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Government Relations

The Hydrogen Economy 19.12.18

The hydrogen economy describes an energy system relying upon hydrogen. Hydrogen can be applied as a low-emission source of energy for transportation, power generation and other applications. Globally, hydrogen is increasingly seen as an important part of a decarbonised, low emissions energy policy.

Australia's Chief Scientist, Alan Finkel, has briefed energy Ministers on Australia's potential to contribute the Hydrogen Economy. This Brief overviews the global interest in hydrogen energy and how it is increasingly seen as an important low-emission part of the energy mix.

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What is Hydrogen Energy?

Hydrogen has the highest energy content of any common fuel by weight. It typically does not exist alone in it gas form (H_2) and needs to be produced by extracting it from compounds such as water (H_20), methane (CH_4), other hydrocarbons, wood and petroleum.

Hydrogen is a low polluting fuel that can be used for transportation, heating, and power generation. It has the highest energy content of any common fuel by weight, but the lowest energy content by volume. Hydrogen can be produced and stored for on-demand applications.

The simple chemical reaction of hydrogen in combination with oxygen creates heat - with water as the by-product. The release of energy can be also be achieved through devices called fuel cells (FCs). Fuel cells create energy electrochemically, with direct current (DC) voltage and water produced. Fuel cells do not burn fuel although hydrogen can be burned in an internal combustion engine. There is also research underway in Australia looking at the use of catalytic release of energy in the form of steam.

Sources of hydrogen include reformation of natural gas, diesel, gasified coal, or gasified biomass. Renewables such as wind and solar are seen as a complementary low-cost energy source able to produce hydrogen for storage and later use.

Combining Renewables in Energy Production

Electrolysis and steam reformation of hydrocarbons are currently the main methods of producing hydrogen. Electrolysis has the advantage of not producing greenhouse gases as a by-product, but has its drawbacks, namely the high cost of electricity from the grid to power the process and its low level of production efficiency.

The electrolytic process occurs when an electrical current is passed through water, separating the water molecules into oxygen and hydrogen gas.

These cost and volume challenges of hydrogen production are assisted with advancements in renewable technologies, seeing their efficiencies increase and costs reduced thus improving the viability of large-scale commercial carbon-free hydrogen production. Given the volatility of wind and solar production, the excess energy can be used to produce hydrogen which can then be stored for later use.

Key Challenges for Hydrogen Energy

Industry uncertainty over government policy

Government advocacy and clear policy is required to enable in the decision-making process of industry. Some leading jurisdictions such as the EU have stronger policy direction whereas Australia could benefit from a nationally coordinated approach pulling together disparate approaches from individual States.

Lack of demand

One simple explanation for lacklustre growth in the sector relates to demand for hydrogen. Industrial demand has remained relatively stable over the years, hence not providing the needed demand for innovation in the sector. Additionally, the rise in popularity of electric vehicles in the last decade has delayed demand for hydrogen fuel cell electrical vehicles (HFCEV).

With general consumer applications requiring hydrogen such as HFCEVs gaining traction in markets world-wide, and new projects in stationary energy, transport and heating being supported by governments, the demand for hydrogen as an energy carrier is only set to significantly increase. A recent Federal government agreement with Japan does recognise the potential Australia in supplying to the hydrogen export market.

High costs of hydrogen production

A key constraint to the growth of the hydrogen economy is the cost and inefficiency of hydrogen production. Electrolysis, the emissions-free process, is inefficient and can be costly. In addition, the conventional platinum electrodes used in the process are materially expensive.

Research and technological innovations are finding solutions to these issues. A range of electrodes with equal or greater efficiency to conventional ones have been developed using a combinations of polymers and alloys while the explosion of renewables has led to an opening for hydrogen production to fill. The common criticism of renewable systems is the absence of storage for periods of excess production, and this is where electrolysis can step in to generate hydrogen from the excess which to then be stored in a pressurised tank or in the local gas system.

