EXECUTIVE SUMMARY

A technology-neutral, export-oriented and adaptive hydrogen strategy

The Australian government released the National Hydrogen Strategy (the Strategy) in November 2019 and has continued to outline its support for hydrogen through the First Low-Emissions Technology Statement, released in September 2020. Since the release of the Strategy, the government's efforts have focussed on its implementation, with numerous policy announcements targeting key focus areas of the Strategy, such as international partnerships and engagement, a hydrogen certification scheme, national coordination, support to priority industry projects and legislative reviews. Since 2018 (and up to May 2021), at least 1.5 billion Australian dollars (AUD) (US$1.1 billion) have been awarded or committed by the Commonwealth and state governments, industry and research institutions to progressing clean[1] hydrogen projects.

Implementing the Strategy is intended to deliver a clean, innovative, safe and competitive hydrogen industry that benefits all Australians, and helps Australia become a major global player in the hydrogen market by 2030. The Strategy takes an adaptive approach to industry development, with a focus on actions that remove market barriers and technical uncertainties, efficiently build supply, create demand, and accelerate the global cost-competitiveness of Australia's hydrogen industry. The Strategy contains measures of success, but no key performance indicators (e.g. targets for electrolysis capacity), nor targets for hydrogen use in prioritized applications. The Strategy aims to build the hydrogen market in two phases. In the first phase up to 2025, pilot and test facilities as well as demonstration projects for hydrogen hubs will be set up. In the second phase from 2025 onwards, the first commercially oriented large-scale plants to open up national and international markets are to be built.

The government has taken a technology-neutral approach and the Strategy refers to 'clean' hydrogen. Clean hydrogen is defined as being produced using renewable energy (green hydrogen) and using fossil fuels (steam reformation of natural gas (SMR) or gasification of coal) with substantial carbon capture and storage (CCS) (blue hydrogen).

The Strategy is export oriented. It aims to build large-scale supply chains to make Australia a leading exporter of hydrogen energy and technologies, and one of the top three exporters to the promising Asian markets by 2030. Australia is a major fossil-fuel exporter. LNG and coal make up a quarter of Australian exports and contributed US$72 billion in annual revenues in 2020. The global move to net zero-emissions could present a threat to Australian energy exports, but it also presents opportunities for Australia to diversify its energy exports, by exporting clean hydrogen and derivatives (such as green ammonia). Australia's key energy export markets, such as Japan and South Korea, have established long-term ambitious strategies for clean hydrogen, which largely rely on imports. Europe, especially Germany, despite the shipping distance, also appears as a potential importing region of Australian green hydrogen. Recent analyses assess the potential global hydrogen demand addressed to Australia at up to 45 Mt/y by 2050, representing US$90 billion in export revenues.

Australia has significant competitive advantages to become a leading exporter of clean hydrogen. The vast country has the natural resources needed to make both green and blue hydrogen. It has huge wind and solar resources, an internationally recognized natural gas and coal resources industry, carbon capture and storage capabilities, a track record in building large-scale energy industries through its LNG experience, a strong research and innovation capability, and an established reputation as a trusted energy supplier to Asia. The establishment of a hydrogen certification scheme is a government priority to facilitate clean hydrogen trade. Since May 2020, Australia has led consultations with domestic and international stakeholders to develop a hydrogen certification scheme for Australia and a trial will be conducted in the second half of 2021.

[1] In this report, to be consistent with the terms used in the Strategy, clean hydrogen is used as an umbrella term for green (renewable) and blue hydrogen (low carbon).

While primarily focused on the export market, the Strategy looks to initially concentrate hydrogen use in large hydrogen hubs - areas where users of hydrogen across industrial, transport and energy markets are co-located - facilitating sector coupling and fostering domestic demand. A strong domestic hydrogen sector will underpin Australia's exporting capabilities. The government has committed more than AUD300 million to the development of Australia's first five hydrogen hubs. States and territories' governments have started to develop their most prospective export hubs. Australia has also selected 15 hydrogen technology clusters to enable faster innovation and facilitate national coordination and uniform legislative reform across all Australian jurisdictions.

The government has stated its commitment to reducing Australia's emissions through technology investment, rather than through carbon pricing, with the Technology Investment Roadmap a core element of its long-term emissions reduction strategy. The First Low-Emissions Technology Statement outlines five priority technologies, including clean hydrogen, and economic stretch goals to make new technologies as cost-effective as existing technologies. An investment package of AUD1.9 billion over 10 years from 2020-21 aims to accelerate the development and commercialisation of these new technologies. One of the government's priorities and a key success factor for Australia's hydrogen industry is to reduce the production cost of hydrogen below AUD2/kgH_2 — US$1.4 ('H2 under $2').[2]

CCS is also one of the five key prioritized low emissions technologies. The government anticipates that CCS will be critical to the development of new low emissions industries, such as hydrogen production, and to provide a potential decarbonisation pathway for gas processing, power generation and hard-to-abate industrial processes. The government has set the goal of reducing the cost of CO_2 compression, hub transport (in the vicinity of 100 km), and storage for CCS below AUD20/tCO_2 (US$14). The government supports the commercial deployment and uptake of carbon capture, use and storage (CCUS) and is funding the creation of CCS/CCUS hubs. In addition, in a major step towards the uptake of the CCS technology, the government has released plans to issue carbon credits to operators of CCS projects for the GHG emissions they abate, monetising CCS for the first time in Australia.

