Hydrogen Energy: Its role in Australia's Future Economy

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Australian policymakers have been aware of hydrogen as a potential source of lower-emissions energy since at least the early 2000s. At that time, the energy policy framework was predicated on a technology-neutral basis. At some point, to successfully compete in the race for low-emissions technology, Australia needs to convert that historically neutral framework to one that picks a specific technology, or a suite of them. What are the possibilities for hydrogen, and what does society need to do to embrace a new technology?

Energy change and the outlook for hydrogen

Hydrogen is an important future industry for Australia and a key focus of an institute researching the outlook for energy change from a position of technology and policy neutrality.

In this context it is useful to talk about hydrogen as an energy "vector". It is not a primary energy source, but a product of other processes which can – and at present, typically do – produce significant greenhouse gas emissions. For zero-emissions results, coal gasification and natural gas reforming, two common methods of producing hydrogen, require carbon abatement. This is expensive and not entirely effective. Alternatively, emissions-free hydrogen can be produced via electrolysis using renewable electricity – an approach being explored for its huge potential in Australia.

International Energy Agency (IEA) data published in 2019 shows a tiny fraction of current hydrogen production using processes that eliminate or minimise emissions.

If we are to move to a hydrogen economy, one in which we use hydrogen in everything from transport and heating to chemical feedstock and grid electricity, this will need to change. Carbon-free manufacture of hydrogen must play a dramatically increased part in the future hydrogen value chain.

The institute's researchers are exploring new industries to enable Australia to retain its status as an export powerhouse in the Asia-Pacific region while reducing greenhouse emissions. Key export possibilities include renewables-based electricity; liquified hydrogen; green aluminum; and green steel (refined domestically, using renewable energy). In pursuing this, purely with renewable electricity and using hydrogen to help refine the steel, Australia has potential to produce the equivalent of 23 times its current electricity generation.

What are the barriers? "With hydrogen in particular, price is all-important." A hydrogen price of $2 or less per kilogram is one of the "stretch goals" of Australia's national technology road map; this is where foreign markets are pitching future demand. The cost of producing hydrogen using electrolysers must fall considerably; this relies on reductions in the cost of electrolysers, and of renewable electricity. In good news, Australian wind and solar power are increasingly competitively priced. "We are moving down a path where the production of renewable hydrogen by electrolysis is going to become cost-competitive in the coming decade."

Can hydrogen replace gas?

Gas is expected to play an important role as a "peaking fuel" in the transition to renewables, to provide back-up and consistency ("it will be a part of the system for a while yet") yet there is potential in the future for hydrogen to replace it.

Internationally, the IEA forecasts that demand for gas will continue to rise to 2030 in Asia but in established markets, easy gains from coal-to-gas switching will dissipate in the mid-2020s due to "environmental considerations, increasing competition from renewables, efficiency gains, growing electrification of end-use demand and improving prospects for alternative low-carbon gases, including hydrogen."

Much, but not all of this is applicable to Australia.

In looking to replace gas, network distributors need to know whether hydrogen can fill the role of gas in pipelines and not create stranded assets. Australia's abundant renewable energy sources mean "it makes no sense to turn renewables in the hydrogen and then back to electricity when you could just produce electricity with renewables in the first place." At household level, electric heat pumps are more likely replacements for gas than hydrogen. Hydrogen may, however, have a partial role to play in high-temperature processes, in industrial feedstock. It is also a potential successor to gas in long-range transport.

For these reasons, exports appear likely to dominate Australia's future domestic hydrogen consumption.

How much land will we need?
If Australia were to produce 6000 TWh per year of renewable electricity – 23 times more electricity than it produces now – how much land is needed? Around 130,000 square kilometres – an area comparable to that used for forestry but with a significantly higher GDP-to-land ratio. The land most suitable would be in Australia's north and west, away from populated areas and in many cases, in areas that are under Indigenous land use agreements. This may offer opportunities for those communities to become involved in the new industries.

Is Australia likely to rely on hydrogen as a seasonal storage medium? Probably not to the same extent as markets in the northern hemisphere, where there is significantly more seasonal variation in energy demand than in Australia.

Building a hydrogen highway
From an infrastructure perspective, how can authorities prepare for deployment of zero-emission and autonomous vehicles?

Modelling of a scenario in which all vehicles in Victoria other than rail – light vehicles, commercial vehicles, buses – were powered by hydrogen by 2046 suggests the transport sector alone would demand 800,000 tonnes of hydrogen per year. The conclusion reached was that in Victoria, hydrogen is best suited to use in heavy vehicles, with the conversion of freight vehicles to act as the catalyst for industrial-scale hydrogen generation.

Additionally, hydrogen trucks create much less noise than diesel trucks, a potentially significant factor in securing social licence for infrastructure projects (such as a second container port for Melbourne) expected to generate increased night traffic.

