GLOBAL CCS INSTITUTE

COAG Energy Council Hydrogen Working Group

via: Online submission

28 March 2018

Re: Submission to inform Australia's National Hydrogen Strategy

Please find enclosed the Global Carbon Capture and Storage Institute's submission to inform Australia's National Hydrogen Strategy.

The Global CCS Institute is an international think-tank and a leading authority on carbon capture and storage (CCS). Our mission is to accelerate the deployment of CCS as an imperative technology to achieve global climate change goals and provide energy security.

The Institute supports the development of an Australian Hydrogen industry and appreciates the opportunity to provide a submission regarding this critical Strategy.

Yours sincerely

Brad Page

Chief Executive Officer
Global CCS Institute

P: +61 (0)3 8620 7318
E: page.bw@globalccsinstitute.com
W: globalccsinstitute.com

Global Carbon Capture and Storage Institute Submission on the Development of a National Hydrogen Strategy

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

Rather than provide a general submission, the Institute has provided answers to the key policy questions identified in the on-line survey. Where applicable, references are provided for each question.

What do you think are the two or three most significant recent developments in hydrogen?

The most significant recent developments in hydrogen are:

- The development of commercial scale hydrogen production facilities which utilise coal or methane as a feedstock and carbon capture and storage to produce clean hydrogen.
- The establishment of the Hydrogen Energy Supply Chain project to demonstrate the production of hydrogen from Latrobe valley brown coal and the transport of hydrogen to Japan.
- The completion of detailed studies into replacing natural gas with hydrogen for domestic heating utilising existing (modified where necessary) gas reticulation infrastructure.

Each of these developments is briefly discussed below.

Commercial scale clean hydrogen production from fossil fuels with CCS

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. 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 with the remainder produced from fossil fuel feedstocks (66 per cent) or chemical processes (30 per cent).

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.[2] The availability of sufficient nuclear and renewable generation capacity to meet this demand for hydrogen production, and 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 plentiful, and the technology is proven at large scale to be the lowest cost source of clean hydrogen. 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 (NETL, n.d.)
- 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 (IEAGHG, 2018)
- 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 (CVR Partners, 2013)
- Quest CCS in Alberta, Canada, commenced operation in 2015, produces approximately 900 tonnes of hydrogen per day from natural gas reforming with CCS (IEAGHG, 2017)
- Alberta Carbon Trunk Line (ACTL) in Alberta, Canada, is in construction, when operating, ACTL will enable clean hydrogen production in two projects:
    - Alberta Sturgeon Refinery, producing more than 240 tonnes of hydrogen per day via asphaltene residue gasification with CCS (Weiss and Walter, 2014)
    - Agrium fertiliser, producing more than 800 tonnes of hydrogen per day via natural gas reforming with CCS (Nutrien, 2017)

[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.

These commercial facilities prove the maturity of clean hydrogen production from fossil fuels with CCS.

Establishment of the Hydrogen Energy Supply Chain Project (HESC)

The HESC, which will demonstrate hydrogen production from brown coal in the Latrobe Valley and the export of hydrogen from Victoria to Japan, is an extremely significant development. This project brings together leading Japanese companies (Kawasaki, JPower, Iwatani, Marubeni), Shell, AGL and the Japanese, Victorian and Australian governments to take the first step towards establishing the new low emissions industry of the future.

Within the next ten years or so, a decision will be taken on whether to proceed to full commercial scale with CCS, utilising the enormous geological storage resources of the Gippsland Basin, and the Latrobe Valley's brown coal endowment. This development will be the epitome of a *just transition*; creating a new low emission industry hub to create and sustain high value jobs and investment for the local community whilst generating export revenue for Australia.

The clean hydrogen could also be used by Australian industry and in domestic heating (greater than 10-15% hydrogen requires conversion of appliances) and to generate electricity, providing dispatchable near zero-emissions power. 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. This investment also demonstrates the Japanese government's vision for hydrogen as an essential component of its national strategy to reduce greenhouse gas emissions, and the Australian and Victorian government's recognition of the economic opportunity presented by the juxtaposition of world class fossil fuel and storage resources, backed by the formidable engineering abilities of the private sector.

The completion of detailed studies into replacing methane with hydrogen for domestic heating utilising existing (modified where necessary) gas reticulation infrastructure.

