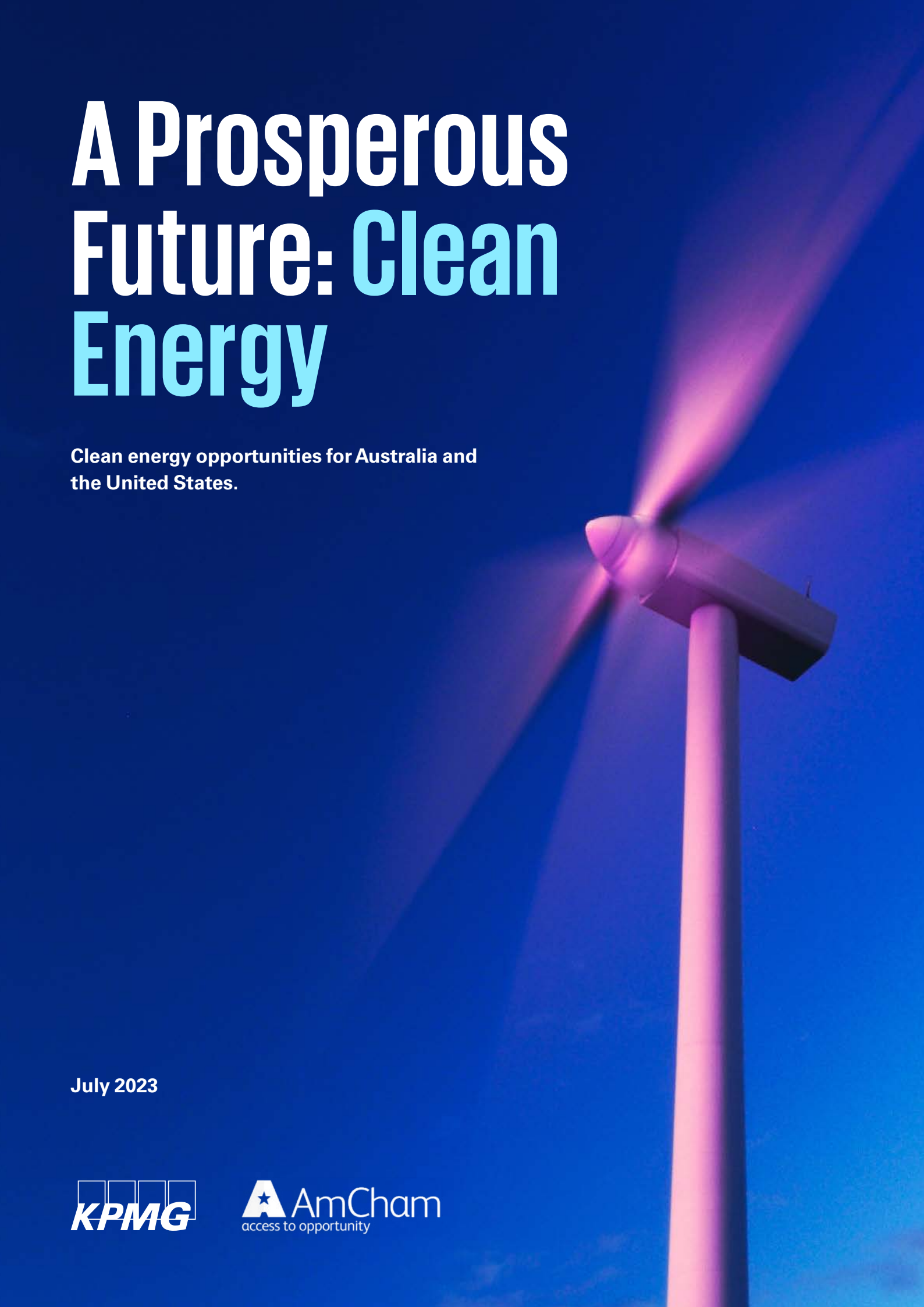
A Prosperous Future: Clean Energy

Clean energy opportunities for Australia and the United States.



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Foreword

Australia's comprehensive relationship with the United States is vitally important for our nation's economic wellbeing and security. It has been shaped by shared history, democratic systems, values, cultural ties and common interests.

But what will that relationship look like into the future? Where will our economic and commercial connections and complementarities lie in a rapidly changing world?

Both countries are looking towards the future – a future characterised by a range of geo-strategic, geo-political and geo-economic issues, including rapid technological, climate and clean energy challenges. These pressures are accelerating and testing our nations' resilience while also creating new opportunities. The United States and Australia are committed to working together to face into this uncertain future.

Currently, Australia and the United States share many complementarities. From a business perspective, we are very close trading partners despite often overlapping and competing sectoral interests. With the Australia-United States Free Trade Agreement (AUSFTA) now in place for 16 years, our bilateral trade balance has grown strongly to exceed AU$80 billion in 2019-2020, making this our second largest bilateral corridor. Australian exports were valued at AU$27 billion in 2019-2020 and 96 percent of Australian goods and services exports are now duty free, providing a solid platform for future export growth. Meanwhile, imports from the United States were AU$53 billion.[i]

The United States is also the largest country source of foreign direct investment to Australia, with just over AU$1 trillion historically invested by US companies across many sectors, companies and assets.

Facing into a dynamic and volatile future, the United States and Australia need to ensure we build on the existing connections and focus carefully on identifying the opportunities of the future.

As a national partner of AmCham in Australia, KPMG is delighted to partner with and co-sponsor this 'A Prosperous Future' report series which to date has profiled opportunities for business collaboration in artificial intelligence (AI), digital economy, quantum computing and space industries.

This report focuses on opportunities for trade and investment in the clean energy sector, surely one of the largest and most critical challenges facing our nations' futures. It specifically examines opportunities for Australian trade participation in the vast US clean energy market in the context of changing geopolitics and foreign investment regulations.

We sincerely thank AmCham's CEO April Palmerlee, executive team, and corporate members who have participated in this report. Our sincere thanks also to KPMG colleagues Thu Hoang, Dr Merriden Varrall and Julie Bever for their enormous contributions towards this important research report series.

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[i] https://www.dfat.gov.au/trade/agreements/in-force/ausfta/australia-united-states-fta

AmCham – a new era of cooperation

The great global trend towards achieving net zero emissions draws Australia and the United States closer to a new era of cooperation in clean energy.

Recognising the immense environmental, economic, and strategic imperatives of the energy transition, Australia and the United States have elevated energy and climate to become a third pillar of the alliance, alongside economic and strategic cooperation.

The longstanding defence and national security relationship our countries have shared for over a century grows ever stronger through the ANZUS, Five Eyes, and AUKUS partnerships. In addition, the trade and investment relationship – which accounts for over 25 percent of Australia's total foreign direct investment and $80 billion in two-way trade – brings clean energy to the fore in the unbreakable alliance.

US President Joe Biden announced his intention to include Australia as a domestic source for critical minerals and clean energy under the Defence Production Act. If passed by Congress, this would open the door for Australia to share in the economic benefit of the world's most historic climate legislation, the AU$520bn Inflation Reduction Act.

Australia is on the verge of a new era in its resource opportunity. Already the world's number one producer of lithium and rutile (titanium), the second largest producer of zircon (zirconium), and a top five producer of cobalt, manganese, antimony, and rare earth minerals, Australia could become a critical minerals superpower. According to Geoscience Australia, 80 percent of the nation is still considered 'under-explored.'

From resources giants like BHP to innovative companies at the forefront of emerging industries like Tritium, Australia can leverage its experience, exports, and investment relationship with the United States to become a global leader in the materials that will power our energy future, generating and sustaining the indispensable role of clean energy in the unbreakable alliance.

AmCham thanks Doug Ferguson, Dr Brendan Rynne, Dr Merriden Varrall, and Julie Bever for their contribution to the 'A Prosperous Future' report series and our AmCham colleagues Sara James and Josh Edwards. This report series identifies and analyses key industries for the future of US-Australia economic collaboration, and we commend the inclusion of clean energy to this important body of work.

APRIL PALMERLEE
Chief Executive Officer
AmCham Australia

Report foundation

As outlined in KPMG's 2021 introductory report, *A Prosperous Future: Key industries for Australia/US collaboration*, in consultation with the Australian Department of Foreign Affairs and Trade, and the US Embassy in Australia, AmCham and KPMG identified six emerging industries will be key to the future of the US-Australia economic relationship: artificial intelligence, biotechnology, digital economy, energy and clean technology, quantum computing, and space. This report focuses on clean energy.

Executive summary

The pace and scale of change in the global clean energy industry is immense. The increasing threat of severe climate change, intensifying global geopolitics and the need for energy security are key factors driving the rapid growth of this industry. This growth momentum is creating vast clean energy trade and investment opportunities between Australia and the United States.

The global geopolitics of clean energy

The global power order is undergoing a shift with implications for clean energy. Geopolitical uncertainty is influencing how nations pursue reliable and affordable energy, particularly as the shift to renewables alters energy competition. Clean energy trade relationships are being reshaped, creating new connections and dependencies. Nations are racing to secure critical minerals needed for clean energy, with some countries having made significant advances in the supply of critical minerals.

In this context, countries are seeking closer cooperation with trusted partners to ensure clean energy security. Trust and reliability are becoming more important factors in clean energy trade relationships, with countries possessing key elements of the supply chain gaining greater geopolitical power. Australia, as a trusted and large-scale supplier of critical minerals, stands to economically benefit from growth in the global clean energy industry. It holds the second-largest lithium reserves globally and is already the most prominent producer of lithium in the world, supplying about 50 percent of the world's lithium. Australia is also among the world's largest reserves for other key materials required for EV batteries including cobalt, manganese, and nickel.

"We are going to establish climate and energy as the third pillar of the Australia–US alliance. This will enable the expansion and diversification of clean energy supply chains, especially as it relates to critical minerals." – President Biden

Climate and energy as the third pillar of the US–Australia alliance

The United States requires international partnerships to secure its clean energy supply chain, with its plans to significantly increase onshore renewable energy and battery manufacturing reflecting a desire to build up sovereign battery supply. However, the growing US industry will still need to source minerals from international markets as domestic supply will be insufficient to meet demand.

The United States has already recognised the need to build stronger supply chains with trusted security allies and is actively looking to partner with Australia in the broad field of clean energy, in particular critical minerals. In order to supplement local capacity, President Biden has stated he will ask Congress to view Australia (along with Canada) as a domestic US source of critical minerals, providing access for Australian exporters to US government-supported renewable energy projects. In May 2023, Australia and the United States signed the Climate, Critical Minerals and Clean Energy Transformation Compact (the Compact), establishing climate and clean energy as the third pillar of the US–Australia alliance. Free trade and national security agreements between the two countries, such as AUKUS or the Compact will significantly increase the level of cooperation, including in clean energy and clean technology.

To take advantage of these opportunities, Australia must leverage its natural advantages in critical minerals, undertake further value-adding activity on raw minerals, utilise its high-quality engineering talent pool and its proven ability to innovate. Australia must also leverage its long-term, positive relationship with the United States government to ensure any unnecessary barriers to further entry are lifted, allowing Australian companies to fully engage in the US clean energy industry.

A range of benefits from successful collaboration with the US

This report will demonstrate that successful collaboration has the potential to generate large economic benefits for Australia in terms of significant export trade opportunities with the United States and increased US investment in the Australian clean energy and critical minerals industries. Additional US investment will lead to further domestic skilled job creation, a boost to domestic productivity and increased exports not only to the United States but also to other global markets. All of this progress will assist Australia's domestic clean energy transition in achieving the 2050 target.

There will be other additional indirect economic benefits. The increased demand for clean energy and strengthened partnership with the United States will present a greater opportunity for Australian mining companies to pivot towards clean energy and greater value capture in mining through developing downstream capabilities. This could kickstart the next commodity super-cycle for Australia, albeit with new technology minerals rather than with traditional mining products.

The US Inflation Reduction Act (IRA) will increase the supply of new energy technologies which will reduce prices over time, benefitting all countries, not just the United States. Therefore, while Australia to some extent will benefit from direct engagement with the United States, it is also (like many other countries) likely to 'free ride' on the technology price gains that will occur over this decade turbocharged by subsidies given by the US government.

Achieving this outcome depends on both industry and government working cooperatively to maximise the opportunities created by a stronger economic and strategic relationship between the United States and Australia.

Assessing Australia's capacity and opportunities to participate in the US clean energy value chain

Strengths in innovating renewable energy technologies, while not having a comparative advantage in commercial-scale manufacturing

Australia has strengths in developing world-leading clean energy technologies; its innovations that have been used globally range from world-record solar photovoltaic and evacuated tube technology to advanced wave and geothermal technologies.

The country's strong focus on research and development, with excellent universities, research institutes and well-educated workforce, along with collaboration with international partners and support from funding and tax incentives, enables the development of new solutions for the clean energy industry and supports the sector's growth. Australia's capabilities span various subsectors of renewable energy, including solar, wind, microgrids, energy storage, ocean energy, hydropower, geothermal, and bioenergy.

While excelling at innovating, Australia does not have a comparative advantage in manufacturing components used in renewable power systems such as solar panels or wind turbines on a commercial scale. The cost of labour in Australia is relatively high, and the country faces material competition from China. While Australia may not be able to offer the lowest cost of production, it is able to provide technical services globally, which is likely to be attractive to markets like the United States, who are looking to increase local production to mitigate sovereign risk.

Vast feedstock for biofuel production; opportunities to produce more biofuel for domestic use and exports

Australia is a large producer of agricultural inputs used to produce biofuel with its large supply of feedstock for bioethanol and biodiesel production. Over the next five years, the United States is expected to continue leading global demand and production, and Australia is well-positioned to provide key inputs to their biofuel production. Despite its vast feedstock, Australia currently uses only a small amount of this for domestic biofuel production and ships much of its supply overseas to assist foreign biofuel programs.

There are opportunities for Australia to leverage the existing capabilities in its small biofuel industry and expertise in agriculture and forestry (such as capability and expertise in agricultural production and arable land), and engineering to expand domestic biofuel production. Less productive land also has significant potential for use in growing hardier or slower-growing biomass sources. The Australian Renewable Energy Agency (ARENA) has announced funding to projects aimed at developing advanced biofuel production technologies, which may boost domestic production of sustainable aviation fuel in the coming years.

Natural advantage in raw material exports of critical minerals; opportunities exist further down the mining value chain

As highlighted earlier, Australia is abundant in natural resources, with high or very high production potential for many critical minerals, including those that are indispensable for clean energy technologies: lithium, cobalt, manganese, and rare earth elements. It has the potential to position itself as a key global source of critical minerals supply, to accelerate the production and uptake of clean energy technologies as demand for critical minerals for clean energy technologies is set to increase fourfold by 2030 due to the expanding deployment of renewables, EVs, battery storage and electricity networks. The competitive edge of Australia's resources industry is further strengthened by its advanced mining equipment, technology and services (METS).

While being a large exporter of raw materials to the world, Australia has not had strong processing capabilities. For example, in 2019, Australia extracted 52 percent of global lithium but undertook little value-adding processing, while China's share of refining was around 58 percent, with China refining over 95 percent of Australia's lithium exports.

Australia can do more refining near mine sites and capture more of the global supply chain by moving into advanced material manufacturing. In addition to advanced METS capabilities and skilled workforce, Australia can co-locate raw material extraction, processing, and manufacturing, which helps reduce operating costs and emissions. There is also the potential for mines and processing facilities to be powered by renewable energy which should reduce operating costs by up to 30 percent. However, high capital and labour cost remain a major challenge, although advancements in technology and growing ESG expectations are changing the overall feasibility of downstream processing opportunities in Australia.

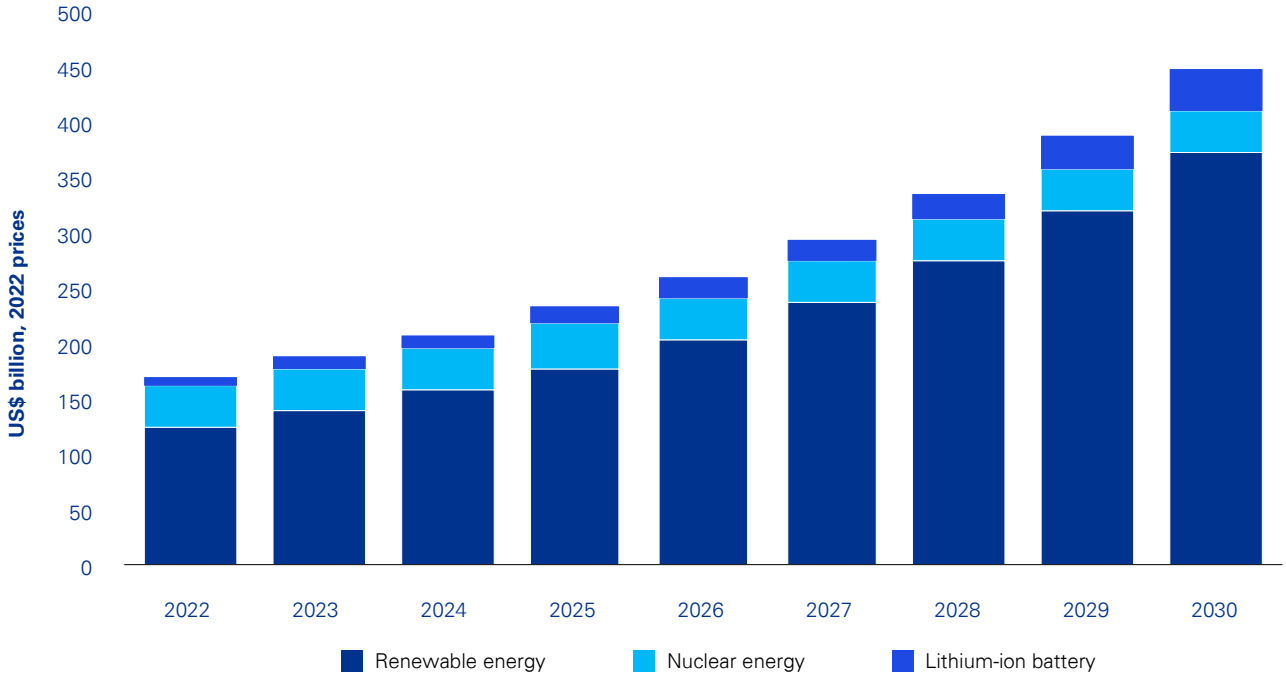
Rather than competing with the United States in battery manufacturing, Australia can try to capture value through mining and domestic production of battery chemicals. Australia has the potential to move further along the supply chain to sell advanced materials to the United States who can do cell component and battery production. Australia will then receive finished goods such as EV, batteries or even cell components to assemble, and trade these with the rest of Asia.

The size of the US market and potential uplift in Australian exports to the United States

In the United States, while petroleum and natural gas are expected to remain the most-consumed energy sources through 2050, renewables consumption will grow the fastest. The combined consumption of wind and solar power is projected to grow at 5.2 percent per annum on average towards 2050. Renewables are also anticipated to displace fossil fuels and nuclear power in the electricity mix, increasingly meeting power demand over the projection period thanks to decreasing capital costs for solar panels, wind turbines, and batteries, and rising direct and indirect subsidies for renewable power such as those provided by the IRA.

The size of the US renewable energy industry, measured in revenue terms, is expected to grow at an annual compounded rate of 15 percent over the period 2022-2030 from US$122 billion to US$373 billion. Substantial growth in renewables and adoption of EVs will boost demand for battery storage capacity. As such, the US lithium-ion battery industry is projected to grow at a compounded annual growth rate of 18 percent in our baseline US market growth scenario. This suggests a large potential for Australian businesses to participate in the US clean energy sector's supply chains.

