Submission to the Joint Standing Committee on Trade and Investment Growth inquiry into Australia's transition to a green energy superpower

Geoscience Australia

20 December 2022

Contents

Terms of Reference

This submission addresses the Terms of Reference (ToR) of the Joint Standing Committee on Trade and Investment Growth inquiry into Australia’s transition to a green energy superpower, including:

1. where trade and investment activities are already having a positive impact;
2. emerging and possible future trends;
3. the role of key Commonwealth agencies including Austrade, in identifying new trade and inward investment opportunities, and assisting Australian companies to access these opportunities, including through whole of government coordination of investment;
4. areas of growth, and how can these be accelerated and/or assisted, including through the use of Commonwealth Special Investment Vehicles; and how Australia can capitalise on existing and future trade agreements and economic frameworks with countries or regions around the world.

The Committee will have particular regard to the areas that play to Australia's strengths, including: renewable energy, battery storage, energy supply and infrastructure, electric vehicle industry, infrastructure, advanced manufacturing, and services and technology.

Introduction

Geoscience Australia is Australia's national geoscience public sector organisation. Our mission is to be a trusted source of information on Australia's geology and geography for government, industry and community decision making. Our work covers the Australian landmass and marine jurisdiction, including external territories. Geoscience Australia delivers enduring data and advice that helps government, industry and the community to address challenges and enhance opportunities facing Australia now and into the future.

Geoscience Australia is the Australian Government's technical advisor on the geography and geology of Australia and its marine territories, and supports government policy development and implementation. We do this by delivering publicly available geoscience data and knowledge on Australia's energy and mineral resources and geological storage capacity, and foundational information on Australia's geography that are critical to Australia's goal to be a global green energy superpower.

As a market driven economy, trade and investment has been, and remains, critical to Australia's economic and social prosperity. This is evident in the success of Australia's traditional energy (oil, gas and coal) and mineral (iron ore and gold) sectors. Geoscience Australia's data and knowledge has helped underpin this success and there are many opportunities to address key knowledge gaps to further unlock new opportunities in the emerging renewable and green energy industries, both onshore and offshore. Augmentation and application of our data and information through digital technologies, including online decision-support tools, can also help inform investment decisions for future green energy projects.

This submission identifies strategic opportunities to enhance Australia's competitive advantage as an investment destination in supporting our transition to a green energy superpower, with reference to Geoscience Australia's work in supporting current and future investment and trade activities.

Supporting Australia to be a green energy superpower

Australia's success in capitalising on market opportunities and capturing a relatively large share of the global investment in energy commodities has depended largely on the accessibility and quality of Australia's understanding of its resource base. This success has been supported by scientific data and information, including from Geoscience Australia's work program over many decades and our commitment to enabling an informed Australia through best practice data delivery and management.

As Australia positions itself to be a green energy superpower, there is opportunity to utilise scientific data and information about our natural resources to inform policy and decision-making by governments, industry and communities.

Energy Sources

Australia is a net exporter of energy. Australia's primary energy production in 2019-20 was black coal followed by natural gas. Over a 10 year period, renewables had an average annual growth of 4%, exceeding coal and oil (Table 1).

Table 1: Australian primary energy production by fuel type (2019-20)[1]

Energy source	Production (PJ)	Share (%)	Average annual growth 2019–20 (%)	Average annual growth 2009-10 to 2019–20 (%)
Energy Commodities				
Black coal	12,317	52.4	-2.2	2.4
Brown coal	425	1.8	-4.3	-5.6
Natural gas	5,945	25.3	7.9	11.2
Oil, NGL	798	3.4	18.0	-2.2
LPG	151	0.6	47.8	4.7
Uranium	3,454	14.7	-3.5	0.4
Total Energy Commodities	*23,090*	*98.2*	*0.8*	*3.1*
Renewables	419	1.8	4.6	4.0
Total	**23,509**	**100.0**	**0.9**	**3.1**

[1] Geoscience Australia, 2022. Australia's Energy Commodity Resources, 2022 Edition. Geoscience Australia, Canberra. https://www.ga.gov.au/digital-publication/aecr2022

Natural gas / LNG

Predictions of future global energy supply and demand indicate that while the consumption of fossil fuels will peak at around 2030 and decrease with increasing uptake of renewable and other green energy sources, fossil fuels will necessarily remain part of the energy equation.[2]

Of these, natural gas remains the most in-demand energy resource, replacing other, more emissions-intensive fossil fuels (fuel switching), providing dispatchable electricity, and potentially providing feedstock for the generation of (blue) hydrogen. Australia's liquefied natural gas (LNG) export earnings in 2021-22 were $70 billion and are expected to rise to $90 billion in 2022-23, largely because of the Russian invasion of Ukraine.[3] Australian LNG export volumes are predicted to be ~80 Mtpa after 2023-24, and likely to rise from 2026 when the Scarborough Field and Pluto Train 2 projects commence.

Greenhouse gas emissions from the consumption of natural gas are less than half of the emissions from the consumption of coal. Technologies such as carbon capture and storage (CCS) used in conjunction with the extraction and/or consumption of gas/LNG resources can further reduce the generation of greenhouse gas emissions from this fuel source.

These considerations are important for noting the value of LNG exports to Australia's economy and the role it has in supplying energy and decarbonising Australia and the Asia-Pacific region, by providing a lower emissions fuel than the alternatives (such as coal and oil).

Australia has a wealth of gas resources, and further opportunities for trade and investment. Enabling technologies, such as CCS, to decarbonise the scope 1, 2, and potentially scope 3 emissions, can be instrumental to supporting Australia and the region's future net zero emissions target.[4] Further, Geoscience Australia's technical advice and knowledge of Australia's offshore area underpins the Australian Government's annual offshore acreage release program, which includes greenhouse gas acreage as well as petroleum exploration acreage.

Hydrogen

Hydrogen is seen as a pathway to decarbonise Australia's economy and as a potential source of ongoing green energy export revenue in future years. Australia is well placed to develop a large-scale clean hydrogen export industry, with extensive natural resources (e.g. renewable energy, land, natural gas and geological storage potential) and established international energy commodity supply chains.

