawater, existing ports, existing gas pipeline easements and electricity power networks.

Figure 7 shows potential fossil hydrogen production. Highly suitable areas for production are mainly located inland in NSW and Queensland, with some suitable areas on the WA coast and Victorian coast.

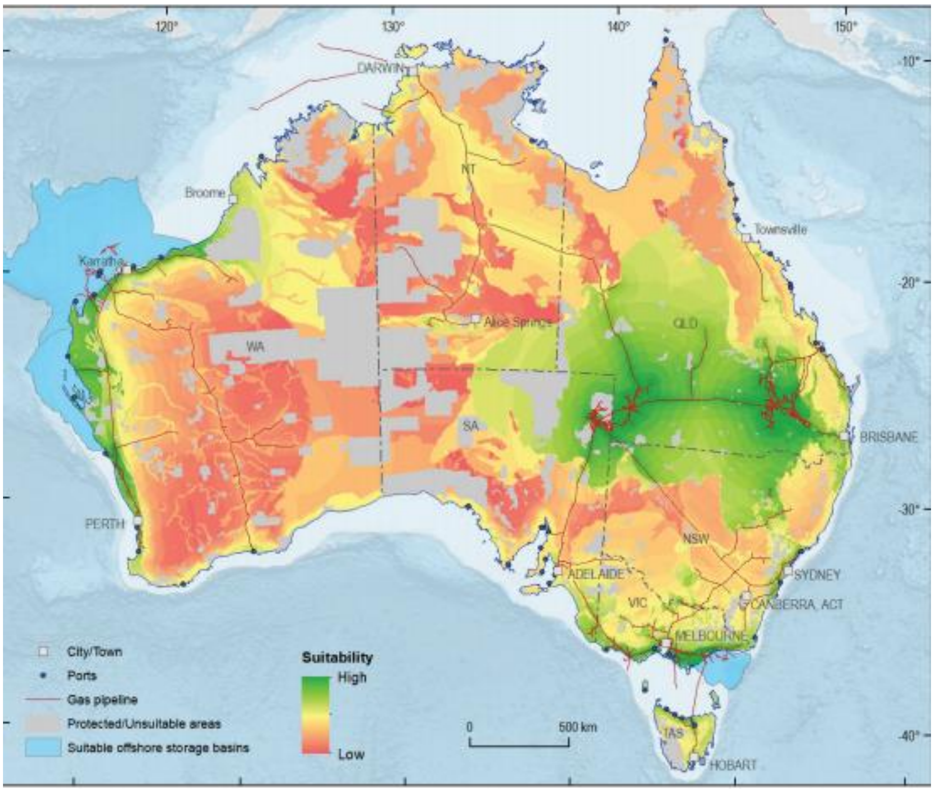
[89] Geoscience Australia (2019) *Prospective Hydrogen Production Regions Of Australia.* https://corpdata.s3-ap-southeast-2.amazonaws.com/130930/Rec2019_015.pdf

Figure 6: Green hydrogen production areas



Source: Geoscience Australia (2019) *Prospective Hydrogen Production Regions Of Australia* p. 10

Figure 7: Fossil hydrogen production areas



Source: Geoscience Australia (2019) *Prospective Hydrogen Production Regions Of Australia* p. 12

Absent a policy framework to focus attention on renewable-fuelled elecrtrolysis, it is likely that these methods will still be used to provide hydrogen exports even in the likelihood that electrolysis becomes cost competitive in 5 to 10 years.

Once hydrogen production plants are built, their capital is sunk and production from these plants may continue at below prices than would justify their construction, in turn undermining the market for green hydrogen. This is especially the case if infrastructure or production is subsidised.

Problems of carbon “lock in” through new fossl fuel infrastructure are well understood. Establishing a high emitting fossil hydrogen industry in areas not suitable for transition to green hydrogen increases the economic and political costs of following through on Australia’s commitments to reduce emissions in the future.

Conclusion

Hydrogen is currently being used to redress Australia's fossil fuel industries, much in the same way as the promise of "clean coal" using CCS technology.

The emphasis of Australia's hydrogen strategy is on securing Australia's spot in the global hydrogen market as quickly as possible, at the expense of long-term sustainability.

Australian pro-hydrogen rhetoric can largely be traced back to a single report from ACIL Allen that vastly overstates Japanese and South Korean hydrogen import demand over the next decade. This has created a false sense of urgency, used to justify the fast-tracking of Australia's hydrogen economy.

Hydrogen industries in Japan and South Korea are still in infancy, and their import demand for the next 10 years will be low. Official import demand figures show Australia has the time necessary to invest in research, development and deployment so that a low-cost, sustainable green hydrogen industry can be developed.

Public funds should not be used to produce coal- and gas-based hydrogen but should instead be directed to lowering the cost of renewable hydrogen production.