Storage and transport of hydrogen

The properties of hydrogen present a challenge in its storage and movement. Its low density means it must be stored at pressure, and therefore cooled to become a liquid should it need to be moved long distances. Because hydrogen also has a relatively low volumetric energy density, its transportation, storage, and final delivery to the point of use comprise a significant cost and result in some of the energy inefficiencies associated with using it as an energy carrier.

Innovations now allow for hydrogen to be converted into both methanol and ammonia which can leverage existing industrial transport infrastructure and in turn reduce transportation costs. An added benefit of methanol production means captured carbon dioxide from industrial processes can be recycled into the chemical.

Infrastructure

Hydrogen produced for transportation requires different infrastructure to hydrogen produced for energy. Where energy production only requires connection to the local gas network, production for vehicles needs to be transported to fueling stations. Some infrastructure is already in place because hydrogen has long been used in industrial applications, but it's not yet sufficient to support widespread consumer use of hydrogen as a fuel source.

As well as outright costs of transportation, inefficiencies stemming from manipulation for transport should be taken into consideration. The three methods of transportation available are:

- Pipeline: This is the least expensive method to transport large quantities of hydrogen if there is an existing network, otherwise there are high initial capital costs as well as other considerations to construct a pipeline.
- High-pressure tube trailers: Transporting compressed hydrogen gas by truck, railcar, ship, or barge in high-pressure tube trailers is expensive and used primarily for distances of 300 kilometres or less.
- Liquefied hydrogen tankers: Cryogenic liquefaction is a process that cools the hydrogen to a temperature where it becomes a liquid. Although the liquefaction process is expensive, it enables hydrogen to be transported more efficiently (when compared with using high-pressure tube trailers) over longer distances by truck, railcar, ship, or barge.

Given hydrogen can be produced from a wide variety of resources, regional or even local hydrogen production can maximise use of local resources and minimise distribution challenges.

Production and distribution challenges aside, to support any HFCEVs, a network of fuelling stations, which are unlikely to be developed without government subsidies, needs to be established. In sum, this requires a coordinated policy approach from government to all stakeholders in the supply chain.

Safety

Hydrogen is flammable, colourless and odourless, which means safety mechanism and protocols need to be effective and rigorous.

Global Hydrogen Energy Policy

European Union

The European Union, California and Japan are leaders in hydrogen policy. Their governments have taken action developing and implementing forward-looking policy to tackle greenhouse gas emissions, air quality and boost their domestic manufactures of hydrogen applications.

In September 2018, European energy officials from 25 countries pledged to increase research into hydrogen technology and accelerate its everyday use to power factories, drive cars and heat homes and includes the idea of using existing gas grids to distribute hydrogen produced with renewable energy. Steps have already been taken in this regard with areas in Germany and the Netherlands already mixing hydrogen into their gas networks. For transport, a Joint Initiative for hydrogen Vehicles across Europe (JIVE) strives to advance the commercialisation of FC buses through large-scale deployment of vehicles and infrastructure.

Combined, the JIVE projects will deploy nearly 300 FC buses in 22 cities across Europe by the early 2020s – the largest deployment in Europe to date. The increased scale of deployment through the JIVE initiatives creates the conditions for accelerated development of European bus manufacturers' production capabilities by the early 2020s. This will enable them to achieve the economies of scale needed for mass roll out of fuel cell buses, positioning this technology to become a key zero emission public transport alternative in the coming years.

Japan

Japan's approach centres on its plans to use the 2020 Tokyo Olympics to showcase the city's 'hydrogen society' with HFCEVs, a network of filling stations, and a hydrogen-powered athletes' village. It forms part of the country's national strategy towards achieving an emissions-free society and increasing its 'hydrogen economy'.

While the technology is still costly, HFCEV sales are not expected to increase without more refueling stations. To combat this chicken and egg problem, 11 companies backed by the Japanese government - including Toyota, Honda and Nissan - announced a venture in March 2018 to pool resources to build 80 hydrogen stations in the next four years.