In 2019, the Australian Government released the National Hydrogen Strategy,[5] identifying hydrogen as a future clean fuel source in Australia and potential new multi-billion-dollar export industry. The Strategy considers both green hydrogen (hydrogen produced from renewable energy) and blue hydrogen (hydrogen produced from fossil fuels with CCS).

Geoscience Australia is providing analysis, data and information that will support the sustainable establishment of a hydrogen industry in Australia. We are tracking hydrogen projects around Australia, and

[2] McKinsey & Co., 2022. Global Energy Perspective 2022, 26 April 2022. https://www.mckinsey.com/industries/oil-and-gas/our-insights/global-energy-perspective-2022
[3] Office of the Chief Economist (OCE), 2022. Resources and energy quarterly, September 2022. https://www.industry.gov.au/sites/default/files/minisite/static/8f915ab4-c06d-41cf-98ee-5bc628230bdc/resources-and-energy-quarterly-september-2022/documents/Resources-and-Energy-Quarterly-September-2022.pdf
[4] https://www.nationalgrid.com/stories/energy-explained/what-are-scope-1-2-3-carbon-emissions#:~:text=Definitions%20of%20scope%201%2C%202,owned%20or%20controlled%20by%20it
[5] https://www.dcceew.gov.au/sites/default/files/documents/australias-national-hydrogen-strategy.pdf

providing access to our extensive national data holdings (e.g., natural gas pipelines, electricity transmission lines, roads, solar and wind resources), all of which will underpin trade and investment in this nascent industry. Under the Exploring for the Future program, we are undertaking research in underground (geological) hydrogen storage – an emerging opportunity for Australia.

Even though industrial-scale clean hydrogen production is not yet operational in Australia, there are over 100 pilot, demonstration and very large-scale projects in various stages of development as reported on HyResource[6] and AusH2[7]. A total of 97% of these planned projects are for hydrogen produced from renewable energy.

Natural (geologic) hydrogen

An emerging source of hydrogen is natural or gold hydrogen, which involves producing hydrogen that has naturally accumulated in the sub-surface over time. While our understanding of Australia's natural hydrogen resources is in its infancy there are tantalising prospects for this non-renewable resource based on new research to understand how natural hydrogen accumulations form and where they may occur.[8] There is also recent industry interest in hydrogen exploration tenements in all states and the Northern Territory based on this work, and over the last two years exploration for natural hydrogen resources has increased, particularly in South Australia.

Geothermal

Geothermal energy is a dispatchable, green and renewable source of energy that can be used directly for heating buildings, for industrial processes, and for generating electricity. Previous work by Geoscience Australia has indicated that there could be considerable potential for geothermal energy across Australia from low-to-high temperature sedimentary aquifers.

To better understand the resource potential, Geoscience Australia, as part of the Exploring for the Future program, is looking at new potential geothermal energy resources across the country. A notable example of industry investment in geothermal energy is Strike Energy, who are exploring the hot sedimentary aquifer potential of the onshore Perth Basin for geothermal energy generation. Other areas of potential, identified by industry, include: the Great Artesian Basin, especially overlying the Cooper Basin region; the Otway Basin; the (onshore) Gippsland Basin; possibly the Amadeus Basin and parts of the Bowen Basin; and the Perth and Carnarvon Basins. Several of these areas already host small scale direct-use installations.

Wind

Australia has world class wind resources. Renewable sources, including wind, currently only contributes a small percentage (1.4%) to the total amount of energy produced in Australia. However, renewable energy

[6] https://research.csiro.au/hyresource/
[7] AusH2.ga.gov.au
[8] Boreham Christopher J., Edwards Dianne S., Czado Krystian, Rollet Nadege, Wang Liuqi, van der Wielen Simon, Champion David, Blewett Richard, Feitz Andrew, Henson Paul A., 2021. Hydrogen in Australian natural gas: occurrences, sources and resources. The APPEA Journal 61, 163-191. https://doi.org/10.1071/AJ20044

has grown on average by 4.0% per annum over the past decade and will become an increasingly important part of energy production in coming years.[9]

Geoscience Australia has developed national offshore and onshore wind capacity factor maps (Figure 1). These maps have assisted in improving the understanding of regional patterns of wind capacity which is relevant to site selection for wind energy projects.

