# Australian Hydrogen Research Conference 2023

## *The Fish That Got Away or the Fish in the Bucket?*

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## Time to shift balance between production and use

Some of you might have seen a movie called Field of Dreams. An Iowa corn farmer, played by Kevin Costner, has a dream and hears a voice repeatedly telling him, "If you build it, he will come. If you build it, he will come." Haunted by the dream, the farmer builds a baseball diamond in the middle of his corn fields.

After he finishes, his long dead hero, baseball player Shoeless Joe Jackson and a whole team of other dead baseball players step out from between the corn stalks to start playing baseball. Soon after, hundreds of spectators arrive to watch the game. Kevin Costner smiles, his character's financial future is assured.

That's a movie.

In the real world, it's not so easy. When it comes to hydrogen, gone are the days where anybody should be thinking, "If we make it, they will buy it."

The focus needs to be on demand, not production.

Actually, I take that back. Both are true. We need a supply and demand *equation*, with an expression on both sides of the equals sign.

As I survey progress in Australia since the adoption of the National Hydrogen Strategy, I see an enormous number of projects in planning, but most of them are focussed on production rather than utilisation.

## What's happening internationally?

The production-focussed pathway faces the basic problem that the competition is intense and the commodity is identical wherever it comes from. It could be blue hydrogen and ammonia from Qatar in the Middle East, or from Texas in the United States. It could be green hydrogen from Chile in South America, from Mauritania in Africa, or from Quebec in Canada.

Internationally, there is a frenzy of activity.

Most prominent recently are two pieces of legislation from the United States. Their genesis was a clear commitment by Joe Biden during his 2020 presidential campaign to commit America to net zero by 2050. He promised to spend $2 trillion. That, and all the dollar amounts I will mention today are in U.S. dollars.

He also promised the biggest investment into manufacturing since World War II. Now, as President, he is delivering on both those campaign promises.

The first step was the 2021 Bipartisan Infrastructure Bill. Among many other expenditures, the Bill included approximately $100 billion for electric vehicles and the electricity grid's adjustment to clean energy.

In climate policy terms, that was dwarfed by the strangely named Inflation Reduction Act passed in August last year. It is a massive climate policy bill, designed to help America get a jump start on its ambition to reduce emissions by 50% in 2030 from its 2005 baseline.

Under the Inflation Reduction Act, the United States is committed to providing tax credits and other incentives for a swathe of green technologies. The expenditure is open ended. It is estimated to be a minimum of $400 billion and quite likely $800 billion over the next ten years. It will attract two to three times that in private sector funding. Roughly, that is between 1 trillion and 3 trillion dollars. Trillion, not billion.

The Inflation Reduction Act is all carrot, no stick. That is, investments in solar, wind, hydrogen, batteries, electric vehicles and other zero emissions technologies will be encouraged by subsidies for capital expenditure and production costs. There are no carbon taxes; there is no emissions trading scheme.

The Act is not just climate policy. It is also industrial policy. It is full of made-in-America provisions. For example, tax credits are linked to employing unionised labour, and training apprentices. The $7,500 federal tax credit for consumers who purchase an electric car is only paid if the car is assembled in America and at least half the battery is made in America. For wind and solar projects to earn tax credits, half of their manufactured components must be made in America. Projects will receive bigger subsidies if using American iron and steel.

There are carve outs for Canada and Mexico, and for countries that have a free trade agreement with America, of which Australia, fortunately, is one.

The Inflation Reduction Act focuses on outcomes, not specific technologies. Thus, it incentivises battery production, but does not specify whether they should be lithium ion, zinc bromine or any other chemistry. It incentivises hydrogen production that meets an emissions intensity threshold, but does not specify how the hydrogen should be produced.

The investments in hydrogen are substantial.

The Bipartisan Infrastructure Bill put aside $9.5 billion for clean hydrogen hubs. "Clean" refers to low emissions hydrogen, not renewable hydrogen. To avoid ambiguity, the Bill specifically says that at least one hub must produce blue hydrogen from natural gas with carbon capture and storage, one must produce pink hydrogen from nuclear electricity, and one must produce green hydrogen from renewables.