Despite interest in hydrogen-powered light vehicles, they are subject to cost and efficiency issues relative to battery vehicles, and broader constraints around converting petrol station networks to hydrogen. Safety is a concern and hydrogen refuelling facilities need a large footprint that poses challenges in urban settings.

The 2046 modelling assumed electrolysis would be the preferred hydrogen production process, adding 64,000 gigawatt hours to annual Victorian demand for electricity from renewables. The extra electricity required to produce the hydrogen would be around one-and-a-half times the total forecast consumption of electricity from all Victorian households and businesses in 2046. The investment required for generation, distribution and transmission infrastructure would be about $15 billion.

The world sees Australia as a big player in terms of potential for hydrogen export. The overseas experience suggests motivations for government investment in hydrogen technology vary. Japan, South Korea and Germany, with their substantial automobile industries, have industrial demand; Japan also seeks energy diversification from a strategy point of view; South Korea and California are looking to reduce emissions.

Domestically, heavy vehicles such as trucks and buses offer the most effective transport opportunities. Blending hydrogen into the existing gas network is another way forward. It can bring hydrogen into households' daily lives, aiding community acceptance. It will also help create demand internally and bring down the price of electrolysers, factors that will help us reach a price of $2 per kilogram.

Australia's Hydrogen Industry Mission

CSIRO has identified six major challenges to Australia's quality of life and established 'missions' to address them – collaborative R&D initiatives and programs. One of these, aiming to help address the challenge of sustainable energy and resources, is Australia's Hydrogen Industry Mission.

The mission supports the building of a clean, competitive hydrogen industry for Australia. It is developing a national knowledge centre – one that can track industry projects and R&D activity, provide connections to expert advice, and offer a window into Australia for trading and investment. It is also working on feasibility studies and strategy; demonstration projects; and ways of enabling science and technology through identifying and overcoming barriers.

In this context, working with partners is critical to the mission's success. "You'll have some people who are the first movers who are willing to invest, initiate some of these projects…or undertake the first feasibility study to see what the next steps might be. And then you'll have others who are saying 'well, we're interested and we've heard all the hype around hydrogen, but we really don't know where to start'. What it means for us and our industry, and what we hope to achieve through creating this framework, is to give people a way to start that engagement."

Partner projects under way include a hydrogen refuelling station and demonstration facility at Clayton in Victoria, and having some vehicles travel to Geelong (a distance of about 100 kilometres). The mission seeks partners for further activities of this kind, to test different hydrogen production, use and storage technologies, and to make hydrogen technology more visible, helping increase community awareness and acceptance.

The mission is also exploring remote area power systems, looking at five scenarios where it could be applicable. The next stage would be to see other partners willing to come on board to have a demonstration. "At the end of the day, if there isn't sufficient interest for that multi-sector investment to take it forward… (that means) it's not ready yet. That changes how we might proceed with certain projects."

What are the sector-by-sector trajectories for likely hydrogen uptake? Export is forecast to lead, with rapidly increasing commercial uptake after 2030; natural gas substitution will be gradual, with switching to 100 per cent hydrogen taking place over three decades; uptake for light and heavy vehicles is expected to pick up in the 2030s. Energy storage and grid support, and industrial processes are expected to take longer, with more activity towards 2050.

Work underpinning these forecasts was qualitative. The mission is interested in conducting a more numbers-focused study, and seeks feedback about what industry, government and the broader research community need to help to scale up Australia's emerging hydrogen industry.

From another perspective – that of a high-tech manufacturer who expects to need millions of cubic metres of hydrogen for processing titanium – CSIRO is insufficiently funded by government and should not have to engage in entrepreneurial activity to raise money. Concern was expressed that CSIRO had formed a relationship with an Australian corporate that gives it "control of all IP being generated by the CSIRO relative to hydrogen".

This is "not entirely prescriptive across the board", from the mission's point of view; it is "already engaging and exploring project partnerships" with others. "Some things will be restricted, those being the ones that we've agreed already with (the corporate partner) as would be the case if we were to enter partnership with anyone else…but we're still open to seeing how we can partner together on new developments."

Bringing the research-commerce gap

Australia continues to contend with a seemingly perennial gap between research success and commercial outcomes. In the experience of a long-time government policy leader, the clean energy space has been an exception thanks in large part to the government's Clean Energy Finance Corporation. Set up with capital of about $10 billion, it has been able to take minority stakes in companies broadly in that area, provided a return above hurdle rate is assured.

"I think this is another area where we need something akin to the Clean Energy Finance Corporation, to partner a flow of investments from government with a flow of investments from the private sector."

This is more than a way of getting things done – it also keeps IP in Australian hands, rather than, "as has so often been the case, having a struggling startup try to scale up and either sell up overseas, or send the profit overseas, or basically fold and go away."

"So, we've got a problem as a country in thinking through what the new challenges we face – and this is one of them – mean in terms of how are we going to go about getting useful economic benefits for Australia itself. Because the way we've been doing it and the way the Commonwealth…has handled it is just not working, and we need a debate about a new system."