Hydrogen demand: four key domestic applications

The Strategy has prioritized four applications for hydrogen in the domestic market: its use in transport, as industrial feedstock, blended in gas networks and for electricity grid support. The first three applications are key to building widespread domestic hydrogen demand. Hydrogen will also be crucial to integrate more renewables in the electricity mix and decarbonise power generation, today dominated by coal (54% of the electricity mix in 2020).

The use of hydrogen in the transport sector is just starting in Australia. The first commercial trials of fuel cell electric vehicles (FCEVs) in niche fleets started in March 2021. However, the sector has received a lot of interest by state governments and corporations. Around 40% of all Australian hydrogen projects (as of July 2021) include hydrogen in transport as a potential end use. This strong interest on hydrogen in mobility applications reflects commitments by state governments and large corporations to decarbonise their fleets, especially in the mining sector. It also reflects the fact that the prospective hydrogen cost gap against alternative fuels is the narrowest in transport applications, especially in heavy transport applications.

Natural gas provides 21% of Australia's total energy supply. The government is looking at introducing hydrogen into the gas networks to decarbonise gas supplies. Currently, hydrogen can be added to gas distribution networks at concentrations of up to 10%, and a number of trials are being explored. Australian Gas Networks started operating a 1.25 MW electrolyser in South Australia in May 2021 (so far the biggest electrolyser in Australia) to produce renewable hydrogen for blending (at 5% level) in an existing gas distribution network. Studies also investigate the blending of hydrogen in gas transmission networks. The industry's Gas Vision 2050 targets 10% renewable gas (including

[2] The Technology Statement does not indicate a target date for the cost reductions for clean hydrogen, nor for CCS transport and storage.

biomethane) in networks by no later than 2030, and full decarbonisation of the networks by 2050 at the latest, and by 2040 as a stretch goal.

The Strategy identifies the use of hydrogen as feedstock as a widespread growth opportunity to scale up the market. In addition to supplying clean hydrogen to current users (ammonia plants and oil refineries), and decarbonising industrial processes, like iron and steel manufacturing, the role of clean ammonia in facilitating international supply chains is highlighted as it is both an end-use and an important carrier. A feasibility study carried out by BP Australia has confirmed that producing green ammonia using renewable energy is technically feasible at scale, though it would require significant investment and public support. Several mega-scale green ammonia projects targeting the export market are under development. "Smaller" green ammonia projects (10 MW to 250 MW) initially target the domestic market. The production and export of blue ammonia (SMR with CCS) is also assessed by several companies. There are also ammonia projects based on coal gasification.

In the iron and steel sector, the direct reduction of iron ore (DRI) route is expected to be commercially viable in Australia by 2030, using natural gas, with hydrogen steel-making available by 2040. Australian steel makers, but also iron ore miners, have started to adopt new strategies in view of rapid technological changes in the sector, which create new opportunities to produce green steel or DRI for further processing in the importing country. Fortescue Metals Group (FMG) is the most ambitious. The group has pledged to develop massive renewable power resources to produce green hydrogen and build Australia's first green steel production plant as early as 2023.

In the power sector, the Strategy highlights three roles for hydrogen in electricity systems: to support the grid system/provide energy storage, to power remote sites and to co-fire or use hydrogen-based fuels for electricity generation. Pilot and demonstration projects are in various stages of development for the three applications. In addition, the government supports new gas generators to become hydrogen ready and is co-funding the building of a dual-fuel peaking plant in New South Wales.

A growing pipeline of hydrogen projects, and the world's largest pipeline of export projects

Australia is emerging as a key player in the global hydrogen supply chain, taking the lead, together with Europe, on renewable hydrogen developments around the globe. As of July 2021, Australian corporations, the Commonwealth and state governments, together with international partners, have proposed 88 pilot, demonstration and small-to-mega/giga scale hydrogen projects (both green and blue hydrogen). The hydrogen production and hydrogen export businesses are evolving in parallel: around 44% of the projects envisage exports (39 projects), as the sole end use or, very often, in combination with domestic use. At full development stage, the electrolysis capacity of utility-scale green hydrogen projects totals 65.2 GW, with almost 97% of this capacity coming from seven gigawatt-scale plants (> 1 GW), focussed on the export market. This represents almost a quarter of the 280-GW capacity of the largest projects proposed in the world. These giga-scale projects are at the earliest stages of development planning, as would be anticipated given the emergent stage of the industry. Few could realistically be operational before the second half of the decade. It remains to be seen how these giga-scale projects can overcome the challenges of their huge costs and how the grid can be adapted to the massive production of intermittent solar and wind energies.