The Bill also includes $3.5 billion for CCS projects and $3.5 billion for Direct Air Capture projects.

Adding to that, the Inflation Reduction Act increases the tax credit for CCS to $85 per tonne sequestered, unless the CCS is being used with Direct Air Capture in which case it jumps to a whopping $180 per tonne sequestered.

Those are significant numbers, but what has everybody excited are the production incentives.

The tax credit for hydrogen production is up to $3 per kg of hydrogen produced. Given that some manufacturers in the United States are already selling hydrogen for less than $5 per kg, they will be able to sell their hydrogen today for less than the holy grail of $2 per kg.

But entitlement is not for all. There is a quality test. Using yet to be decided measurement methodologies, the emissions associated with the production will have to be less than 0.6 kg of carbon dioxide equivalent per kg of hydrogen produced. That is tough. It is less than a tenth of the emissions from burning natural gas for the same amount of energy.[i]

Other countries are responding to the American broadside.

Canada quickly announced plans for its own investment tax credit of up to 40% for clean hydrogen. It's worth noting that Canadian hydrogen producers have a second advantage in that they have access to copious amounts of hydroelectricity, which means that they can run their electrolysers at close to 100% capacity factor.

The European Union last month announced the Green Deal Industrial Plan for the Net Zero Age. Details are sketchy, but it will support key sectors such as hydrogen, CCS, electric vehicles and building energy efficiency. At a minimum, it includes two hydrogen specific policies. The first is 315 million euros for hydrogen automotive propulsion systems. The second is an auction to pay a premium for each kg of green hydrogen produced. It is specifically intended to have a similar impact to the production tax credit in the United States Inflation Reduction Act. The pilot program has a budget of 800 million euros.

Last month, India announced a Green Hydrogen mission aiming to produce 5 million tonnes annually by 2030, which is equivalent to India's current grey hydrogen consumption. The policy includes direct financial incentives for electrolyser manufacture and green hydrogen production.

China is a huge user of grey hydrogen, about a third of global consumption. As the policy brief by Zhou, Gosens and Jotzo from the ANU reported last year, the top level commitments are not dramatic. It is expected that by 2025, the annual output of renewable hydrogen in China will be approaching 200,000 tonnes. This is small compared with Europe's target of 10 million tonnes of onshore production in 2030 and 10 million tonnes of imported hydrogen. But that is comparing targets with targets, and different dates. China has a history of outperforming.

It is already the largest market for fuel cell trucks and buses in the world. In other clean technologies, China's performance is incredible. China leads the world on solar panel manufacturing and deployment. They lead the world on wind generation, batteries, electric cars and heat pumps. A punter would be prepared to bet that they will lead the world on hydrogen, too. They do this with a mixture of mandates, targets, subsidies, support from local governments and the central government, their broader industrial policies, and their innovative companies.

## What are the integrated opportunities?

We can't match these international subsidies on an absolute dollar basis. So, we have to be smart. Instead of aiming to be a commodity supplier of hydrogen, we should aim to be an added-value supplier.

Added value for the sake of it is futile. It has to be added value because we have something to add.

Here are a few to think about. In two categories.

The first category is decarbonised products. These are products in which hydrogen is an essential feedstock. This category includes green iron, green alumina and green fertiliser.

A quick disclaimer. I am using the adjective green, which means renewable, not to rule out blue hydrogen but because renewable hydrogen is the most likely starting place.

The underlying rationale for decarbonised products is a *use-it-where-you-make-it* philosophy. The intention is to eliminate the cost of shipping and to take advantage of other locally available feedstocks.

Green iron is a perfect example. Today, we ship 250,000 tonnes of iron ore in a very simple iron ore carrier, while at the same time we ship about 200,000 tonnes of metallurgical coal in a very simple coal carrier. The ships themselves are inexpensive and the total shipping costs are a small percentage of the value of the goods.

