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CONSULTATION SUBMISSION

Global Carbon Capture and Storage Institute Response to the National Hydrogen Strategy Issues Papers

July 2019

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Introduction to the Global Carbon Capture and Storage Institute

The Global Carbon Capture and Storage Institute (the Institute) is an international think-tank whose mission is to accelerate the deployment of carbon capture and storage (CCS) as an imperative technology in tackling climate change.

The Institute is headquartered in Melbourne, Australia, with offices in Washington DC, London, Brussels, Beijing and Tokyo. The Institute is a specialist global organisation with deep expertise in all aspects of CCS including capture technology, geological storage, policy, law and regulation, economics, and public engagement.

Structure of this submission

The Institute welcomes the opportunity to comment on the recent National Hydrogen Strategy Issues Papers. The Institute previously made a submission to the COAG Energy Council Hydrogen Working Group to inform the development of Australia's National Hydrogen Strategy. This submission reiterates key conclusions drawn from the Institute's original submission, many of which appear to not have been appropriately reflected in the Issues Papers. This submission then provides brief comments on a selection of passages from the Issues Papers where the potential contribution of CCS to the production of clean hydrogen in Australia has not been recognised. Where applicable, references are provided for each comment.

The Role of CCS in enabling a competitive Australian clean hydrogen industry

This section draws conclusions from the Institute's March 2019 submission to the COAG Energy Working Group on the development of Australia's National Hydrogen Strategy. The reader is encouraged to review that submission, including the comprehensive references provided therein.

The production of hydrogen from coal or methane with carbon capture and storage is the lowest cost source of clean hydrogen by a considerable margin.

- The cost of hydrogen produced from methane or coal with CCS today is approximately $2.50-$3.50 per kilogram. The cost of hydrogen produced using renewable electricity and electrolysers is approximately $11 per kilogram for dedicated renewable generation capacity and $26 per kilogram for otherwise curtailed renewable generation[i].

The production of clean hydrogen from coal or methane with carbon capture and storage is proven and operating at commercial scale now.

- Today there are four facilities in operation and two under construction that produce clean hydrogen from fossil fuels with CCS at large scale (200 to 1,300 tonnes hydrogen/day).
    - Great Plains Synfuel Plant in North Dakota, United States, commenced operation in 2000, produces approximately 1,300 tonnes of hydrogen per day in the form of hydrogen rich syngas from brown coal gasification with CCS[ii]

- Air Products Steam Methane Reformer for Valero Refinery with CCS in Texas, United States, commenced operation in 2013, produces approximately 500 tonnes of hydrogen per day from natural gas reforming with CCS[iii]
- Coffeyville Gasification Plant in Kansas, United States, commenced operation in 2013, produces approximately 200 tonnes of hydrogen per day from petroleum coke gasification with CCS[iv]
- Quest CCS in Alberta, Canada, commenced operation in 2015, produces approximately 900 tonnes of hydrogen per day from natural gas reforming with CCS[v]
- Alberta Carbon Trunk Line (ACTL) in Alberta, Canada, is in construction, when operating, ACTL will enable clean hydrogen production in two projects[vi]:
  - Alberta Sturgeon Refinery, producing more than 240 tonnes of hydrogen per day via asphaltene residue gasification with CCS
  - Agrium fertiliser, producing more than 800 tonnes of hydrogen per day via natural gas reforming with CCS

The utilisation of renewable electricity to produce hydrogen using elctrolysers is an inefficient use of a scarce and valuable resource that is better used to displace higher emissions electricity generation capacity in the grid to deliver greater emissions abatement.

- The production of clean hydrogen using PEM electrolysis uses 25 times more electricity than steam methane reforming with CCS and 12 times more electricity than coal gasification with CCS.
- For example, the electricity demand of a small hydrogen production facility (100 tonne per day production) using PEM electrolysers would exceed that of a facility using coal with CCS by more than 200MW. The opportunity cost, in terms of emissions abatement of using that 200MW of renewable electricity to produce hydrogen instead of using it to displace coal generation in the grid, is approximately 1.5Mt CO_2 per year.

Hydrogen is only being pursued because of the emissions abatement that it can deliver. For hydrogen to make a meaningful contribution to global greenhouse gas emission reductions, it will need to be produced in very large quantities to displace a significant proportion of current fossil fuel demand. Scaling up clean hydrogen production to a meaningful level from renewable energy and electrolysers in the foreseeable future is not credible.

