Response ID ANON-J1PE-Z6Y8-H

Submitted to **National Hydrogen Strategy Issues Papers**
Submitted on **2019-07-28 20:00:48**

Privacy agreement and your details

1 Do you agree to the Privacy Collection Statement?

Yes, I agree and would like to make a non-confidential submission

2 What is your name?

Name:
Professor Ken Baldwin

3 What is your email address?

Email:
kenneth.baldwin@anu.edu.au

4 Are you an individual or organisation?

Organisation

If organisation, please specify:
The Energy Change Institute, Australian National University

5 What is your location?

Australian Capital Territory

6 Did you make a submission to our Request for Information in March?

Yes:
Yes

Issue 1: Hydrogen at scale

1 What scale is needed to achieve scale efficiencies and overcome cost barriers?

What scale is needed to achieve scale efficiencies and overcome cost barriers?:

2 What approaches could most effectively leverage existing infrastructure, share risks and benefits and overcome scale-up development issues?

What approaches could most effectively leverage existing infrastructure, share risks and benefits and overcome scale-up development issues?:
Required infrastructure depends on end use:

The optimal technologies for producing, transporting and storing hydrogen depend on end use. Hydrogen for export or industrial uses benefit from being produced at large scale, and stored and transported as ammonia or another liquid carrier. For domestic transport and heating it may be better to generate hydrogen at or near the point of use and store it as compressed gas.

Further technoeconomic analysis of the hydrogen value chain for different uses is needed to understand the optimum pathways, and to gauge how much of the infrastructure will be shared between pathways.

Hydrogen for export could benefit from existing ports and leverage existing infrastructure for ammonia export. More analysis is needed to ensure that leveraging existing natural gas reserves and infrastructure will provide a pathway for clean and competitive Australia hydrogen, without locking the industry into a reliance on largely unproven CCS technologies.

The production method should determine the location of the infrastructure:

The two different commercial hydrogen production methods – SMR and electrolysis – represent different investment pathways for a hydrogen export industry. SMR needs to be located near natural gas source and near suitable CCS sequestration sites. Electrolysis can be run off the grid or using dedicated renewables. It is also scalable. Whilst it can be intermittent, it is more economical when run at a high capacity factor.

3 What arrangements should be put in place to prepare for and help manage expected transitional issues as they occur, including with respect to transitioning and upskilling the workforce? How do we ensure the availability of a skilled and mobile construction workforce and other resources to support scale-up as needed?

What arrangements should be put in place to prepare for and help manage expected transitional issues as they occur, including with respect to transitioning and upskilling the workforce? How do we ensure the availability of a skilled and mobile construction workforce and other resources to support scale-up as needed?:
Generation of zero-carbon hydrogen with electrolysis and renewables at scale requires a large deployment of renewables, roughly doubling our current NEM generation over the next 2-3 decades. This would require us to greatly expand the number of skilled renewable installers. Training needs include specialist electricians and engineers with a background in heavy industrial maintenance, and manufacturing. Electrolysis installation and hydrogen storage and transport, require similar skills to those currently employed in the chemical/and or LPG industry, but with specialist skills in handling hydrogen.

4 What lessons can be learned from the experience of scaling up supply chains in other industries?

What lessons can be learned from the experience of scaling up supply chains in other industries?:
The development of the Liquified Natural Gas (LNG) industry in Australia offers an obvious point of comparison as it was driven substantially by export demand from the Asia Pacific region, centred on Japan. Before lessons can be learned it is important to take into account differences in end-uses in export markets, and the degree of integration of hydrogen, compared with natural gas, in domestic energy markets.

In addition, Australia has had success in training high level PV renewables experts for the Asia Pacific in the solar photovoltaic industry, and is well placed to play a similar role in the clean hydrogen industry.

5 When should the various activities needed to prepare for hydrogen industry scale-up be completed by? What measures and incentives are needed to achieve?

When should the various activities needed to prepare for hydrogen industry scale-up be completed by? What measures and incentives are needed to achieve:

Issue 2: Attracting hydrogen investment

1 What changes to existing government support and additional measures are needed to:

What changes to existing government support and additional measures are needed rnment support and additional measures are needed :
Contributing authors (in alphabetical order): Dr Emma Aisbett, Associate Professor Paul Burke, David Gourlay, Professor Warwick McKibbin

The OECD Recommendation of the Council on Regulatory Policy and Governance emphasises the importance of adopting a welfare-economic approach. This approach suggests that government interventions be targeted at addressing market imperfections that would otherwise lead to sub-optimal outcomes. If governments choose to undertake measures that do not follow from this approach, there should be a clear distributional justification for these measures.

The relevant market failures for a nascent hydrogen industry in Australia include:

imperfect information on behalf of potential creditors leading to potential credit constraint – particularly for new and risky investments,

carbon emissions (avoided) and other environmental externalities,

public goods such as basic research,

static and dynamic economies of scale (i.e. learning by doing), both at firm and industry level, and

network externalities (such as those caused by the need for compatibility of technical standards along supply chains).

Targeted responses to the first market failure include the provision of finance and risk reduction measures such as some of those mentioned already in the issue paper.

A key domestic policy reform to address the second market failure and encourage the use of zero-carbon hydrogen domestically is the introduction of a carbon price or, alternatively, regulatory restrictions on emissions.

Efficient responses to the latter two issues require more focus on Australia’s potential role in global value chains. Australia is a small market. Australian consumers will ultimately have relatively little say in the technologies and technical standards around hydrogen consumption. The Australian market is also insufficient to achieve the economies of scale required to drive down costs to make green hydrogen competitive with fossil fuels.

Ideally, policy would be trade non-distortionary. This would be in keeping with Australia’s open economy stance. Examples of policies that could have a distortionary effect include an export tax or domestic reservation. These measures would discourage exports and encourage the use of hydrogen in some lower-value domestic applications.

It would be efficient to focus government policy and market development efforts on large-scale export markets in the short term, and move towards servicing domestic customers thereafter. This is not to say that policy should be designed to favour international consumers over domestic ones. Using the scale economies of larger overseas markets to drive down costs rapidly will lead to the lowest-cost supply of gaseous fuels to Australian consumers in both the short and long term.

2 How do we ensure an attractive investment environment for private sector finance? Which methods would be most effective in leveraging maximum private sector finance and which activities should governments prioritise with limited funds? How should these methods change over the short, medium and long term?

How do we ensure an attractive investment environment for private sector finance? Which methods would be most effective in leveraging maximum private sector finance and which activities should governments prioritise with limited funds? How should these methods change over the short, medium and long term?:
The cost of finance is heavily influenced by risk considerations. Establishing a clear framework for the industry from the outset would reduce uncertainty over future regulatory settings, helping to reduce the cost of finance.

Governments should prioritise activities that the private sector is likely to undersupply, such as research, education, market facilitation services (such as trade agreements, rule setting ,and standardisation), and the provision of some types of shared infrastructure.

3 What level of domestic market support is needed to achieve COAG Energy Council's ambition of being a major global player in hydrogen? In particular, what types of support will best provide the necessary domestic skills and capabilities and ensure domestic markets are available in the event that international markets do not emerge as quickly or as extensively as expected?

What level of domestic market support is needed to achieve COAG Energy Council's ambition of being a major global player in hydrogen?:
Prospering in the age of global value chains requires understanding and capturing the parts of the global value chain in which you have a competitive advantage, as emphasised in the World Bank's Draft World Development Report 2020.
[http://pubdocs.worldbank.org/en/124681548175938170/World-Development-Report-2020-Draft-Report.pdf]

Other countries potentially not wanting to purchase hydrogen from Australia is not a good reason for Australia to seek to develop a domestic demand for hydrogen. It is possible to be a successful exporter of a product without a particularly large domestic demand. In relative terms, future demand for hydrogen might be smaller in Australia than in Japan or South Korea due to our comparative advantages in land and in renewable resources (sun and wind). We might well be much more reliant on renewable electricity rather than hydrogen.

Australia has a potential to be a world-leader in development of technologies for production, storage and long-distance transport of green hydrogen. We also have potential for involvement in down-stream export-oriented industries such as hydrochemicals. Focussing on providing policy support to complement our natural comparative advantages (high-skilled labour in addition to renewable energy resources) is the best means to ensure maximum benefit to Australia from the global hydrogen economy.

4 What market and revenue designs and settings will best allow for sustainable growth of the hydrogen industry and an appropriate level of benefits flowing back to the Australian public?

What market and revenue designs and settings will best allow for sustainable growth of the hydrogen industry and an appropriate level of benefits flowing back to the Australian public? :
It is important that mechanisms to ensure the covering of relevant government costs and an appropriate flow of benefit sharing from the hydrogen industry be established at the outset. As noted above, policy uncertainty in this regard could have a depressing effect on investment. Furthermore, future changes designed to increase the share of benefits accruing to the Australian people could become the subject of an investor-state dispute under one of the many trade and investment treaties Australia has ratified in recent years.

It is important that any cost-covering and benefit-sharing arrangements be as efficient as possible and have a clearly-articulated rationale. The ANU is currently devoting resources through its Zero-Carbon Energy for the Asia-Pacific Grand Challenge to research on optimal industrial policy to grow the green hydrogen industry while ensuring fair benefit sharing for communities, tax-payers and investors alike. Preliminary responses to some of the ideas floated in the Issues Papers as well as some alternative ideas are briefly presented below. We would be happy to engage further with you on this question.

Export tax

Export taxes would distort the industry in an inward-looking direction. Export taxes on a product that could help to speed the decarbonisation of the global economy would be doubly distortionary. They would likely lead to complaints from partner countries, including our neighbours in the AsiaPacific. Further, an export tax is likely to run afoul of Australia's commitments under international trade law, including the WTO and numerous FTAs, such as those Australia has signed with Japan and South Korea. If the goal is to rapidly develop an export industry, an export tax would not be a recommended policy approach.

Fuel excise or road usage charges

While fuel excises apply in Australia to the use of other fuels (including petroleum products and gaseous fuels), excisable fuel products are exempt if they are exported. An excise on hydrogen would discourage domestic take-up.

Road congestion charges have high potential as an approach for addressing traffic jams and for replacing fuel excise. They ideally would not be linked to what type of fuel is being used.

Any revenue-raising measures applied to the transport sector should ideally not advantage either fuel cell vehicles or battery electric vehicles over the other.

Resource-related royalties and taxation arrangements

Green hydrogen would be produced using Australian land, sunshine, wind and water. The case for applying royalties to compensate for the depletion of Australian assets thus does not apply. We note, however, that agricultural industries face industry levies to cover costs associated with research and development, safety, and other services. Examples include the wheat levy, the rice levy, and the sugar cane levy.