FIGURE 1: US CLEAN ENERGY MARKET ESTIMATES AND FORECAST, 2022-2030 (US$ BILLION)



Source: Grand View Research, IBISWorld, KPMG analysis

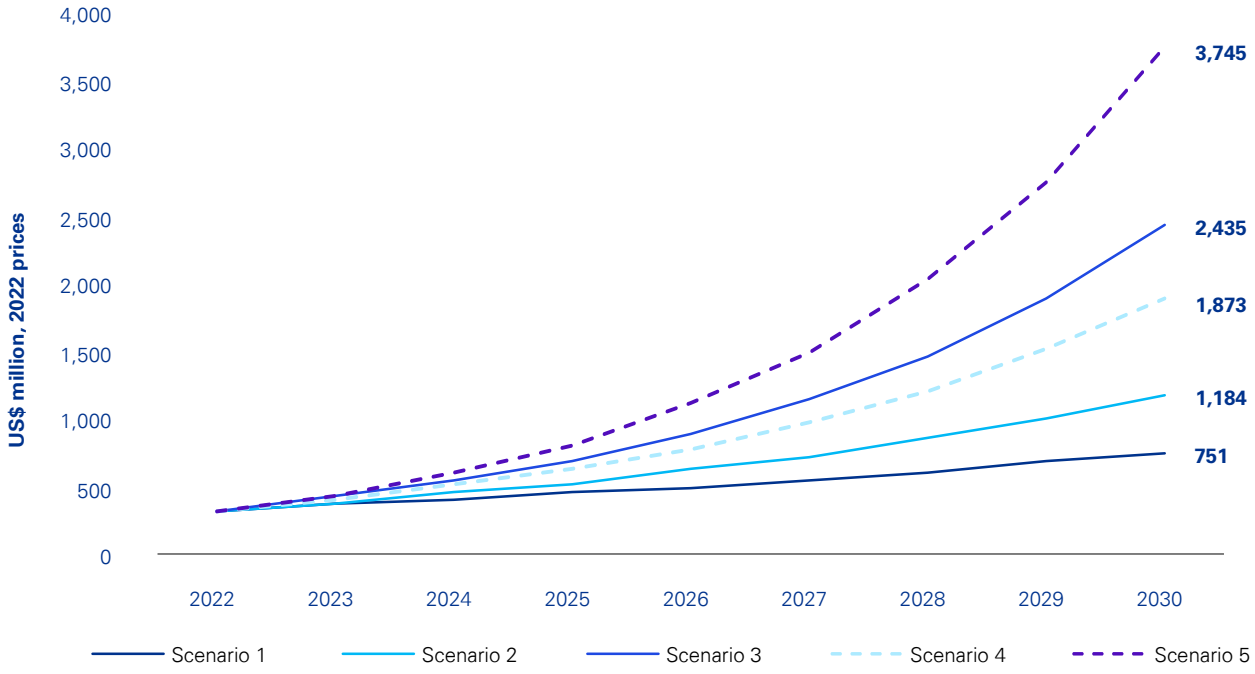
We have extrapolated five scenarios to estimate the benefit of an uplift in trade between the United States and Australia in the clean energy sector, in which two growth scenarios for the US market have been considered, including a baseline growth and an accelerated growth scenario.

- **Scenario 1:** Australian exports to the United States in the clean energy sector are assumed to continue growing at its historical rate. Under this scenario, the historical growth rate of Australian exports is lower than the projected growth of the US market size, implying Australia will lose its share in the US market.
- **Scenario 2:** Australia is assumed to maintain its current share of trade to the exponentially growing US clean energy sector.
- **Scenario 3:** Australia is assumed to increase its share of trade to the exponentially growing US clean energy sector by combining growth rates derived from scenarios 1 and 2. This scenario represents growth in trade between the countries due to trade and national security agreements between the two countries in addition to Australia's ability to capture more value through critical minerals mining.
- **Scenario 4:** Both the renewable energy and lithium-ion battery industries in the United States are expected to grow at a more optimistic pace than in the first three scenarios, reflecting a steeper S-curve to reach maturity faster. Australia is assumed to maintain its current share of trade.
- **Scenario 5:** Both the renewable energy and lithium-ion battery industries in the United States are expected to grow at the same rate as in Scenario 4. Australia is assumed to increase its share of trade through to 2030.

KPMG modelling reveals tremendous potential for Australia under the accelerated US market growth scenario. If Australia can increase its market share in the exponentially growing US clean energy market, **Australia could generate up to US$3.7 billion in exports, US$4.1 billion in incremental capital investment, and nearly 12,500 Australian jobs within nearly 10 years.**

KPMG modelling has examined the potential growth in the Australian clean energy sector industry exports to the United States (relating to primary clean energy, energy equipment, and materials for battery supply chain).

FIGURE 2: SCENARIOS FOR INCREASING TRADE BETWEEN THE UNITED STATES AND AUSTRALIA



Source: KPMG analysis, GVR, IBISWorld

KPMG has also taken into consideration capital investment from the United States and new highly skilled Australian sector jobs created. This analysis solely considers the direct economic opportunities from the US clean energy market alone; it does not estimate broader and indirect economic benefits or capture Australian exports to other global markets.

Table 2: Incremental capital stock and labour force required to meet trade-uplift scenarios, 2030

	Capital stock (US$b, 2022 prices)	FTE ('000)
Scenario 1: business as usual	0.8	2.5
Scenario 2: fair share – baseline US market growth	1.3	3.9
Scenario 3: increasing share – baseline US market growth	2.7	8.1
Scenario 4: fair share – accelerated US market growth	2.1	6.2
Scenario 5: increasing share – accelerated US market growth	4.1	12.5

Source: KPMG analysis

Getting this right could kickstart the next commodity super-cycle for Australia, albeit with new technology minerals rather than with our traditional mining products.

Advice for Australian businesses

For the private sector to take advantage of this increased focus, this report identifies several key factors for success. Some may need policy intervention.

Locating part of operations in the United States can allow companies to better access US funding, comply with onshore component requirements, and reduce shipping time.

Identification of points of differentiation can make Australian companies more competitive, leveraging Australian know-how and engineering talent to provide high quality offerings that optimise customer experience and asset value over its lifetime.

Australian critical minerals mining companies can do more refining near mine sites, which also helps with better ESG compliance and emission capturing benefits, and have the potential to move further along the supply chain to sell advanced materials to the United States.

Early identification of potential barriers, including legal liability and requirements such as reporting and traceability, can facilitate operations.

More actions need to be taken, both by the public and private sectors, to attract international original equipment manufacturers (OEMs) and revamp the Australian manufacturing industry.

It is important to build Australian energy security for a stable, low-cost energy market, which can then lead to a significant amount of job creation, technology development, and export opportunities.

Glossary of terms

Clean energy

Clean energy is energy derived from renewable, low or zero-emissions sources, as well as energy saved through energy efficiency measures. These typically include non-fossil fuel sources of energy such as hydro, wind, solar, bioenergy, geothermal, and nuclear power, as well as advanced and emerging technologies predicated on preserving and storing energy. In addition, a key goal of this sector is to reduce the cost and increase the accessibility of these sources of power.

ESG

ESG is an acronym for Environmental, Social, and Governance. It is a framework that helps stakeholders understand how an organisation manages risks and opportunities related to environmental, social, and governance factors.[ii]

[ii] Corporate Finance Institute (2023), ESG (Environmental, Social and Governance), https://corporatefinanceinstitute.com/resources/esg/esg-environmental-social-governance/.

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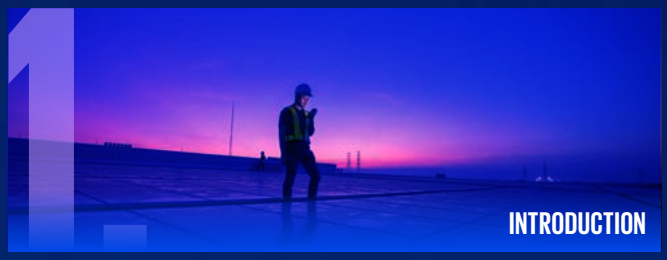

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Introduction

"We are going to establish climate and energy as the third pillar of the Australia–US alliance. This will enable the expansion and diversification of clean energy supply chains, especially as it relates to critical minerals." – President Biden

As outlined in KPMG's 2021 introductory report, *A Prosperous Future: Key industries for Australia/US collaboration*, in consultation the Australian Department of Foreign Affairs and Trade, and the US Embassy in Australia; AmCham and KPMG identified six emerging industries that will both shape the living standards of our citizens and drive the strategic competition between states: artificial intelligence, the digital economy, quantum science, biotechnology, energy and clean technology, and space technology.

KPMG released *A Prosperous Future: Emerging Tech*, the first report of the series in September 2022, and *A Prosperous Future: Economic opportunities in the space industry*, the second report in April 2023. These two reports explored opportunities for US and Australian technology partnerships in artificial intelligence (AI), quantum science, the digital economy, and space technology.

This report explores the clean energy sector. The pace and scale of change in this sector is immense. The real threats of climate change, and the need for energy security and reliability are the key factors rapidly driving demand for solutions from the industry. Increasing the supply of renewable energy would allow us to replace carbon-intensive energy sources and significantly reduce global warming emissions. The risk of disruptive events will also increase in the future as droughts, heatwaves, intense storms, and wildfires become more frequent due to global warming – increasing the need for clean energy and related technologies. Using more renewable energy can also lower the prices of and demand for natural gas and coal by increasing competition and diversifying our energy supplies.

As the costs of renewable energy technologies become cheaper over time, renewable energy will further stabilise energy prices and provide affordable energy in the future. As such, they will become fundamentally important in driving living standards and broad economic development.

This report explores the industry's current state in the United States and Australia. This includes market size estimates, key companies, startups, how the technology has been adopted by various end-use industries and a supply chain analysis. The outlook for these industries and their potential impact are also discussed. To identify potential opportunities for Australia to participate in the US supply chain, Australia's strengths in the industry are assessed against the level of openness in the United States.

To understand the export potential for Australian businesses, AmCham and KPMG consulted with clean energy industry companies who have succeeded in generating new business in the US and Australian markets.

The report also examines the elements in assessing the future export growth potential for Australia in the clean energy sector. Leveraging Australia's strengths and aligning them to the opportunities in the United States has the potential for a significant uplift in the already strong trade relationship between Australia and the United States.

1.1

Purpose of study

AmCham and KPMG have undertaken a detailed assessment of the current and future growth potential of the clean energy industry. The purpose of this study was to gain an understanding of how trade and investment between Australia and the United States in these sectors could enable better outcomes for the two countries as opposed to 'going it alone'.

1.2

Introduction to AmCham and KPMG

The American Chamber of Commerce in Australia (AmCham) was founded in 1961 and now has offices in Sydney, Melbourne, Perth, Brisbane, Adelaide and Canberra. AmCham aids US and Australian companies by promoting trade, commerce and investment to and from Australia.

KPMG is a global network of professional services firms providing audit, tax and advisory services. We operate in 146 countries and territories and in FY20 had close to 227,000 people working in member firms around the world. In Australia, KPMG has a long tradition of professionalism and integrity, combined with our dynamic approach to advising clients in a digital-driven world. We have approximately 10,000 people, including over 600 partners, with offices around the country.

1.3

Report structure

The remainder of this report has been organised into the following sections:

- **Section 1** (this section) has defined the purpose and the structure of this report
- **Section 2** describes the context on the geopolitical landscape
- **Section 3** explores the clean energy industry in the United States and Australia
- **Section 4** assesses the future export growth potential for Australia in the clean energy industry
- **Section 5** discusses the economic benefits of achieving improved trade between the two countries
- **Appendix A** describes the methodology for estimating market size
- **Appendix B** presents supplementary information on the industry
- **Appendix C** lists the most prominent US businesses in the industry
- **Appendix D** provides a bibliography list of references.

Geopolitical landscape

We are currently in the midst of a shift in the global power order with implications for the future of clean energy. How nation-states pursue their clean energy needs in a climate of geopolitical uncertainty could create new connections and dependencies that reshape the geopolitical map.

The world order established at the end of the Second World War is being increasingly challenged by nations who want more voice and influence in how the world works. Established powers are responding with efforts to maintain their influence. Many states increasingly view their own and each other's success in zero-sum terms – their gain is our loss.

Because of the critical importance of energy for national security, this global mistrust is impacting how nations pursue reliable and affordable energy. And, as we move into the 'net zero' era, the source of energy security is shifting away from hydrocarbons and towards renewables, shaking up energy competition and cooperation.

New energy, new trade relationships

The shift in energy demand and supply towards clean energy is creating new patterns of trade relationships, connections and dependencies. A range of nation-states, many of which have not been traditional energy producers or suppliers during the hydrocarbon era, are establishing themselves as key actors in the supply of clean energy. As the primary players in energy supply change, nation-states will have to fundamentally rethink their energy trade relationships to ensure reliable and affordable access to the clean energy needed for future national security.

Clean energy (in)security

For much of the past century, geostrategic power has been strongly connected with domestic energy security, and energy export capability. Russia's recent weaponisation of gas supply to Europe is an example of how energy can be used as a tool of geostrategic power – to whatever extent it is ultimately successful.[1] As the world transitions away from reliance on hydrocarbons to pursue net zero emissions, nation-states see that their future energy security, and therefore national security, will depend on the ability to generate their own clean energy, or buy it from others.

However, in a fragmenting and mistrustful geopolitical context, nation-states will need to ensure that their clean energy supply sources are not only cost-effective, but also geopolitically reliable. Countries will not want to be in a position where they are dependent on a potentially hostile foreign nation for their energy security.

For this reason, energy policy thinking from Washington to Canberra,[2] from Beijing to Brussels,[3] increasingly runs along security lines: we should aim for self-sufficiency, and where that may not be possible, we should rely on only our closest and most trustworthy allies.

Countries with clean energy commodities are becoming very popular

One aspect of the changing trade relationships developing in the clean energy era is in the demand and supply of commodities required for batteries, including lithium and cobalt. In past decades, major oil exporting countries have managed global oil supply for both economic and geostrategic gain.[4] In the clean energy era, it will be the minerals critical for clean energy that have the potential to provide some nations with global power.[5]

Reflecting the competitive geopolitical landscape and the understanding that clean energy security is essential to national security, nations have been racing to ensure reliable supply of critical minerals. Some countries have made significant advances in the supply of critical minerals necessary for clean energy.[6] For example, China supplies 90 percent of rare earth elements to the global renewable energy sector,[7] processes most of the world's lithium,[8] and owns the majority of global cobalt extraction.[9] Australia is currently the number one supplier of unprocessed lithium,[10] but the raw

product is almost all processed in China.[11] Latin America hosts the largest lithium deposits;[12] however, both the United States and China have invested heavily in lithium mining projects in the region,[13] as well as in Australia.

In addition to striving to develop their own clean energy commodities capacity, some countries have also taken actions that are arguably designed to preclude others from advancing their energy security interests. For example, some countries have excluded other nation-states from lithium mining projects,[14] or are considering export restrictions to limit others' access to critical minerals.[15]

Exporting nuclear dependence

Nuclear generation is considered by some nations an important source of clean energy security. However, when nations establish nuclear energy capabilities, they must manage strict international rules and protocols aimed at stopping the proliferation of nuclear weapons[16] They must also develop supply relationships to access technology and nuclear fuel, which create long-term dependencies between nations.

Nuclear energy supply and demand is already organised along geopolitical lines. A 2020 report found that countries generally purchase nuclear systems from their geopolitical allies, and that such exports can in turn strengthen ties.[17] At the moment, China (along with Russia) is a major exporter of nuclear reactors, an industry that was previously dominated by the United States, Japan and Europe.[18] China plans to build another 30 nuclear reactors in Asia, the Middle East and Africa in the coming years in countries that have signed up to its Belt and Road Initiative.[19]

Geopolitical uncertainty is driving clean energy cooperation with friends and allies

In an increasingly mistrustful geopolitical environment, trusted relationships between like-minded nations may become almost a prerequisite for trade in clean energy and the technology, infrastructure and commodities that make clean energy possible. Because governments around the world are growing more wary of geopolitically driven disruptions to what they need for clean energy, many are seeking closer cooperation with geopolitical allies. Where Russia was formerly Germany's major energy supplier, Germany has now turned to fellow NATO allies Norway and Portugal.[20]

US plans to significantly increase onshore renewable energy and battery manufacturing reflect a desire to build up sovereign battery supply.[21] However, the growing US industry will still need to source minerals from elsewhere and is seeking to build stronger supply chains with security allies.[22] President Biden has stated he will ask Congress to view Australia (along with Canada) as a domestic US source of critical minerals,[23] providing access for Australian exporters to US government-supported renewable energy projects. Canada leads the Sustainable Critical Minerals Alliance,[24] a group of nations including Australia, which aims to raise ESG standards in the critical minerals sector and provide a geopolitically reliable alternative to current supply sources. The European Union has also directed significant funding and policy attention towards clean energy and is seeking to build geopolitically secure supply chains for the necessary inputs.[25]

Clean energy relationships will be built on trust

In a fracturing geopolitical environment, clean energy security is becoming increasingly equated with national security. In the clean energy future, countries with advantages in key elements of the supply chain could wield greater geopolitical power, and be highly sought-after trade partners, as was the case with hydrocarbons in the past. Those who are not so fortunate will need to find trusted partners – more and more challenging in a mistrustful world. Trade relationships for accessing clean energy will not primarily be about cost efficiencies but will also need to factor in political reliability. For Australia, as the country with the world's sixth-largest deposits of critical minerals, there are many opportunities for growth and prosperity as a trustworthy and reliable partner in supplying others with the key components of a clean energy future.[26]

Clean energy

3.1

Definition and main activities

Clean energy is defined as energy derived from renewable, low or zero-emissions sources, as well as energy saved through energy efficiency measures. These typically include non-fossil fuel sources of energy such as hydro, wind, solar, bioenergy, geothermal, and nuclear power, as well as advanced and emerging technologies predicated on preserving and storing energy. In addition, a key goal of this sector is to reduce the cost and increase the accessibility of these sources of power.

In response to the increasing threat of climate change, a growing coalition of countries, businesses and institutions have undertaken a commitment to achieving net zero emissions. Over 70 countries, more than 1,000 cities, over 1,000 educational institutions, and over 400 financial institutions have taken the pledge to halve global emissions by 2030.[27] In addition to this, the COVID-19 pandemic and current conflicts in Europe have triggered costly energy supply challenges around the world, emphasising the need to accelerate the transition towards clean energy.

Unlike fossil fuels, which are non-renewable sources of energy, clean energy is acquired from natural sources that have the potential to be generated at higher rates than they are consumed. Below we provide an overview of common types of clean energy, including renewable energy sources (hydro, solar, wind, biomass, and geothermal) and nuclear power.

TABLE 3: COMMON TYPES OF CLEAN ENERGY

HYDRO ENERGY	Hydro is a renewable energy source that is generated using water from flowing water from rivers, streams or waterfalls that is channelled through water turbines.[28] Hydropower is the most advanced form of renewable energy technology and is used to produce electricity in more than 160 countries.[29] Hydro energy emits lower levels of greenhouse gas emissions and is cheaper to operate, making it a suitable source for base and/or peak load electricity generation.[30]
SOLAR ENERGY	Solar power is generated when energy from sunlight is converted into electricity. There are two main types of solar energy technologies. First, solar thermal which involves the conversion of solar radiation into thermal energy (heat). Second, solar photovoltaic (PV) which converts sunlight directly into electricity using photovoltaic cells.[31] Solar energy is the most abundant energy resource which can be harnessed even in overcast conditions. The rate at which solar energy is intercepted by the Earth is approximately 10,000 times greater than the rate at which the global population consumes energy.[32]
WIND ENERGY	Wind power is currently the cheapest source of large-scale renewable energy. It involves generating electricity from the naturally occurring power of the wind. Turbines capture energy using mechanical power to spin a generator and create electricity.[33] Wind is an abundant energy resource that produces electricity without polluting the air.
BIOENERGY	Bioenergy is produced from a variety of organic materials, called biomass, such as wood, charcoal, dung and other manures for heat and power production, and agricultural crops for liquid biofuels. Modern biomass systems include dedicated crops or trees, residues from agriculture and forestry, and various organic waste streams. Energy created by burning biomass creates greenhouse gas emissions, but at lower levels than burning fossil fuels like coal, oil or gas.
GEOTHERMAL	Geothermal energy utilises the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means. Once at the surface, fluids of various temperatures can be used to generate electricity.
NUCLEAR POWER	Nuclear energy is a form of energy released from the core of atoms, made up of protons and neutrons. Nuclear energy is produced either by fission, when nuclei of atoms split into several parts, or fusion, when nuclei fuse together.[34]

The energy generated from renewables, such as solar and wind, is intermittent and dependent on the weather and season. The role of energy storage solutions is therefore increasingly important in accelerating the transition away from fossil fuels and responding to electricity demands with green energy supplies. It helps strengthen the grid resilience by serving as a backup energy supply when there is a disruption to power plant generation. Energy storage has been around for a long time – recent demand for a cleaner and more resilient grid has resulted in a substantial rise in the construction of new energy storage projects and the development of new or improved storage solutions.[35]

Pumped hydroelectric storage is the most used technology for grid-scale storage. It is a configuration of two water reservoirs at different elevations – when electricity is needed, water is discharged from the higher reservoir to the lower one, passing through a turbine and generating power.[36]

Batteries are the most scalable type of grid-scale storage, with strong growth in recent years.[37] Battery storage, or battery energy storage systems, are devices that enable energy from renewables to be stored and released later when consumers need power most.[38] Currently, the lithium-ion battery, used in mobile phones and electric vehicles, (EVs), is the most popular battery storage technology due to its high energy density and light weight, controlling more than 90 percent of the global grid battery storage market.[39, 40]

Other storage technologies include compressed air and gravity storage, although they play a relatively small role in current power systems. Hydrogen is also an emerging technology with a potential for the seasonal storage of renewable energy.[41]

Given Australia's relative strength in exporting inputs for batteries compared to equipment for other kinds of technologies, we have therefore limited our study of energy storage solutions to batteries, especially the lithium-ion type.