- The COAG briefing paper provides one estimate of future hydrogen demand; growing from around 60Mtpa today to over 530Mtpa by 2050. Currently, only around 4 per cent of global hydrogen production (approximately 2.5Mtpa) is from electrolysis of water[vii].
- The production of 500Mtpa of clean hydrogen via electrolysis would require approximately 25,000TWh[1] of electricity supplied by renewable or nuclear generation. This is approximately 2.8 times the total electricity generated from all renewable sources and nuclear combined in 2017[viii].[2] The availability of sufficient nuclear and renewable generation capacity to meet this demand for hydrogen production, as well as the future demand for low emissions electricity is simply not credible.
- In comparison, scaling up hydrogen production from methane or coal with CCS is far less challenging. The necessary inputs (coal, methane, pore space for CO_2 storage) are

[1] Assuming 50kWh of electricity per kilogram of hydrogen produced.

[2] IEA World Energy Outlook 2018: Estimated electricity generated in 2017 from Nuclear was 2637TWh, from all renewables combined was 6351TWh.

plentiful, and the technology is proven at large scale to be the lowest cost source of clean hydrogen.

The most important pre-requisite for a successful hydrogen production and export industry is price. The lowest cost source of clean hydrogen is coal or gas with CCS. The market will choose the lowest cost supplier. Australia must be a low-cost producer to win market share. It is commercially naïve to assume that Australia's competitors will not move to establish themselves as the suppliers of low-cost clean hydrogen to a growing global market. If Australia chooses the uncompetitive, high cost option of renewable powered electrolysis, Australia will miss the opportunity to build a clean hydrogen production and export industry.

- For example, the United States of America enjoys very low-cost methane, progressive policies that create significant incentives to incest in CCS, large demand for CO_2 for enhanced oil production, massive geological storage capacity for CO_2, significant pipeline infrastructure for the transport and storage of CO_2, 50 years of experience doing CCS at commercial scale, a powerful industrial base and capital available for investment.

The creation of a clean hydrogen production industry can minimise the damaging economic and social disruption that may occur in communities that depend upon fossil fuel production or utilisation as a primary source of employment, protecting and creating skilled and high value jobs and delivering a *just transition* for those communities.

- The Latrobe valley of Victoria is one such community that risks severe economic and social impacts from the inevitable closure of the existing brown coal fired electricity generating facilities. Clean hydrogen production with CCS in regions with access to necessary feedstocks and geological storage resources can be the anchor investment required to establish a low-emission industry hub. Nearby existing high-emission industries can utilize the CO_2 transport and storage infrastructure to reduce their emissions (e.g. Longford gas plant in South Gippsland).
- The alternative is the flight of capital, economic activity and jobs from the Latrobe Valley as the existing fleet of brown coal fired power stations inevitably close and are not replaced.

Other governments are significantly more advanced than Australia in enabling investment in, or studying the potential of, low emissions hydrogen production to deliver economic and climate benefits. The proven low-cost clean hydrogen production option of fossil fuel feedstock with CCS is the chosen technology.

- Examples of significant government support for activities related to clean hydrogen production from coal or gas with CCS are listed below.
  - The Canadian and Alberta governments have collectively provided grant funding of CAN$558m for the Alberta Carbon Trunk Line (ACTL), which commenced construction in 2018. When in operation by the end of 2019, ACTL will enable clean hydrogen production at the Sturgeon refinery (asphaltene residue gasification) for use in the oil refinery, and in the Agrium fertiliser plant (natural gas reforming) for fertiliser production.
  - Teesside CO_2 hub study: Objective is to decarbonise the UK 's largest energy intensive industrial center where 50 per cent of the UK's hydrogen is produced (Teesside has the UK's largest steam Methane Reformer and largest fertiliser plant).
  - CO_2-Sapling Transport and Infrastructure Project: Through this, the ACT Acorn project aims to open up commercial opportunities for CO_2 transport and storage and the production of clean hydrogen from natural gas at St Fergus.

- The Rotterdam Nucleus: This study is exploring the large-scale production and use of clean hydrogen produced from fossil fuel feedstocks with CCS in the Rotterdam industrial area.
- CO_2 cross-border transport connections: This study is investigating options to decarbonise Teesside and to convert Vattenfall/Nuron's Magnum gas fired power station in Netherlands to hydrogen.