The largest commercial green hydrogen project currently proposed in Australia, the Western Green Energy Hub (WGEH), was unveiled in July 2021 by the same corporations behind the flagship Asian Renewable Energy Hub (AREH) project. With an expected cost of AUD100 billion and FID expected post 2028, WGEH would convert wind and solar energy (50 GW) into green hydrogen and ammonia for domestic use and exports (28 GW of electrolysis capacity). WGEH would spread across 15,000 square kilometres in the southwest of Western Australia. The second largest project, the flagship AREH, suffered setbacks in June 2021 when the Australian Environment Minister rejected the project in its current form due to its impacts on wetlands and migratory bird species. The project aimed at deploying up to 26 GW of solar and wind in Western Australia, of which 14 GW of electrolysis capacity to produce

green hydrogen and green ammonia for domestic and global markets. The consortium behind the project has committed to resolving the issues raised by the Minister, but its status under its current form is uncertain. The next five largest export projects involve electrolysis capacity of 1.5 GW to up to 8 GW, to be developed in phases, while several export-oriented projects under development have capacities in the range of 100-500 MW.

Although the Strategy considers both blue and green hydrogen, there are a limited number of blue hydrogen projects (either coal or natural gas with CCUS): 9 projects only, compared with 74[3] for green hydrogen (and/or green ammonia), confirming the country's growing global status as a supplier of hydrogen from renewable sources. However, this may change rapidly with the recent adoption of funding dedicated to CCUS and the forthcoming legislation incentivising CCS. All blue hydrogen projects target the export market, and most of them are in the stage of concept or feasibility studies, with the exception of the Hydrogen Energy Supply Chain (HESC). This key project is a full supply chain involving the production of hydrogen from coal gasification in Victoria (with CCS in the commercial phase) and the export of liquefied hydrogen (LH_2) to Japan. HESC started operation at pilot scale in March 2021. With first shipments of LH_2 by the end of 2021, it will be the first time that LH_2 is transported between two continents.

All three forms of seaborne transportation (LH_2, liquid organic hydrogen carriers (LOHC), and ammonia) are considered by potential Australian exporters and their partners. The possibility of using compressed hydrogen gas (C-H_2) is also investigated by some projects. However, almost half of the projects' carriers are still undecided. Ammonia could be the first hydrogen carrier in the export market: most projects that indicate the carrier tend to emphasize production of renewables-based hydrogen and ammonia, the latter as both an export product and an energy carrier. But some projects are specifically evaluating LH_2 production and export.

Two states, Queensland and Western Australia, concentrate over 60% of hydrogen projects. These states were the first to adopt a hydrogen strategy and funding for hydrogen projects. Both have the resources and ambition to become leaders in hydrogen production, domestic use and exports. The mining and energy sector drives significant economic activity in both states. Hydrogen will be a critical component for decarbonisation of the sector, creating a strong domestic demand and a pathway to realizing ambitious hydrogen exports.

Among the 88 projects (both blue and green hydrogen, or unspecified), nearly 30 projects are under construction or in the advanced planning stages. Their combined electrolysis capacity totals 360 MW (not all of them report electrolysis capacity). Many of these will come on stream by 2025. This includes the first three commercial-scale (10 MW) electrolyser projects that received funding from the government in May 2021. These first steps, dedicated to creating domestic demand across a range of end-use applications, will support much wider deployment targeting the export markets.

Deepened international cooperation and international partnerships

Australia has been working on building international supply chains in promising Asian importing markets since 2018. Since June 2021, Australia has stepped up its efforts and has pursued wider international and technology-led cooperation to attract investment, build supply chains, advance Research, Development and Demonstration (RD&D) and accelerate cost reductions along the full chain. The government has committed AUD566 million to establish international low emissions technology partnerships with key trading and strategic partners, such as Japan, Singapore, South Korea, Germany, the United Kingdom and the United States. As part of this commitment, Australia has deepened its ties with Japan and South Korea, the largest potential hydrogen/ammonia importing markets in Asia and has expanded cooperation with Japan to support ASEAN members in their clean energy transitions. Australia has signed a bilateral alliance on hydrogen production and trade with Germany, a key technology player in renewable hydrogen and a potential significant hydrogen importer. The alliance will support industry-led hydrogen technology demonstration programs along

[3] The remaining 5 projects do not specify the production method for hydrogen (e.g. clean ammonia).

the hydrogen supply chain and facilitate green hydrogen trade from Australia to Germany. The government has also signed a cooperation agreement with Singapore to reduce emissions in maritime and port operations and has partnered with the United Kingdom to collaborate on six low carbon technologies, including hydrogen and CCUS.

These partnerships, backed by business interests and financial incentives, lay the foundations for a global, clean hydrogen market, and position Australia at the forefront of developing a huge hydrogen export industry.