ATSE EXPLAINER

TECHNOLOGY TOWARDS NET ZERO

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Here and now:

The state of low emissions technology in Australia

Australian Academy of Technological Sciences & Engineering

Australia is in the throes of an energy crisis, with electricity generation prices around 115% above the previous highest average wholesale price ever recorded.

Meanwhile all states are achieving record highs for renewables powering our electricity system. Looking beyond the current crisis, what are the opportunities for Australia's transition to a decarbonised electricity system as is strives towards reliable provision, competitive pricing and reduced emissions over the coming decades?

While the opportunity is here and now with Federal and State Governments looking to technology to achieve net zero emissions by 2050, it is critical to determine how these technologies will work harmoniously to decarbonise energy systems, provide new economic opportunities, and meet the needs of Australian industries, communities, and people. This is a snapshot of several key mature and emerging low-emissions energy technologies which are already playing a significant role in Australia's technology-led transition to net zero.

KEY POINTS

Electricity accounts for 34 per cent of Australia's CO_2 emissions[1], and decarbonisation of the sector will be key for Australia to meet net zero by 2050.

Electrification of transport, heating and industry allows decarbonised electricity to eliminate 80% of Australia's emissions[2].

Australia is leading the world in per capita deployment of solar and wind power.

Renewable energy is tracking towards 50 per cent of Australia's electricity generation in 2025[3], by which time the Australian Energy Market Operator (AEMO) expects Australia's electricity grids to be capable of running on 100 per cent renewables[4]. By 2030 it is expected that renewables will supply 69% of Australia's main electricity grid.

The critical technology mix for Australia includes solar power, wind, pumped hydro and batteries, electricity transmission infrastructure, and electrification of transport and heating.

ATSE

MATURE TECHNOLOGIES

Mature energy technologies are existing and proven technologies which are already enjoying widespread usage within Australia's energy network.

SOLAR POWER

Solar PV is by far the leading contender to decarbonise global energy systems.

Solar photovoltaics (PV) convert sunlight into electricity using solar cells. Long-term global growth rates point to solar PV deployment rates above 1,000 GW (1 Terawatt) per year by 2030, worth $1 trillion per year: this approaches the automobile industry in scale. Solar PV is by far the leading contender to decarbonise global energy systems.

As of 2022, there was approximately 24 Gigawatts (GW) of installed solar (roof and ground mounted) in Australia and this is growing by 4-5 GW per year. In 2022, Solar PV is producing 15 per cent of Australia's electricity[5]. Australia has more solar PV per capita than any other country, and about one in four households now have rooftop solar installed.

Solar is variable, fluctuating with the day-night cycle, clouds, and the seasons. Balancing high levels of solar is straightforward using storage (batteries and pumped hydro), strong interstate transmission (to compensate for local weather conditions) and demand management (to handle peaks in electricity demand).

The cost of solar is falling rapidly. In 2020 solar power became the cheapest source of electricity[6]. The declining cost of solar is due to lower manufacturing costs, improved solar cell efficiency, and lower cost of capital due to reduced risk of investment. The costs of electricity from solar and wind energy generation technologies (without storage and transmission costs) are now the lowest of all energy generation technologies, at between $35 and $50 per megawatt hour (MWh) while the incremental cost of solar and wind energy production is near zero[7,8]. The Australian Government's ultra-low-cost solar plan predicts solar costs to reach as little as $15/MWh by 2030, which will undercut every other energy technology in price.

CASE STUDY

Queensland's Western Downs Power Hub

As a result of the decreasing cost of solar, there are now several large-scale solar farms in development, including a 460MW farm being constructed in Queensland's Western Downs area. The project is expected to start in late 2022 and once completed will produce 1,080 GWh of energy per year.

In 2020-21 Queensland consumed 54,500 GWh of electricity, meaning this project will contribute 1.98 percent of the state's annual electricity needs. This is enough electricity to power 235,000 homes for one year.

The project is backed by the state government-owned renewable energy generator CleanCo, which has committed to buying 70 percent of the farm's capacity. This constitutes a significant contribution towards Queensland's 2025 renewable energy target.