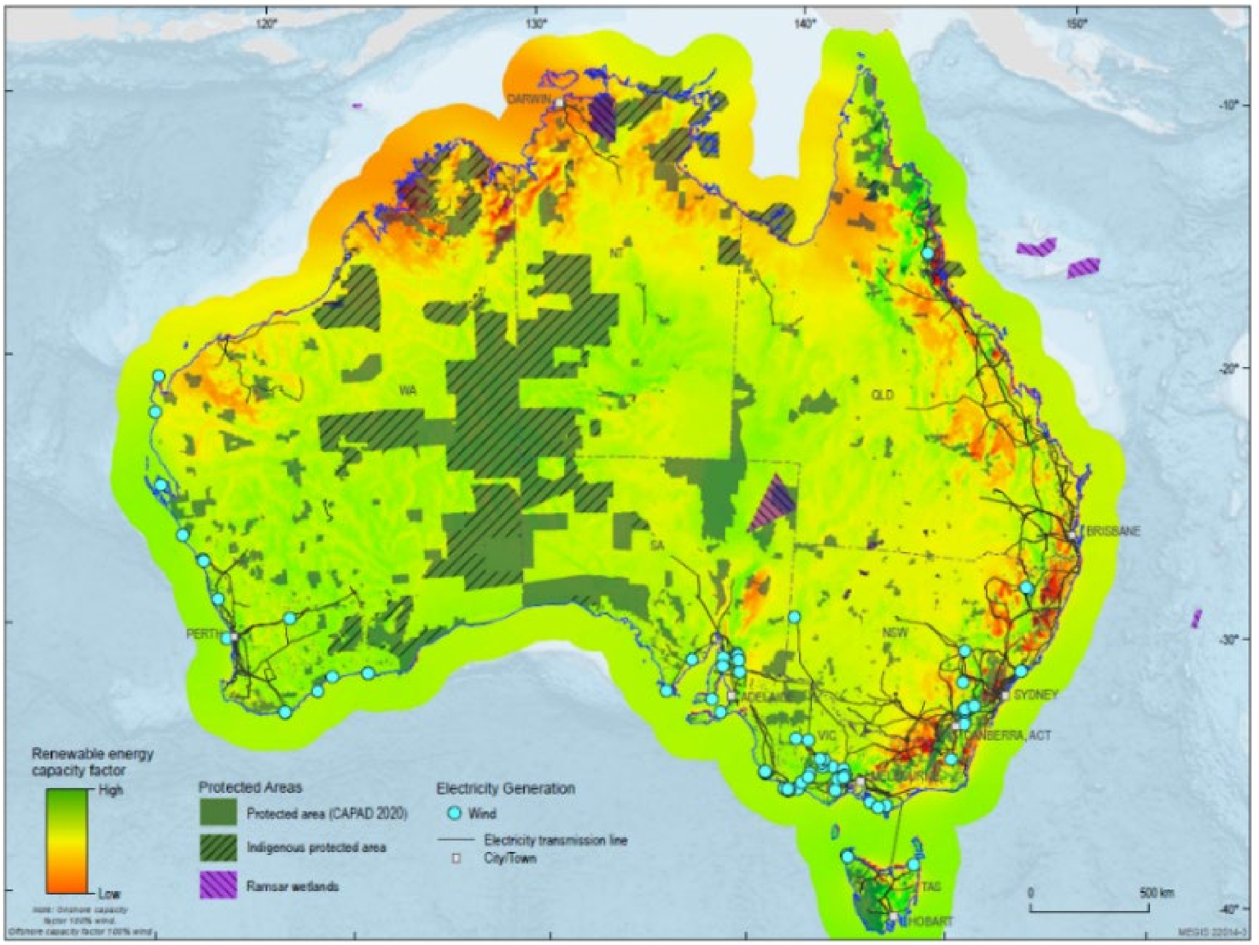

Figure 1: Onshore and offshore wind capacity factor map with operating wind farms. Note the majority of wind farms are located in southern Australia

Australia's extensive marine jurisdiction is approximately double the size of Australia's land mass and comprises 4% of the world's oceans. Our oceans have provided the majority of Australia's oil and gas resources, and offer opportunities for new economic growth, with emerging ocean industries (e.g. offshore renewable energy) generating new job opportunities and contributing to Australia's future economic prosperity. With increasing global pressures on energy security and societal demands for a transition to net zero carbon emissions, offshore wind will help Australia to reduce its reliance on fossil fuels to generate electricity and reduce future greenhouse gas emissions.

Geoscience Australia's marine geoscience activities provide a proven, trusted framework on which this success can be capitalised. Geoscience Australia's foundational seabed data and information improves the understanding of the marine environment and reduces investment uncertainty. Seabed mapping data is a

[9] Geoscience Australia, 2022. Australia's Energy Commodity Resources, 2022 Edition. Geoscience Australia, Canberra. https://www.ga.gov.au/digital-publication/aecr2022

critical input into the establishment of offshore energy infrastructure as it provides information on the seabed characteristics (e.g. depth, topography and stability) and surrounding environment (e.g. benthic habitats) that can:

- inform optimal site selection;
- provide evidence to support obtaining environmental and planning approvals; and
- inform the engineering and design process in establishing the required infrastructure (e.g. pipelines, cables and wind turbines).

Offshore electricity generation through wind is part of the Government's energy framework, through its *Offshore Electricity Infrastructure Act 2021*. Geoscience Australia's marine data and information is being used to underpin decisions for offshore wind developments. An example of Geoscience Australia's activities supporting new investment is the development of a regional-scale bathymetry compilation[10] and characterisation of seabed geomorphology for Bass Strait in the Gippsland area, Victoria. This information was used to inform the recent area declared by the government for offshore wind farms and has already informed the Star of the South Offshore Wind Farm project, which has the potential to supply 20% of Victoria's energy needs. The seabed information also provides the baseline environmental information for government and industry to monitor, manage, and ultimately minimise impacts on the natural environment from an offshore electricity industry.

[10] Beaman, R.J. 2022. High-resolution depth model for the Bass Strait - 30 m. Geoscience Australia, Canberra. https://dx.doi.org/10.26186/147043

Digital platforms informing investment decisions

Geoscience Australia delivers trusted, openly accessible geological and spatial data through online digital platforms and provides decision-support tools to inform decisions by government, industry and the community. This includes the Geoscience Australia Portal[11] and the Digital Atlas of Australia[12]. Our digital platforms help reduce government and private sector investment uncertainty by providing information essential for the planning, exploration, approvals, construction and ongoing operations of renewable and green energy projects.

The **Digital Atlas of Australia** is a $40.2 million investment by the Australian Government over 4 years and is in the early stages of delivery. This free, secure, interactive, geospatial platform will enable users to access, download and personalise content from a rich and authoritative suite of national data about Australia's geography, people, economy, and the environment.

Geoscience Australia operates the **Australian Marine Spatial Information System (AMSIS)**[13] - the Australian Government's digital platform for official information on Australia's maritime boundaries, the geographic extents of Commonwealth regulation, official information on use of the marine environment (e.g. shipping lanes), and relevant scientific information (e.g. wind capacity maps, seabed maps). AMSIS provides access to the information on which government can make decisions and enable users to visualise existing rights in the offshore and the spatial interactions between existing and proposed activities. This provides certainty for investment in offshore renewable energy projects by providing clarity of regulatory responsibilities, avoiding conflicts between activities, and improving understanding of likely costs and investment risk.

AMSIS also supports public consultation for offshore energy projects. The Department of Climate Change, Energy, the Environment and Water (DCCEEW) has recently used the AMSIS digital platform to support the public consultation period for the Gippsland Proposed Area for offshore renewable energy. AMSIS provides transparency of information and an improved understanding of rights, restrictions and use of the offshore jurisdiction, which contribute to increased investor confidence.