In 2016, a detailed study of the economic and technical feasibility of converting the existing natural gas network in the UK city of Leeds to 100 per cent hydrogen was completed. Clean hydrogen would be produced by Steam Methane Reformation with CCS. Conversion of the gas reticulation network and end-user appliances would be staged over several months to years with minimal disruption to consumers. This process would be similar in many respects to the conversion from town gas to natural gas that was completed in the UK between 1966 and 1977.

The study included a detailed roll-out plan, confirmed the availability of sufficient methane and CO_2 storage resources, and concluded that minimal new energy infrastructure would be required compared to alternatives (e.g. electrification) (Leeds Citigate, 2016). This study was particularly significant because it confirmed the opportunity to decarbonise domestic heating with hydrogen in a real gas network, including the development of a detailed implementation plan.

References for Question 1

European Commission. (2018), *Technical Information on Projects of Common Interest*, available at: https://ec.europa.eu/energy/sites/ener/files/technical_document_3rd_list_with_subheadings.pdf

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

IEA. (2017) World Energy Outlook 2017

IEAGHG. (2018), *The CCS Project at Air Products' Port Arthur Hydrogen Production Facility 2018/05*.

Ju et al. *A comprehensive review of carbon and hydrocarbon assisted water electrolysis for hydrogen production*, Applied Energy, 231, 502–533, 2018.

NETL. (n.d.). "Great Plains Synfuels Plant", available at: https://www.netl.doe.gov/research/Coal/energy-systems/gasification/gasifipedia/great-plains (accessed 25 March 2019).

NETL. (n.d.). "Hydrogen Production", available at: https://www.energy.gov/eere/fuelcells/hydrogen-production . (accessed 25 March 2019).

Northern Gas Networks. (2018), *H21 North of England*, available at: https://northerngasnetworks.co.uk/h21-noe/H21-NoE-23Nov18-v1.0.pdf.

What are the most important safety issues to consider in producing, handling and using hydrogen in Australia?

Other than noting that safety requirements for the production, transport and handling of hydrogen are very well established, the Global CCS Institute has no comment to make on this question.

What environmental and community impacts should we examine?

Investment, jobs and a *just transition*

The opportunity to use clean hydrogen production as the enabler of investment in new low emission industries to support a *just transition* for communities should be closely examined. As Australia decarbonises, clean hydrogen production with CCS can reduce the damaging economic and social disruption that would otherwise arise 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).

Over time, CCS hubs, enabled by initial investment in clean hydrogen production, could attract further investment from other emissions intense industries seeking to establish operations in precincts that offer carbon dioxide storage services and/or hydrogen as an input to industrial processes, to serve a global market that will increasingly value low emissions products.

Low emissions electricity requirement

Today, and for a considerable time into the future, near-zero emissions electricity provided by renewable (or potentially nuclear energy) will be scarce in Australia. The majority of electricity will continue to be generated using coal or gas.

The production of clean hydrogen will add to demand for relatively scarce near-zero emissions electricity. To illustrate, consider a plant that produces sufficient hydrogen to supply 100MW of electricity production using fuel cells. This plant would produce approximately 100 tonnes of hydrogen per day.

The following table compares the power requirements for clean hydrogen production using steam methane reforming with CCS, coal gasification with CCS and Proton Exchange Membrane electrolysis. All figures quoted are approximate and based upon data contained in the paper by Mehmeti et al (see references).

	Specific Electricity Consumption (kWh/kg of H_2)	Approximate Continuous Power Requirement (MW)	Required Renewable Electricity Installed Capacity Assuming a Capacity Factor of 0.3
Electrolysis (PEM)	54.6	227	757MW
Steam Methane Reformation with CCS	2	9	30MW
Coal Gasification with CCS	4	18	60MW

Table 1. Electricity requirements for 100 tonne per day hydrogen production

This illustrative analysis shows that production of clean hydrogen using electrolysis uses 25 times more energy than steam methane reforming with CCS and 12 times more energy than coal gasification with CCS. A plant producing 100 tonnes per day of clean hydrogen via electrolysis would require 750MW of installed renewable electricity capacity to power it.