Western Downs Green Power Hub (under construction) is located near Chinchilla in the Western Downs region of Queensland, 300 km north east of Brisbane, on Barunggam country, QLD.
Source: westerndownsgreenpowerhub.com.au

WIND ENERGY

Australia is leading the world in per capita deployment of solar and wind power.

Wind energy uses large turbines powered by the kinetic energy of the wind to turn propellers that spin gears connected to an electric generator. Often, wind generators are paired with storage (batteries and pumped hydro) and solar farms to maintain reliable electricity supply. Wind is being deployed faster globally than any other technology except solar and produces the second-cheapest electricity after solar. During the 2014-2016 period solar and wind comprised 99% of new electricity generation capacity in Australia.

Australia is well-suited to the use of utility-scale wind turbines, with vast amounts of open space and reliable, predictable wind patterns. Wind power is currently producing approximately 12 per cent of Australia's electricity[9]. As with solar PV, wind is a variable energy resource.

CASE STUDY

Star of the South

All current wind turbines in Australia are on land. However, in 2021 The Offshore Electricity Infrastructure Bill was introduced to the Federal Parliament, passing the Senate in November. The legislation clears the way for several offshore wind projects. This includes the Star of the South windfarm, a 2.2GW project approved for construction by the Victorian Government off the coast of Gippsland. Victoria possesses some of the best offshore wind resources in the country, however it has previously been prevented from using this resource, as exploration and construction occur in Commonwealth waters. Once completed the Star of the South project will be one of the largest offshore windfarms in the world, with current proposals stating that 200 wind turbines will be installed. This 2.2GW project has the potential to provide nearly 20% of Victoria's annual energy needs. This is enough electricity to power approximately 1.2 million homes a year.

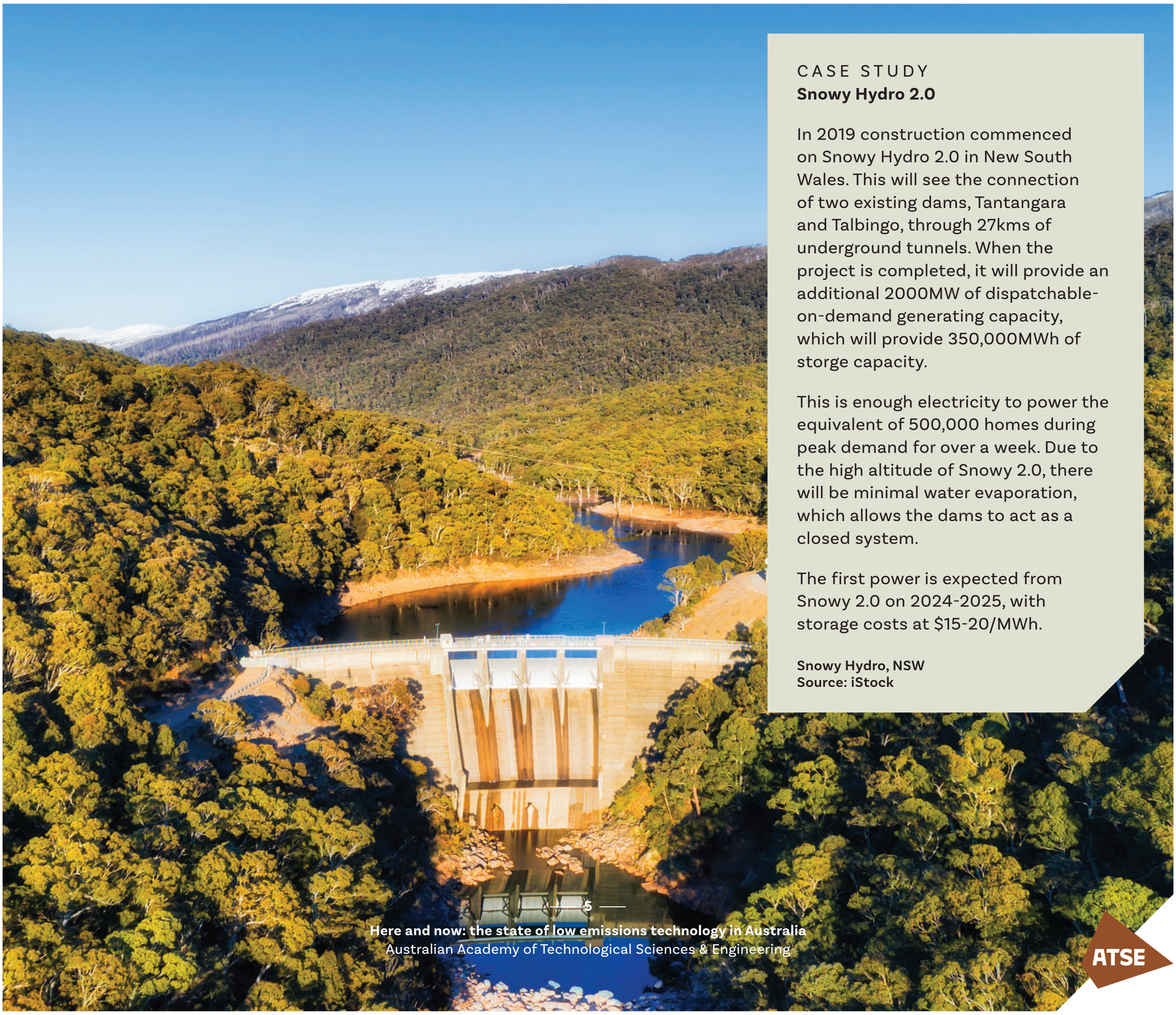
Star of the South offshore windfarm, Gippsland, VIC
Image source: starofthesouth.com.au