One option for consideration is a potential tax on "rents" – i.e. a profit tax with a rate that steps up after profits exceed some certain threshold level. Because such taxes have minimal effects on investment decisions (relative to an export tax regime, for example), they tend to be more economically efficient. This approach is one means by which the Australian Government could capture, for the Australian community, profits above those required for an adequate return on capital.

Learning from the experience of the LNG industry, any rent tax for hydrogen would need to be designed to ensure that it generates adequate revenues and minimises the potential for avoidance.

Government investment

Direct government investment or financing through loans can overcome the risk of credit constraints on the growth of a new industry as well as providing a potential revenue stream to governments. This could take a number of forms. The government could provide debt and/or equity financing, such as it has for the renewable energy industry through the Clean Energy Finance Corporation. The repayment of loans could be profit- or revenue- contingent (like HECS for hydrogen). Joint ventures could produce a revenue stream for government that grows in line with corporate profits.

5 What market signals and settings are needed to capture hydrogen's sector coupling benefits? When should these market signals and settings be applied?

What market signals and settings are needed to capture hydrogen's sector coupling benefits? When should these market signals and settings be applied?:
Ideally Australia would adopt a price signal on carbon emissions. This would provide a strong incentive to use zero-carbon energy, including green hydrogen, on an economy-wide basis. Alternatively, a regulatory approach would be able to speed the adoption of low-carbon technologies.

Issue 3: Developing a hydrogen export industry

1 How do we best position and sell the benefits to international partners of investing in Australia's emerging hydrogen industry?

How do we best position and sell the benefits to international partners of investing in Australia's emerging hydrogen industry?:
Dr Emma Aisbett , Professor Ken Baldwin, Dr Fiona J Beck, Associate Professor Paul Burke, Associate Professor Llewelyn Hughes, Professor Frank Jotzo, Professor Warwick McKibbin, Dr Robin Purchase and Dr Mahesh Venkataraman

o Highlight Australia's competitive advantage of low renewable energy costs
Australia has vast renewable energy resources, including some of the best solar and wind assets in the world. Because of this Australia has the opportunity to rapidly develop low-cost, 100% renewable electricity at scale. There is a clear opportunity for Australia to take the lead in developing a hydrogen export industry based on renewable energy, which would demonstrate the feasibility of a truly zero-carbon approach to the world.
The current rate of large-scale renewables capacity installation would only have to increase from the current rate of 4GW/year to 4.8GW/year to meet the increase in demand for electricity due to zero-carbon hydrogen production.

o Leverage existing commercial and inter-governmental links to emerging Asian hydrogen markets (Japan, Korea)
A key strength of Australia in developing a clean hydrogen industry is our proximity to important markets in the Asia-Pacific region, beginning with South Korea and Japan. Japan, in particular, has been a long-standing importer of Australian energy resources, providing a key competitive advantage in the form of existing commercial and inter-governmental links.

o Ensure consistent and predictable policy frameworks to attract international investment
A renewables-hydrogen production system for export will require large investments, the payback on which will in part depend on policy settings. Reliable and predictable policy is essential to unlock large-scale private investment; by contrast, policy uncertainty will stymie investment. It will be particularly important to develop sound and stable rules for taxation of a hydrogen export industry.

The need for policy consistency includes the treatment of any greenhouse gas emissions that may arise from hydrogen production if this were to involve fossil fuels. Fundamentally, building a hydrogen production industry in Australia is compatible with national and international climate change goals only if it is 'green hydrogen', produced using renewable energy.

o Continue to provide research support e.g. through ARENA (and in time the CEFC), to keep at the cutting edge of hydrogen research
Australia already has a strong research profile in the hydrogen economy. Continued investment in research across the hydrogen value chain including public/private initiatives will ensure Australia remains an attractive option for future hydrogen investment.

o Highlight Australia's highest per capita renewable energy deployment capacity currently being demonstrated
Australia is currently demonstrating the world's highest per capita renewable installation rate at 250 W per person p.a. – several times higher than our closest competitors.

o Investment in Australia's nascent green hydrogen industry is likely to provide excellent medium- to long-term returns because Australia has:
• Natural comparative advantage due to strong relative abundance of renewable energy resources, a high-skilled workforce to develop and service the industry, and geographical proximity to major markets in Asia;
• Policy-induced comparative advantage due to its geopolitical neutrality and stability, its open trade and investment regime, and its strong public and private links with key export markets; and
• Low political risk as demonstrated by its exemplary track-record with regard to treatment of investors in large-scale export industries.

2 How could governments support the cost competitiveness of Australia's hydrogen exports?

How could governments support the cost competitiveness of Australia's hydrogen exports?:
o Employ policy based on objective analysis
A fundamental requirement for government efforts to support to the cost competitiveness of Australia's hydrogen exports is that these efforts be developed based on high-quality, objective analysis, and that they are not influenced by politically-power incumbent fossil fuel interests. For example, potential markets such as Japan have made clear that they have a preference for hydrogen produced from renewable energy, c.f. from reforming fossil fuels. It is essential to avoid policies

which (explicitly or implicitly) favour fossil fuel derived hydrogen. Similarly, it is essential to ensure that the policies adopted are actually efficient, and that policy uncertainty due to lobbying on behalf of fossil-fuel interests is minimised.

As discussed in the response to questions on Issue Paper 2, Investment, the welfare-economic approach is emphasised by the OECD Recommendation of the Council on Regulatory Policy and Governance. The welfare economic approach would suggest that government interventions be targeted at specific market failures. For example, direct government investment via joint ventures could help to alleviate capital constraints arising from incomplete information, risk aversion, and potential political risk. By lowering the costs of raising capital, government investment can improve the competitiveness of Australian hydrogen. Such joint ventures could also ensure long-term benefits to government revenues grow in step with those of the private partners.
o Implement trade agreements e.g. export forward contracts, to guarantee supply to Asian markets

Justifying large up-front investments in hydrogen infrastructure requires a level of certainty that there will be sufficient demand. Certainty can be provided, in part, by using government to support the development of commercial arrangements that provide certainty to suppliers and purchasers.

o Continue to provide research support e.g. through ARENA (and in time to the CEFC), to keep at the cutting edge of hydrogen research
See response to Q1 above.

3 What could governments do to encourage commercial offtake agreements for export?

What could governments do to encourage commercial offtake agreements for export?:
o Implement trade agreements e.g. export forward contracts, to guarantee supply to Asian markets

See response to Q2 above.

4 How do we balance our global competitiveness with ensuring all Australians benefit when considering the collection of government revenues from hydrogen exports?

How do we balance our global competitiveness with ensuring all Australians benefit when considering the collection of government revenues from hydrogen exports? :
o Ensure consistent and predictable policy settings are essential across the renewable energy/hydrogen value chain
See response to Q1 above.

o Efficient taxation and/or investment for the public benefit
A successful hydrogen export industry could be highly profitable. A share of profits beyond those required for an adequate rate of return on private capital investments should accrue to Australian governments, and thus the Australian community. Clarifying taxation arrangements at the outset is important to facilitate investment and to achieve a positive outcome for the community overall. Options should be systematically investigated, including the case for a resource rent tax (progressively higher taxation at higher levels of profitability), with possible investment of proceeds into a sovereign wealth fund.

Distortionary and inefficient taxation such as export taxes should be avoided as they generate dead weight losses which decrease the surplus available for sharing between Australian and overseas interests.

Similarly, revenue-generating mechanisms which are inappropriate for a green hydrogen industry should be avoided. In particular, the economic justification for royalties on fossil fuel industries arises from the fact they are based on extraction of non-renewable resources. There is no such justification for royalties on renewable hydrogen.
Finally, alternative mechanisms such as public-private joint ventures and income-contingent loans may prove to be more efficient than taxation as a means of ensuring competitiveness and national benefit. The ANU Grand Challenge Zero-Carbon Energy for the Asia Pacific is currently undertaking thorough and objective analysis of a range of options to achieve these twin goals.

5 What can (or should) be done to ensure an appropriate balance between export and domestic demand?

What can (or should) be done to ensure an appropriate balance between export and domestic demand?:
It is possible to be a successful exporter of a product without a particularly large domestic demand.

In relative terms, future demand for hydrogen might be smaller in Australia than in Japan or South Korea due to our comparative advantages in land and in renewable resources (sun and wind). We might well be much more reliant on renewable electricity rather than hydrogen.

A key domestic policy to encourage use of zero-emission hydrogen would be the introduction of a price signal on carbon emissions. In the absence of this, regulations on emissions levels would also induce substitution towards zero-carbon options, such as potentially hydrogen.

o Hydrogen generation/hub locations – benefit sharing with local communities (LNG lessons)
Key hydrogen generation and export facilities would ideally be located in areas that are closest to Asian markets and that have a comparative advantage in zero-carbon energy. The development of the hydrogen industry is thus closely linked to the Northern Australia development agenda. Frameworks are needed for participation and benefit-sharing between investors and communities – particularly indigenous communities in Northern Australia.

o Domestic hydrogen price driven by exports (LNG lessons)
If a major hydrogen export industry develops, Australia's domestic hydrogen price will be exposed to international price fluctuations. The history of linking of domestic gas with regional gas markets shows this could have an important impact on Australian consumers as the importance of hydrogen in the domestic energy mix increases.

The efficient solution to such concerns is for the Australian utilities to negotiate long-term purchase agreements. Such agreements will also stimulate investment by providing demand-certainty for generators.

6 How ambitious is the target of fulfilling 50% of Japan and Korea’s hydrogen imports by 2030?

How ambitious is the target of fulfilling 50% of Japan and Korea’s hydrogen imports by 2030?:
From a technology perspective, fulfilling 50% of Japan and South Korea’s hydrogen imports by 2030 is achievable. Based on the current rate of growth of renewable energy capacity, it is feasible that Australia will be able to generate sufficient renewable energy to support “zero-carbon” hydrogen production with electrolysis to meet the export demand [see ref http://energy.anu.edu.au/files/Combined%20ZCWP03-19.pdf]. This estimate does not rely on any significant technology improvements and only a marginal increase in electrolyser efficiency over the next 20 years. However, very few electrolysis systems have been imported and installed in Australia, and the infrastructure for storing and transporting hydrogen would need to be developed. It is likely that a coordinated effort between governments and industry would be needed to support the industry to ramp up quickly enough to meet this target; including training up a skilled workforce.

Issue 4: Guarantees of origin

1 When should Australia aim to have a guarantee of origin in place? Why is this timing important?

When should Australia aim to have a guarantee of origin in place? Why is this timing important?:
(This section authored by Dr James Prest, Senior Lecturer, ANU College of Law)

If Australia wishes to encourage, cultivate and develop markets for the production of green hydrogen, the short answer is, as soon as possible. The longer there is delay on this question, then the longer the development of a mature market at scale will take. Logically, the associated cost reductions with market scale will increase the competitiveness of Australian green hydrogen exports.