Geoscience Australia, in collaboration with Monash University, has produced an open-source economic model - the **Hydrogen Economic Fairways Tool (HEFT)**[14] - to assist investors and policymakers to explore future scenarios of large-scale commercial hydrogen production under different scenarios (Figure 2). HEFT uses a detailed geospatial-economic model that includes the cost of hydrogen production, electricity generation, associated rail and road transportation infrastructure, pipelines to export ports, carbon dioxide (CO_2) pipelines, and access to wastewater or ocean desalination water resources.

Geoscience Australia's modelling indicates that hydrogen produced using solar and electrolysis could be more profitable than brown coal with CCS in 2030 in Australia (Figure 2). For a range of scenarios, ultra-low cost solar with electrolysis appears to be the only feasible option to achieve very low hydrogen costs of US$1/kg H_2 in 2050.[15] This indicates that countries that can host large-scale solar, like Australia, will be well placed to meet the future global demand for clean hydrogen.

[11] https://portal.ga.gov.au/
[12] https://www.ga.gov.au/scientific-topics/national-location-information/digital-atlas-of-australia
[13] https://amsis-geoscience-au.hub.arcgis.com/
[14] https://portal.ga.gov.au/persona/heft
[15] Rees, S., Walsh, S., Haynes, M., Wang, C. and Feitz, A. (2022) Mapping Australia's Hydrogen Future. Proceedings of the 16th Greenhouse Gas Control Technologies Conference (GHGT-16) 23-24 Oct 2022, http://dx.doi.org/10.2139/ssrn.4295339

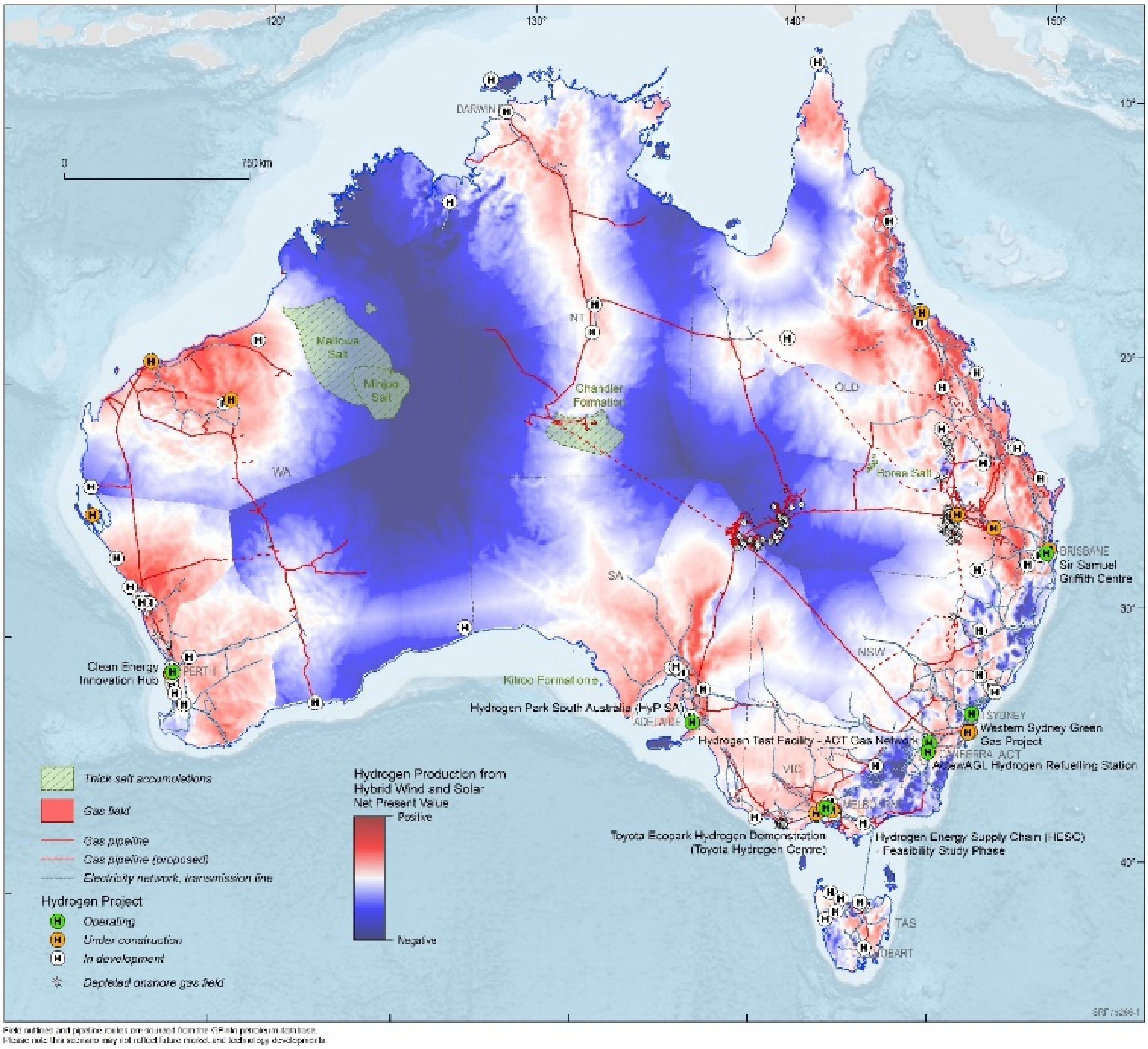

Figure 2: Hydrogen production potential using off-grid hybrid wind and solar with areas in red showing regions of high potential.

Opportunities

Australia's transition to a green energy superpower can be accelerated and assisted through trusted and accessible information on Australia's geology and geography. Geoscience Australia is well-positioned to provide our geoscience data and knowledge and our online decision-support tools to help government identify strategic opportunities for investment supporting the transition, and reducing investor risk for green energy projects. Our data, information and advice in the following areas will be critical to stimulating investment and helping Australia achieve its objective of being a global green energy superpower.

Energy Storage

Energy storage is needed to assist with daily to seasonal variability in demand, with large-scale storage being one of the biggest challenges for large-scale deployment of renewable energy technologies such as solar and wind power.