PUMPED HYDRO STORAGE

When complete, Snowy Hydro 2.0 will provide more energy storage capacity than all the utility-scale batteries in the world combined.

Pumped hydro (hydro) storage constitutes 96% of global storage power capacity, and 99% of global storage energy volume. While batteries are rapidly falling in price, they are currently unable to compete with the low cost of pumped hydro for large-scale energy storage[10]. Australia has three existing pumped hydro storage systems, the Wivenhoe System in Queensland, the Shoalhaven Scheme in New South Wales, and the Tumut 3 System also in New South Wales. There are two more systems currently under construction, Snow 2.0 in New South Wales and Kidston in Queensland, with a dozen more under serious consideration across both states.

Pumped hydro energy storage works by pumping water to an uphill reservoir when the wholesale price of electricity is cheap, which usually occurs during periods of high wind or solar generation or when demand is extremely low. Later, when the wholesale price of electricity is expensive, either due to a reduction in generation or an increase in demand, the water is released back downhill to produce electricity. These large energy reserves can be used for system security by rapidly increasing generation during periods of supply – demand imbalance.



CASE STUDY
Snowy Hydro 2.0

In 2019 construction commenced on Snowy Hydro 2.0 in New South Wales. This will see the connection of two existing dams, Tantangara and Talbingo, through 27kms of underground tunnels. When the project is completed, it will provide an additional 2000MW of dispatchable-on-demand generating capacity, which will provide 350,000MWh of storge capacity.

This is enough electricity to power the equivalent of 500,000 homes during peak demand for over a week. Due to the high altitude of Snowy 2.0, there will be minimal water evaporation, which allows the dams to act as a closed system.

The first power is expected from Snowy 2.0 on 2024-2025, with storage costs at $15-20/MWh.

Snowy Hydro, NSW
Source: iStock

GAS-FIRED GENERATION

While not a low-emission technology, gas turbines can be applied for flexible energy supply during periods when energy demand is high, and when wind and solar are insufficient to generate the energy needed.

This means gas is useful as a transition technology, as the nation's constructs the wind and solar infrastructure that will be required for a renewable energy future.

Gas turbines use natural gas (methane) to generate energy and are an existing, widely used technology. Combustion of methane directly produces significant CO_2e emissions[11], and fugitive emissions of methane (a potent greenhouse gas) from coal and gas mining cause 10% of Australia's total greenhouse emissions.

Capacity factors[12] for gas turbines are generally low since they are used infrequently, this means a gas plant may only be used to produce a small fraction of its energy generation potential. This limited use means that the cost of the electricity generated is high (when both the capital and operating costs are considered). Gas turbines would therefore likely only be used when electricity prices and electricity demand are both high, and/or when Frequency Control Ancillary Services (FACCS) or capacity are required.