On the other hand, if a poorly thought-out system for guarantee of origin is introduced, and especially if necessary associated technical issues and definitional thresholds are not carefully designed in consultation with industry and others with relevant technical knowledge, then this could create legal uncertainties and investor uncertainty, delaying the growth of a domestic mature market for green hydrogen. Likewise, in terms of participation in international markets, if Australia does not undertake sufficient research into the requirements of international buyers, then the lack of appropriate guarantees of origin could prove in the near future to be a barrier to accessing premium prices in premium markets.
Australia is already far behind Europe in terms of the development of certification of hydrogen production. To some extent, this mirrors our position in terms of environmental sustainability certification. Other examples of guarantees of origin schemes, with a variety of features involving supply chain traceability, relate to fair trade/sustainable coffee and chocolate, organic food, renewable electricity, sustainable palm oil, and sustainable forest products. Some of these certification efforts are undertaken by the private sector bodies such as ISCC (International Sustainability and Carbon Certification, e.V.) and the FSC Forest Stewardship Council.

In terms of hydrogen, the main European efforts are the CertifHy project and the HyLaw project both run from Brussels by Hydrogen Europe (an association of 185 companies and research institutes and national associations) and the Hydrogen Council. It is still the case that “Despite national / private initiatives (DE, DK, BE) to certify “green” hydrogen. There is no binding or uniform guarantee certification system at European level.” However, given the advanced level of thinking in Europe on these questions, this state of affairs will not remain static.

European efforts on certification, are affected by the Second Renewable Energy Directive (RED II) approved by the European Parliament in November 2018. New categories in the European RED II including ‘Renewable fuels of nonbiological origin’ which is applicable to hydrogen.

If Australia ‘goes it alone’ in terms of inventing entirely new certification systems that are not congruent with international approaches this is likely to meet with buyer resistance outside of Australia in target markets such as Japan and Korea.

Preliminary steps for Guarantee of Origin System
Certain preliminary steps can be identified in order to set up a guarantee of origin system. These involve questions of legislative and administrative design.

Initial steps should include:
I. Devise definition of “Green Hydrogen” including precise threshold of CO2-e emissions per MJ and involving consideration of a Definition of ‘green hydrogen’ as ‘a renewable fuel of non-biological origin’.
II. Review of existing platforms for GO by examining lessons from other initiatives such as electricity and traded commodities (coffee, chocolate, palm oil)
III. Determine definition of framework for guarantees of origin for green hydrogen
IV. Devise Roadmap for the implementation of a nation wide GO scheme for green hydrogen

Among these is the passage of legislation to provide the legal authority for the operation of a guarantee of origin (‘GOO’) system relating to hydrogen.

This could be done quickly by making of regulations under an existing Act. However there is no parent Act that has the necessary breadth of scope in order to authorise the making of regulations relating to green gas. One option is to enact a Federal Hydrogen Act, the other is to enact amendments to existing energy legislation. Two options are outlined below.

The Renewable Energy Electricity Act 2000 (Cth) is confined to the making of certificates of origin relating to renewable electricity rather than energy.

The other potential parent legislation for hydrogen origin tracking regulations is the National Greenhouse and Energy Reporting Act 2007 (NGER Act).

This Act provides a national framework for reporting information about greenhouse gas emissions, as well as energy consumption and production. The NGER Act requires corporations that exceed reporting thresholds to report on their greenhouse gas emissions and energy consumption and production. Methodologies for emissions estimations have been set by regulation in a Measurement Determination (National Greenhouse and Energy Reporting (Measurement) Determination 2008).

Because the NGER Act requires reporting on energy production and GHG emissions, it is possible that this framework could be adapted by legislative amendments to include reporting of specific information in relation to hydrogen production and its emissions intensity per MJ.
In this sense, the NGER Act appears better adapted to the enactment of a scheme for hydrogen guarantees of origin than the REE Act.

A related question is the identification of an agency to act as administrator and regulator of the hydrogen GOO scheme. (This is discussed further below at #5) The logical choice is the Clean Energy Regulator, an independent statutory authority established by the Clean Energy Regulator Act 2011 (Cth).

2 What would be the best initial scope for a guarantee of origin? Why? Should there be two separate schemes for international and domestic requirements?

What would be the best initial scope for a guarantee of origin? Why? Should there be two separate schemes for international and domestic requirements?:
(This section authored by Dr James Prest, Senior Lecturer, ANU College of Law, with sub-section on international aspects by Dr Emma Aisbett, ANU Energy Change Institute)

In relation to the relationship of the hydrogen certification system to legal frameworks, three broad phases can be conceived of:
• Trial phase independent of / outside of regulatory frameworks
• Trial phase within a new regulatory framework
• Full operational phase under regulatory system.

In terms of principles involved, the European approach has been to initially focus on GO for the Production of Hydrogen only. The reason for this is that the primary objective of the Guarantee of Origin is to certify the origin of the product in order to assist consumers of the product with transparent and credible assurances about its origin, rather than to regulate its application.

In Europe, at least initially, all other aspects of certification of the hydrogen cycle have been excluded from the Guarantee of Origin deliberations, for example,
• Transport of Hydrogen
• Storage of Hydrogen
• Application of Hydrogen into Gas Grids
• Application of Hydrogen into Fuel Cells and Power Applications
• Application of Hydrogen in Mobility
• Application of Hydrogen in Chemistry (eg petroleum products, ammonia)

Main actors in a GO system include:
• Producers (supply data seeking certification for units of production)
• Auditors (assessing information provided by producers to see if it meets Green Hydrogen requirements),
• Certification Body (to Check auditors report and certify OK)
• Issuing Body or Bodies,
• Registry,
• Accreditation Body (to accredit Auditors and Certification Body).

European approaches have identified steps including:
i. Definitions of the types of premium hydrogen (ie green hydrogen and low carbon hydrogen)
ii. Publish Guidelines for the setup of the GO scheme
iii. Create a Registry by Deciding on its Structure
iv. Decide who will be the Issuing Body ?
v. Draft a Roadmap for implementation
vi. Encourage and document participation of Stakeholders in the Platform
vii. Set up pilots in which the GOs scheme can be tested
viii. Manage / Build ICT system and registry platform
ix. Create Issuing body for GOs
x. Creation of EU-wide buy-in for the GO scheme and the CertifHy labels

Although it is possible to consider certification of hydrogen in particular applications, for example Hydrogen as a transport fuel or certification of Hydrogen as an energy storage medium, this approach is not preferable.

The priority should be placed on certification of the origin or source of hydrogen.

The European approach described by CertifHy is that:
"A GoO certification of hydrogen should include the carbon intensity and other relevant parameters (e.g. renewable origin) as for electricity in order to encourage the production and use of hydrogen from low carbon and/or renewable processes. Also, the renewable origin of the hydrogen should be transferrable independently of the molecules to which it relates (subject to reasonable conditions pertaining to mass balance and avoidance of double-counting)".

Should there be two separate schemes for international and domestic requirements?
[This section with input from Dr Emma Aisbett]

The answer to the question of separate schemes for international and domestic requirements is an unequivocal "no". The COAG members are more than aware of the high costs of establishing, implementing and operating regulatory and certification systems. Ultimately these costs are borne by producers and consumers. Doubling this cost load by having two systems will make Australian hydrogen less competitive on global markets. As discussed elsewhere in this submission, Australia should concentrate its efforts on working with international partners to develop certification systems that facilitate trade, not hamper it.

The issue of inefficient doubling of rules and certification schemes for domestic and international markets also has implications for market structure and hence the competitive environment in the Australian industry. A large body of evidence shows that small producers in a range of products suffer a competitive disadvantage from certification schemes because of the high fixed costs of meeting the requirements. Doubling this load by having two systems in place will disadvantage small producers and hence lead to a less competitive market in Australia, leaving Australian consumers exposed to the costs of rent extraction by large players with substantial market power.

Given Australia's comparative advantage in zero carbon hydrogen from renewable energy based on our high quality renewable energy resources, it is in Australia's national interest to participate actively and negotiate actively in discussions about the direction of international certification for green hydrogen.

The general literature on international trade shows that misalignment of technical standards is a key barrier to trade. If Australia does not align its production with international standards on the origin of hydrogen, a risk exists that Australian producers may miss out on access to key markets.

The establishment of standards and rules for a new hydrogen export industry should be forward looking, thereby future proofing Australia's exports of hydrogen.

3 Beyond the University of Queensland report referenced above, and published hydrogen strategies from Japan and Korea, what intelligence on consumer and market preferences is available to inform an Australian guarantee of origin?

Beyond the University of Queensland report referenced above, and published hydrogen strategies from Japan and Korea, what intelligence on consumer and market preferences is available to inform an Australian guarantee of origin?:
Design of an Australian guarantee of origin scheme for hydrogen should be based on the objectives and purposes of the scheme, as well as documented experience with the operation of other GO schemes both in Australia and internationally.

In turn, these should be guided by Australia's obligations for greenhouse gas emissions reduction to the international community under the Paris Agreement made under the UN Framework Convention on Climate Change.

It is likely that many buyers of hydrogen will prefer hydrogen with a market feature of certification. However, the extent of demand for certified hydrogen with guarantees of origin must be determined with market research. Determining market preference for GOs and Certified Hydrogen in markets such as Japan, Korea and Taiwan will require in-country market research by experts with sufficient foreign language competence to survey the buyers accurately about their preferences.

For internal European purposes, the European approach has been to define a baseline of emissions intensity in terms of gCO2-e/MJ.

4 Should a guarantee of origin have an eligibility threshold? If yes, what should it be based on?

Should a guarantee of origin have an eligibility threshold? If yes, what should it be based on?:
A key principle in this context is to ensure consistency or, failing that, at least interoperability of Australian standards with European or international standards. This eligibility threshold would refer to the Emissions intensity of the hydrogen production process. It would be measured in grams or Kg or CO2-equivalent emissions per MJ or kilogram of hydrogen.
The CertifHy standard sets a threshold for 'low emissions' hydrogen at 4.4 kg CO2-e/kg hydrogen.

Expressed slightly differently, grey hydrogen has emissions of around 91g CO2 eq/MJH2 (=SMR benchmark). Under the CertifHy framework, green hydrogen must be below 36.4 g CO2 eq/MJH2 (-60% below the SMR benchmark for steam methane reforming).

It will be important to define the pressure and temperature at which the measurement is undertaken, and it is best if this is undertaken in relation to an international standard. For example highly relevant is ISO/TC 197 – Hydrogen technologies, relevant to the production of hydrogen. This standard covers "standardization in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen."