The coal and iron ore are processed in blast furnaces in the destination countries, and huge amounts of carbon dioxide are released to the atmosphere.

To make green iron, the metallurgical coal is eliminated. It is replaced with a combination of renewable electricity and hydrogen, and the blast furnace is replaced with a hydrogen direct reduction shaft.

If we look at the equivalent export model, we see that shipping hydrogen economically is difficult. There is confidence everywhere I look that even without subsidies, renewable hydrogen production will eventually achieve the incredibly low price of $1 per kg. But shipping is difficult and it is not forecast to fall below $2 per kg. So the landed cost of hydrogen in another country will be three times or more than the price at the production facility.

The alternative is to establish integrated green iron production facilities in Australia, right where the hydrogen is made. These facilities will be dramatically different to the blast furnaces used for traditional iron production. Instead of a conventional factory site, the integrated green iron facilities will use hundreds of square kilometres of land for gigawatt scale solar and wind generation. These will feed electricity to a hydrogen production plant, and the hydrogen direct reduction plant housed in a relatively modest building. The last piece of the picture is the railway line for the iron ore coming in and the end product going out.

What value have we added? To the locally available iron ore we have added our land, sunshine and wind to produce renewable electricity required to run the green iron factory. Even more renewable electricity combined with water produces the needed hydrogen. The end product is hot briquetted iron. Small pellets of nearly pure iron that can be shipped at low cost to the traditional steelmaking countries where they will continue to make the steel.

The second category is energy molecules – clean hydrogen and green liquid fuels, both for the decarbonisation of our own economy, and to continue our role as an energy exporter to Asia.

As I have said, exporting pure hydrogen is important but it is competing in a level playing field. Other energy molecules such as hydrogen treated biofuels and synthetic jet fuel are more sophisticated and might build on Australia's comparative advantages.

Take synthetic jet fuel. We all know that aviation fuel for long distance flights is regarded as a hard to abate sector. There is considerable interest in using renewable jet fuel made from hydrogen treated biomass feedstock, where the process is much more efficient and the end product far superior than conventional biofuels.

Even more exciting is the ultimate: synthetic jet fuel. All that you need to make jet fuel, also known as kerosene, are two elements – carbon and hydrogen. The carbon can be extracted from the air using direct air removal and the hydrogen extracted from water. Air and water, two of the four fundamental elements identified by the Ancient Greek philosophers – air, water, fire and earth. The end product is normally referred to as synthetic jet fuel, but I prefer to call it solar kerosene. It can be shipped to international customers at much lower cost than the feedstocks.

What value have we added? The economics of synthetic jet fuel are terrible unless the inputs are cheap. Once again, ultra low cost solar and perhaps wind electricity are required, at vast scale, to power the direct air capture equipment and the electrolysers. It needs water; it needs open spaces. We have all of that, and we have experience with financing and managing complex resource projects.

## The need for an updated National Hydrogen Strategy

As always, progress happens faster than can be expected although slower than can be imagined. Opportunities give way to other technologies, needs emerge that were underplayed, and competitors come out of the woodwork.

For these reasons, although it is only four years old, it is perhaps time for the national hydrogen strategy to be refreshed.

I cannot foreshadow what a refreshed hydrogen strategy might look like, but it would have to address the following.

First, the *use-it-where-you-make-it* philosophy should be given a starring role, to produce decarbonised products for export. So that we can add value and produce a more complex export product that will compete on multiple grounds, not just price.

Second, funding. Which is better, generic funding for infrastructure and multiple users in the form of hydrogen hubs, or outcomes funding for specific decarbonised products such as green iron and green alumina? The type of funding would also have to be considered. Auctions for hydrogen trade, production linked incentives, absolute grants, contingent grants, contracts for difference? There are many models being rolled out in many countries.