3.2

US clean energy industry

3.2.1 State of play

Renewable energy

The United States' renewable energy sector is the second largest in the world, with China the leading market.[42] While petroleum and natural gas remain the most common source of energy in the country, renewable forms of energy are growing at the fastest rate of all the energy sources. Today, the United States generates more renewable electricity than Germany, Japan, and the United Kingdom combined.[43] Wind and solar incentives, coupled with falling technology costs are making cleaner forms of energy more accessible, allowing for increased competition and choice between traditional and renewable forms of energy. Currently, renewable forms of energy contribute approximately 21.5 percent of electricity generation in the United States, and it is estimated that this share will grow to 44 percent by 2050.[44]

Renewable energy consumption in the United States is increasing as a consequence of this improved supply. As shown in Figure 3, renewable energy contributed 13.1 percent of total primary energy consumption in 2022.[iii] This is more than double the share in 2000, representing an average annual growth rate of 3.3 percent over that time. Compared to other types of renewable energy, consumption of solar and wind energy has grown the fastest, at 16.3 and 21.4 percent respectively thanks to government incentives and falling technology costs (Figure 4). Within the remaining renewable energy categories, biofuel recorded the largest growth in consumption, increasing 11.2 percent on average each year since 2000.

[iii] Primary energy is energy in the form in which it is first accounted for in a statistical energy balance, prior to any transformation to a secondary or tertiary form of energy. Sources of primary energy entail fossil fuels, nuclear energy, and renewable sources. Electricity is a secondary energy source generated from primary energy sources.

FIGURE 3: RENEWABLE ENERGY AS A SHARE OF TOTAL PRIMARY ENERGY CONSUMPTION

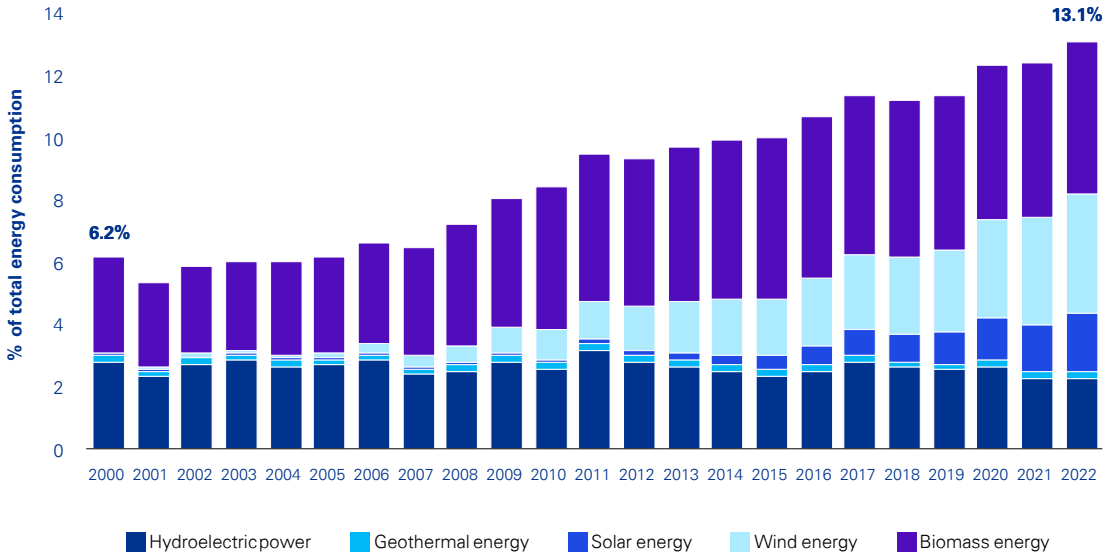
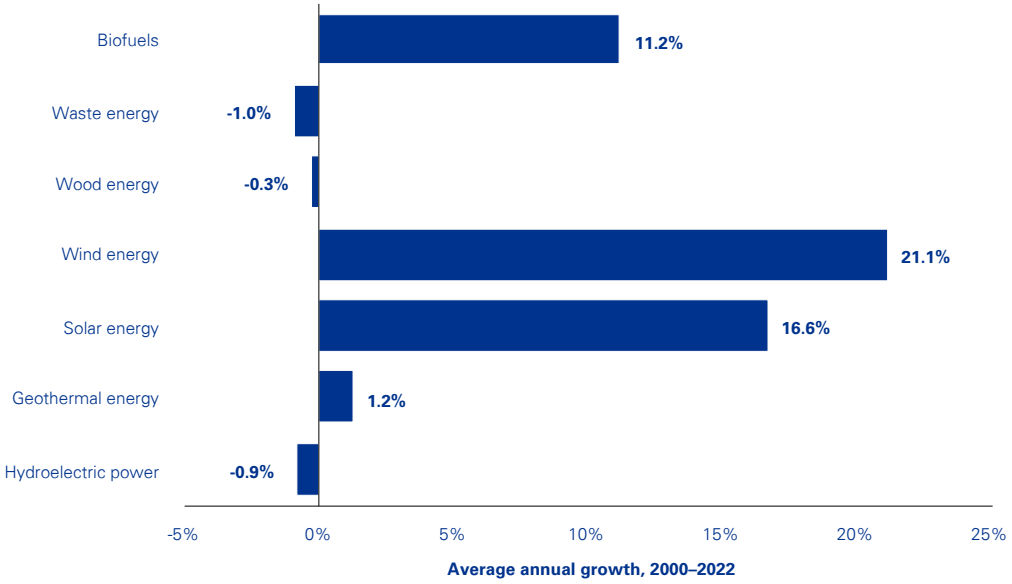


FIGURE 4: AVERAGE ANNUAL GROWTH RATES OF RENEWABLE ENERGY CONSUMPTION BY SOURCE



Source: US Energy Information Administration, April 2023 Monthly Energy Review

The renewable power market size is estimated to be approximately US$122 billion in 2022, with recent growth in the industry propelled by government tax credit assistance and state renewable portfolio standards (RPS) that require local utility companies to diversify their energy portfolio with renewables.[45]

Geothermal investment has lagged wind, solar, and hydro because the feasibility of producing this power on a commercial scale is constrained by geography as geothermal electricity generation requires deposits of high-temperature subsurface water.[46] Biomass, on the other hand, has experienced a fluctuation in industry revenue over the five years to 2022 after a period of moderate growth that was fuelled by government incentives. The Production Tax Credit (PTC) introduced under the Bush administration expired in 2017, disincentivising the purchase of biomass energy and resulting in the decline of industry revenue from 2018 to 2022.[47]

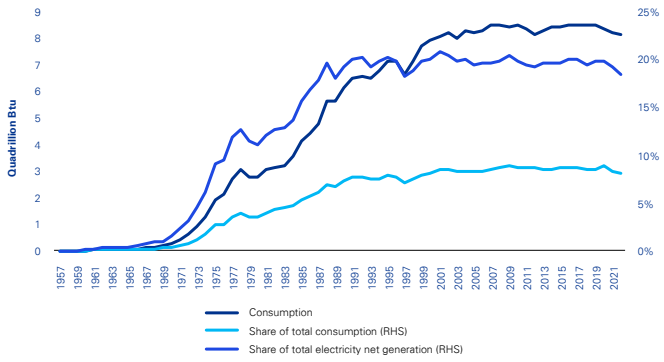
Nuclear power

The nuclear power industry is defined as comprising companies (excluding government-owned nuclear facilities) that operate nuclear-powered, electricity generation plants that use nuclear fuel to generate steam, which is then used to power turbines and generate electricity.[48] The United States is the dominant producer of nuclear power in the world, making up more than 30 percent of worldwide nuclear generation of electricity.[49]

There are currently 30 different nuclear power companies operating across 30 different states, with these plants having achieved an average capacity factor of over 90 percent since 2001, an improvement from 50 percent in the early 1970s and 70 percent in 1991.[50] In 2022, nuclear was the type of non-fossil fuel energy recording the highest capacity factor, 92.6 percent, as opposed to wind (36.1 percent), solar (24.8 percent), and solar thermal (23.1 percent).[51]

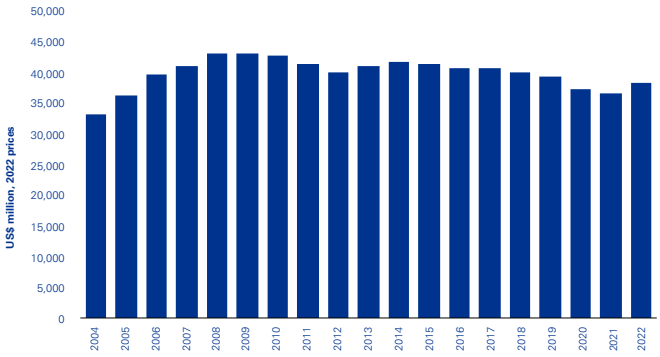
Nuclear energy consumption grew sharply from 112 billion Btu in 1957 to 7.8 quadrillion Btu in 2000, although it has remained stable around 8 quadrillion Btu since the 2000s, representing 8 percent as a share of total primary energy consumption.[52] In 2022, nuclear reactors in the United States generated 772 billion kWh, about 18.2 percent of total electricity output.[53, iv]

FIGURE 5: ENERGY CONSUMPTION AND ELECTRICITY NET GENERATION FROM NUCLEAR



Source: IBISWorld, KPMG analysis

FIGURE 6: US NUCLEAR POWER MARKET SIZE



Life cycle stage: **Mature**

Product & services segmentation: **54.8% nuclear generation from utilities, 45.1% nuclear generation from independent power procedures, 0.1% other**

Market segmentation: **46.8% industrial, 28.9% residential, 24.3% commercial**

Source: IBISWorld, KPMG analysis

The US nuclear power industry revenue is estimated to be around US$38 billion in 2022.[54] After a period of steady growth prior to 2009, industry revenue growth slowed down and even entered negative territory for seven consecutive years from 2015 to 2021 before surging by 5 percent in 2022. Following the Fukushima nuclear disaster in the early 2010s, the industry has faced increased concerns from the public regarding the safety of nuclear power, as well as more competition from renewable and traditional energy sources, leading to slow nuclear capacity additions and closures of older facilities.[55] While existing plants have received a slight boost from government tax credits, the increase of uranium price has limited plant profit.[56]

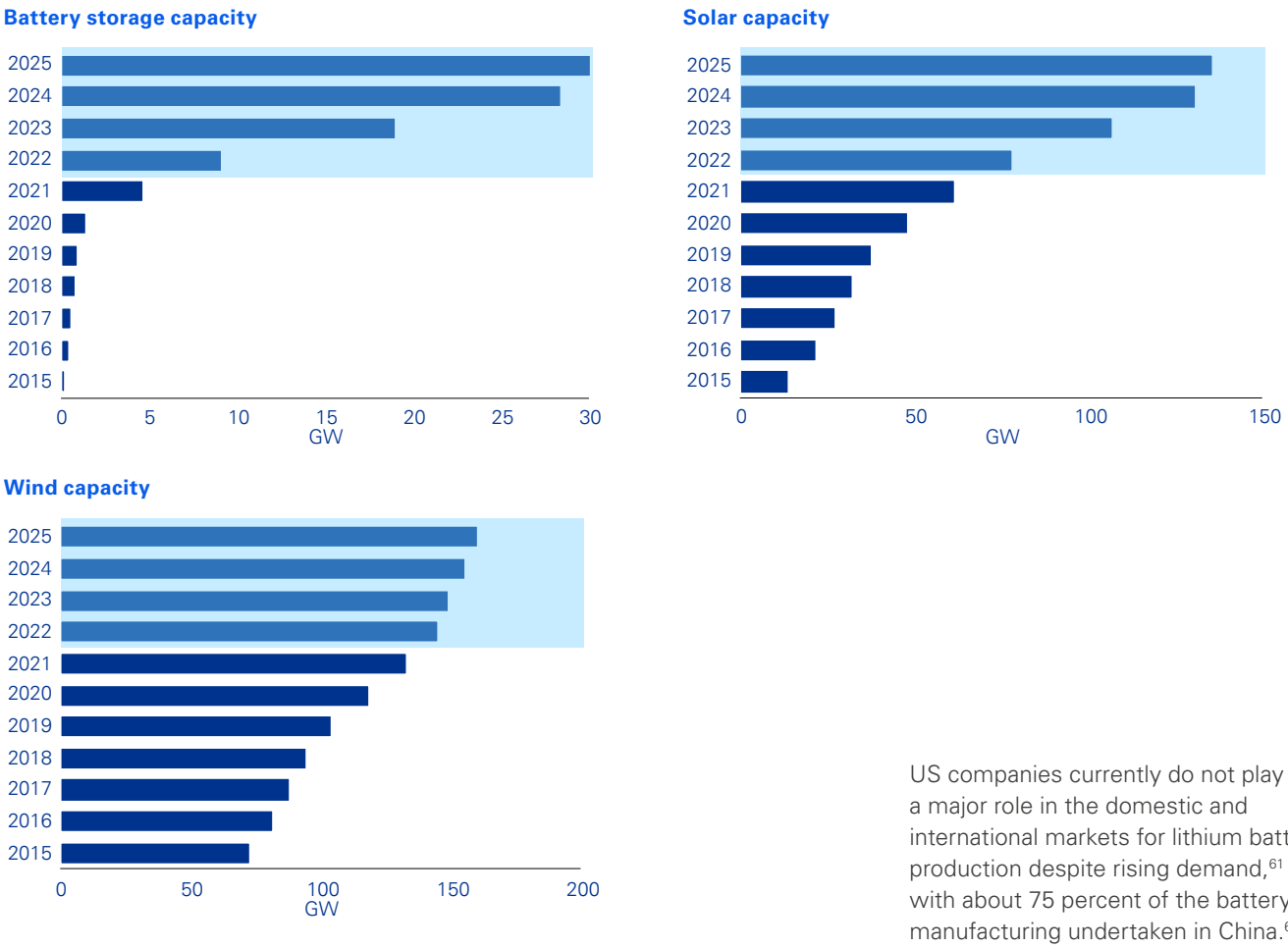
[iv] See the preceding footnote on the difference between primary energy consumption and electricity output.

Battery storage

Mirroring the stellar rise of clean energy, demand for battery storage in the US has also risen sharply. Many states, including California, Massachusetts, New York and Oregon, have legislated storage targets. In the case of California, the policy has resulted in new investments by Applied Energy Services and Siemens, contributing to boosting the states' storage capacity.[57]

In the context of greater availability of battery capacity to the US grid, the US Energy Information Administration highlights that large-scale battery projects have also emerged. As such, 23 large-scale projects with capacities ranging from 250 MW to 650 MW are expected to be deployed by 2025. A significant proportion of earmarked projects will take place in Texas and California, which top wind and solar energy capacity, respectively, amongst all states.[58]

FIGURE 7: US BATTERY STORAGE



Source: US Energy Information Administration

The industry relies extensively on imports. Inexpensive shipping and lower labor costs overseas, both for upstream suppliers of input materials and for lithium battery manufacturers themselves, have incentivised offshoring.[59]

The US lithium-ion battery market is still in its growth stage and will grow rapidly, with lithium batteries expected to power most vehicles manufactured over the next 50 years and be essential to military systems, electricity grids, and consumer, medical, and industrial electronics.[60]

US companies currently do not play a major role in the domestic and international markets for lithium battery production despite rising demand,[61] with about 75 percent of the battery manufacturing undertaken in China.[62] Recognising that the lack of domestic lithium battery supply chain and the lack of secure access to energy materials could pose threats to the national and economic security,[63] the Biden administration has introduced initiatives to ramp up onshore production and processing of critical minerals for EV batteries and defence technologies, and build out a battery manufacturing industry.

3.2.2 Clean energy investments and policies

Global clean energy investment has picked up strongly since 2020 with its annual average growth rate rising to 12 percent, as opposed to just above 2 percent in the five years after the Paris Agreement in 2015. The United States was among the top three jurisdictions leading clean energy investment in 2021 (US$215 billion), third to China (US$380 billion) and the European Union (US$260 billion). These investments have been driven by the increasing cost-competitiveness of many clean energy technologies as well as policy and fiscal measures to support decarbonisation of energy supply.[64]

The largest investments have been poured into renewable power because clean technologies such as wind and solar PV are among the most low-cost options for new electricity generation in many countries. Other major investment areas include improved efficiency and electrification of mobility. Emerging technologies, albeit receiving relatively small investment in absolute terms, are also seeing high growth, including battery energy storage, low-emissions hydrogen, and carbon capture.[65]

In the United States, startups have raised significant funds for innovative energy storage, hydrogen, and renewable energy technologies.[66] Since late 2021, three bills in which one of the key goals is to boost clean energy have been signed into law.

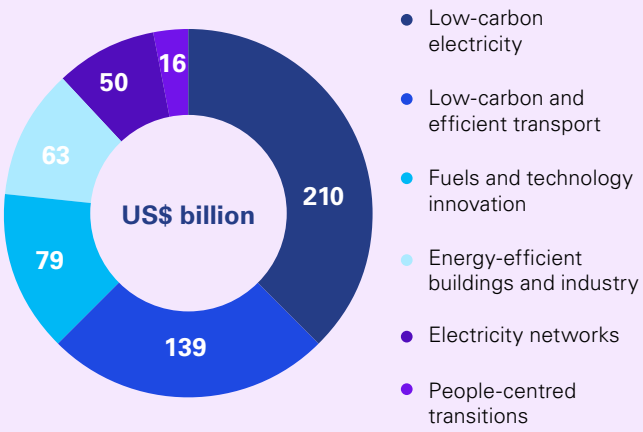
- *Infrastructure and Jobs Act* invests US$73 billion in power grid infrastructure, including new transmission lines for renewable energy and research for new clean energy technologies such as nuclear power and carbon capture and storage; US$7.5 billion to build out a national network of charging infrastructure for EVs; US$5 billion in zero emission and clean school buses and US$2.5 billion for ferries; US$17 billion in ports and US$25 billion in airports to address repairs and maintenance backlogs, reduce congestion and emissions, and boost electrification and other clean technologies; and other infrastructure areas such as rail, public transit, to enable low-carbon and efficient transport.[67]
- *CHIPS & Science Act* provides US$280 billion to boost semiconductor capacity, research activities, and set up regional technology and innovation hubs across the country to spur regional economies and expanding access

to innovation among rural and micropolitan communities. The law will also increase funding for the US Department of Energy (DOE), National Science Foundation, and National Institute of Standards and Technology across a range of activities.[68]

– *Inflation Reduction Act 2022 (IRA)* commits US$370 billion of the US government funding to energy security and climate change, delivered in the form of tax incentives, grants, and loan guarantees, with the greatest allocations towards clean electricity and transmission, followed by clean transportation.[69] The largest beneficiaries include batteries and renewables, together with other clean electricity sources, carbon capture and transport.[70] It creates assistance programs for utility cooperatives, US$27 billion green bank, US$270 billion in clean energy and energy efficiency tax credits, including US$158 billion for investment in clean energy, and US$36 billion for home energy upgrades from public utilities.[71] A major feature in the IRA is incentives for investment in domestic manufacturing capacity and procurement of critical supplies domestically or from free-trade partners.[72]

The US government has committed US$559.54 billion since Q2 2020 across a range of policies aimed to support clean energy investment and provide energy affordability measures to help alleviate high energy prices due to the global energy crisis. The top spending categories include low-carbon electricity (US$210.5 billion), low-carbon and efficient transport (US$139.6 billion) and fuels and technology innovation (US$79 billion).[v]

FIGURE 8: US ENERGY POLICY AND MEASURE SPENDING CATEGORIES



Source: International Energy Agency (IEA)

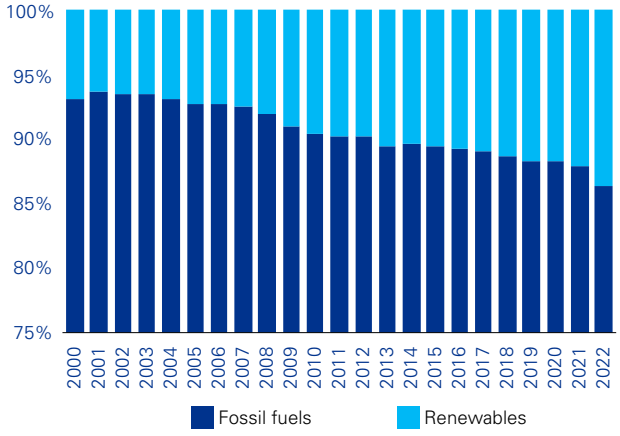
[v] For a detailed list of energy policies and measures, see IEA – Government Energy Spending Tracker: Policy Database.