Large scale energy storage is required to meet electricity demand when renewable energy is not being generated (e.g., when the wind is not blowing, or the sun is not shining). The timeframes and applications of energy storage vary from long duration energy storage (up to a day or longer), such **as compressed air energy storage,** to short term (up to hours) options, such as **batteries.** For longer term energy storage, **hydrogen** provides a means for transforming renewable energy into a versatile and dispatchable fuel (e.g., for transport), energy source for electricity generation and input into chemical processes (e.g., fertiliser production, oil refining), and will require storage, similar to current natural gas storage facilities.

Compressed air energy storage (CAES)

Compressed air energy storage is emerging globally as a potential solution for energy storage and supporting renewable energy generation. There are currently no commercial CAES projects in Australia and only one in development, while another has been discontinued.[16] The **Silver City Energy Storage Centre** in Broken Hill, NSW, will be an emissions-free 200 MW Advanced-CAES facility developed by Hydrostor and Energy Estate. The facility will make use of a decommissioned mine and mining infrastructure that will supply up to 8 hours (up to 1,600 MWh) of electricity at a time to up to 200,000 homes. This will prevent 11 $MtCO_2$ from being emitted over the project's lifetime (Hydrostor, 21 Oct 2022). The project has received funding from the NSW Government's Emerging Energy Program and the Australian Renewable Energy Agency's (ARENA) Advancing Renewables Program,[17] and will integrate renewable energy technologies. The $652m project's design life is more than 50 years, commencing operation in 2025.

Through the Exploring for the Future program, Geoscience Australia is examining sub-surface resources that may be suitable for compressed air storage, including underground salt accumulations and permeable sandstone rocks. This work potentially opens up new opportunities to support additional investment and trade for Australia by providing large-scale, commercial energy storage solutions to support its renewable energy transition. This work has also identified potential opportunity for energy storage in hard rock caverns, where salt or permeable sandstone rocks are absent. There is an opportunity to better understand the feasibility of this emerging potential solution for energy storage, through further geological and technical investigations.

[16] https://indaily.com.au/news/2021/01/21/canadians-pull-plug-on-strathalbyn-energy-storage-project/
[17] ARENA, 2022. Repurposing Broken Hill mine for renewable energy storage using compressed air, 21 October, 2022. https://arena.gov.au/news/repurposing-broken-hill-mine-for-renewable-energy-storage-using-compressed-air/

Battery energy storage

There are several different types of batteries that are currently in use or have planned deployments into the national energy market: lithium ion (and similar battery chemistries) and vanadium flow batteries (VFB). These battery systems are typically used as short-term storage (less than 3 hours, typically an hour or less) as a firming measure for the grid and a frequency control measure. The frequency control measures are especially important for wind farms with many having associated smaller battery systems.

Geoscience Australia's work programs currently do not focus on battery technologies. However, we do provide advice and carry out research to identify new investment and trade opportunities for battery raw materials, some of which have been classified by the Australian Government as critical minerals.[18]

Hydrogen storage

Hydrogen can be stored in large quantities and over long time periods making it ideal for large-scale, commercial energy storage. Commercial storage is critical to support international trade of hydrogen into the future and ensure Australia's reputation as a reliable energy supplier is maintained.

Underground geological storage is considered the most practical and cost-effective option for commercial operations. Options for geological storage include salt caverns, depleted gas fields, rock caverns and aquifers.[19] Presently, all large-scale storage of commercially produced hydrogen (from unabated fossil fuels) occurs in underground salt (halite) caverns in the UK and USA.

Australia is an ancient continent featuring thick salt accumulations dating back approximately 800 million years. Onshore, Australia has several opportunities for geological hydrogen storage which could be used to stabilise and improve reliability of intermittent renewable energy, balance seasonal fluctuations in the natural gas network and potentially balance the frequency of shipping schedules to support hydrogen export. Through the Exploring for the Future program, Geoscience Australia is mapping salt accumulations across Australia and developing techniques to find new salt prospects, including using airborne electromagnetic surveys (Figure 3). With the exception of the Maka Sarakham salt in Thailand, Australia possesses the only known thick and extensive salt accumulations in the Southeast Asian – Pacific region.

Offshore, hydrogen storage in salt accumulations has received little attention, but is under active consideration in the UK[20], Ireland[21, 22] and EU[23]. In Australia, halite accumulations are distributed across many offshore sedimentary basins. Geoscience Australia has identified a large salt accumulation in the offshore Polda Basin (over 1 km thick) that looks prospective for large scale underground hydrogen

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[18] Critical Minerals Strategy 2022 https://www.industry.gov.au/publications/critical-minerals-strategy-2022

[19] https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf

[20] Williams J., et al., 2022. Does the United Kingdom have sufficient geological storage capacity to support a hydrogen economy? Estimating the salt cavern storage potential of bedded halite formations, Journal of Energy Storage, 53:105109, https://doi.org/10.1016/j.est.2022.105109

[21] dCarbonX. 2021. Large scale offshore hydrogen storage to enable Ireland's Energy Transition. Hydrogen Ireland. https://hydrogenireland.org/2021/10/06/working-paperdcarbonx-large-scale-offshore-hydrogen-storage-toenable-irelands-energy-transition/

[22] Chedwynd, G. 2021. Irish green hydrogen potential spurs ESB to subsea storage partnership. Upstream Energy Explored. https://www.upstreamonline.com/energy-transition/irishgreen-hydrogen-potential-spurs-esb-to-subsea-storagepartnership/2-1-1016687

[23] Caglayan D. G., et al., 2020. Technical potential of salt caverns for hydrogen storage in Europe. International Journal of Hydrogen Energy, 45. 6793-6805, https://doi.org/10.1016/j.ijhydene.2019.12.161

storage.[24] There are many other offshore basins that may have salt accumulations but the total resource potential is unknown.

While several new prospects have been identified offshore and onshore, for Australia to truly capitalise on its natural assets requires further detailed work to fully assess the national potential for salt resources to be used for underground hydrogen storage to de-risk areas for future investment.