South Korea

Hyundai and Kia have announced they will boost annual fuel-cell production from today's 3000 units to more than 700,000 by 2030. The Hyundai Motor Group and its suppliers will invest $9.2 billion over the next 12 years on hydrogen technology that will see the Korean car-maker become a key global player in the zero-emission fuel.

The move is unprecedented in the industry, with the South Korean government confirmed it will back its domestic manufacturer by establishing 310 new hydrogen filling stations in South Korea by 2022 creating more than 51,000 jobs over the next decade.

China

China has its own plans to mobilise for global hydrogen deployment. Viewed as one of the key growth markets for clean technologies such as hydrogen, the government has announced plans to put in place 300 hydrogen refueling stations by 2025 and 1,000 by 2030. This hydrogen infrastructure will be able to support about 50,000 fuel cell electric cars by 2025, expanding to one million by 2030. In addition, leading Chinese cities and regions including Wuhan, Rugao, Shanghai, and Guandong have put in place their own ambitious roll-out plans.

California

California as of September 2018 has a mandated goal of 100% carbon-free energy by 2045. The state is thus aggressively pursuing a renewable hydrogen economy as part of a range of renewable sources with high state governmental support. The state has funded a network of at least 100 hydrogen stations to support the successful launch of the commercial HFCEV market in addition to state tax incentives, income-eligible rebates and other benefits.

Australia

Australia has a range of smaller scale initiatives and partnerships involving the CSIRO, ARENA, private sector and governments. Some of these are summarised in Appendix 1.

There are also a range of Australian research projects which are summarised in Appendix 2.

Global Hydrogen Applications

Most current applications of hydrogen are for industrial use, though increasingly it is used in the transport sector.

Cars

Several manufacturers have now released hydrogen fuel cell cars commercially, with heavy investment in the technology as the world shifts to alternatives of the combustion engine. Hyundai and Volkswagen have signed an agreement, as have General Motors and Honda, to develop and share their hydrogen technology together to reduce costs and improve profitability.

Trucks

Development and production of hydrogen powered trucks is also underway. Toyota has unveiled their second-generation testing truck call the Beta, capable of travelling almost 650 km on a single tank, meanwhile Hyundai has partnered with H2 Energy and fuel cell operators in Switzerland to provide 1,000 similarly capable hydrogen trucks over the next five years.

Buses

Hydrogen fuel cell buses currently operate in a number of countries with Western Europe and North-Eastern Asia leading the way, either operating or expanding fleets. An EU program is set to supply 300 vehicles and refueling stations to 22 European cities, as South Korea plans to add another 30, and Japan 100.

Ferries and freighters

Norway is funding a hydrogen-powered high-speed ferry and a freighter in a joint venture between Nel, Hexagon Composites and PowerCell Sweden.

The fast ferry will utilise hydrofoils and will have a cruise speed between 25 and 45 knots (up to 83 kilometres an hour). Fuel cells and batteries will power the vessel, carrying 100 to 300 passengers.

The coastal freighter will realise emission-free container transport for the short-sea market based on hydrogen fuel cells with automated cargo handling from road to sea.

Trains

The world's first hydrogen powered train was rolled out in Germany this year by TGV-maker Alstom. It can run for about 1,000 km on a single tank, similar to the range of diesel trains, though is much quieter, leaves no air pollution, and requires no overhead electrical infrastructure. Britain, the Netherlands, Denmark, Norway, Italy, Canada, and naturally France have all expressed interest.

Blending with natural gas

Cadent's HyDeploy project in the UK will to blend up to 20% hydrogen with the natural gas supply in part of Keele University's private gas network. The pilot project will begin in early 2019. The UK currently has a limit of 0.1% hydrogen in the UK gas network, though they were granted an exemption for the trial after the project gathered extensive evidence to demonstrate the hydrogen blend would be as safe as natural gas.