3.2.3 Clean energy adoption by sector

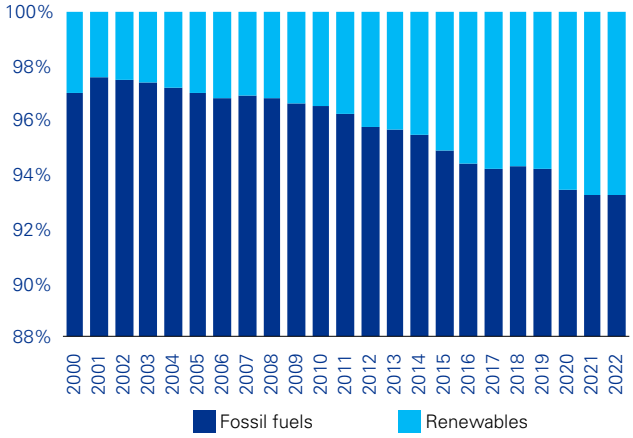
The adoption of renewable energy has increased significantly over the past two decades across all sectors, including residential, commercial, transportation, and electric power.[vi]

FIGURE 9: SHARES OF PRIMARY ENERGY CONSUMPTION BY SOURCE IN EACH SECTOR

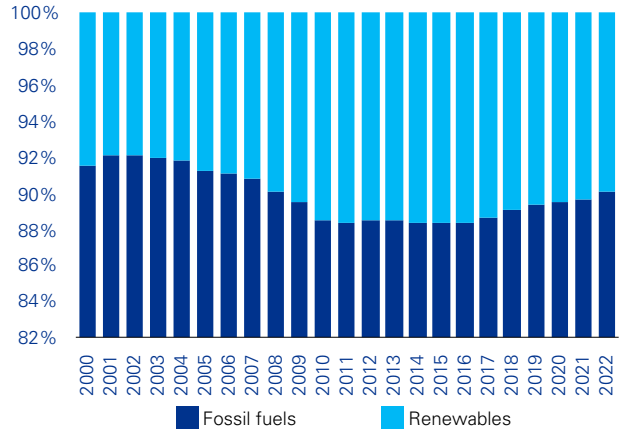
Residential sector energy consumption



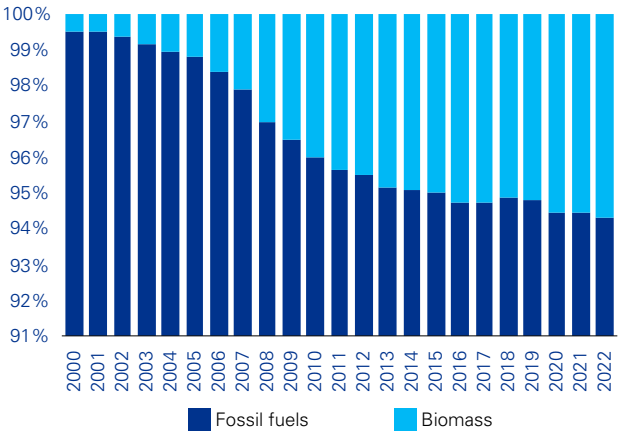
Commercial sector energy consumption



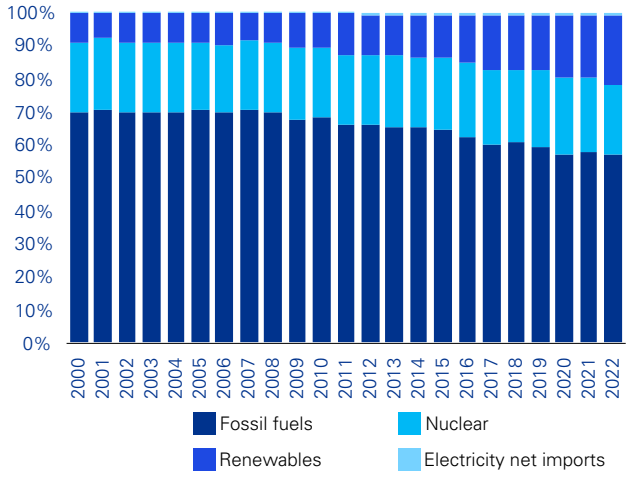
Industrial sector energy consumption



Transportation sector energy consumption



Electric power sector energy consumption

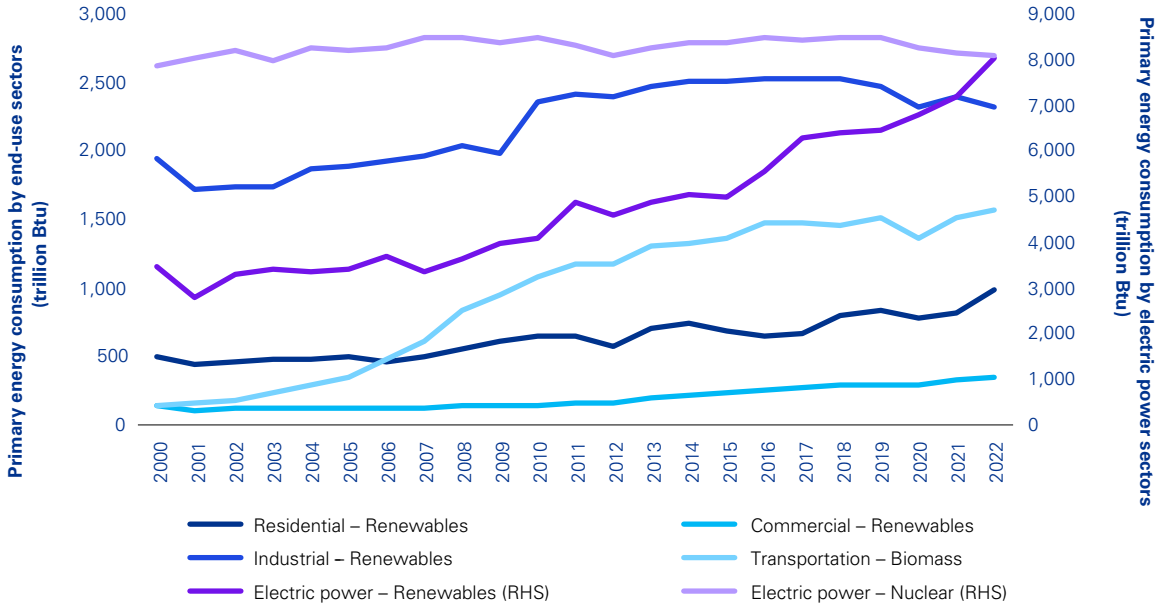


Source: US Energy Information Administration, KPMG analysis

[vi] The residential, commercial, industrial, and transportation sectors are end-use sectors as they consume primary energy and electricity produced by the electric power sector.

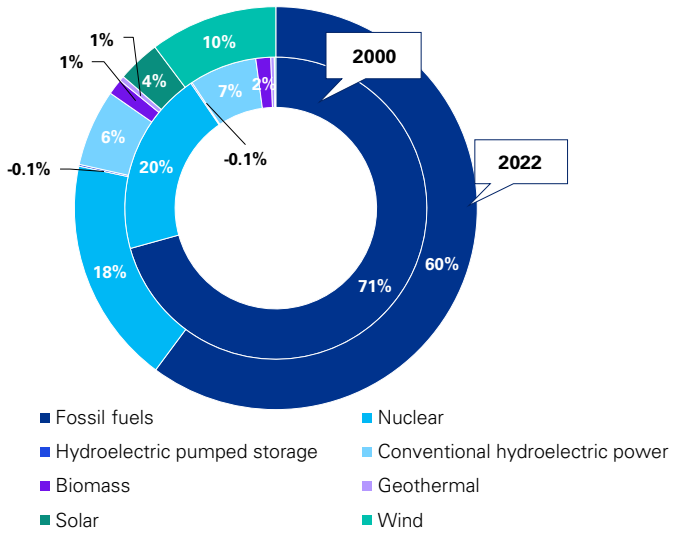
From 2000 to 2022, renewables as a share of total energy consumption more than doubled in the residential (6.8 percent to 13.7 percent) and commercial sectors (3 percent to 6.8 percent), while increasing from 8.5 percent to 10 percent in the industrial sector and having remained stable at this level. The transportation sector saw a substantial increase in biomass consumption from only 0.5 percent of total energy used to 5.7 percent. In the electric power sector, the use of renewable sources to generate electricity jumped from 9 percent to over a fifth of total energy consumption (21.2 percent), whereas nuclear energy remained relatively flat in the 20 percent range. In level terms, primary energy consumption from clean sources grew most rapidly in biomass used in the transportation sector at a compounded annual growth rate of 11.8 percent from 135 trillion Btu in 2000 to 1,565 trillion Btu in 2022 (Figure 10).

FIGURE 10: PRIMARY ENERGY CONSUMPTION FROM RENEWABLE AND NUCLEAR POWER BY SECTOR



Source: US Energy Information Administration, KPMG analysis

FIGURE 11: SOURCES OF ELECTRICITY NET GENERATION, ALL SECTORS



The share of electricity net generation from renewables in all sectors also rose sharply from 9.2 percent in 2000 to 21.4 percent in 2022, driven by the exponential increase in adoption of wind and solar technologies. The proportion of wind and solar jumped by 10.1 percentage points and 3.4 percentage points respectively.

Source: US Energy Information Administration, KPMG analysis

Note: Hydroelectric pumped storage plants are net electricity users that typically consume low-cost surplus off-peak electric power to run the pumps and produce electricity when demand is high.

3.2.4 US clean energy industry's supply chain

To understand the nature of the clean energy industry in the United States, we have investigated which countries and goods are involved in the industry's supply chain. Between 2017 and 2022, there were over 170,000 recorded shipments of physical goods to US businesses operating within standard industry classifications (SIC) most relevant to the industry. For more detail on SIC codes, please see Appendix B.

Overall, the US clean power and battery industries are highly dependent on foreign supplies.

Shipment of origin[vii]

China ranks first in terms of imports by US businesses, contributing 32.2 percent of total imports, followed by India (8.5 percent) and Germany (8.4 percent). When combined, these countries export close to half (49.1 percent) of all clean energy related exports to the United States. South Korea, Japan and Hong Kong are also major exporters to US businesses, making up 17.5 percent of total clean energy related imports by the United States. Australia ranks 34th on this list and currently contributes 0.3 percent. This data suggests that Australia has limited capability in the manufacturing of clean energy related goods, but as section 4.2 will discuss, Australia has strengths in minerals mining due to the country's natural resource endowment, critical to producing equipment in clean power systems and battery storage capabilities.

Values of imports[viii]

As the United States continues to build its renewable energy sector, it has also increased its imports of renewable energy related products over the years. In 2022, the US renewable energy related imports totalled US$22 billion (in 2022 prices), up by nearly 30 percent from a year ago, and by 40 percent from 2012. It should be noted that the value of renewables imports appears to be rather volatile, potentially driven by large-scale projects and their timings. As shown in Table 4, a major share of US renewable imports in 2022 pertained to solar energy, followed by wind energy and non-petroleum derived biodiesel.

TABLE 4: TOTAL RENEWABLE ENERGY RELATED IMPORTS BY THE UNITED STATES IN 2022

Description of imports	US$ million (2022 prices)
Solar cells, crystalline silicon photovoltaic cells assembled in modules or made up into panels	11,581
Solar cells made into panels or modules	2,967
Biodiesel not containing petroleum oils or oils obtained from bituminous minerals	2,102
Wind turbine blades and hubs	1,818
Solar cells, photovoltaic cells not assembled in modules or made up into panels	909
Parts of wind-powered generating sets	643
Photovoltaic AC generators	452
Ethyl alcohol undenatured	343
Wind-powered generating sets	288
Towers and lattice masts of iron or steel, tubular	271
Total value of US renewable energy related imports	**22,094**

Source: US International Trade Administration (ITA)

[vii] The SIC codes used do not include trade items in the battery supply chain. Imports in the battery supply chain are explored in more detail in the value of imports section below.

[viii] Values from the US International Trade Administration data are constant prices in 2005. Data in this section are reported in 2022 prices, inflated using the US GDP implicit price deflator.

TABLE 5: SHARE OF TOTAL IMPORTS OF RENEWABLE IMPORTS BY COUNTRY OF IMPORTS

Country of imports	Share of total US renewables-related imports (%)
Vietnam	24.7
Malaysia	11.6
Thailand	11.0
South Korea	10.6
Mexico	7.7
Canada	6.3
Australia	0.1

Source: US ITA

Although Australia's share of total US renewable energy imports seems negligible at first sight, deeper analysis reveals that US renewable imports from Australia jumped from just US$3.8 million in 2021 to US$30 million in 2022, of which $28 million related to solar cells, and the remaining trade constituted of biodiesel and hydraulic turbines.

Nuclear power

Uranium and uranium-based chemical compounds constitute the main imports of the US in the nuclear power category. More than a quarter of nuclear fuels imported by the United States were sourced from Russia in 2022, followed by Germany (19.4 percent), Netherlands (18.9 percent) and the United Kingdom (16.0 percent). In addition to nuclear fuels, the US nuclear power industry also necessitates equipment imports. In 2022, the United States imported US$4.6 billion worth of nuclear fuels, and equipment for nuclear power stations valued at US$100 million. More than 85 percent of equipment including cartridges, parts of nuclear reactors and isotopic separation machinery were imported from France, Germany, and Japan.

TABLE 6: TOTAL NUCLEAR ENERGY RELATED IMPORTS BY THE UNITED STATES IN 2022

Description of imports	US$ million (2022 prices)
Uranium fluroide enriched in U235	4,121
Natural uranium hexafluoride	242
Fuel elements cartridges	132
Uranium oxide enriched in U235	126
Plutonium and its compounds	120
Natural uranium compounds	31
Parts of nuclear reactors	12
Isotopic separation machinery	10
Total value of US renewable energy related imports	**4,795**

Source: US ITA

TABLE 7: SHARE OF TOTAL IMPORTS OF NUCLEAR ENERGY IMPORTS BY COUNTRY OF IMPORTS

Country of imports	Share of total US civil nuclear-related imports (%)
Russia	25.2
Germany	19.8
Netherlands	18.3
United Kingdom	15.5
France	9.1
Canada	7.6
Australia	0.0001

Source: US ITA

Battery supply chain

Supporting the US transition to clean energy is the expansion of its battery storage capacity, which helps address the intermittency of renewable energy. In 2022, the United States imported US$47.7 billion worth of inputs used in the lithium-ion battery supply chain. The major battery supply chain imports were lithium-ion storage batteries (US$19.6 billion, of which US$3.4 billion were for electric vehicles), storage battery parts (US$6 billion), nickel (US$3.4 billion) and polyethylene (US$2.2 billion).

Australia just captures a place in the top 10 US importers in the battery supply chain. China ranks first with a share of 35.8 percent, followed by South Korea (15.7 percent), Canada (12.8 percent) and Japan (10.8 percent). Australia's US-bound exports in the battery supply was mainly minerals, with the majority being nickel (US$377 million) and aluminium oxide (US$121 billion).[ix] Australia's exports of lithium-ion storage batteries were only US$2 million, making up less than 1 percent of US total lithium-ion batteries. The US imports of lithium-ion storage batteries were predominantly from China whose share was 68 percent, followed by South Korea whose share was just under 11 percent.

More than half of the world's lithium production is sourced from Australia. Australia is the largest lithium exporter in the world, with over 95 percent of the exports destined for China.[73] These facts suggest that the US battery supply chain is generally one where Australia provides the raw materials, including lithium, to China who processes them and then manufactures and exports batteries onwards to the United States.

[ix] It should be noted the import values of these inputs contain all end uses, rather than only for lithium-ion battery. In Section 4.2, we provide estimates of imports used for lithium-ion battery only based on ITA and IBIS World import data for the US lithium battery manufacturing industry.

TABLE 8: TOTAL BATTERY STORAGE RELATED IMPORTS BY THE UNITED STATES IN 2022[x]

Description of imports	All end use (US$ million, 2022 prices)
Lithium-ion storage batteries	16,127
Storage battery parts	6,014
Mixtures of two or more inorganic compounds	5,096
Lithium-ion batteries for electric vehicles	3,448
Nickel	3,435
Polyethylene	2,175
Aluminium oxide	1,238
Polypropylene	845
Artificial graphite	688
Aluminium foil of a thickness not exceeding 0.01 mm	686
Total value of US renewable energy related imports	**47,740**

Source: US ITA

TABLE 9: SHARE OF TOTAL IMPORTS OF BATTERIES BY COUNTRY OF IMPORTS

Country of imports	Share of total US imports in the battery supply chain (%)
China	35.8
South Korea	15.7
Canada	12.8
Japan	10.8
Mexico	2.6
Germany	2.6
Brazil	1.7
Norway	1.6
Hungary	1.2
Australia	1.2

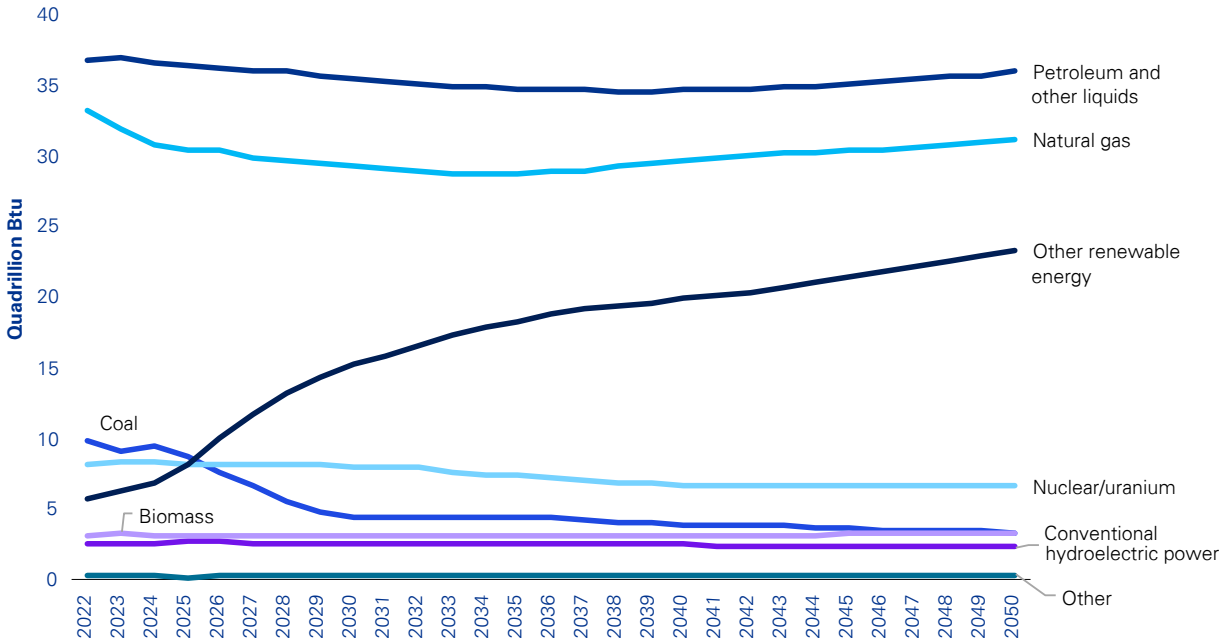
Source: US ITA

[x] See the preceding footnote.