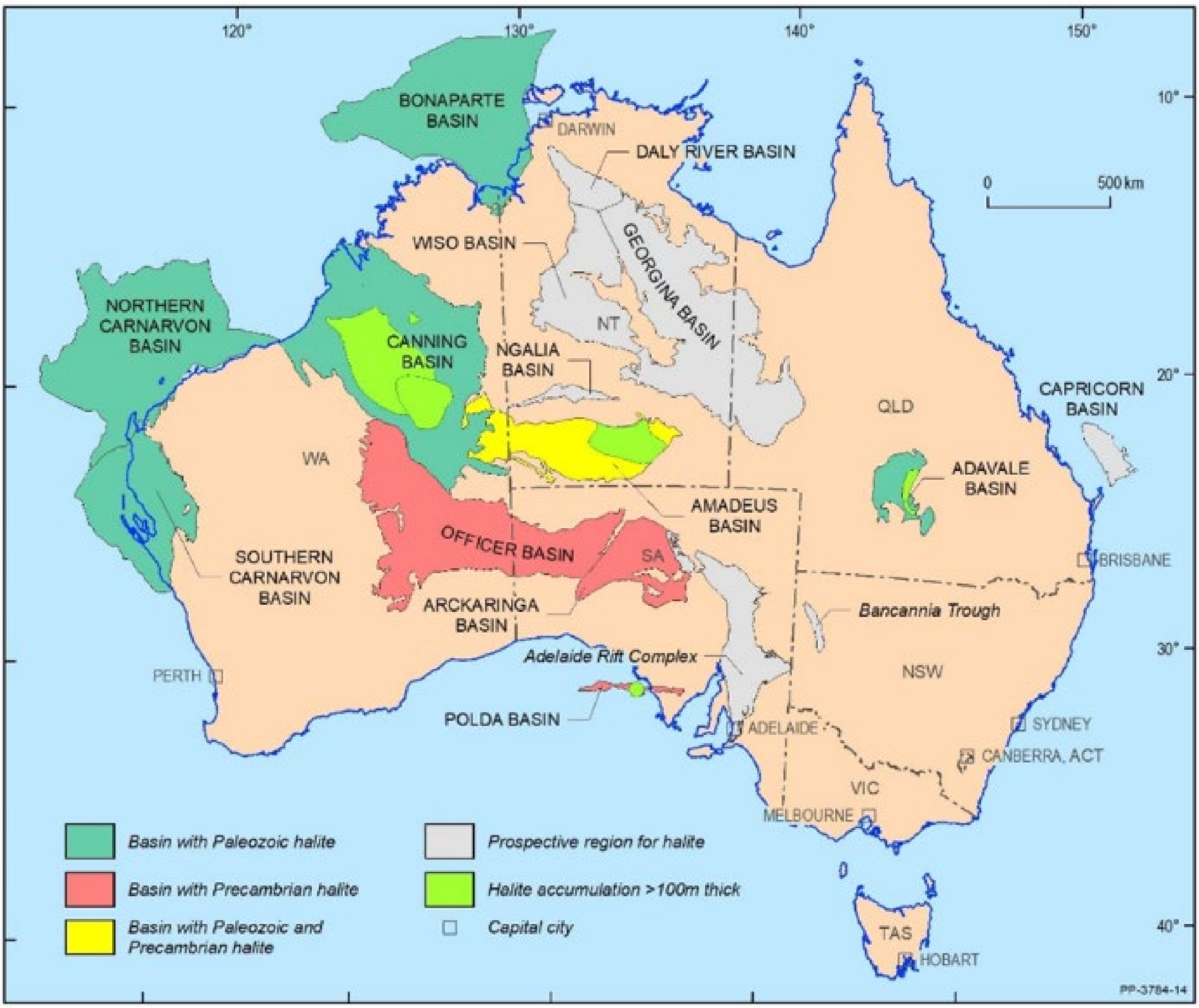

Figure 3: Salt bearing basins in Australia and known thick salt (halite) accumulations

Offshore Wind

Offshore wind energy projects are expected to be the largest and most significant infrastructure development in Australia's marine environment. The offshore wind energy industry is predicted to create up to 8,000 Australian jobs each year from 2030. Furthermore, other forms of renewable ocean-based energy (including wave, tidal and ocean thermal) are still at an early stage of commercialisation, but wave energy has the potential to contribute up to 11% of Australia's total electricity generation by 2050.

[24] Feitz, A. Wang, L., Rees, S., and Carr, L., 2022. Feasibility of underground hydrogen storage in a salt cavern in the offshore Polda Basin. Geoscience Australia, Canberra. https://dx.doi.org/10.26186/146501

With only around 25% of Australia's seabed mapped in sufficient detail to inform sustainable use of the marine environment, existing seabed information for many areas identified for offshore wind development is inadequate for planning and monitoring activities. There is an opportunity to develop new regional seabed information products in high priority areas to support decision-making and encourage investment. These products improve the regional understanding of the seabed and provide the context needed to give utility to local scale studies that will be undertaken by industry.

Critical Minerals

Raw materials, including lithium, copper, nickel, silicon, manganese, graphite, rare earth elements and cobalt are the building blocks of clean energy technologies, such as batteries, electric vehicles (EVs), wind turbines and solar panels. The shift to a clean energy system is set to drive huge increases in the global demand for these minerals.

The Australian Government considers 26 resource commodities to be critical minerals, listed in Appendix A, with more information available in Australia's Critical Minerals Strategy.[25] These minerals have been selected by assessing Australia's geological endowment and potential with global technology needs (including for clean energy technologies), particularly the needs of partner countries such as the United States, United Kingdom, Japan, India, South Korea and Canada. World rankings for Australian critical minerals are listed in Appendix B.

Australia's vast resource endowment, exploration and mining expertise, world-class mining equipment, technology and services sector and existing infrastructure mean we are well-placed to support the growth in demand for critical minerals and development of green energy technologies. There is significant opportunity to discover new mineral deposits in the vast areas of Australia that remain underexplored and unexplored, including the 80% of our landmass where the resources may be buried deep underground. The Exploring for the Future program is making early and significant in-roads into establishing the potential for these critical resources. Through ongoing characterisation of Australia's geology, our mineral resource potential will continue to be harnessed to support development of green energy projects in Australia and across the world, including with like-minded international trade partners.