In terms of existing legislation that measures emissions and energy consumption, the National Greenhouse and Energy Reporting (Measurement) Determination 2008 at 1.8 in Definitions, under 'appropriate unit' states that gaseous fuels are to be measured in metres cubed or gigajoules. This may require amendment if Australian approaches for hydrogen certification are to be inter-operable with European standards.

5 Who is the most appropriate body to develop and maintain criteria for a guarantee of origin and administer certification? Why?

Who is the most appropriate body to develop and maintain criteria for a guarantee of origin and administer certification? Why?:
A key question is the identification of an agency to act as administrator and regulator of the hydrogen GOO scheme. The logical choice is the Clean Energy Regulator, an independent statutory authority established by the Clean Energy Regulator Act 2011 (Cth). This is because of the role of the CER in administration

of the renewable energy certificates system under the RET Renewable Energy Target, as provided for in the Renewable Energy (Electricity) Act 2000 (Cth). The CER also has a key role under the various emissions tracking and reduction efforts of the Carbon Farming Initiative and Safeguards Mechanism. This provides it with invaluable experience in methodological issues and the operation of a Registry.

If this is done at State and Territory level due to Federal inaction, the problems of differing industry standards and inconsistency of State legislation will arise. The introduction of a national (i.e. Commonwealth led) regulatory framework for Hydrogen certificates of origin is preferable.

Issue 5: Understanding community concerns for safety and the environment

1 Do existing regulations adequately manage the potential carbon emissions of a large-scale national hydrogen industry?

Do existing regulations adequately manage the potential carbon emissions of a large-scale national hydrogen industry?:
Please refer to regulation issue responses.

2 What are the main community concerns about the use of CCS? How can we better manage these concerns and potential CCS projects in regional areas?

What are the main community concerns about the use of CCS? How can we better manage these concerns and potential CCS projects in regional areas?:
CCS is politicised – this is a core challenge for any project involving CCS. CCS has become synonymous with 'clean coal', which is perceived by some groups as a delaying tactic for decarbonisation used by government and industry. A core risk for the emerging hydrogen industry is that any deployment of hydrogen with CCS leads to the politicisation of CCS being 'transmitted' to hydrogen (see Colvin et al. 2019). Please note this is a reflection on the contours of political and social discourse regarding CCS, not a comment on its financial, technical or political viability.

A great benefit of the potential for hydrogen is that it has aspects that appeal across traditional ideological divides regarding industry and energy. It can appeal to those who appreciate industry growth, innovation, and economic prosperity through the opportunities for development of a new export and domestic sector. It can also appeal to those who value decarbonisation of the energy sector and Australia's contributions to energy security in less developed countries, though offering a means for generation of low-emissions energy that is export-suitable (e.g. to countries with lower energy security).

Bringing these two ideological standpoints together via hydrogen will be most successful if the potential for hydrogen to be 'bundled' with CCS is avoided. As such, this suggests that prioritising hydrogen developments that make use of renewable energy will be most beneficial in building a strong, cross-ideology base of support for the new sector.

Colvin, R. M., Kemp, L., Talberg, A., De Castella, C., Downie, C., Friel, S., Grant, W. J., Howden, S. M., Jotzo, F., Markham, F. & Platow, M. J. 2019 (in press). Learning from the climate change debate to avoid politicisation and polarisation on negative emissions. Environmental Communication, DOI: 10.1080/17524032.2019.1630463.

Response contributed by (alphabetised):
- Dr Bec Colvin, Lecturer, Crawford School of Public Policy, Rebecca.Colvin@anu.edu.au
- Associate Professor Katherine Daniell, Research Lead, Autonomy, Agency and Assurance Institute & Fenner School of Environment and Society, Katherine.Daniell@anu.edu.au
- Dr Will J. Grant, Senior Lecturer, Centre for the Public Awareness of Science, will.grant@anu.edu.au
- Dr Catherine Gross, Visiting Fellow, Fenner School of Environment and Society, Catherine.Gross@anu.edu.au
- Paul Wrywoll, Postdoctoral Fellow, Crawford School of Public Policy, Paul.Wyrwoll@anu.edu.au

3 What are the risks about using desalination plants or water recycling facilities to produce water for electrolysis?

What are the risks about using desalination plants or water recycling facilities to produce water for electrolysis?:
The use of desalination plants or water recycling facilities may be a valuable means through which opposition or resistance to hydrogen can be avoided. This is through sidestepping competition with other sectors for water resources. However, the fact that these facilities require energy means that a whole of life cycle approach will be necessary to ensure that emissions reduced or avoided via the hydrogen sector are not balanced out by emissions across the hydrogen value chain.

This is important not just from an emissions accounting perspective, but for protecting the image of hydrogen as innovative and clean (as a determinant of public support and acceptance). There are also instances of localised resistance to development of such facilities (desalination plants and water recycling), so making use of existing facilities, rather than the development of new facilities, will be more desirable from a community perspective. If new facilities are required, developing them in ways that provide additional co-benefits to local communities (e.g. enhanced local water security) could mitigate or reduce such resistance.

A core risk of using desalination plants or water recycling is economic. If Australia is competing to capture a share of an emerging market, it is necessary to ensure that production is lowest cost. Page 6 of the issues paper states that "using desalinated seawater adds just a few percent to the cost of producing hydrogen". A few percent could be the difference between Australian-produced hydrogen being competitive in international markets or not. As such, this must be considered carefully in economic analyses.

Desalination produces hyper-saline brine waste that can damage ecosystems (see Jones et al. 2018 for a review). While brine waste can be managed sustainably, the costs and risks of storing and disposing of it need to be accounted for.

Jones, E., Qadir, M., van Vliet, M.T.H., Smakhtin, V., Kang, S. 2018. The state of desalination and brine production: A global outlook. Science of the Total Environment 657: 1343-1356.

Response contributed by (alphabetised):
- Dr Bec Colvin, Lecturer, Crawford School of Public Policy, Rebecca.Colvin@anu.edu.au
- Associate Professor Katherine Daniell, Research Lead, Autonomy, Agency and Assurance Institute & Fenner School of Environment and Society, Katherine.Daniell@anu.edu.au
- Dr Will J. Grant, Senior Lecturer, Centre for the Public Awareness of Science, will.grant@anu.edu.au
- Dr Catherine Gross, Visiting Fellow, Fenner School of Environment and Society, Catherine.Gross@anu.edu.au
- Paul Wrywoll, Postdoctoral Fellow, Crawford School of Public Policy, Paul.Wyrwoll@anu.edu.au

4 How can we best balance the water and land use requirements for environmental, agricultural, community and hydrogen production uses?

How can we best balance the water and land use requirements for environmental, agricultural, community and hydrogen production uses?:
This is an important question. There need to be national, regional and local community discussions about the value placed on resources in any area or locality. These resources include such things as the landscape as a whole (for example where proposed developments have an impact on the features of a landscape); surface water and groundwater systems; the agricultural landscape including type of soil and access to water; woodland/forest; estuaries etc.

The type of value includes economic, aesthetic, environmental, social etc. such as: economic for human benefit; environmental ecosystem service – for environmental as well as human benefit; aesthetic for community benefit; wilderness for biodiversity protection; agricultural land for food production and so on. Recognising the multifaceted ways in which people value landscapes and resources is essential in effective engagement approaches that seek to build on and/or foster positive community perceptions.

For example, it may well be that the economic value of agricultural production – for owners, communities, regions or the nation at large – is greater than the potential economic value and potential environmental impact of a hydrogen production facility. A conversation between stakeholders needs to take place as to how these values can be determined. In other words, to determine the “best balance” a vision is needed for the resource/set of resources in question. Developing a vision – or multiple future visions in which hydrogen production plays a valued role – will require discussion involving a broad range of stakeholders.

Multi-stakeholder processes like this are successful when they are focused on prioritising future options, rather than examining the case for or against a specific project. The former approach encourages deliberative and constructive engagement whereas the latter approach can easily devolve into polarisation and dysfunctional conflict. Community consultative committees, as noted in the issues paper, do offer great promise as a mechanism through which this can be achieved, though the process by which CCCs are managed is critical (see Colvin et al. 2016 as an example – the potential value of a CCC for wind energy was undermined by the lack of a third-party facilitator and other details of process and context). CCCs would allow for deliberative assessments of water use requirements, informed – importantly – by local information and modelling of water supply and demand.

Regarding water use, ACIL Allen Consulting for ARENA (2018, p. 37) highlights that the potential water demand for hydrogen production (up to 28.62 GL by 2040) is very small when compared to the total consumption of water in Australia. However, aggregated figures at the national (or state) level miss the point: if that 28 GL of water was drawn from freshwater sources in 2-3 locations, then the hydrogen industry could indeed have a major impact on local water security.

Water balance assessments need to account for a range of scenarios for water supply under climate change and projected total water demand (across all users) in coming decades.

Importantly, communities and existing commercial water users (e.g. agriculture and industry) need to know the institutional arrangements by which water will be secured for hydrogen production by each proposed plant. For example, through purchase of existing water entitlements (where water markets exist) or the issue of new water licenses by state governments. How this is implemented will have implications for perceptions of fairness of treatment of the hydrogen industry compared to other existing or future sectors (see Gross 2014). Maintaining perceptions of fairness matters for both promoting positive attitudes toward the industry, and offering assurances that the governance regime is trustworthy.

Additional consideration needs to be given to the impact on water users (including the environment) of any water storage/supply infrastructure, such as dams, that is needed for hydrogen production.

It would seem unlikely that a hydrogen production plant would secure water through purchase of water allocations (see Meridian Energy note on p. 5 of Issues Paper), but such concerns could only be dispelled through concrete, evidence-based water plans for each planned plant, established very early in any project proposal. Public perceptions will be shaped by the interplay between individual projects and impressions of the industry as a whole. As such, ensuring a responsible approach across all projects is important in the pursuit of a social licence to operate for both the industry and distinct projects.

ACIL Allen Consulting for ARENA, 2018. ‘Opportunities for Australia from Hydrogen Exports’.

Colvin, R. M., Witt, G. B. & Lacey, J. 2016. How wind became a four-letter word: Lessons for community engagement from a wind energy conflict in King Island, Australia. Energy Policy, 98, 483-494.

Gross, C. 2014. Fairness and Justice in Environmental Decision Making: Water Under the Bridge, Abingdon, Routledge.

Response contributed by (alphabetised):
- Dr Bec Colvin, Lecturer, Crawford School of Public Policy, Rebecca.Colvin@anu.edu.au
- Associate Professor Katherine Daniell, Research Lead, Autonomy, Agency and Assurance Institute & Fenner School of Environment and Society, Katherine.Daniell@anu.edu.au
- Dr Will J. Grant, Senior Lecturer, Centre for the Public Awareness of Science, will.grant@anu.edu.au
- Dr Catherine Gross, Visiting Fellow, Fenner School of Environment and Society, Catherine.Gross@anu.edu.au
- Paul Wrywoll, Postdoctoral Fellow, Crawford School of Public Policy, Paul.Wyrwoll@anu.edu.au

5 Hydrogen production projects will require significant project and environmental approvals at the local, state and federal level. What approaches could help to manage these approvals to facilitate industry development while providing suitable environmental and natural resource protections and managing community expectations? When do these approaches need to be in place by?