Given the scarcity of renewable electricity, and its critical role in displacing high emission fossil fuel generation in the grid, its efficient utilisation should be a key consideration when comparing options. On that basis, the best option would be to produce clean hydrogen from gas or coal with CCS. In this example (100 tonne per day production), electricity demand would be reduced by over 200MW, or, if sufficient renewable electricity was available, an additional 200MW of coal generation would be displaced from the grid, delivering over 1.5Mt CO_2 of domestic abatement per year.

Decarbonisation on life-cycle basis

The climate change mitigation value of hydrogen production should be determined using lifecycle analysis. Doing so mitigates the risk of sub-optimisation; that is considering benefits at one point of the supply chain (e.g. reduced tailpipe emissions by fuel-cell vehicles), whilst ignoring the costs at the other (e.g. baseload electricity from unabated fossil fuel-based power plants for water electrolysis, unabated natural gas from natural gas processing).

Limited window for super-profit economic benefits

As demand for low carbon goods and services grows, it is likely that there will be a limited period during which there is a global and/or regional supply deficit of low-carbon hydrogen. That could produce a material price premium, rewarding first movers to supply the market. Any economic evaluation should consider this temporary price premium to inform investment decisions in clean hydrogen production and create an opportunity to exploit a window of super-profit for Australia.

Environmental co-benefit from clean hydrogen

The production and utilization of clean hydrogen reduces emissions of air pollutants such as oxides of nitrogen and sulfur and particulates, providing additional environmental benefits at no additional cost. Production of clean hydrogen from fossil fuels with CCS, or renewable electricity and electrolysis, and the utilization of hydrogen in stationary energy, transport or industry produces near-zero life cycle pollutant emissions.

References for Question 3

Mehmeti, A., Angelis-Dimkakis, Athanasios., Arampatzis, G., McPhail, S., Ulgiati, S., (2018), "*Life Cycle Assessment and Water Footprint of Hydrogen Production Methods: From Conventional to Emerging Technologies*", Environments, 2018, 5, 24.

How can Australia influence and accelerate the development of a global market for hydrogen?

Australia can significantly contribute towards the development of a global market for clean hydrogen by hosting the development of a low-cost clean hydrogen supply chain. The cost of clean hydrogen compared to its competitors (e.g. hydrocarbons) will be the primary determinant of the growth (or absence of growth) of the global market for hydrogen. Production of clean hydrogen from fossil fuel feedstocks with CCS is the lowest cost pathway. Australia is very well endowed with methane, coal, and pore space in which to permanently store CO_2. Further, Australian fossil fuel resources are often located in regions with access to excellent geological storage resources which creates the opportunity to benefit from the economies of scale delivered by hubs and clusters. These natural advantages provide necessary inputs for the production of competitively priced hydrogen.

Australia also has very well-developed extractive industries and supply chain expertise. Australia's status as a trusted and reliable supplier of commodities, especially energy commodities into the rapidly growing markets of Asia, creates opportunities to leverage existing commercial relationships to build a new clean hydrogen supply business.

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.

What are the top two or three factors required for a successful hydrogen export industry?

Price

The most important pre-requisite for a successful hydrogen export industry is price. Ultimately, the market will choose the lowest cost sources first. Australia must be a low-cost producer to win market share, and there are significant potential competitors. For example, the Aspen Institute reports that new technologies and low-cost natural gas combined with the value provided by the newly expanded Section 45Q tax credit available for CO_2 storage, could produce clean hydrogen in the USA for USD0.63 per kilogram. Even at double that suggested price, this represents extremely low-cost clean hydrogen.

To be competitive, Australia must choose the lowest cost clean hydrogen production technology, and that is production from fossil fuels with CCS.

Proximity

Australia's existing comparative advantage lies in the proximate location of natural resources necessary for clean hydrogen production and Australia's proximity to Asia's large markets. Australia has five sites where fossil fuel resources, suitable CO_2 storage sinks, and export infrastructure (e.g. ports) are located relatively close to each other. Having these three factors co-located enables the development of low emission industry hubs, reducing costs through:

- Economies of scale delivered by access to common-user infrastructure, including CO_2 transport and storage infrastructure;
- Shorter CO_2 pipeline distance to storage site(s);
- Utilisation of existing port and rail infrastructure.