Australia's Critical Minerals Strategy has been designed to grow our critical minerals sector, expand downstream processing, and help meet future global demand. Geoscience Australia supports the objectives of the Australian Government to position Australia as a reliable supplier of critical minerals to our strategic and commercial partners.

Internationally, Geoscience Australia is working with the USA and Canada as part of the Critical Minerals Mapping Initiative (CMMI) to leverage their scientific expertise in helping build a diversified critical minerals industry in Australia. In this context, the CMMI is developing an understanding of known critical mineral resources, geologic controls on distribution and identifying new sources of supply through mineral potential mapping and assessments. However, challenges for successful economic extraction remain, including the need to develop new processing technology, attracting new investment and the immaturity and volatility of many critical mineral markets.

Geoscience Australia is a partner, along with the Australian Nuclear Science and Technology Organisation, in the new Critical Minerals Research and Development Hub, to be hosted by the CSIRO. The aim of the Centre is to address barriers across the critical mineral value chains including resource potential,

[25] https://www.industry.gov.au/publications/critical-minerals-strategy-2022#:~:text=Australia%E2%80%99s%20Critical%20Minerals%20Strategy%20outlines%20the%20government%E2%80%99s%20policy,innovation%20to%20lower%20costs%20and%20increase%20competitiveness%20

production and refinement. A particular focus is placed on high purity alumina and silica, and a criticality assessment that will identify priority areas for future resource and development initiatives where targeted effort could address national supply chain vulnerabilities and potential strategic opportunities for further investment by government and industry. To help address a strategic knowledge gap in understanding Australia's total critical mineral resource potential, Geoscience Australia is also leading an initial collaborative and innovative program to assess the resource potential of mine waste, including technical and economic factors in extracting these resources.[26]

Capture Technologies

Carbon capture and storage (CCS), sometimes referred to as carbon capture, utilisation and storage (CCUS), is the process of capturing carbon dioxide (CO_2) from stationary emission sources and injecting it deep underground into porous and permeable sedimentary rocks. CCS can be used to mitigate emissions from stationary sources such as power stations, natural gas production, hard to abate sectors in manufacturing such as steel and cement plants, and for negative emissions, that is, to remove CO_2 directly from the atmosphere and store it permanently underground.

Australia has considerable potential for geological storage of carbon dioxide to support emissions reduction/removal from stationary sources and from the atmosphere. Improved understanding of Australia's geological storage potential underpins our low emission energy production and export industry. Activity in this space is rapidly evolving and the number of projects in development is growing.

Australia's only currently operating CCS project is the Gorgon Carbon Dioxide Injection project in Western Australia. To date, the project has stored more than 7 million tonnes of CO_2 since injection commenced in late 2019, and, at full operational capacity, will inject 3.5 - 4 million tonnes of CO_2 per year ranking it among one of the world's largest CCS projects.

The project has experienced some technical challenges, particularly concerning the pressure management system. Geoscience Australia has supported the Australian Government in understanding the challenges and recognises that such challenges are not unusual for a project of this scale and complexity. The challenges have also provided an opportunity to test various aspects of the greenhouse gas legislation and regulations under which the project operates.

Globally, research is also underway to develop methods to extract CO_2 directly, cheaply and efficiently from the air to generate new products or for permanent geological storage (direct air capture and storage, or DACS). DACS has the net effect of removing CO_2 from the atmosphere which can then be transported from the emission source to the storage location via pipelines, ships, by road (truck) or rail, much like natural gas.

Captured CO_2 can also be used to make other products. For example, CO_2 may be injected underground to enhance oil recovery in mature oil fields or used to create new products, such as fertilisers, fuel or food products. At the moment, most of the CO_2 that is used by industry is supplied from naturally occurring geological accumulations of CO_2. Captured anthropogenic CO_2 could replace some of these natural sources. Geoscience Australia, through the Exploring for the Future program, has reviewed and identified basins in Australia with potential for enhanced oil recovery in conventional fields or residual oil zones which could reduce the cost of CO_2 storage, supporting commercial storage viability. Further opportunities exist to undertake more detailed assessments and characterisations of these potential early targets within basins suitable for storage to support development of green energy projects.

[26] https://www.ga.gov.au/news-events/news/latest-news/atlas-of-australian-mine-waste-puts-secondary-prospectivity-on-the-map

Digital Platforms

There are opportunities for Geoscience Australia to support Australia's transition to a green energy superpower through our digital platforms. Open-access to geoscience data and innovative decision-support tools can unlock new activity in emerging renewable and green energy industries. Enhancements to Geoscience Australia's digital platforms will encourage investment and support decision-making across the full investment lifecycle. For example, through the Digital Atlas of Australia initiative, Geoscience Australia could focus on the spatial data needs to support the electricity components of the *Powering Australia* plan.[27] This will enable government and business make more informed, data-driven decisions at the local, regional and national level regarding green energy investment and trade.

Through the Exploring for the Future program, and aligned with the Australian Hydrogen Strategy goal of for Australia becoming a top three exporter of hydrogen in the region, Geoscience Australia is broadening the application of the Hydrogen Economic Fairways Tool. These additions will support a wider spectrum of investment possibilities across the broad range of hydrogen products, including ammonia and liquid hydrogen, thus accelerating investment in this emerging industry in Australia.

[27] https://www.energy.gov.au/government-priorities/australias-energy-strategies-and-frameworks/powering-australia

Appendices

Appendix A: Australian List of Critical Minerals

From Australia's Critical Minerals Strategy 2022

Figures as at 31 Dec 2020, (*Australia's Identified Mineral Resources*[28])