Hydrogen production projects will require significant project and environmental approvals at the local, state and federal level. What approaches could help to manage these approvals to facilitate industry development while providing suitable environmental and natural resource protections and managing community expectations? When do these approaches need to be in place by?:
Effective governance is critical to community trust in the sector. Balancing an adaptive governance system that enables responsible development while protecting other things of value will be critical. A vast body of work has been undertaken to answer questions of this nature, especially in fields such as policy formulation, environmental law, community consultation and justice research. Drawing on expertise from these (and other cognate) fields of research will offer a useful resource to the governance and development of the hydrogen sector in Australia. Brief highlights from the literature include:

- Availability of an adequately powerful, 'neutral' referee over the industry – for example an ombudsman or commissioner for not just managing complaints (i.e. resolving problems after the fact), but overseeing processes and practices.

- Clear separation of government and industry interests (e.g. compared to perceptions about the coal seam gas industry development especially in Queensland), where government is perceived to be a fair adjudicator protecting the public interest.

- Transparency of processes and evidence, including genuine opportunities for community and environmental (and other interest-based) groups to contribute as legitimate participants in decision-making processes.

- Adopting processes that prioritise deliberation over binary choice to enable meaningful engagement rather than polarised conflict (e.g. Dryzek and Pickering 2017).

- Avoiding the industry becoming a political wedge issue, noting that cues from political and policy elites make a strong impression on citizens' views. Building alliances with leaders of a broad range of interest and ideological groups will help to limit the risk of political polarisation.

Dryzek, J. S. & Pickering, J. 2017. Deliberation as a catalyst for reflexive environmental governance. Ecological Economics, 131, 353-360.

Response contributed by (alphabetised):
- Dr Bec Colvin, Lecturer, Crawford School of Public Policy, Rebecca.Colvin@anu.edu.au
- Associate Professor Katherine Daniell, Research Lead, Autonomy, Agency and Assurance Institute & Fenner School of Environment and Society, Katherine.Daniell@anu.edu.au
- Dr Will J. Grant, Senior Lecturer, Centre for the Public Awareness of Science, will.grant@anu.edu.au
- Dr Catherine Gross, Visiting Fellow, Fenner School of Environment and Society, Catherine.Gross@anu.edu.au
- Paul Wrywoll, Postdoctoral Fellow, Crawford School of Public Policy, Paul.Wyrwoll@anu.edu.au

6 What are the most important standards and regulations to have in place to ensure a safe hydrogen industry and address the community expectations?

What are the most important standards and regulations to have in place to ensure a safe hydrogen industry and address the community expectations?:
Appropriate standards and regulations will need to be established as the technology is further developed and understood. A first standard should be that full disclosure of information is required as to the state of development of the technology as well as the known risks identified, and acknowledgement that there could be further risks not yet identified. A balance is needed between responsive, adaptive management to account for future innovation and information and a trustworthy and dependable regulatory system.

Debates in recent years regarding the devolution of environmental decision-making authority from the Federal to State governments and discourse regarding 'green tape' likely have contributed to seeding community perceptions that Australia's environmental regulatory processes are either: 1) overly bureaucratic as to be ineffective, or 2) defunded or deinstitutionalised such that they are not trustworthy. Recognising this legacy of the political discourse on regulatory approval processes in Australia, and proceeding in a way that is cognisant of the risks it has created, is important to developing standards and regulations that are both effective and responsible AND perceived as such.

Response contributed by (alphabetised):
- Dr Bec Colvin, Lecturer, Crawford School of Public Policy, Rebecca.Colvin@anu.edu.au
- Associate Professor Katherine Daniell, Research Lead, Autonomy, Agency and Assurance Institute & Fenner School of Environment and Society, Katherine.Daniell@anu.edu.au
- Dr Will J. Grant, Senior Lecturer, Centre for the Public Awareness of Science, will.grant@anu.edu.au
- Dr Catherine Gross, Visiting Fellow, Fenner School of Environment and Society, Catherine.Gross@anu.edu.au
- Paul Wrywoll, Postdoctoral Fellow, Crawford School of Public Policy, Paul.Wyrwoll@anu.edu.au

7 As an individual, how would you like to be engaged on hydrogen projects? Which aspects would you like to be kept informed of? Which aspects would you like to be consulted on? Are there any types of issues or challenges that you, or affected communities, would want to be a part of formulating solutions and recommendations?

As an individual, how would you like to be engaged on hydrogen projects? Which aspects would you like to be kept informed of? Which aspects would you like to be consulted on? Are there any types of issues or challenges that you, or affected communities, would want to be a part of formulating solutions and recommendations?:
As researchers, we would be pleased to be engaged throughout the process where there are opportunities for input, with regard to both the industry broadly and

distinct projects. The ANU Energy Change Institute is a vehicle through which suitable expertise can be connected with need.

With regard to the nature of engagement for stakeholders, it is good practice to engage stakeholders throughout all stages of a process, particularly including:

- How the technology works and the potential risks to the local community and environment – how will these risks be managed and mitigated.

- Examples of where the technology has already been or is being implemented and full disclosure of the experiences of that implementation including unexpected problems and how they were solved.

- Full disclosure of the life cycle cost-benefit of the proposed infrastructure from manufacture, implementation, operation, and end of project life cycle clean-up. This cost-benefit should be structured in terms of carbon emissions as well as the economics of the project and who pays for what part.

Response contributed by (alphabetised):
- Dr Bec Colvin, Lecturer, Crawford School of Public Policy, Rebecca.Colvin@anu.edu.au
- Associate Professor Katherine Daniell, Research Lead, Autonomy, Agency and Assurance Institute & Fenner School of Environment and Society, Katherine.Daniell@anu.edu.au
- Dr Will J. Grant, Senior Lecturer, Centre for the Public Awareness of Science, will.grant@anu.edu.au
- Dr Catherine Gross, Visiting Fellow, Fenner School of Environment and Society, Catherine.Gross@anu.edu.au
- Paul Wrywoll, Postdoctoral Fellow, Crawford School of Public Policy, Paul.Wyrwoll@anu.edu.au

8 What are the best ways of engaging diverse communities in regional and remote areas?

What are the best ways of engaging diverse communities in regional and remote areas?:
Approaching a community as an 'outsider' can limit the potential for meaningful, two-way engagement that is of benefit to both parties. This approach is typical of short-term consultative processes, where there is little opportunity for genuine rapport and trust to be developed between parties. Instead, developing a long-term relationship with the community and – critically – on the community's terms is important for success. This requires listening and learning from the community about important local matters, understanding who are the community leaders, power-holders and those potentially marginalised, and respecting community priorities and values.

Developing an understanding of local identity, in particular, is very important to this (e.g. Manzo and Devine-Wright 2014). Local identity is a combination of both the local culture and the physical place – and it underpins a range of local norms and practices, as well as being an important antecedent for place-protective behaviour (e.g. local opposition to a locally unwanted land use). Multiple identities always exist in a single place, and the interplay between identity groups can be a core driver of local politics, conflict, innovation, and cultural growth.

With regard to Aboriginal or Torres Strait Islander communities, a fundamental point of respect and regard is to engage with communities in a way that embraces and promotes their sovereignty. Projects that are First Nations led and governed are those that are most successful in Aboriginal and Torres Strait Islander communities. This can require government and/or industry to adopt different governance and engagement practices, but such an approach not only will enhance the potential for successful engagement, it will also be a mark of respect for the First Nations of this continent, and their people.

In a more general sense, there are insights across community engagement that are instructive and generalisable. The issue paper flagged a good coverage of community engagement concepts as they currently stand. However, we note that despite these concepts being well established in the realms of academia and practice, community conflict and disenchantment remains. Building standards for engagement on principles of justice (further elaborated in response to Q9) offers opportunities.

First, and foremost, people want to be dealt with honestly. They do not want to be told lies, partial lies or have the truth somewhat hidden. If there is a problem, they want to know about it. They want to know who stands to gain from the proposed infrastructure, who stands to lose, and in what way. They want to know if the decision-makers have any "skin in the game", and what sort (such as mates who could benefit from it, or political/financial affiliations.) They want honest straight-talking. This is the essence of being treated with fairness.

People want to be respected as having a genuine interest in the proposal and having legitimate concerns about it. They want full and respectful answers to the questions they put forward and they want detailed information. Importantly, any issues with how the project might affect their livelihood, personal life, community and the local environment need to be fully considered and responded to.

Individuals and communities want to interact with people who have the potential to understand their position. Many people from towns and cities have limited or no understanding of rural living - they don't dress in the same way and they don't talk the same language. Many don't understand how farming works and they don't understand what makes small rural communities tick, or the unique challenges with regional living compared with urban life.

So, choosing the right people to run the community consultation is a major part of setting off on the right foot. Related to the points on local identity, having people leading consultation who have life experiences that align them with the communities they are engaging will be a benefit. Critically, too, those people leading engagement must be empowered to have authority to make decisions based on community feedback. Best intended community engagement practitioners have had their effectiveness undermined by not having - or not being perceived by the community to have - real power to influence the project or initiative based on community input (e.g. Colvin et al. 2016).

Colvin, R. M., Witt, G. B. & Lacey, J. 2016. How wind became a four-letter word: Lessons for community engagement from a wind energy conflict in King Island, Australia. Energy Policy, 98, 483-494.

Manzo, L. C. & Devine-Wright, P. (eds.) 2014. Place Attachment: Advances in Theory, Methods and Applications, London and New York: Routledge.

Response contributed by (alphabetised):

- Dr Bec Colvin, Lecturer, Crawford School of Public Policy, Rebecca.Colvin@anu.edu.au
- Associate Professor Katherine Daniell, Research Lead, Autonomy, Agency and Assurance Institute & Fenner School of Environment and Society, Katherine.Daniell@anu.edu.au
- Dr Will J. Grant, Senior Lecturer, Centre for the Public Awareness of Science, will.grant@anu.edu.au
- Dr Catherine Gross, Visiting Fellow, Fenner School of Environment and Society, Catherine.Gross@anu.edu.au
- Paul Wrywoll, Postdoctoral Fellow, Crawford School of Public Policy, Paul.Wyrwoll@anu.edu.au

9 What role could an industry code of conduct play in gaining community support for hydrogen projects? What community engagement principles would you like to see in an industry code of conduct?