Third, mandates. One way to build up volume and thereby drive costs down is to mandate use. The only practical sector to do that in Australia is ammonia production, for which we use about 425,000 tonnes of hydrogen. For the sake of an example, imagine that this were gradually replaced with renewable hydrogen. This domestic use would ultimately require nearly 7,000 MW of electrolysis.[ii] Not a huge challenge for electricity, but it would be big for electrolysis. By the end of 2021, the cumulative installed capacity of electrolysers worldwide was only 513 megawatts. Besides reducing our domestic carbon dioxide emissions by about 4 million tonnes per year, the learning curve benefits would be huge. Of course, mandates without support could stifle industry competitiveness in the years prior to the elimination of the green premium, so the mandates would have to be supported by some kind of funding program.

Fourth, domestic supply in the existing reticulated gas distribution pipeline system. In the last four years, progress has been slow. The refreshed strategy could take another look at the role of hydrogen for building heating, cooking and hot water.

Fifth, specialised transport and associated logistics. The obvious niches include long distance trucking and interstate trains, 24/7 vehicle use such as forklifts in a distribution centre and mine site haul trucks. If fuel cell passenger cars are to compete, it will be for drivers who do not have off street parking. But that will only be possible if there are refuelling stations in Australia. Today, I don't think that there are more than three or four. Hydrogen vehicle availability is also growing very slowly. It is not just a chicken and egg situation, it is a question of dramatically reducing the price of refuelling stations and lowering their real estate footprint. Onsite electrolysers are too costly, so the refreshed strategy should give consideration to the means of distributing hydrogen from dedicated production facilities to where it is needed, be it a refuelling station or a hospital backup system. Whether the distribution system is swap and go compressed gas containers, or liquid hydrogen tankers, is immaterial as long as the refuelling stations or backup systems are low cost and small footprint.

Sixth, certification. This is covered in the existing strategy but there is growing awareness of the importance. One of the key requirements for robust international trade is for buyers to know what they are buying. However, with hydrogen, there is not a forensic science lab anywhere in the world that can work out what the carbon dioxide by-product emissions were during production. Instead, rigorous certification schemes will be central to ensuring market transparency. Australia has been at the forefront of global certification efforts to date. Internationally, the Australian Department of Climate Change, Energy, the Environment and Water has been working as a member of the International Partnership for Hydrogen in the Economy, known as the IPHE, to develop globally consistent carbon accounting methods for the clean hydrogen supply chain, including derivative chemical products that will be used to transport clean hydrogen, such as ammonia. The Clean Energy Regulator is trialling the IPHE's methods with industry, and developing a Guarantee of Origin certification scheme, based on the IPHE's work.

The Guarantee of Origin scheme will not decree to countries or companies the acceptable value of emissions. Instead, each country will retain responsibility for deciding its own acceptability threshold. The important thing is that the certification scheme be robust and give great confidence to decision makers that the emissions intensity was accurately tabulated and tracked. Similar certification schemes will be required for other commodities such as ammonia, steel and aluminium. Market transparency helps to build an efficient global supply chain. Transparency not only covers price and sources, but also red lines for unacceptable practices such as human rights abuses. The refreshed national hydrogen strategy would ideally ensure a leadership role for Australia in establishing the global certification schemes.

Seventh, research. As Australia increasingly participates in the global decarbonisation agenda and to the extent that hydrogen plays a key role, we will need to invest in research. Research to make lab scale dreams work at commercial scale. Research to understand the economic underpinnings of new technologies. Research to ensure that we understand community expectations so that the industry will be able to earn social licence. Research to support workforce training at our universities and registered training organisations.

## Research Alignment

Where do the research opportunities lie? Here are a few to think about as you share your ideas during the next three days of the Conference.

Blue hydrogen will be developed in the United States, in the gulf countries and other places. Given that, it is important to think about how it can meet an emissions intensity target as stringent as the 0.6 kg per kg threshold in the United States Inflation Reduction Act. Achieving this emissions intensity will require very low upstream leakage, and greenfield steam methane reforming or autothermal reforming plants that use renewable electricity for their process heat and process pressure, and capture the carbon dioxide emissions stream at high capture rates.