The five potential hydrogen hubs include:

1. Queensland: Surat/Bowen coal/natural gas – onshore Surat/Bowen basins storage
2. Victoria: Latrobe Valley coal – offshore Gippsland Basin storage
3. Northern Territory: Bonaparte/ Timor natural gas – offshore Bonaparte Basin storage
4. Central Western Australia: Pilbara natural gas – offshore Carnarvon Basin storage
5. Northern Western Australia: Browse natural gas – offshore Browse Basin storage

Being relatively close to markets is also advantageous as it reduces shipping costs.

People

Natural resources and infrastructure aside, Australia's strong skills and knowledge base in the production, conversion, and export of gas is an additional advantage. This LNG-based technical expertise (including construction) can also be applied to hydrogen production.

References for Question 5

The Aspen Institute. (2018), *Designing Transitions for the New Energy Economy*, available at: https://assets.aspeninstitute.org/content/uploads/2019/01/2018-Aspen-Energy-Week-Report.pdf?_ga=2.120595597.448679980.1551925370-968001146.1541191805.

What are the top two or three opportunities for the use of clean hydrogen in Australia?

Reducing the emissions intensity of reticulated natural gas supply is a significant, immediate and low-cost opportunity. Hydrogen can be introduced into the natural gas network at concentrations of 10-15% without any modification of the network or end-user appliances. This would deliver commensurate emission reductions. Over time, the gas network and end-user appliances can be modified to accept 100% hydrogen, completely decarbonizing domestic heating.

The availability of competitively priced clean hydrogen in Australia, with staged investment in hydrogen refueling infrastructure, would initiate demand for hydrogen fuel cell powered vehicles. Over time, as refueling infrastructure expands, and costs reduce, hydrogen could play a significant role in decarbonizing Australia's transport sector, particularly heavy transport where batteries are inadequate.

Hydrogen is an input to many industrial processes such as fertilizer production and can also decarbonize heat and electricity generation. A competitively priced and reliable supply of clean hydrogen could enable the creation of low emission industrial products. As previously discussed, this opportunity can deliver a *just transition* to communities that currently rely upon the production and utilisation of fossil fuels for employment and economic activity.

What are the main barriers to the use of hydrogen in Australia?

Cost and lack of infrastructure

Hydrogen competes primarily with gas and oil. The gas/oil industry benefits from over a century of experience in reducing the cost of supply, and investment in infrastructure to facilitate its production and distribution. The hydrogen industry is embryonic in comparison. Cost and lack of

infrastructure are the most significant barriers to entry into any market including Australia for hydrogen.

To overcome those barriers, the lowest cost clean hydrogen production technologies must be utilised to maximise its competitiveness with oil/gas, and investment in infrastructure for production and distribution of hydrogen must be incentivised.

What are some examples where a strategic national approach could lower costs and shorten timelines for developing a clean hydrogen industry?

There are several examples where governments are making strategic investments in CO_2 transport and storage infrastructure for the development of a clean hydrogen industry. For example:

- 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 fertilizer plant (natural gas reforming) for fertilizer production (Global CCS Institute, 2019).
- Projects of Common Interests supported by the European Commission includes “Cross-Border Carbon Dioxide Transportation Infrastructure” – a thematic area focused on the development of CO_2 transportation networks (European Commission, 2018; Global CCS Institute, 2019):

  - Teesside CO_2 hub: Objective is to decarbonise the UK ‘s largest energy intensive industrial center where 50% 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.

- <u>The Rotterdam Nucleus</u>: 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.
- <u>CO_2 cross-border transport connections</u>: This study is investigating options to decarbonise Teesside and to convert Vattenfall/Nuron's Magnum gas fired power station in Netherlands to hydrogen.

Should these projects proceed to construction, they will enable the transportation of CO_2 from multiple capture facilities, spreading the fixed costs of the infrastructure over multiple users and helping to bring down the unit costs of CCS not just from clean hydrogen production. They also provide a direct route to market for potential capture project developers, rather than each having to go through the process of finding an individual transport and storage provider, helping to shorten the timelines for capture facilities to come online.

The Australian government could consider similar strategies to share risk with the private sector and incentivise investment. In particular, government could declare an intention to create a low emission industrial hub including clean hydrogen production, work with potential private sector investors to understand barriers and opportunities, and then put in place policy measures designed to mobilise significant private capital.