What role could an industry code of conduct play in gaining community support for hydrogen projects? What community engagement principles would you like to see in an industry code of conduct? :
An industry code of conduct could be useful if there was some certainty that it would be followed and accompanied by governance structures to enable enforcement.

An example is the Clean Energy Council's guidelines for best practice engagement for wind energy development (Clean Energy Council 2013), however, as guidelines only there is no guarantee that project proponents will adhere to the recommendations in the guidelines. Additionally, even in cases where minimum statutory requirements are exceeded (e.g. jurisdictional legislation), adverse outcomes for communities can still result (Colvin et al. 2019).

Should a code be developed, existing examples such as the Clean Energy Council could be used as a template. However, there is good opportunity for innovating on existing processes. For example, there would be benefit from incorporating the principles of justice (see diagram "Three Constructs of Justice" below) as the basis for an industry code of conduct. This would incorporate the process for decision-making, the distribution of benefits and burdens from developing the hydrogen industry, and the norms for the nature of interactions between people and groups. There is also good opportunity for implementing pre-contact review of the appropriateness of the community engagement plan (e.g. as promoted in Colvin et al. 2019).

As we are unable to include the figure of the three constructs of justice, figure from Gross (2014), we instead describe here the elements:

PROCEDURAL JUSTICE includes:
- Participation
- Information
- Unbiased decision-making

DISTRIBUTIVE JUSTICE includes:
- Need
- Equity
- Equality

INTERACTIVE JUSTICE includes:
- Respect
- Recognition
- Inclusion

These three elements of justice interact during processes of community engagement. They describe the fairness of outcomes (distributive justice), the design of process (procedural justice), and the nature of relationships (interactive justice).

Community engagement principles are numerous, and include:
- being treated with respect;
- being included in the decision-making process;
- being able to participate in the process;
- having one's voice heard; having questions and issues answered and resolved;
- having information at the right level available;
- having enough time for information to be understood and discussion to take place; and
- an unbiased decision-maker.

These implicitly reflect principles of justice as shown in the diagram above.

Clean Energy Council. 2013. Community Engagement Guidelines for the Australian Wind Industry. Clean Energy Council. Available: https://www.cleanenergycouncil.org.au/dam/cec/technologies/wind/guides/CEG-Australian-Wind-Industry-web-2013.pdf.

Colvin, R. M., Witt, G. B., Lacey, J. & Witt, K. 2019. The community cost of consultation: Characterising the qualitative social impacts of a wind energy development that failed to proceed in Tasmania, Australia. Environmental Impact Assessment Review, 77, 40-48.

Gross, C. 2014. Fairness and Justice in Environmental Decision Making: Water Under the Bridge, Abingdon, Routledge.

Response contributed by (alphabetised):
- Dr Bec Colvin, Lecturer, Crawford School of Public Policy, Rebecca.Colvin@anu.edu.au
- Associate Professor Katherine Daniell, Research Lead, Autonomy, Agency and Assurance Institute & Fenner School of Environment and Society, Katherine.Daniell@anu.edu.au
- Dr Will J. Grant, Senior Lecturer, Centre for the Public Awareness of Science, will.grant@anu.edu.au

- Dr Catherine Gross, Visiting Fellow, Fenner School of Environment and Society, Catherine.Gross@anu.edu.au
- Paul Wrywoll, Postdoctoral Fellow, Crawford School of Public Policy, Paul.Wyrwoll@anu.edu.au

10 What governance structures (such as legislation and regulation) would the federal, state and local governments need to put in place for a large scale hydrogen facility?

What governance structures (such as legislation and regulation) would the federal, state and local governments need to put in place for a large scale hydrogen facility?:
Please refer to regulation issue responses.

11 What further lessons can we learn from the mining, resources and renewable energy sectors about establishing and maintaining community support?

What further lessons can we learn from the mining, resources and renewable energy sectors about establishing and maintaining community support?:
The renewable energy industry has many examples of infrastructure development in which community experiences and subsequent lessons learned are described and analysed. For example, wind farm implementation has been studied since approximately 2005 and lessons are still being learned about the technology itself as well as its impacts on local communities. A thorough and major review of what has been learned so far should be a prerequisite for any new technology, such as hydrogen technologies. There is a wealth of expertise across Australian research institutions, especially at the ANU, The University of Queensland & CSIRO. Additionally, local community based expertise is of great value. A multi-sector and multi-institution effort to synthesise lessons from community engagement in the energy sector would provide an excellent knowledge resource for the hydrogen industry as it develops.

Across sector types, there are interactions between different scales of operation. An industry as a whole can have a social licence (or not), and the same goes for distinct and specific projects. However, the social licence of an industry, broadly, affects the social licence for specific projects. The legacy of a specific project will affect the social licence for the industry more generally.

Accordingly, for the emerging hydrogen industry, ensuring that all actors – industry, government, and otherwise – adhere to high standards of social, environmental, and economic responsibility will be important for opening opportunities of benefit to all.

Response contributed by (alphabetised):
- Dr Bec Colvin, Lecturer, Crawford School of Public Policy, Rebecca.Colvin@anu.edu.au
- Associate Professor Katherine Daniell, Research Lead, Autonomy, Agency and Assurance Institute & Fenner School of Environment and Society, Katherine.Daniell@anu.edu.au
- Dr Will J. Grant, Senior Lecturer, Centre for the Public Awareness of Science, will.grant@anu.edu.au
- Dr Catherine Gross, Visiting Fellow, Fenner School of Environment and Society, Catherine.Gross@anu.edu.au
- Paul Wrywoll, Postdoctoral Fellow, Crawford School of Public Policy, Paul.Wyrwoll@anu.edu.au

Issue 6: Hydrogen in the gas network

1 Which existing gas distribution networks or stand-alone systems are 'hydrogen ready' and which are not? What safe upper limit applies? Does this readiness include meters, behind-the-meter infrastructure, and appliances?

Which existing gas distribution networks or stand-alone systems are 'hydrogen ready' and which are not? What safe upper limit applies? Does this readiness include meters, behind-the-meter infrastructure, and appliances?:
(This section authored by John Pye, in consultation with other members in the ANU Energy Change Institute)

I would argue that no existing gas distribution networks are 'hydrogen ready' because hydrogen in the gas network does not make economic sense in Australia, and will result in over-investment similar to what we saw with our electricity 'poles and wires' fiasco. Before any networks should be considered 'hydrogen ready' there must be a very thorough evaluation of the community, environmental and economic outcomes implied by this concept.

2 What is the potential to have a test project of 100% hydrogen use in a small regional location and where?

What is the potential to have a test project of 100% hydrogen use in a small regional location and where?:
Of course this could be done, but there is little point in going down this path before clearly demonstrating that this has some kind of long-term economic and enviromental benefit in the Australian context. As discussed below, it is at the very least doubtful that renewably-produced hydrogen could ever beat electricity as a domestic energy source in this country. See to Question 4 below.

3 Which standards and regulations can be harmonised across jurisdictions considering the different structures and market settings (e.g. safety, codes of practice)?

Which standards and regulations can be harmonised across jurisdictions considering the different structures and market settings (e.g. safety, codes of practice)? :
Standards should be developed that allow end consumers to evalute their energy choices wisely from an environmental point of view. Government is responsible for setting policy that keeps Australia safe, and that includes managing the risk of climate change. Part of this policy work requires that we ensure consumers have ready access to information that avoids poor investment choices.

Many people will choose to pay a few extra dollars for a piece of equipment that is cheaper to run, or is better for the environment. From the policy side, we should ensure that the precious little information that the consume sees is that information which most effectively guides good decision making.

For example, what rating scheme could we devise that accurately communicates the cost-benefit ratio of an investment in a hydrogen-based heating system, versus PV panels, versus a heat-pump hot water system, versus a more efficient fridge? How can we make those choices as easy as possible for our citizens? Can we provide some kind of unified framework to help people with this?

The overarching principle here should be that fact that we are in the middle of a VERY FAST energy transition, where our electricity supply will be moving rapidly towards renewables, and where the use of fossil fuels is increasingly deprecated (and would eventually be subject to disincentives). Products could be labelled as being the 'Paris compatible', for example, if adoption of those products is consistent with an Australia-wide strategy to reduce overall emissions at the required rate for 1.5°C of global warming.

4 What roles should government and industry play in addressing any consumer concerns and building social acceptance?

What roles should government and industry play in addressing any consumer concerns and building social acceptance? :
The government in Australia should play NO ROLE in seeking to increase or build social acceptance of local consumption of hydrogen until such time as it is very clear that a migration to hydrogen in the gas network is to the long-term advantage of our citizens, in terms of both economic and environmental outcomes.

Under the Paris Agreement, Australia has committed to efforts to limit global warming to a maximum of 1.5°C. The recent IPCC SR15 report (https://www.ipcc.ch/sr15/) contained various scenarios in which this is achieved, and in all cases, the global use of natural gas must be reduced by *at least* 20% by the year 2030, relative to 2010 levels, and by more than 50% by the year 2050 in some scenarios.

Clearly there are strong corporate interests around the extraction, distribution and consumption of natural gas, and companies who would be very happy to be subsidised or supported during some preferably very gradual migration from fossil fuels to some sustainable alternative. We saw how strong corporate lobbying resulted in the 'poles and wires' over-investment that occurred in Australia's electricity network, which resulted in large increases in electricity bills without any meaningful reduction in energy-related GHG emissions. This appears to have been a huge missed opportunity: could not the same investment have been used to deploy large amounts of renewable energy instead, had the market rules been designed better, at the same cost to end users? We must absolutely avoid having Australia's strategy in this area hijacked by corporate interests at a time when the environmental imperatives are so critical. We must avoid investing in equipment which slows down or delays our migration to the renewable alternatives to fossil fuels. It is possible that hydrogen in the gas network could have exactly that effect, and may even increase costs to consumers in the process for only marginal benefit.

More broadly, it may be difficult to justify any continued investment in the residential gas network at all. For example:
• Natural gas hot water is not dramatically cheaper than electric hot water, and in many locations may cost more than electricity hot water. The present-day GHG emissions from natural gas hot water are substantially lower than electric hot water, and marginally lower than electric heat pump hot water, but these advantages will quickly disappear as people make increasing use of PV or solar thermal collectors for their hot water, and as we migrate to large penetrations of renewable electricity on the network. It should be noted that electric hot water represents one of the cheapest forms of energy storage that we have.
• Natural gas heating is more expensive than reverse cycle air conditioning (RCAC), and with global warming, people increasingly want an air conditioner anyway, so their heating equipment is essentially 'free'. The CO2 emissions from a high-end RCAC powered by brown coal are already similar to those from natural gas heating (calculation conducted by John Pye, July 2018 – details available on request), so there is no substantial emissions benefit from the use of natural gas heating today. As we migrate to a increasingly renewable electricity mix, the RCAC option will become increasingly advantageous.
• Induction cooktops are faster and cleaner than gas cooktops. This technology was until recently very costly, but it is now at a price point where essentially anyone can use it. IKEA has a $50 single-pot induction cooktop, for example, which is more than capable of providing the same heat output as a large gas hob. A preference for gas cooktops will increasingly be seen as dated and old-fashioned.