Power generation

Fusina hydrogen power station is a hydrogen-fueled power station located in Fusina, in Italy. It is the first commercial-scale power station in the world that is fueled with pure hydrogen. The power station is operated by Enel and has an installed capacity of 12 MW.

Appendix 1

Australian Hydrogen Initiatives and Applications

ACT

Location **Canberra**

Stakeholders **Evo Energy** and **Canberra Institute of Technology**

Evo Energy and the Canberra Institute of Technology are beginning to test hydrogen in a number of practical situations where natural gas is currently used. The first phase will run tests on existing Australian network components, construction and maintenance practices on 100 per cent hydrogen. Phases two and three will test hydrogen as a broader grid-scale energy storage source, and test hydrogen and mixed gases in existing appliances like gas cooktops and hot water systems.

Location **Canberra**

Stakeholders **Neoen, Megawatt Capital, Siemens** and **Hyundai**

Neoen and Megawatt Capital (developers of the Hornsdale Wind Farm) will invest $55 million in partnership with Siemens and Hyundai to establish a 1.25MW hydrogen electrolyser in Canberra. The initiative will include a refuelling station and service centre and an initial fleet of 20 hydrogen fuelled cars, including a technical support and research program.

NSW

Location **Western Sydney**

Stakeholders **Jemena**

Jemena is set to build its H2GO project in Western Sydney - a 500-kilowatt electrolyser in which will be powered by excess renewable energy to create hydrogen which will then be partly stored. Most of the hydrogen produced will be injected into the gas network, while a portion of the hydrogen will be utilised, via a gas engine generator, for electricity generation, with the remainder stored for use in an onsite Hydrogen Refuelling Station (HRS) for hydrogen vehicles. In its first stage, the trial will be able to deliver enough hydrogen to power 250 homes.

Location **Newcastle**

Stakeholders **CSIRO**

A CSIRO project will demonstrate Australia’s first solar thermal beam down system in Newcastle, concentrating solar energy from a heliostat field in order to heat a fluidised bed on the ground to 1300 °C. Water added to this bed will be split into hydrogen and oxygen using a two-step chemical process. Additional research will examine the conversion of the produced hydrogen into methanol to export. The fluidised bed reactor will also be the largest of its kind in the world with the project taking the technology from the laboratory to demonstration.

Queensland

Location **Gladstone**

Stakeholders **Northern Oil** and **AFC Energy**

Australian company Northern Oil, beginning in early 2019, is planning to incorporate AFC Energy's hydrogen power generation unit to its Advanced Biofuels Refinery in Gladstone. Instead of purchasing expensive hydrogen on the open market, Northern Oil will produce its own hydrogen using steam over iron reduction and chemical looping. In essence, the technology will convert its plant's waste gasses into a cheaper source of hydrogen, preventing waste gasses from being released into the atmosphere, and making the entire site self-sustainable.

Location **Central Queensland**

Stakeholders **Sumitomo Corporation** and **Queensland State Government**

Japanese industrial giant Sumitomo Corporation has made a proposal to the QLD Government to build a solar-to-hydrogen plant in Central Queensland to export hydrogen to Japan. Negotiations are on-going.

Victoria

Location **Latrobe Valley**

Stakeholders **AGL, Kawasaki Heavy Industries, J-Power, Iwatani Corporation, Marubeni, Japanese Government, Victorian State and Australian Federal Government**

A demonstration plant will be built in the Latrobe valley harvesting brown coal from AGL's Loy Yang mine for gasification. The state and federal governments have each granted $50 million each to the project.

Location **Moreland**

Stakeholders **Victorian State Government, Moreland Council** and **Hydrogen Utility (H2U)**

The Victorian State Government and Moreland Council in partnership with Hydrogen Utility (H2U) is undertaking a $9 million effort to run 12 of its 18 garbage trucks on hydrogen by early 2020, with plans to establish a hydrogen fueling station by late 2019. The hydrogen will be produce by the councils existing solar panels with extra wind energy from the grid.