Sharing opportunities

On a global scale, hundreds of billions of dollars are going to be invested in this sector. Assuming Australia catches this wave, we need to think about how we all – including Indigenous people – share in its benefits. How do we structure our

economy, institutions and policy so we don't lock up this wealth for a small number of people?

From an energy change specialist's point of view, enormous export opportunities on the horizon mean we have to be clever about the way in which there is returned benefit to the nation. One path may be through co-investment in some of the industries we envision, such as green steel. Although it is unlikely China will start to make all its steel in Australia's north-west, there is potential for more iron ore processing before exporting to China for high value-added manufacturing. This would mean massive investment in new hydrogen-based production – what co-investment models can we explore for the benefit of Australia? We will need to "do what we've never really done before" and capture the enormous opportunity we have not only in minerals but in renewables.

Framing the numbers

In getting technology to market, an international investor in the energy sector makes the point that it is important to consider how numbers are presented.

"For instance, if it comes down to cost for renewable energy there should be a difference made by cost per unit, but it should be also hinted at whether you have this unit for eight hours a day, or only when the wind blows, or if you have it for 24 hours, so that always comes with a different price tag – which is a very important input for the application that you then need.

"Then, if you approach with a technology that provides energy for 24 hours, you meet people who have these tables in mind which just have the cost per unit and they say, 'oh, it's much more expensive'. Then you start to have to explain that it's not for one unit but for 24-hour energy supply.

"I'm looking for things that can actually beat the market for fossil fuel energy sources…so far, from this presentation, I can't see how you get to this competitive price." One example is a company that can provide renewable energy by heat for 24 hours, teaming with an industry technology partner to provide desalinated water on a large scale, more cheaply than if it were operated by gas. "I'm always trying to find things that are actually working without subsidies."

In response, an Australian research organisation seeking industry partners noted that investors' need for detailed costings is recognised, and that relevant economic modelling should become public by year's end. It was also argued that – counter to criticism of government funding levels earlier in the discussion – "there is a positive in not being fully funded" because the imperative to find external partners ensures the projects being pursued have valid commercial applications.

A second response, from an infrastructure perspective, was that the investment requirements around an orderly transition from gas to hydrogen domestically differ from those of export customers in countries such as Japan or Germany. "These are two different markets and that calls for two different investment approaches."

Will customers pay a green premium?
Future customers are going to want to know what they're buying in terms of carbon content and, from an energy change specialist's point of view, this means introducing certification. Research is under way into systems for certifying hydrogen throughout the supply chain. Along with Australia's edge in renewables, certification can deliver a competitive advantage with international customers "who have told us they only want green hydrogen."

From the perspective of an agency looking to promote trade and investment, it is critical to understand customer needs as well as the likelihood that some international demand will be driven by large corporates looking to decarbonise. "Clearly a range of large commercials around the world are looking at effectively introducing carbon pricing into the way they procure energy…when you think about the customer mix and the price point, you have to factor in that customer needs might include being able to pay a little bit more for green hydrogen than they would for a more traditional energy source."

In summary: Some key questions
From the public policy perspective, we remain in a technology race. As we move towards commercialisation, the time has come to move away from the traditional technology-neutral approach. "You have to back some technologies that come to the fore, and I do think that we're in that process."

The question of whether the industries involved are new, or replacing others, and how these come together is important. Land issues, at a very practical level, become important, particularly in view of likely locations and Australia's First Nations people. Infrastructure issues: can we use existing infrastructure or is there a replacement requirement? Economic questions include how to reach $2 per kilogram pricing. There are further questions around community acceptance. Finally: when returns start coming through, what should they be and who gets them?

When big technology changes loom there is a question of tipping points and the role of government in creating the environment in which they take place. Australia has "a way to go" before we really understand how the elements will come together to bring us to that tipping point. When it comes, the opportunities will be immense.

Postscript: Setting investment frameworks – a cautionary case study
An investor points to a situation in which a new technology that should readily find finance has struck obstacles. The technology uses renewable energy to desalinate water in a non-polluting process that produces pure salt as a byproduct, instead of the traditional method in which saline solution becomes waste. It is clean, it is cheaper than using fossil-fuel energy and it does not need subsidies. "You think, if you get to that point that it's easy to build the first plant, to get this technology established, but it's not the case at all."

“Some of the technologies just need a couple of $10 million to make it work and to be commercialised, which is the equivalent of a couple of wind turbines, basically, and it's very, very hard to get this first plant up and running…we should be mindful to set up the correct investment framework because there are, I think, some frameworks that benefit technologies that are almost outdated. But investors will get the return, the banks are going to finance it because there, are for instance, guaranteed offtake prices by governments.

This can make it hard for technologies that are genuinely ready to go to market because investors seeking to invest in green technologies will choose the ones where they have a guaranteed return. “This is something to be mindful of.”

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