In fact there is little justification for most householders to continue to be connected to the conventional natural gas network, as these above points suggest, then people will start to disconnect, saving money as well as contributing to significantly lowering GHG emissions over the lifetime of any new equipment that they purchase, due to the rapid migration of the electricity network to renewable energy. If we are to implement policies that go against this natural retirement of an obsolete energy system, then we should be very careful about our reasoning and out justifications.

A residential gas network transporting ~10% hydrogen with 90% natural gas would provide some marginal reduction in GHG emissions, assuming the hydrogen is carbon neutral, but will not provide customers with cost savings, since renewable hydrogen is not going to cost less than natural gas any time soon. This hydrogen-injection scenario simply props up the gas distribution network using a high-cost energy source which cannot easily increase beyond 10% penetration, and saturates well before we reach GHG emission reductions that meet the needs of the Paris Agreement.

A residential gas network with 100% hydrogen would provide strong GHG emission reductions, but would necessitate replacement of most or all equipment currently connected to the network. New burners would be required for heating, cooking and hot water systems. There may be some additional benefits of such a network, for example the effective energy storage capacity resulting from the large volume of hydrogen in the network (althoug pipe embrittlement issues are noted). There might also be benefits to transport, in the sense that this renewable hydrogen could be compressed and pumped into vehicle tanks for local-area transport. However in this scenario, we would be using hydrogen produced renewably from electrolysis. The hydrogen produced incurs all of the efficiency losses relating to electricity production. However, unlike electricity, it cannot be used to power a RCAC at the far end. When these effects are considered, domestic space heating based on the combustion of renewable hydrogen would require an astonishing four to seven times more renewable electricity to be produced for the same carbon-neutral domestic space heating outcome as that required by PV-powered RCAC systems (calculation details can be provided on request).

Why might we *still* wish to use a 100% hydrogen gas network?

Perhaps the energy storage benefits of the hydrogen network are attractive. However, as earlier noted, this benefit comes at the cost of ~4–7× higher deployment of electricity generation capacity.

Perhaps if we shut down our gas network then our current electricity network would be unable to meet demand. Winter peak heating demand would likely be the difficulty here, however it seems unlikely that the winter peak heating demand would be so much greater than the summer peak cooling demand. Ironically, the market error that resulted in over-investment in our electricity network may be just what is needed to allow us to more rapidly shut down our domestic gas networks. It should also be noted that improvements to building codes can soften the peak winter heating demand, through better insulation, solar orientation, thermal mass, door sealing, and so on, and probably has a better environmental return than investment in PV-powered electrolysers and hydrogen burners.

Perhaps it is going to be argued that hydrogen will be produced using 'free' electricity from curtailed PV and wind production. Will this surplus electricity be available in winter when the solar resource is far lower than in summer? Will alternative forms of energy storage, such as domestic electric hot water systems, not be more cost-effective than all the extra equipment required to produce and transport hydrogen? Even if the electricity used to produce hydrogen is free, note again that four to seven times more electricity is needed for hydrogen-based domestic space heating compared to RCAC-based space heating. There are almost certainly going to be options that provide more cost-effective use of that free electricity than domestic space heating. Much more likely is the production of compressed hydrogen for use in transport.

Or perhaps we are just copying what others are doing in other countries, without considering our local conditions. There may be other places where hydrogen in the gas network makes more sense. Japan or Korea may be such places, where there are quite limited renewable energy resources, and where the economy is dependent on importable forms of energy. Such forms will be significantly more expensive, as a result of the complex processes and the larger raw electrical energy input, but they may still be the best choice in those economies. This does not imply that is also the best choice in Australia, where we have excellent renewable resources.

5 How could the actions included in Table 2 be improved? Are there other actions that should be added?

How could the actions included in Table 2 be improved? Are there other actions that should be added?:
No comment.

Issue 7: Hydrogen to support electricity systems

1 How can hydrogen production best be integrated with current electricity systems (for instance, should large-scale hydrogen production be connected to current electricity systems)? Are there barriers or risks to integration that need be addressed in the Strategy?

How can hydrogen production best be integrated with current electricity systems (for instance, should large-scale hydrogen production be connected to current electricity systems)? Are there barriers or risks to integration that need be addressed in the Strategy?:
Responses contributed by (alphabetised):

Dr Fiona J. Beck, Senior Lecturer, ARC DECRA and ANU FERL Fellow, Research School of Electrical, Energy and Material Engineering Fiona.beck@anu.edu.au

Dr Matthew Stocks, Research Fellow, Research School of Electrical, Energy and Material Engineering. matthew.stocks@anu.edu.au

The challenge for this question is the definition of best.

Best from the perspective of hydrogen producers is access to low cost electricity at a high capacity factor as these are the primary drivers of cost. Meeting the high export growth scenario from the Acil Allen report "Opportunities for Australia from Hydrogen Exports" of 1.1MT of hydrogen in 2030 requires approximately 70TWh of additional electricity generation or around 35% of current National Electricity Market generation. Large hydrogen producers are likely to have sufficient market power to contract the cheapest sources of energy with no obligations to meet reliability standards given their flexible profile. It is not clear if electricity generation for hydrogen production will occur behind the meter to avoid transmission costs (at the sacrifice of capacity factor). Competition for generation resources is likely to lead to increases in electricity costs.

Hydrogen for grid firming and storage also seems to be unlikely to be economically viable in the near future. The round trip efficiency is currently very low, and cannot compete on cost with batteries, for short-term storage, and pumped-hydro, for longer term, larger scale storage. It may be possible that hydrogen has a role to play in a future 100% renewable grid for very large-scale storage where hydrogen is stored in salt-caverns, however this is largely untested.

Best for other electricity consumers may be development of schemes in regional areas such as the Pilbara where there are good renewable energy resources but the existing market structures have not delivered low electricity prices. These schemes are less likely to connect to the larger SWIS and NEM markets and therefore less likely to negatively impact on existing markets due to increased demand. There may be some second order benefits of increased installations of renewable electricity in Australia which will help accelerate price reductions for the non-hydrogen market.

2 What, if any, future legislative, regulatory and market reforms are needed to ensure hydrogen supports, rather than hinders, electricity system operation and delivers benefits for consumers (for example by reducing demand during high price events)? What is the timeframe, and priority, for these changes?

What, if any, future legislative, regulatory and market reforms are needed to ensure hydrogen supports, rather than hinders, electricity system operation and delivers benefits for consumers (for example by reducing demand during high price events)? What is the timeframe, and priority, for these changes?:
It is likely that any regulation that ensures benefits for electricity system operation and consumers must be at the detriment of the cost of electricity for hydrogen producers . Given that the cost of electricity is a key cost driver , there is significant risk of impact on the cost of hydrogen production and reduction in Australia's competitive advantage.
While increasing in relative terms, the FCAS market in the NEM (~$200 million in 2018) is small in comparison to the wholesale energy market (~$200 billion for 18/19). Ancillary service revenues will, appropriately, be a minor component of hydrogen producers' considerations compared to energy costs. Hydrogen producers will reduce production if exposed to high price events or may choose to sell excess contracted capacity into the market.

3 Do current market frameworks incentivise the potential value of hydrogen to support electricity systems? What initiatives or changes required?

Do current market frameworks incentivise the potential value of hydrogen to support electricity systems? What initiatives or changes required?:
Hydrogen production is one of a myriad of potential suppliers of flexibility services in the electricity network including other sources of demand response, storage (pumped hydro and batteries) and conventional hydro. The focus of policy should be delivering the necessary outcomes for the secure and reliable supply independent of the technology.

The use of hydrogen for seasonal storage can be supported by existing market payments for energy. There are discussions regarding migration towards markets which have some capacity component which may assist investment in all sources of energy storage, including hydrogen. The need for seasonal storage in Australia is significantly lower than for Europe due to our lower latitude so hydrogen is unlikely to have a major role.

4 Do current market frameworks allow for sector coupling and interactions between different markets that may result from hydrogen production (such as the interplay between gas, electricity, and transport sectors)? If not, what changes are required?

Do current market frameworks allow for sector coupling and interactions between different markets that may result from hydrogen production (such as the interplay between gas, electricity, and transport sectors)? If not, what changes are required?:
Good market data is a major limitation to efficient sector coupling. While electricity market data is relatively easily available via AEMO's databases and software that mines this data, the gas market has less visibility. Good data access drives good decisions. Improving access to gas data will allow better coupling of these markets.

The current market structure allows decisions for electricity to be used for transport, heating or hydrogen production based on relative costs. Uncertainty regarding the emissions policy and technology mix is likely having greater impact than the electricity market structure.

5 What factors should be considered when selecting pilot and demonstration projects? How can government best support pilots and demonstrations?

What factors should be considered when selecting pilot and demonstration projects? How can government best support pilots and demonstrations?:
Demonstration projects should be focused on comparing technologies to identify when hydrogen has an advantage or on testing gaps in understanding of commercial feasibility. ARENA is well positioned to make informed decisions regarding support for projects in this space and should have its funding expanded beyond its current legislated life to support continued support for such development projects.

Issue 8: Hydrogen for transport

1 What groups or companies could lead a consortium approach to building refuelling infrastructure?

What groups or companies could lead a consortium approach to building refuelling infrastructure?:
Responses contributed by (alphabetised): Associate Professor Paul Burke, Dr Matt Stocks

The petroleum distribution industries are best placed to consider the opportunity for hydrogen refuelling infrastructure given their close links with Australia's current transport needs and customer interfaces. They should consider whether the most sensible investment is in hydrogen or fast charging infrastructure in their business plans, given the impact of future emission reductions.

2 What groups or companies could coordinate procurement of hydrogen cars, buses and ferries?

What groups or companies could coordinate procurement of hydrogen cars, buses and ferries?:
The case for hydrogen in these sectors in Australia is weak given the strong growth in battery electric vehicles world-wide, lower fuel costs and rapid improvements in range and charging times for battery electric vehicles.

3 Other than emissions limits and procurement policies, how could government actions (federal, state or local) support private investment in vehicles and infrastructure?

Other than emissions limits and procurement policies, how could government actions (federal, state or local) support private investment in vehicles and infrastructure?:
Emission limits and/or levies on higher-emitting vehicles are the most sensible approaches for encouraging private adoption of zero-emission vehicles. Subsidy schemes for private purchasers of zero-emission vehicles should be cautioned against on both equity and cost-effectiveness grounds.