3.2.5 Future potential of US clean energy industry

Based on the 2023 reference case projections from the US Energy Information Administration, petroleum and natural gas are expected to remain the most-consumed energy sources in the United States through 2050; however, renewables consumption will grow the fastest (Figure 12). Combined consumption of wind and solar power is projected to grow at 5.2 percent per annum on average towards 2050.[74]

FIGURE 12: OUTLOOK FOR TOTAL ENERGY CONSUMPTION BY SOURCE, 2022-2050



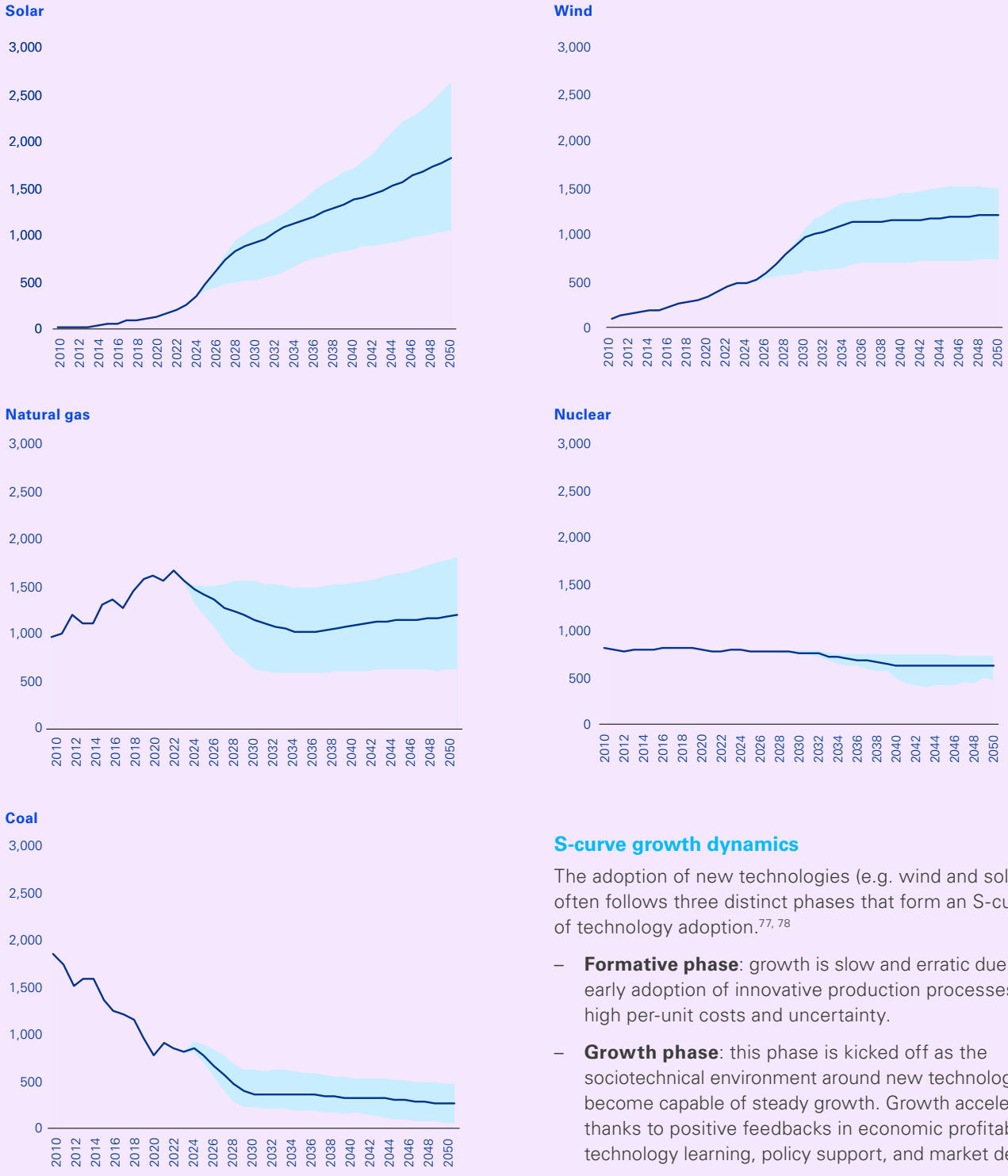
Source: US Energy Information Administration

Renewables are also anticipated to displace fossil fuels and nuclear power in the electricity mix, increasingly meeting power demand over the projection period (Figure 13), thanks to decreasing capital costs for solar panels, wind turbines, and batteries, and rising subsidies for renewable power such as those provided by the IRA.[75]

Because wind and solar have zero fuel costs, they require the least operating cost to meet electricity demand once built and when the resource is available.

The combined investment and operating cost advantage will drive the increase in the share of clean electricity generation. As a result, compared with 2022, solar generating capacity is projected to grow by approximately 325 percent to 1,019 percent by 2050, and wind generating capacity to grow by around 138 percent to 235 percent.[76]

FIGURE 13: PROJECTIONS FOR US ELECTRICITY GENERATION BY SELECTED TECHNOLOGIES FOR ALL CASES (BILLION KWH) (2022-2050)



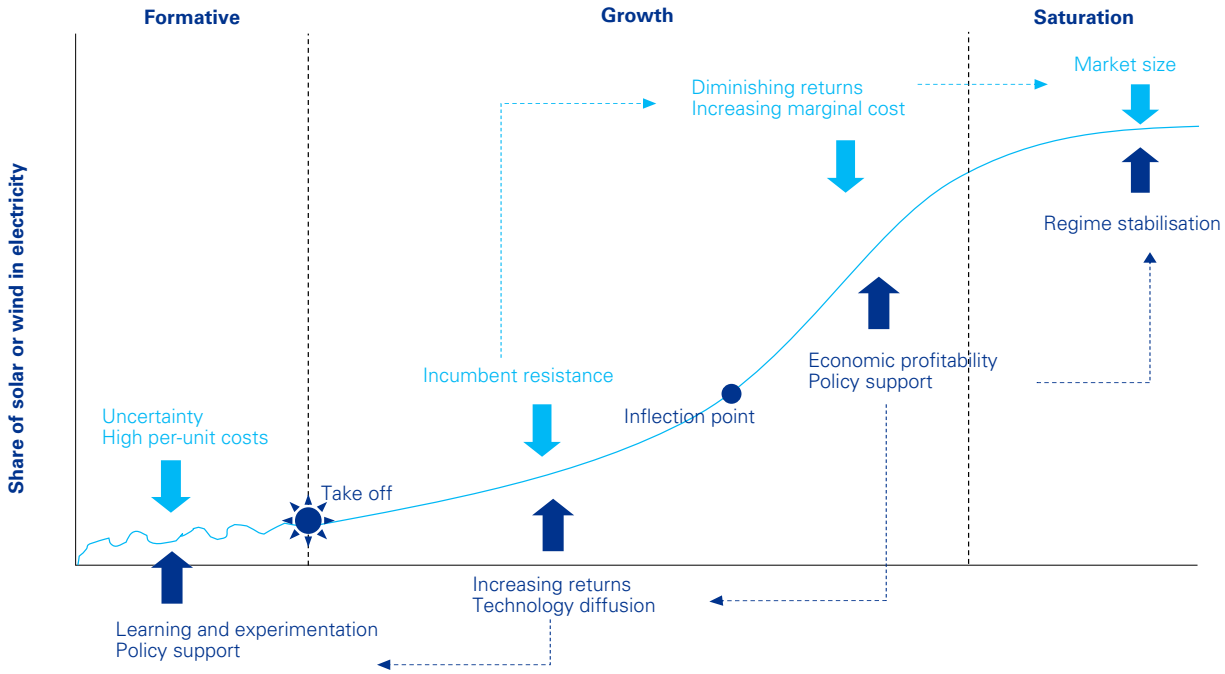
Source: US Energy Information Administration

S-curve growth dynamics

The adoption of new technologies (e.g. wind and solar) often follows three distinct phases that form an S-curve of technology adoption.[77, 78]

- **Formative phase**: growth is slow and erratic due to early adoption of innovative production processes, high per-unit costs and uncertainty.
- **Growth phase**: this phase is kicked off as the sociotechnical environment around new technologies become capable of steady growth. Growth accelerates thanks to positive feedbacks in economic profitability, technology learning, policy support, and market demand.
- **Saturation phase**: growth begins to slow down as the technology reaches its inherent limits, leading to diminishing returns to effort and increasing marginal cost of improvement. This results in the stalling of a technology's market share, and the S-curve flattens out.

FIGURE 14: S-CURVE GROWTH DYNAMICS OF WIND AND SOLAR POWER ADOPTION



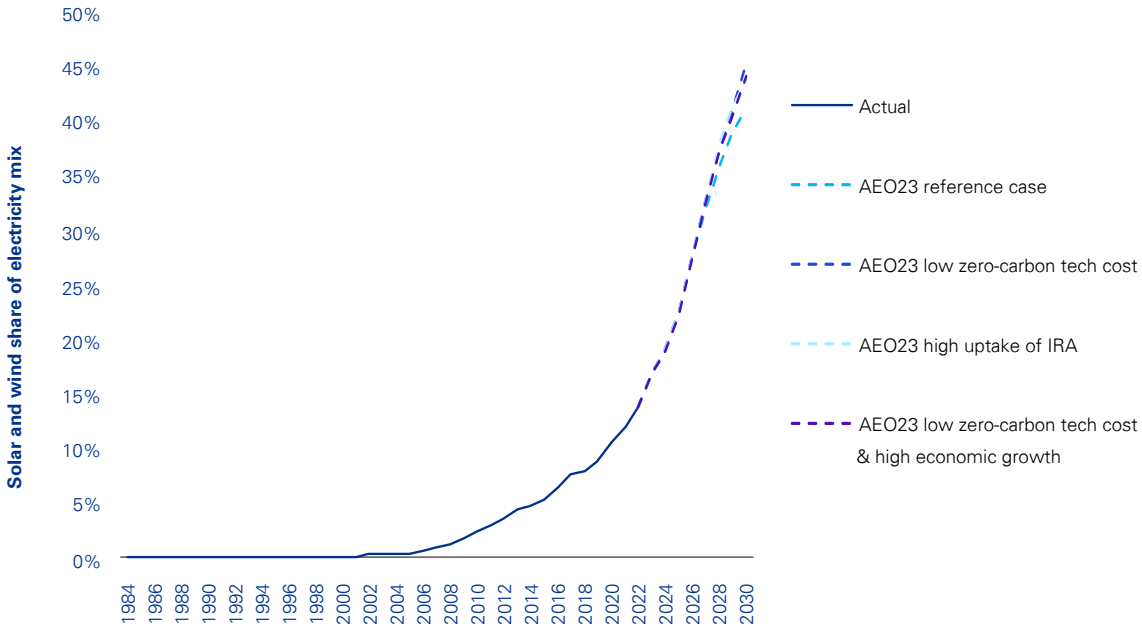
Source: Nature Energy

To limit global warming to no more than 1.5°C as per the Paris Agreement, emissions need to be cut by 45 percent by 2030 and reach net zero by 2050.[79] Renewables, with solar and wind accounting for a major share, will therefore need to reach 61 percent of global electricity by 2030 and 88 percent by 2050.[80] For wind and solar combined, it needs to be 40 percent by 2030 and 68 percent by 2050.[81]

The adoption of solar and wind technology in the electricity mix in the United States is currently below the suggested benchmark for 2030 and believed to be in the growth phase of the S-curve.

Wind turbines were first installed in the United States in the early 1980s, and the share of the US electricity generated from wind has grown from less than 1 percent in 1990 to 10.2 percent in 2022.[82] Similarly, electricity generated from solar has expanded from only 0.01 percent in 1990 to 3.4 percent in 2022. The projection of this share by the US Energy Information Administration towards 2030 follows an S-curve trajectory with exponential growth (Figure 15).

FIGURE 15: PROJECTED SHARE OF SOLAR AND WIND IN NET ELECTRICITY GENERATION IN SELECTED SCENARIOS

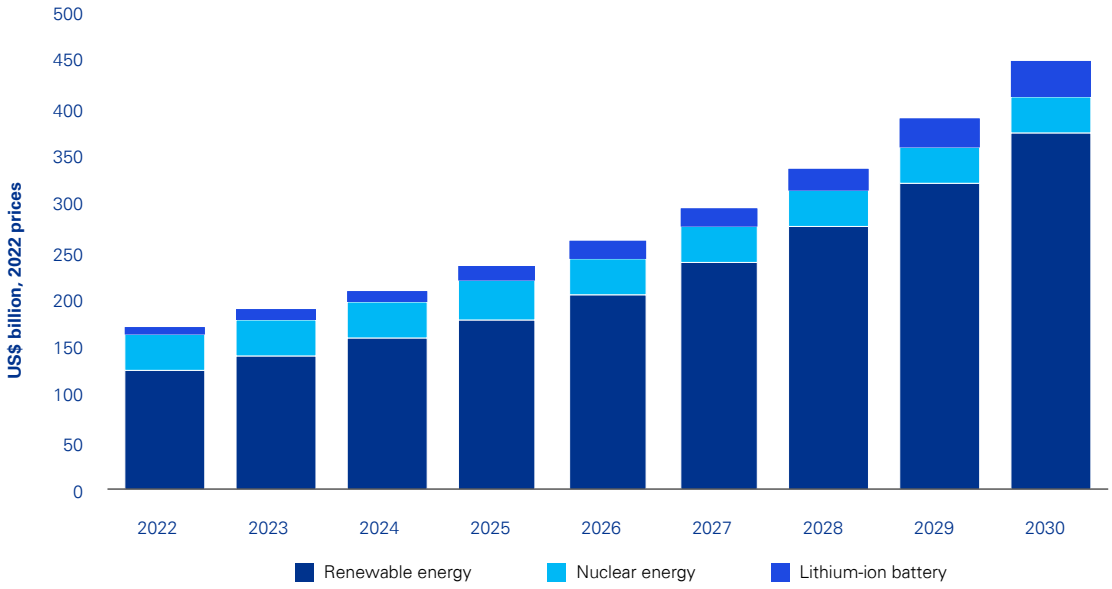


Source: US Energy Information Administration – Annual Energy Outlook 2023

US clean energy market size estimates

As renewable energy technologies, especially wind and solar, are in their growth stage, the US renewable energy industry is projected to grow exponentially at an annual compounded rate of 15 percent from 2022 towards 2030.[83] On the other hand, the US nuclear energy industry revenue is anticipated to fall at a compounded annual growth rate of 0.2 percent as nuclear power producers will continue to be hindered by the fast adoption of renewable energy sources.[84] More nuclear power plants will be shut down because they cannot compete with lower prices from other energy sources; and uranium price is expected to rise through the end of 2028, weighing on profitability.[85]

FIGURE 16: US CLEAN ENERGY MARKET ESTIMATES AND FORECAST, 2022-2030 (US$ BILLION)



Source: Grand View Research, IBISWorld, KPMG analysis

The US lithium-ion battery industry is estimated to be about US$9 billion in 2022.[xi] Substantial growth in renewables and adoption of EVs will boost demand for battery storage capacity. Grand View Research projected the global lithium-ion battery industry to grow at a compounded annual growth rate of 18 percent, and this can be a reasonable growth to apply to the US counterpart. There is also another accelerated market growth scenario in which the market size can reach US$55 billion by 2030.[xii]

[xi] The US lithium-ion battery industry size is estimated based on Li-Bridge's *Building a robust and resilient US lithium battery supply chain.*

[xii] This scenario is based on the same Li-Bridge's report.

3.3

Australia's capacity to participate in the value chain

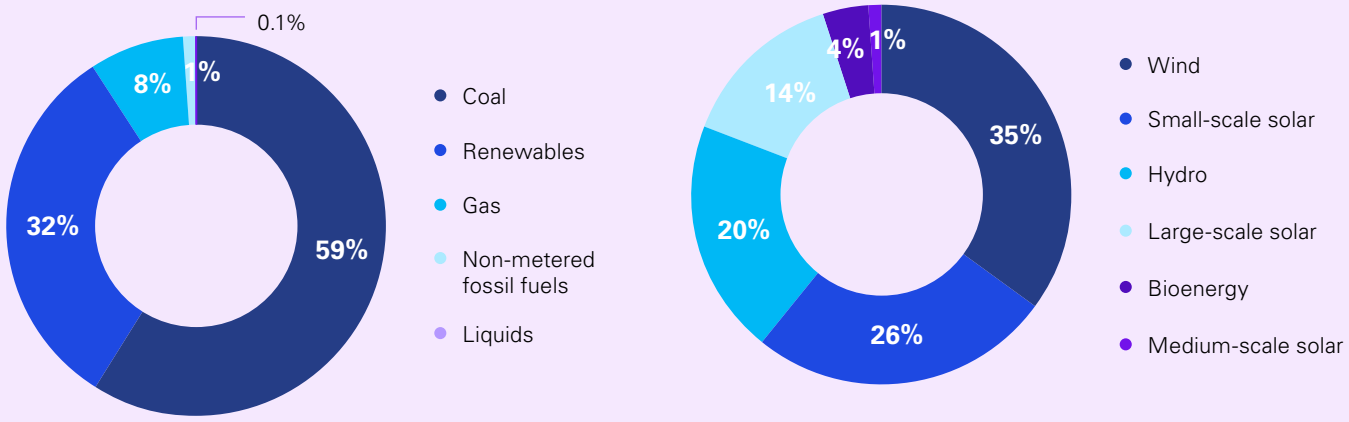
3.3.1 Australian clean energy industry

Clean energy provided 32.5 percent of Australia's electricity generation in 2021, an increase of nearly 5 percent from 2020. Similarly, clean energy generation has more than doubled during the last five years, growing from 16.9 percent in 2017. Wind and small-scale solar have led the growth of clean energy, accounting for 35.6 percent and 24.9 percent of Australia's total renewable energy respectively. Notably, wind accounts for one-third of renewable energy generation in Australia and one-third of total generation in South Australia.

Australia completed some of its largest wind and solar projects in 2021 and 2022 which has substantially raised Australia's capacity in generation of renewable energy.[86] The industry is also showing strong growth and transitioning faster than ever before.

The growth of renewable energy use has led to a lower emission intensity. The increase in renewable energy resulted in a reduction in consumption of coal, which witnessed a decline in share of total generation from 62 percent in 2020 to 59 percent in 2021. Similarly, gas generation also fell from 9.9 percent in 2020 to 7.7 percent in 2021.

FIGURE 17: AUSTRALIAN ANNUAL ELECTRICITY GENERATION AND RENEWABLE GENERATION BY TECHNOLOGY TYPE, 2021



Source: Clean Energy Council, 2022

TABLE 10: RENEWABLE ENERGY ELECTRICITY GENERATION

Technology	Generation (MWH)	Generation (GWH)	Percentage of renewable generation	Percentage of total generation	Equivalent number of households powered over the course of the year
Wind	26,803,711	26,804	35.90%	11.70%	5,831,965
Small-scale solar PV	18,607,417	18,607	24.90%	8.10%	4,048,611
Hydro	16,127,522	16,128	21.60%	7.00%	3,509,034
Large-scale solar PV	9,166,577	9,167	12.30%	4.00%	1,994,468
Bioenergy	3,187,047	3,187	4.30%	1.40%	693,439
Medium-scale solar PV	786,692	787	1.10%	0.30%	171,169
National	**74,678,965**	**74,679**	**100.00%**	**32.50%**	**16,248,687**

Source: Clean Energy Council, 2022

The clean and renewable energy sector accounted for around 35,100 full-time jobs in Australia by the end of 2021. The Australian Government has committed to increase clean energy jobs to reach net zero emission by 2050. Hydrogen will create a significant percentage of these jobs and the government has promised AU$464 million to build seven hydrogen hubs in regional areas that will create 130,000 new jobs by 2030. Based on Australian Labor Party climate policy released in December 2021, the policy will create 604,000 new clean energy jobs.[87]

3.2.2 Public investment into clean energy in Australia

From 2017 to 2022, a total of AU$12.4 billion of investments have been made in the renewable energy sector which is expected to enable the generation of 8,631 megawatts of clean energy.