South Australia

Location **Adelaide**

Stakeholders **Australian Gas Infrastructure Group (AGIG), Siemens, SA Power Networks** and **KPMG**

Australian Gas Infrastructure Group (AGIG) in partnership with Siemens, SA Power Networks and KPMG are in the process of designing and building an electrolyser pilot plant in Adelaide as a demonstration of 'power to gas' injection of hydrogen into the natural gas grid. The project will utilise potential on-site solar or excess renewable electricity from the grid to produce hydrogen via electrolysis to subsequently be fed into their local gas network.

Location **Chrystal Brook**

Stakeholders **Neoen**

French renewable energy developer Neoen is set to build a 50MW hydrogen electrolyser that would be powered by a new wind and solar complex at Crystal Brook, north of Adelaide. It would include 150MW of solar, about 150MW of wind, as well as up to 50MW hydrogen plant along with up to 400MWh of battery storage, most likely with Tesla. The company also owns and operates the Hornsdale Wind Farm in Jamestown, SA, the site of the Tesla lithium-ion battery.

Location **Port Lincoln**

Stakeholders **Hydrogen Utility (H2U)** and **thyssenkrupp**

Hydrogen Utility and thyssenkrupp in Port Lincoln on the Eyre Peninsula are proposing a $117.5 million facility with a 15-megawatt electrolyser plant to convert renewable power into hydrogen and an ammonia production facility for fertiliser production. It will contain a 10MW hydrogen-fired gas turbine, fueled by local wind and solar power, and a 5MW hydrogen fuel cell, both to supply electricity to the grid from stored hydrogen during periods of high demand.

Western Australia

Location **Jandakot**

Stakeholders **ATCO**

Canadian gas giant ATCO is building a micro-grid at its Jandakot base, which will convert solar power into hydrogen fuel. The micro-grid will use 1,100 solar panels to produce electricity, any leftover will be diverted to battery storage or be used to power an electrolyser which will mix the produced hydrogen into the natural gas network. It's slated to begin producing in the first quarter of 2019.

Location **Perth**

Stakeholders **State Government, Transperth**

The WA Government completed a three-year trial in 2007 that saw three hydrogen fuel cell Transperth buses cover more than 260,000km and carry more than 330,000 passengers during that time. The SA Government is to begin similar trials in Adelaide starting in 2019.

Appendix 2

Australian Research Projects

Stakeholders **ANU** and **University of Wollongong**

ANU and University of Wollongong have developed technology to convert water into hydrogen using a catalytic centre. The project uses renewables to power the electrolysis process involving the catalytic centre.

Stakeholders **Monash** and **University of Wollongong**

Monash and University of Wollongong developing scalable methods for the fabrication of efficient, low-cost and robust electrodes for hydrogen production from renewable energy sources via electrolysis.

Stakeholders **Macquarie University, Bioplatforms Australia Ltd** and **BOC Australia**

A Macquarie University-led project seeks biological hydrogen production using genetically engineered microorganisms. It relies on microorganisms to transform carbohydrates into hydrogen. It notes carbohydrates as an efficient and safe storage mechanism and the process overall as having no net impact on atmospheric carbon dioxide levels.

Stakeholders **Monash University**

Monash University is scaling up technology for electrosynthesis of ammonia from air nitrogen, water and renewables. A fuel in of itself, ammonia can also be split into nitrogen gas and hydrogen fuel. The present project will further advance this technology by developing new electrodes that will provide higher ammonia production rate, longer lifetime and maintain high selectivity.

Stakeholders **UNSW, Beijing Zhongchao Haiqi Technology Co Ltd, RayGen Resources Pty Ltd** and **Shenzhen Kohodo Sunshine Renewable Energy Co. Ltd**

A UNSW project aims to produce hydrogen for export from sunlight and water using photovoltaic electrolysis, an integrated system which harvest the whole spectrum of sunlight as the sole source of electricity, heat and light, which then will power an alkaline water electrolyser to convert solar energy to hydrogen. The main obstacle to utilising PVE to produce renewable hydrogen is the high cost and modest efficiency.