These measures should be focused on de-risking investment to a level consistent with normal business practice for capital intensive investments, aligning private sector investment incentives (profit) with public good investment incentives (stable climate). This will remove or greatly reduce the risk premium on the cost of capital that would otherwise be applied inflating total project costs and severely impairing the bankability of the project.

The policy measures should be carefully designed after rigorous study and consultation however they may include direct investment in carbon dioxide transport and storage infrastructure required to support clean hydrogen production, and the establishment of a low emission industrial hub. Direct investment may extend to public ownership of this infrastructure until such time as the hub is established, asset utilisation is high, unit costs is reduced through economies of scale, and the CO_2 transport and storage business becomes profitable.

References for Question 8

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

European Commission. (2018), *Technical Information on Projects of Common Interest*, available at: https://ec.europa.eu/energy/sites/ener/files/technical_document_3rd_list_with_subheadings.pdf

What are Australia’s key technology, regulatory and business strengths and weaknesses in the development of a clean hydrogen industry?

Strengths:

Australia’s existing comparative advantage lies in the proximate location of natural resources necessary for clean hydrogen production and Australia’s proximity to Asia’s large markets. Australia has five sites where fossil fuel resources, suitable CO_2 storage sinks, and export infrastructure (e.g. ports) are located relatively close to each other. Having these three factors co-located enables the development of low emission industry hubs, reducing costs through:

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Natural resources and infrastructure aside, Australia’s strong skills and knowledge base in the production, conversion, and export of gas is an additional advantage. This LNG-based technical expertise (including construction) can also be applied to hydrogen production.

Australia also has very well-developed extractive industries and supply chain expertise. Australia’s status as a trusted and reliable supplier of commodities, especially energy commodities into the rapidly growing markets of Asia, creates opportunities to leverage existing commercial relationships to build a new clean hydrogen supply business. The longstanding and excellent relationship with Japan has been a significant enabling factor of the Hydrogen Energy Supply Chain project in Victoria.

Early strategic developments in CCS have positioned Australia high in the *Global CCS Institute’s CCS Readiness Indicator* (Havercroft and Consoli, 2018). Australia has benefited from supportive policy frameworks that have delivered a comprehensive legal and regulatory framework. To date, CCS-specific legislation has been developed by the Commonwealth and the States of Victoria, Queensland and South Australia. Project-specific legislation has also been developed to regulate injection activities associated with the Gorgon project in Western Australia.

Australia has a well-defined system of common law, which offers a solid foundation for the regulation of a nascent clean hydrogen industry. A comprehensive body of planning, resource and environmental legislation, developed at the federal and state-level, is widely understood by industry and regulators alike and is likely to offer confidence to those seeking to invest in the industry. Australia also benefits from detailed and targeted CO_2 storage assessments.

Weaknesses:

Whilst an Australian clean hydrogen industry would derive the large majority of its revenue from export, a significant weakness is the absence of a material commercial incentive for emissions abatement across the Australian economy. In the absence of such a commercial incentive, hydrogen will not be competitive with its competitors in the Australian market. A policy intervention to place a material value on carbon (i.e., a cost for emission, a financial reward for abatement, or the establishment of regulatory emission constraints) is necessary to drive domestic demand for clean hydrogen.

The other significant weakness is the lack of necessary infrastructure for the transport and storage of carbon dioxide and distribution of hydrogen. Our potential competitors, particularly the USA and UK, either have already invested in infrastructure (CO_2 transport networks in the USA), or have studies underway or completed to inform the development of low emissions industrial hubs including hydrogen production.

What workforce skills will need to be developed to support a growing clean hydrogen industry?

A successful clean hydrogen industry will require all the skills currently required by the extractive 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. The demand for engineering skills will be most significant during the design and construction phase of facilities. Once commissioned, fewer engineers are required as the plant is primarily operated and maintained by skilled technical staff and tradespeople. Relatively unskilled labour is also necessary for various tasks throughout the development and operation of the facilities. These skills all exist today across Australian industry, particularly in the oil and gas and mining industries.

However, if the clean hydrogen industry fulfills its potential, there will be competition with existing industries for these skillsets, which are already well remunerated. In the short term, any shortfall in available skills can be met through immigration, however it would be prudent to develop longer term strategies to ensure Australia produces sufficient skilled and qualified workers to supply its own demand.