The Australian Government wants Australia to become a renewable energy superpower. According to the 2023-2024 Budget, it has committed over AU$40 billion to this ambition, of which AU$23 billion is committed to growing and modernizing the electricity grid and boosting energy performance, and AU$17 billion is committed to capturing opportunities in hydrogen, critical minerals and upstream industries.[88]

TABLE 11: KEY INITIATIVES FOR CLEAN ENERGY IN AUSTRALIA

ACT	New South Wales	Northern Territory	Queensland
• Net-zero emissions target by 2025 • Big Canberra Battery system to establish a 250 MW network of distributed batteries • AU$300 million over five years to tackle climate change	• 50 percent emissions reduction target by 2030 • AU$3 billion in incentives for new hydrogen projects • AU$380 million over four years to support renewable energy zone development	• 50 percent renewable energy target by 2030 • 35 MW battery to support the Darwin-Katherine grid • AU$2.8 million to extend the Home and Business Battery Scheme	• 50 percent renewable energy target by 2030 • AU$1.5 billion top-up of the state's renewable energy fund • Proposed 1 GW pumped hydro system at Borumba Dam
South Australia	**Tasmania**	**Victoria**	**Western Australia**
• 100 percent renewable energy target by 2030 • 330 kV interconnector between SA and NSW approved • 250 MW battery announced at Torrens Island gas-fired power station	• 200 percent renewable energy target by 2040 • Net-zero emissions target by 2030 • AU$100,000 towards hydrogen cluster initiative at Bell Bay	• 50 percent renewable energy target by 2030 • VRET2 auction to add 600 MW of new renewable energy capacity • 240 MW battery announced for the Mornington Peninsula	• 2030 emissions reduction target • AU$50 million to stimulate demand for hydrogen in the transport and industrial sectors • AU$118 million to develop hydrogen hubs in the Pilbara and the state's mid-west

Source: Council of Clean Energy, 2022

The Australian Energy Market Operator (AEMO) is also anticipated to undertake significant investment to increase the capacity of Australian Renewable Energy sector ninefold by 2050, mostly constructed in coordinated Renewable Energy Zones (REZs).

The Clean Energy Outlook Confidence Index, which is constructed based on biannual survey data collected from industry leaders, found that investment confidence and employment metrics have seen wide fluctuations over the years, while grid connection processes have been indicated the most critical challenges for clean energy.[89]

3.3.3 Clean energy technology specialisations in Australia

Australia has developed many of the world's leading clean energy technologies, such as world-record solar photovoltaic efficiencies and evacuated tube technology, and continues to develop new products and solutions to support the global growth of the sector. Australian companies have access to global markets and work closely with other international players on joint projects.

Excellent universities and research institutes, and a well-educated workforce have been the key drivers for the growth of the clean energy industry in Australia. Australian universities and research institutions deliver world-leading solutions for the clean energy industry.[90] The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is also rated in the top 1 percent of the world's scientific institutions in 15 research areas.

Australia has facilitated a well-developed innovation ecosystem for transforming research into real-world solutions. Having a mature market and advanced business skills, inventions are converted into profitable businesses that produce world's best technologies and projects.

The clean energy sector in Australia is strongly backed by funding and tax incentives. The Australian renewable energy firms benefit from research and development (R&D) tax incentives and R&D funding provided by public and private sectors. Entities with less than AU$20 million turnover may be eligible for a refundable R&D tax offset, which is equal to the company tax rate plus an 18.5 percent premium.

Australian capabilities span across key subsectors of the renewable energy industry, including solar, wind, microgrids, energy storage, ocean energy, hydropower, geothermal and bioenergy.[91] The table below provides an overview of these capabilities, with examples of some of the Australian companies with specialist expertise.

TABLE 12: AUSTRALIAN CAPABILITIES IN THE RENEWABLE ENERGY SECTOR

Solar	Wind
Australia is a leading innovator in solar energy technologies due to its high solar insolation and widespread use of solar panels. The University of New South Wales' School of Photovoltaic and Renewable Energy Engineering is internationally recognised for its research, while Australian organisations have invented technologies such as evacuated tubes and concentrating solar technologies. There is a focus on next-generation technologies such as flexible solar cells, and companies such as RayGen Resources are improving efficiency and construction costs. Australian companies are also leaders in developing and delivering solar hybrid technologies and world-leading monitoring and control systems, such as Fulcrum3D's CloudCAM. The future of solar in Australia looks promising with continued investment in technology development, residential and commercial-scale projects, and large-scale solar farms.	Australia's favourable conditions, including wide open spaces, coastal breezes near populated areas, and supportive regulations, make it well-suited for wind power. Extensive modelling and network design have been undertaken to maintain grid stability and reliability. Australia's expertise in wind farm design, monitoring, and modelling, as well as effective community engagement, contribute to the sector's continued growth. The country's mature regulatory environment and efficient grid connection processes support the development of wind farms. Australian innovations such as the ground-based SODAR systems and the energy prospecting and assessment tool developed by CSIRO and delivered by Windlab Systems enhance wind farm development. With the Renewable Energy Target and cutting-edge technologies, Australia's wind sector is poised for strong growth domestically and globally in the coming years.

Micro-grid, smart grid & energy storage solutions

Australia's large geographic area and long electricity grids, combined with regional communities having their own micro-grids, have prompted the development of solutions for micro-grids, peak shaving, and energy storage. With the increasing use of intermittent generation sources like wind and solar, these capabilities are being applied to design the future of electricity grids, positioning Australia as a global leader. The country is expected to pioneer widespread energy storage deployment, driving further innovation in network design and operations.

Leading technology companies, including GreenSync, Reposit Power, and GoZERO Energy, are integrating renewable energy into existing networks, providing smart grid solutions for various settings. Off-grid solutions, with improved energy storage technologies, are also well-established in Australia and being deployed globally to island and remote communities. These solutions aim to deliver cost-effective systems with high reliability.

Hydro-electric generation

Australia boasts over 120 operational hydro-electric power stations, generating nearly 20 GWh annually. The sector's foundation lies in two notable projects: the Snowy Mountains Hydro-electric Scheme and Tasmania's hydro-electric initiatives. The expertise gained from these endeavours is now globally shared by engineering organisations SMEC and Entura.

While large-scale hydro-electric projects are not currently pursued in Australia, the country's operators possess sought-after knowledge for low-emission projects. Australian innovators are focusing on lower impact technologies such as run-of-the-river and mini-hydro schemes to generate power from water flows in pipelines. Local companies also excel in developing flood mitigation strategies and conducting environmental and social sustainability assessments for hydro developments worldwide, adhering to stringent Australian environmental standards.

Geothermal

Australia pioneered Enhanced Geothermal Systems (EGS), extracting energy from deep, hot rocks for electricity. Different from surface hot springs, EGS demands advanced engineering and geological expertise. Expertise from pilot projects such as Geodynamics' Habanero Plant is now applied globally. Australian organisations, such as the South Australian Centre for Geothermal Energy Research (SACGER), lead in geothermal reservoir characterisation, mapping, and production design. Australia actively deploys shallow geothermal systems for cost-effective building heating and cooling using soil temperature, with this service being provided by companies such as GeoExchange.

Bioenergy

Australian technology is also at the forefront of bioenergy solutions, ranging from advanced biofuels production to waste-to-energy projects. The sector is expected to experience significant growth over the next decade, supported by a AU$200 million Bioenergy Fund provided by the government.

Australia excels in developing advanced biofuels technologies, such as algae-to-biofuels work by companies such as Muradel. Licella has developed a technology to convert low-cost, non-edible biomass into stable bio-crude oil, while Microbiogen's yeast development work improves ethanol production efficiencies. Sustainable aviation fuels have been explored through the University of Sydney's Alternative Transport Fuel Initiative. In addressing feedstock availability, innovative business models have emerged, such as Biocube's portable biodiesel processor, enabling previously uneconomical opportunities to be realised.

Ocean energy

Australia leads in a number of innovative technologies that are reshaping the global ocean energy industry that is still at an early stage of development. With supportive ocean leasing regimes, abundant and consistent ocean power resources, and a coastal population, the local market is poised for strong growth. Australian companies such as Carnegie Wave Energy have simplified offshore installations by utilising pressurised water for electricity generation or desalination. Others, such as Biopower Systems and Bombora Wavepower, have adopted unique approaches, including biomimicry and integrated coastal protection with energy generation, respectively, to deliver robust and cost-effective ocean energy solutions.

Source: Australian Trade and Investment Commission

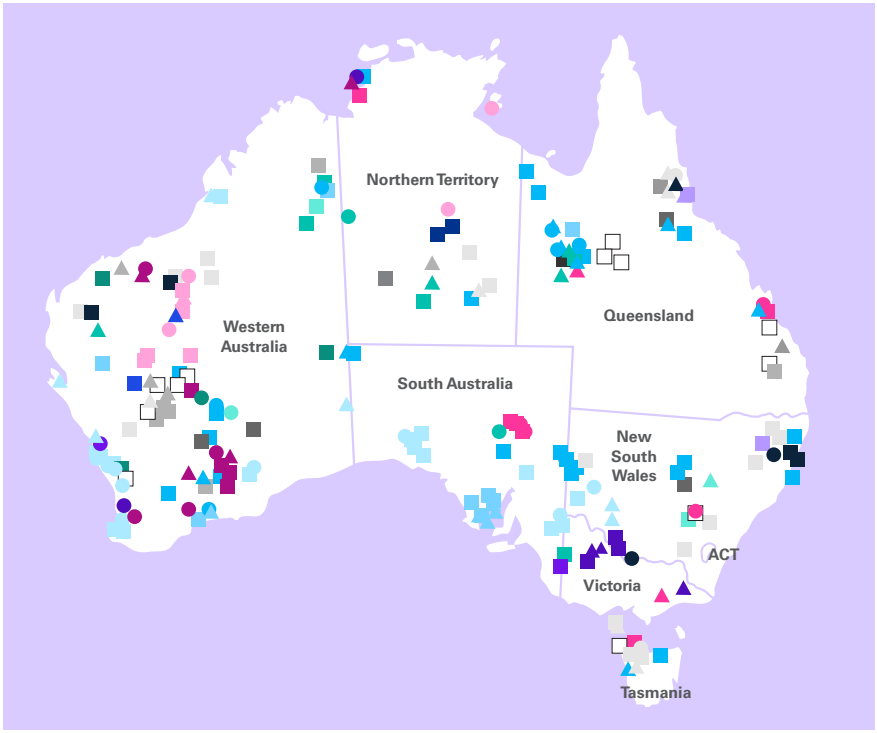
3.4

Clean energy trade opportunities with the United States

Australian comparative advantage in critical minerals exports

Australia is abundant in natural resources. According to Geoscience Australia, Australia has high or very high production potential for many critical minerals, including those that are indispensable for clean energy technologies: lithium, cobalt, manganese, and rare earth elements. Australia holds the second-largest lithium reserves globally and is already the most prominent producer of lithium in the world, supplying about 50 percent of the world's lithium. Australia is also among the world's largest reserves for other key materials required for EV batteries including cobalt, manganese, and nickel.

FIGURE 18: AUSTRALIAN CRITICAL MINERALS AT OPERATING MINES AND MAJOR DEPOSITS



Property

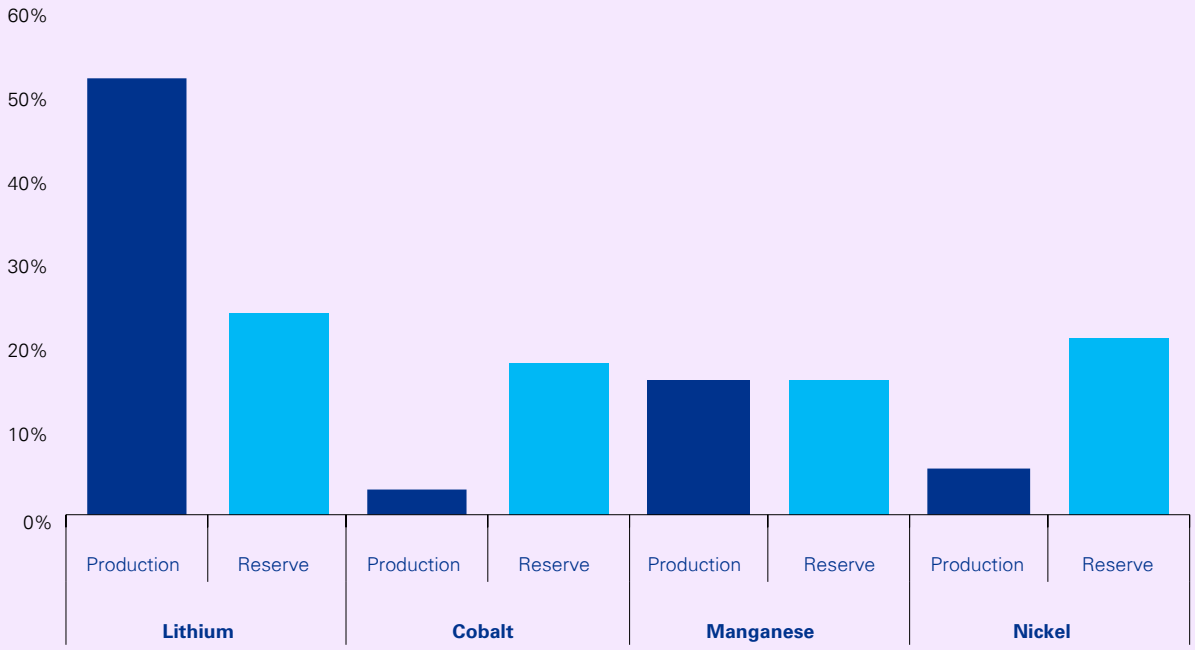
Operating mine | Mine under development or maintenance | Mineral deposit

Element

Antimony	Helium	REE, Zirconium, Niobium, +/- Hafnium, Lithium, Tantalum, Gallium
Bismuth, +/- Cobalt, +/- Indium	Indium	Rhenium
Chromium, +/- Cobalt, +/- PGE	Lithium, +/- Tantalum, +/- Niobium	Scandium, +/= Cobalt, +/- PGE
Cobalt	Magnesium	Titanium
Graphite	Manganese Ore	Titanium, Vanadium
Heavy Minerals Sands (HMS) – Titanium, Zirconium	Platinum Group Elements (PGE), +/- Cobalt	Tungsten
HMS - Titanium, Zirconium, REE	Rare Earth Elements (REE)	Vanadium

Source: IEA[92]

FIGURE 19: AUSTRALIA'S GLOBAL POSITION IN KEY MINERAL FOR EV BATTERIES



Source: National Minerals Information Centre, 2023, U.S. Geological Survey Mineral Commodity Summaries

Australia has the potential to position itself as a key global source of critical minerals supply, to accelerate the production and uptake of clean energy technologies. As highlighted in the World Energy Outlook 2022 by IEA, demand for critical minerals for clean energy technologies is set to increase fourfold by 2030 due to the expanding deployment of renewables, EVs, battery storage and electricity networks. The competitive edge of Australia's resources industry is further strengthened by its advanced mining equipment, technology and services (METS).

Additionally, the growing adoption of clean technologies in Australia necessitates the advancement of recycling, reuse, supply chain resilience, and innovative mineral substitution techniques.

Changing geopolitical dynamics are causing dramatic shifts in the supply and demand of critical minerals, given they are not only necessary to address climate change but are also essential to ensure security of energy supply. In June 2022, Australia and the United States joined forces on the path to net zero by signing the Australia–United States Net Zero Technology Acceleration Partnership. The partnership aims to accelerate development and deployment of zero emissions technologies, advance collaboration on critical minerals supply chains, and support energy security, economic growth, and decarbonisation goals across both economies. This partnership will set up favourable market conditions for investment, trade, and development of commercial opportunities between Australia and the United States in the clean energy sector.

Albemarle: "Australia is essential to the global supply chain for energy storage and an important part of our diverse portfolio."

Albemarle, a US battery chemicals company, is set to invest over AU$4 billion in downstream processing in Western Australia. The company will double the size of its lithium hydroxide plant in Kemerton, near Bunbury. This expansion will increase the plant's capacity to 100,000 tonnes per year, potentially making it the world's largest lithium hydroxide plant.

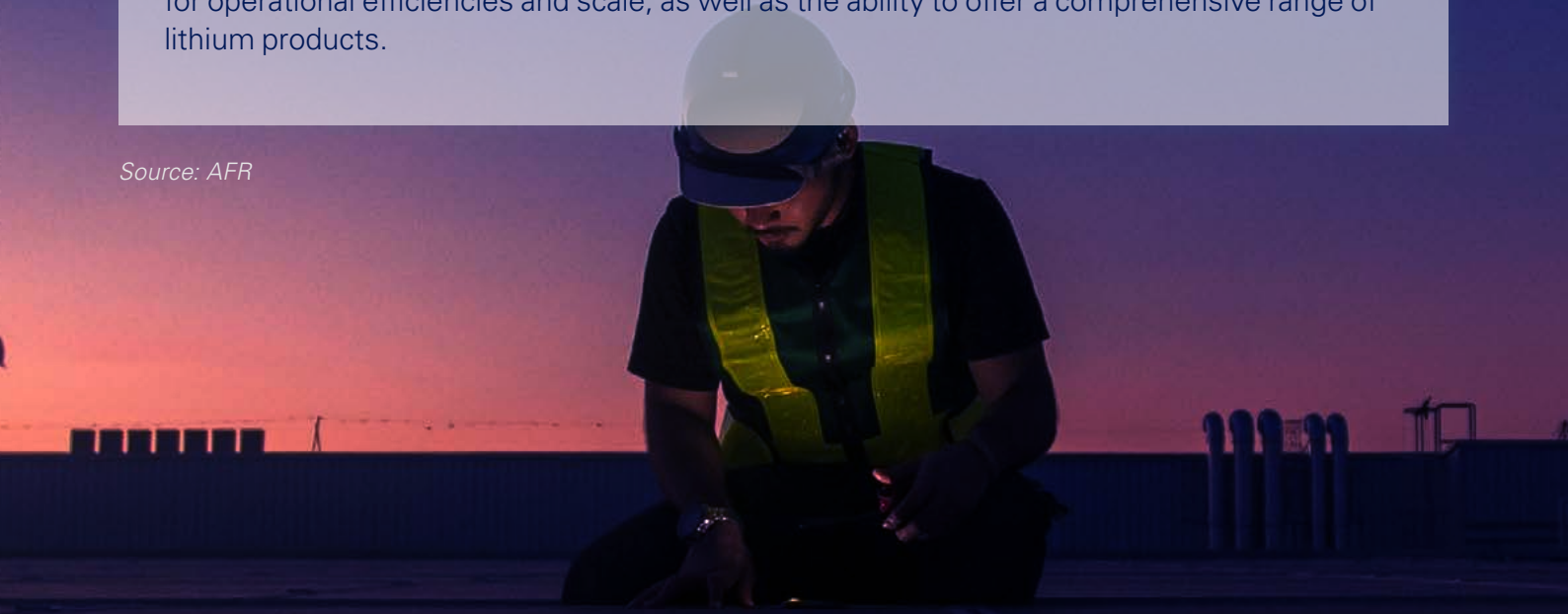
Albemarle's investment solidifies its position as the largest investor in lithium downstream processing in Australia and the largest producer. The decision to expand was driven by the company's confidence in future demand and its aim to offer additional supply to customers. The expansion project is expected to employ around 1,000 workers during construction and create approximately 370 operational jobs by 2026.

The merger between Allkem (Australia) and Livent (US) is set to create another powerhouse in the lithium industry

The merged company will be ideally positioned to take advantage of the increasing demand for lithium, driven by the growth of EVs and energy storage applications. The deal reflects the ongoing energy transition and the importance of lithium as a key component in batteries.

The combined group is expected to become the world's third-largest lithium producer, with a projected production of nearly 250,000 tonnes by the end of 2027. This consolidation allows for operational efficiencies and scale, as well as the ability to offer a comprehensive range of lithium products.