CASE STUDY
Kurri Kurri Gas Plant

In May 2021, the Federal Government announced the public funded Kurri Kurri Gas Peaking Plant. The power plant will be comprised of two open cycle gas turbines and is being designed to provide dispatchable power during periods of high demand, low supply periods from intermittent renewable sources, supply outages at other baseload power stations, and transmission line constraints or outages.

Pokolbin, near Kurri Kurri, Hunter Valley, NSW
Source: Unsplash

GRID TECHNOLOGIES

Australia's electricity grid and transmission infrastructure will need to be upgraded to enable more distributed renewable energy and energy storage.

A large increase in long-distance electrical transmission infrastructure is required to support reliable renewable energy generation[13]. This is required for two reasons:

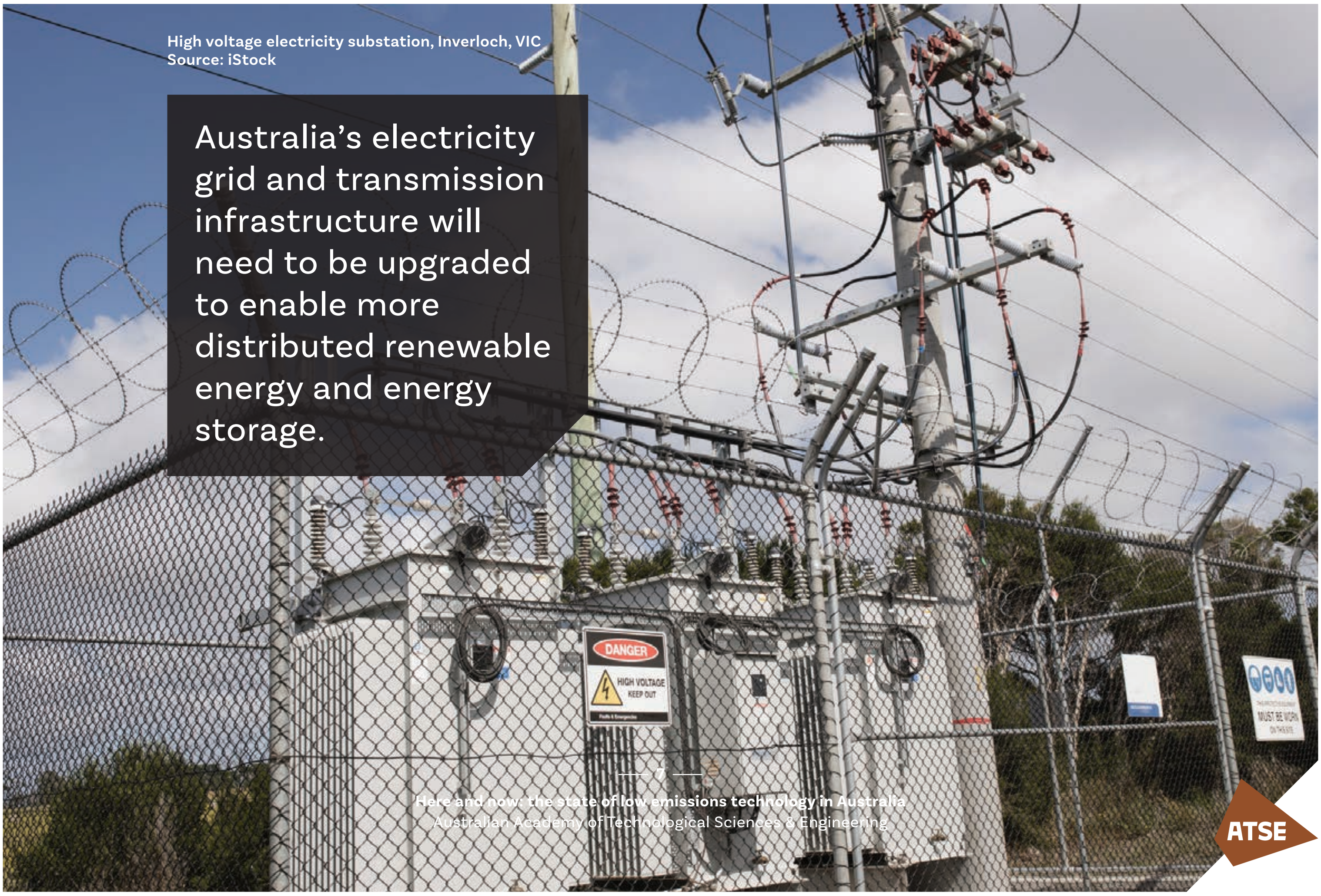
– to bring energy from new solar and wind farms into the cities

– to share energy from state to state so that good weather in one state can compensate for poor weather in another state.