Critical Mineral		US list[1]	EU list[2]	Japan list[3]	India list[4]	Australia's Geological Potential[5]	Australia's Economic Demonstrated Resource[6]	Australia's Production	Global Production	Market Value (Global) (US$m)[7]
1	High purity alumina	Yes	Yes			Moderate	-	-	-	$1,300[10]
2	Antimony	Yes	Yes	Yes	Yes	Moderate	125.2 kt	3.9 kt	155 kt	$185.2
3	Beryllium	Yes	Yes		Yes	Moderate	-	-	240 t	$918.6[8]
4	Bismuth	Yes	Yes		Yes	Moderate	-	-	17 kt	$69.2
5	Chromium	Yes		Yes	Yes	High	- kt	0	40,000 kt	$4,705.3
6	Cobalt	Yes	Yes	Yes	Yes	High	1,495 kt	5.6 kt	135 kt	$541.8
7	Gallium	Yes	Yes	Yes	Yes	High	-	-	300 t	$918. 6[8]
8	Germanium	Yes	Yes	Yes	Yes	High	-	-	130 t	$918. 6[8]
9	Graphite	Yes	Yes	Yes	Yes	Moderate	7,970 kt	0	1,100 kt	$1,076.1
10	Hafnium	Yes	Yes			High	14.5 kt	-	-	$918. 6[8]
11	Helium	Yes	Yes			Moderate	-	4 hm^3	140 hm^3	$591.0
12	Indium	Yes	Yes	Yes	Yes	High	-	-	900 t	$918.6
13	Lithium	Yes		Yes	Yes	High	6,174 kt	40 kt	82 kt	$1,430.6
14	Magnesium	Yes	Yes	Yes		Moderate	Magnesite: 286,000 kt	Magnesite: 799 kt	Magnesite: 26,000 kt	$716.4
15	Manganese	Yes		Yes		High	Mang. ore: 276,000 kt	Mang. ore: 4,800 kt	17,200 kt	$5,443.7
16	Niobium	Yes		Yes	Yes	High	216 kt	0	78 kt	$1,709. 5[9]
17	Platinum Group Elements	Yes	Yes	Yes	Yes	High	107 t	0.522 t	380 t	$19,316.6
18	Rare Earth Elements	Yes	Yes	Yes	Yes	High	4,200 kt	20 kt	240 kt	$415.4[9]
19	Rhenium	Yes		Yes	Yes	Moderate	-	-	53 t	$918. 6[8]
20	Scandium	Yes	Yes	Yes		High	30.34 kt	0	-	—[10]
21	Silicon		Yes	Yes	Yes	High	-	-	8 kt	$7,000[10]
22	Tantalum	Yes	Yes	Yes	Yes	High	99.4 kt	0.1	1.8 kt	$1,552.9

[28] https://www.ga.gov.au/digital-publication/aimr2021

23	Titanium	Yes		Yes		High	Ilmenite: 274,000 kt Rutile: 35,300 kt	Ilmenite: 1,100 kt Rutile: 200 kt	Ilmenite: 12,000 kt Rutile: 1,000 kt	$1,609.9
24	Tungsten	Yes	Yes	Yes		Moderate	577 kt	<1 kt	84 kt	$164.0
25	Vanadium	Yes	Yes	Yes	Yes	Moderate	7,408 kt	0	86 kt	$1,709.5[9]
26	Zirconium	Yes		Yes	Yes	High	79,300 kt	400 kt	2,000 kt	$1,003.4

Note: t = tonne; kt = kilotonnes; hm^3 = million cubic metres.

[1] The United States lists 35 minerals and commodities as critical to their economic and national security. The full list may be accessed here: https://www.usgs.gov/news/interior-releases-2018-s-final-list-35-minerals-deemed-critical-us-national-security-and

[2] The European Union lists 27 raw materials as critical due to risks of supply shortage and their impacts on the economy being higher than those of most of the other raw materials. The full list may be accessed here: https://eur-lex.europa.eu/legal-content/GA/TXT/?uri=COM%3A2017%3A0490%3AFIN

[3] In March 2018, the Japanese Ministry of Economy, Trade and Industry released a report that identified the following 31 minerals as key: Li, Co, Ni, Cu, REE, PGM, W, Mg, Be, Re, Ti, Cr, Mo, Mn, Nb, P, Zn, Sn, Pb, Sb, Ta, In, Ga, C, Ge, Zr, Sr, V, F, Au and Ag.

[4] Source: Geoscience Australia

[5] Geoscience Australia (2021) *Australia's Identified Mineral Resources 2020*; US Geological Survey *Mineral Commodity Summaries 2020*.

[6] United Nations CommTrade database, figures from 2019. Highest-importing countries only are summed, as shown in mineral summaries following. They are not market totals, and aggregates across various mineral groups (see next footnote) will not sum.

[7] Data are aggregated for Be, Cr, Ge, V, Ga, Hf, In, Nb, Re and Ti articles of metals including scrap, waste and powder.

[8] Data are aggregated for Nb, Ta, V and Zr ore and concentrates.

[9] Scandium has been included with rare earth elements by the UN CommTrade database.

[10] This figure is from Australia's *2022 Critical Minerals Strategy*

Appendix B: World Rankings for Australian Critical Minerals

Figures as at 31 Dec 2020, (*Australia's Identified Mineral Resources*[29])

Critical Mineral	World Ranking		Australia's Geological Potential 2019
	Economic Resources	Production	
High Purity Alumina	n.a.	n.a.	Moderate
Antimony	5	5	Moderate
Beryllium	n.a.	n.a.	Moderate
Bismuth	n.a.	n.a.	Moderate
Chromium	n.a.	0	High
Cobalt	2	3	High
Gallium	n.a.	n.a.	High
Germanium	n.a.	n.a.	High
Graphite	8	0	Moderate
Hafnium	n.a.	n.a.	High
Helium	n.a.	4	Moderate
Indium	n.a.	n.a.	High
Lithium	2	1	High
Magnesium	4	5	Moderate
Manganese	4	3	High
Niobium	3[#]	n.a.	High
Platinum Group Elements	minor	minor	High
Rare Earth Elements	6	4	High
Rhenium	n.a.	n.a.	Moderate
Scandium	n.a.	0	High
Silicon	n.a	n.a	High
Tantalum	1[#]	5	High
Titanium	1[##]	1	High
Tungsten	2	minor	Moderate
Vanadium	2	0	Moderate
Zirconium	1	2	High

n.a. – not available. These markets are opaque and/or under-reported and/or small.
Ranking based on reliably and transparently reported resources.
Ranking based on rutile resources and production. For ilmenite, Australia ranks 2 for resources and 3 for production

[29] https://www.ga.gov.au/digital-publication/aimr2021