Appendix A

COAL GASIFICATION

The process of coal gasification begins by combusting coal (C) with oxygen (O_2), thus creating heat and carbon dioxide (CO_2):[90]

$$C + O_2 \rightarrow CO_2.$$

This carbon dioxide is combined with more coal and gasified to create carbon monoxide (CO):

$$C + CO_2 \rightarrow 2CO.$$

Steam (H_2O) is then added to the carbon monoxide to produce the final result of carbon dioxide and hydrogen:

$$CO + H_2O \rightarrow CO_2 + H_2.$$

STEAM METHANE REFORMING

Under high-temperature and pressurised conditions, methane (CH_4) is combined with steam to produce carbon monoxide and hydrogen:[91]

$$CH_4 + H_2O \rightarrow CO + 3H_2.$$

The resulting carbon monoxide is combined with steam again to produce carbon dioxide and more hydrogen:

$$CO + H_2O \rightarrow CO_2 + H_2.$$

[90] United States Office of Energy Efficiency and Renewable Energy (2019) *Hydrogen Production: Coal Gasification,* https://www.energy.gov/eere/fuelcells/hydrogen-production-coal-gasification

[91] United States Office of Energy Efficiency and Renewable Energy (2019) *Hydrogen Production: Natural Gas Reforming*. https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming

ELECTROLYSIS

This method utilises renewable energy to create electricity, which is then used to split water into hydrogen and oxygen atoms.[92] Specifically, at the anode, water is separated into oxygen and hydrogen atoms:

$$2H_2O \rightarrow O_2 + 4H^+ + 4e^-.$$

The positively charged hydrogen atoms move through the electrolyte and react with the electrons (e^-) at the cathode to form hydrogen gas:

$$4H^+ + 4e^- \rightarrow 2H_2.$$

[92] United States Office of Energy Efficiency and Renewable Energy (2019) *Hydrogen Production: Electrolysis.* https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis

Appendix B

JAPAN

Using Japan's official import targets, we can calculate the approximate size of its potential import market in 2030. As stated in both the *Basic Hydrogen Strategy* and the 2^{nd} Strategic Roadmap for Hydrogen and Fuel Cells, Japan intends to import hydrogen at 30 yen per normal cubic metre (Nm^3) in 2030.[93] While there is no universal definition of a normal cubic metre, it is generally considered to be a cubic metre at 0 degrees Celsius and at atmospheric pressure (approximately 1.013 bar).[94] Under these conditions, an ideal gas would occupy

$$1 \text{ [mol]} = 22.4 \text{ [L]}.$$

Since 1 litre is the equivalent to 1 cubic decimetre, or 1/1000 cubic metre, it follows that

$$1 \text{ [mol]} = 0.0224 \text{ [Nm}^3\text{]}.$$

We can rewrite this to show how many gas molecules (in moles) are in 1 normal cubic metre:

$$1 \text{ [Nm}^3\text{]} = 1 \text{ [mol]} / 0.0224$$

$$1 \text{ [Nm}^3\text{]} = 44.643 \text{ [mol]}.$$

Hydrogen gas (H_2), which consists of two hydrogen atoms, weighs approximately 2.016 g/mol.[95] Assuming that hydrogen is an ideal gas, the weight of hydrogen per normal cubic metre is

$$2.016 \text{ [g/mol]} * 44.643 \text{ [mol/Nm}^3\text{]} = 90.000 \text{ [g/Nm}^3\text{]}.$$

To reiterate, Japan expressed their intention to procure 300,000 tonnes, or 300 million kilograms of hydrogen per year by 2030, at 30 yen/Nm^3.[96] At 90 g/Nm^3, or 0.09 kg/Nm^3, the approximate total cost of this target is

$$300{,}000{,}000 \text{ [kg]} / 0.09 \text{ [kg/Nm}^3\text{]} * 30 \text{ [yen/Nm}^3\text{]} = 100{,}000{,}000{,}000 \text{ [yen]}.$$

At an exchange rate of 0.013 Australian dollars per yen, 100 billion yen is equivalent to

[93] Ibid.

[94] Tokyo Keiso (2019) *Technology FAQ.* https://www.tokyokeiso.co.jp/techinfo/faq/f-0005/index.html

[95] Lenntech (2019) *Chemical elements listed by atomic mass*. https://www.lenntech.com/periodic/mass/atomic-mass.htm

[96] Ministry of Economy Trade and Industry (2017) *Basic Hydrogen Strategy*,

100,000,000,000 [JPY] * 0.013 = 1,300,000,000 [AUD].

SOUTH KOREA

Assuming 20% import share of South Korean supply, 2030 imports are

1,940,000,000 [kg] * 0.20 = 388,000,000 [kg],

and at the target price of 4,000 won/kg, the value of hydrogen exports would be

388,000,000 [kg] * 4000 [won/kg] = 1,552,000,000,000 [won].

Assuming a conversion rate of 0.0012 Australian dollars per won, this value becomes

1,552,000,000,000 [KRW] * 0.0012 = 1,862,400,000 [AUD].