Synchronous condensers are spinning electromagnetic shafts that produce or absorb grid power, this assists with voltage regulation and allows the energy system to continue to operate in its current state, without dips in energy supply[14]. Synchronous condensers are now being deployed across Australia for energy security, particular in areas with high renewable energy penetration or when generation is far from cities and where electricity demand is concentrated[15].

Renewable networks will require further development of comprehensive software systems and data for monitoring and decision-making for region-wide energy generation allocation, optimisation, and demand management. Emerging 'nowcasting' technology developed in Australia is being trialled in South Australia and could become widespread to improve the accuracy of wind and solar forecasting to enhance the demand forecasting system for the National Energy Market (NEM)[4].

With the widespread electrification of a range of sectors (including transport, stationary energy, and industrial processes), global electricity demand is expected to double by 2040[16]. Almost all of this new electricity will come from solar and wind. Australia's electricity grid and transmission infrastructure will need to be upgraded to be prepared for more distributed renewable energy and energy storage.



High voltage electricity substation, Inverloch, VIC
Source: iStock

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EMERGING TECHNOLOGIES

Emerging technologies are low emissions technologies that have transformative potential, but require continued monitoring of global learning rates, research, and investment trends.

BIOENERGY

By 2050, bioenergy could be providing more than 20% of Australia's electricity needs.

Bioenergy is a form of renewable energy generated from the combustion, gasification, or anerobic digestion of biomass, which is organic matter derived from agriculture or forestry waste, or from combustible municipal waste[17]. Bioenergy is experiencing rapid uptake. In 2020 bioenergy produced 1.4 per cent of Australia's electricity, and 5 per cent of the total renewable energy[18]. However whether bioenergy is carbon neutral depends on a range of factors, such as the feedstock used, and the method of energy generation.

Bioenergy has huge potential as an emerging industry. ARENA's 2021 Bioenergy Roadmap found that by early 2030's, Australia's bioenergy sector could contribute an estimated $10 billion in additional GDP (Gross Domestic Product) per annum and create 26,200 new jobs. It also has the potential to reduce Australia's emissions by about 9 per cent and divert an extra 6 per cent of waste from landfill. By 2050, bioenergy could be providing more than 20% of Australia's electricity needs[19].

The applications and opportunities for bioenergy are broad. It can also support fuel security through the generation of liquid fuel from biomass, create biofuel for aviation and land transport, and presents opportunities for regional development.

East Rockingham Waste to Energy, WA
Source: erwte.com.au

LARGE SCALE BATTERY

The costs of battery energy storage fell in 2020-21 - more than any other generation or storage technology.