Comments on Issues Papers

ISSUE PAPER 1

<table>
<tr><th>Section and page</th><th>Statement</th><th>Comment</th></tr>
<tr>
<td>Challenges, Barriers and Risks, ‘Technology commercialisation’, p.4</td>
<td>“The International Energy Agency expects CCS could lead to reductions of up to 90% of carbon emissions from steam reformation, if applied to both process and energy emissions streams”.</td>
<td>Up to 94% of emissions from hydrogen production via auto thermal reforming (ATR) of methane can be captured.

Up to 98% of emissions from hydrogen production via brown or black coal gasification can be captured, if applied to process and energy streams.</td>
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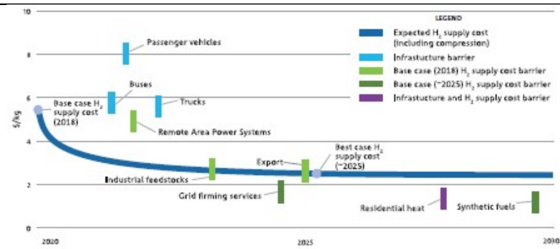
<td>Figure 2, “Hydrogen competitiveness in targeted applications” within the Challenges, Barriers and Risks, ‘Supply Chain Cost Reductions’ section, p.5:</td>
<td>
</td>
<td>This chart plots the cost of dirty hydrogen generated from grid powered electrolysers, which is currently estimated by CSIRO to be $5.50/kg[i]. This hydrogen would have an emission intensity of approximately 50kg of CO_2 per kilogram of hydrogen if produced in Australia (NEM). Thus, it has no value as an emissions abatement option, and no marketability in any low emissions hydrogen market.

The cost of clean hydrogen production from coal or gas with CCS, which is currently around $2.50-$3.50/kg, is a glaring omission from this chart.</td>
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<tr>
<td>Challenges, Barriers and Risks, ‘Supply Chain Cost Reductions’ section, p.5:</td>
<td>“There is currently only one hydrogen project using CCS technology at commercial scale globally, which captures 40 per cent of the carbon dioxide produced by the facility.”</td>
<td>This statement is incorrect. Today, there are four facilities in operation and two under construction, that produce clean hydrogen from fossil fuels with CCS at large scale (200 to 1,300 tonnes hydrogen/day) utilising local resources:

Great Plains Synfuel Plant in North Dakota, United States, commenced operation in 2000, produces approximately 1,300 tonnes of hydrogen per day in the form of hydrogen rich syngas from brown coal gasification with CCS[ii]
Air Products Steam Methane Reformer for Valero Refinery with CCS in Texas, United States, commenced operation in 2013, produces approximately 500 tonnes of hydrogen per day from natural gas reforming with CCS[iii]
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Quest CCS in Alberta, Canada, commenced operation in 2015, produces approximately 900 tonnes of hydrogen per day from natural gas reforming with CCS[v]

Under construction

Alberta Carbon Trunk Line (ACTL) in Alberta, Canada, is in construction. ACTL will enable clean hydrogen production in two projects[vi]:

Alberta Sturgeon Refinery, producing more than 240 tonnes of hydrogen per day via asphaltene residue gasification with CCS and;
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</table>