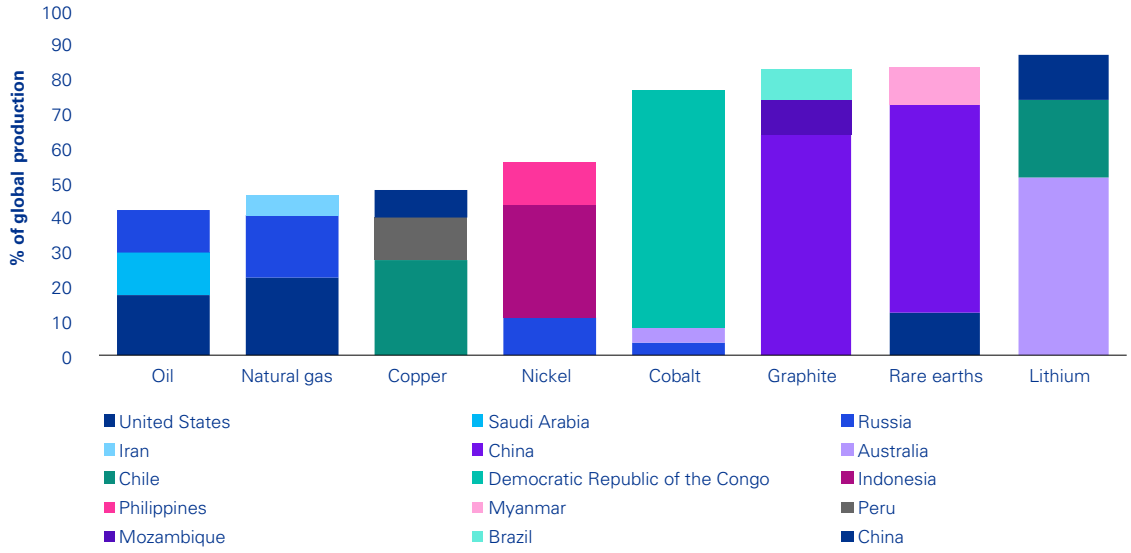
Source: AFR



While being a large exporter of raw materials to the world, Australia has not had strong processing capabilities, as illustrated in Figure 20 and Figure 21. For example, in 2019, Australia extracted 52 percent of global lithium but undertook little value-adding processing, while China's share of refining was around 58 percent.[93]

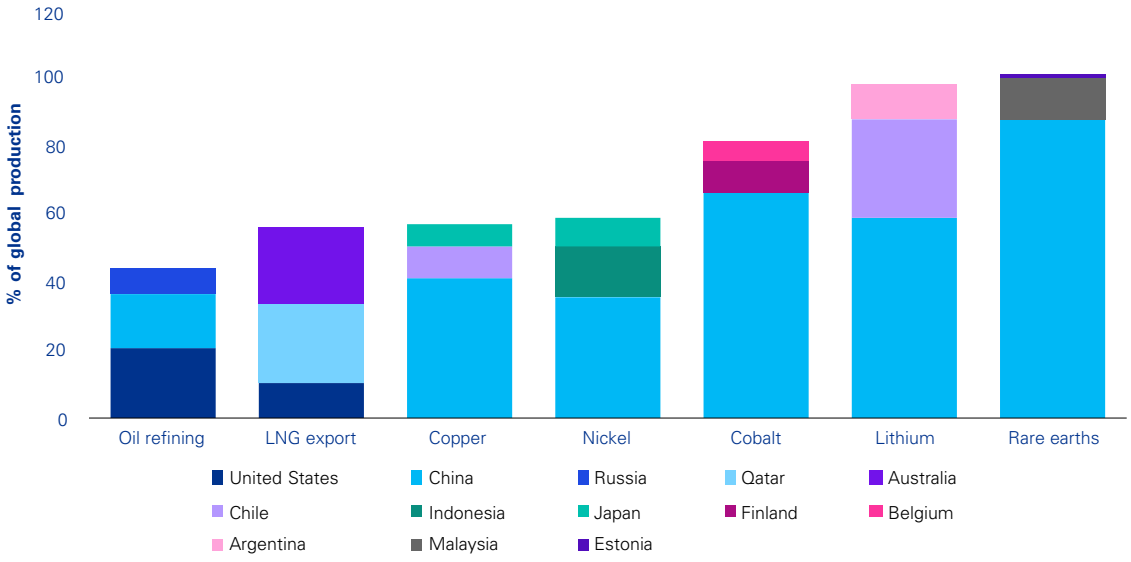
Australia has the potential to capture more of the global supply chain by moving into advanced material manufacturing. In addition to advanced METS capabilities and a skilled workforce, Australia can co-locate raw material extraction, processing, and manufacturing, which helps reduce operating costs and emissions.[94] There is also the potential for mines and processing facilities to be powered by renewable energy which should reduce operating costs by up to 30 percent.[95] However, high capital and labour cost remain a major challenge, although advancements in technology and growing ESG expectations are changing the overall feasibility of downstream processing opportunities in Australia.[96]

FIGURE 20: TOP PRODUCING COUNTRIES IN EXTRACTION OF SELECTED MINERALS, 2019



Source: IEA

FIGURE 21: TOP PRODUCING COUNTRIES IN TOTAL PROCESSING OF SELECTED MINERALS, 2019



Source: IEA

Chevron invested in RayGen, a Melbourne-based solar technology developer

Chevron Technology Ventures has participated in a capital raising round for RayGen, investing US$300 million to enable RayGen to continue its development of innovative technology. This is Chevron Technology Ventures' first investment in Australia, demonstrating RayGen's merging of solar power generation with long-duration energy storage and highlighting Chevron's approach to partnering with innovative developers on a lower carbon future.

Source: Chevron

Australian strengths in innovating renewable energy technologies

Australian research institutions and entrepreneurial companies remain at the forefront of innovation in the renewable energy industry. The country has developed ground-breaking technologies that have been used globally, ranging from world-record solar photovoltaic efficiencies and evacuated tube technology to advanced wave and geothermal technologies.[97]

Nonetheless, Australia does not have a comparative advantage in manufacturing components used in renewable power systems such as solar panels or wind turbines on a commercial scale. The cost of labour in Australia is relatively high, and the country faces material competition from China. While Australia may not be able to offer the lowest cost of production, it is able to provide technical services globally, which is likely to be attractive to markets like the United States, who are looking to increase local production to mitigate sovereign risk.[98]

More opportunities for Australian exports of biofuel and its inputs

In 2021, the United States was the largest consumer of biofuel, accounting for 36.1 percent of global biofuel consumption.[99] Over the next five years, the United States is expected to continue leading global demand and production, and Australia is well-positioned to provide key inputs to their biofuel production as the country produces a very large supply of feedstock for bioethanol and biodiesel production.[100]

Despite its vast feedstock, Australia uses only a small amount of this for domestic biofuel production and ships much of it overseas to assist foreign biofuel programs.[101] Australia produced 180 million litres of fuel ethanol and 18 million litres of biodiesel in 2021, with the main feedstock of its three ethanol producers being wheat starch and molasses from sugarcane, and the main biodiesel feedstocks being tallow and vegetable oil. Australia is the world's third largest sugarcane producer; while most excess bagasse is burnt to generate electricity, other countries have used its energy potential for biofuel.[102]

There are opportunities for Australia to leverage the existing capabilities in its small biofuel industry and expertise in agriculture and forestry (such as capability and expertise in agricultural production and arable land), and engineering to expand domestic biofuel production.[103] Less productive land also has significant potential for use in growing hardier or slower-growing biomass sources.[104] The Australian Renewable Energy Agency has announced funding to projects aimed at developing advanced biofuel production technologies, which may boost domestic production of sustainable aviation fuel in the coming years.[105]

Australian companies given millions of dollars to build or expand US facilities

Syrah Resources was given US$220 million in grants in October 2022 to expand the capacity of its natural graphite facility in Vidalia, Louisiana. Their facility will be the only large-scale natural graphite producer outside China and the first large-scale natural graphite producer in the United States.

Lynas Resources was also awarded a US$120 million contract in June 2022 by the US Department of Defence to establish a rare earth refinery in Texas to process ore mined in Western Australia and material from other companies.

Source: Australian Financial Review

Impacts of the US IRA and agreements between the United States and Australia

The US IRA is expected to have both positive and negative impacts on Australia's clean energy sector. The huge amount of incentive for renewable energy and other green projects in the Act favours US projects and has started a 'global green arms race' for capital and talent. This means capital could be diverted away from Australia into the United States as the Act reduces the capital cost for US-based projects, making them more competitive. As the size of the implementation of infrastructure required for renewables and critical minerals is massive, and Australia is already experiencing an underinvestment in renewables capacity, coupled with long project development lead times, this redirection of capital could slow Australian supply even further in the global race to catch up with demand.

On the other hand, there are more opportunities coming from the IRA for Australia in the United States. While there could be an outflow of investment from Australia to the United States due to the Act, returns will flow back to Australia. In addition, Australia is a free trade partner with the United States and has a great source of critical minerals, as well as know-how and expertise to mine and extract them. The United States has emphasised,

> **"We want to work with our trusted partners to secure the supply chains, to build those alliances into even stronger partnerships than they are today."**[106]

The United States has indicated the goal of strengthening its manufacturing of battery and battery component critical minerals, and has already shown allegiance to Australia through support for its rare earths and critical minerals groups, such as Syrah Resources and Lynas Resources.

Several US senators have provided public feedback after the release of the IRA in which they noted Australian companies are likely to play a crucial role in terms of providing a major share of raw materials. Some Australian resources firms are confident that they or their US partner are likely to receive a low-interest loan, a tax incentive, or a combination of them through the IRA. Free trade and national security agreements between the two countries, such as AUKUS or the Australia–United States Climate, Critical Minerals and Clean Energy Transformation Compact, which establishes climate and clean energy as a third pillar of the Australia–US alliance, will also create a large amount of cooperation, including in green energy and clean technology.

A US$3,750 tax credit will be available to batteries that source at least 40 percent of their critical minerals from the US, or countries that have free trade agreements with the United States, including Australia.[107] This threshold is expected to rise to 50 percent in 2024, 60 percent in 2025, 70 percent in 2026, and 80 percent after 2026.[108]

As critical minerals supply chains are geographically concentrated, thus fragile and vulnerable to disruption, there is an increasing recognition of the importance of diversifying global supply chains.[109] The IRA not only provides support to grow the domestic processing capability, but also incentivises manufacturers to source their inputs outside established supply chains. This presents an opportunity for Australia to develop its downstream capabilities and increase its export potential for processed inputs.

Australia's export potential to the United States

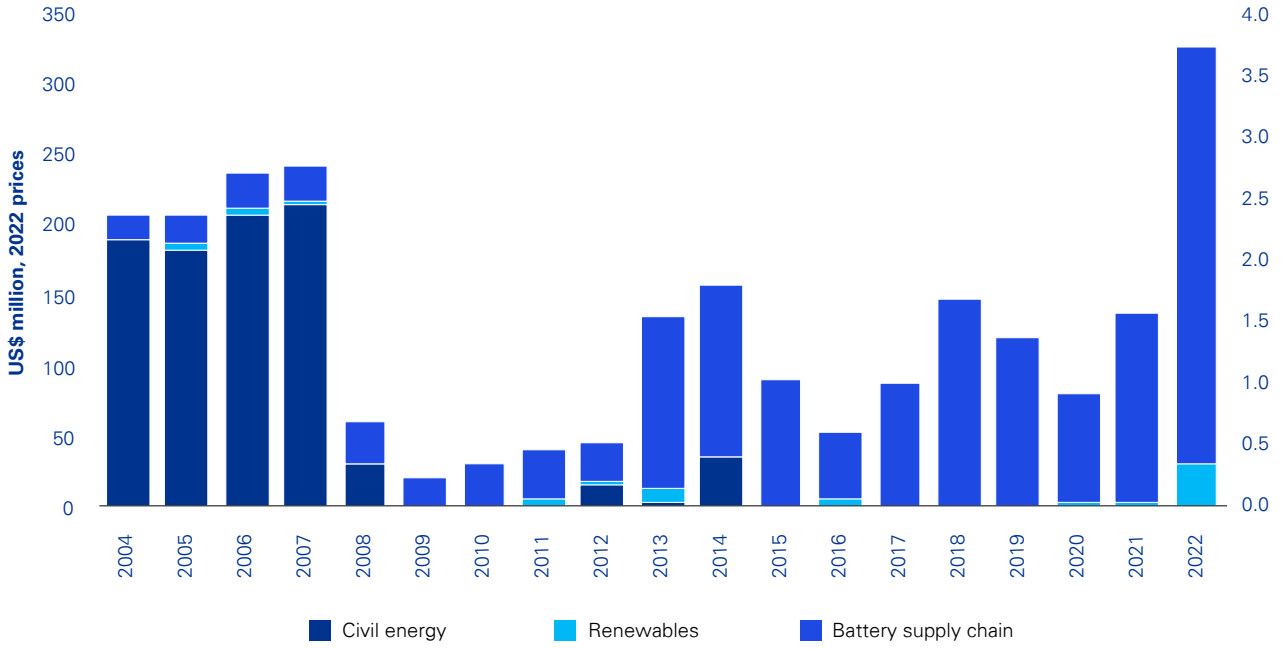
4.1

Estimated trade uplift for increasing US engagement

4.1.1 Historical trade

The below section provides insights into Australian exports to the United States relating to primary clean energy, energy equipment, and materials for lithium-ion battery supply chain. Data is sourced from the International Trade Administration (ITA).[110]

FIGURE 22: AUSTRALIA'S EXPORTS OF CLEAN ENERGY, EQUIPMENT, AND MATERIALS FOR BATTERY SUPPLY CHAINS TO THE UNITED STATES (US$ MILLION)



Source: International Trade Administration, KPMG analysis[xiii]

Battery supply chain[xiv]

Over the last decade, from 2008, the top contributor to Australian exports in the clean energy sector to the United States was inputs for battery manufacturing. In 2002, aluminium oxide was the largest battery input Australia exported to the United States (US$404 million, in 2022 prices), followed by nickel (US$90 million). Two decades later, nickel and aluminium oxide swapped their positions in terms of relative export market importance, with Australia exports of nickel being US$377 million and aluminium oxide being US$121 million in 2022.

Australia fell from being the top aluminium exporter to the United States in 2002 (35.8 percent of total import value) to the 6th position (5.4 percent) in 2022 as countries such as Brazil, Germany, South Korea, Thailand, and China expanded their market shares. On the other hand, Australia has been able to maintain its position among the top four dominant nickel exporters.

It should be noted that in the ITA data, while the commodities in the battery supply chain are primarily for lithium-ion batteries, the US import amounts of commodities in the battery supply chain represent shipments from Australia to the United States for all end uses and do not exclusively end up in lithium-ion batteries. As a result, only a percentage of the imports, including the import values of the minerals above, is assumed to be ultimately used in batteries (Figure 22).[xv]

[xiii] Dollar values are converted into 2022 prices using the US GDP implicit price deflator.

[xiv] The battery supply chain in the ITA Energy Trade Dashboard is focused on lithium-ion batteries and does not include traditional lead acid batteries, although certain commodities may be applicable in other battery technologies (e.g. vanadium, iron chloride). The supply chain input commodities were catalogued based on analysis by the Commerce Department, Department of Energy and US Geological Survey.

[xv] This assumption is calibrated using ITA data and IBISWorld's Lithium Battery Manufacturing in the US.

Renewables

From 2020 to 2022, Australia saw an acceleration in exports of renewable energy, its equipment, and materials, particularly biodiesel and mixtures thereof and solar cells. Australia was among the top 10 exporters of items in the biofuel category to the United States over this period. This resurgence in biofuel exports may be short-lived as the major biodiesel producer in Australia whose targeted markets involved the United States has ceased their production.[111]

On the other hand, Australian exports of feedstock used for biofuel production to the United States are expected to remain strong. Finnish company Neste Oil, a world leader in hydrogenation derived renewable diesel production, is the main buyer of Australia's tallow to support its biodiesel production facilities in Singapore, Netherlands, and Finland, up until 2021. The United States has now become the major destination for Australia's tallow exports in 2022.[112]

Civil nuclear

The ITA data shows Australia's exports of items for the US civil nuclear power were in their prime during 2003-2007, with exports being mainly natural uranium compounds and natural uranium oxide. After this period, Australia's exports in the civil nuclear category appears volatile and subdued. Nonetheless, it is likely uranium exports that are processed in third countries are not reflected in official data, or some exports are made confidential. While merchandise trade data from the Australian Department of Foreign Affairs and Trade (DFAT) also does not reveal Australian uranium exports to the United States, according to the Australian Safeguards and Non-Proliferation Office's *Annual Reports 2018-19*, the United States was the largest market for Australian uranium, constituting more than half of final demand.[113] Total Australian uranium ore concentrates exports to the world were 4,933 tonnes in 2021-2022, translating to AU$564 million in value and comprising 6.7 percent of global uranium requirements.[114]

Australia, a major uranium exporter that holds the world's largest uranium reserves, is likely to experience a positive impact on the demand for its uranium exports as the United States aims to enhance domestic production capabilities. Carbon emissions targets and the disruptions to global energy markets following the Russian invasion of Ukraine are renewing interest worldwide in nuclear power. The US government has implemented, or is considering, mechanisms to extend the operation of current nuclear power plants and encourage new builds.[115]

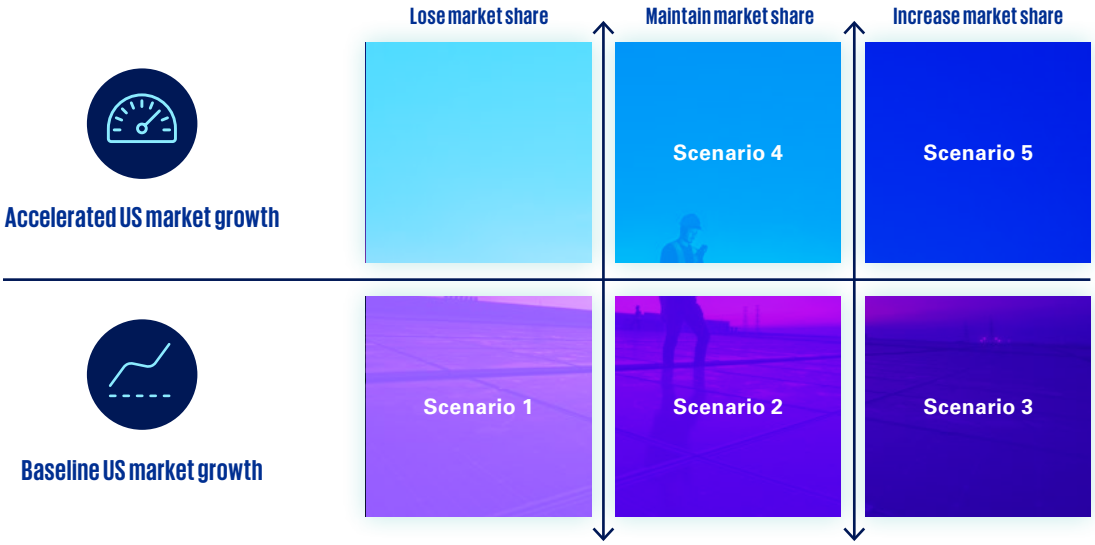
In addition, advanced and small modular reactor companies, supported by substantial investment from the government and the private sector, are aiming to deploy new capabilities later this decade. Many of these new reactors will require high-assay low enriched uranium fuel that has been predominantly supplied by Russia.[116]

4.1.2 Trade uplift scenarios

Looking ahead, Australia is well-placed to capture the trade benefits associated with the rapidly increasing demand for clean energy and energy storage solutions in the United States. There is plenty of potential to be realised if Australia can leverage its comparative advantage in producing critical minerals and several inputs to generate renewable energy, as well as its strong relationship with the United States and the agreements between the two countries. Different to our previous *Prosperous Future* studies, KPMG has extrapolated five scenarios to estimate the benefit of an uplift in trade between the United States and Australia in the clean energy sector, including renewable energy, nuclear energy, and lithium-ion battery industries, between 2022 and 2030.

That is, with the massive current and expected demand for clean energy and batteries, the potential capacity in the US clean energy market can be even greater than the baseline growth projected for the first three scenarios. KPMG has therefore extrapolated two additional scenarios that attempt to capture this additional growth.[xvi]

FIGURE 23: SCENARIO MATRIX

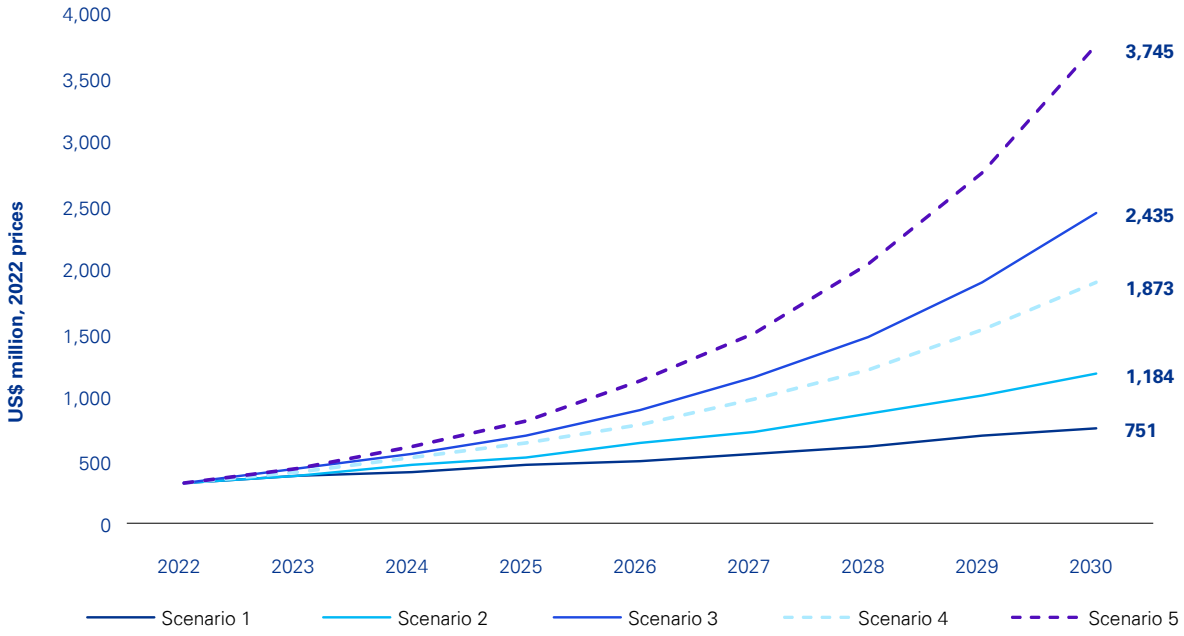


- **Scenario 1:** Australian exports to the United States in the clean energy sector are assumed to continue growing at its historical rate. Under this scenario, the historical growth rate of Australian exports is lower than the projected growth of the US market size, implying Australia will lose its share in the US market.
- **Scenario 2:** Australia is assumed to maintain its current share of trade to the exponentially growing US clean energy sector.
- **Scenario 3:** Australia is assumed to increase its share of trade to the exponentially growing US clean energy sector by combining growth rates derived from scenarios 1 and 2. This scenario represents growth in trade between the countries due to trade and national security agreements between the two countries and Australia's ability to capture more value through critical minerals mining.
- **Scenario 4:** Both the renewable energy and lithium-ion battery industries in the United States are expected to grow at a more optimistic pace than in the first three scenarios, reflecting a steeper S-curve to reach maturity faster. Australia is assumed to maintain its current share of trade.
- **Scenario 5:** Both the renewable energy and lithium-ion battery industries in the United States are expected to grow at the same rate as in Scenario 4. Australia is assumed to increase its share of trade through to 2030.