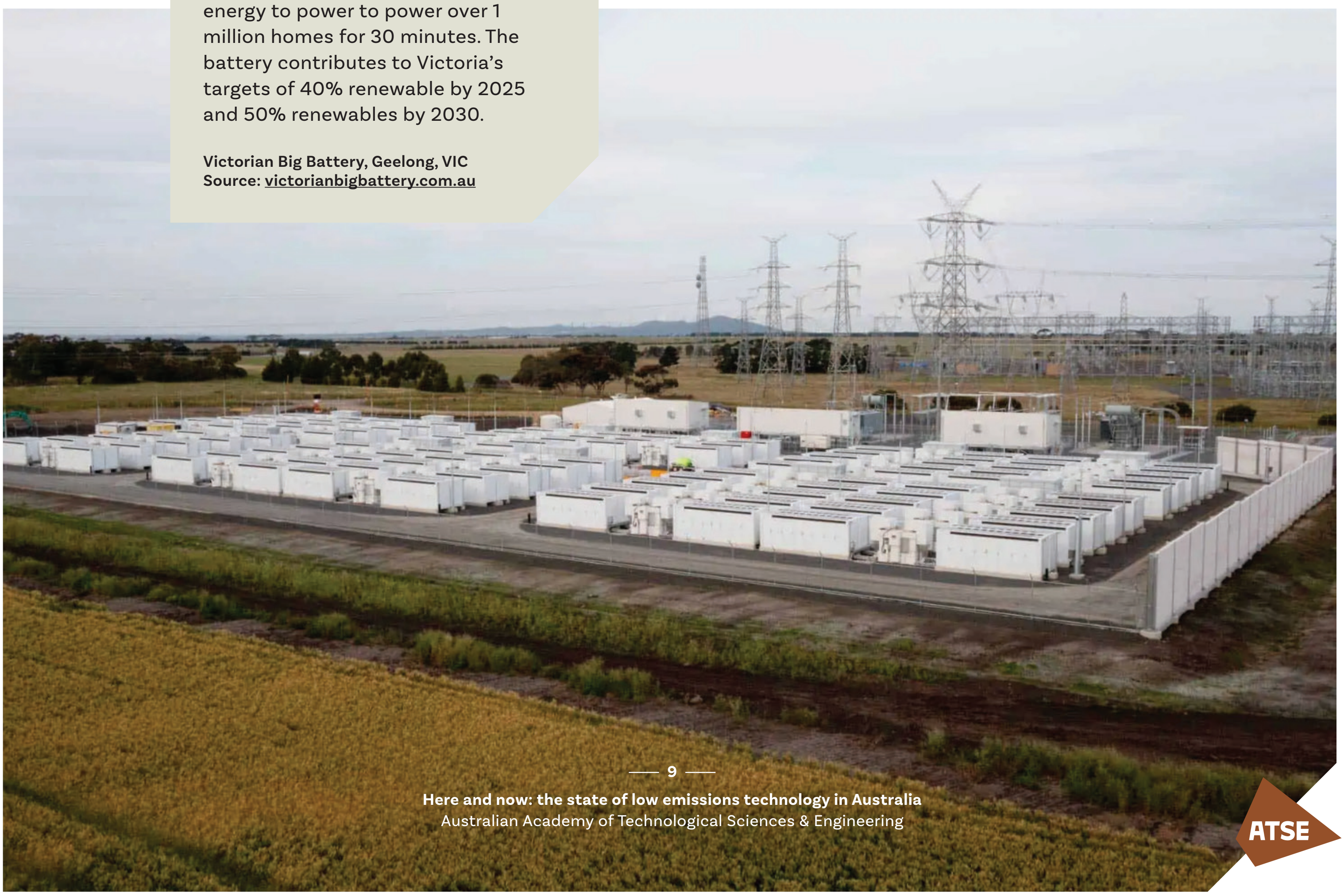
Battery Energy Storage is gaining significant traction in Australia as the nation prepares for a future energy system based primarily on electrification. AEMO's 2020 Integrated System Plan[20] projects the retirement of 63 per cent of coal fired power generation capacity by 2040. These installations will be replaced by wind and solar farms supported by energy firming from pumped hydro, batteries, and gas.

As renewable energy uptake grows rapidly, Australia's need for dispatchable power is increasing. Battery storage (along with pumped hydro storage) is emerging as a key enabling technology for widespread uptake of renewable energy by storing energy in periods of high supply and providing energy on demand.

Batteries based on lithium-ion chemistry are also becoming increasingly cost-effective, with costs falling in 2020-21 more than any other generation or storage technology, and they are projected to continue to fall in the future[21]. The 2021 Low Emissions Technology Statement identifies energy storage as a priority technology, with a view to get electricity from storage to a cost under $100/MWh.

CASE STUDY
Victorian Big Battery

The largest grid connected battery in the Southern Hemisphere is the Victorian Big Battery, located near Geelong. Opened in December 2021, the battery provides 450MWh of energy storage for the state, discharging at 300MW. This is enough energy to power to power over 1 million homes for 30 minutes. The battery contributes to Victoria's targets of 40% renewable by 2025 and 50% renewables by 2030.