Section and page	Statement	Comment
		○ Agrium fertiliser, producing more than 800 tonnes of hydrogen per day via natural gas reforming with CCS.
Challenges, Barriers and Risks, 'Supply Chain Cost Reductions' section, p.5:	*"The International Energy Agency estimates the cost of achieving a 90% or more reduction in carbon dioxide using CCS to be around $80 US per tonne of carbon dioxide in hydrogen production facilities, and up to $90-115 per tonne of carbon dioxide in integrated ammonia/urea and methanol production facilities (as these facilities have more diluted carbon dioxide streams, increasing carbon capture costs)".*	The familiar process of cost reductions with increasing deployment that is observed in all technologies is also being observed in CCS. New technologies will deliver further cost reductions. One current example is the Allam cycle which uses supercritical carbon dioxide to drive a highly-efficient gas turbine, producing power with inherent 100 per cent carbon capture. It has been proven at the 30MW (electrical output) scale and is about to be scaled up to 300MW. In June 2019, Bill Brown, CEO of 8 Rivers Capital and NET Power, stated that Net Power can integrate its innovative power cycle technology with hydrogen production technology to deliver clean hydrogen production at around $1/kg[ix]. This is half the current cost of clean hydrogen production from coal with CCS.
Challenges, Barriers and Risks, 'Supply Chain Cost Reductions' section, p.6	*"The cost of hydrogen produced from renewable-based electrolysis is currently expensive. However, there is potential for ongoing volume-driven innovation to bring electrolysis costs down in the near to mid-term"*	For completeness and full transparency, the costs of renewable-based electrolysis should be outlined in the same detail as hydrogen production using fossil fuels in the previous paragraph. The current cost is $11 per kg for hydrogen production via electrolysis using dedicated renewable electricity compared to approximately $2.50-$3.50 per kilogram for clean hydrogen produced using coal or methane with CCS[i].
Challenges, Barriers and Risks, 'Supply Chain Cost Reductions' section, p.8	*"Australia will need to actively develop international markets to achieve scale cost efficiencies. Australia's hydrogen largest opportunity is as a supplier to other countries. This means the speed at which our industry scales up will be highly dependent on demand stimulus in other countries.* *Preliminary estimates by the Working Group indicate that Australia would need to build around the equivalent of 3 GW of new solar power or around 2GW of new wind power in the next ten years to supply one-third of Japan's target of 300,000 tonnes of carbon-free hydrogen imports by 2030. This target could be easily achieved – for example Australia currently has around 14.5GW of new wind and solar under construction."*	A more realistic option, which has not been discussed in the paper, is to build just *one* coal gasification hydrogen production facility with CCS with the capacity to supply 100% of Japan's 2030 clean hydrogen import target. This technology is commercially available today and has been proven at large scale to be the lowest cost source of clean hydrogen. It would produce competitively priced clean hydrogen. An example is the Great Plains Synfuel Plant in North Dakota, United States. This facility commenced operation in 2000, produces approximately 1,300 tonnes of hydrogen per day in the form of hydrogen rich syngas from brown coal gasification with CCS[ii]. This option would also enable the utilisation of new renewable electricity generation capacity to displace higher emissions generating capacity from the NEM (rather than being used for hydrogen production), delivering millions of tonnes of additional emission abatement.
Scale-up support, p.10	*"Establishment of hydrogen production, transport and storage facilities, particularly if coupled with extensive renewable energy generation development, may represent a significant change to the current landscape and economies of the regions in which they are established".*	Regions with existing allied industries, for example coal production in the Latrobe Valley, could support the establishment of a competitive clean hydrogen industry at a globally relevant scale, with negligible change to the current landscape, and minimal disruption to the economy of the region. It would not require significant additional land (e.g. for windfarms) as activity would be largely contained within the footprint of existing industrial activities (e.g. coal mining). Further, the jobs, investment and economic activity associated with coal mining and utilisation in the region would continue as the use of that resource switches from current high-emissions power generation to future low emissions hydrogen production.

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Section and page	Statement	Comment
	"While communities could benefit significantly from the availability of co-located renewable energy and electrolysis facilities, particularly where they provide for new local industries, issues could arise if changes lead to a loss of amenity or cost of living increases. Ideally, efforts to provide support for and build community acceptance and understanding of hydrogen would occur ahead of and during large-scale construction, so that this can occur quickly and with the endorsement of the host community". *"The emergence of a new industry in hydrogen will see the need for ongoing support for the local workforce and community. Re-training and skilling of the local workforce is likely to be needed to ensure capable and skilled staff are available to meet ongoing industry needs. Establishment of new community facilities or upgrade of existing facilities may be needed in response to changes to local communities".*	This statement notably excludes any mention of the ability to avoid most of the economic and social disruptions of a new hydrogen industry if clean hydrogen production with fossil fuels and CCS is adopted. For regions with existing mining and industrial infrastructure (e.g. Latrobe Valley of Victoria), this would avoid additional amenity impacts. The requirement to devote land currently used for other purposes to hydrogen production (e.g. windfarms to supply electrolysers) would be minimal as the physical footprint of the development would be largely retained within the existing mining and industrial developments. The continued use of local resources, and the extension of extractive industries already sustaining these regions, has the added benefit of enjoying high levels of community acceptance. In addition, the requirement for reskilling the local workforce is diminished. A successful clean hydrogen industry will require all the skills currently required by the extractive and chemical industries including general management, community and environmental management, project management, commercial and legal services, civil, chemical, process, electrical, mechanical and petroleum engineers, geologists supported by a skilled technical workforce.