On the renewables front, efficiency is important. Great progress has been made on electrolysis. For example, the electrolysers and basic balance of plant from an Australian company named Hysata, where I note that I am an adviser, operate at 95% of the theoretical limit.

However, fuel cells that use hydrogen are miles away from this kind of efficiency, mostly producing electrical energy at 50% of the chemical energy in the hydrogen consumed. Incremental improvements in fuel cell efficiency would be highly valued.

Are there efficiency gains that can be eked out of the compressors, or the liquefaction units?

Storage is still a challenge; it needs more attention. How can the costs be dramatically reduced and the convenience improved?

Perhaps your research should align with some of the current opportunities. In recent times we are starting to see some big wins for hydrogen. Last year, under its first contract to supply hydrogen trains, French train manufacturer Alstom started delivering 14 hydrogen powered passenger trains to completely replace diesel powered trains in Lower Saxony, Germany. These emissions-free trains have a range of more than 1,000 kilometres and can carry 300 passengers. Alstom also has contracts to supply many dozens of these trains for Frankfurt, Lombardy in Italy and four different regions in France.

In August 2022, global e-commerce company Amazon announced that it signed a contract to purchase over 10,000 tonnes per year of green hydrogen from hydrogen mobility company Plug Power. Amazon says this will be enough to operate 30,000 forklifts or 800 heavy-duty trucks used in long-haul transportation. Amazon already uses more than 15,000 fuel cell forklifts.

We are in the early days of a clean energy revolution, and the investments across the world are huge, so a sense of urgency in all that we do, including the hydrogen sector, is important. Think big. Ask yourself, can you align your research to any of the hydrogen moonshots?

Can your research add value to Australian industry? Our requirements for electrolysers will be huge. We would need about 600,000 MW just to replace LNG exports, let alone all the other things I have talked about and have been documented in an analysis by Ken Baldwin and colleagues at the ANU. How can they be designed to be more reliable, smaller and lower cost?

It's early days, so early that there is no existing market, but the opportunities in using direct air capture of carbon dioxide combined with hydrogen production to make synthetic jet fuel, in the long term, might be huge. The price today for synthetic jet fuel is so high that nobody is yet willing to pay for it, but the direct air capture stage will come down in price through mass production of capture units. Are there ways to reduce the cost of the carbon capture medium or make it more efficient?

It's more than technology. We need other research – to understand international markets, international financing and economics, regulatory hurdles and domestic community expectations.

## Conclusion

Just like we need to focus on producing integrated products, we need an integrated approach to development. We need to use science and engineering to improve every aspect of everything we do. Otherwise, our products will not be competitive and investors will not invest.

Remember, there is a continuum. Money funds research to produce knowledge. Engineering innovates that knowledge into products that benefit society and generate money that can be used to fund the next round of research.

The title of this talk was suggested by our Conference Co-Chair, Ken Baldwin: *The Fish That Got Away or the Fish in the Bucket?*

If I can paraphrase Kevin Costner in Field of Dreams, the fish that got away is the simple idea that if we make hydrogen, they will buy it.

The fish in the bucket, is integrated supply and demand, with a constant focus on improving efficiency, lowering costs and ensuring quality.

To fill the bucket with fish, we will need strategy and money, engineering and science.

May the Force be with you,

Thank you!

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[i] Emissions from natural gas compared with hydrogen. Calculated from methane being 2.75 kg CO2 per kg of CH4 burned; difference in LHV in MJ of hydrogen compared with methane is 120/50 = 2.4; Thus, must burn 2.4 kg of methane for same energy of combustion as hydrogen, so 2.75 kg x 2.4 yields 6.6 kg emissions.
[ii] For example, 425,000 tonnes at 30% capacity factor. 1 MW Hysata at 41.5 kWh/kg efficiency = 578 kg per day = 211 tonnes per year. Thus 425,000 tonnes requires 2,013 MW electrolysis and renewable electricity. Divide by 0.3 for capacity factor, thus 6,711 GW. Round it up to 7,000 GW.