Victorian Big Battery, Geelong, VIC
Source: victorianbigbattery.com.au

HYDROGEN

To realise the potential for 'sustainable' hydrogen, further development, and demonstration of supporting technologies is needed.

Hydrogen is required as a chemical feedstock for synthesis of chemicals, metals, plastics, and synthetic aviation fuels. However, it is unlikely to contribute substantially to future energy production due to the heavy efficiency losses using current production methods. As three quarters of the renewable electricity used to produce hydrogen is lost in the electricity-hydrogen-electricity cycle, it is far more efficient to use renewable electricity directly in transport (electric vehicles) and heating (electric heat pumps and furnaces).

Hydrogen exports for the chemical industry may become a major economic opportunity for Australia, although most countries will be able to produce their own hydrogen from solar and wind and hence avoid heavy transport costs and losses[22,23].

Hydrogen can be produced by four main methods:

GREEN HYDROGEN
Electrolysis of water (including wastewater and desalinated seawater) using renewable energy. This does not produce greenhouse emissions.

BLUE HYDROGEN
Chemical reformation of natural gas or coal. This method produces CO_2 which might in principle be sequestered by Carbon Capture and Storage (CCS). However, there is no significant commercial CCS because of excessive costs. Because of this blue hydrogen is more greenhouse intensive than simply using the methane directly.

GREY HYDROGEN
Hydrogen produced from natural gas or methane, without attempting to capture the greenhouse gases made in the process. This is currently the cheapest, and therefore the most common, way to produce hydrogen.

BLACK HYDROGEN
Hydrogen produced through the gasification of coal.

Global demand for hydrogen grew to approximately 90MT in 2020, and since most hydrogen is still produced using fossil fuels, it is responsible for the production of 830 million tonnes of carbon dioxide equivalent per year[24]. To realise the potential for 'sustainable' hydrogen, further development, and demonstration of supporting technologies is needed.

The advancements in technology and infrastructure required include improving electrolysis cost and efficiency, reducing at scale capital and operating costs in the methane steam reformation process (which involves heating methane with steam, to produce carbon monoxide and hydrogen), CCS of the CO_2 stream from fossil fuel reformation, and conversion to ammonia. While sustainable 'green' hydrogen production is an opportunity for job growth and a source of renewable energy, recent analysis highlights that the cost of the hydrogen produced is still high compared with natural gas[25].

CASE STUDY
National Hydrogen Strategy

The Australian Government released the National Hydrogen Strategy in 2019, and an updated State of Hydrogen report in 2021. The hydrogen strategy outlines several of the Federal Governments priorities in the hydrogen space, including the development of 7 hydrogen hubs in regional Australia. These hubs will likely be in Bell Bay (TAS), Darwin (NT), Eyre Peninsula (SA), Gladstone (QLD), Latrobe Valley (VIC), Hunter Valley (NSW), and Pilbara (WA).

CONCLUSION

To meet net zero emissions by 2050, Australia will need a portfolio of low emissions technologies which act in concert, supported by a clear research agenda and policy framework to provide an environment for industry to act with confidence.

Immediate investment in the deployment of mature technologies, demonstration of emerging technologies and development of grid infrastructure capable of running a renewable energy-based system is necessary to ensure Australia can meet its unique geographical and sectoral challenges.

Critical path planning and development by industry, government and other stakeholders must start immediately to meet the emissions reduction aspirations described in Australia's Long-Term Emissions Reduction Plan.

Some important considerations for government and industry include:

- Selection of the most efficient wind farm and solar farm sites that ensure efficiency in supply
- Design, preparation, and construction of pumped-hydro and large battery energy storage sites to ensure electricity security
- Planning and implementation of transmission infrastructure to accompany the large increase in distributed renewable energy production and the overall electricity supply across a distributed network
- Facilitation of upskilling and employment of the existing energy generation industry workforce.

If Australia is to meet its 2050 target of net zero emissions, this strategic planning and investment in Research Design & Development (RD&D) will be essential.

Policy and investment decisions should be guided by Australia's commitment to limiting global warming to well below 2, preferably to 1.5 degrees Celsius as enshrined in the 2015 Paris Agreement.

Strategic future planning, as well as evolving markets for mature and emerging energy technologies, will be decisive factors in accelerating the race to net zero.

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