ISSUE PAPER 2: ATTRACTING HYDROGEN INVESTMENT

Comment
Issue paper 2 fails to mention the most important factors in attracting investment – risk and return. In both factors, the production of clean hydrogen using fossil fuels with CCS is the optimal solution. It is a mature technology with years of operational experience at commercial scale, meaning it is low risk, and is the lowest cost clean hydrogen production method, meaning it is competitive and delivers the highest return. It is commercially naive to believe that a private sector investor will choose a higher risk/lower return technology like renewable powered electrolysers over a lower risk/higher return technology like coal gasification with CCS. Put another way, very significantly less public policy support or subsidy will be required to attract private sector investment to fossil clean hydrogen production with CCS than renewable hydrogen production with electrolysers. The scaling up of hydrogen production from methane or coal with CCS is far less challenging compared to electrolysis. The necessary inputs to produce hydrogen with fossil fuels and CCS (coal, methane, pore space for CO_2 storage) are plentiful, and the technology is proven at large scale to be the lowest cost source of clean hydrogen. This is demonstrated by the four facilities in operation and two under construction that produce clean hydrogen from fossil fuels with CCS at large scale (200 to 1,300 tonnes hydrogen/day) utilising local resources. Australian governments (i.e. federal and state) could kick-start this new industry by working with foreign governments seeking a reliable and competitively priced supply of clean hydrogen to make strategic investments in hydrogen related infrastructure to attract private capital. The Australian, Victorian and Japanese governments' support for the Hydrogen Energy Supply Chain project is an example.

ISSUE PAPER 5: COMMUNITY CONCERNS

Section and page	Statement	Comment
Carbon emissions, p.3	*"In its submission, the ANU Energy Change Institute noted that 'generating hydrogen with electrolysis may lead to short term increases in greenhouse gas emissions, if the electricity used is not fully renewable".* *The study conducted by ANU Energy Change Institute noted this depends on whether the rate of growth of renewable electricity capacity matches the pace of growth in demand. Additional fossil-fuel based electricity will be required to meet the hydrogen demand between 2025 and 2040, if the rate of renewable capacity installation remains constant at 2018 levels. A new hydrogen facility using electrolysis will not result in increased emissions if the operators choose to build new renewable electricity production capacity to power it".*	The concerns raised by the ANU are valid. Suggesting that Australia invest in a technology that will materially increase emissions from fossil fuel power generation in order to produce hydrogen by electrolysis is incomprehensible. Further, the opportunity cost, in terms of emissions abatement, of using giga watts of renewable electricity to produce hydrogen via electrolysis instead of using it to displace high emissions coal generation in the Australian grid would be measured in tens of millions of tonnes per year. The alternative, rational option, is to maximise the use of renewable electricity in the grid to displace high emissions coal and produce clean hydrogen from coal or gas with CCS.
Water consumption and land use, p.6	*"Using existing desalination plants for hydrogen production might improve efficiency of utilisation of these assets. In any event, when implemented at large scale, using desalinated seawater adds just a few percent to the cost of producing hydrogen"*	Desalination is an energy intensive process. To make environmental sense, the energy used for this process must be low emissions. Increasing the demand for desalinated water for hydrogen production will increase demand for grid electricity. This demand cannot be met with intermittent renewable sources alone, hence will increase fossil fuel energy production and, in turn, increase emissions.
Lessons from other sectors, p.7	*"Community expectations about safety, land and water use are not unique to hydrogen: any proposed large industry, renewable electricity or resource project will need to address similar expectations in order to build the trust and support of the public".*	A notable omission in this section is a case study/case studies on examples of successful community engagement on hydrogen production from fossil fuels with CCS, for example the community consultations and outreach activities undertaken by Japan CCS Co., Ltd for the Tomakomai CCS Demonstration Project in Japan and by Shell for the Quest CCS Project in Alberta, Canada.