Ideally, the policy framework for zero-emission vehicles would not be considered as part of a standalone strategy on hydrogen. Battery electric vehicles may well turn out to be more competitive. It would make more sense to instead consider the issues as part of an overall strategy on zero-emission vehicles. (See California Battery electric versus hydrogen electric uptake).

4 How can governments and industry reduce the financial, technology and operational risks of purchasing new technology vehicles?

How can governments and industry reduce the financial, technology and operational risks of purchasing new technology vehicles?:
Policy on emission limits is the most sensible driver. The market can then determine the best approach to deliver the lower emissions outcome.

5 What are some ways hydrogen vehicles could be showcased and demonstrated to the community at large?

What are some ways hydrogen vehicles could be showcased and demonstrated to the community at large?:

6 What are the key enablers and realistic timelines for a transition to:

What are the key enablers and realistic timelines for a transition to::
All of these sectors could be directly electrified rather than using hydrogen.

Long distance freight is the only sector where there may be a stronger case for hydrogen for transport. The rail and shipping industries should be engaged in discussions regarding their vision for a low emission future to determine the relative merits of hydrogen over electricity in these sectors. There are both pure electric and hydrogen fuel cell bases rail and trucks being developed. Given the significant fuel costs associated with long distance transport, the advantages of hydrogen (space, weight, refuelling time) would need to overcome the fuel cost savings of direct electrification. The commuter rail network already has extensive experience of the benefit of direct electrification via catenary lines in most capital cities.

It is difficult to see hydrogen have a significant role in light transport (see additional comments).

Hydrogen fuelled forklifts are a minor part of the transport mix. This should not affect policy direction.

Additional Comments:

There is clearly a need for a transition to zero emissions vehicles. Most of the questions that are being asked (1, 2, 5 and 6) should be reframed in the context of zero emissions transport rather than presenting hydrogen as the solution. The questions should be asked how to best manage the broader transport transition.

The electric to wheel fuel costs of hydrogen based on fuel cells is fundamentally higher than direct electric due to much lower efficiency. A variety of studies indicate between a factor or two and four greater electricity consumption [https://theconversation.com/why-battery-powered-vehicles-stack-up-better-than-hydrogen-106844]. The case for hydrogen in transport needs to demonstrate advantages in other areas for the case to be made for hydrogen (e.g. seasonal storage, avoided electricity peaks, consumer preferences). Hydrogen will have the benefit of accessing wholesale prices for electricity for production, reducing fuel generation costs. It is not clear what the future costs for charging electric vehicles will be (e.g. domestic overnight time of use charges) but domestic charging from roof top PV would be lower in cost than hydrogen. It is not unrealistic to envisage autonomous vehicles returning home to charge.

Light vehicles are the largest consumers of fuel and consequent producers of emissions from transport. The primary competition to hydrogen as a transport fuel for light vehicles are battery electric vehicles. The references in the Issues Paper to the case study of California is a case in point. The 2018 Annual Evaluation of Fuel Cell Electric Vehicle Deployment & Hydrogen Fuel Station Network has projections for electric vehicles that vastly exceed those for hydrogen based (FCEV) vehicles. Californian residents have similar driving behaviour (commutes/annual distance) to Australia. The presence of 64 hydrogen re-fuelling stations have not been sufficient to drive a strong uptake in hydrogen vehicles relative to electric. California has cumulative sales of electric vehicles of over 500,000 with 7% of new sales now electric, predominantly pure battery sales [http://www.thedetroitbureau.com/2018/12/sales-of-electric-vehicles-growing-steadily-in-california/]. This compares to the 4411 FCEV vehicles registrations in California reported in the Issues Paper.

There is no air quality advantage in hydrogen over battery electric vehicles. The transition to zero emissions vehicles benefits air quality with all approaches.

The primary driver for hydrogen fuel cell development for transport has been in Japan. If hydrogen is being imported as a fuel source, it may make sense to use it as a transport fuel. Given Australia is unlikely to have shortage of electricity, the case for hydrogen is less strong. Fuel cells have not delivered the price reductions of batteries to be competitive. Even the presence of a large export market for hydrogen does not directly lead to transport uptake given the likely concentration of the hydrogen generation at export hubs and the need to transport it to the point of use.

Electric vehicles have a head start in that infrastructure already exists. The electricity network covers the vast majority of the Australian population. The electricity distribution network has significant space capacity after the evening peak for charging electric vehicles. Daytime charging would also help increase load when rooftop solar is exporting. Hydrogen may be able to benefit from the existing electrical infrastructure if electrolysers were distributed on the transmission networks at the point of use (e.g refuelling station), avoiding the need for pipelines or trucking infrastructure.

Trials of hydrogen buses, ferries and the like should be supported by government on the basis of comparison with direct electric to determine the optimum solution for that transport service. This needs to include the likelihood of the fuel source being widely available in the needed timeframes.

Issue 9: Hydrogen for industrial users

1 Hydrogen as a chemical feedstock

Hydrogen as a chemical feedstock:
Metal production can be done using either hydrometallurgical, pyrometallurgical or electrolysis routes. The question is answered in two parts:
(a) “Reducing” emissions from metal manufacture – this can be done to varying degrees by efficiency improvements, new reactor designs, heat recuperation, partly replacing coal with biomass etc. For example, specific to steel making, cyclone converter (HiSarna) technology, dry-slag granulation, top-gas recovery turbine (TRT), charcoal-based reduction, renewable electricity can all lead to reduction in emissions [1].
(b) “Zero-carbon” metal production – For the metals which are produced using electrolysis (such as Hall-Heroult process for aluminium), renewable electricity is the key. The Bayer’s process for production of alumina from bauxite is also energy intensive and requires high temperature heat. Integration of solar thermal into such processes would be quite attractive [2].
Steelmaking: First of all, retrofitting of current BF-BOF plants with CCS can yield about 50-60% reduction in CO_2-emissions, not completely eliminate CO_2 [3, 4]. Hydrogen on the other hand, if prepared from green energy sources, has the potential to yield 98+% reduction in CO_2-emissions footprint [5]. Apart from H_2-reduction, there are other technologies (at various stages of development) for zero-carbon steelmaking. These are electrolysis based. Low temperature aqueous phase electrolysis [6] is at the pilot demonstration stage, whereas the high temperature molten-oxide electrolysis is still very early stages of development [7].

[1] Koen Meijer, Mark Denys, Jean Lasar, Jean-Pierre Birat, Gunnar Still & Bernd Overmaat (2009) ULCOS: ultra-low CO2 steelmaking, Ironmaking & Steelmaking, 36:4, 249-251, DOI: 10.1179/174328109X439298

[2] University of Adelaide, Solar thermal in the Bayer alumina process, https://www.adelaide.edu.au/cet/solar-alumina/partners
[3] IEAGHG, Iron and Steel CCS Study (Techno-economics integrated steel mill), pp. 3, 2013. https://ieaghg.org/docs/General_Docs/Reports/2013-04.pdf
[4] H. Mandova, P. Patrizio, S. Leduc, J. Kjärstad, C. Wang, E. Wetterlund, W. Gale (2019) Achieving carbon-neutral iron and steelmaking in Europe through the deployment of bioenergy with carbon capture and storage. Journal of Cleaner Production, 218, 118–129. DOI: 10.1016/J.JCLEPRO.2019.01.247
[5] HYBRIT (2018). Fossil free steel, Summary of findings from HYBRIT pre-feasibility study.
[6] SIDERWIN (2018). Development of new methodologies for industrial CO2-free steel production by electrowinning.
https://siderwin-spire.eu/sites/template.drupal.pulsartecnalia.com/files/documents/SIDERWIN-Project%20Presentation%20-%20WEB_v0.1.pdf
[7] Boston Metals, Molten Oxide Electrolysis, https://www.bostonmetal.com/moe-technology/#moe-process

2 Hydrogen for industrial heat

Hydrogen for industrial heat:
The industrial heat applications can range from low-grade heat (<200ºC) to medium temperature (200-400ºC) to very high temperature (>400ºC up to 2000ºC). Assuming that the heat recuperation and efficiency improvement options have been exhausted, alternative sources of energy/heat need to be employed for reducing emissions. Due to hydrogen’s high calorific value and it’s high adiabatic flame temperature, hydrogen is a high-value, high-energy fuel. Given this fact, it is not ideal to use hydrogen for low and medium temperature heat applications, unless the price of green hydrogen falls drastically.
Options: <150ºC – heat pumps, solar thermal (evacuated tubes/parabolic troughs).
Up to 400ºC – solar thermal (parabolic troughs), biofuels.
High temperatures – solar thermal (tower, dish), biofuels.
There are alternatives to hydrogen for providing industrial heat, in each temperature range. However, there are several considerations in addition to the cost. In case of solar-thermal, integration with existing process is non-trivial and may not be possible in many cases. Bio-fuels are resource-constrained and may be economical only under certain scenarios and in certain regions [8].
The advantage of using hydrogen (if it can be produced economically) are dispatchability, storage, ease-of-integration with existing reactor/processes, no contaminants (soot, char, sulphur).

[8] Elie Bellevrat and Kira West (2018) Commentry: Clean and efficient heat for industry.
https://www.iea.org/newsroom/news/2018/january/commentary-clean-and-efficient-heat-for-industry.html

3 Supplying clean hydrogen for industrial users

Supplying clean hydrogen for industrial users:

4 Technical considerations in transition to clean hydrogen

Technical considerations in transition to clean hydrogen :

5 Hydrogen safety and regulation for industrial users

Hydrogen safety and regulation for industrial users:

6 Role for governments in supporting a transition to clean hydrogen

Role for governments in supporting a transition to clean hydrogen:
Even if the cost of renewable hydrogen production becomes comparable to the fossil-based hydrogen (which may take more time without incentives), the industries which use hydrogen as a chemical feedstocks (ammonia/fertilizer, petrochemicals etc.) may not readily adopt renewable hydrogen technologies. This is due to the fact that the technologies for producing green hydrogen require significantly new infrastructure development compared to the currently dominant steam methane reforming route. Cost of emitted CO2 would be imperative to provide motivation for moving to a new process.
The issue is further compounded in case of new applications for hydrogen, such as, H2-based steelmaking. In addition to the new infrastructure required for hydrogen productions, the old blast-furnaces and its associated process units need to be scrapped in favour of new H2-reduction reactors. The cost of stranded assets and new greenfield development costs would be even higher for such applications. Hence, implementation of appropriate carbon-pricing, push for safety, codes and standards development for hydrogen would be imperative for supporting an Australian industry transition.

Additional upload

1 Upload supplementary evidence or document

Upload your file:
hydrogen issues paper cover.doc was uploaded