[xvi] The US market size projections in the additional scenarios are in line with the US Energy Information Administration's projections of solar and wind adoption and Li-Bridge's estimates for the lithium battery demand.

As seen in Figure 24, Scenario 1, the baseline for the clean energy sector estimates the value of Australian exports to the United States in 2030 to be approximately US$751 million. Scenario 2 indicates that if Australia can maintain its share of the fast-growing US clean energy market, the value of exports to the United States will grow to US$1.2 billion. Scenario 3 shows that if Australia can increase its share of trade through trade and national security arrangements, the value of exports could be as high as US$2.4 billion.

FIGURE 24: SCENARIOS FOR INCREASING TRADE BETWEEN THE UNITED STATES AND AUSTRALIA



Source: KPMG analysis, GVR, IBISWorld

Under the accelerated market growth scenarios, Scenario 4 suggests if Australia can maintain its share of the exponentially expanding US clean energy market, including clean energy and battery industries, which can be close to four times its current size, the value of exports to the United States is estimated to be US$1.9 billion, about halfway between scenarios 2 and 3. In Scenario 5, if the Australia can increase its share of this exponentially expanding market, then the value of exports can reach US$3.7 billion.

Table 13 summarises the estimated value of exports from Australia to the United States as a share of the US domestic industry revenue across the five scenarios. Across all scenarios, Australia maintains a small share of the total US industry size, despite the significant increase for Australia's exports. This highlights that the export potential is more constrained by Australia's capacity to provide manufactured goods, as well as by the potential raw material supply constraint, and fierce competition from other countries in the global resources race, than by a lack of opportunity in the United States. It also highlights that under the 'business as usual scenario', Australia could lose market share if trade does not keep up with the high growth of the US clean energy sector.

TABLE 13: TRADE SCENARIO ESTIMATES AS A SHARE OF US DOMESTIC INDUSTRY REVENUE

	Clean energy
Australian exports to US, 2022	US$325m
% of US domestic industry revenue	0.19%
US imports from Australia as a share of 2030 US industry revenue	
Scenario 1: business as usual	0.17%
Scenario 2: fair share – baseline US market growth	0.27%
Scenario 3: increasing share – baseline US market growth	0.55%
Scenario 4: fair share – accelerated US market growth	0.30%
Scenario 5: increasing share – accelerated US market growth	0.60%

Source: KPMG analysis

4.2

Investment and employment implications

If Australian businesses are to step up and participate more actively in bilateral trade with the United States in the field of clean energy, they will require a corresponding step-up in investment in physical capital and labour.

Using information from various ABS datasets, including the national accounts and those associated with estimating multifactor productivity, KPMG has estimated the incremental capex spend and employment that would be necessary for the trade uplift forecasts to be achieved. We note these are broad estimates using industry-wide averages and apply today's capital-labour ratios. Table 14 presents estimates of necessary investment in new capital stock and incremental FTE workers required to achieve the potential trade-uplift forecast in Section 4.2.

TABLE 14: INCREMENTAL CAPITAL STOCK AND LABOUR FORCE REQUIRED TO MEET TRADE-UPLIFT SCENARIOS, 2030

	Capital stock (US$b, 2022 prices)	FTE ('000)
Scenario 1: business as usual	0.8	2.5
Scenario 2: fair share – baseline US market growth	1.3	3.9
Scenario 3: increasing share – baseline US market growth	2.7	8.1
Scenario 4: fair share – accelerated US market growth	2.1	6.2
Scenario 5: increasing share – accelerated US market growth	4.1	12.5

Source: KPMG analysis

The above analysis shows the economic benefits to Australia are significantly higher under the accelerated market share scenarios. The achievability of these outcomes depends on both industry and government working cooperatively to maximise the opportunities that will come with even stronger defence and security relationships that will arise under the AUKUS pact and the Climate, Critical Minerals and Clean Energy Transformation Compact, leveraging the already well-functioning Australia–US Free Trade Agreement.

4.3

Advice for businesses expanding to the US market

To understand the export potential for Australian-based businesses in the clean energy sector, AmCham and KPMG consulted companies who have been successful in generating new business in the United States and Australian markets. We have also complemented key learnings gleaned from the consultations with our own research. While most of the takeaways are aimed for private businesses, some may need policy intervention. These include:

Having part of operations in the United States can help companies access funding, comply with onshore component requirements, and reduce shipping time

There are substantial opportunities in the United States, with the amount of funding available for the energy transition such as renewables and electrification outstripping other countries. The US value chain therefore presents a larger market size and significant opportunities that Australian businesses can tap into, especially in EV mobility and battery minerals. To take advantage of the funding pool, Australian businesses should consider having some of their operations in the United States – a few Australian businesses have already done this such as Tritium and SEA Electric. Having a facility in the United States also helps Australian businesses access the European markets as the United States is geographically closer to Europe, which reduces the time it takes for products to be shipped to that market, as well as comply with the Build America Buy America obligations that certain contents of components need to be sourced onshore. With the United States shoring up its domestic manufacturing, Australian businesses' facilities based in the United States can benefit from a diversified supply chain in the future, especially for semiconductors that are usually sourced from Asia.

While investment might flow from Australia to the United States as companies set up or expand their operations over there, the growing presence of Australian businesses in the United States will generate more business opportunities for Australia over the long term.

Find differentiation points to compete leveraging Australian know-how and talents

Australia is disadvantaged in terms of geographical proximity to the United States and the world, meaning that shipping costs could be high and impact products' competitiveness. Therefore, Australian businesses should choose to operate in the right market segments and find differentiating features to absorb high shipping costs, leveraging the country's engineering talent. While the country's engineering talents do not focus on low-cost markets, they have leading capabilities and can make high quality offerings that optimise customer experience and asset value over its lifetime. Australian businesses also have unique know-hows that stem from the need to design some products to suit Australia's harsh environment, which in turn results in differentiating features.

Australian businesses have certain advantages over overseas peers, such as cultural advantages as the United States and Australia both speak English, which assists with collaboration between Australian and local staff. The US fragmentation across states in terms of legislation is not atypical for Australia, suggesting it is not too difficult for Australian businesses to understand and deploy funding at different government levels, from federal to state. Australian businesses also benefit from the free trade and national security agreements between the two countries.

Critical minerals mining companies can move projects downstream

In the battery space, Australia is a large exporter of raw materials, and it would make sense for the country to do more refining near mine sites – this also helps with better ESG compliance and emission capturing benefits. Rather than competing with the United States in battery making, Australia can try to capture value through mining and domestic production of battery chemicals.[117] Australia has the potential to move further along the supply chain to sell advanced materials to the United States who can do cell component and battery production. Australia will then receive finished goods such as EV, batteries or even cell components to assemble, and trade these with the rest of Asia.

For Australia to develop substantial critical minerals processing capabilities, some mining industry leaders have remarked a major government intervention such as a domestic reservation policy or tax credits for local production would be needed.[118] In addition to funding, shared infrastructure to reduce the cost base, quicker planning approvals, and more transparent and developed pricing tools will be important too.[119]

Be aware of a few barriers and requirements

Legal liability is a major barrier for Australian businesses investing in the United States as large fines and public liability that settles in large amounts of money of over US$5 billion do not happen in Australia. It is difficult to find solutions – a suggestion is Australian businesses could ringfence Australian parent company from their US-based

subsidiary. The accounting system is also different in the United States, with the Australian system being more like that of the EU, and there will be obligations around reporting attached to funding.

For the battery minerals industry, industry stakeholders have noted traceability will become a key issue in the future as the United States wishes to know more about where original materials in the battery supply chain are sourced from, which then becomes sensitive. In a consultation held before the announcement of the United States and Australia signing the Climate, Critical Minerals and Clean Energy Transformation Compact, industry stakeholders commented the existing free trade agreements may not be enough, and more would be needed to strengthen the Australia–US partnership further in this sensitive and important industry. Approvals for critical mineral mines is another issue to address as large backlog cannot keep up with demand. The Australian Government can prioritise approvals for investments by US companies or Australian companies committing to supply to the United States.

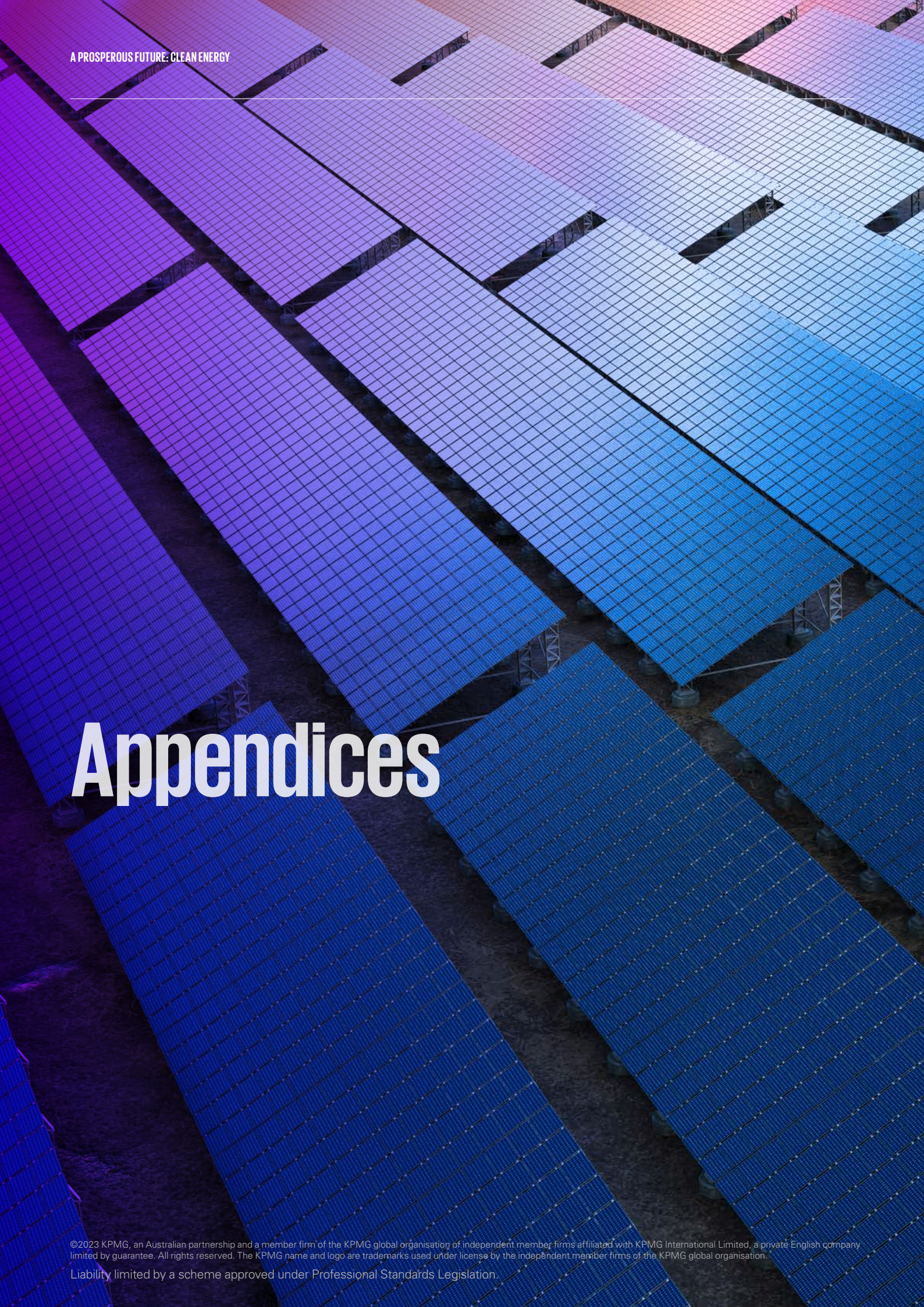
More actions need to be taken to revamp Australian manufacturing

US original equipment manufacturers (OEM) in the clean energy sector recognise Australian natural advantages in wind and solar resources across the country, along with large land size that makes finding areas to build large-scale projects easier without impacting communities. The scale of projects discussed also makes the Australian market attractive for US companies. However, the Australian market is geographically dispersed, with each state having its own localisation requirements, which can constrain supply as it forces capital investment in ways that are not naturally competitive. Together with other risks that OEMs have through logistics, locally managing contracts and workforce, and others that increase their cost base, profitability is therefore limited in the Australian market. As a result, the country needs a more proactive policy framework to help reduce the risks and cost base for international OEMs to increase the attractiveness of the Australian market, which in turn generates more opportunities for domestic suppliers.

As high-volume manufacturing is not an Australian strength, Australia needs to develop bespoke manufacturing and be able to do things faster and more effectively. This can be achieved by focusing on our comparative advantage in supply chain and how Australian firms can be more competitive on the global market. Innovation and industrialisation are important as they help reduce labour intensiveness in the cost equation. Opportunities exist in niche areas, and many Australian manufacturers are world-class in these markets.

It is important to build Australian energy security

Building out and securing Australian energy security will lead to a significant amount of job creation, technology development, and opportunities to export skill sets in clean energy. Australia has the resources to have a stable, low-cost energy market, but will need a policy framework to support it. The US IRA provides a good example of how policies can assist in strengthening a local supply chain for energy security; for example, the IRA incentivises undertaking green steel production approaches to accelerate the US steel industry's effort to reduce its carbon emissions. Australia is a major iron ore producer, implying the country has great capacity to increase production of steel and green steel. Australia also does not have to be a standalone market but can partner up with other countries to build the transition.



Appendices

Appendix A: Market size estimates

This appendix outlines the methodologies used to estimate the market size and trade opportunity for the clean energy sector.

US market size

It is important to note that the sector analysed does not follow specific industry classification codes and so a degree of subjectivity and classification is required to determine market sizes. The market size for the clean energy sector in the United States captures the direct revenues of businesses in the hydro power, wind power, solar power, bioenergy, and other renewable power subsectors, as well as nuclear power and lithium-ion battery industries.

- Estimates for the renewable power market are provided by Grand View Research, which uses a combination of data mining of its proprietary database, consolidation of company reports and other financial statements, and interviews with key opinion leaders in the industry.
- Estimates for the nuclear power market are extracted from IBISWorld, which combines data from official and publicly available sources along with industry contacts, industry associations, and non-public sources, as well as uses proprietary in-house data and statistical modelling to fill in the gaps and form the foundation for forecasts.
- Estimates for the lithium-ion battery market are inferred from the Li-Bridge report *Building a robust and resilient US lithium battery supply chain*.

Appendix B: Supplementary industry information

Using the Panjiva database, we have extracted import data on the clean energy industry in the United States. In extracting this data, we have restricted our search to:

- goods imported to the United States between 2017 and 2022
- consignees with a Standard Industrial Classification (SIC) code relevant to the clean energy industry
- inputs with a Harmonised System (HS) code relevant to the clean energy industry.

The following SIC codes were provided by Grand View Research (GVR):

SIC Code	Description
Clean Energy	
3511	Turbines and turbine generator sets
4911	Electric services
4931	Electric and other services combined
4939	Electric, gas, and other services, not elsewhere classified.

Source: Grand View Research (2022)

Limitations

There are limitations to this approach. First, the SIC code system was last revised in 1987 and therefore may not fully capture emerging industries. SIC code definitions are also broad and no unique codes for clean energy have been defined. As such, searching by SIC codes likely include data relevant to industries that may not be directly related to industries we are interested in. Second, SIC codes most relevant to the clean energy industry are similar and may overlap. Therefore, when extracting data, it is difficult to identify which industry trade data is associated with.

To overcome these limitations, we have used GVR reports which identify prominent companies from the clean energy industry to supplement our data extract. A search in Panjiva is then conducted for these companies and trade data is collated. By doing so, we are able to get an understanding of trade data for industries most relevant to clean energy industry and key companies within the industry.

Appendix C: Prominent US businesses by industry

#	Company name	Listing status	Company size	Location	Year of incorporation
1	Alto Ingredients, Inc.	Listed	Large	Illinois	2003
2	Berkshire Hathaway Energy Company	Unlisted	Large	Ohio	1955
3	Brookfield Renewable Corp.	Listed	Large	New York	2019
4	Clearway Energy, Inc.	Listed	Large	New Jersey	2012
5	Clearway Renew Llc	Unlisted	Small	California	2009
6	Cube Yadkin Generation Llc	Unlisted	Small	North Carolina	2016
7	Dorchester Biomass Llc	Unlisted	Medium	South Carolina	2013
8	Edf Renewables Inc.	Unlisted	Medium	California	1987
9	Edf Renewables Distributed Solutions Inc.	Unlisted	Small	Vermont	2006
10	Enel North America Inc.	Unlisted	Large	Massachusetts	2000
11	Enviva, Inc.	Listed	Large	Maryland	2013
12	Eqm Technologies & Energy Inc.	Listed	Small	Ohio	1990
13	Green Plains, Inc.	Listed	Large	Nebraska	2004
14	Helix Generation Llc	Unlisted	Small	New Jersey	2016
15	Lucid Group, Inc.	Listed	Medium	California	2007
16	Nexamp Inc.	Unlisted	Small	Massachusetts	2018
17	NextEra Energy Partners LP	Listed	Large	Florida	2013
18	NEXTracker, Inc.	Listed	Large	California	2013
19	North American Hydro Midwest Holdings Llc	Unlisted	Small	Wisconsin	1999
20	Ormat Technologies, Inc.	Listed	Medium	Nevada	1965
21	Poet Llc	Unlisted	Medium	South Dakota	2007
22	Proman Usa Inc.	Unlisted	Small	Texas	2012
23	Recurrent Energy Llc	Unlisted	Small	California	2015
24	Renewable Energy Group, Inc.	Unlisted	Large	Iowa	1996
25	Renewable Energy Systems Americas Inc.	Unlisted	Medium	Colorado	1998
26	REX American Resources Corp.	Listed	Medium	Ohio	1984
27	Rivian Automotive, Inc.	Listed	Large	California	2009
28	Stp Nuclear Operating Company	Unlisted	Medium	Texas	1997
29	Suniva Inc.	Unlisted	Small	Georgia	2021
30	Terraform Power Inc.	Unlisted	Medium	New York	2017
31	Tesla, Inc.	Listed	Large	Texas	2003
32	Titan Solar Power Ca Inc.	Unlisted	Medium	Arizona	2019
33	Western Area Power Administration	Unlisted	Medium	Colorado	1977

Source: Factiva Database

The selection comprises firms operating in the 'Alternative Fuel Vehicles', 'Alternative Fuels', 'Biofuels', 'Biomass Heat', 'Renewable Energy Generation', 'Hydropower Energy', 'Solar Energy', 'Wind Energy', 'Geothermal Energy', and 'Nuclear Power Generation'.

Notes: Small, medium, and large businesses refer to those with less than US$50m revenue, between US$50m and US$1b and over US$1b respectively. This list is not exhaustive and only contains a number of representative firms for each business size range.

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