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ISSUE PAPER 9: HYDROGEN FOR INDUSTRIAL USE

Section and page	Statement	Comment
Hydrogen feedstock supply, p.3	*"Presently, however, a transition to clean hydrogen for those currently producing hydrogen on-site would most likely involve replacing SMR by production of hydrogen from water via electrolysis using renewable electricity".*	A more realistic pathway would be to transition to coal gasification or Steam Methane Reformation with CCS to produce low emissions hydrogen. These technologies are proven at scale, are already commercially deployed, and have demonstrated lower cost for large scale production than renewables with electrolysis. Examples of this process working today, and referenced previously, include: • Great Plains Synfuel Plant in North Dakota, United States, commenced operation in 2000, produces approximately 1,300 tonnes of hydrogen per day in the form of hydrogen rich syngas from brown coal gasification with CCS • Air Products Steam Methane Reformer for Valero Refinery with CCS in Texas, United States, commenced operation in 2013, produces approximately 500 tonnes of hydrogen per day from natural gas reforming with CCS • Coffeyville Gasification Plant in Kansas, United States, commenced operation in 2013, produces approximately 200 tonnes of hydrogen per day from petroleum coke gasification with CCS • Quest CCS in Alberta, Canada, commenced operation in 2015, produces approximately 900 tonnes of hydrogen per day from natural gas reforming with CCS.
Technical issues for hydrogen as a feedstock, p.4	*"During recent roundtables, current users of hydrogen explained that technology to produce clean hydrogen via electrolysis already exists and the method of operation is well understood. However, as electrolysers are not yet mass-produced, their cost remains high. Consultations with electrolyser manufacturers revealed they have capacity for higher production but demand has not yet reached a point to deliver cost reductions through economies of scale. While the demand for electrolysers builds, industrial users could look to transition their equipment incrementally, perhaps in line with retirement of existing SMR units".*	A commercial operation that requires hydrogen production at an industrial scale i.e. through Steam Methane Reformation is not going to transition to a more expensive source of hydrogen that is unproven at commercial scale (i.e. electrolysis with renewables). Renewable powered electrolysers may become competitive with fossil based clean hydrogen production with CCS in decades to come, however neither the clean hydrogen market, nor the global climate, will wait.

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Section and page	Statement	Comment
Hydrogen for industrial heat, p.4	*"While hydrogen might not be cost-competitive for industrial heating now, the price of hydrogen produced from electrolysis is projected to decrease considerably over the next decade".*	Clean hydrogen production from fossil fuels with CCS is proven, operating at commercial scale and available for deployment right now at one third the cost of renewable hydrogen produced via electrolysis.
The transition pathway, **Table 1: Actions along the transition pathway for industrial users, p.8**	***2025-2030*** • *Share learnings from demonstration projects to other industrial users* • *Support the transition from demonstration to large scale use of hydrogen in industry* • *Identify other potential industries that can use hydrogen and continue demonstration projects* • *Continue research, development as required* • *Continue education and training activities* • *Review regulatory framework to ensure it is fit for purpose*	The deployment of commercial production of clean hydrogen from coal or gas with CCS in this period should be the priority. The urgency attached to climate action and the rising risk of Australia missing the economic opportunity to establish itself as a competitive supplier of clean hydrogen should be the primary concerns. Continued research and demonstration of renewable powered electrolysers should continue, however action to reduce emissions and take a position in the market cannot wait for renewable powered electrolysers to become competitive and be proven at commercial scale.

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References

[i] Bruce S, Temminghoff M, Hayward J, Schmidt E, Munnings C, Palfreyman D, Hartley P (2018) National Hydrogen Roadmap. CSIRO, Australia.

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[iv] CVR Partners (2013), "CVR Energy Annual Report", available at: http://www.annualreports.com/HostedData/AnnualReportArchive/c/NYSE_CVI_2013.pdf

[v] International Energy Agency. (2017) "World Energy Outlook 2017", available at: https://www.iea.org/weo2017/

[vi] Global CCS Institute. (2019), "CO2RE Database, Facilities Report", available at: https://co2re/FacilityData

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[viii] International Energy Agency. (2018) "World Energy Outlook 2018", available at: https://www.iea.org/weo2018/

[ix] Page, Brad (GlobalCCS_Brad). "Stunning numbers from @billmetoday on NetPower – CO_2 capture at $2 / tonne and hydrogen production at around $1/kg. Breadth of application incredible. Full size plant in Texas expected in 2021 following successful demonstration #gamechanger"" 12 June 2019, 12:49pm. Tweet.