Stakeholders **UNSW, Beijing Origin Water Technology Co. Ltd** and **Apricus Energy**

UNSW, Beijing Origin Water Technology Co. Ltd and Apricus Energy are developing technology to turn waste biomass to renewable hydrogen. The biomass reforming system will comprise a biomass pre-conditioning reactor coupled with a flow electrolyser cell, the energy requirements of each satisfied by captured heat and solar energy respectively. The benefits exclusive to this project are that electrocatalytic hydrogen extraction from the pre-conditioned biomass is generally easier than water electrolysis and the biomass reforming process can produce value-added organic products.

Stakeholders **CSIRO**

The CSIRO is investigating the production of synthetic methane as a readily exportable, renewable fuel, derived from atmospheric carbon dioxide and hydrogen produced from renewable sources. It hopes to use the both the energy and heat produced from renewables, for electrolysis to create hydrogen, and to capture carbon dioxide in the liquid absorbent-based process respectively. Innovations still need to be made in liquid reagents for carbon dioxide contacting devices, and the devices' optimisation in the methanation process.

Stakeholders **RMIT, Eldor Corporation**, **Institute for Carbon-Neutral Energy Research** and **Kyushu University**

RMIT with Eldor Corporation, Institute for Carbon-Neutral Energy Research and Kyushu University aim to develop an integrated system for storage of electricity from renewable energy and export the stored energy as hydrogen within hydrogenated carbon-based material. The reactor and C-powder still require considerable technical innovation.

Stakeholders **University of Melbourne, UNSW, MAN Diesel & Turbo SE, Energy Power Systems Australia Pty Ltd, Continental Automotive Systems Inc** and **Energy Australia Pty Ltd**

The University of Melbourne-led team aim to demonstrate the most efficient, hydrogen fuelled, medium to heavy duty, spark (SI) and compression (CI) ignition engines to date. It also aims to analyse how these engines are an important part of different, economically optimal, integrated systems that generate, transport or use renewable hydrogen.

Stakeholders **CSIRO, Johnson Matthey** and **BG Negev Technologies and Applications Ltd**

This CSIRO-led project proposes a game changing technology for conversion of solar energy to liquid fuels. Both solar heat and solar PV electricity will be used to drive a solid oxide electrolyser device for a production of hydrogen and syngas which then can be converted onsite into transportable liquid fuels enabling large-scale energy export and storage. Their focus is on improving the efficiencies of the catalytic synthesizing and electrolysis processes.

Stakeholders **UoWA** and **Anergy Pty Ltd**

UoWA with Anergy Pty Ltd are exploring converting biomass via methanol synthesis and biomass pyrolysis to produce renewable methanol for export. As the project is in its infancy only a theoretical concept and framework exist at this stage with research and development to continue.

Stakeholders **CSIRO, Orica Australia Pty Ltd** and **Grains Research and Development Corporation**

The CSIRO together with Orica Australia Pty Ltd and the Grains Research and Development Corporation are developing an ammonia production process which is less energy intensive than the conventional Haber-Bosch process and does not contribute to any greenhouse gas emissions. Utilising solar PV and wind turbines to power the electrolysis process to create hydrogen, and an air separation unit to source nitrogen, the CSIRO's membrane-based process converts the hydrogen into ammonia.

Stakeholders **ANU, UNSW** and **Shenzhen Kohodo Hydrogen Energy**

ANU along with UNSW and Shenzhen Kohodo Hydrogen Energy are in development of practical, highly efficient, stand-alone solar water splitting system for hydrogen production using low-cost semiconductors and non-noble metal-based catalysts.

For more information on Australian research projects, click here.

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